Ministry of Defence

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E-mail: DNO-Secretariat Team (MULTIUSER)

Our Ref: FOI2019/08634

[redacted]

20 December 2019

Dear [redacted]

Thank you for your email requesting the following information:

File reference: AB38/2122

As confirmed previously, we have treated your correspondence as a request for information under the Freedom of Information Act 2000 and we can advise that the Ministry of Defence (MOD) holds information in scope of your request.

We attach the following document:

- File AB38/2122 - Chernobyl Accident UKAEA Reaction

If you wish to complain about the handling of your request, or the content of this response, you can request an independent internal review by contacting the Information Rights Compliance team, Ground Floor, MOD Main Building, Whitehall, SW1A 2HB (e-mail CIO-FOI-IR@mod.gov.uk). Please note that any request for an internal review should be made within 40 working days of the date of this response.

If you remain dissatisfied following an internal review, you may raise your complaint directly to the Information Commissioner under the provisions of Section 50 of the Act. Please note that the Information Commissioner will not normally investigate your case until the MOD internal review process has been completed. The Information Commissioner can be contacted at: Information Commissioner's Office, Wycliffe House, Water Lane, Wilmslow, Cheshire, SK9 5AF. Further details of the role and powers of the Information Commissioner can be found on the Commissioner's website at https://ico.org.uk/.

Yours sincerely,

Defence Nuclear Organisation Secretariat

Box 12468

2597

AB38/2122

Chernobyl Incident
UKAEA Reaction - Notes, papers
1986

15.11.65 -

Reviewed: 22/1/01
Class: DECLASSIFIED
J.J.Clifton, UKAEA, Risley J.J. Clifton

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UNTIL
2017

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HJT
3772
14/10

10 October 1986

To: Dr J H Gittus
Mr H J Teague
Dr R S Peckover
Dr F R Allen
Dr G M Ballard

You will see from the enclosed that I have to gather together an Authority view of the proposals being considered for further action by the IAEA in their post-Chernobyl activities. I would very much appreciate any SRD input to this process and so would ask for a response by Friday, 17 October.

S Carbery
pp M R Hayns
SRD

SRD United Kingdom
Atomic Energy Authority

Visit Report

IAEA General Conference: Scientific Programme on Nuclear Safety, 2-3 October 1986

By

M R Hayns

UKAEA
SRD Culcheth

10 October 1986

Visit Report

IAEA General Conference: Scientific Programme on Nuclear Safety, 2 - 3 October 1986

Contents

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Note for the Record

Scientific Programme for Safety during the General Conference of the IAEA, Vienna, 2-3 October 1986

Summary

As part of the IAEA's General Conference, a closed meeting was held to allow technical people to have an exchange of views. This naturally concentrated on the impact of Chernobyl and covered both Nuclear Safety and Radiological Protection matters. I was accompanied by Mr J Sheehan of the NII.

Prof Konstantinov chaired the proceedings but Dr Rosen took the lead in guiding the discussions.

The first item on the agenda was the review for 1985 of the agencies activities in Nuclear Safety. This was not presented in any detail as a full document was handed out. Instead, Rosen outlined the current situation in the Agency vis a vis post-Chernobyl expansion. He said that the chronology of events for the immediate future was:

1. An expert meeting in Vienna, probably to be held during the first week in November. This meeting would consider the priorities and resources for the various proposals made for the future work of the Agency. There are three sets of proposals"

    a. Those contained in annex VII on the INSAG report following the information meeting.

    b. The proposal in GN(xxx)/777/Add 1 "The Agencies Programme and Budget for 1987 and 1988 - Expanded Nuclear Safety Activities", particularly areas H and I (Nuclear Safety and Radiological Protection).

    c. Resolutions and proposals arising out of the Special Meeting of the General Conference and the General conference itself. This would include, for example, specific proposals contained within national statements to the Special Meeting.

Privately Rosen agreed that some kind of filtering and nationalisation of all these proposals would be required prior to the November meeting. He could not give a timescale for a final set of proposals to be considered by the Expert Group.

2. There would be a meeting of the Scientific Advisory Committee of the IAEA in early December, which would consider the recommendations of the Expert Group.

3. A further meeting of the Board of Governors would be called in mid December to ratify the new programme.

Rosen emphasised that these meetings were not yet finalised but represented his 'best guess' at what will happen.

He indicated that an increase in budget of $2M was being sought; this represents a rise of ~30% over the existing $6M budget.

(This does not take into account voluntary contributions of some $4M). It was suggested that some 15 new professional positions would be created in the Agency.

In his general introduction, Rosen pointedly introduced four papers (in addition to the Nuclear Safety Review).

1. Safety Series No 75 - INSAG 1. This is the Summary Report of the post-accident review meeting on the Chernobyl accident. It represents the first in the series of reports to come from the INSAG group (the second will be on the source term). They are readily recognised by a striking purple cover.

2. The bulletin of the IAEA, Vol 28, No 3, autumn 1986 - this contains a preponderance of papers relating to Chernobyl, including articles by Petrosyants, Blix, Rosen and Lord Marshall.

3. Radiation; Doses, Effects, Risks. United Nations Environmental Programme. This is a literate laymans guide to the effects of radiation on man - rather along the lines of NRPB's "Living Radiation".

4. Rosen made a "heavy sell" of a paper by Risto Lautkaski of the Technical Research Centre of Finland entitled, "Comparative risks from fossil and uranium fuel cycles - a literature review". Rosen said that this paper provided criteria upon which sensible comparisons could be made between the various means of generating electricity. He felt much more should be done in this area.

Finally, Rosen reported that as of ~10 am on Thursday 2 October, some 50 countries had signed the two conventions approved by the special meeting.

The remainder of the meeting was devoted to technical discussions as indicated in the agenda (attached). The format was for invited presentations, either from Agency personnel, consultants or national delegates. Pre-prepared statements were made from the floor. There was relatively little round table discussion. There were 3 sessions, each with a different chairman. During the final (open) session these Chairmen summarised their respective sessions. These summaries are available, or are described more fully in the main visit report. The following are very brief comments or highlights from the sessions.

Operational Safety - Chairman Lando Zech, Chairman, USNRC.

A detailed description of the OSART system was given by IAEA member Franzen. He indicated that Italy had now offered to host a mission to the LATINA reactor. Further, he pointedly said that no missions to other gas reactors, or to LMFBRs, HTRs, etc had been offered. Even though the scheme had been running since 1982, it was still too early to provide any general insights into operational safety 'culture'.

The IRS and ASERT programmes were described. More effort was needed to make the data from different countries compatible with other international agencies, eg. the NEA. The following 3 levels of information were identified:

1. Detailed plant specific data
2. Data relating to plants of the same basic type, perhaps operated in different countries.
3. General data covering all plants and all operational practices.

Most agreed that level 3 could provide only broad generic insights, but that this was likely to be the principal type of data availble in the IAEA's IRS. Cogne of CEA made the strong point that France's standardisation programme meant that their data was only really useful at level 1. It was generally agreed that the principal that the operator is responsible for his plant should never be forgotten and that any changes to regulation, whether national or international, could only be effective if it were actually transmitted into operational practice. Chairman Zech made the point very strongly that no amount of talk in regulatory meetings was of any value unless the plant operators were kept fully 'educated' in safety matters.

Management and Response to Radiological Emergencies - early warning systems - review of NUSS - Chairman W Danyich (Budapest)

In his opening remarks, the Chairman expressed his belief that the response to radiological emergencies was more important in the public's mind than the causes of accidents. There was a strong need for authoritative and firm advice when the public asks "what do we do now?" following a radiological emergency. Discussion centred around a description of the Swiss response to the Chernobyl accident. One problem encountered was that with many surrounding countries beaming TV channels into Switzerland, a wide range of conflicting and confusing information was available to the population. Thus, French TV projected a rather low key approach to the radiological consequences whilst the German TV took a much 'greener' line. When multi-channel, multi-national satellite TV is widely available, this problem will be exacerbated - hence the urgent need to come to both national and international agreement on intervention levels, etc.

Carter - Vice President of IEAL in Washington gave a detailed presentation on US early warning systems. Finally, in this session, the NUSS (Nuclear Safety Standards) work was reviewed. Konstantinov said that he hoped the NUSS documents could form the basis of a "legally binding" set of standards. This was strongly resisted, first by Benninson and then by other countries, indicating that the NUSS represented a minimum standard which could be achieved by consensus so that it did not embarrass any particular country. There was a great deal of interchange on what constituted safety standards or safety principles. The Swedes wished to have numerical safety standards set for international use, which would be binding. Other countries took a less stringent view. However, there is clearly going to be a good deal of further discussion on this matter before the proposal of INSAG (item 6, annex VII) on safety philosophy is resolved.

Safety research priorities - advanced safety designs - Chairman Siderenko, USSR

From the chair Siderenko summarised that for most countries with safety related R&D programmes, the present understanding of the cause and course of the Chernobyl accident did not give rise to any significant new requirements to change the existing programmes. Some change in emphasis may be called for but no new phenomena had been identified needing research. Two areas in particular demanded more attention. First, on methods to reduce the consequences of severe accidents; second, on the man-machine interface. Many of his comments seemed to come from his own experience, rather than a consensus of the meeting. Thus, he emphasised the need to consider further ways of stopping operators by-passing safety sytems. Other western countries would not put this high on their list - arguing that there already exists a full appreciation of this problem. Containment was highlighted as it represented a final barrier to protect people from a severe accident. In private, Harrold Denton indicated that NRC calculations had shown that most US containments would have survived the explosions at Chernobyl.

On advanced designs, Denton gave an overview of work in progress in the USA. There were two kinds of activity, evolutionary and revolutionary. The former were currently finding more favour with US utilities as they felt the need to build from experience rather than trust to brand new concepts and designs. The advanced PWR and BWR designs were described as being simpler. Simple to design, simple to operate and more forgiving of operator error. A design goal had been set of a core melt frequency of 10^{-5} from <u>all causes</u>. Other aims included a high capacity factor, a 60 year plant life and a low occupational exposure (<100 man/rem/year). Siderenko described a small district heating reactor almost ready for commissioning in the USSR which had a very low power density and was intended for siting very close (2 km) to large urban areas. The Swedes included an advertisement for their secure design - suggesting an international effort to design and build a prototype. This was not taken up for further discussion. Canada presented detailed information on their plans for improved automation and raised the interesting question of how much automatic control is appropriate? They are developing system oriented software which can optimise operational procedures from a given starting point - thus, an operator can test various options before trying them on the plant. The natural extension to this would be to give control to the computer to implement the preferred option. The operator is then reduced to a "watch dog". Clearly decisions concerning the amount of automatic control will need to be examined now that the equipment and software presently available have removed many of the systems constraints which limited such procedures before. They also described their 'slow poke' design for a small 2 - 10 MW plant, specifically for unattended operation at remote places in the Canadian arctic. Apart from the Swedish contribution, the discussions were not related to "inherent safey" but rather covered a wide range of safety design concepts and advances. This, perhaps indicated that the discussions proposed by INSAG for agency activity in this area would be of wide use and less contentious than the more selective interpretation in terms of inherent safety only.

Finally, the question of safety goals was addressed by the Chairman. In the context of severe accidents he said that there was general agreement that the most important area was the limitation of societal risks, particularly such topics as land contamination and societal disruption. Individual risk was a relatively simple matter as there was a clear idea of what the hazards were and what could be done about it.

M R Hayns
Head, Nuclear Safety
Technology Branch
SRD

6 October 1986

Programme

During the 1986 General Conference senior officials of safety and regulatory agencies of Member States will meet for closed informal discussions of policy matters of mutual interest.

The meeting will begin with a review of the highlights of international activities in the field of nuclear safety during 1985. The main part of the meeting will be devoted to a discussion of ways to strengthen international co-operation in nuclear safety and radiation protection. The accident at Chernobyl has indicated that nuclear safety and radiation protection are truly international issues. The post-accident review meeting in August, 1986 has already provided the possibility of a very open discussion among the nuclear safety community. During these two days of informal and closed talks at the General Conference the opportunity to further discuss important issues will be provided.

The aim of this meeting among senior policy makers will be the further development of international co-operation.

The main issues to be discussed will be:

- operational safety
- management and response to radiological emergencies
- early warning systems
- future direction of NUSS
- safety research priorities
- advanced safety designs

Brief opening presentations highlighting the main aspects of these issues will be made by selected participants. These opening statements will then be followed by free discussion by all participants in attendance.

The meeting will be concluded with an open session. Each of the previous chairmen will prepare a brief summary of his closed session and give the opportunity for questions and further discussion from the floor.

AGENDA

THURSDAY, 1986-10-02 — **LOCATION**

MORNING SESSIONS (closed) — Vienna International Centre
Meeting Room C07 V

Item 1 — **Nuclear Safety Review 1985**

9.30 a.m.
- 10.30 a.m.

Item 2 — **Strengthening International Co-operation in Nuclear Safety**

10.30 a.m.
- 12.30 a.m. — - operational safety

2.30 p.m.
- 5.30 p.m. — **AFTERNOON SESSION** (closed) — Vienna International Centre
Meeting Room C07 V

Strengthening International Co-operation in Nuclear Safety (continued)

- management and response to radiological emergencies (decision making, protective measures, intervention levels)
- early warning systems
- review of NUSS

FRIDAY, 1986-10-03 — The Ratsaal, Hofburg

9.30 a.m.
- 11.00 a.m. — **MORNING SESSION** (closed)

Strengthening International Co-operation in Nuclear Safety (continued)

- safety research priorities
- advanced safety designs

11.00 a.m.
- 12.30 a.m. — **MORNING SESSION** (open)

Item 3 — Summary and open discussion

Annex 5.A

The International Atomic Energy Agency
(IAEA) shall seek to
accelerate and enlarge the contribution
of atomic energy to peace,
health and prosperity throughout the
world.
It shall ensure, so far as it is able,
that assistance provided by it or at its
request
or under its supervision or control
is not used in such a way as to further
any military purpose.

INTERNATIONAL ATOMIC ENERGY AGENCY
A-1400 VIENNA • WAGRAMERSTRASSE 5 • AUSTRIA

ASSET

TEAMS FOR THE ANALYSIS OF SAFETY-SIGNIFICANT EVENTS

nformation

IAEA ADVISORY SERVICES

The International Atomic Energy Agency (IAEA) has a long-standing reputation for good management of technical expertise in nuclear safety for the benefit of its Member States. It provides various advisory services to Member States on request:

- sending missions composed of a small number of experts for periods of time ranging from two or three days to a month, or
- assigning individual experts for periods of from about a month to as long as a year to the requesting country.

Such missions can be either very specific, addressing singled-out problems arising in siting, designing, constructing or operating a nuclear facility; or devoted to broad tasks such as the safety review and assessment required before grant of an operating licence. Individual experts are usually requested to assist in the resolution of specific problems.

In the past, Member States have most frequently requested advice on such matters as:

- organization of a regulatory body within the government structure
- site survey, site evaluation and related topics
- safety reviews required for licensing purposes
- evaluation techniques to be used in safety analyses
- emergency planning and preparedness.

There were 374 power reactors in operation worldwide at the end of 1985, and the number is rising steadily as units which are currently under construction come into service. Whatever the long-term impact of the accident which occurred at Chernobyl, in the USSR, in 1986 it was already clear that increasing attention should be paid to matters of operational safety.

ASSET: ANALYSIS OF SAFETY-SIGNIFICANT EVENTS TEAM

Since 1982, the International Atomic Energy Agency has been sending, on request, Operational Safety Review Teams (OSARTs) to carry out evaluations of the operational safety of nuclear installations. Such evaluations have been performed successfully in Member States such as Korea, Yugoslavia, the Philippines, Brazil, Pakistan, France, Mexico, and Finland; and are planned to take place in other countries, among them Sweden, the Netherlands, the Federal Republic of Germany and the Republic of Korea.

However, OSART reviews may be incomplete, in that they may not deal in sufficient detail with abnormal safety-related events (deviations from planned operating conditions, or incidents or accidents). This may detract from the achievement of a good understanding of the condition of the plant as a whole, and reduce the accuracy of assessments.

The prime responsibility for identifying problems, and for taking appropriate corrective actions to improve the operational safety of their plants, rests with the authorities in each Member State. They identify and analyse safety-related problems which arise at operating installations day by day. However, even these analyses too frequently stop when the direct cause of a safety-related event has been identified; and corrective actions are often limited to the improvement or the replacement of the component (or the individual) which failed, without taking into account the various root causes which could explain why a latent direct cause was not detected earlier. If analyses are to be done efficiently, the authorities need an additional tool to help them to evaluate more quantitatively both the operational safety of the use of their plants for electricity production, and the effectiveness of work done to improve the feedback of operating experience.

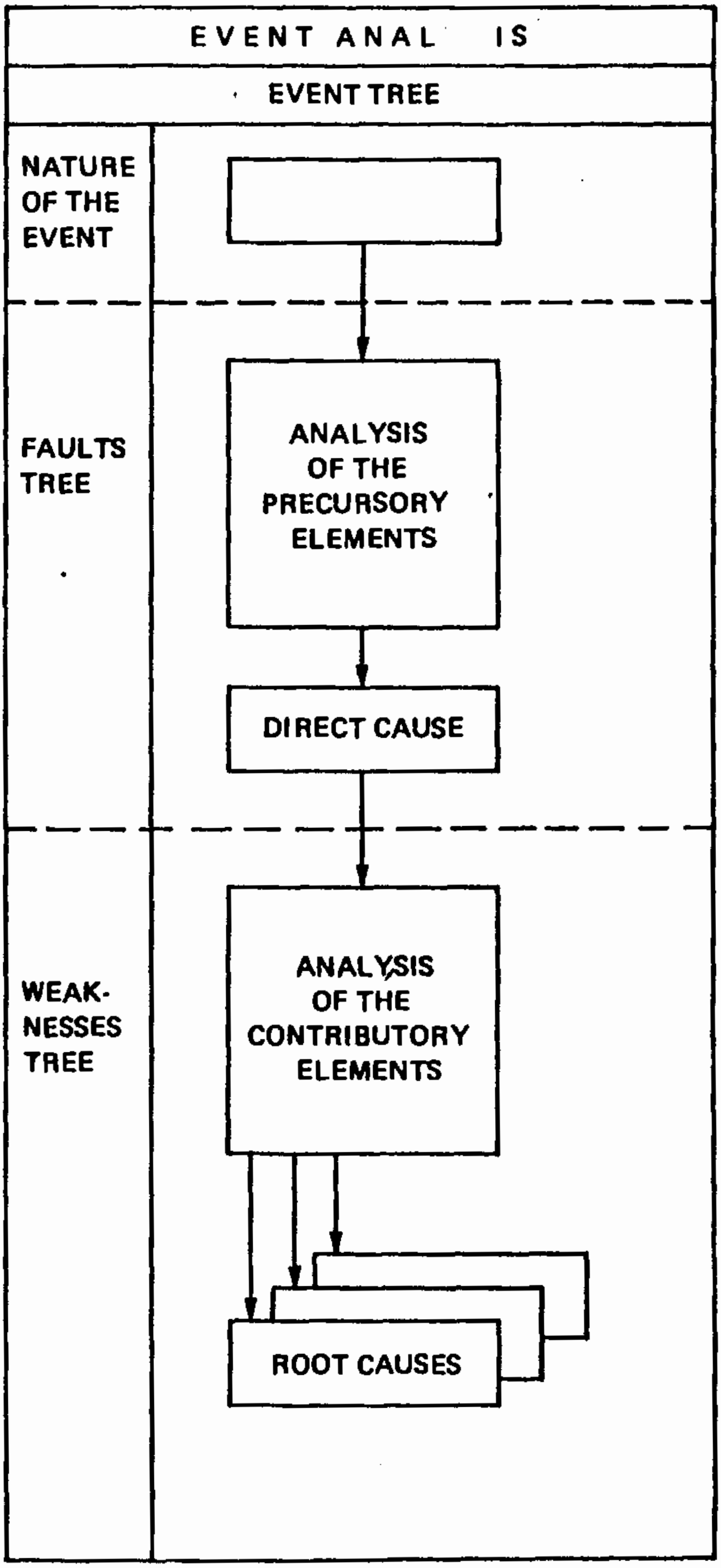
Human factors almost always contribute to the initiation of a safety-related event. ASSET investigations focus particularly on such factors.

Feedback from operating experience has proven conclusively that the operational safety of a plant is highly dependent upon the people who operate it. Two units of the same design, but operated by different operating organizations, could exhibit completely different performance. Some plants may exhibit better operational performance than others where designed safety margins are higher, largely because the performance of the personnel responsible for their operation is better.

The ASSET Service

The International Nuclear Safety Advisory Group (INSAG) recommended that the IAEA should make available specialized teams capable of performing in-depth analyses of operational experience related to the safety of nuclear power plants. The objective is to enable the IAEA to reinforce its contribution to the improvement of operational safety worldwide. The teams will consider operational safety concerns in general, but will focus especially on events categorized as deviations, incidents and accidents:

- *Deviations* are events such as discrepancies or concerns discovered as a result of the surveillance activity carried out by the operating organization on equipment, on personnel qualification, or on the man-machine interface. Deviations may be precursors of incidents, and lessons learned from this kind of event are by far the most important for preventing incidents and accidents.
- *Incidents* are events with consequences which affect either the availability or safety of a plant (such as a trip, transient, scram, unplanned shutdown, forced outage, violation of technical specification, or radioactive release), or the safety of personnel (such as contamination, overexposure to radiation, or injury). Incidents may be precursors of accidents.


EVENT ANAL IS
EVENT TREE
NATURE OF THE EVENT
FAULTS TREE
ANALYSIS OF THE PRECURSORY ELEMENTS
DIRECT CAUSE
WEAK-NESSES TREE
ANALYSIS OF THE CONTRIBUTORY ELEMENTS
ROOT CAUSES

- *Accidents* are events which result in significant damage to the plant, or to people.

An ASSET analysis may concern, for example, either a single abnormal event which is considered to have very important implications for safety; or the whole record of safety-related events of lesser importance which occur more frequently; or any other safety issue. Each investigation will be tailored to meet individual needs.

Each ASSET analysis will be undertaken at the request of the national authority responsible for safety. Analyses will be performed by a number of experts who have long experience in the operation of different types of nuclear power plant. Their missions will last as long as is necessary, depending on the nature of the demand, the information available and the preparatory work that can be done in advance.

ASSET investigations may also be initiated at the suggestion of Technical Committees associated with the IAEA, NEA, or other regional Incident Reporting Systems, which screen and assess information about incidents and accidents at nuclear power plants to derive "lessons learned" for dissemination to interested utilities.

ASSET OBJECTIVES

The ASSET service aims to support responsible bodies in requesting Member States, helping to ensure that the required safety level is maintained at all times during nuclear power plant operation. The ASSET team will seek to work in close co-ordination and co-operation with all organizations and individuals concerned in the Member State, in order to obtain results which are as useful as possible.

The result of each ASSET analysis will be a comprehensive report on the subjects investigated, identifying the direct causes of incidents or accidents and their root causes, and underlining the generic safety lessons learned and the appropriateness of any corrective actions which were taken.

In this way, the national safety authority and the operating organization will receive the information they themselves need to evaluate the performance of operators and equipment within the plant, insofar as they relate to the problems which have been investigated. They can then check easily whether attention and resources have been oriented in such a way as to improve the operational safety of the plant concerned.

The ultimate goal is to assist operating organizations in requesting Member States in their striving for safety in operating nuclear power plants.

How an ASSET is performed

Other organizations see their main task as co-ordinating various national efforts in nuclear safety, arranging for information exchange, and organizing joint research and development projects. With respect to regulatory matters, they usually restrict themselves to giving general advice — for example, by developing standards. The IAEA is very active in these areas too, but was urged to supplement its activities by shifting emphasis from the production of standards, recommendations and other guidance material, to their implementation, using feedback from operational experience as appropriate in the revision of the documents.

Several Member States saw a need to supplement the routine inspection and enforcement activities of their regulatory bodies with action programmes, such as analyses of operational safety experience.

Comprehensive programmes in this respect have been introduced in some countries — and expanded after the Three Mile Island and Chernobyl accidents — in order to contribute to the feedback of experience in operational safety matters which the whole nuclear community needs if continuous improvement is to ' ensured.

Important elements of these endeavours have been used in establishing the objectives and procedures of the ASSET service.

The purpose of each ASSET mission will be defined in agreement with the organizations requesting it, in accordance with the needs expressed by the Member State. It may be devoted to different types of event investigation, always with the aim of identifying the direct causes and the root causes and of reviewing the appropriateness of corrective actions. For example:

- *The analysis of a safety-related accident:*
  analysis of an accident sequence from an independent point of view
- *The analysis of safety-related incidents:*
  analysis of the whole population of the safety related incidents which have occurred in the past

  analysis of a single incident which is considered to be very significant for safety
- *The analysis of safety-related deviations:*
  In the same way the technical and human implications of other safety issues can be investigated, by:

  analysing weaknesses in certain safety-related components — active components such as pumps, valves, and diesel generators, and passive components such as steam generator tubes, and safety-valves

  analysing the collective radiation dose received by the entire work force

  analysing the amount of radioactivity released to the environment when the plant is in normal operation (whether it is in the form of solids, liquids, or gases)

Composition of the team

An ASSET investigation team comprises six experts, recruited from IAEA in-house staff and from outside, and carefully chosen according to their experience in both the operation of nuclear power plants and their knowledge of analysis techniques.

The external consultants may change from one team to the other but the team manager and the in-house members ensure continuity and uniformity in objectives, analysis methodology and performance of the ASSET. Feedback from one mission to another will ensure further improvement in the service.

What advance information is needed?

To enable an ASSET to perform as efficiently as possible, the regulatory body in consultation with the operating organization must submit to the members of the team all documents which they consider may be useful in familiarizing themselves with the plant whose operation is being reviewed. Obviously, comprehensive documentation concerning the plant itself, its licensing status, operating history and procedures, instructions and so on — up-to-date, but not necessarily too detailed — serves the purposes of the investigation best and, therefore, is also in the interest of the operating organization and the regulatory body. The following list of documents, in one of the working languages of the IAEA (English, French, Russian or Spanish) should be considered the minimum information required in advance:

- Plant description
- Latest annual reports
- Organization charts, identifying individuals filling key positions
- Operating licensing conditions and technical specification
- Most recent reports on safety-related events linked to the subject of the investigation, such as incident reports or deviations reports

These latter reports are carefully studied by the experts before the mission. According to the scope of the Member State's request, a detailed programme of the investigation the ASSET team plans to make at the plant is sent in advance, so that the plant manager can make available appropriate counterpart experts.

Methodology of the safety events analysis

Procedures are defined in detailed guide. The analysis methodology consists of the following steps:

- Event review
- Analysis of precursor elements and identification of the direct cause
- Analysis of contributory elements and identification of the root causes
- Selection of areas needing improvement
- Suggested corrective actions

Event review

Each event review begins with the completion of a questionnaire comprising more than 700 questions which are oriented particularly to the human aspect. The event review is the most essential part of the analysis, since it enables the ASSET team to acquire an accurate knowledge of what has occurred. The quality of analysis depends on the care taken in information collection.

Analysis of precursor elements

This is conducted by establishing a "faults tree" (as a "series" diagram) which takes into account only the logical sequence of the various facts which led to the event.

Why did the event happen? This basic question must be answered to properly identify the direct cause and then determine the necessary preliminary improvements, in the three following areas:

- equipment area
    - design
    - manufacturing
    - installation

- man-machine interface area
    - work control
    - information

- personnel area
    - qualification

Analysis of contributory elements

This is conducted by establishing a "weaknesses tree" (as a "parallel" diagram), which takes into account only the various weaknesses which are considered to have contributed to the direct cause of the event. A "weight" is assigned to each contributory root cause, in order to identify those which underlie the initiation of the direct cause having led to the event.

Why was this direct cause not detected earlier? Once this question has been answered, it is possible to determine any necessary fundamental improvements in the following areas:

- equipment surveillance programme
- man-machine interface surveillance programme
- personnel qualification surveillance programme

This last step of the event analysis is certainly the most important, because it is specific to the plant which is being investigated.

The experts in charge of the analysis must be at the same time knowledgeable in technical and human aspects of the operation of nuclear power plants, and in analysis techniques; and must feel themselves to be completely independent of the operating organization. This ideal situation is often difficult to meet, but it is necessary if an in-depth analysis is to be performed without constraints.

Selection of areas needing improvement

Areas needing improvement may not necessarily exhibit a one-to-one correspondence with the direct cause and the root causes of events. To address properly the areas needing improvement, two basic questions have to be considered:

- How could the direct cause of an event be eliminated?
- How could the root causes be eliminated or mitigated?

Suggested corrective actions

The number of corrective actions should not be limited, and several solutions are usually possible. However, ASSET teams will aim to make four suggestions for corrective action:

- One addressing the direct cause of the event; and
- three aimed at mitigating the influence of the most important root causes in each of the following areas: surveillance of equipment, man-machine interface and personnel qualification.

FINAL PRODUCTS OF THE ASSET INVESTIGATION

Analysis Report

One of the final products of an ASSET investigation will be the analysis report. This will identify the direct cause of the event, and its underlying root causes. Generic aspects will be drawn from the lessons learned in connection with operational safety.

It must be emphasised that the first draft report will propose only sample corrective actions, unless the IAEA is requested to make specific recommendations. This draft report will be sent by the ASSET within 30 days of the end of the mission. The regulatory body and the operating organization will then have an opportunity to comment on its conclusions.

It is expected that the operating organization will respond to this initial report within about three months, informing the IAEA about decisions taken with respect to direct and root causes in order to prevent a recurrence of the events.

The final analysis report will include both the conclusions of the ASSET investigation, and decisions of the operating organization.

The final analysis report will then be submitted through official channels to the Member State, which will determine the internal and external distribution it is to be given. The IAEA will keep the report confidential unless otherwise instructed.

Analysis techniques and training

Each national safety authority and operating organization will be able to take advantage of such an investigation to derive the information needed for improving their own analysis methodology. The opportunity to discuss the matter on a training basis between the IAEA experts and some local professional observers can be envisaged. Such discussions would not disturb the investigation conducted jointly by the experts and their counterparts in the plant.

Participation in future investigations

Professionals in the Member State requesting an investigation will be able, if trained in the IAEA analysis methodology, to take part as experts in an ASSET investigation requested by another country.

CONCLUSIONS

The proposed ASSET service might seem to be a limited effort given the large number of units operating worldwide; but by concentrating the service on those Member States that request it, assistance will be provided where it is most effective for safety in operation. The ASSET service could therefore be the starting point for a greater contribution to the improvement of operational safety worldwide.

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An exclusive sales agent for IAEA publications, to whom all orders and inquiries should be addressed, has been appointed in the following country:

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Wagramerstrasse 5, P.O. Box 100
A-1400 Vienna, Austria

Present status

By the middle of 1986, the IAEA-IRS served 24 countries with nuclear power programmes, 15 taking part directly, six through the NEA-IRS, and three through participation in annual meetings. The IAEA-IRS database comprised 250 incident reports. Additional guidelines for reporting and evaluation, which are being developed in co-operation with the NEA, were expected to become available during the year. These would expand the IAEA-IRS to include events which do not cause incidents — such as certain equipment failures, and operational difficulties. The Agency is also making available specialized on-site teams to conduct in-depth incident analyses, either in conjunction with the visits of Operational Safety Review Teams (OSARTs) or separately; and in other ways seeking to strengthen the IRS and related activities.

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5. Appeals to all States to examine the question of the elaboration of draft binding safety standards for existing and new nuclear plants to be submitted at the thirty-first regular session of the General Conference, taking into account the views expressed on this matter during the first special session of the General Conference, especially with regard to the desirability of the verification of the observance of such standards by specialized IAEA staff;

6. Adopts the attached texts of the Convention on Early Notification of a Nuclear Accident and the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency and decides to open the Conventions for signature on 26 September 1986;

7. Takes note of the statements made by several States as to the need for the early notification of all nuclear accidents with radiological safety significance and of the declarations made by several States as to their readiness to notify also nuclear accidents other than those specified in Article 1 of the Convention on Early Notification;

8. Recognizes the role entrusted to the IAEA in the implementation of the Conventions;

9. Appeals to all States to sign and become party to the Conventions as promptly as possible;

10. Appeals to all signatory States for which the Conventions will not enter into force immediately to declare, whenever possible, that they will provisionally apply either or both of the Conventions pending their entry into force for them; and

11. Requests the Director General to report to the General Conference at its thirty-first regular session on the progress made in the implementation of the present resolution.

GC

International Atomic Energy Agency

GENERAL CONFERENCE

GC(SPL.1)/16
26 September 1986

GENERAL Distr.
Original: ENGLISH

First special session

MEASURES TO STRENGTHEN INTERNATIONAL CO-OPERATION IN NUCLEAR SAFETY AND RADIOLOGICAL PROTECTION

Draft resolution submitted by Austria

The General Conference,

(a) *Aware* that nuclear activities are being carried out in a number of States,

(b) *Noting* the common interest of all States in ensuring the safe operation of nuclear activities everywhere,

(c) *Desiring* to strengthen international co-operation at both the bilateral and the multilateral level with regard to nuclear safety, radiological protection, physical security and environmental acceptability,

(d) *Realizing* that close co-operation between neighbouring States is of particular importance in order to enhance mutual nuclear safety, and

(e) *Appreciating* the worldwide role of the IAEA in the area of nuclear safety and radiological protection,

1. *Urges* all Member States to supply, within the framework of bilateral and multilateral arrangements between neighbouring States, all necessary safety relevant information and data on existing and planned nuclear activities;

2. *Urges* all States to accede to requests from neighbouring States to hold consultations on safety standards at existing facilities and on plans for new activities;

3. *Urges* the Director General to initiate a process of negotiations aimed at a multilateral agreement regarding liabilities resulting from nuclear accident damage;

4. *Appeals to* the international community to co-operate in research and development work on new sources of energy capable of supplementing and replacing technologies which might appear obsolete in the light of new developments;

GC

GC(SPL.1)/14
25 September 1986

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International Atomic Energy Agency

GENERAL CONFERENCE

First special session

NOTIFICATION OF ALL SERIOUS NUCLEAR ACCIDENTS
Draft resolution submitted by the Netherlands

The General Conference,

(a) Recognizing that a serious nuclear accident may have transboundary consequences, and

(b) Taking into account the Convention on Early Notification of a Nuclear Accident,

Calls upon Member States to notify on a voluntary basis to the IAEA, and through the IAEA to other Member States, all nuclear accidents which lead to an off-site emergency response.

GC

International Atomic Energy Agency

GENERAL CONFERENCE

GC(SPL.I)/13
25 September 1986

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First special session

NUCLEAR LIABILITY

Draft resolution submitted by the Netherlands

The General Conference,

(a) Recognizing that a nuclear accident may have serious transboundary consequences,

(b) Recognizing also the need for internationally binding arrangements concerning nuclear liability in the event of a nuclear accident,

(c) Taking into account that at present international nuclear liability is governed by two different international conventions - namely, the OECD or Paris Nuclear Liability Convention and the IAEA or Vienna Nuclear Liability Convention,

(d) Noting that some countries with nuclear programmes are not signatories of any of these conventions,

(e) Recognizing that the IAEA and OECD are together studying the possibility of simultaneous application of the two Conventions,

1. Urges the IAEA to continue, together with OECD, the study on the harmonization of the two Conventions with renewed vigour with the ultimate objective of establishing a common protocol;

2. Calls upon all States which have not yet done so to become party to one of these Conventions; and

3. Requests Governments, especially those operating nuclear facilities, to consider whether additional steps may be necessary in order to arrive at adequate international legal arrangements concerning nuclear liability.

5. At the end of the second paragraph under the heading "Role of the IAEA", add ", with special emphasis on - inter alia - the need for training personnel in this area and the need for the further development of inherently safe designs of reactors of various sizes."

6. In the second paragraph under the heading "Conventions on Notification and Assistance", replace "several States as to the need" by "many States as to the need".

7. In the same paragraph, add "in the context of the Convention on Early Notification" after "and of the declarations made".

8. In the same paragraph, change "several States on their readiness" to "the nuclear-weapon States on their readiness".

9. At the end of the same paragraph, add "Texts of the declarations made by the nuclear-weapon States are attached."

GC

International Atomic Energy Agency
GENERAL CONFERENCE

GC(SPL.I)/17
26 September 1986

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First special session

DRAFT OF A FINAL DOCUMENT OF THE SPECIAL SESSION OF THE GENERAL CONFERENCE

Note by the Director General

The following amendments to the draft text circulated in document GC(SPL.I)/4 have been proposed by Algeria and Mexico:

1. In the paragraph headed "International Co-operation", replace "Appeals for a strengthening of" by "Resolves to strengthen".

2. In the same paragraph, insert "and in particular between neighbouring States," after "the multilateral level),".

3. In the same paragraph, add "and to develop further international arrangements concerning nuclear liability" after "environmental compatibility".

4. Under the same heading, add a new paragraph as follows:
" - Requests the Director General to explore the possibility of the establishment of an emergency assistance fund to help developing countries in cases of nuclear accidents".

GC

International Atomic Energy Agency
GENERAL CONFERENCE

GC(SPL.I)/10
25 September 1986

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First special session

DRAFT OF A FINAL DOCUMENT OF THE SPECIAL SESSION OF THE GENERAL CONFERENCE

Note by the Director General

The following amendment to the draft text circulated in document GC(SPL.I)/4 has been proposed by Denmark, Finland, Iceland, Norway and Sweden:

> Amend the first paragraph under the heading "Role of Nuclear Energy" to read "Recognises that for many States nuclear power will continue to be an important source of energy for social and economic development."

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International Atomic Energy Agency
GENERAL CONFERENCE

GC(SPL.I)/9
25 September 1986

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First special session

DRAFT OF A FINAL DOCUMENT OF THE SPECIAL SESSION OF THE GENERAL CONFERENCE

Note by the Director General

The following amendments to the draft text circulated in document GC(SPL.I)/4 have been proposed by Luxembourg:

1. Amend the paragraph under the heading "Responsibility of States" to read "Reaffirms that each country engaged in nuclear energy activities bears the responsibility for its nuclear facilities and activities, and especially for ensuring their nuclear and radiation safety, physical security and environmental compatibility."

2. Under the same heading, add the following paragraph:

   "Takes note of the statements made by the delegates of several States concerning the need to give further consideration to the question of liability in connection with the 'polluter pays' principle."

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- Development of medicines, equipment and techniques for treatment of radiation sickness;

- Development of methods for training personnel servicing nuclear power plants.

* * *

Today, mankind faces an historic choice: either to allow itself to slide down the path of the arms race towards the abyss of a nuclear holocaust, or to bring its thinking and its actions into line with the realities of the nuclear and space ages.

The continuing arms race, above all the nuclear arms race, poses a direct threat to the existence of mankind. Guided by the philosophy of shaping a secure world, the Soviet Union advocates a broad constructive programme of action aimed at ending the arms race and at disarmament.

A regime for the safe development of nuclear energy would make a tangible contribution to ensuring universal security. Such a regime, meeting the interests of all mankind, can and must be established by the joint efforts of all States.

The Soviet Union calls upon all States and international organizations concerned to co-operate in this important endeavour, vital for the further development of human civilization.

<u>Eighth</u>: The question of liability for nuclear damage occupies an important place in activities relating to the international regulation of various aspects of nuclear power safety. Attempts have already been made to draw up international legal instruments governing these matters, but the issue of the material, moral and political damage caused by nuclear accidents has not yet been sufficiently studied; this has resulted in sporadic attempts to make use of nuclear accidents for creating tension and mistrust in relations between States.

It is essential, in the event of a nuclear accident, for States to provide free medical assistance, housing and other material support for the population concerned. A possible multilateral international legal instrument could envisage the liability of States for international damage in terms of the transboundary effects of nuclear accidents, as well as for material, moral and political damage caused by unwarranted action taken under the pretext of protection against the consequences of nuclear accidents (the spreading of untrue information, introduction of unjustified restrictive measures, etc.).

<u>Ninth</u>: A reliable regime for the safe development of nuclear energy will require efforts not only on the part of the States themselves, but also of international organizations and institutions that could serve as focal points in the implementation of nuclear safety measures. The IAEA should take the lead in this field. It is essential to enhance the role and potential of this unique international organization, to broaden the scope of its activity, and to make greater use of its experience in studying various aspects of the nuclear safety problem.

Specialized United Nations agencies, such as the World Health Organization, United Nations Environment Programme, UNESCO and various others, could make a substantial contribution to the regime for the safe development of nuclear energy. We believe that the UN Committee on the Effects of Atomic Radiation should be more active in making the regime efficient.

Joint co-ordinated research and exchange of views on various matters related to the development of nuclear energy should involve the active participation of international organizations; these matters should include the following:

- Development of methods related to accident prevention and clean-up operations;
- Analysis of accident causes and evolution of emergency situations, including a probability analysis;
- Development of robots, machinery and equipment to be used in clean-up operations;
- Development of effective decontamination methods, machinery and equipment as well as reliable means for protecting people against radiation;

The Agency's system for nuclear power plant incident reporting is a good basis for establishing a data bank on nuclear accidents to be used by all nuclear energy countries. It is desirable that this system be further expanded and developed.

__Fifth__: Joint elaboration of a project or projects related to new generation reactor systems based both on thermal and fast neutrons could be an important element in focusing the efforts of countries aimed at ensuring nuclear plant safety. These projects could incorporate the most up-to-date safety technology when dealing with problems such as reducing the sensitivity of a reactor system to operator error, or, in other words, taking into account the "human factor", reducing the possibility of a meltdown, and monitoring hydrogen formation.

In organizational terms, such a project or projects for fail-safe reactors or energy centres could be implemented within the IAEA in exactly the same way as the international thermonuclear reactor project. What is more, the relevant Agency working groups could contribute to those activities.

__Sixth__: As is known, the deliberate destruction of nuclear power plants, research reactors and other similar facilities could trigger a release of radioactive materials and cause radioactive contamination of the terrain.

All this shows that, in terms of its effects, the destruction of peaceful nuclear plants even with conventional weapons would, in fact, be tantamount to a nuclear attack, i.e. to actions that the United Nations has already described as the gravest crime against humanity.

The Soviet Union proposes that a reliable system of measures to prevent attacks against nuclear installations should be developed. It is essential to work out a relevant international convention under which all States would undertake not to attack nuclear power facilities.

An equally sound set of measures should be devised with regard to nuclear terrorism. The instances that have occurred of deliberate damage to nuclear industrial plants as well as cases of the theft of highly concentrated fissionable materials cannot but cause concern.

The radiation hazard and high toxicity of nuclear materials make it imperative to ensure reliable protection of them against criminal designs. It is conceivable that such materials, if seized, might be used to fabricate some sort of elementary nuclear explosive device for the purposes of sabotage and terrorism, blackmail and extortion. There is urgent need to develop a reliable set of measures to prevent any form of nuclear terrorism. We are ready to work towards reaching a separate, independent agreement on this issue and addressing this matter as part of the overall efforts to combat international terrorism.

__Seventh__: Steps must be taken to ensure that the Convention on Physical Protection of Nuclear Materials enters into force as soon as possible. The Soviet Union has signed and ratified the Convention. We call upon other States to promptly follow suit so that it can become operational as a factor promoting nuclear safety.

However, even the peaceful uses of the atom are fraught with considerable hazard. This is evidenced by the effects of accidents at nuclear installations. That is why the USSR has proposed that all countries should work together with a view to minimizing any risk of a nuclear accident in the world and to ensuring the safe development of nuclear energy.

These two tasks - ensuring the safety of the peaceful uses of nuclear energy and ridding our planet of nuclear weapons - call for broad international co-operation and joint efforts by all States, first and foremost [illegible] States, by international organizations and by public bodies interested in establishing a comprehensive and reliable system of international security. This applies equally to both the community of nations and each individual State.

* * *

At present there are about 370 nuclear power reactors operating in the world. By the year 2000 nuclear power is expected to account for more than 20% of the world's total energy production. In some countries nuclear power stations already generate more than [illegible] of the electric energy produced. More than 30 years of experience in operating nuclear power plants have convincingly proved their viability, economic efficiency and ecological safety.

In recent years the geography of nuclear power production has considerably expanded. Nuclear power plants and research reactors are being built and operated in the developing countries of Asia, Latin America and Africa.

The time has also come to speed up the exploitation of controlled thermonuclear fusion, potentially an inexhaustible source of energy. Following the initiative by the Soviet Union, and with the participation of scientists from a number of West European countries as well as from the United States and Japan, an international fusion reactor pilot project, known as INTOR, has been under way in Vienna since 1978. Further development of international co-operation in nuclear fusion meets the interests of the overwhelming majority of countries of the world who, given the current situation, are vitally interested in obtaining new sources of energy. And what is of special importance, this trend has nothing to do with any military use. Equally significant is the fact that thermonuclear energy will have only a very slight effect on the environment compared with other sources of energy. Today we are already in a position to state that building such a reactor is feasible and that it may take only a relatively short time to do so.

Peaceful uses of the atom will make it possible to meet ever increasing needs of mankind in energy for industry, agriculture and scientific research.

At present there is no other equivalent alternative in the field of energy resources. At the same time, [illegible] see that in the process of developing nuclear energy mankind faces the danger that this formidable force may get out of control.

More than 150 accidents with resultant radioactive leakage have been recorded at nuclear power plants throughout the world. Some of those accidents in the United States, Federal Republic of Germany and Great Britain, and finally in Chernobyl', have been very serious and have led to grave consequences causing economic and psychological damage. Events of this kind can affect neighbouring States as well. They show how small, in fact, is the world we live in, how great is the interdependence of States. The realities of the nuclear and space ages make it imperative for the peoples to see themselves as members of one family on planet Earth.

The conclusion that the Soviet Union has come to, following the Chernobyl' accident, is clear and unambiguous: the nuclear power industry should develop under conditions ensuring maximum safety for people and the environment. The accident has shown that wide-ranging international co-operation and joint efforts are necessary to guarantee nuclear safety in the broad sense of the word.

Convinced of the necessity to tackle, without delay and in a practical manner, the task of ensuring the safe development of nuclear energy, the Soviet Union wishes to propose to the international community of States a programme of action for establishing an international regime for the safe development of nuclear energy on the basis of close co-operation between all States. This programme envisages the creation of a material, scientific and technological base for the safe development of nuclear energy, supplemented with international regulations and agreements.

<u>First</u>: It is necessary to set up, in the immediate future, a system of early notification of nuclear accidents or breakdowns at nuclear power plants with concomitant radioactive discharges that may involve the risk of a transboundary release. The objective of such a system would be to minimize the consequences of such accidents for other countries and to take timely measures to protect the health and safety of the population, as well as property and the environment.

The draft international convention on early notification of a nuclear accident, worked out at the IAEA meeting, could lay the basis for such a system. The Soviet Union is prepared to become party to that convention. It would strictly comply with all its provisions, including those that envisage notification of all nuclear accidents, particularly, nuclear weapons- and nuclear test-related accidents, and it calls upon all other States to do likewise.

The establishment of an international data bank on radiation background levels in some agreed geographical areas could be an important component of that system, thereby supplementing the convention. These data could be used to assess the effects of a possible transboundary release in the event of a nuclear accident. Data could be collected by national centres and subsequently transmitted to a single international centre or centres. A significant role in this context could be played by the World Meteorological Organization.

In view of the fact that the scope of the protective measures is determined by the concentration of radioactive substances in the environment, there is a need to agree upon common international standards for accident-induced concentrations of radionuclides and levels of radioactive contamination of the affected area. Such internationally agreed standards and norms could be used both for the adequate application of protective measures by all States as well as for the justification of claims for damages in connection with a transboundary release of radioactivity.

Second: Since many States are not able to cope with a major accident on their own, it is proposed to set up a well co-ordinated mechanism for providing assistance in emergencies and accidents as a component of the international regime for the safe development of nuclear energy.

The draft convention on assistance in the event of a nuclear accident or radiological emergency worked out at the special IAEA meeting of government experts could be an important part of that regime.

The drafting of international recommendations on methodological principles for eliminating the consequences of nuclear accidents and for emergency planning could be a part of the mechanism for assistance to States in eliminating the consequences of accidents.

Third: Another component of the international regime for the safe development of nuclear energy could be agreement that all States in their nuclear activities should be guided by the recommendations formulated by the IAEA on the safety of nuclear installations. These recommendations could cover, in particular, such questions as the siting of a facility, its design, construction, exploitation and decommissioning, and the treatment of the radioactive waste.

A first step in that direction could be the reaching of an agreement between States exporting nuclear installations and nuclear fuel to observe IAEA recommendations on the safety of nuclear power plants in their exports.

To render practical assistance, the IAEA might send, at regular intervals and at their request, groups of competent experts on nuclear safety to States party to the agreement.

Fourth: An essential element in the system of accident-prevention measures is the collection, processing and exchange of information on nuclear plant accidents, their causes, their development and their consequences.

The IAEA workshop on enhancing nuclear energy safety, held in late August, was of great importance for strengthening international co-operation in this field. The objective and detailed information provided by the Soviet Union concerning the causes, evolution and consequences of the Chernobyl' accident, as well as an exchange of information about accidents and clean-up operations in other countries, make it possible to draw up major guidelines for international co-operation in technical arrangements to ensure the safe development of nuclear energy.

GC

International Atomic Energy Agency

GENERAL CONFERENCE

GC(SPL.I)/8
25 September 1986

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First special session

PROGRAMME FOR ESTABLISHING AN INTERNATIONAL REGIME FOR THE SAFE DEVELOPMENT OF NUCLEAR ENERGY

Proposals by the USSR

The use of nuclear energy is a reality of today. Yet nuclear power became part of the life of mankind not through creative endeavour, but through the death of hundreds of thousands of people. The sinister shadow of the tragedy of Hiroshima and Nagasaki lies between the development by Enrico Fermi of the first facility and the first industrial atomic power station designed by Igor Kurchatov.

The nuclear arsenals have now increased to such an extent that they threaten to exterminate our very life on Earth. The time has come to realise that the preservation of human civilization is a matter of concern to all States, for nuclear war will inevitably affect each and every one. While there is still time, it is imperative to put an end to the suicidal build-up of nuclear arms, to abandon the policy of catastrophic confrontation and embark upon the process of genuine disarmament.

In putting forward its programme for eliminating nuclear arms and other weapons of mass destruction throughout the world, the Soviet Union has been guided by an awareness of the reality of the danger threatening mankind. The close of the twentieth century should be marked by the complete elimination of nuclear weapons under conditions of peace and genuine and equal security for all States and peoples. The security of the peoples on our planet is inconceivable without an end to material preparations for nuclear war. The Soviet Union is convinced that the cessation of nuclear-weapon tests can become a turning point in efforts to achieve this goal. That is why the USSR announced, and has since repeatedly extended, a unilateral moratorium on all nuclear explosions.

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International Atomic Energy Agency

GENERAL CONFERENCE

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GC(SPL.1)/7
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First special session

DRAFT RESOLUTION ON THE PROHIBITION OF ARMED ATTACKS ON ALL NUCLEAR INSTALLATIONS

Submitted by Mexico on behalf of the Group of 77

The General Conference, at its special session,

(a) Recalling IAEA General Conference resolution GC(XXIX)/RES/444, and in particular its operative paragraphs 3 and 4,

(b) Aware of the fact that an armed attack on a nuclear installation could result in radioactive releases with grave consequences within and beyond the boundaries of the State which has been attacked, and

(c) Convinced of the need to prohibit armed attacks on all nuclear installations and of the urgency of concluding an international agreement in this regard,

1. Requests the Director General to convene at an early date a governmental expert group to draft an international agreement prohibiting armed attacks on all nuclear installations; and

2. Further requests the Director General to keep the Board and the General Conference informed about the progress in this regard.

(f) Appreciating the role of the IAEA in the area of nuclear safety and radiological protection and the usefulness of the Expanded Nuclear Safety Programme contained in document GC(XXX)/[illegible], and

(g) Noting that the sharing of relevant information on nuclear safety for supplied facilities on a continuing, regular and assured basis between the supplier and recipient is a special responsibility of the supplier,

1. Urges the supplier States to ensure an uninterrupted supply of relevant information on nuclear safety to the recipient States during the entire operational life of the nuclear facilities supplied by them;

2. Decides to intensify efforts by the IAEA in promoting co-operation between States, particularly between supplier and recipient States, on the exchange of relevent information on nuclear safety; and

3. Requests the Director General to keep the Board and the General Conference informed about the progress in this regard.

GC

GC(SPL.I)/6
24 September 1986

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International Atomic Energy Agency
GENERAL CONFERENCE

First special session

DRAFT RESOLUTION ON THE SHARING OF NUCLEAR-SAFETY-RELATED INFORMATION

[illegible] on behalf of the Group of 77

The General Conference, at its special session,

(a) Recognizing that nuclear power continues to be an important source of energy and is increasingly contributing to electricity generation in a number of countries,

(b) Recognizing also that nuclear power has a potentially increasing role to play for the developing countries in their social and economic development,

(c) Convinced that States have the legitimate right to develop and use nuclear energy to meet their growing energy demands,

(d) Taking note of the common interest of all States in ensuring the safe operation of nuclear power plants and other nuclear facilities everywhere,

(e) Desiring to strengthen international co-operation in the safe development and use of nuclear energy,

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86-05042

TEXT OF A LETTER TO THE DIRECTOR GENERAL FROM THE RESIDENT REPRESENTATIVE OF DENMARK

"1. With reference to my letter of 19 September 1986 to the Chairman of the Board of Governors, I would like formally to submit the enclosed draft as an amendment to the paragraph on "International Co-operation" in the draft text of a "Final Document" submitted to the special session of the General Conference by the Board of Governors.

"2. I would like to underline that this submission does not mean that the Danish delegation is in disagreement with the draft text from the Board of Governors. It only means that Denmark feels that it might be in the interest of several Member States if the urgent need for co-operation between neighbouring States could be stressed and elaborated in more concrete terms.

"3. In the opinion of the Danish delegation, this might be achieved either by amending the draft from the Board of Governors or - if this is not convenient - by passing a special resolution with an appeal to neighbouring States on the strengthening of vicinity co-operation. My delegation is prepared to discuss these two alternatives."

International and vicinity co-operation

Appeals for a strengthening of international co-operation especially between neighbouring States, at both the bilateral and the multilateral level, including the conclusion of consultation arrangements for existing and planned nuclear activities with regard to nuclear safety, radiological protection, physical security and environmental acceptability.

Annex 4 c.

GC

GC(SPL.I)/5
24 September 1986

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International Atomic Energy Agency

GENERAL CONFERENCE

First special session

DRAFT OF A FINAL DOCUMENT OF THE SPECIAL SESSION OF THE GENERAL CONFERENCE

Note by the Director General

On 24 September 1986, the Director General received a letter from the Resident Representative of Denmark concerning the draft of a final document of the special session of the General Conference attached to document GC(SPL.I)/4. The text of the letter is attached.

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86-05036

which have experienced safety-significant events will be initiated; this will permit the identification of accident precursors and the carrying out of preventive measures.

54. The Agency will expand its activities aimed at promoting exchanges of safety information relating to different reactor types - with a specialists' meeting on safety aspects of pressurized-heavy-water reactors.

55. The Agency's role in the feedback and sharing of operational safety experience will be strengthened in co-operation with other international bodies, the existing Incident Reporting Sytem (IRS) being expanded to include a broader range of events, the in-depth analysis of selected events with a view to learning generic lessons and a data base on the main safety features of operating nuclear power plants and research reactors. Wider and more active participation by Member States will be encouraged.

study will be made and a publication issued on mechanisms for managing severe accidents at nuclear power plants taking into account national and international activities on the subject. In order to facilitate the international exchange of information from severe accident analyses, including the latest results of the Chernobyl' accident analysis, technical exchanges will be initiated on fuel behaviour research, on the modelling of reactivity transients and their consequences and on the behaviour of materials under extreme accident conditions. In order to draw lessons from the Chernobyl' accident regarding source term estimates, a co-ordinated research programme will be initiated in 1988.

48. The Agency will strengthen its work in promoting and facilitating the use of probabilistic safety assessment (PSA), by reviewing the techniques developed in Member States for the use of PSA, assisting in the formulation of guidelines for its use and helping Member States to apply such guidelines in order to enhance safety in all nuclear power plant operating modes. In this connection, the Agency will promote an exchange of information on computer codes available or being developed for the probabilistic assessment of accident consequences.

Area of Activity I.3

Safe Siting, Design and Construction of Nuclear Installations

(see paras VII.A.2 (4, 7 and 12) in section VII of INSAG's report)

49. The Chernobyl' accident underlined the need to re-examine all types of accident sequences, including power excursions, and to consider the safety features necessary in order to cope with them. The accident scenarios considered in the safety designs of various reactor types will be re-examined with a view to strengthening design features such as control capability, shutdown capability, fire prevention and protection, degree of automation (with particular emphasis on the balance between automation and direct human action and on the need for additional operator aids in the nuclear power plant control room) and containments capable of withstanding severe accidents. This will be done in co-operation with the Nuclear Power programme (see Table 1 in Annex 2).

36. On the assumption that the draft Conventions will be adopted by the General Conference at its special session and that they will enter into force soon, the Agency plans to establish appropriate communications and data processing capacities and to enhance its existing response capacity by developing an emergency response unit in order to carry out its functions under the two Conventions. Also, the Agency will assist Member States, on request, in establishing national mechanisms relating to the Conventions.

37. The first stage of implementation of the Agency's plans, in 1987, will entail the consideration of Secretariat proposals by experts from Member States and other international organizations.

38. The Agency will develop technical guidance on the use of real-time models able to accept actual meteorological and radiological monitoring system data in predicting the radiological consequences of a nuclear accident for persons and the environment and in determining what protective measures are necessary.

39. The Agency will examine the experience gained in sheltering and evacuating the public after the Chernobyl' accident with a view to determining the effectiveness of such protective measures, the problems associated with their introduction and their applicability as a function of time and environmental contamination levels.

40. On the basis of experience gained from the Chernobyl' accident, the Agency will, in collaboration with organizations such as WHO and FAO, develop additional guidance on intervention dose levels and corresponding derived intervention levels appropriate to reducing the stochastic risk and collective dose equivalent commitment, especially at distances beyond the immediate area of accident impact.

41. The Agency will develop technical guidance on criteria and procedures for radiological sampling and monitoring under emergency conditions, where the time and accuracy requirements, the radiation environment and the decision-making needs differ from those associated with routine radiological sampling and monitoring.

42. The Agency will develop technical guidance for the rapid reporting, compiling and collating of large quantities of data after a nuclear accident

programmes will be enhanced to ensure compatability with the Agency's recommendations in operational radiation protection.

28. The Agency will initiate a programme for evaluating the considerable experience gained through accidents in the assessment, prognosis and treatment of non-stochastic effects in highly exposed persons - particularly the acute radiation syndrome and radiation-induced skin lesions. Also, guidance will be developed for the establishment of basic therapeutic schemes and the formulation of correct prognoses. This work will be done in co-operation with WHO.

29. The Agency will, in collaboration with other organizations (for example, UNSCEAR, WHO, and NEA/OECD), arrange for an exchange of experience of past epidemiological studies with a view to determining the usefulness of their results for the development of a methodology (including procedures for the establishment of a data base and of registers of individuals) for an epidemiological study of the late effects in selected groups exposed in the Chernobyl' accident.

30. With a view to enabling physicians to give appropriate advice to members of the public concerning the health consequences of accidental radiation exposures and to provide early treatment to accidentally exposed persons, the Agency will initiate, in collaboration with WHO, a study on what needs to be introduced into the basic and post-graduate training of physicians.

Area of Activity H.2

Radiation Protection of the General Public

(see paras VII.B.2 (1 and 11) in section VII of INSAG's report)

31. In order to improve predictions of the consequences of accidental releases of radioactivity, the Agency will, in collaboration with WMO, review and intercalibrate models of atmospheric transport of radionuclides over short and long distances and of radionuclide deposition on terrestrial surfaces (soils, vegetation, buildings, etc.) and establish a data base for validation studies on such models. In addition, it will carry out similar activities with regard to models of the transfer of radionuclides through the terrestrial

Area of Activity E.4

Nutritional and Health-related Environmental Studies

19. If assistance and inputs are obtained from WHO, UNSCEAR, WMO, FAO and national health authorities, the Agency will initiate activities aimed at providing a set of reference methods for measuring key radioactive contaminants in environmental samples (such as air, rainwater, soil and vegetation) and foodstuffs. In the first phase, advisory and consultants' meetings will be convened to identify which type of basic sample should be considered and which key radioactive contaminant should be measured. Once these substrates and analytes have been identified, current analytical methods will be compared and assessed in the second phase of the project. Simple and detailed guidelines will be prepared on sampling methods, analytical procedures and result reporting in order to provide health and radiation protection authorities and relevant international organizations with reliable and comparable data. Laboratory intercomparisons using certified reference materials will be the basis for quality control. Developing Member States will be given help in setting up environmental monitoring laboratories through technical assistance projects.

H. RADIATION PROTECTION

20. The following activities are planned in connection with basic criteria for the radiation protection of the general public and workers.

21. The Agency, together with WHO, will co-operate in assessments - planned by UNSCEAR - of the individual doses and the collective dose resulting from the Chernobyl' accident. The Agency will establish a comprehensive data base for this purpose (see Annex 2, Table 5, H.2 and para. VII.B.1 (3) in section VII of INSAG's report).

22. During the post-accident period the Agency received numerous inquiries from developing Member States from all regions seeking guidance on radiation protection, and it is expected that there will be an increased demand for the services of Radiation Protection Advisory Teams (RAPATs) in strengthening the

the preparation (in co-operation with the Safety of Nuclear Installations programme - see Table 6 in Annex 2) of a Safety Series document on spent fuel management after a nuclear accident.

13. The accident also raised a problem to which little attention had previously been given, namely the handling, conditioning, transportation and storage/disposal of fuel severely damaged during an accident. Existing spent fuel management concepts are not adequate for such situations. It is therefore planned to review the current technologies, methodologies and safety procedures and to issue a Safety Series document. This will be done in co-operation with the Safety of Nuclear Installations programme (see Table 6 in Annex 2).

C. RADIOACTIVE WASTE MANAGEMENT

Area of Activity C.2

Radioactive Waste Disposal

14. The damaged reactor at Chernobyl' is being entombed with cement grout. Construction of the tomb is due to be completed this month. Most of the data needed for basic consideration of this operation (data on the design of the entombment system, waste characteristics, etc.) and information about experience gained in constructing the tomb will be available soon, and data on radionuclide migration in the biosphere will be available in due course. The entombment technologies and the radioactive waste isolation system, including their safety aspects, will be reviewed.

Area of Activity C.3

Decommissioning of Nuclear Installations

15. A review will be made of the alternatives and special technologies required for the decommissioning and isolation of nuclear facilities after a major accident, including the extensive use of remotely operated equipment. Technical reports on technologies, methodologies and safety procedures will be issued in 1989 and 1990.

studied in Member States. The design and the technical and economic viability of reactor concepts with enhanced safety features will be reviewed at an advisory group meeting in 1987 and at three technical committee meetings in 1988. The scope and objectives of a co-ordinated research programme on the thermal hydraulics of natural convection systems will be defined at a consultants' meeting in 1987.

7. The status of nuclear power plant robotics will be reviewed and the main near-term development issues defined at a specialists' meeting in 1987.

8. An exchange of information on safety-related core parameters such as reactivity effects, control rod efficiency and core flux stability needs to be established in the light of the Chernobyl' accident in order to facilitate better predictions of core behaviour under normal and accident conditions. The creation of core data files including neutron physics and thermal dynamics analyses is necessary for the modelling of reactors, for both operator training and safety analysis. The status of work in the field of reactor physics and thermal hydraulics will be reviewed at an advisory group meeting and two subsequent specialists' meetings in 1988.

B. NUCLEAR FUEL CYCLE

Area of Activity B.1
Resources and Supply of Uranium and Thorium

9. The environmental radiation measurements performed in many countries after the accident at Chernobyl' showed that there is a need for reliable information on the natural radiation environment. The high-quality airborne and ground radioactivity surveys which have been performed in many countries for exploration and geological purposes have produced a wealth of information on natural radiation backgrounds due to the radionuclide content of the earth. With a view to the establishment, in due course, of international standards for the collection, compilation and publication of national radionuclide distribution data, the Agency will arrange for a review of

Annex 4b

REVISED SUPPLEMENTARY NUCLEAR SAFETY AND RADIATION PROTECTION PROGRAMME

A. NUCLEAR POWER

(see paras VII.A.2 (3, 4, 5 and 10) in section VII of INSAG's report)

Area of Activity A.2

Technical and Economic Performance of Nuclear Power

1. The data bank of the Agency's Power Reactor Information System (PRIS) has until now mainly been used in analysing the technical performance of nuclear power plants, but it could also have other uses. A consultants' meeting in 1987 and an advisory group meeting in 1988 will consider additional potential uses of the data bank in studying, inter alia, the probable - but complex - general link between high levels of plant performance and safety, the benefits of quality assurance (QA) and the potential usefulness in connection with OSART missions of outage information as general "problem indicators". Integrated use will be made of PRIS and other data banks and sources of information within the Agency, notably the International Nuclear Information System (INIS), the Incident Reporting System (IRS) and reports on visits to plants. Starting in 1988, PRIS will be made accessible on-line for Member States in response to requests made by a number of them.

2. The post-accident review brought out the importance of the man-machine interface and of simulator training, subjects to which the International Working Group (IWG) on Nuclear Power Plant Control and Instrumentation has been devoting an increasing number of specialists' meetings since 1982. Early in 1987 the IWG will consider the implications of the post-accident review, and a specialists' meeting will be held in 1987 and in 1988 on subjects to be recommended by the IWG, which will also take into account the results of analyses carried out with the help of PRIS. At the first specialists' meeting, in 1987, specific aspects of experience with the man-machine interface will be examined with a view to promoting improvements in control room design.

regard to models of the transfer of radionuclides through the terrestial environment and in food chains, their transfer through surface waters (fresh water and seawater) and their transfer in urban environments.

(12) The IAEA should promote an exchange of information on computer codes available or being developed for the probabilistic assessment of accident consequences.

(13) It is very important to enable physicians, such as specialists in various fields and general practitioners, to give appropriate advice to members of the public concerning health consequences of accidental radiation exposure of various magnitudes and in various conditions. It appears an equally valid requirement that physicians who may be engaged in medical first aid and early treatment of accidentally exposed persons should possess adequate education and training. Therefore the IAEA should initiate, in collaboration with WHO, a study of which subjects should be introduced, and to what extent, into the basic and postgraduate training of physicians to assure fulfilment of these specified needs and requirements.

C. GENERAL

Under the IAEA expanded programme in nuclear safety there are actions intended to help nuclear plant operators to maintain the highest possible safety level, with priority given to prevention of accidents.

These actions are already under way in the Agency programme, but could be significantly expanded with a clear safety benefit for the international community.

In particular, provision should be made for the IAEA to provide special assistance on request, particularly in support of countries with limited resources.

and the decision-making needs differ from those associated with routine radiological sampling and monitoring.

(4) The IAEA should develop technical guidance for the rapid reporting, compiling and collating of large quantities of data after a nuclear accident (including environmental contamination data and meteorological data) to be used as input for radiological assessments.

(5) The IAEA should develop criteria for re-entry into facilities affected by nuclear accidents and into off-site areas and guidelines for recovery operations.

(6) The IAEA should develop, in the light of the Chernobyl accident, technical guidance (criteria and specifications) for clothing which will protect against very high levels of airborne beta contamination.

(7) The IAEA should develop technical guidance on assessments of the large-scale contamination of people (external and internal contamination), equipment, facilities, premises, ground, water and air after a nuclear accident with a view to determining the scale of decontamination operations needed, and on radiation protection of the personnel carrying out such assessments.

(8) The IAEA should develop technical guidance on radiation protection aspects of the decontamination of a nuclear power plant and large areas of surrounding land after a nuclear accident.

(9) The IAEA should formulate practical guidance for responding to releases of radioactive material into the national environment which originate outside national boundaries but nevertheless require measures to be taken for the protection of the public.

(10) The IAEA should develop technical guidance on the use of real-time models able to accept actual meteorological and radiological monitoring system data in predicting the radiological consequences of a nuclear accident for persons and the environment and in determining what protective measures are necessary.

(11) In order to improve predictions of the consequences of accidental releases of radioactivity, the IAEA should, in collaboration with WMO, review and intercalibrate models of atmospheric transport of radionuclides over short and long distances and of radionuclide deposition on terrestrial surfaces (soils, vegetation, buildings, etc.) and establish a database for validation studies on such models. In addition, it should carry out similar activities with

epidemiological studies with a view to determining the usefulness of their results for the development of a methodology (including procedures for the establishment of a database and of registers of individuals) for an epidemiological study of the late effects in selected groups exposed in the Chernobyl accident.

(3) The IAEA should, together with other international organizations, co-operate in the assessment of the individual doses and the collective dose resulting from the accident, planned by UNSCEAR as a part of its continuing assessment of the impact of all radiation sources.

(4) The IAEA should examine the experience gained in sheltering and evacuating the public after the Chernobyl accident with a view to determining the effectiveness of such protective measures, the problems associated with their introduction and their applicability as a function of time and environmental contamination levels.

2. FURTHER IAEA AND OTHER INTERNATIONAL ACTIVITIES

(1) Given the fact that the lack of internationally recommended values for the dose per unit intake (by inhalation or ingestion) of radionuclides as a function of the age of the individual and as a function of the physico-chemical forms of radionuclides found in the environment was a problem encountered in many countries in assessing the consequences of the Chernobyl accident, the IAEA should promote the establishment of agreed values - initially for the most relevant radionuclides.

(2) On the basis of experience gained from the Chernobyl accident, the IAEA should, in collaboration with organizations such as WHO and FAO, develop additional guidance on intervention dose levels and corresponding derived intervention levels appropriate to reducing the stochastic risk and collective dose equivalent commitment, especially at distances beyond the immediate area of accident impact.

(3) The IAEA should develop technical guidance on criteria and procedures for radiological sampling and monitoring under emergency conditions, where the time and accuracy requirements, the radiation environment

information provided to the IRS should be analysed more extensively with a view to learning lessons which can be made available to Member States.

(10) The IAEA should organize a conference on 'The Interaction between Reactor Design and the Operator', with particular emphasis on design features which can assist operators in carrying out their safety responsibilities and which provide automatic protective action when operator actions put the plant into a potentially unsafe state.

(11) Member States, through the activities of regulatory authorities, should arrange for reviewing procedures for the safe operation of nuclear power plant during non-routine tests. This procedure also should be included in the NUSS programme.

(12) The IAEA should organize a symposium on fire protection covering:

(a) The development of the scientific and technical bases for fire prevention and fire-fighting techniques, account being taken of severe conditions such as high temperatures and of the nuclear materials present;

(b) Improvements in fire prevention and fire-fighting equipment for nuclear power plants.

It is expected that the results of the symposium would serve as input in developing possible new standards for fire prevention and fire-fighting (see point 7).

RADIATION PROTECTION

1. FOLLOW-UP ACTIVITIES

(1) The IAEA should take the lead in evaluating the considerable experience gained through accidents in the assessment, prognosis and treatment of non-stochastic effects in highly exposed persons - particularly acute radiation syndrome and radiation-induced skin lesions. Also, guidance should be developed for the establishment of basic therapeutic schemes and the formulation of correct prognoses.

(2) The IAEA should, in collaboration with other international organizations, arrange for an exchange of experience of past

(3) The IAEA should devote special effort to promoting exchanges of experience, developing additional guidelines - in particular relating to the prevention of severe accidents - and giving assistance in the field of operator qualification, education and training so as to create a 'safety culture' in nuclear power plant operation. The feasibility of voluntary international accreditation of operator training programmes should be considered.

(4) The IAEA should increase its efforts to promote exchanges of experience concerning the man-machine interface, with particular emphasis on the balance between automation and direct human action and on the need for additional operator aids in the nuclear power plant control room. Exchanges should include, in particular, the experience of nuclear power plant operators, and the IAEA should co-operate with international organizations representing such operators.

(5) The IAEA should organize a programme of work including an international topical meeting on 'Quality Assurance Activities in Nuclear Power Plant Operation' with particular emphasis on control room procedures. The topic includes detailed prescription of procedures, required verification, shift turnover, confirmation of follow-up actions and notifications to proper authorities.

(6) The Secretariat should provide INSAG with the support necessary to formulate in a self-supporting document the basic safety principles for existing and future reactor types, with special attention given to those principles which emerge from post-accident analyses. These principles should be common to all reactor types, even if some accommodation to specific design concepts is needed.

(7) Existing international standards (NUSS) should be reviewed in order to ensure the incorporation of the lessons learned from accidents regarding important matters such as reactivity-initiated accidents and fire prevention and fire-fighting.

(8) Member States may consider strengthening their co-operation with the IAEA through the voluntary invitation of OSART missions and the provision of experts for such missions. The IAEA should enhance its capability to provide OSART services.

(9) The IAEA's Incident Reporting System (IRS) should be upgraded and expanded so as to broaden the information input base, and the

Annex 4

Section VII

RECOMMENDATIONS

A. NUCLEAR SAFETY

1. FOLLOW-UP ACTIVITIES

Evaluation and analysis of the complex physical and chemical phenomena of the Chernobyl accident sequence and consequences are in their early stages. Further work is necessary in order to allow a more consistent evaluation of the simulation of the accident. The IAEA should promote international co-operation to achieve this objective. It should make the necessary arrangements to do so. It should disseminate the corresponding technical information and facilitate the interchange of analytical methods and the results of the analyses. INSAG wishes to be kept informed of the progress of these activities.

2. FURTHER IAEA AND OTHER INTERNATIONAL ACTIVITIES

(1) The IAEA should promote and, where appropriate, co-ordinate analyses of severe accidents for all reactor types and facilitate the flow of the necessary information.

(2) The IAEA should strengthen its work in promoting, assisting and facilitating the use of probabilistic safety assessment (PSA), by reviewing the techniques developed in Member States for the use of PSA, assisting in the formulation of guidelines for its use and helping Member States to apply such guidelines in order to enhance safety in all nuclear power plant operating modes.

Annex 3

Document List for IAEA Scientific Program Session on Operational Safety

1. "Safety Research Priorities", Birkhofer

2. "Swiss Response to the Radiological Emergency 'Chernobyl'", S Pretre.

3. "Informe-Resumen Sobre el Impacto En Espana Del Accidente De La C N Chernobyl", E Gonzalez.

4. "Radiation Exposure and Measures: Reactor Accident at Chernobyl", O Paakkola

5. "Initial Impact of Chernobyl Accident upon the Finnish Nuclear Safety Programme", A Vuorinen.

6. "Consequences in Sweden of the Chernobyl Accident", J Snihs.

7. "Early Warning Systems for United States Commercial Nuclear Power Plants".

8. "Management of and Response to a Radiological Emergency", J H Aitken.

9. "Candu Safety R&D Program", G L Brooks.

10. "EPRI - ALWR Requirements Document", Denton.

Annex 2

List of papers presented to the IAEA General Conference "Scientific Afternoon", Vienna, 1 October 1986

1. "The Cost and Financing of the Decommissioning of Nuclear Power Plants, H J Thexton, OECD/NEA.

2. "The Recovery of a Nuclear Power Plant from an Unplanned Event; the Three Milse Island Experience", D J McGoff, USDOE.

3. "Safety and Regulatory Aspects of Decommissioning", F Luykx, CEC.

4. "An Overview of Past, Present and Future Activities Relevant to Decommissioning including Unplanned Events", J M Liederman, IAEA, Vienna.

5. "Dismantling and Decontamination of Metal and Concrete Structures", A Cregut, CEA.

6. "The Characterisation and Decontamination of Large Contaminated Areas", M A Feraday, IAEA, Vienna.

7. "Decommissioning and Decontamination of Nuclear Facilities for Normal and Unplanned Situations", L V Konstantinov, IAEA, Vienna.

8. "The Methodology and Technology of Decommissioning", E G Delaney, USDoE, Washington.

Annex 1

ANNEX

Tenatative Agenda for the Scientific Programme for Safety during the General Conference

THURSDAY, 1986-10-02

	MORNING SESSIONS
Item 1	**Nuclear Safety Review 1985**
9.30 a.m. - 10.30 a.m.	
Item 2	**Strengthening International Co-operation in Nuclear Safety**
10.30 a.m. - 12.30 a.m.	- operational safety (e.g. IRS and OSART)
2.30 p.m. - 5.30 p.m.	**AFTERNOON SESSION** **Strengthening International Co-operation in Nuclear Safety (continued)** - management and response to radiological emergencies (decision making, protective measures, intervention levels) - early warning systems - review of NUSS

FRIDAY, 1986-10-03

9.30 a.m. - 11.00 a.m.	**MORNING SESSIONS** **Strengthening International Co-operation in Nuclear Safety (continued)** - safety research priorities - advanced safety designs
11.00 a.m. - 12.30 a.m.	**MORNING OPEN SESSION**
Item 3	Summary and open discussion

room design. This was also a relatively small reactor of between 400 and 600 MW. The power density would be 30% below current values and the number of components in the systems would also be reduced.

In describing some of the more revolutionary designs, he mentioned the high temperature reactor, the prism design for a pool-type LMFBR and the SAFR design which is of a loop type.

Brook of Canada then described some of the advanced design concepts being studied in Canada. Much of this was concerned with advanced designs for operator aids including an evolutionary design from their existing experience which they claimed had given them the lead in the use of computer systems in reactor control. A computer system will be devised to analyse trends in computer operations and will provide the operator with a continuous update on information on these trends so as to give early warning if the operational parameters seem to be heading towards difficulties. They would also develop a means whereby various options for action could be tested on a computer before actually performing it on the reactor. He made the interesting comment that with the systems they envisaged, the machine could actually take over total control of the reactor with the operator just monitoring what goes on. He said this had raised some difficult philosophical problems on how far to go in having software control complex machines like reactors.

He then described the development of a Canadian reactor called Slow Poke which was being developed for use in remote areas in Northern Canada. This was a very small reactor of between 2 and 10 MW which would be able to operate completely unattended and provide heat and electricity in very remote spots.

Because of pressure on time there was very little discussion after this session and the closed part of the meeting was drawn a conclusion.

The open session of the meeting

Following the 1+ days spent in closed session, the meeting was thrown open to other attendees of the general conference, the public and the media. Not a great number of non-participants appeared to take part in this open session. The format of the open session was that each of the Chairmen summarised their session and Rosen and Konstantinov wound up.

a design, they made maximum use of what he called "internal devices' for safety and passive means. The design had been simplified to the maximum possible extent as had the power density in the core. The latter point he said was crucial to providing more forgiving reactors. He said that because of the low potential temperature levels, this reactor could not be used for the generation of electricity but he felt that their experience in designing this reactor would make a good basis when exchanging ideas in this area. He said that the risk to the public from these reactors was some 3 - 4 orders of magnitude less than the usual Soviet power reactors. He said that the prototype of this design was virtually complete and they expected commissioning next year.

Harold Denton of the USNRC then gave a summary of the situation on advanced reactor designs in the United States. He said there would be some 120 plants in operation in the United States in the next few years and their prime task was devoted to running them safely. However, they had spent some effort in considering advanced designs. As an aside Denton said that they had recently licensed their 101st plant in the US at Clinton in Southern Illinois but this statement implies that another 19 plants or so will be licensed by the NRC in the next few years.

He said there were 2 categories of advanced reactor design, they were:

1. Evolutionary
2. Revolutionary

He said that the evolutionary concept was currently favoured by US utilities who felt more comfortable with the idea of moving on from familiar territory rather than starting again with untried systems that would need development. The basic principles being followed for the evolutionary designs of both PWRs and BWRs was to make them simpler. That is, simpler to design, build and more forgiving of operator error. The design goals for these reactors include the requirement that the core melt frequency is no greater than 10^{-5}/reactor year from all causes. They should have a high capacity factor and a 60 year plant life. The occupational exposure targets should be less than 100 man rem per reactor year. He then described briefly the progress towards the Westinghouse advanced PWR - an evolutionary design which had a lower power density, a larger pressure vessel and a much larger inventory of water in the primary circuit. He said that in this design there was no need for boron injection and that there would be 2 diverse auxiliary feedwater systems. Furthermore, the pump seals will be provided with their own dedicated cooling water systems. These items seem very familiar following the Sizewell B exercise where the latter were identified as being of special importance. An interesting feature was the passive capacity to flood the core. Thus, even in the largest pipe break the core would not be uncovered.

He also described an advanced BWR which had internal circulating pumps, better control rod systems and a better ergonomic control passing of safety measures in the control systems of reactors. He said that such a risk had not been fully thought out. This, I thought indicated a very Russian view of the situation and would not necessarily be shared by everyone in the West.

Professor Birkhoffer then related some of the safety R&D priorities of the FDR programme. He said that the TMI accident had had a very strong effect on safety research programmes and he did not see any major changes needed following from Chernobyl. He did believe that there was a need to see whether our systems had sufficient failure tolerance. But the whole area of accident management for controlling severe accidents was one that he suggested the Germans would be very active in in the near future. He indicated that they were planning to build a simulator to test procedures more effectively so that operational groundrules could be established for managing severe accidents. Other points that he raised as being particularly important were the need for more work on the problem of plant ageing, the development of loose part monitoring systems and further automation of control systems.

The remainder of the time on this topic was taken up with remarks concerning safety goals rather than safety priorities and this was highlighted first by Vorinen from Finland who said that the first requirement was to establish targets which society was willing to accept and then set the priorities on safety research once these goals are known. Beninson of Argentina indicated that the ICRP are setting goals on risk and this could form the basis of nuclear safety targets too. There clearly seems to be a requirement for the interface between the radiological protection community and nuclear safety people to be better defined as this is the same problem that arose during the earlier meeting under the Agency auspices in February between the RP and nuclear safety people.

The Swiss made a strong point that from their point of view when setting safety targets the area of land contaminated is more important than the number of deaths. This he said came from the particular culture of a small country where a very high value indeed is placed on land and this provides a quite different perspective as to which attributes are important when trying to assess risk.

The second part of the session was devoted to advanced safety designs. Introducing this session, Siderenko argued that the future development of nuclear power would require demonstration that enhanced safety levels had been achieved. However, it was important for safety requirements not to contradict economics. He then described some Soviet work in this area going back to 1976 when energy sources for new uses were discussed. He explained that in Russia heat supply for domestic and industrial heating was more important than electricity because of their very severe winters. Further, because of the large distances involved in transporting hydrocarbons, the problem was particularly exacerbated. Hence, there was a strong need for means for district heating. They have designed a reactor specifically for this purpose which is safe enough in their terms to permit siting very close to major urban conurbations. In order to provide such

4. Safety Research Priorities and Advanced Designs

The third session was concerned with safety research priorities and advanced designs for reactors. It was chaired by Siderenko of the Soviet State Committee for the safe operation of nuclear plant.

In his opening statement Siderenko suggested that for most countries with a significant safety R&D programme, there was no basis for changing our attitude or programme following the Chernobyl accident. He said that the on-going programmes should be seen as essentially correct with no need for radical review. No new phenomena had been exposed by the Chernobyl accident which would require significant research activity. However, there were several aspects of the accident and the existing R&D programmes which indicated that some change of emphasis might be required. His comments of course were based upon his Russian background and this perhaps offers some insight into the priorities of their own safety R&D programme. The points that he particularly raised requiring further work were:

1. The formation of Hydrogen and its combustion
2. Mechanical damage and how it occurs in severe accident scenarios
3. The development of diagnostic techniques
4. The development of quantitative methods for safety assessment, including probabilistic safety assessment
5. The development of what he called the risk concept

This was not a full list but clearly represented, in the Soviets mind, the first items that come to light which they felt needed attention. In trying to express how priorities for safety research could be set he asked the question, what are the criteria against which safety R&D should be judged? He then invoked a paper from Professor Farmer dating back to a 1973 symposium, which discussed permissible levels of risk, both individual and societal. In the paper he produced suggestions for limiting figures. The Soviet interpretation of the paper was that in the societal risk area, a limiting figure of something like 10^{-3} - 10^{-4} for a major accident per reactor per year was the borderline between an acceptable nuclear power industry and an unacceptable one. Siderenko then went on to say that with 4000 reactor years behind us, the acceptable levels of risk were very near the levels that had been put forward by Farmer in 1973. Because of this we cannot admit the possibility of another accident like this in the near future and the criteria for safety R&D must be to ensure that non such can occur. He then identified two trends for priority items.

1. The study of the cause and course of major accidents and how to reduce their consequences.

2. A study of the interaction between man and machine. On the latter he emphasised the need to study the means of control for complex machines and how to neutralise mistakes made by man. He further said that there was a strong need to eliminate the by-

meeting in June had indicated the need to set up a working group to further safety standards and that a re-examination of the NUSS system with a view to implementing lessons learned from Chernobyl was justified. Particularly they were interested to know whether the NUSS documents could be transferred into some minimum safety standards. There was a suggestion that the proposals in annex 7 of the INSAG document, particularly those for a self-supporting document describing safety principles and those concerning the use of the NUSS in establishing the lessons to be learned, could be a useful starting point for discussions in this area. The INSAG document was considered to be extremely valuable as forming a basis and providing some of the nomenclature for further discussions concerning safety principles and the establishment of safety targets.

The mood of the meeting was well caught I thought by Beninson who, having been so adamant concerning the inapplicability of the NUSS to international regulation, said that it was absolutely essential to find a compromise between the political requirements and reasonableness. There was a need for a coherent safety philosophy. Existing safety philosophies were not homogeneous and it was important to put effort in to make them so. He indicated that the original idea of the INSAG group was to do what ICRP have done in the area of radiological protection and that is to evolve a homogeneous set of standards which can then be used by all countries but taking into account national needs and organisational practices. The ICRP does not give regulations, they give guidance. The idea is that national bodies can then use this guidance in setting their own regulations. This has been remarkably successful and the majority of countries adopt the ICRP guidelines for their own national regulatory requirements. This was the aim for the new work in homogenising nuclear safety standards.

There was much support for this view and the discussion was finally summarised by Rosen and he used the analogy of standards which had been achieved in other spheres which could give some guidelines as to how it may be achieved in nuclear safety. He referred to the operation of international airlines, marine transport and the post office, as having trans-boundary implications. He also said that closer to home the agencies guidelines for transport of radioactive materials and the requirements on transport flasks had been widely taken up by a number of countries and implemented in their own regulations. His point was that international standards could be laid down but they always had to be implemented by national governments. There seemed to be, at this point, a difference in semantic interpretation on what was meant by a binding standard and regulation. Clearly, one of the first activities of any group set up in this area will be to establish an understanding of just what is meant by international regulation and standards and if it can be established that the practices evolved in some of these other spheres are relevant to nuclear safety then my view is that there is a good chance that internationalisation of nuclear safety and homogenization of standards is a real possibility.

3. Design
4. Operation
5. Quality assurance

Some 60 documents have now been produced over a period of 10 years which represent a major source of information on safety standards. Furthermore, these documents represent the consensus of all the countries that were involved in their preparation. This was ensured through the operation of SAG (Senior Advisory Group). The requirement to get consensus made for a very lengthy process producing these documents, 4-5 years was not unusual in order to get agreement. The SAG held its final meeting in 1985 and came to the conclusion that there was no need for any substantial revision of the documents at that time but that future developments of the technology may mean that some revisions are necessary. They set up the NUSSAG group which was intended to oversee any implementation and revision of the NUSS documents. Some countries use the NUSS outright in their regulatory processes whereas others take them purely on an advisory basis. For example, Italy and Argentina have adopted the quality assurance procedures lock, stock and barrel and Pakistan for nuclear regulation. There is no requirement of course that these documents have to be included in any national regulatory process.

Konstantinov summarised the situation concerning NUSS and essentially made the proposal that these documents form the basis of a binding requirement on countries for a minimum set of nuclear safety standards. This proposal caused a great deal of interesting and heart searching discussion amongst the delegates concerning the question of whether there should be binding international standards. This may be summarised by saying that there are two differing and apparently irreconcilable requirements in this area. The first as expressed very eloquently by Beninson from Argentina, no country can be expected to give up its sovereign right to determine the safety standards which it would require of its own plant. He said that it was inconceivable that a national authority would take the NUSS as an international standard. He said that the NUSS represented a minimum so far as safety requirements were concerned and that certainly his country would never consider these to be adequate as a means of regulating safety. However, the opposite view was put by the Federal Republic of Germany. Here, Ragod from the FRG said that whilst for the professionals the idea of international safety standards might be very difficult, from their political standpoint it was absolutely vital that the public saw that there was an internationally accepted level of safety standards to which all plant were designed. Furthermore, it was important that that level be the highest level possible. He did say that a consensus meant that that represented the minimum standards but of course a politician would actually express that as the highest level possible. This difficulty between the technical requirements for standards and the need to demonstrate public acceptability was not resolved of course at this meeting. But the discussion at this level at least indicated that all facets of the problem were well understood and that there was a will to make progress in this very difficult area. It was pointed out that the Board of Governors the decision making process involved those first early decisions during the acute phase of a serious accident. He was very firm in indicating that the most important requirements were for considerable thought to be given to specific intervention levels which must be set up before an accident occurs. This is so that the people involved on the spot in dealing with the acute phase of a very serious accident have specific guidelines laid down for them which then they can implement immediately. Coming through his presentation seemed to be a story that they had had difficulty themselves in knowing what to do because no-one had seriously thought about what sorts of radiation dose levels should form the basis for extremely serious and wide-ranging intervention activities. It is extremely important to recognise that the intervention levels have to be geared to the practicability of the measures and other risks involved. Thus, if intervention at a very low dose level is easy to implement and involves no risk to people then that intervention can be taken at a very low dose level indeed. Examples of this would be issuing iodine tablets or interdicting particular items of food. However, at some point very serious intervention may be called for, for example, mass evacuation or the banning of very large amounts of agricultural food stuffs. In that case, the level at which intervention would be instigated would be higher than if there were little risk in the implementation of the intervention levels. This was a point taken up again by Beninson who said that there should never be a reference to intervention levels without the practicability of those levels being implemented and being stated at the same time.

An interesting presentation on the environmental impact of the Chernobyl accident on Poland was given and the data was made available in the information for the meeting. In this discussion it was interesting to note that whilst the countermeasures put into place in Poland only reduced doses by about a factor of 1.5 in adults and were therefore questionable, reductions of about 4+ times in dose to children and infants were indicated and this was felt to be a very worthwhile reduction as a result of countermeasures introduced in that country.

Carter from IEAL, USA then gave a presentation on early warning systems for accidents at nuclear power plants. This was a very professional presentation giving the background to the siren and tone alarm systems being implemented for all US nuclear power stations. Again all the information is available on overheads which were handed out at the meeting. A number of NUREG documents referenced in that material indicate the basic requirements for emergency planning and particularly for local implementation in the US. These include the establishment of the 10 mile zone for warning and the design objectives of the early warning systems.

Review of the NUSS

The NUSS (Nuclear Safety Standards) was established in 1974. The aim was to provide an integrated set of standards for:

1. Government organisation
2. Siting

were exceeded. Quite a bit of the discussion was based upon how to interpret upper and lower levels for intervention but one of the talks later brought this into sharper focus.

The discussions on this general topic of administrative response to radiological emergencies centred around interpretation of of ICRP limits and the need for emergency plans. The latter was the subject of a separate discussion later. There was a suggestion that the Agency could host an exchange of information on local planning activities so that a beneficial exchange of views could be held. There was much discussion concerning difficulties in evacuating people, particularly from rural areas where there were quite different aspects and the psychology of evacuation other than in urban areas. In fact it was suggested that it was essential that plans were laid to evacuate animals as well as people from rural communities. A further point of discussion was how essential the response of the media was in defining the public response to accidents. This may not be important in the acute phase of evacuation or emergency intervention close in to a plant, but would certainly be important in the long term or long range implementation of intervention levels on milk or other foodstuffs for example.

A presentation was made by Harry Aitkin of Canada who advises the Government of Ontario on matters related to radiological protection. This was a rather pedantic and long winded lecture, the overheads of which are available. He tried to advertise the use of decision theory in applications to emergency planning but I suspect had not been properly briefed on his audience and was pretty well torn apart, particularly by Beninson who proceeded to instruct him on what the ICRP had done on these topics over a large number of years.

A very interesting presentation was made by Vorinen from Finland in which he described intervention level discussion within the Scandanavian countries which had taken place at a convention in Reykajavik in Iceland and which had led to consistent intervention levels being laid down for the Scandanavian countries. This again, is available on overheads referred to in the annex. His presentation was augmented by that from the delegate from Sweden who then indicated the consequences to Sweden from the Chernobyl release. He indicated that the total collective dose in Sweden was estimated to be approximately 3000 mSv with the most exposed group receiving a few mSv. He did indicate the particular difficulties in the Laps where their consumption of reindeer meat was so high that if nothing had been done their dose could have gone up to tens of mSv per year, hence the need to ban reindeer meat. He said that confusion in peoples minds had been introduced by having different action levels in different countries and the fact that an interdiction level had often been interpreted as an absolute level and this had led to worry when people failed to understand this. He called for more education for the public so that they could understand the position being taken by local authorities when it came to interdicting foodstuffs.

Siderenko indicated that the most difficult and important part of trips led to failures of equipment in addition to the trip and that this was something that required further consideration by utilities.

The final discussions included a suggestion from Sweden that since they had agreed to an Osart mission to the Baresebeck plant in September, would it not be possible to extend the concept of Osart missions to include regulatory authorities. This proposal was not followed up by any other delegates at the meeting at the time and it will be interesting to see whether the secretariat include this in their reporting of this meeting. Finally, Konstantinov advertised the fact that a large conference on the man-machine interface had been arranged by the agency to be held in Japan in 1988 and this would form an important aspect of the agency's programme in this particular aspect of operational safety.

3. Radiological matters and emergency planning

This session was chaired by Danyich from Budapest. In his introductory remarks his main point was that the public were not interested in the intricacies of the accident itself, why it happened and what went on in the reactor, they were more concerned with what to do in the case of emergency. Experience had not been good in that in many countries there had been confusion and conflicting advice to the public. He said that he thought that this aspect of reactor accidents was the most important.

The first formal presentation in this session was by Pretre from Switzerland. He described the Swiss response to the Chernobyl radiological emergency and in a very comprehensive series of overheads he showed the breakdown of Swiss arrangements to deal with such eventualities. They have 9 laboratories which were brought into play and did some 10000 - 15000 samples during the period April - June. They have a series of automatic continuous air measuring systems around the borders of Switzerland and also close to their nuclear power plants. The dose rates in Switzerland lay in the range 20 - 180 μR/hr and their problem really was what action they should take. This was described quite extensively on overheads which were made available and are included in the list in the annex. He indicated that the maximum doses in the Swiss population were between 1 and 2 mSv whilst the averages doses were of the order of 0.15 mSv. The latter being equivalent to approximately 1 medical X-ray. He made an interesting comment at the end of his presentation and that was that Switzerland, being surrounded by several other countries, was inundated by information coming from outside media sources, particularly foreign television stations. He said that they received very conflicting information from this source where, for example, in France the whole thing was played down whereas in Germany and Austria minute details of information concerning the effects of radiation on people were presented night after night. The speaker made quite a strong attack on the ALARA principle since this he believed was not understood by the public and it was very difficult indeed to explain that intervention levels were there for administrative reasons and not because there was a serious risk of deleterious health effects if the minimum values systems currently in operation should aim at the third level where general trends could be identified and this might be particularly important when it came to human intervention and operator actions. The transportability of experience was the basic topic of this presentation and forms really the heart of the possibility and practicality of any IRS system set up for the pooling of international experience in reactor operations.

Professor Birkhoffer from GRS then presented reflections on operational experience and indicated that a whole range of incidents and reports had led to specific design changes and operational practices on plant in Germany. To implement further work he said that the Federal Government had ordered a review from all operators to ensure that plants meet the required safety levels and particularly that any modifications which had been made to the plant since they were constructed, had been adequately considered so far as safety implications were concerned.

Several further interventions and discussions then took place, emphasising the basic requirements of operational safety, supporting Cogne's contention that understanding was more important than strict regulation and that the overall safety culture was really vital in ensuring the safe operation of nuclear plant.

Voregnen from Finland introduced a new insight into the Osart visits when he said that when Finland had been visited last March, they had discovered that an Osart mission was extremely time consuming both for the utility and for the regulatory body, especially for a country like Finland which had very limited resources in this field. Notwithstanding that he said that afterwards they still considered that it had been a beneficial experience. He also indicated the changes that had been made to the Finnish nuclear programme in the wake of the Chernobyl accident and these are referred to in the list of documents in annex III to this report.

Jennekens from Canada then introduced a rather more formal note by saying that whilst Canada supported the conventions which had been signed the previous week, they noted that a resolution had been placed before the Committee of the whole to set up a group to examine the question of what was meant by significant events in the context of the notification system.

Siderenko of the USSR raised the rather detailed question of spurious trips and the design of the logic of reactor protection systems. He indicated that this had been a particular problem in the USSR and this could provide some insight into why the tests were being done on Unit 4 at Chernobyl. He admitted that the Soviet Union had had difficulty with the problem of spurious trips and the design of the logic systems for RPSs and this could be an insight into some of the problems they have had with their nuclear power programme in general.

Denton of the USNRC supported the view that spurious trips were important and said that in US experience, 1:10 of all spurious strong point that with a standardised programme of reactors the requirements for operational safety were rather different from countries where there were many different kinds of reactors and indeed made the international problem of intercomparisons between different reactor designs and national practices even more difficult to utilise properly. He explained that in the French system they assume that the operators are motivated to be involved in the whole spectrum of activities relating to the safe operation of the plant and in particular that they have to understand the processes going on in the reactors and not just implement a series of instructions which have been set up by others. He explained that he thought that the real problem was setting up a considered screening system so that out of the very large amount of information which could be generated only that which was really pertinent and important to operators was presented to them. He went on to say that even within the OECD system operating as it did a wide range of different reactors, the usefulness of data when transmitted across reactor types and national practices was very limited indeed.

Medina from Mexico described their experience as a developing country with Osart missions. They are currently building two 600 MW boiling water reactors and they are planning fuel loading in 1987. They are following very closely the IAEA guidelines as laid down in the NUSS series of documents. The operators in Mexico have degrees in engineering and are considered to be highly educated. He reported that a simulator was being built. He said the IAEA had played a very large part in assisting the preparations for this country's embarkation into the nuclear power era. The Osart missions had been helpful and another Osart team was due to visit the country next January. On the question of safety goals, he intimated that for most developing countries all they could do was to take on board the safety goals or criteria or standards from the vendors home country.

Sennis from Italy spoke principally on the incident reporting system. He indicated the need to learn from experience and the possible usefulness of data concerning abnormal occurrences if they were properly interpreted. This included the detection of precursors to accident situations. He indicated that there were three levels of information which could be exchanged on an international basis.

1. On a detailed level data relating to the operations of particular plant were available. These were really only of value to plant identical to each other and operated under the same overall procedural rules.

2. Plants with similar technology or design. He said that after some screening it could be possible for useful information transfer between such plant.

3. The wider use of data bringing in more diverse plant to form the data base was much more difficult. Here, only the most global or generic lessons could be expected to be transferrable from one plant or country to another. He indicated that the international

say however, that Italy had offered the Latina plant for an Osart mission in 1988. However, it was pointed out that there were no plans for Osart missions to other gas reactors, LMFBRs, HTRs, etc. It was difficult to know whether the presenter of this talk was trying to make a particular point or was simply making a statement of fact. He said that although there had been missions now over a period of 3 years it was too soon to give general insights and conclusions as to differences which the teams had found in the safety culture in the different countries that had hosted Osart missions.

The second topic introduced by the IAEA secretariat was the incident reporting system. Here the need to make full use of the 4,000 or so reactor years of experience now available had become highlighted by the Chernobyl accident. However, in order to make the data more useful it had to be compatible with that used by national programmes and with other international activities particularly that of the NEA. In 1985 it was reported that 51 reports were issued for inclusion into the IRFs but that it was now important to consider the identification of generic issues which are of use for all plants out of the large number of pieces of data which are rather plant specific. This point was taken up by several interventions from the floor later on.

The meeting then continued with a series of pre-planned presentations from the floor presumably which had been agreed with the Chairman beforehand for presentation. The first of these was by Holander from Sweden. He was the Director General of the Nuclear Power Inspectorate in Sweden and he chose to introduce his personal views on the strengthening of international collaboration on nuclear safety matters. His principal point was that safety is a matter of attitudes and this depends upon the management, the operational crews and the whole range of people and activities involved in running a nuclear power station. Regulation itself cannot make for the safe operation of plant. He said that since there was no competition between utilities in different countries then they should be able to co-operate very fully. It was pointed out that there are various groupings of utilities which do do such co-operative activities. He went on to indicate some of the activities in Sweden for example the reliability evaluation programme to indicate collaboration between Government and utility in trying to improve the general safety standards both for regulators and for operators. His principal point was to indicate that Sweden wished to see the setting up of international safety levels and he interpreted the INSAG proposals for basic safety principles as meaning quantitative safety goals. Later in the meeting he tended to retract from this very hard line and this is covered in the sections concerning the use of the NUSS system of the IAEA. Finally, he made a very strong plea for international efforts for the design of a new generation of power plant utilising inherently safe features. This was due as an item on the agenda for the second morning and was not taken further at this time.

Cogne, Director of IPSN then made a presentation from the floor on the operational safety approach in France. He made the very the special meeting and the Board of Governors meeting. He was confident that by the November meeting of Experts a smaller number of proposals would be available for discussion. He was not able to say when this smaller set of screened proposals would be available for national consideration prior to the meeting of experts.

Rosen said he was pleased to note that out of 33 countries currently operating nuclear power stations, 26 were actually represented at this meeting and that in fact only 5 countries would not be represented in practice because neither Taiwan nor South Africa would be expected to be present at such a meeting. The representation around the table was at quite a high level, the USNRC were represented by Chairman Zech, the USSR by Siderenko, Deputy Chairman of the Soviet State Committee on Nuclear Safety and most other countries were represented at a similar sort of level with France for example, fielding Cogne, the Director of IPSN.

The Russian video of the Chernobyl accident was shown again and in response to a request from the floor for information on the availability of this tape, Konstantinov indicated that difficulties with copyright prohibited the further dissemination of the film outside the IAEA. However, he said that any groups meeting within the IAEA auspices could ask to see the video which is worth noting for UK staff when attending meetings in Vienna that they could seek permission to see this video during those visits. It is certainly well worth seeing to bring home the enormity of the accident. The question was raised concerning the status of Unit 1 at Chernobyl. Rosen indicated that he believed that it was now back on power but Siderenko was unable to confirm this. This was a strange exchange with Rosen's source seeming to be the newspapers but this could not be confirmed by the very senior USSR delegate from the Committee.

2. Strengthening International Co-operation - Operational Safety

The Chairman for this session was Zech of the USNRC. He introduced the session by highlighting the importance of operational safety as it underpinned all aspects of the safe operation of nuclear plant, including the concept of the safety culture. He took advantage of announcing that the US had recently licensed its 101st plant. (Denton later confirmed to me that this was the Clinton Illinois plant). Zech chose to illustrate his belief in the importance of operational safety by saying that he had personally visited some 64 nuclear power plants during his time as a Commissioner for the USNRC prior to his elevation to Chairman of that body.

The first presentation was by an IAEA staff member concerning the Osart programme. This is outlined in a document which is referred to in annex III which lists all of the documents presented at this session and is not repeated here. He indicated that the calls upon the IAEA for Osart visits was increasing and these had concentrated primarily on the PWR and BWR type reactors. He did interpretation of the uncertainties in the data.

Rosen went on to explain that the expanded programme of the Agency was for about $2 million more which may be seen as an increase of about a third over the existing budget of $6 million (not including voluntary contributions). This expansion he said would involve hiring 15 new professional staff to cover nuclear safety and radiological protection.

He indicated that the two conventions ratified at the special meeting of the Board of Governors in the previous week, had now been signed by over 50 countries.

He announced that a new response unit would be set up which would have 3 main areas of work:

1. To compile lists of competent authorities and available resources in member nations. These resources would include both materials and experts.

2. The collection and dissemination of data.

3. Co-ordinating assistance if required - possibly extended to sending experts to sites for specific systems.

Rosen explained that the discussions concerning the expanded programme were not yet finished but that the Board of Governors had indicated that it would support this increase in the programme at least in principle. He then went on to specify the timetable for further meetings during the autumn which would finalise the decision making process.

1. There would be a meeting of experts in November and this would look at the priorities and the resources required internationally to implement the proposals. This would include a wide range of topics some of which were discussed in more detail later in this meeting especially that concerning the unification and homogenization of safety standards.

2. The Scientific Advisory Committee of the IAEA would meet in early December and consider these proposals.

3. There will be a special meeting of the Board of Governors in mid-December specifically to approve the identified programme.

You made it clear that any further comments on the programme and the proposals could still be introduced into the decision making process. I spoke to Rosen privately and he confirmed that the draft terms of reference which had been circulated during the special meeting had not been ratified but in his opinion would not be changed significantly for the expert meeting in November. A draft version of these early proposals is included as annex II to this report. He also said that prior to the November meeting there would be some rationalisation of the proposals coming from the INSAG document, the expanded work programme as proposed by the IAEA secretariat and any resolutions and suggestions coming from

Note for the Record

Special Session for Safety of the Meeting of the Board of Governors of the IAEA, 2-3 October 1986, Vienna

This meeting had been overtaken by the intense activity of the Agency in post-Chernobyl activities. M Rosen explained that the original plans to have an afternoon scientific session on decommissioning and decontamination had been planned before the accident at Chernobyl in April. However, that session had gone ahead and a series of papers were presented. I was not present at that meeting but have a full set of papers, the titles and authors of which are given in Annex 1 and are available in request. Rosen continued by saying that the review of the nuclear safety programme of the IAEA which formed Item 1 of the agenda, would be taken rather quickly and that most of his introductory remarks would be addressed to the post-Chernobyl activities being planned for the Agency. He began by introducing several documents.

1. Introduction - Nuclear Safety Review

The INSAG experts report following the information meeting is now available as a printed document in the IAEA safety series No 75, INSAG-1. This he said, would be the format for future INSAG reports, this being the first. They are readily recognisable by the fact that they have a garish purple cover. He said that the second document in this series would be an INSAG report on the source term. The second document he brought to the meetings attention was the 1986 bulletin of the IAEA. This in fact is volume 28, number 3. This he said had been produced with particular emphasis on safety and included many interesting articles on that topic.

He introduced a document by UNEP (United Nations Environmental Programme) entitled: Radiation - doses, effects, risks. This was meant for the educated public and seems to be quite a good exposition of the effects of radiation on man. It is along the lines of NRPB's "Living with radiation" but rather more comprehensive in its coverage.

The third document he introduced was a Finnish report concerning itself with the comparative risks between nuclear and fossil fuels. Whilst the title indicates that it is a bibliography, he suggested that it was far from that and it actually lays down the guidelines showing the basis upon which comparisons could be made. This he said was particularly important to avoid comparing apples with oranges. The document was based upon comparisons between the supply of 1000 MW of electricity. The basic conclusion to the document were that occupational risks were relatively small and this applied to coal, nuclear and oil. However, it showed that the public health effects of electricity generation are not similar for these different sources of supply and that the gap between nuclear and other forms of producing electricity is very wide indeed. Rosen seemed very impressed by this document, particularly because it gave what he thought was a realistic

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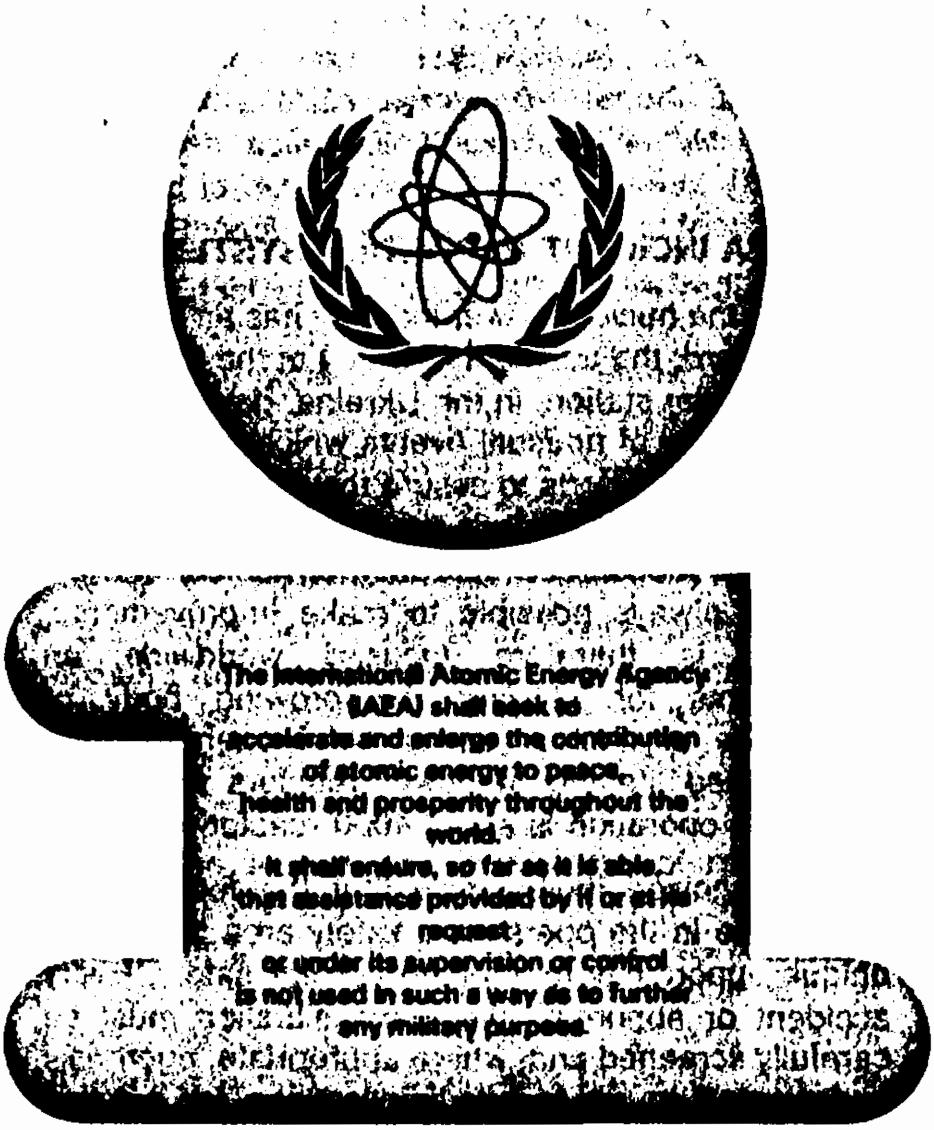
Annex 6.B



The International Atomic Energy Agency (IAEA) shall seek to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world. It shall ensure, so far as it is able, that assistance provided by it or at its request or under its supervision or control is not used in such a way as to further any military purpose.

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THE IAEA
INCIDENT REPORTING SYSTEM
IAEA-IRS

information

THE IAEA INCIDENT REPORTING SYSTEM

Although the nuclear power industry has an excellent safety record, the accident at Unit 4 of the Chernobyl nuclear power station, in the Ukraine, gave evidence of the severity of unusual events which can occur in nuclear plants. Efforts to assure the safe operation of nuclear facilities of all kinds continue to be a prerequisite for the widespread utilization of nuclear energy; and it is always possible to make improvements. Attention is therefore focused worldwide on mechanisms for utilizing the growing body of experience of nuclear power plant operation: the accumulated lifetime of power reactors which are already in operation is about 4000 reactor-years.

It is recognized increasingly that the feedback of experience in the operational safety area provides a unique opportunity to improve nuclear safety. Every accident or abnormal event and situation must be carefully screened and, where appropriate, rigorously investigated to assess its implications for existing system design, equipment design and quality, operator training, computer models of the system, operator training simulators, plant procedures, safety systems, emergency measures, management and regulatory requirements. Implementation of the lessons learned from operational experience improves not only plant safety, but equipment reliability and plant availability.

Systems have been set up in many countries to collect, analyse and disseminate information on safety-related events and situations in nuclear power plants. The International Atomic Energy Agency has recognized the advantages to be derived from joining in the various national and international efforts to exchange operational experience worldwide, and has established an international Incident Reporting System (IAEA-IRS) to complement national systems. In a two-fold approach, the IAEA is assisting Member States in establishing, improving or harmonizing their national systems for collecting, assessing and disseminating safety-related operational experience; and operating the IAEA system for reporting unusual events with safety significance. The IAEA-IRS is described in detail in the IAEA document *The IAEA Incident Reporting System*, published in March 1983.

The end goal of the IAEA-IRS is the reduction in frequency and severity of safety-significant unusual events occurring in nuclear plants. Information about such events is shared with all participating countries. The reporting arrangements include an effective system to ensure that information is used only for official purposes; it is not available to unauthorized persons. A participating country may classify any part of the information it sends as confidential, thereby imposing further restrictions on its distribution. The IAEA-IRS is operated in co-operation with regional organizations such as the Nuclear Energy Agency of the OECD, which has its own system (NEA-IRS).

The routine receipt and distribution of reports on incidents form the basis for in-depth studies on implications and remedies, and also assist in the identification of issues common to certain or to all nuclear power plants. Identification of generic issues commences with national assessments, and the issues are then studied in depth by experts at meetings convened by the IAEA. On request, the IAEA will assist Member States not only to establish and maintain suitable national reporting systems, but to review operating records and to perform assessments of safety-significant events.

Participation

It is assumed that a Member State which wishes to participate in the IAEA-IRS:

- will have embarked on a nuclear programme;
- will have established or intend to establish a regulatory body with the authority necessary to regulate the safety of nuclear power plants (as

described in the IAEA Code of Practice, *Governmental Organization for the Regulation of Nuclear Power Plants,* Safety Series No.50-C-G);
- will have established or intend to establish a national system along the lines set out in IAEA-TECDOC-278, *National Systems for the Collection, Assessment and Dissemination of Information on Safety-related Events in Nuclear Power Plants,* in which it is recommended that the regulatory body of the Member State require operating organizations to report safety-related unusual events;
- will give or have given an appropriate organization, usually the regulatory body, the responsibility for sending information on incidents to the IAEA.

The IAEA would consider proposals to vary the interpretation of the basic IAEA-IRS document if not all these assumptions held true in the case of a particular Member State, as long as the fundamental principles of that document were not compromised. In such a case, the IAEA would inform all participants of the agreed interpretation. However, a Member State should seek to participate in the IAEA-IRS normally only after it has made satisfactory arrangements to meet all requirements of the system.

A Member State in which there are no nuclear power plants in operation, but which plans to participate in the IAEA-IRS, should contact the IAEA about a year before its first nuclear power plant enters service for advice on the arrangements it should make to set up its own national incident reporting system, and on the way in which information should be sent to the IAEA.

Principles

If the IAEA-IRS is to function effectively, each participating Member State must commit itself to send to the IAEA relevant information about safety-related incidents which occur in nuclear power plants in its territory.

Incident reports to be sent to the IAEA should be selected on the basis that they are considered likely to be of general interest to the international nuclear community — whether this is because important lessons can be learned from them, new aspects of safety have been discovered, or hitherto unsuspected inter-relationships between events have been revealed. Further guidance on the selection of reports appropriate for distribution through the IAEA-IRS may be derived from a study of reports actually distributed by the IAEA.

The IAEA expects reporting organizations to send incident reports as soon as the necessary data are available: in general, not later than about four months after an incident has occurred. The IAEA passes on requests for supplementary information to the appropriate co-ordinator for action.

The IAEA passes on incident reports or follow-up reports to all participants in the IAEA-IRS as soon as they are received. All such information is channelled through a national co-ordinator, designated by reference to his position in the national organization. At their discretion, co-ordinators distribute information to governmental and non-governmental organizations for official use. Recipients of such information shall not distribute it further.

If a participant wishes to place special restrictions on the distribution of any part of the information it sends to the IAEA, it may mark those portions confidential. National co-ordinators are required to ensure that such confidential information is distributed only to organizations specified by the participant sending the information. The IAEA removes restrictions placed on the distribution of information only with the consent of the participant sending the information.

To review the information received in the IAEA-IRS, and the operation of the system in general, the IAEA convenes a Technical Committee meeting at least once a year. Reports are first considered by a Working Group, then passed to the Technical Committee for further consideration. The Committee selects for further analysis reports of those events which it considers to be of particular interest to the international community. Its conclusions are distributed to all countries participating in the IRS.

Joint IAEA/NEA meetings for the exchange of information on abnormal events have been held annually since 1983. These meetings have an important role in strengthening mechanisms for the exchange of experience in the assessment of incidents and in improvements made to reduce the probability of similar events occurring in future.

National systems

The IAEA-IRS can exist only in close connection with national systems through which operating organizations can report unusual events to their own regulatory bodies. The IAEA issued guidelines for the establishment of such systems (IAEA-TECDOC-278, *National Systems for the Collection, Assessment and Dissemination of Information on Safety-related Events in Nuclear Power Plants*) in 1983.

National reporting systems are an important element in work to improve the safety of nuclear power plants, because they help regulators to evaluate the performance of operating nuclear power plants. In turn, feedback from regulatory organizations can be made available to organizations which are responsible for operating, designing and manufacturing nuclear plants, and for safety research. The objective in both cases is to reduce the frequency and severity of unusual events, and to give added assurance that structures, systems and components which are important to safety will perform adequately.

National systems should therefore be designed to make it possible to:

- identify, assess and report on unusual events, and to ensure that appropriate organizations receive feedback enabling them to enhance operational safety

- correlate unusual events which may not be significant individually, . taken together indicate that a problem of significance to safety may exist
- by applying lessons learned, reduce the frequency of unusual events, and hence increase nuclear power plant availability, and
- reduce the probability of severe accidents which might have consequences which could be significant to public health and safety, or the economics of power plant operation

Reporting requirements and procedures should specify the types of unusual event reports which should be recorded; channels of communication; and formal requirements, such as formatting and the time intervals within which reports should be made.

The operating organization should report to the regulatory body any event that it judges to be safety-related, in the following categories:

1 Exposure to radiation or release of radioactive material:
  a exposure to radiation that exceeds prescribed dose limits for personnel on site, or members of the public, or
  b releases of radioactive material that exceed prescribed limits whether they are confined to the site or extend beyond it.

2 Degradation of items important to safety:
  a fuel cladding failure, or
  b degradation of the primary coolant pressure boundary, main steam or feedwater line, or
  c loss of containment function or integrity, or
  d degradation of systems required for reactivity control, or
  e degradation of systems required to control system pressure or temperature, or
  f degradation of essential support systems.

3 Deficiencies in design, construction, operation, quality assurance or safety evaluation

4 Events indicating generic problems

5 Events requiring significant consequential actions

6 Events of potential safety significance

7 Unusual events of either man-made or natural origin that directly or indirectly affect the safe operation of the plant

8 And, optionally, events that attract significant public interest.

There is no formal requirement for a certain number of events to be reported in any given year: the number of reports obviously depends on the frequency of events, and may be affected by factors such as plant design, plant age, and operating practices. In some Member States where a reporting scheme similar to that described here is in use the number of reports ranges from 10 to as many as 50 events per year per operating unit. It is envisaged that a report of an unusual event at an operating unit will be considered important enough to be sent to the IAEA only once a year, or once in two years.

Unusual event reports are required to be comprehensive, and to be set out in an orderly and consistent manner. Each report should include:

1 A cover sheet giving basic information such as the name given to the event, date, name of plant, abstract, basis for reporting

2 A narrative description (with relevant plant data and drawings)

3 An assessment of the causes, consequences and implications of the event

4 And a description of corrective actions taken or planned.

The regulatory body should store unusual event reports in such a way that the information they contain can be easily sorted and retrieved for evaluation. It should be possible to make searches for:

1 Similar fault modes, events with similar sequences, multiple independent faults and so on

2 Similar events or occurrences at similar units

3 Faults by system or component involved

4 Trends or patterns

5. Events having similar consequences to the environment or personnel
6. Common-mode faults
7. Events involving similar personnel errors.

Unusual event reports should be screened at the national level to select those which warrant detailed evaluation and comprehensive study, to identify valuable "lessons to be learned" and to enable this information to be fed back to personnel engaged in nuclear power plant operation, construction, manufacture, design, safety analysis and research.

The assessment of unusual events should be sufficiently thorough to give confidence that their safety implications have been fully understood, that their causes have been correctly established and that appropriate corrective actions have been identified. Each event should be assessed as soon as possible after it occurs, and in more detail later. Assessments may be carried out by plant personnel and by personnel from other parts of the operating organization, by system or component designers, and by the regulatory body.

Corrective actions could include those related to:

1. Operating, testing, calibration, maintenance or inspection procedures
2. Operating margins
3. Component design or location
4. System configuration or location
5. System or component reliability
6. Safety analysis methods and assumptions
7. Safety design standards
8. Regulatory processes
9. Design methods
10. Construction methods.

To ensure that each national system is as effective as possible, information concerning unusual events, including evaluations, should be disseminated to such other interested groups as:

1. Governmental organizations with responsibilities related to nuclear power

2 Utilities planning or already running nuclear power programmes

3 Vendor companies (design firms, engineering contractors, manufacturers and so on)

4 Research establishments

5 Technical universities.

The organizers of national reporting systems should consider co-operating closely with other existing or planned unusual event reporting systems, established by international organizations or in other countries, in order to benefit from other Member States' experience. They should make appropriate provision to store reports which they receive from other countries or international organizations, in a form compatible with that of national and international systems.

Selection and transmission of significant safety-related unusual events to IAEA-IRS

Participants should screen reports on safety-related unusual events which have been prepared to meet the requirements of the national system, identify incidents which are of general safety significance, and transmit them to the IAEA as quickly as possible: the more important the incident, the sooner the report should be sent. Each report should indicate whether the urgent attention of other participants is recommended. Follow-up reports should be sent as soon as possible if it is necessary to add or to modify details previously supplied.

Incident and follow-up reports sent to the IAEA-IRS may be written in a free style, edited only enough to make them comprehensible to readers not familiar with terms and abbreviations used locally. Preferably, the language used should be English, or one of the other official IAEA languages (French, Russian or

Spanish). In any case the abstract should be in English. If translation from other languages is necessary, but may cause undue delay, then the report should be sent in the original language with an abstract in English. In such a case, the translated text should be sent as soon as possible.

If information is already in a form suitable for computer storage and retrieval, the participant should discuss with the IAEA methods by which the national system may be harmonized with the IAEA-IRS. The IAEA may then be able to accept information sent by the participant in this form. This would facilitate the exchange of information and reduce the effort needed.

Receipt and distribution of information

As soon as the IAEA receives an incident or follow-up report, it sends it (observing any restrictions) to all participants in the IAEA-IRS. Supplementary information requested by a participant is normally passed on in full only to that participant, but an abstract is sent to all participants.

The incident reports received by the IAEA include all the information listed earlier as being required for the effective operation of a national system. Additionally, it is now recommended that incident reports should include a separate section on lessons learned, and indications of the cause of the incident, the effect on operation, type of failure and other characteristics of the incident (watch list).

There are special procedures for the confidential and restricted handling of IRS information in the IAEA. Full reports and supplementary documents are stored in written form. Essential information is also stored on the IAEA computer, in such a way that analyses can be performed to identify problem areas.

HOW TO ORDER IAEA PUBLICATIONS

An exclusive sales agent for IAEA publications, to whom all orders and inquiries should be addressed, has been appointed in the following country:

United States of America
Bernan Associates - UNIPUB
10033-F King Highway
Lanham, MD 20706

Orders originating from other countries may be sent to:

Division of Publications
International Atomic Energy Agency
Wagramerstrasse 5, P.O. Box 100
A-1400 Vienna, Austria

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Annex 5.C

The International Atomic Energy Agency
(IAEA) shall seek to
accelerate and enlarge the contribution
of atomic energy to peace,
health and prosperity throughout the
world.
It shall ensure, so far as it is able,
that assistance provided by it or at its
request
or under its supervision or control
is not used in such a way as to further
any military purpose.

INTERNATIONAL ATOMIC ENERGY AGENCY

A-1400 VIENNA • WAGRAMERSTRASSE 5 • AUSTRIA

OSART

IAEA OPERATIONAL SAFETY REVIEW TEAMS

Information

IAEA ADVISORY SERVICES

The International Atomic Energy Agency (IAEA) has a long-standing reputation for effective co-ordination of the exchange of nuclear safety technology between Member States. It provides various advisory services upon request:

- sending missions composed of a small number of experts for periods of time ranging from two or three days to a month, or
- assigning individual experts for periods of from about a month to as long as a year to the requesting country.

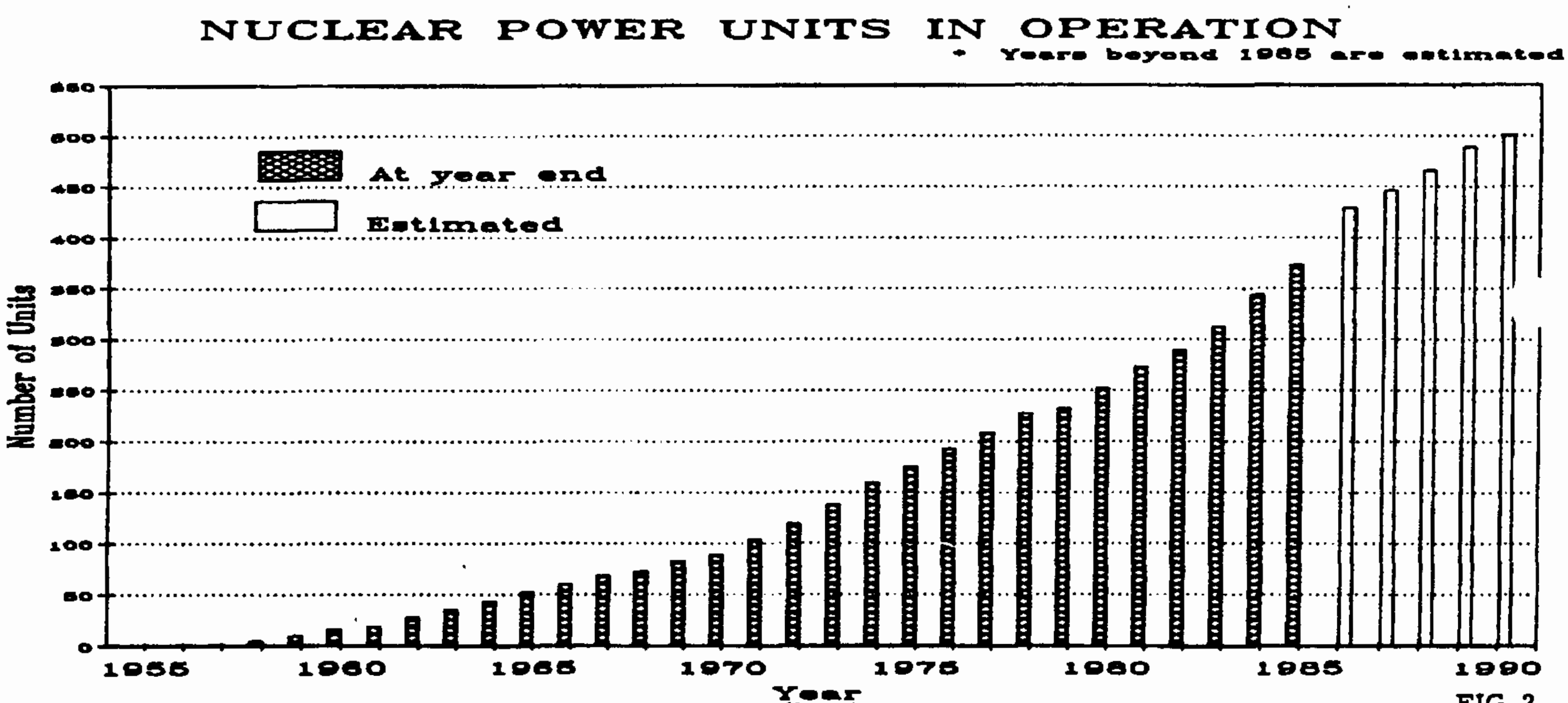
Individual experts are usually provided to assist in the resolution of specific problems affecting nuclear safety. They may help, for example, in the review of construction quality assurance programmes, or in the preparation of a commissioning test programme. The larger missions are generally devoted to broad tasks such as making independent safety reviews of plant construction or licensing preparations.

In the past, the most frequent requests for IAEA advisory services concerned matters such as:

- organization of a regulatory body within the government structure
- site survey, site evaluation and review of site-related design bases
- safety reviews required for licensing purposes
- evaluation techniques to be used in analyses of the safety of nuclear facilities
- general conclusions to be drawn from incidents reported and assessed to avoid recurrence
- measures required to arrange for appropriate emergency planning and preparedness.

Today, however, the number of new nuclear power plants under construction is decreasing (Fig. 1). At the same time, as new plants come on-line, the cumulative operating time of reactors is increasing dramatically (Fig. 2). Therefore, the attention given to nuclear safety is shifting from constructional and design concerns toward operational safety concerns.

In 1982, to meet the increasing needs of Member States in this area, the IAEA announced the availability of Operational SAfety Review Teams (OSARTs).



NUCLEAR POWER UNITS IN OPERATION

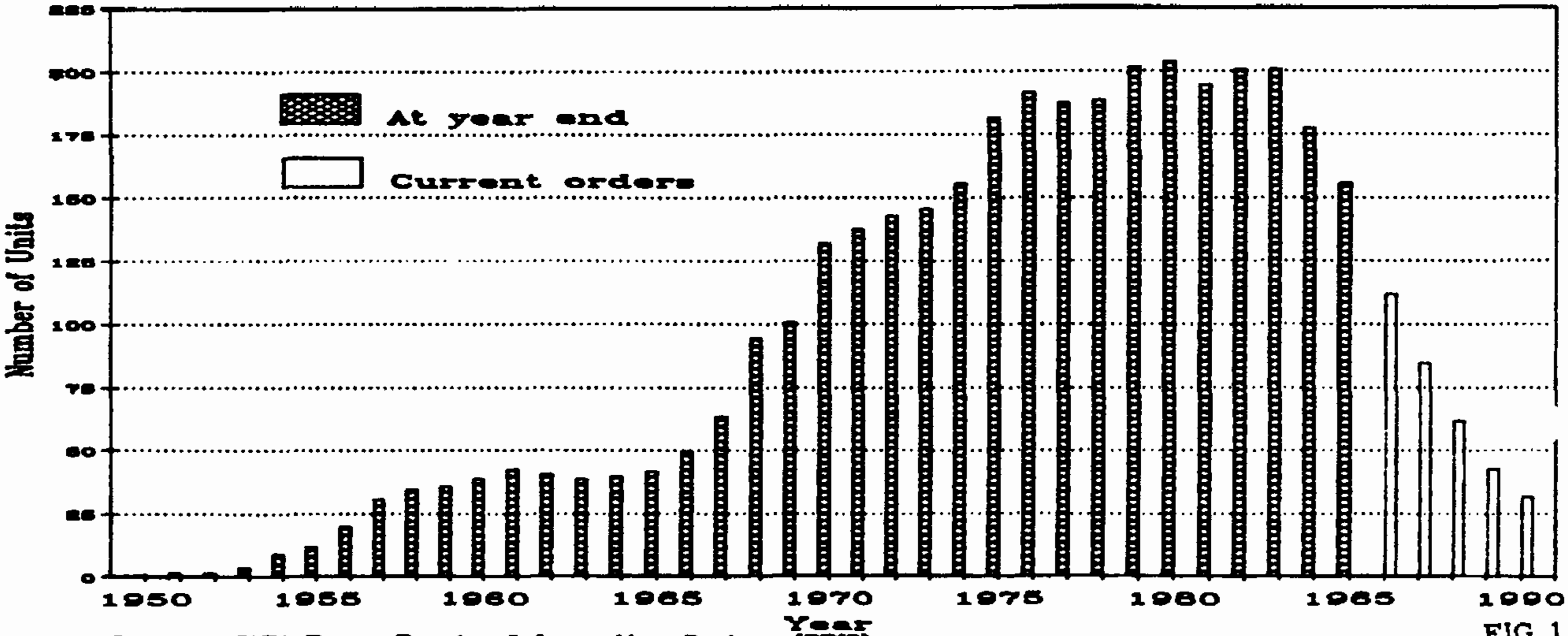
* Years beyond 1985 are estimated

Source: IAEA Power Reactor Information System (PRIS)

FIG. 2.

NUCLEAR POWER UNITS UNDER CONSTRUCTION

Excluding reactors with construction suspended



Source: IAEA Power Reactor Information System (PRIS)

FIG. 1.

OPERATIONAL SAFETY REVIEW TEAMS

The Operational Safety Review Team (OSART) programme was created as a mechanism to provide useful advice with an international perspective to nuclear power plant managers on how to enhance the safety of their plants. The teams are usually composed of ten to 15 very experienced individuals, often managers from other nuclear power plants, who travel to the plant site and perform a three-week in-depth review of local operating practices. These international experts are recruited from external organizations such as nuclear power plants, utilities or operating organizations, consulting firms, and regulatory bodies as well as from the IAEA in-house staff. The external consultants are selected to bring in plant-specific expertise in, for example, operations or maintenance. The external consultants may change from one mission to another, but the regular in-house members ensure continuity and uniformity in objectives, criteria and performance of the OSART teams. Continued improvement in the OSART service is assured by the holding of feedback sessions in which members of the OSART and representatives of the operating organization and the regulatory authority in the Member State take part.

OBJECTIVES

An OSART looks into the operating history of a plant, checks how routine operations are actually conducted, explores the planning and preparation of future work, and verifies the approach taken to cope with unusual events including accidents. The result is a comprehensive evaluation of the overall safety strengths and weaknesses of the plant.

The review is aimed at assessing objectively the plant's safety practices against other successful international practices and to exchange ideas for the improvement of safety at the working level. It is not intended to be a regulatory type inspection that checks compliance with national requirements. An OSART review is performance-based; thus, it does not seek to impose one proven approach to safety in all plants reviewed, but accepts different possible approaches insofar as they reflect good practice and contribute to an operating organization's quest for safety. In the long run it is hoped that an internationally agreed level of operational safety may be achieved — not through direct administrative actions but instead by the spontaneous acceptance of successful, cost-effective safety practices.

Another important aspect of an OSART is the mutual exchange of knowledge and experience between the experts and plant personnel in the course of the review. OSARTs are also utilized as a means for training personnel in developing countries, through assignment alongside experts as observers. Regulatory personnel, who may be assigned to follow the OSART review, also benefit from the information exchange.

SOME POINTS OF INTEREST

How the review is performed

The members of an OSART study information provided in advance by the nuclear plant operating organization to familiarize themselves with the plant, its main design features, operating characteristics, history, basic records and instructions; and the organization of the plant, key persor and regulatory provisions. A preliminary outline of the review programme is prepared in advance (as shown in Table 1).

Simultaneously, the operating organization and the regulatory body make the necessary arrangements for the smooth performance of the review. These include scheduling the review so as to cause a minimum of interference with the operation of the plant. Periods when the plant is shut down for refuelling, maintenance, repair or modification are usually not well suited, because the plant personnel have a heavy workload at such times. Other items to be arranged are the clearances necessary for team members to enter the plant, the provision of appropriately equipped office space, the establishment of a review co-ordinator on site, the designation if necessary of liaison officers to assist the members of the OSART to overcome language barriers, and so on.

During the first week on site the team members complete their familiarization with the plant, assisted by plant personnel, and finalize the review programme. It takes then about two weeks for the team to acquire sufficient detailed information to make it possible for them to arrive at sound findings and recommendations which will enhance operational safety. OSARTs use three basic techniques which supplement each other:

- examining the plant's records and documentation
- discussing technical and administrative details with the competent plant personnel; and
- observing personnel in the course of their activities.

The last days on site are used to discuss the team's principal findings with the operating organization and regulatory body, to eliminate any errors or misinterpretations before preparation of the final report.

What advance information is needed?

To enable an OSART to perform as efficiently as possible while on site at the plant under review, the

TABLE 1: STANDARD OSART SCHEDULE

DAY	1	2	3	4	5
ORGANIZATION AND MANAGEMENT	OVERVIEW & HP COURSE & MEET COUNTERPARTS	SITE ORGANIZATION	QUALITY ASSURANCE PRINCIPLES	QUALITY ASSURANCE PROCESS	DOCUMENT CONTROL SYSTEM
TRAINING	↓	TRAINING ORGANIZATION & ADMINISTRATION	TRAINING SUPPORT & RESOURCES	CONTROL ROOM OPERATOR TRAINING	CONTROL ROOM OPERATOR TRAINING
OPERATIONS		OPERATIONS TOP ORGANIZATION & ADMINISTRATION	SHIFT ORGANIZATION & ADMINISTRATION	CONDUCT OF CONTROL ROOM OPERATIONS	CONDUCT OF FIELD OPERATIONS
MAINTENANCE		MAINTENANCE ORGANIZATION & ADMINISTRATION	MAINTENANCE ORGANIZATION & ADMIN. CONT'D	MAINTENANCE PROCEDURES	PREVENTIVE MAINTENANCE PROGRAMME
RADIATION PROTECTION		R.P. ORGANIZATION & ADMINISTRATION	RADIATION PROTECTION PROCEDURES	R.P. EQUIPMENT INSTRUMENTATION & FACILITIES	EXTERNAL RADIATION PROTECTION
CHEMISTRY		CHEMISTRY ORGANIZATION & ADMINISTRATION	HOT LAB EQUIPMENT & INSTRUMENTS	COLD LAB EQUIPMENT & INSTRUMENTS	RADIOCHEMICAL MEASUREMENT FACILITIES
TECHNICAL SUPPORT		TECH. SUPPORT ORGANIZATION & ADMINISTRATION	TECH. SUPPORT SURVEILLANCE PROGRAMME	TECH. SUPPORT SURVEILLANCE PROGRAMME	REACTOR ENGINEERING
EMERGENCY PLANNING & PREPAREDNESS		DETAILED REVIEW OF SITE EMERGENCY PLAN	SITE PROCEDURES TO IMPLEMENT EMERGENCY PLAN	SITE PROCEDURES TO IMPLEMENT EMERGENCY PLAN	SITE EMERGENCY RESPONSE FACILITIES

DAY	6	7	8	9	10
ORGANIZATION AND MANAGEMENT	RECORDS CONTROL	PLANT OPERATIONS REVIEW COMMITTEE	REGULATORY INTERFACES & REQUIREMENTS	SITE PHYSICAL SECURITY	SITE INDUSTRIAL SAFETY PRACTICES
TRAINING	FIELD OPERATOR TRAINING	FIELD OPERATOR MAINTENANCE TRNG.	MAINTENANCE PERSONNEL TRAINING	RADIATION PROTECTION TRAINING	TECHNICAL SUPPORT TRAINING
OPERATIONS	OPERATIONS HISTORY	WORK AUTHORIZATION PROCESS PROCEDURE CREATION	TAGGING SYSTEMS ADMINISTRATIVE PROCEDURES	SHIFT SURVEILLANCE & LOGKEEPING GEN. OPER. PROCEDURES	SHIFT TURNOVER SYSTEMS & SURVEILLANCE PROCEDURES
MAINTENANCE	CORRECTIVE MAINTENANCE PROGRAMMES	IN-SERVICE INSPECTION PROGRAMME	WORK CONTROL SYST. (WORK PERMITS, RADIOLOGICAL AND INDUSTRIAL SAFETY)	MAINTENANCE FACILITIES & EQUIPMENT	MAINTENANCE FACILITIES & EQUIPMENT
RADIATION PROTECTION	INTERNAL RADIATION PROTECTION	PERSONNEL DOSIMETRY PROGRAMME	R.P. RECORDS & REPORTING SYST.	RADIATION PROTECTION HISTORY	RADIATION PROTECTION HISTORY
CHEMISTRY	PRIMARY SAMPLING SYSTEMS	SECONDARY SAMPLING SYSTEMS	CHEMISTRY CONTROL OF RADWASTE	CHEMISTRY CONTROL OF PLANT MAKEUP SYSTEMS	REVIEW OF PLANT CHEM. PROBLEMS
TECHNICAL SUPPORT	REVIEW OF COMPUTER CAPABILITIES	OPERATING EXPERIENCE EVALUATION & FEEDBACK MECHANISMS	→	→	REVIEW OF HUMAN FAILURE EVENT ANALYSES RESULTS
EMERGENCY PLANNING & PREPAREDNESS	EMERGENCY RESPONSE PROGRAMMES (DRILLS, EXERCISES)	LOCAL OFF-SITE EMERGENCY RESPONSE FACILITIES & EPZ TOUR	REVIEW POLICY AND LAWS GOVERNING EP&P AT THE NATIONAL LEVEL & FACILITIES	REVIEW CORPORATE EP&P POLICIES, RESOURCES, FACILITIES, AND COMMUNICATIONS	PUBLIC AUTHORITIES EMERGENCY PLANS, TRAINING & RESOURCES

DAY	11	12	13	14	15
ORGANIZATION AND MANAGEMENT	MISCELLANEOUS ADMINISTRATIVE FUNCTIONS	COMPLETE ANY OPEN ITEMS	RESERVED FOR REPORT PREPARATION	REPORT PREPARATION AND DISCUSSIONS WITH COUNTERPARTS	9—12 A.M. EXIT MEETING
TRAINING	SUPERINTENDENT, MANAGERS, AND CHEMIST TRNG.	GENERAL EMPLOYEE TRAINING	↓	↓	↓
OPERATIONS	TAGGING SYSTEMS/ KEY CONTROLS EMERGENCY PROCEDURES	FACILITIES & EQUIPMENT (LABELLING, OPER. AIDS)			
MAINTENANCE	STOREROOM ORGANIZATION & ADMIN. AND MATERIAL CONTROL	STOREROOM ORGANIZATION & ADMIN. AND MATERIAL CONTROL			
RADIATION PROTECTION	RADIOACTIVE EFFLUENT CONTROL	RADIOACTIVE EFFLUENT CONTROL			
CHEMISTRY	CHEMISTRY REPORTS AND RECORD SYSTEMS	REVIEW CHEMISTRY PROCEDURES			
TECHNICAL SUPPORT	EQUIPMENT FAILURE EVENT ANALYSES RESULTS	PLANT MODIFICATION PROCESS			
EMERGENCY PLANNING & PREPAREDNESS	TOUR OF OTHER SUPPORTING FACILITIES AS APPROPRIATE	COMPLETE ANY OPEN ITEMS			

operating organization must submit documents considered useful for the advance familiarization of the team members with the plant. It is obvious that comprehensive documentation concerning the plant, its licensing status, operating history, procedures, instructions and so on serves the purposes of the review best, but may not always be readily available in a condensed form. To ensure the most effective transfer of advance information, a brief one- or two-day OSART preparation meeting is usually arranged between the IAEA's OSART co-ordinator and the appropriate representatives of the Member State. Planning and logistic details of the mission are also reviewed during this meeting. Typically the advance information will include such things as:

- schematics of the plant and site layout
- organizational charts or diagrams
- descriptions of functional responsibilities and staffing levels
- the index for plant procedures
- copies of recent monthly and annual management reports
- descriptions of selected facilities in the plant
- brief descriptions of selected administrative controls.

Areas reviewed

The overall review programme can be broken down as requested into several areas. A typical breakdown is as follows:

1 *Management, organization and administration*: This includes checking the organizational structure for clearly defined functions, assignments and responsibilities in implementing and controlling plant activities with emphasis on safety implications. Attention is paid to the fulfilment of regulatory and other requirements imposed. Important aspects are management involvement and commitment, the personnel planning and qualification programme, principles and objectives of the station, the quality assurance programme, industrial safety efforts and the document control system.

2 *Training and qualification:* The major elements of this are the organization and administration of training, the training facilities, equipment and materials, and the various training and qualification programmes. This concerns all staff members, managers and engineers, shift advisers, licensed and non-licensed operators, maintenance personnel and general employees.

3 *Operations:* The main topics are operations organization, staff size, qualifications and motivation, operator working attitudes, knowledge, experience and performance, procedure implementation, operating history, plant status control, and log-keeping practice. The OSART is also interested in subjects such as information transfer on shift turnover, work authorization, temporary modifications, tagging policy, labelling system, cleanliness and order.

4 *Technical support:* This covers the activities of the technical and engineering groups involved in surveillance testing, in-service inspection, operating experience feedback, plant modification and reactor engineering programmes including the use of plant process computers, control of computer software and programme verification.

5 *Maintenance:* Important aspects here are the organization of maintenance and related administrative systems, the upkeep of the plant, the work control system, the manner in which maintenance is performed, the role played by preventive maintenance, in-service inspections, the equipment available, the maintenance history of the plant, and procedures and documentation for maintenance.

6 *Radiation protection:* Among the items covered are organizational and administrative arrangements, the training and qualification of radiation protection personnel, general employee training, control of external and internal exposure, contamination control, radiation protection instrumentation, equipment and facilities, personnel dosimetry, solid waste treatment and disposal, and radioactive contamination control.

7 *Plant chemistry:* This includes organizational and administrative features, personnel training and qualification, laboratories, equipment and instruments, procedures, reporting and record keeping, plant review, chemistry status, and chemical and laboratory safety.

8 *Emergency planning and preparedness:* This relates to the operating organization's responsibilities for preparing for nuclear accidents and radiological emergencies, both on-site and off-site, and the necessary liaison with public authorities. Also included are matters of planning, training, facilities, equipment and resources, accident assessment and notification, personnel protection and public information.

How plant performance is judged

The IAEA carefully selects experts who have extensive experience in nuclear safety, and come from a variety of Member States. Each OSART expert uses his experience, supplemented by the IAEA Nuclear Safety Standards, to evaluate the plant performance against successful and cost-effective safety practices that he has seen elsewhere. If the expert feels that superior methods are available elsewhere regarding a certain safety practice, he will bring it to the attention of the operating organization in the form of a finding and a recommendation. Likewise, if a safety practice is observed which is markedly superior to those available elsewhere, he will also make note of it to ensure the practice is preserved and perhaps made available to other nuclear power plants. The findings are not final safety judgments in themselves but rather constitute advice from an objective international expert regarding particular practices that warrant further consideration by the local organizations.

To ensure that the evaluations are comprehensive and uniform, the IAEA has developed OSART guidelines to assist the experts in the topics to be reviewed. Additionally, daily meetings are held at which each expert's findings and recommendations are discussed with the other experts on the team. This ensures that the process is balanced and that opportunities exist for alternative solutions to be brought forward. Lastly, it should be noted that the expert works on a daily basis with a local counterpart to ensure that he develops a proper understanding of plant practices, and to ensure that the operating organization fully understands his findings and recommendations.

Reporting policy

While at the site, the OSART members develop and prepare a set of detailed Technical Notes regarding their findings for use as a working document. The notes are first discussed with counterparts in the operating organization, then finalized and presented at a plant exit meeting. A draft Summary Report is also prepared for high level management and is left with the local organizations for comment. After incorporating any comments, a final Summary Report is submitted through official channels to the Member State which requested the OSART. Distribution of both the Technical Notes and the Summary Report is restricted to the IAEA and the organizations involved in the mission. Any further distribution is at the discretion of the requesting Member State.

What are other organizations doing?

None of the other international organizations active in nuclear safety — the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development, the Commission of the European Communities and the Council for Mutual Economic Assistance — offers a directly comparable service to its Member States. They see their main task as co-ordination of various national efforts in nuclear safety, arranging for information exchange and organizing joint research and development projects. With respect to regulatory matters, they are not usually involved in individual procedures, but restrict themselves to giving more general advice — for example, by developing standards. The IAEA is very active in these areas too, but was urged to supplement its activities by shifting emphasis from the production of standards, recommendations and other guidance material, to their implementation, using feedback as appropriate in the revision of the documents.

Several Member States saw a need to supplement the routine inspection and enforcement activities of their regulatory bodies with voluntary safety improvement programmes. The most comprehensive programme in this respect was introduced in the United States in 1978 by the Institute for Nuclear Power Operations. Important elements of this endeavour have been used in establishing the objectives, procedures, review areas and schedules of OSART.

TABLE 2: SOME RELATED IAEA PUBLICATIONS

1 IAEA Safety Series No.9

Basic Safety Standards for Radiation Protection (1982 edition)

2 IAEA Safety Series No.50

Codes of practice

50-C-O	Safety in nuclear power plant operation, including commissioning and decommissioning
50-C-QA	Quality assurance for safety in nuclear power plants

Safety Guides

50-SG-O1	Staffing of nuclear power plants and recruitment, training and authorization of operating personnel
50-SG-O2	In-service inspection for nuclear power plants
50-SG-O3	Operational limits and conditions for nuclear power plants
50-SG-O4	Commissioning procedures for nuclear power plants
50-SG-O5	Radiation protection during operation of nuclear power plants
50-SG-O6	Preparedness of the operating organization (licensee) for emergencies at nuclear power plants
50-SG-O7	Maintenance of nuclear power plants
50-SG-O8	Surveillance of items important to safety in nuclear power plants
50-SG-O9	Management of nuclear power plants for safe operation
50-SG-O10	Safety aspects of core management and fuel handling for nuclear power plants
50-SG-O11	Operational management of radioactive effluents and wastes arising in nuclear power plants
50-SG-QA2	Quality assurance records system
50-SG-QA5	Quality assurance during operation of nuclear power plants
50-SG-QA5 (Rev.1)	Quality assurance during commissioning and operation of nuclear power plants
50-SG-QA7	Quality assurance organization for nuclear power plants

3 OSART Guidelines

TABLE 3: OSART PROGRAMME PARTICIPATION

Country	OSART	Number of reactors*	
		Operational	Under construction
Argentina		2	1
Belgium		8	
Bulgaria		4	2
Brazil	yes	1	1
Canada		16	6
Switzerland		5	
People's Republic of China			1
Czechoslovakia		5	11
Cuba			2
German Democratic Republic		5	6
Germany, Federal Republic of	yes	19	6
Spain	yes	8	2
Finland	yes	4	
France	yes	43	20
United Kingdom of Great Britain and Northern Ireland		38	4
Hungary		2	2
India		6	4
Iran, Islamic Republic of			2
Italy		3	3
Japan		33	11
Korea, Republic of	yes	4	5
Mexico	yes		2
Netherlands	yes	2	
Philippines	yes		1
Pakistan		1	
Poland			2
Romania			3
Sweden	yes	12	
Union of Soviet Socialist Republics		51	34
Taiwan, China		6	
United States of America		93	26
Yugoslavia		1	
South Africa		2	
Totals		374	157

* As at 31 December 1985

TABLE 4: MEMBER STATES' PARTICIPATION IN THE OSART PROGRAMME

Member State	Experts + (Observers)*
Argentina	2
Belgium	1
Brazil	2 + (2)
Canada	2
China	(2)
Cuba	(1)
Finland	2
France	10
German Democratic Republic	1
Germany, Federal Republic of	5
Hungary	(2)
Italy	1
Japan	2
Korea, Republic of	2 + (1)
Mexico	(1)
Pakistan	(2)
Philippines	(1)
Spain	2
Sweden	4
Switzerland	1
United Kingdom	1
USA	6
Yugoslavia	3 + (2)
Total external experts	47 + (14)
Total IAEA staff	39

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* Numbers in brackets denote observers

Annex 6

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00060 Rome
Italy

Mr. H. Uchida
Commissioner
Nuclear Safety Commission
2-2-1 Kasumigase-ki
Chiyoda-ku
Tokyo 100
Japan

Mr. M. Medina Vaillard
Director General
Comisión Nacional de Seguridad
Nuclear y Salvaguardias
Insurgentes Sur 1806
01030 Mexico DF

Mr. C.J. van Daatselaar
Head, Division of Nuclear Safety
Ministry of Employment and Social Security
The Hague
The Netherlands

Mr. M. Eugenio
Commissioner
Philippine Atomic Energy Commission
Philippines

Mr. W. Dabek
Central Laboratory for Radiological
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03-194 Warsaw
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Mr. W. Zak
National Atomic Energy Agency
00-921 Warsaw
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Poland

Mr. F. Pascual
Presidente
Consejo Seguridad Nuclear
Madrid
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Mr. E. González
Consejero
Consejo Seguridad Nuclear
Sor Angela de la Cruz 3
28020 Madrid
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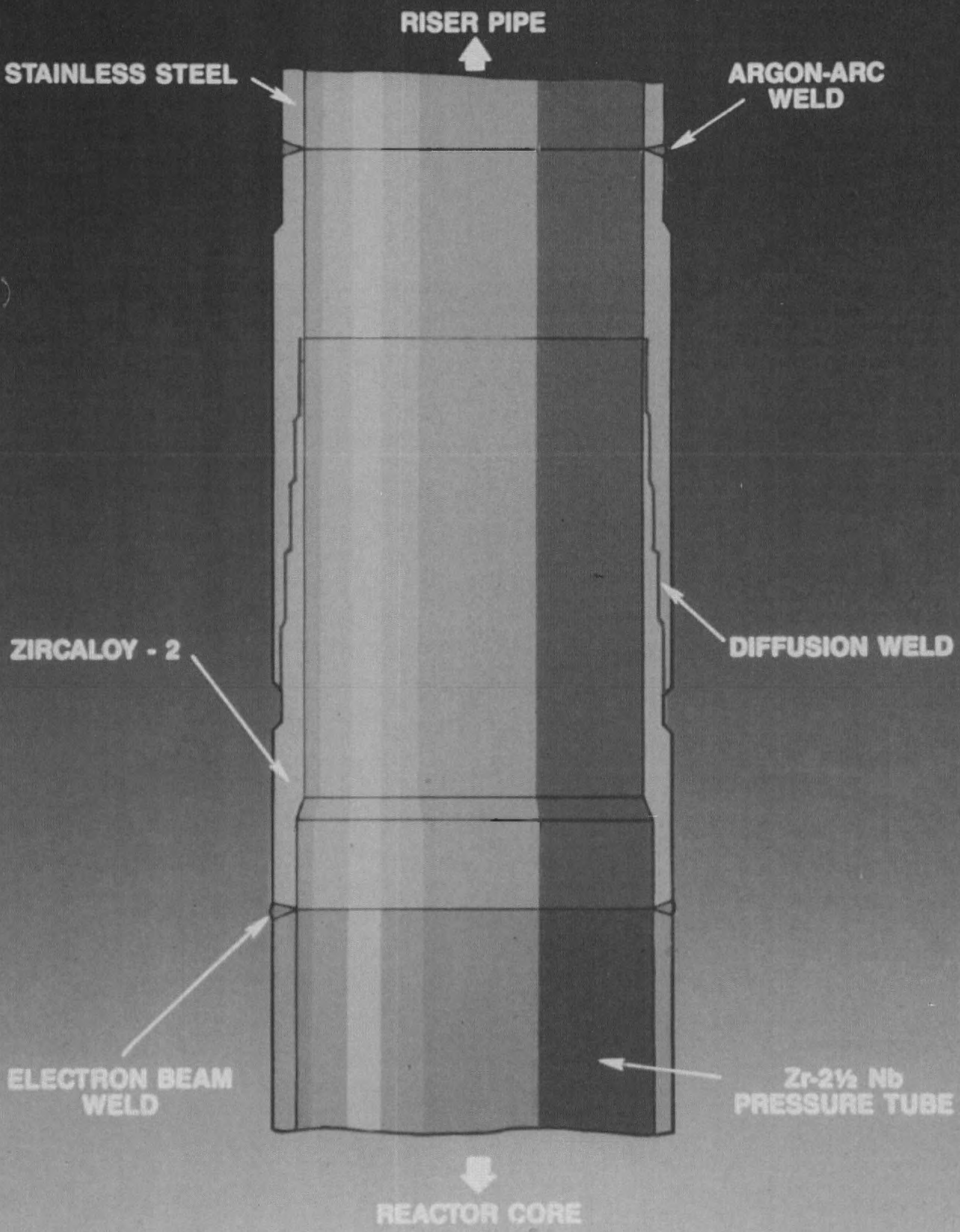
Director General
Swedish Nuclear Power Inspectorate
P.O. Box 27
10252 Stockholm
Sweden

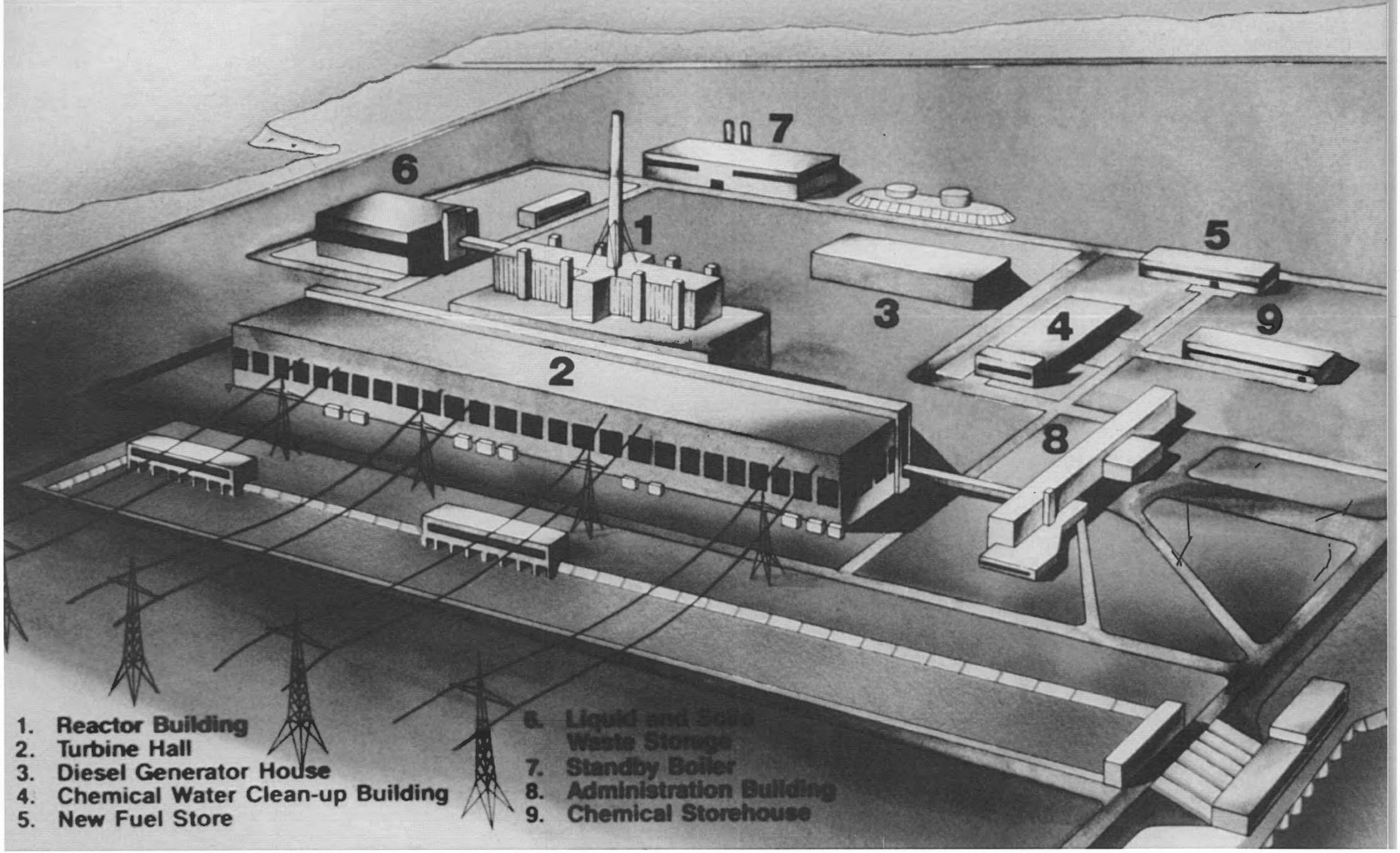
Mr. J-O. Snihs
Deputy Director General
National Institute of Radiation
Protection
Stockholm
Sweden

Mr. S. Prêtre
Nuclear Safety Division
CH-5303 Würenlingen
Switzerland

ZIRCONIUM - STEEL JOINT

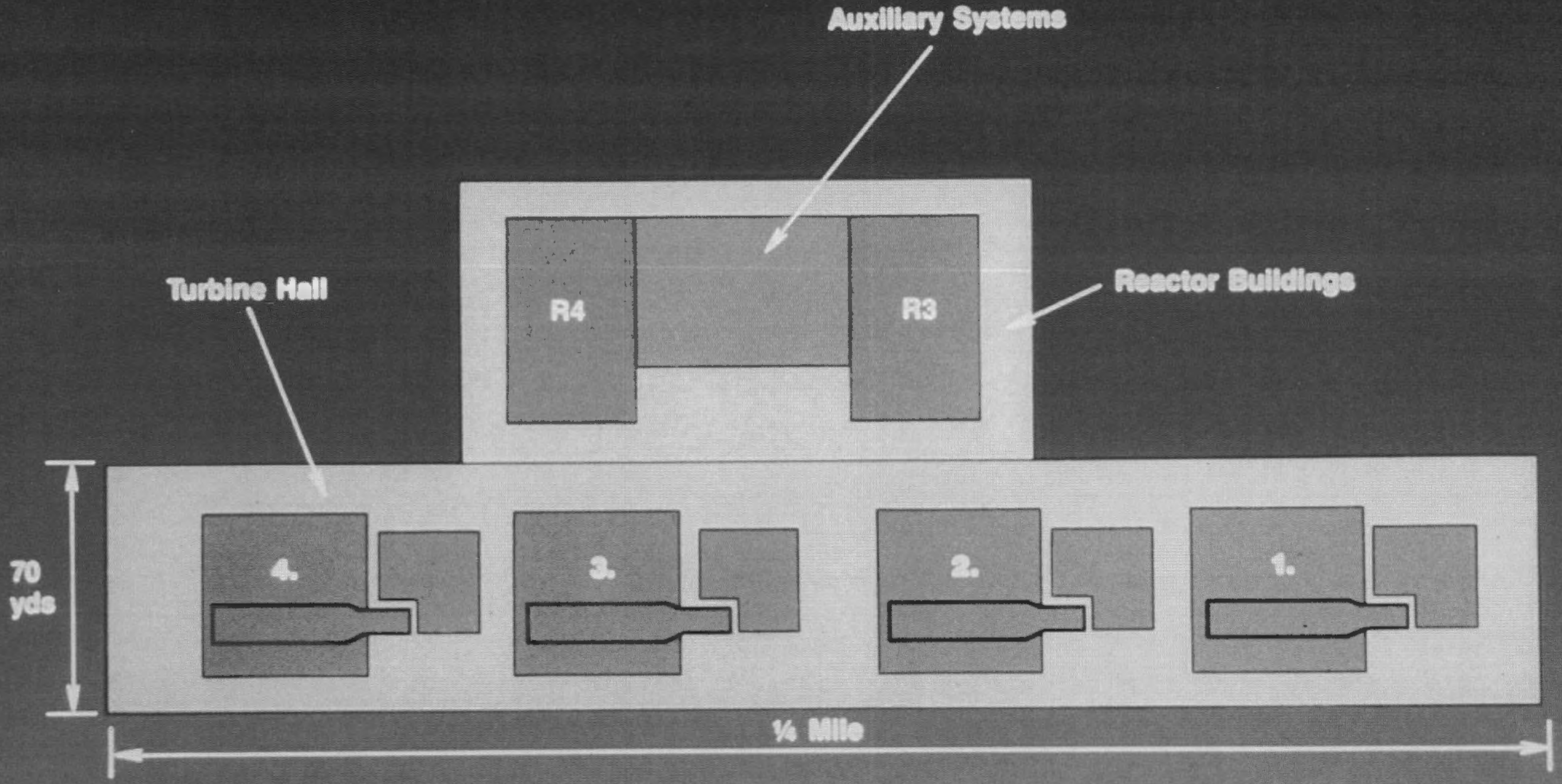


GENERAL VIEW OF SMOLENSK - 1 & 2 RBMK POWER PLANT



1. Reactor Building
2. Turbine Hall
3. Diesel Generator House
4. Chemical Water Clean-up Building
5. New Fuel Store
6. Liquid and Solid Waste Storage
7. Standby Boiler
8. Administration Building
9. Chemical Storehouse

PLAN OF CHERNOBYL 3 AND 4



Auxiliary Systems

Turbine Hall

R4

R3

Reactor Buildings

70 yds

4.

3.

2.

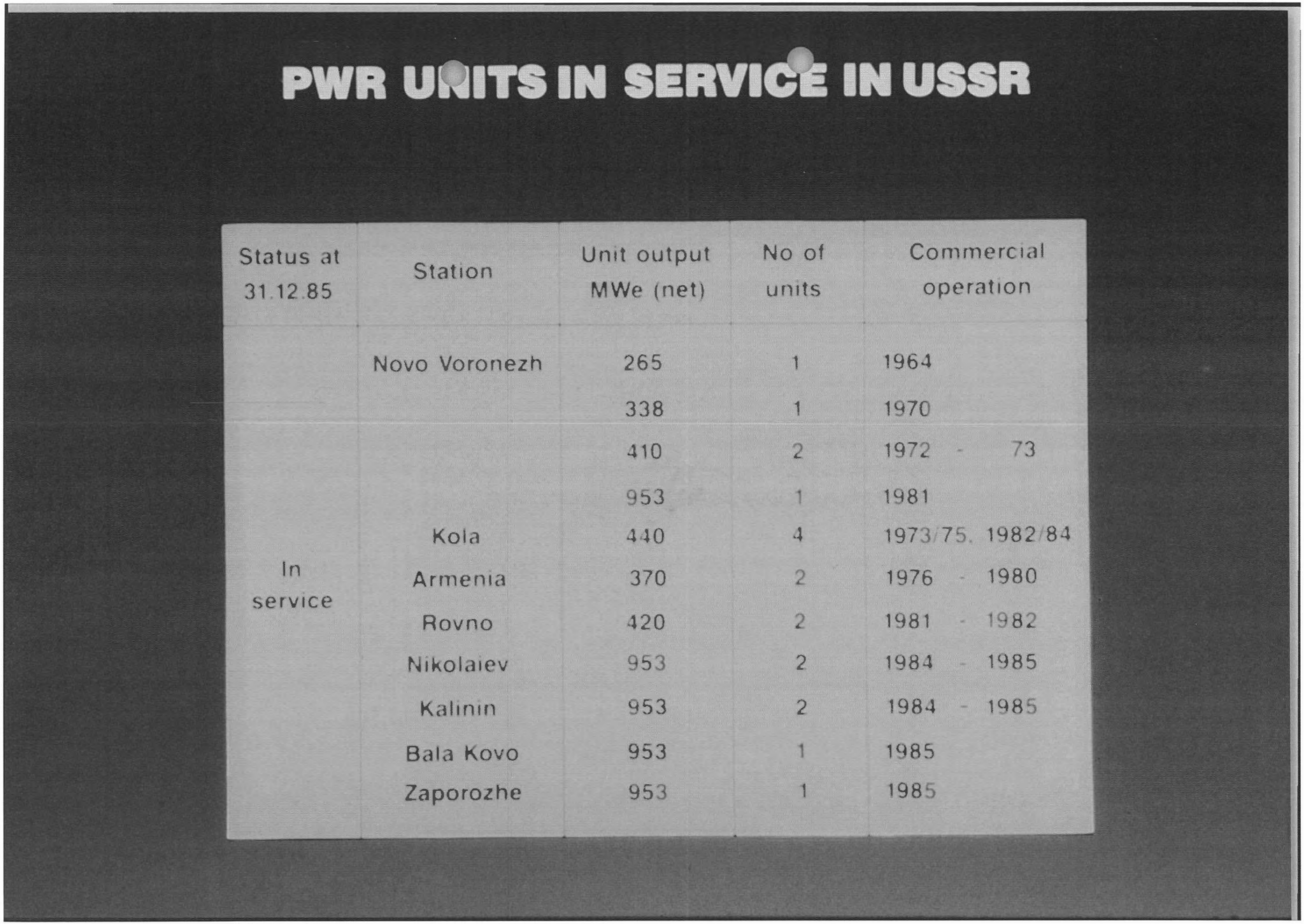
1.

¼ Mile

RUSSIAN PREDECESSORS OF THE RBMK REACTORS

Status at 31.12.85	Reactor	Cycle	Reactor coolant	Unit output MWe net	No. of units	Commercial operation
All in service	APS-1 (Obninsk)	Indirect	Pressurised water	5	1	1954
	Troitsk	Indirect	Pressurised water	90	6	1958 - 1963
	Beloyarsk-1	Direct	Boiling water & sup'd steam	102	1	1964
	Beloyarsk-2	Direct	Boiling water & sup'd steam	175	1	1968
	Bilibino	Direct	Boiling water (1)	11	4	1974 -1976

Note: (1) These reactors supply electric power to the Bilibino mining area in the Arctic and space heat to the village of Bilibino.



PWR UNITS IN SERVICE IN USSR

Status at 31.12.85	Station	Unit output MWe (net)	No of units	Commercial operation
In service	Novo Voronezh	265	1	1964
		338	1	1970
		410	2	1972 - 73
		953	1	1981
	Kola	440	4	1973/75, 1982/84
	Armenia	370	2	1976 - 1980
	Rovno	420	2	1981 - 1982
	Nikolaiev	953	2	1984 - 1985
	Kalinin	953	2	1984 - 1985
	Bala Kovo	953	1	1985
	Zaporozhe	953	1	1985

PWR UNITS UNDER CONSTRUCTION IN USSR

Status at 31.12.85	Station	Unit output MWe (net)	No of units	Commercial operation
Under construction	Zaporozhe	953	5	1986 - 1991
	Khmelnitski	953	4	1986 - 1990
	Nikolaiev	953	2	1987 - 1989
	Aktash	953	2	1987
	Tatar	953	1	1987
	Volgodonsk	953	4	1987 - 1990
	Rovno	953	2	1988 - 1990
	Bashkir	953	2	1988 - 1989
	Odessa	953	2	1988 - 1990
	Balakovo	953	2	1989 - 1990
	Nizhinekamsk	953	1	1989

LARGE RBMK UNITS
AND UNDER CONSTR
USSR

Status at 31.12.85	Station	Unit output MWe (net)
In service	Leningrad	950
	Kursk	950
	Chernobylsk	950
	Smolensk	950
	Ignalinsk	1450
Under construction	Kursk	950
	Ignalinsk	1450
	Chernobylsk	950
	Smolensk	950
	Kostroma	1450

IN SERVICE
RUCTION IN

No of units	Commercial operation
4	1974 - 1981
3	1976 - 1983
4	1978 - 1984
2	1983 - 1985
1	1984
1	1986
1	1986
2	1987 - 1989
2	1988 - 1989
2	1988 - 1989

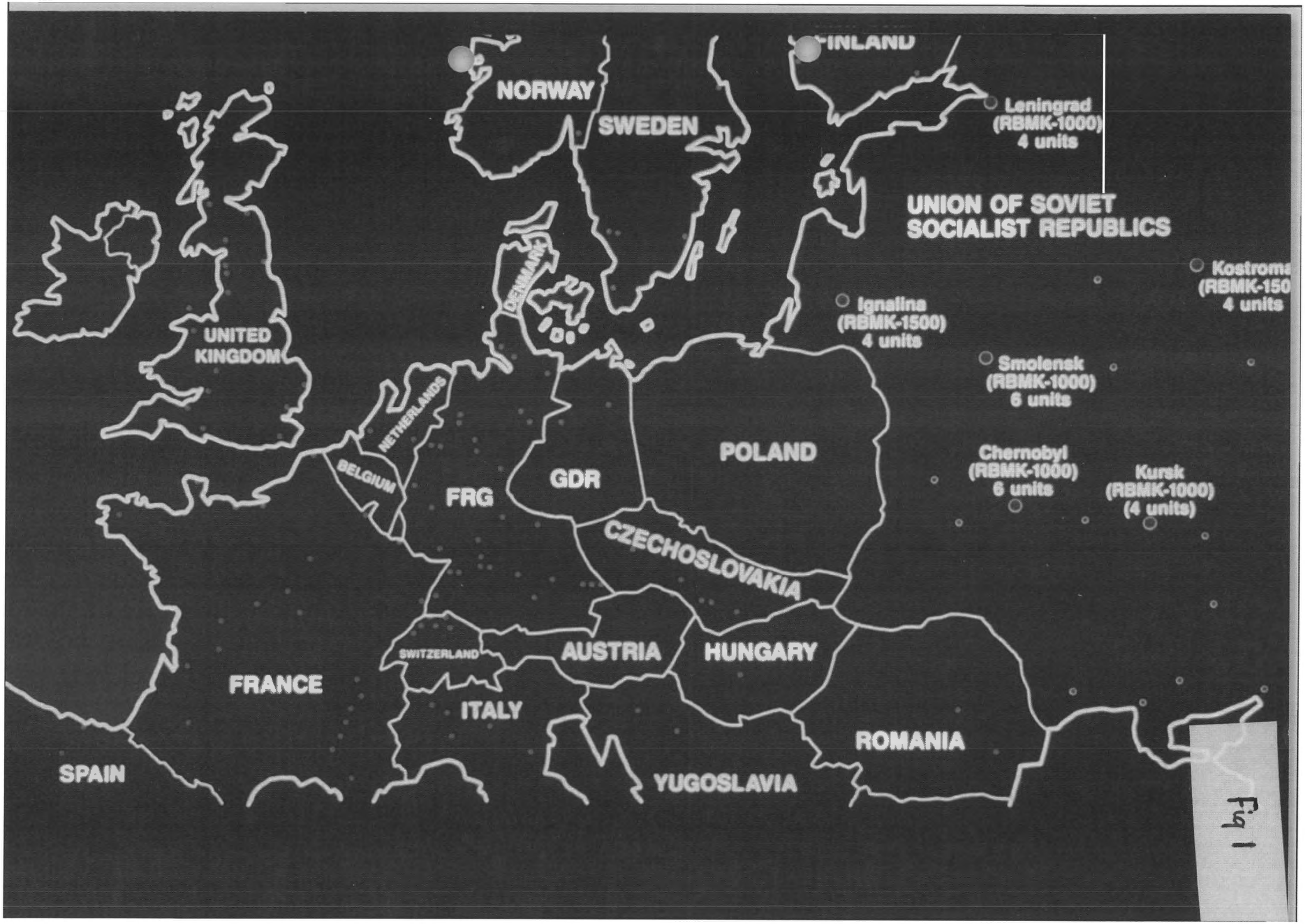

FINLAND
NORWAY
SWEDEN
Leningrad (RBMK-1000) 4 units
UNION OF SOVIET SOCIALIST REPUBLICS
Kostroma (RBMK-150 4 units
Ignalina (RBMK-1500) 4 units
Smolensk (RBMK-1000) 6 units
Chernobyl (RBMK-1000) 6 units
Kursk (RBMK-1000) (4 units)
DENMARK
UNITED KINGDOM
NETHERLANDS
BELGIUM
FRG
GDR
POLAND
CZECHOSLOVAKIA
SWITZERLAND
AUSTRIA
HUNGARY
FRANCE
ITALY
ROMANIA
SPAIN
YUGOSLAVIA

Fig 1

CHERNOBYL UNITS 1 - 4

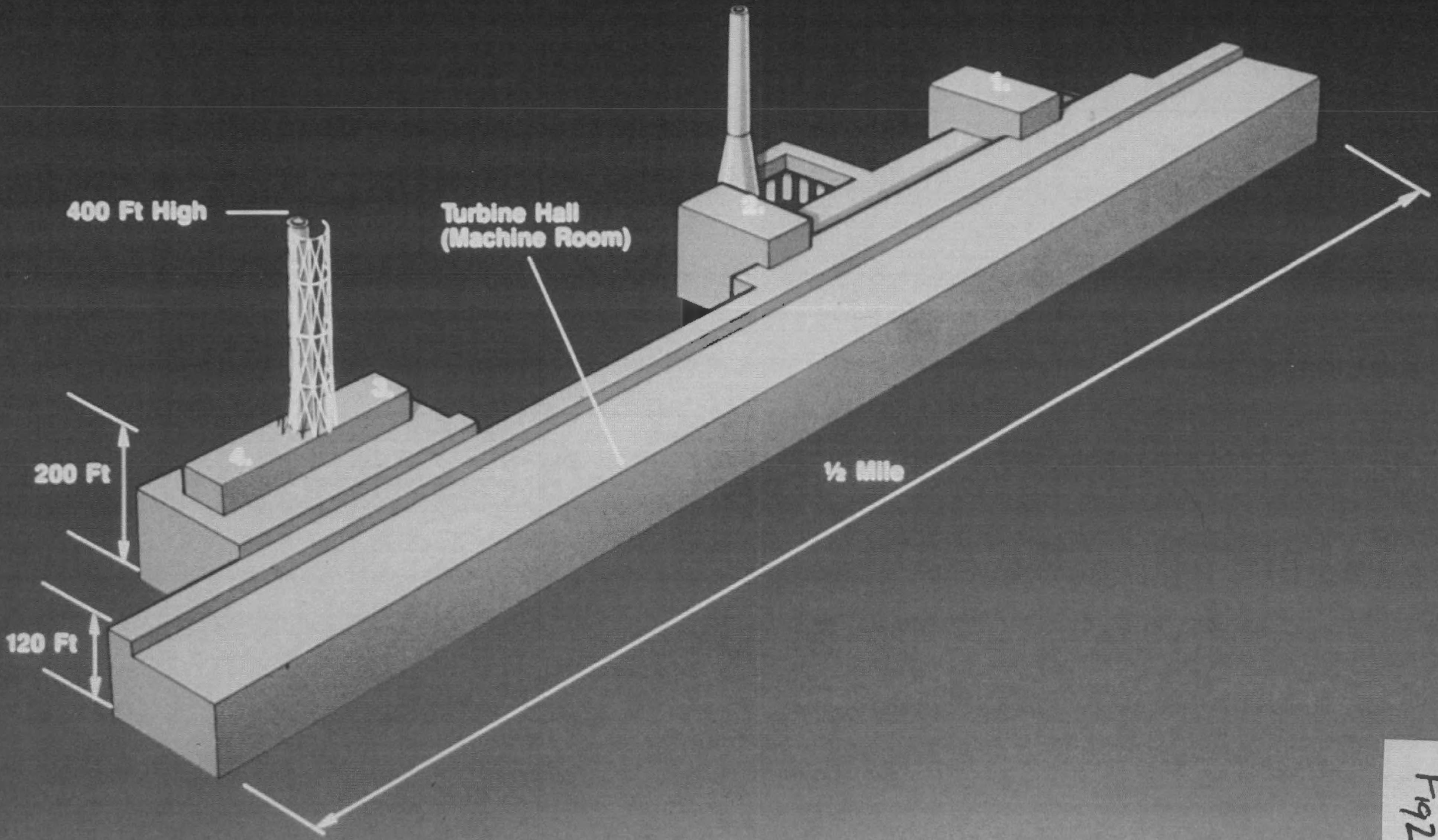
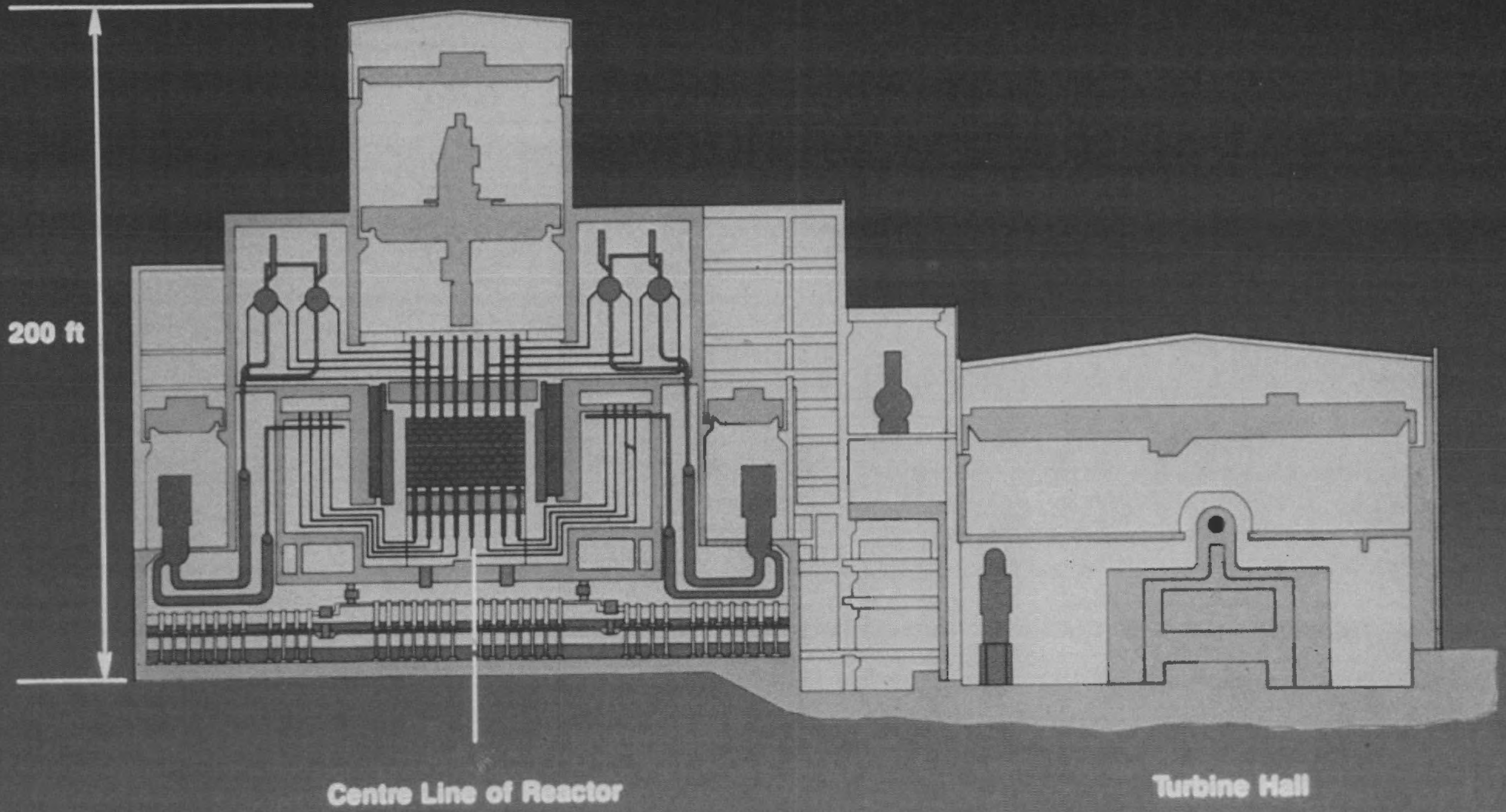


Fig2

CHERNOBYL - 4



SECTION THROUGH RBMK REACTOR

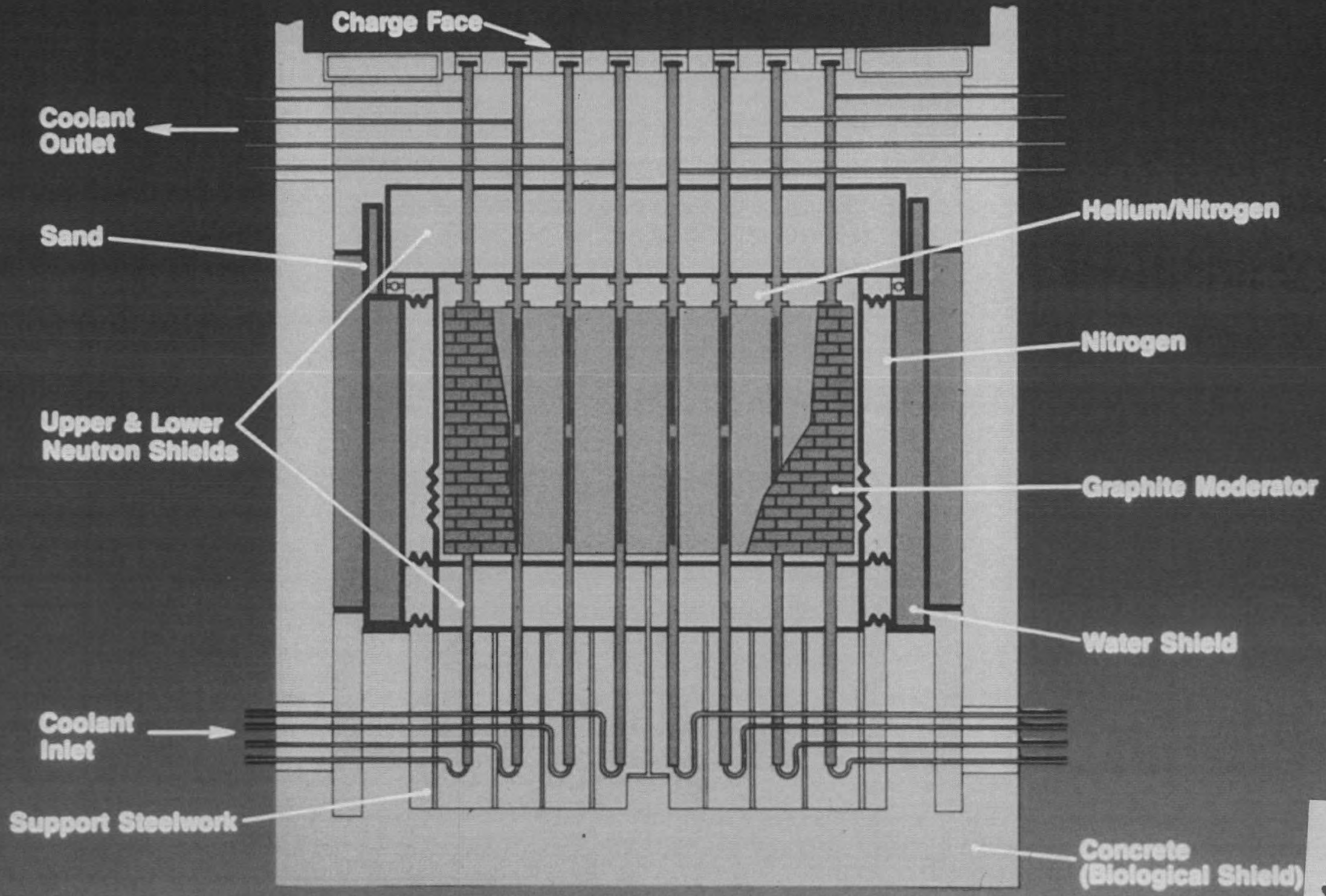
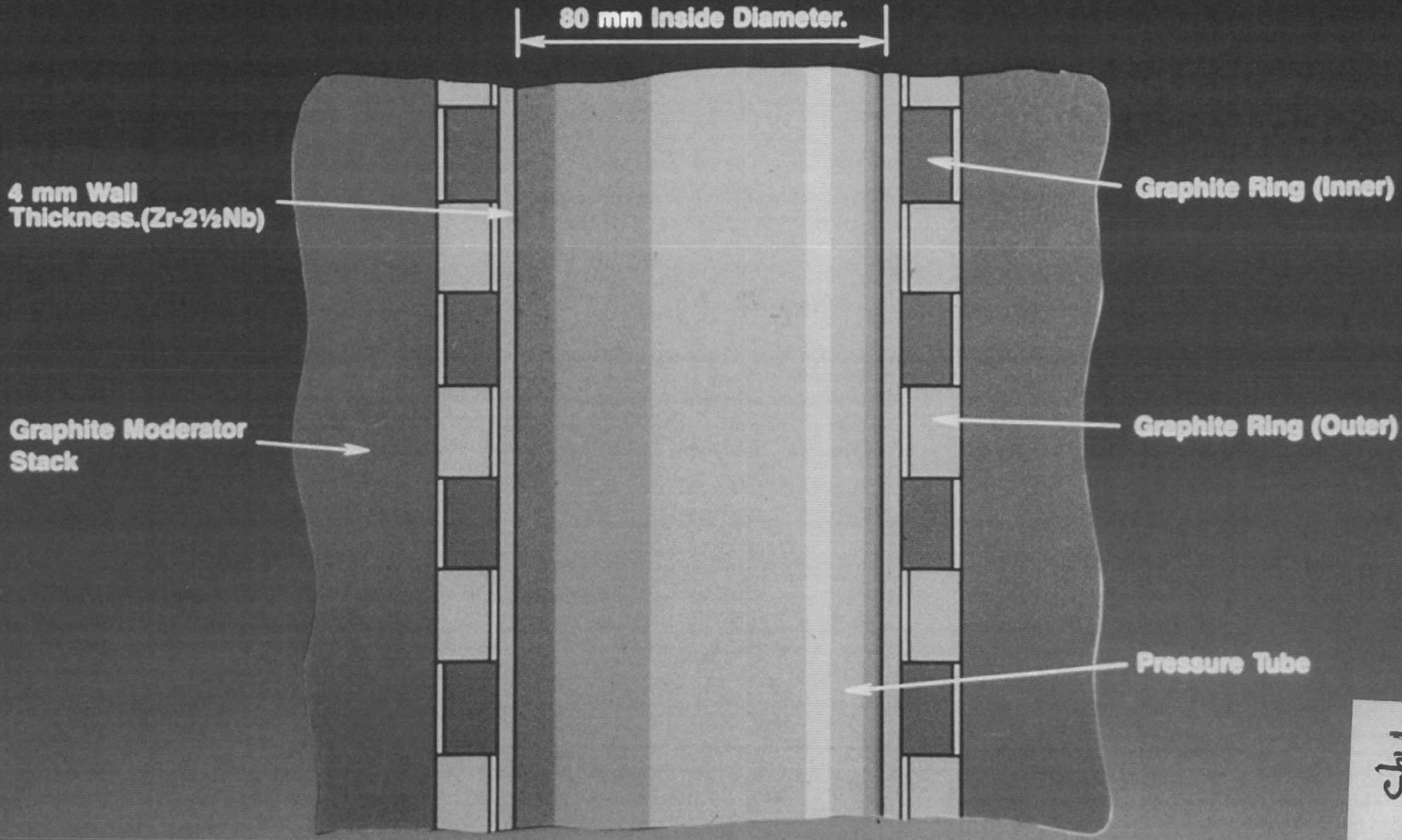


Fig 4

ARRANGEMENT OF PRESSURE TUBES IN REACTOR CORE



80 mm Inside Diameter.

4 mm Wall Thickness.(Zr-2½Nb)

Graphite Moderator Stack

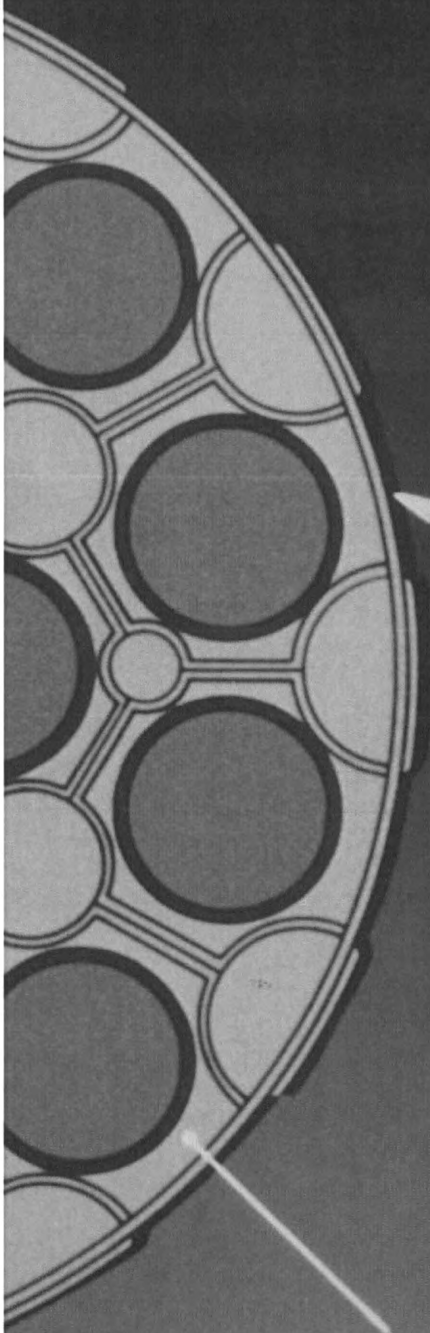
Graphite Ring (Inner)

Graphite Ring (Outer)

Pressure Tube

Fig5

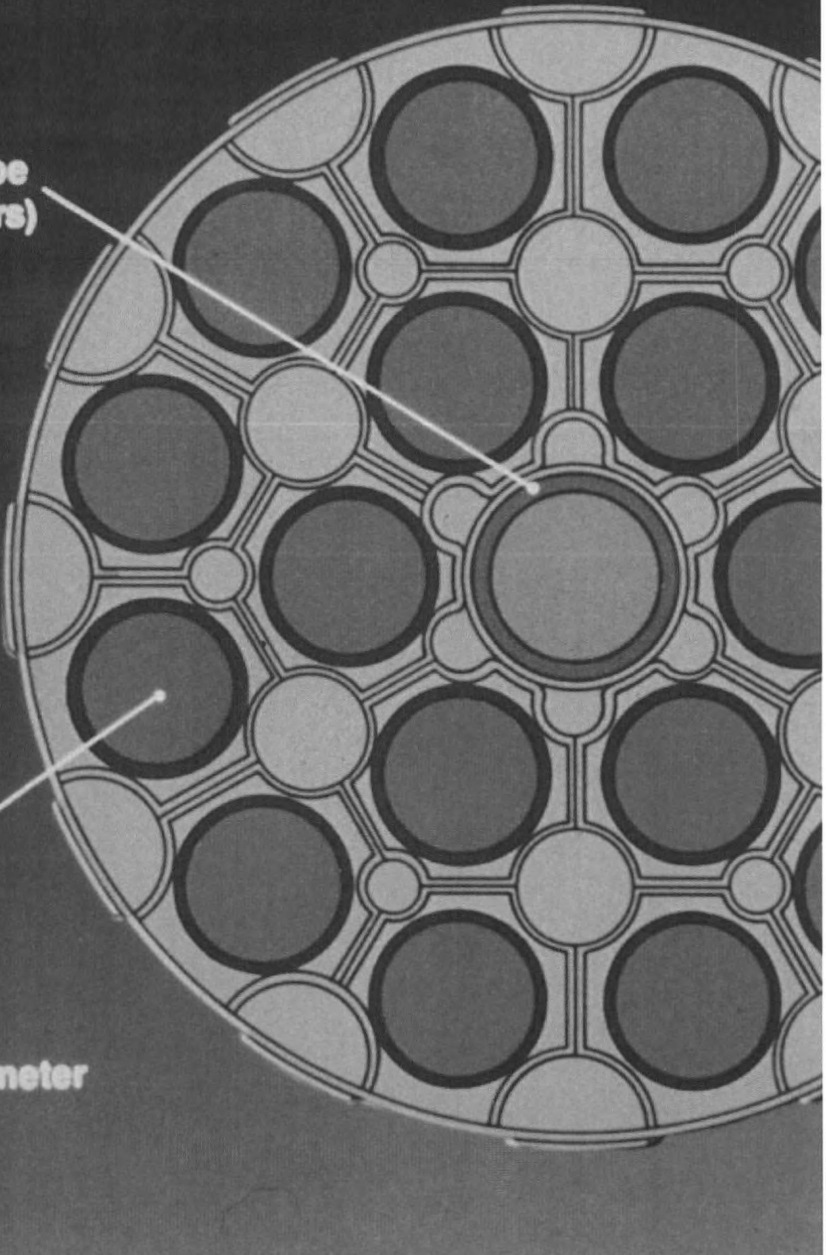
R GRID &



Spacer Grid

18 Fuel Pins 3644 mm Long

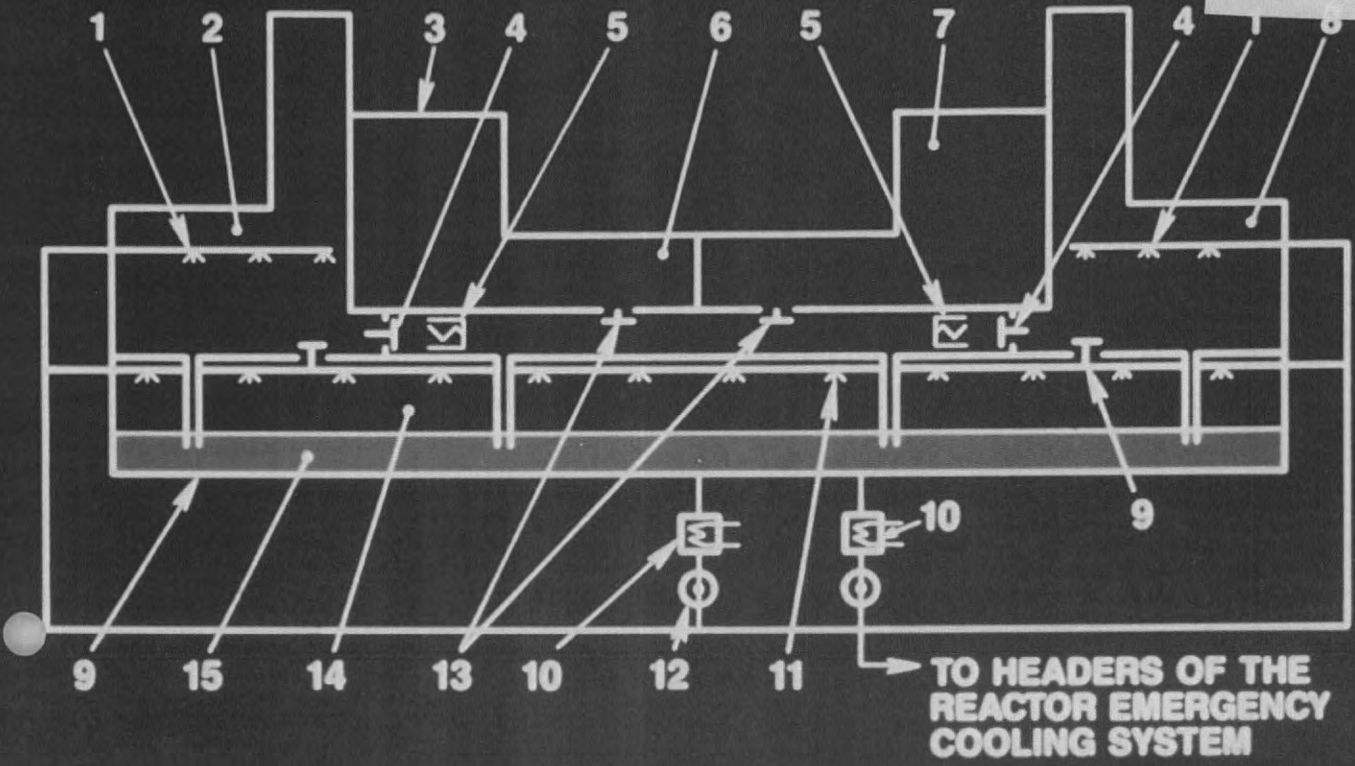
SECTION OF SPACER FUEL PINS



Central Supporting Tube
(With Nuetron Detectors)

Uo_2 Fuel Pellets
(11·5 mm Dia)
Zr-1½ Nb Cladding
13·6 mm Outside Diameter

Fig8



Schematic diagram of the system for retaining and localizing radioactive products in the event of an accident involving an RBMK-1000 type reactor

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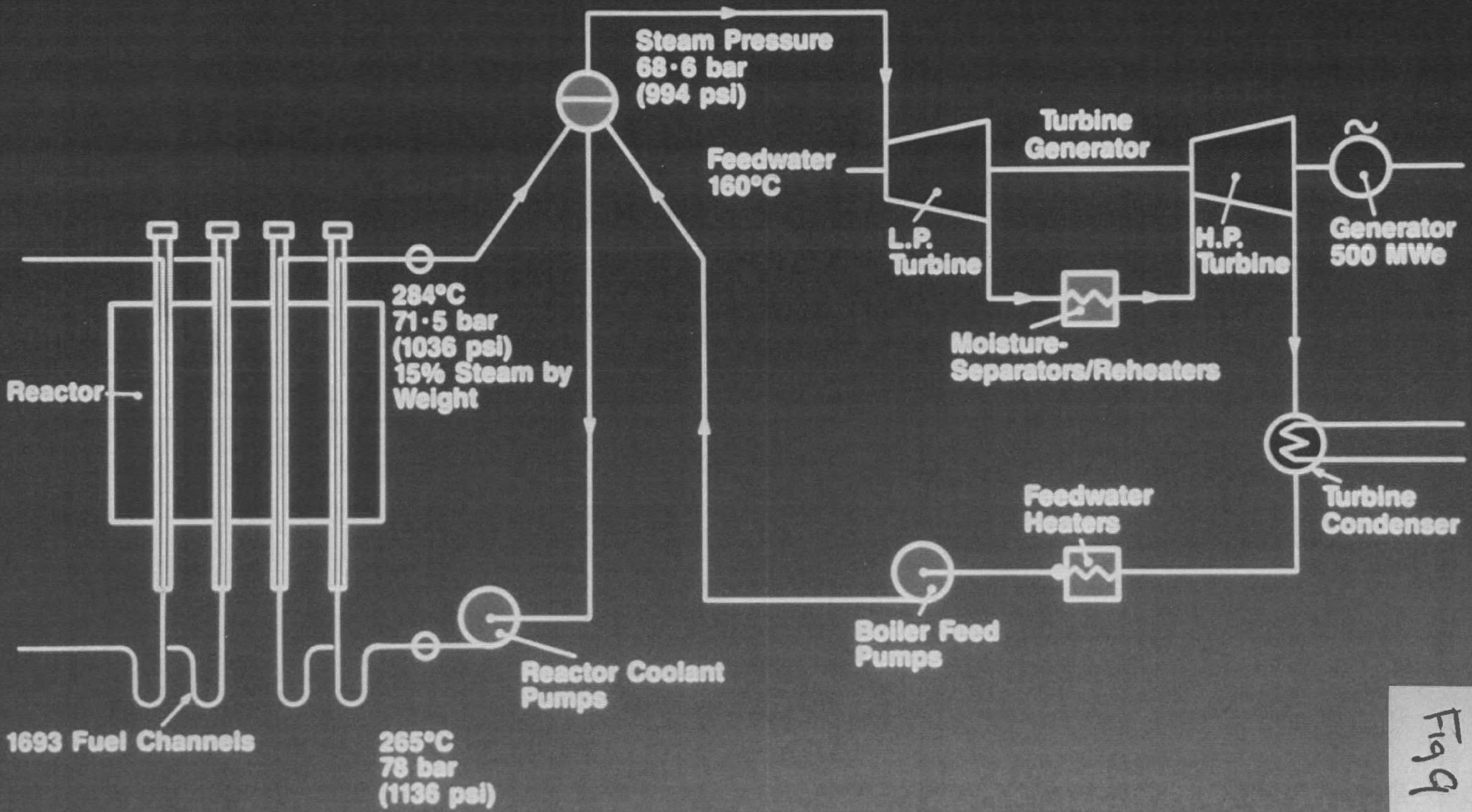
12 - Pump
13 - Check valves
14 - Air space above sparge pond
15 - Depth to which sparge pond is filled with water
16 - To emergency reactor cooling system collectors.

SCHEMATIC FLOWSHEET OF RBMK POWER PLANT



Steam Pressure
68·6 bar
(994 psi)

Feedwater
160°C

Turbine
Generator

L.P.
Turbine

H.P.
Turbine

Generator
500 MWe

Moisture-
Separators/Reheaters

Reactor

284°C
71·5 bar
(1036 psi)
15% Steam by
Weight

Turbine
Condenser

Feedwater
Heaters

Boiler Feed
Pumps

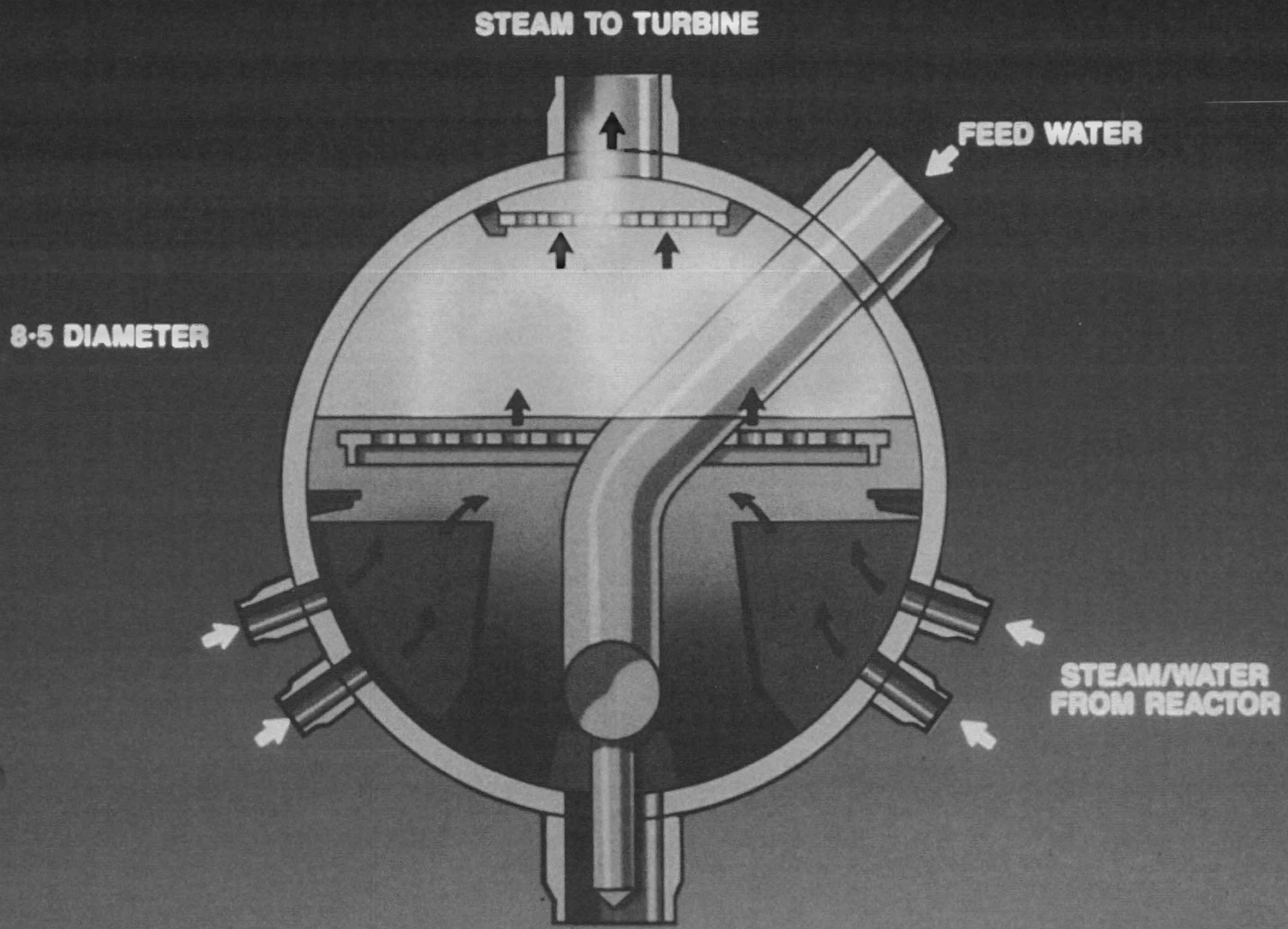
Reactor Coolant
Pumps

1693 Fuel Channels

265°C
78 bar
(1136 psi)

Fig 9

STEAM DRUM


STEAM TO TURBINE
FEED WATER
8·5 DIAMETER
STEAM/WATER
FROM REACTOR

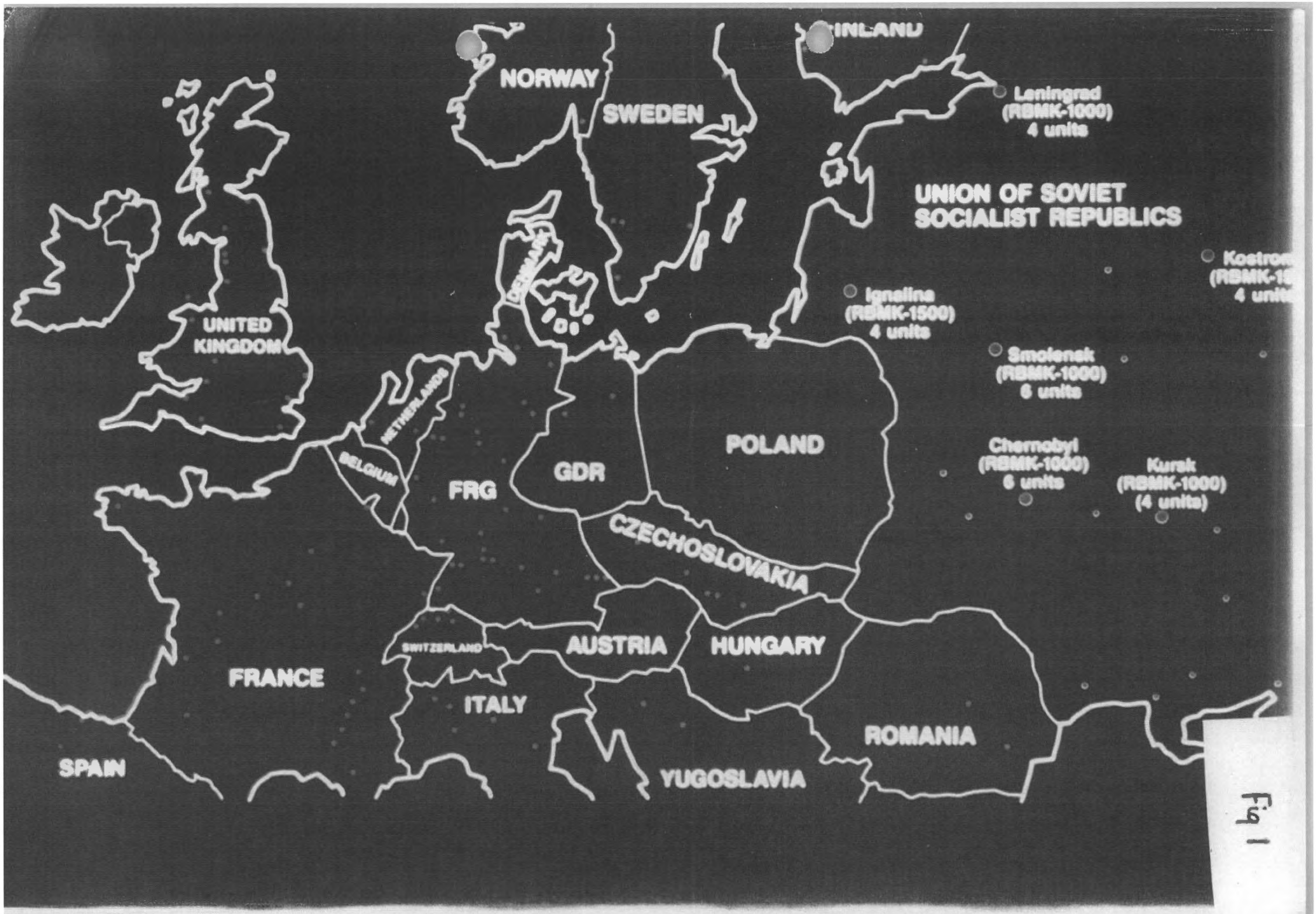
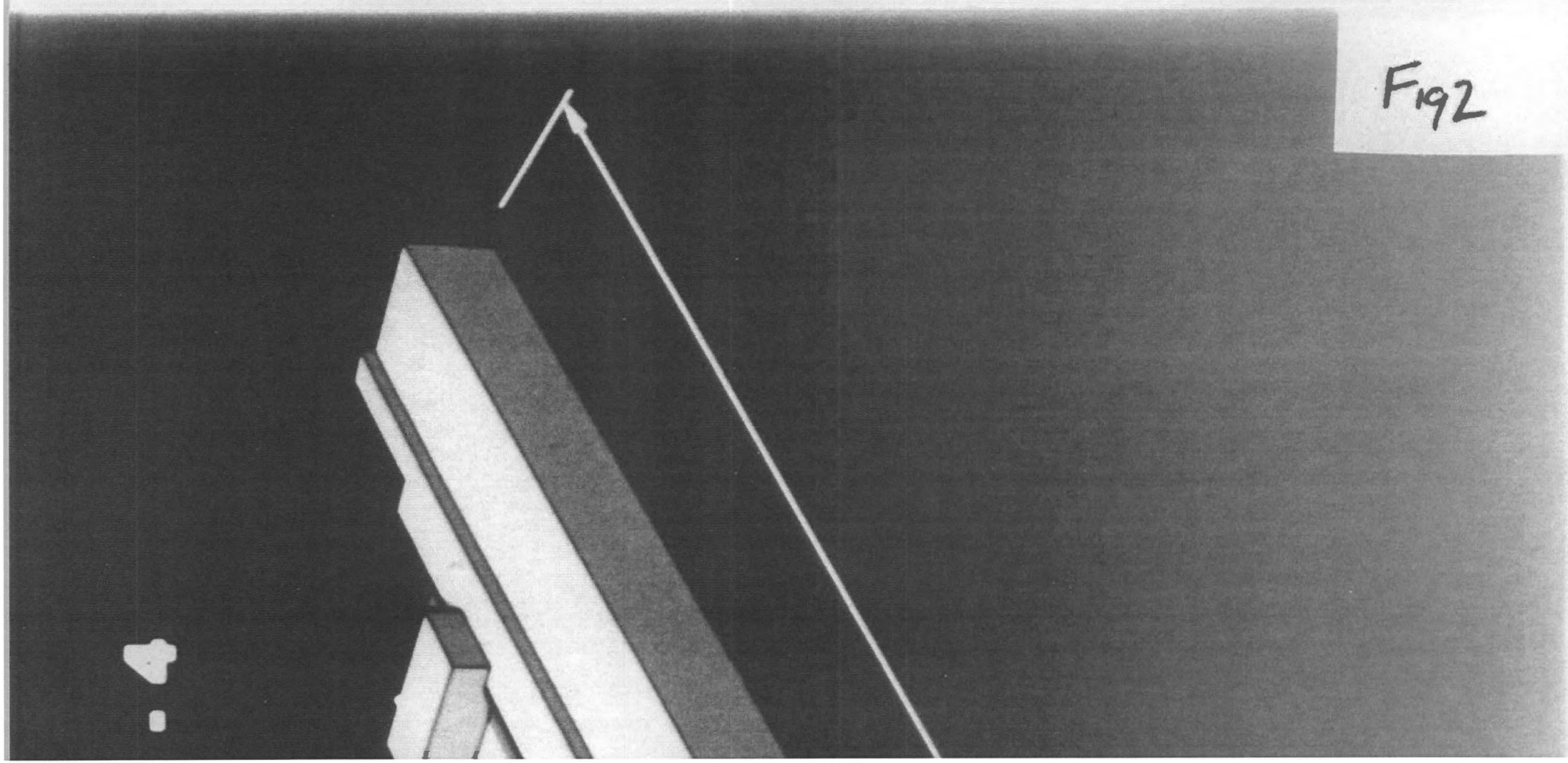
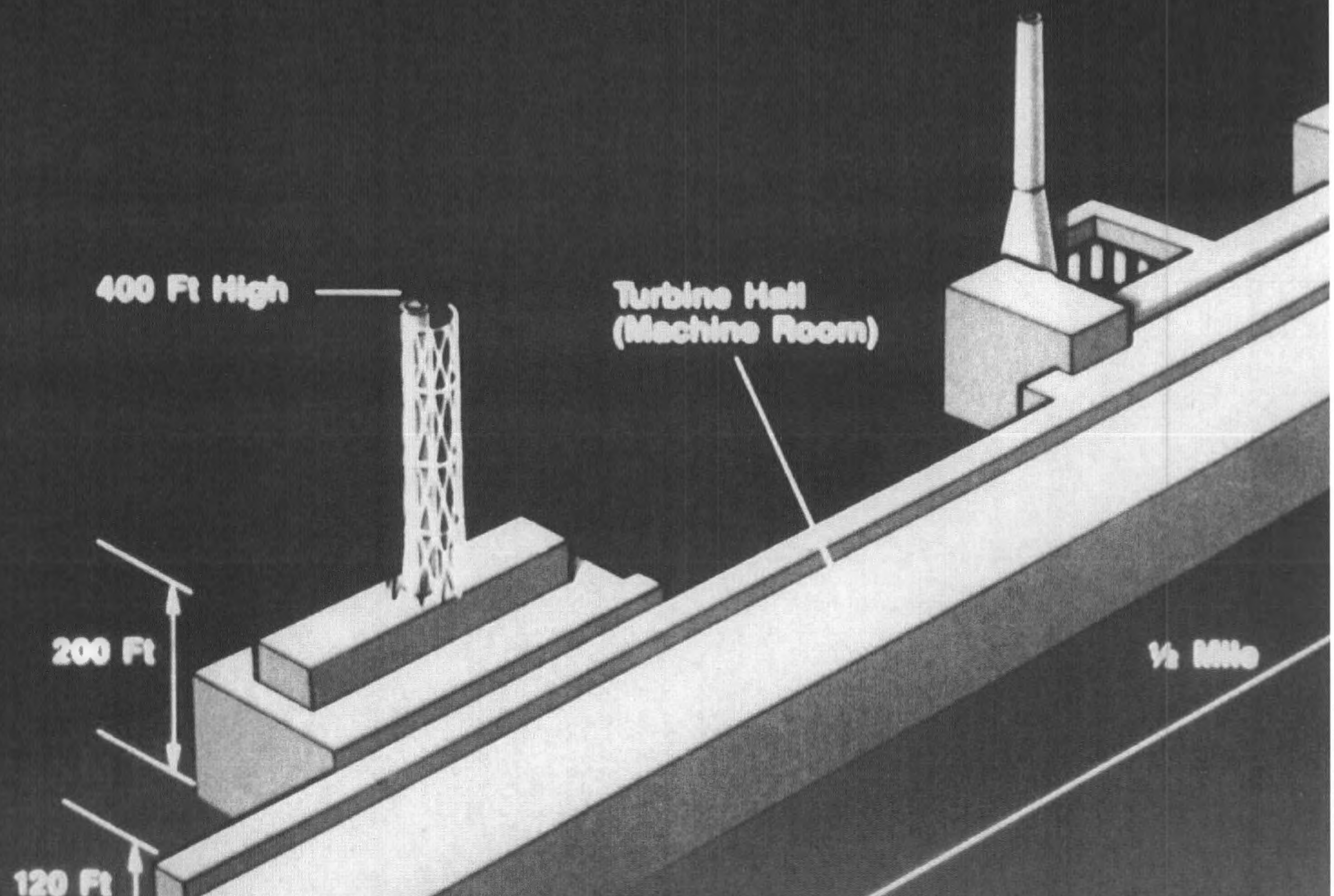

INLAND
NORWAY
SWEDEN
Leningrad
(RBMK-1000)
4 units
UNION OF SOVIET
SOCIALIST REPUBLICS
Kostrom
(RBMK-1
4 unit
Ignalina
(RBMK-1500)
4 units
Smolensk
(RBMK-1000)
6 units
Chernobyl
(RBMK-1000)
6 units
Kurak
(RBMK-1000)
(4 units)
DENMARK
UNITED
KINGDOM
NETHERLANDS
BELGIUM
FRG
GDR
POLAND
CZECHOSLOVAKIA
SWITZERLAND
AUSTRIA
HUNGARY
FRANCE
ITALY
ROMANIA
YUGOSLAVIA
SPAIN

Fig 1

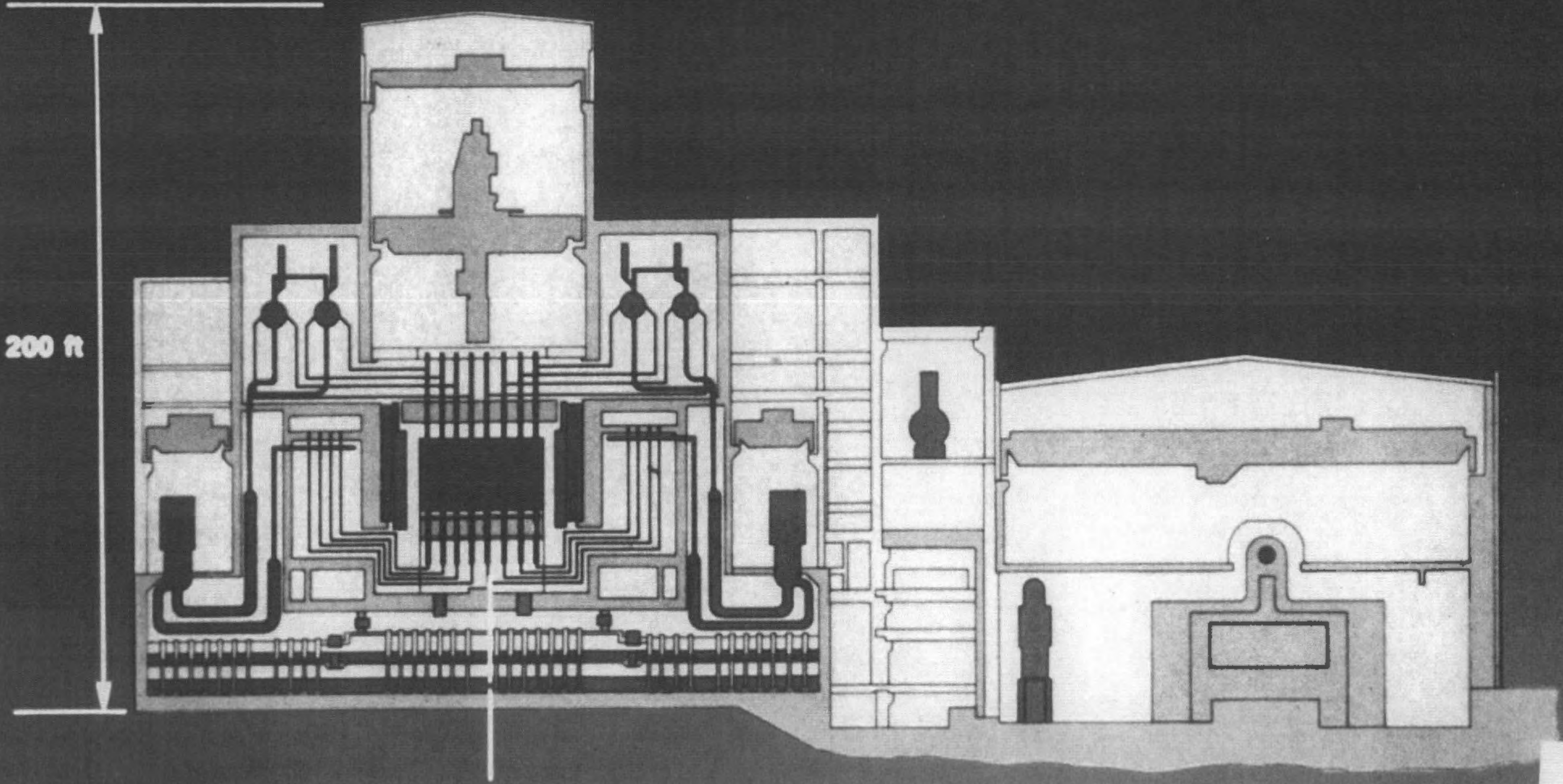
Fig2



CHERNOBYL UNITS 1



CHERNOBYL - 4



Centre Line of Reactor

Turbine Hall

Fig 3

SECTION THROUGH RBMK REACTOR

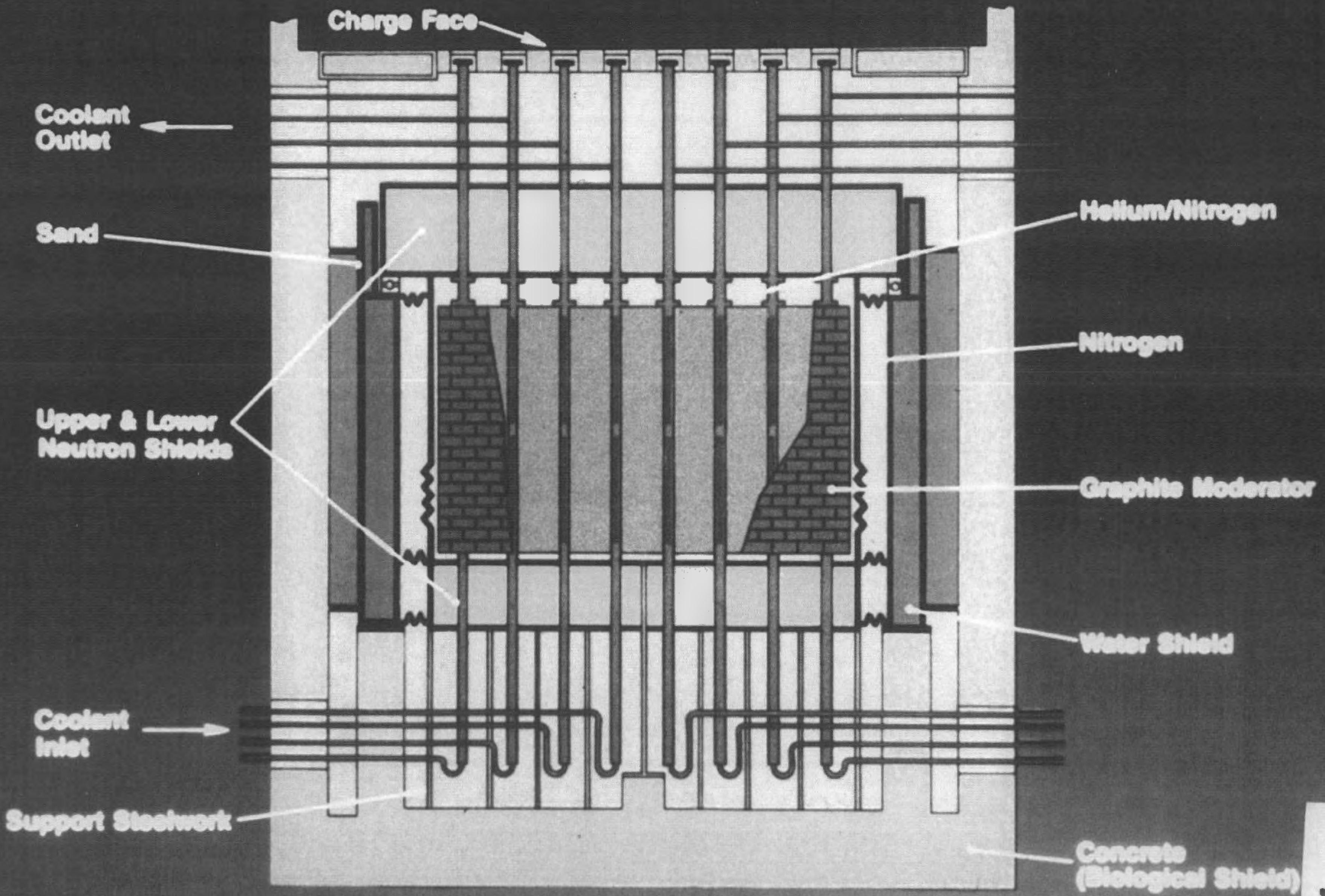


Fig 4

ARRANGEMENT OF PRESSURE TUBES IN REACTOR CORE

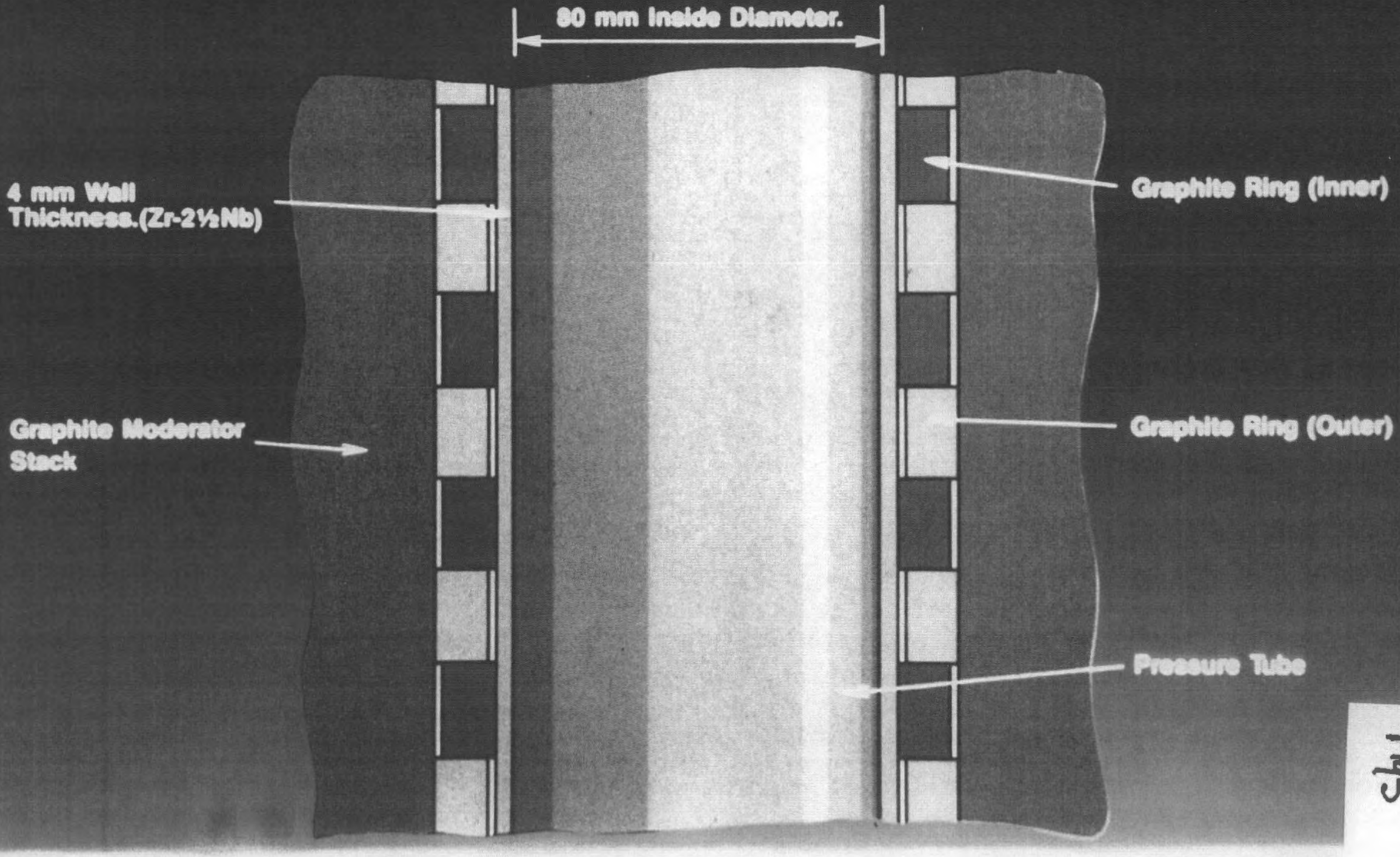
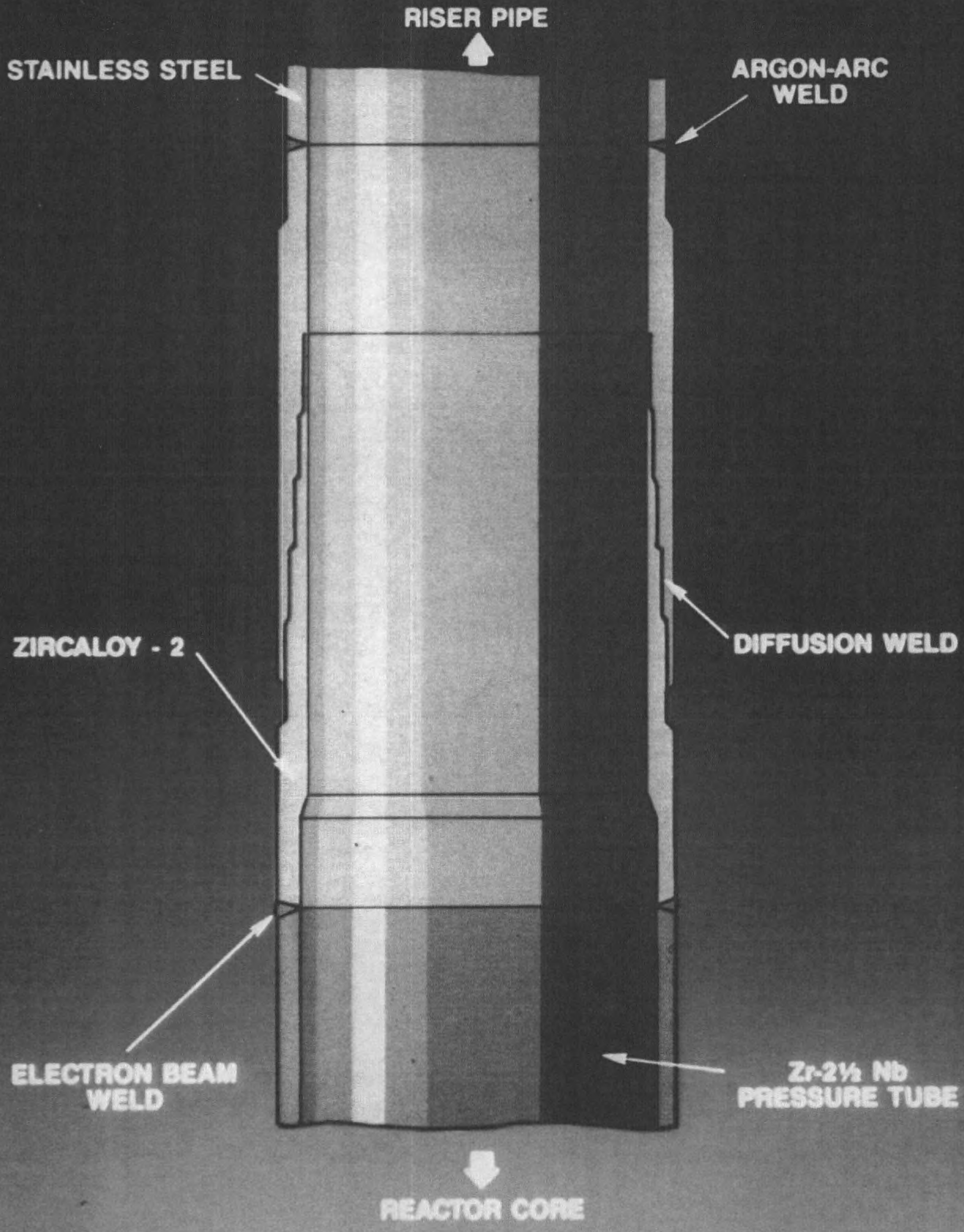


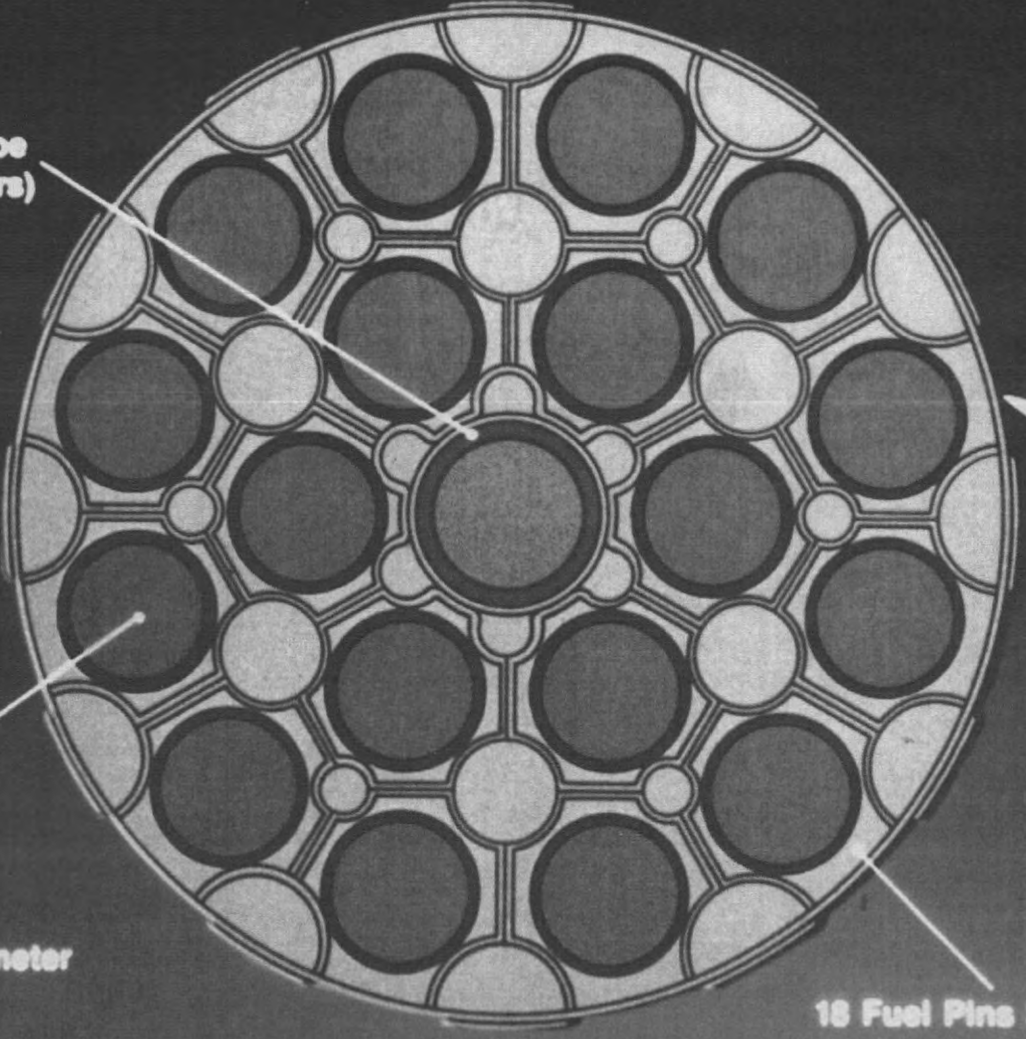
Fig5

FIG. 6

ZIRCONIUM - STEEL JOINT



SECTION OF SPACER GRID & FUEL PINS



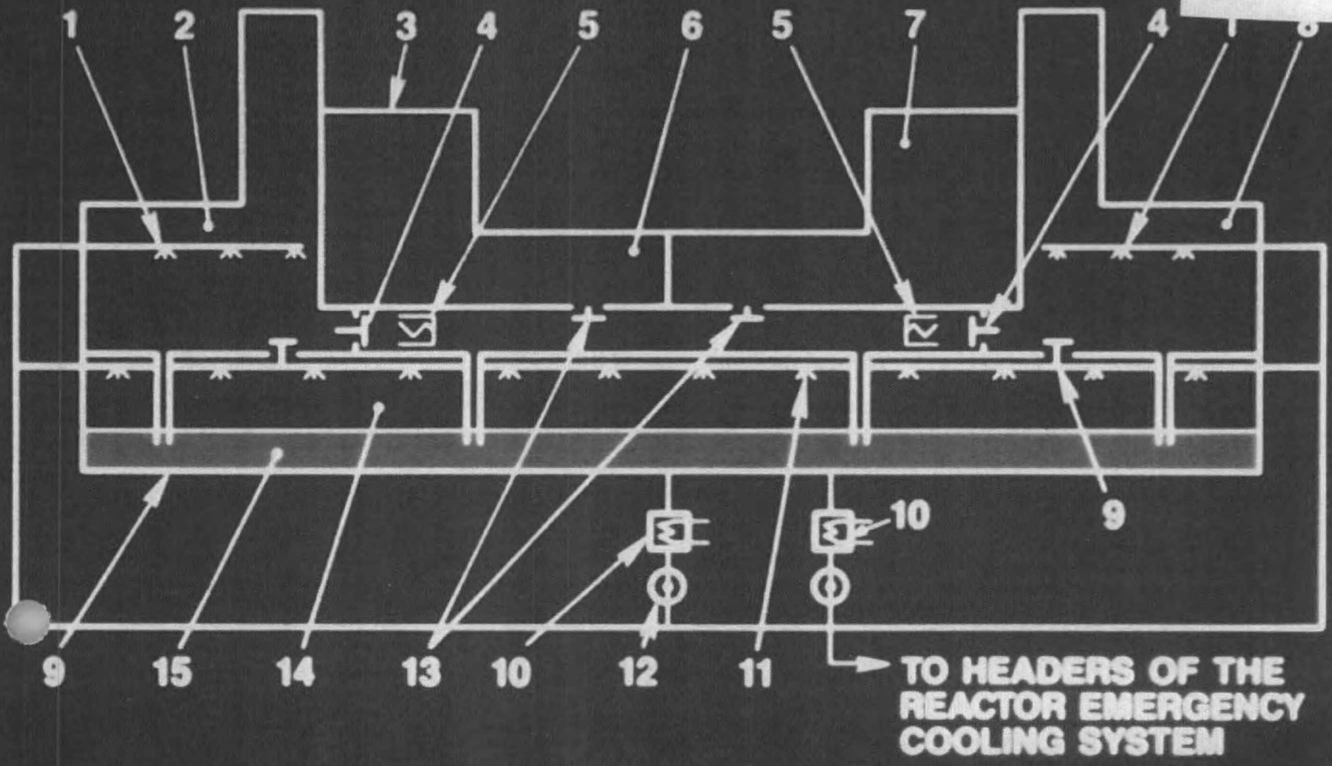
Central Supporting Tube
(With Nuetron Detectors)

Spacer Grid

UO_2 Fuel Pellets
(11·5 mm Dia)
Zr-1½ Nb Cladding
13·6 mm Outside Diameter

18 Fuel Pins 3644 mm Long

Fig 7



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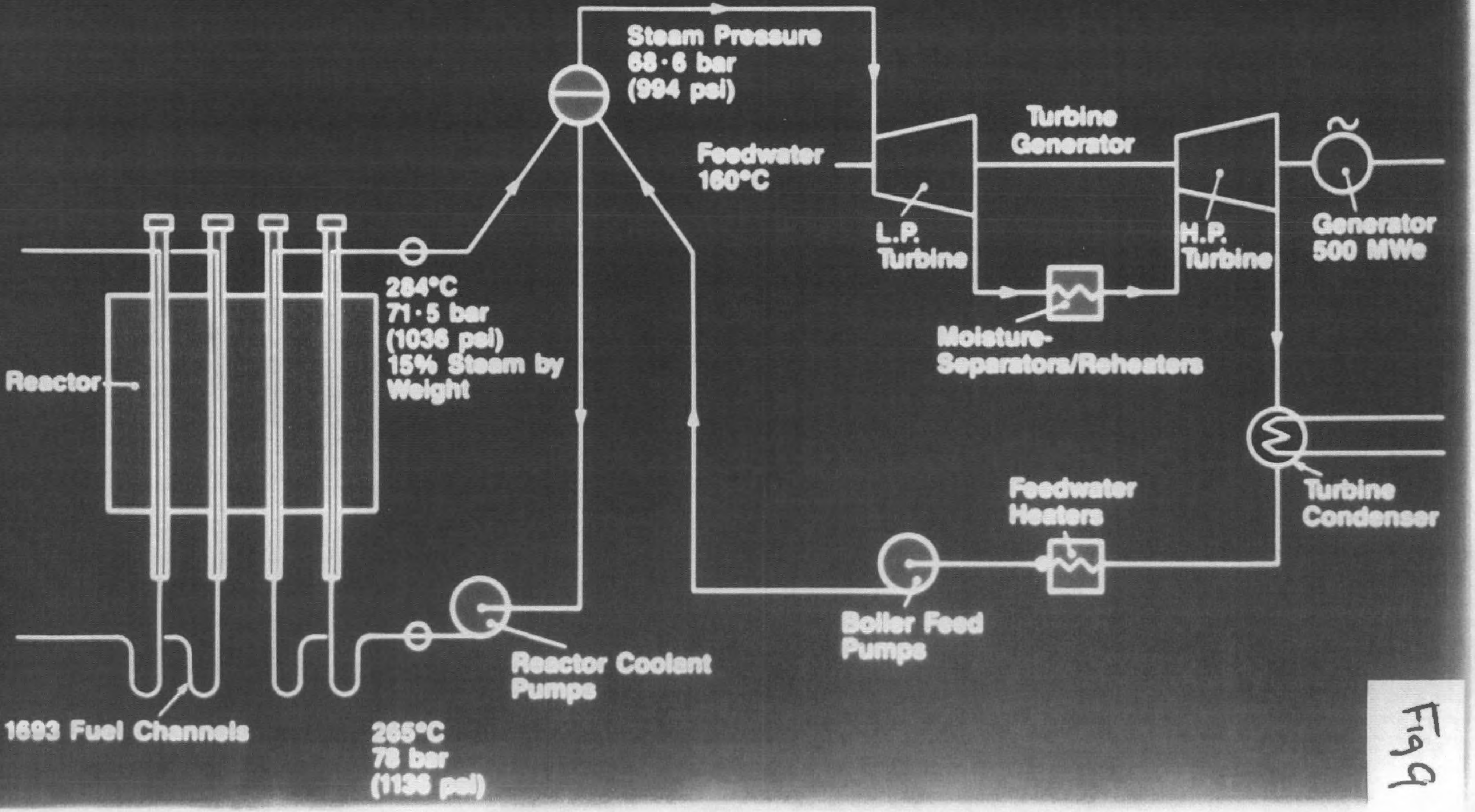
16 - To emergency reactor cooling system collectors.

SCHEMATIC FLOWSHEET OF RBMK POWER PLANT



Steam Pressure
68·6 bar
(994 psi)

Feedwater
160°C

Turbine
Generator

L.P.
Turbine

H.P.
Turbine

Generator
500 MWe

Moisture-
Separators/Reheaters

Reactor

284°C
71·5 bar
(1036 psi)
15% Steam by
Weight

Turbine
Condenser

Feedwater
Heaters

Boiler Feed
Pumps

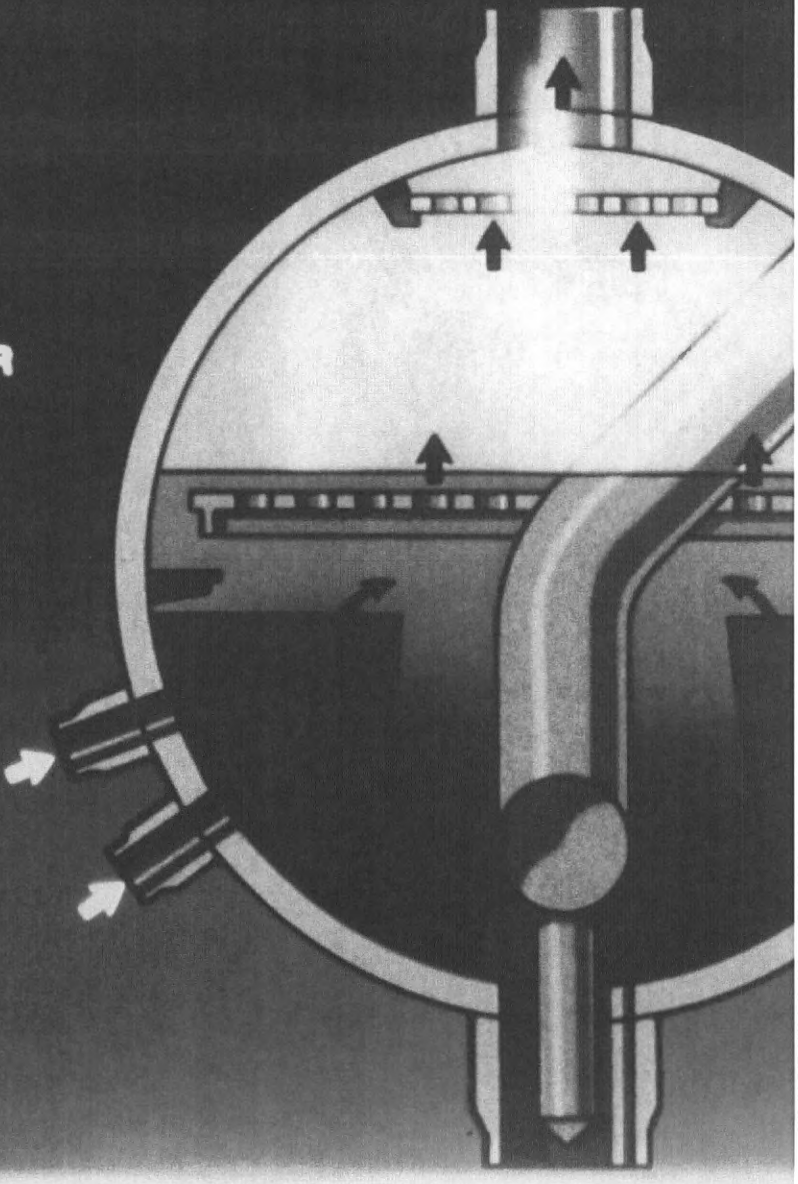
Reactor Coolant
Pumps

1693 Fuel Channels

265°C
78 bar
(1136 psi)

Fig 9

STEAM DRU



STEAM TO TURBINE

8·5 DIAMETER

UM

Fig 10

CHERNOBYL REACTOR SCEMATIC

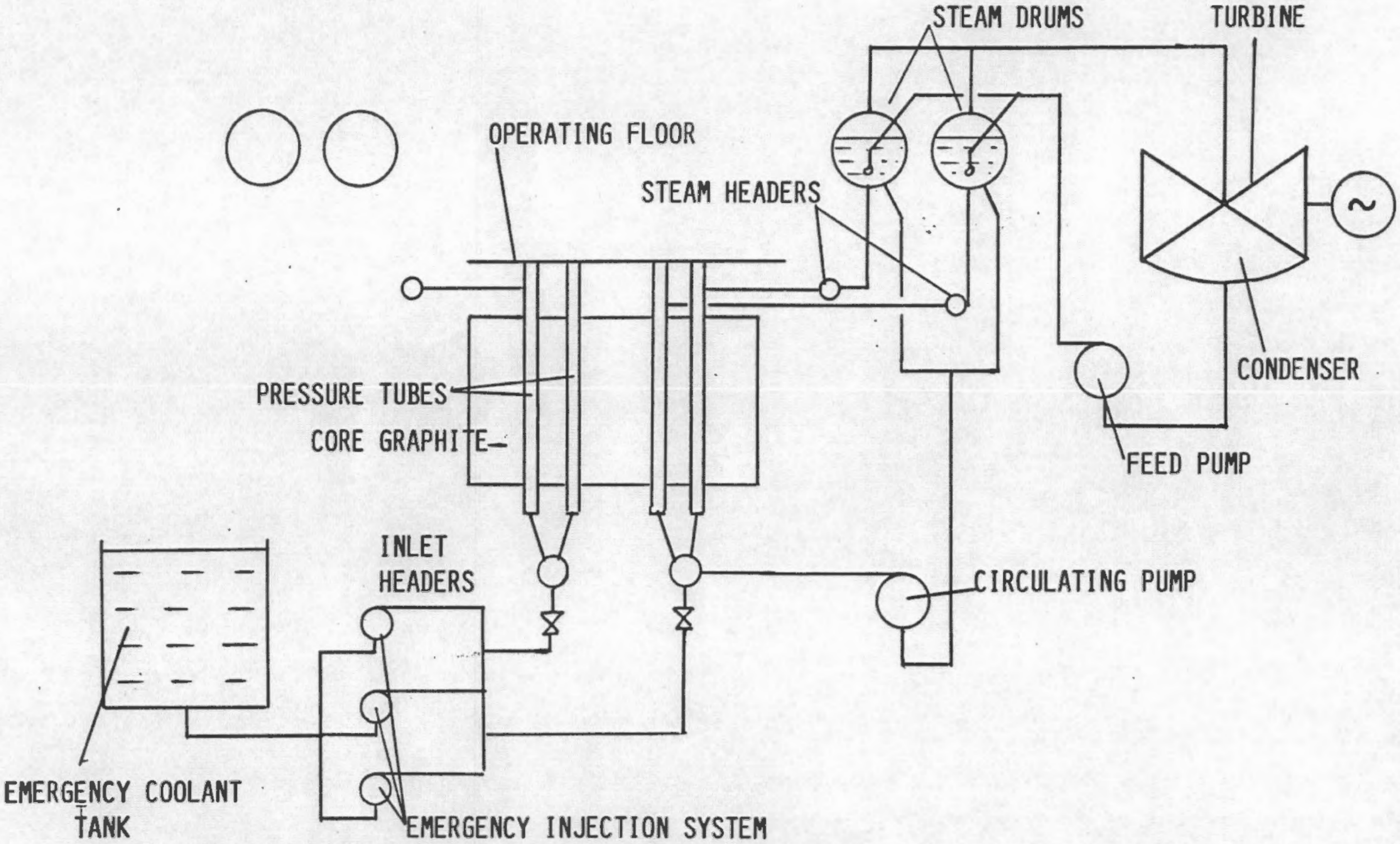
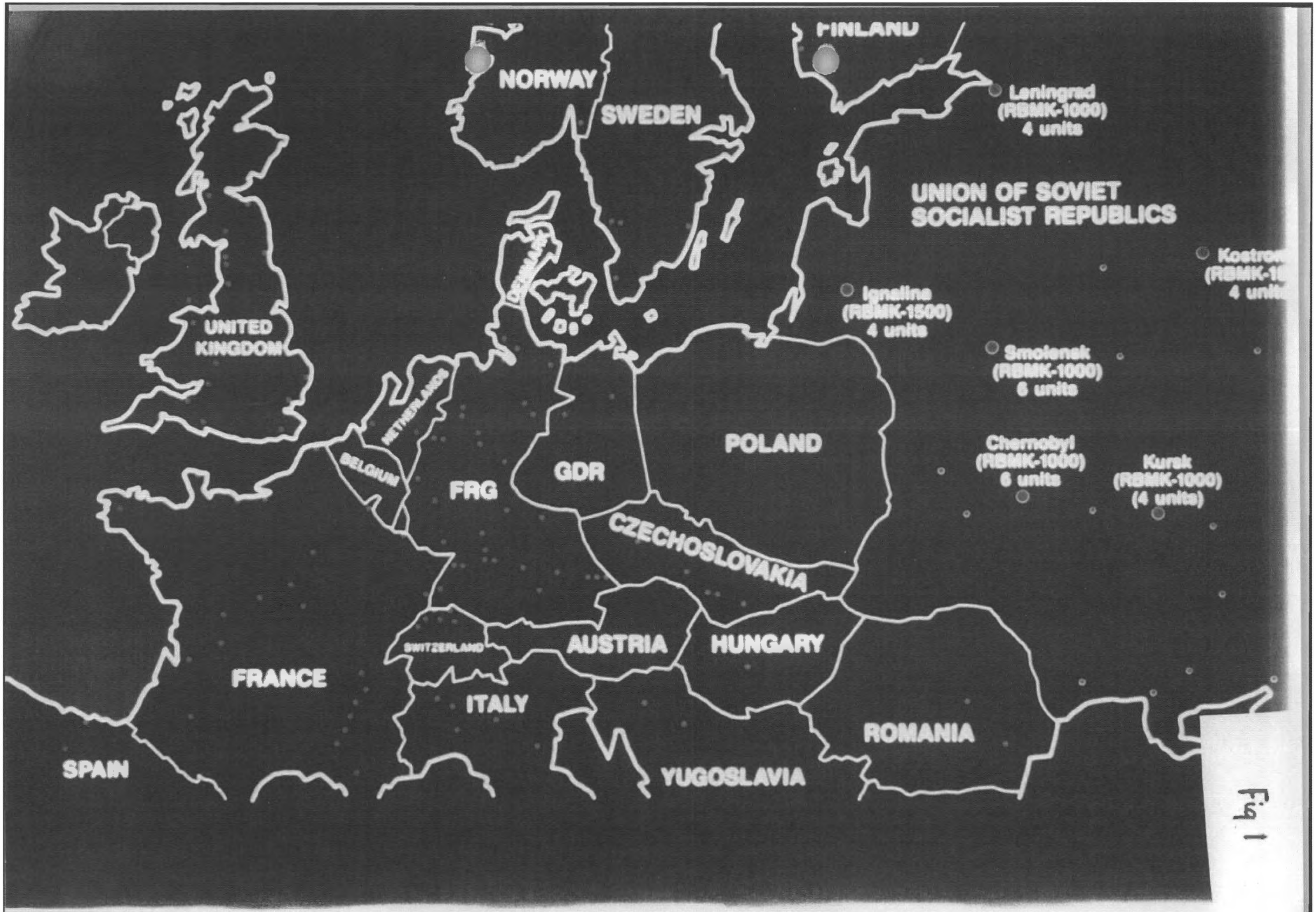


FIG. 11


FINLAND
NORWAY
SWEDEN
Leningrad (RBMK-1000) 4 units
UNION OF SOVIET SOCIALIST REPUBLICS
Kostrom (RBMK-1 4 unit
Ignalina (RBMK-1500) 4 units
Smolensk (RBMK-1000) 6 units
Chernobyl (RBMK-1000) 6 units
Kursk (RBMK-1000) (4 units)
UNITED KINGDOM
DENMARK
NETHERLANDS
BELGIUM
FRG
GDR
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CZECHOSLOVAKIA
SWITZERLAND
AUSTRIA
HUNGARY
FRANCE
ITALY
ROMANIA
YUGOSLAVIA
SPAIN

Fig 1

CHERNOBYL UNITS 1 - 4

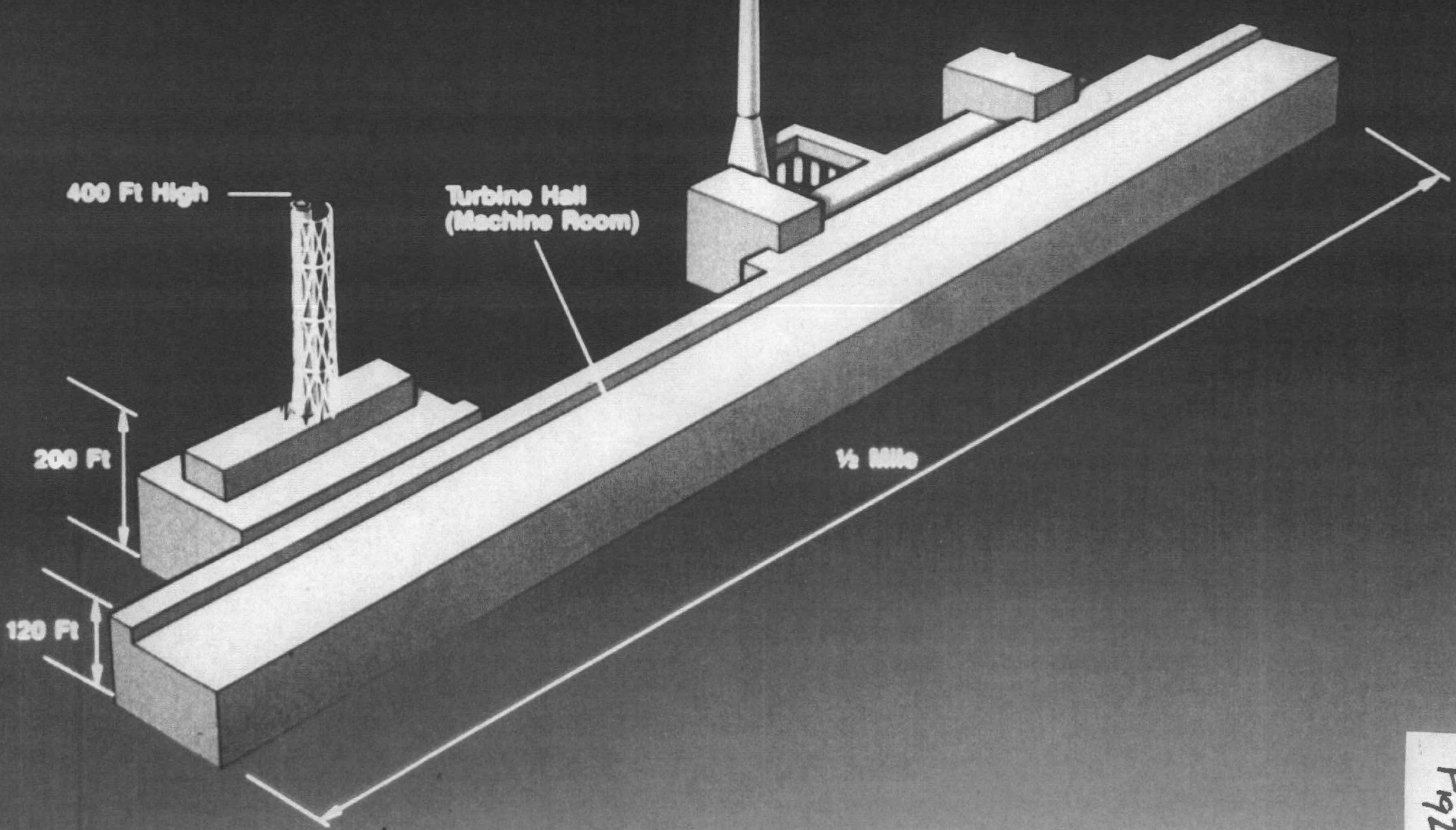

Fig 2

CHERNOBYL - 4

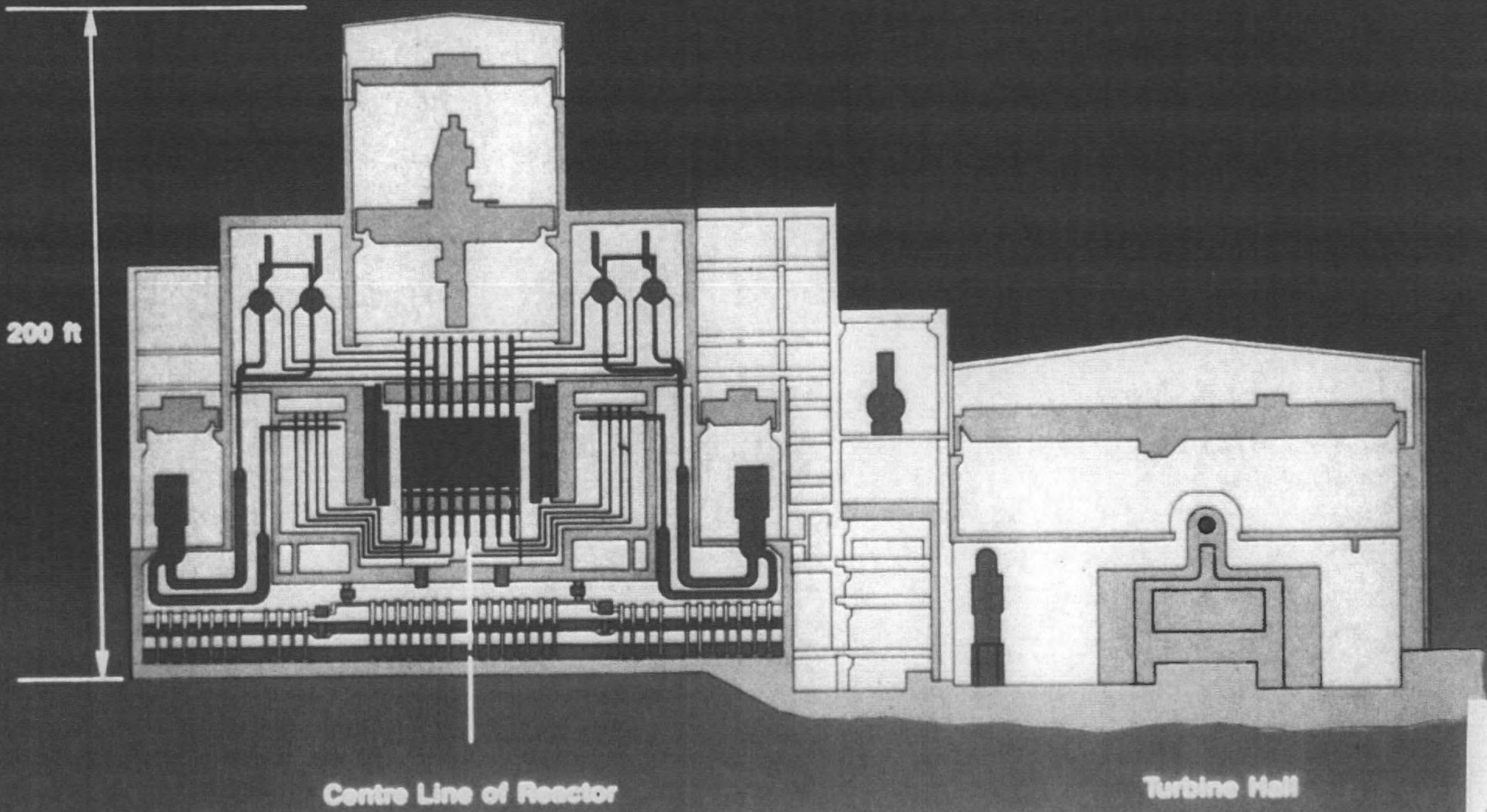

Fig 3

SECTION THROUGH RBMK REACTOR

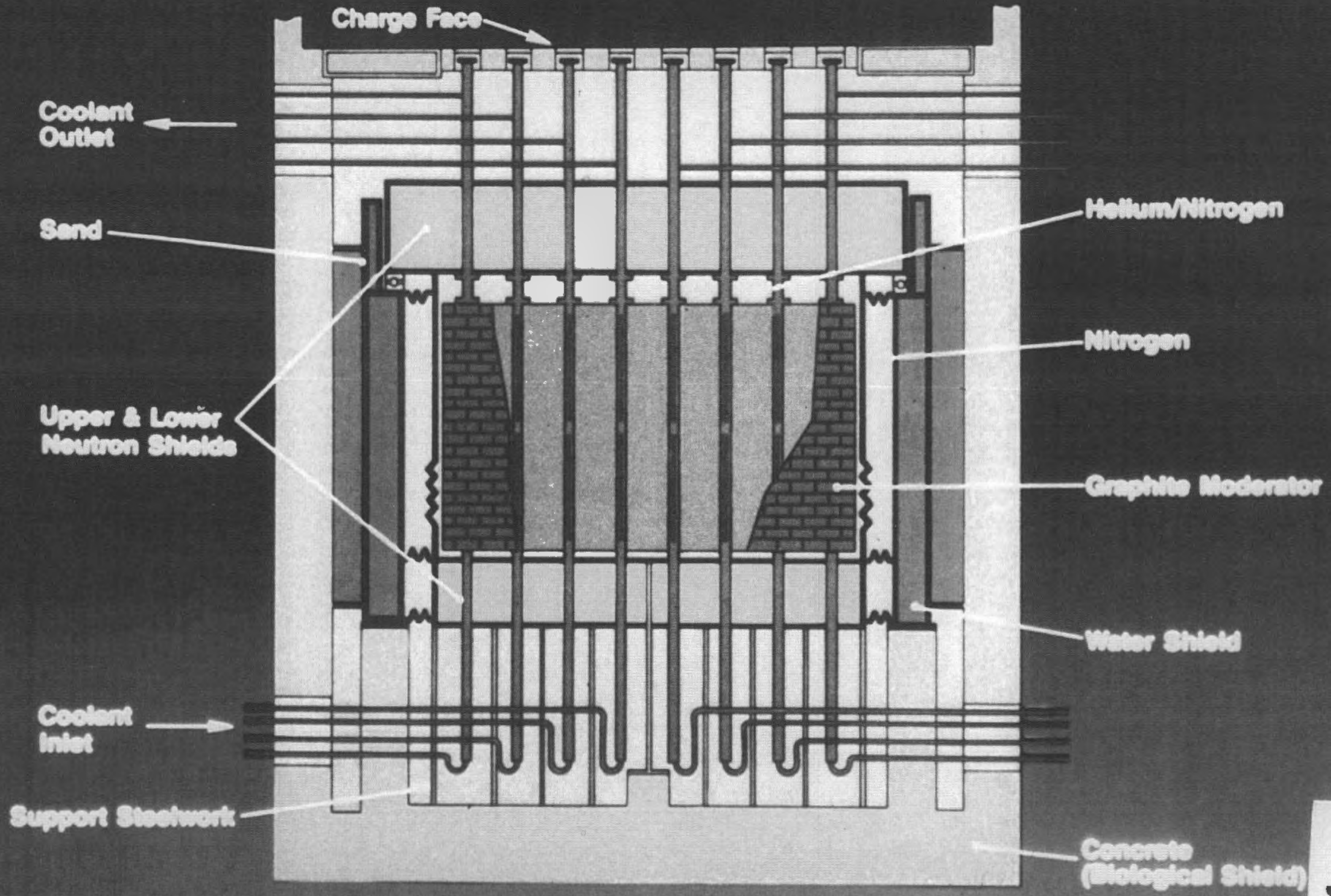

Fig 4

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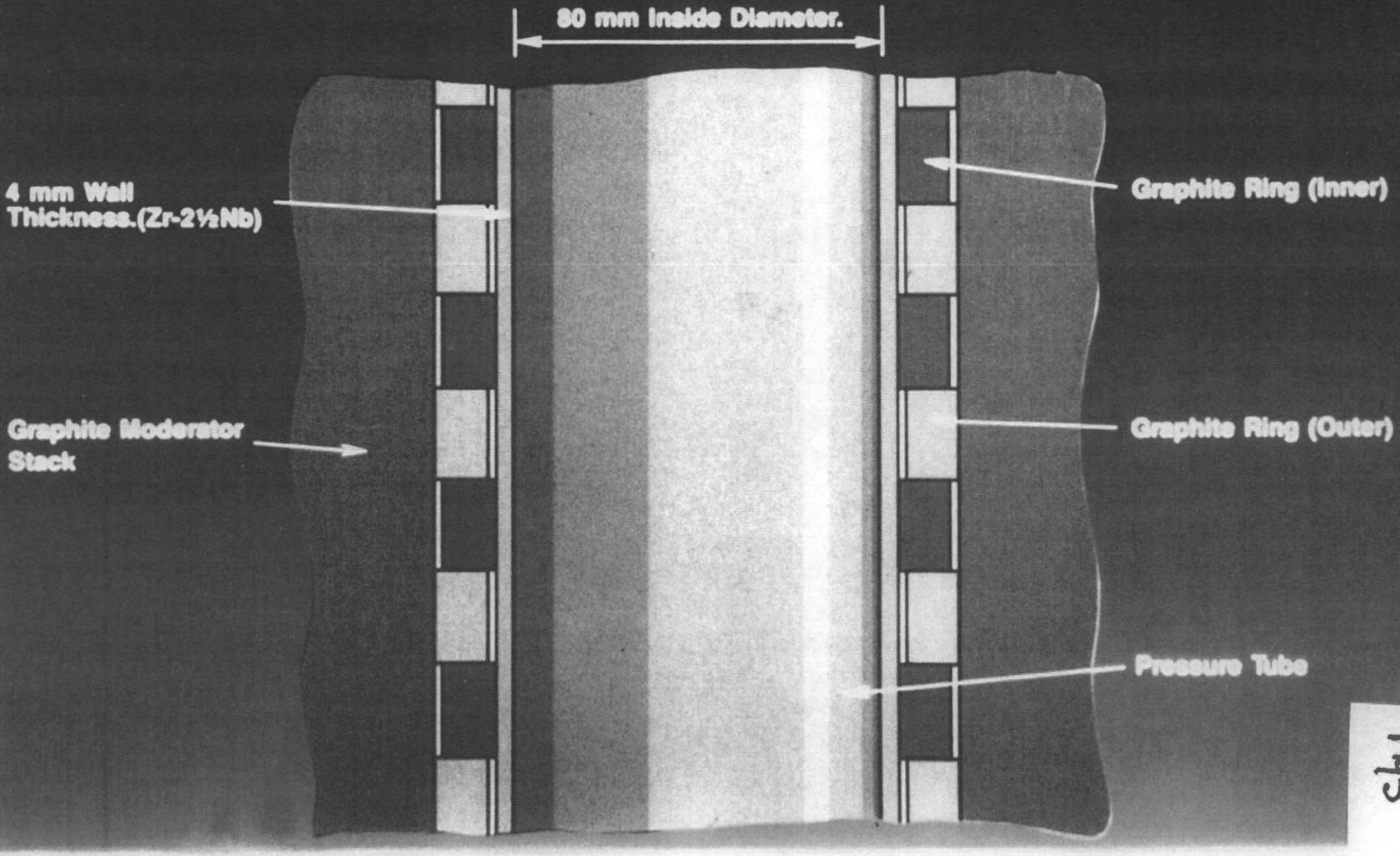
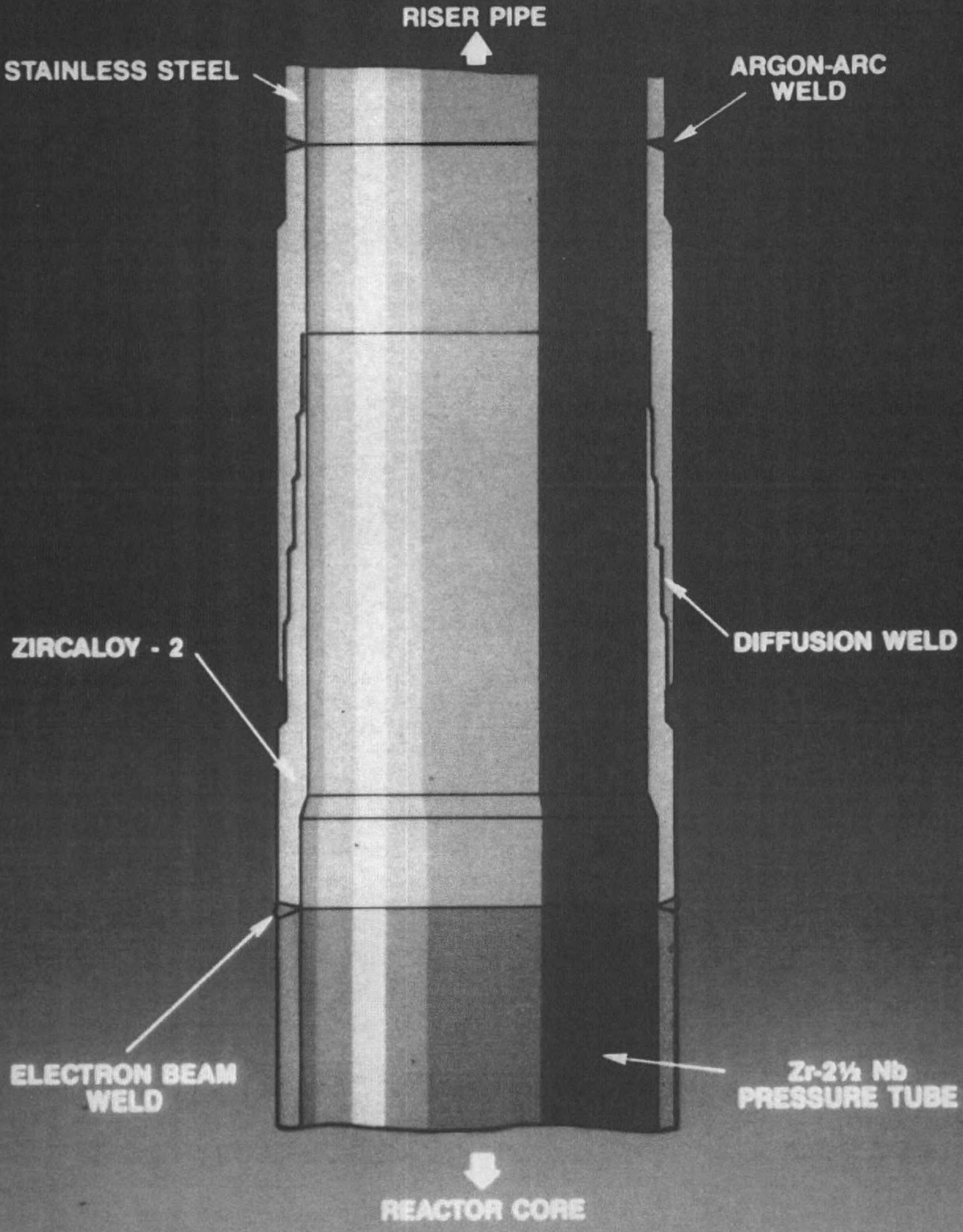


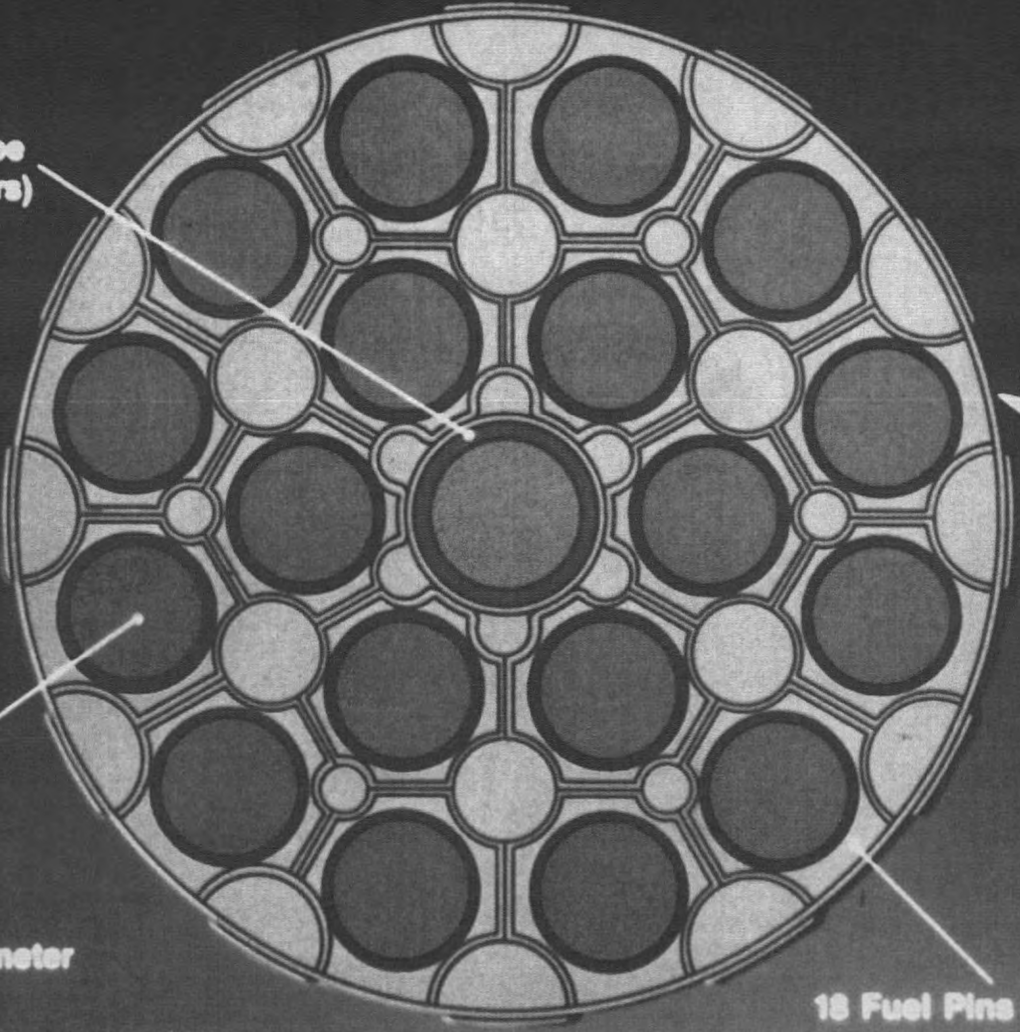
Fig5

FIG. 6

ZIRCONIUM - STEEL JOINT



SECTION OF SPACER GRID & FUEL PINS



Central Supporting Tube
(With Nuetron Detectors)

Spacer Grid

Uo$_2$ Fuel Pellets
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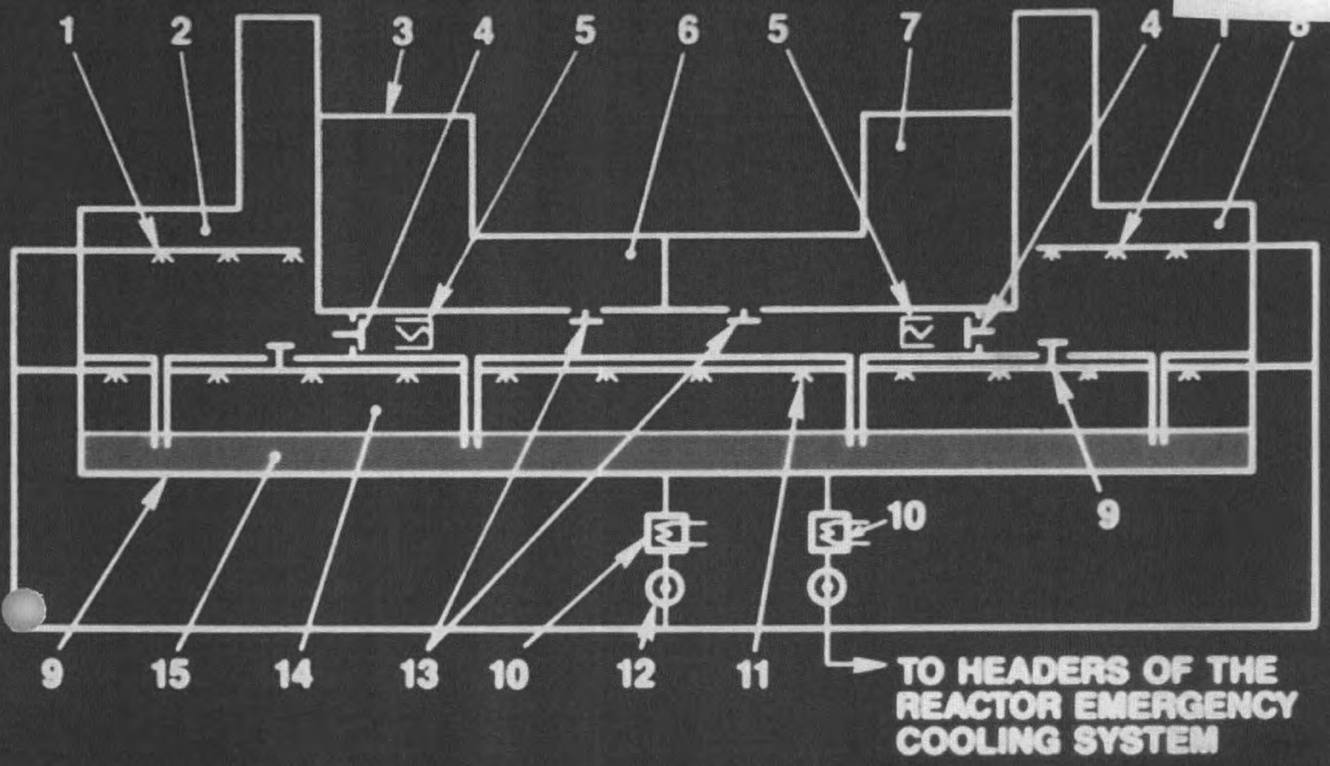
Zr-1½ Nb Cladding
13·6 mm Outside Diameter

18 Fuel Pins 3644 mm Long

Fig 7



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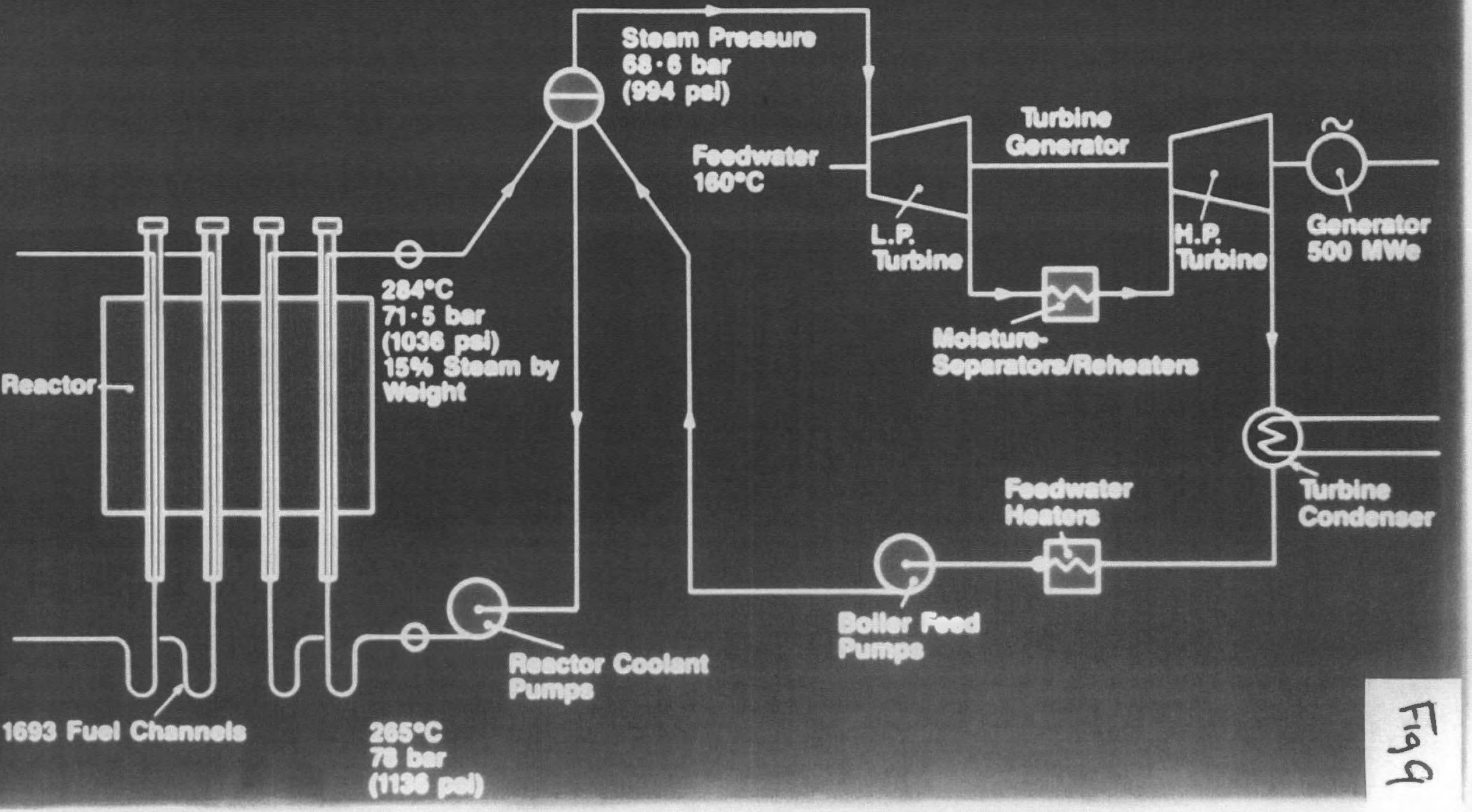
SCHEMATIC FLOWSHEET OF RBMK POWER PLANT



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68·6 bar
(994 psi)

Feedwater
160°C

Turbine
Generator

L.P.
Turbine

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500 MWe

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265°C
78 bar
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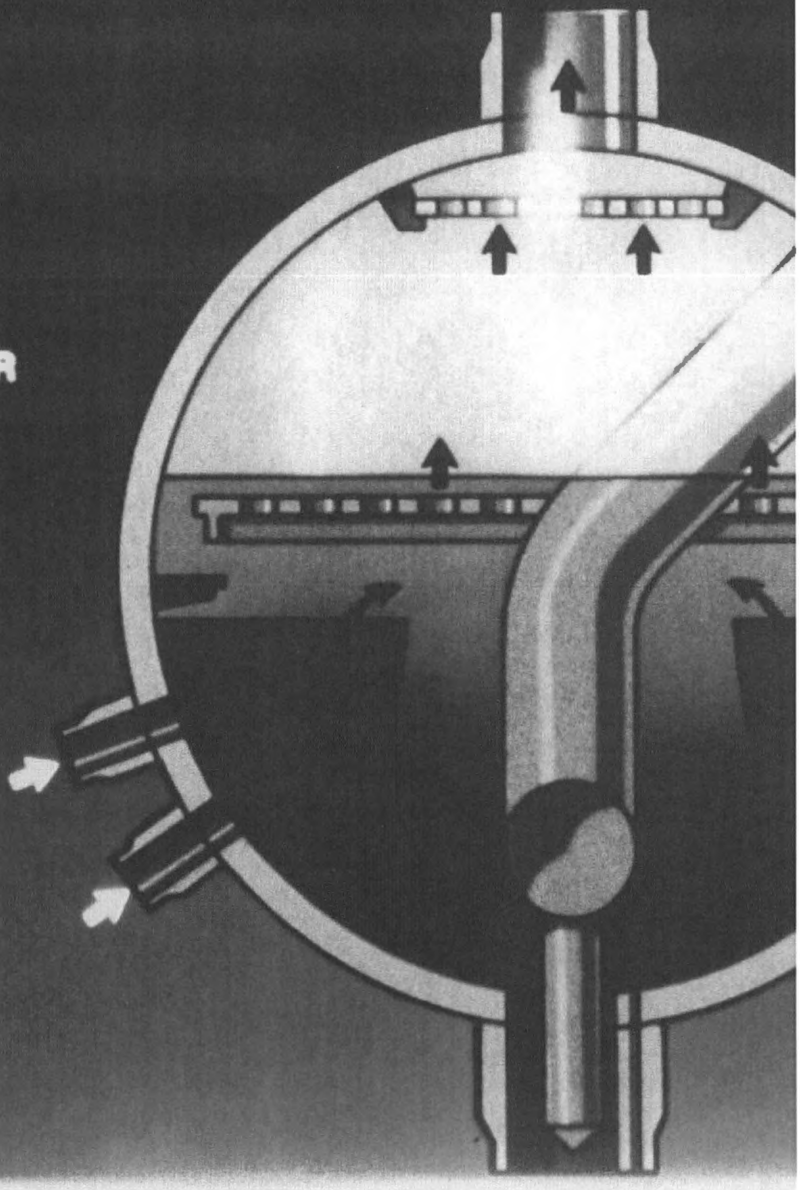
Fig 9

STEAM DRU

STEAM TO TURBINE

8·5 DIAMETER



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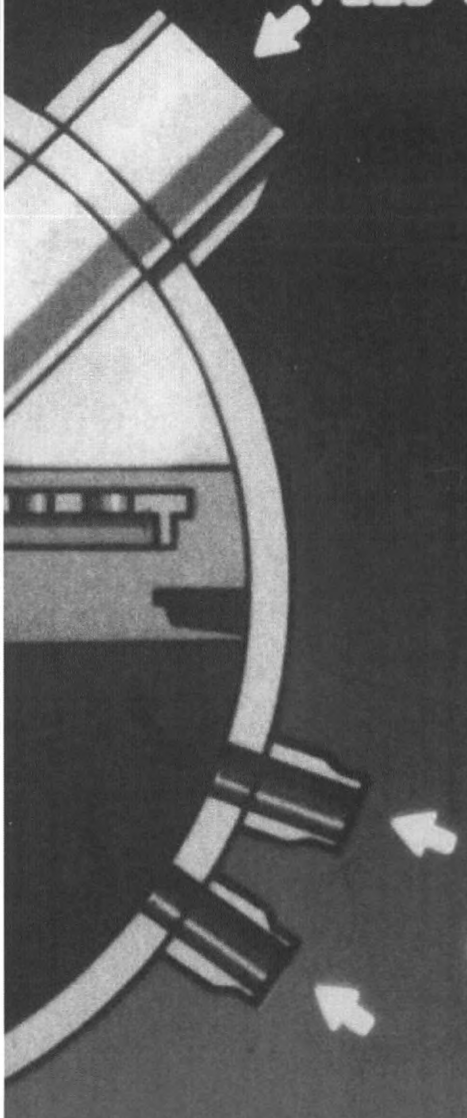


Fig 10

CHERNOBYL REACTOR SCEMATIC

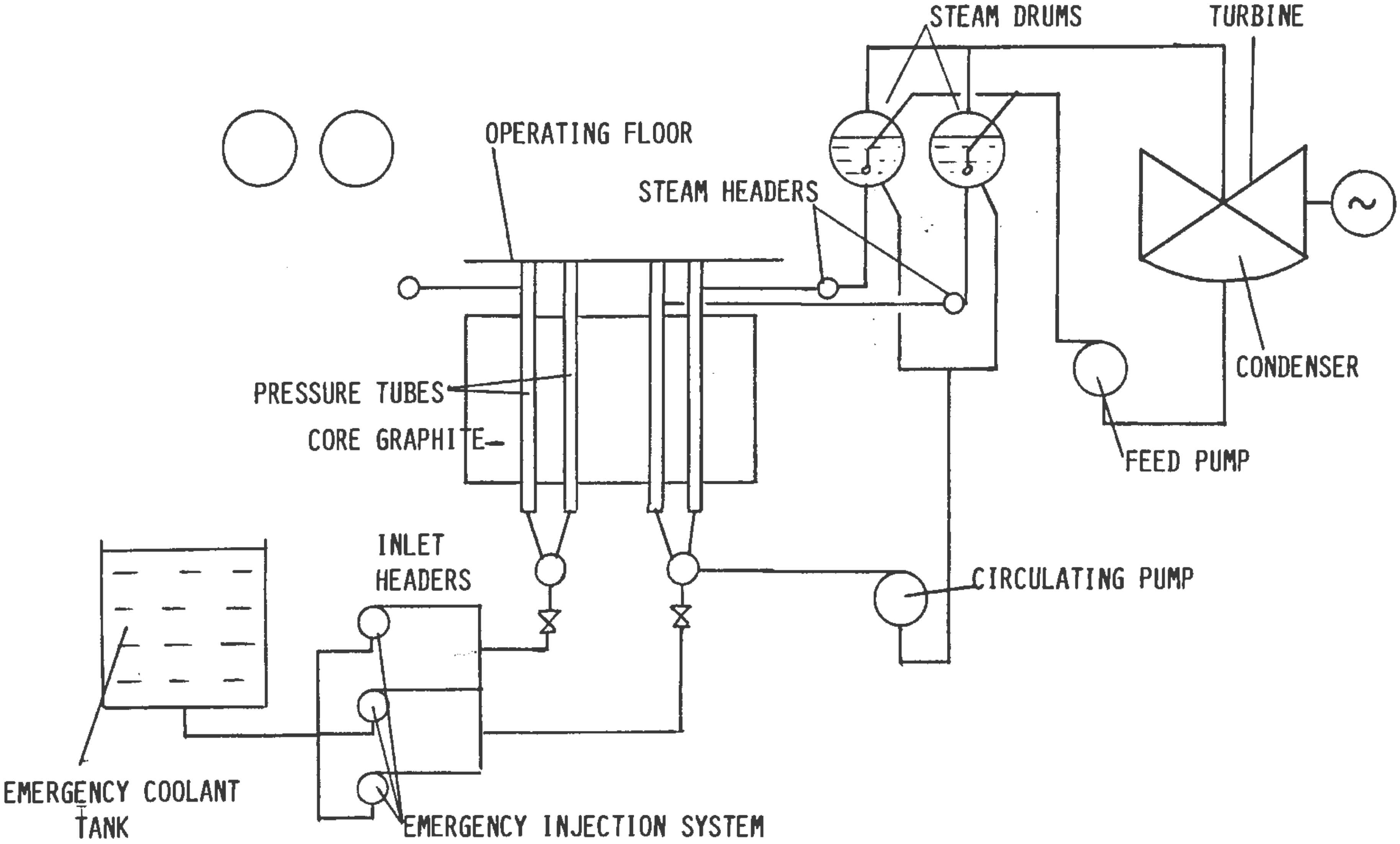


FIG. 11

CHERNOBYL REACTOR SCEMATIC

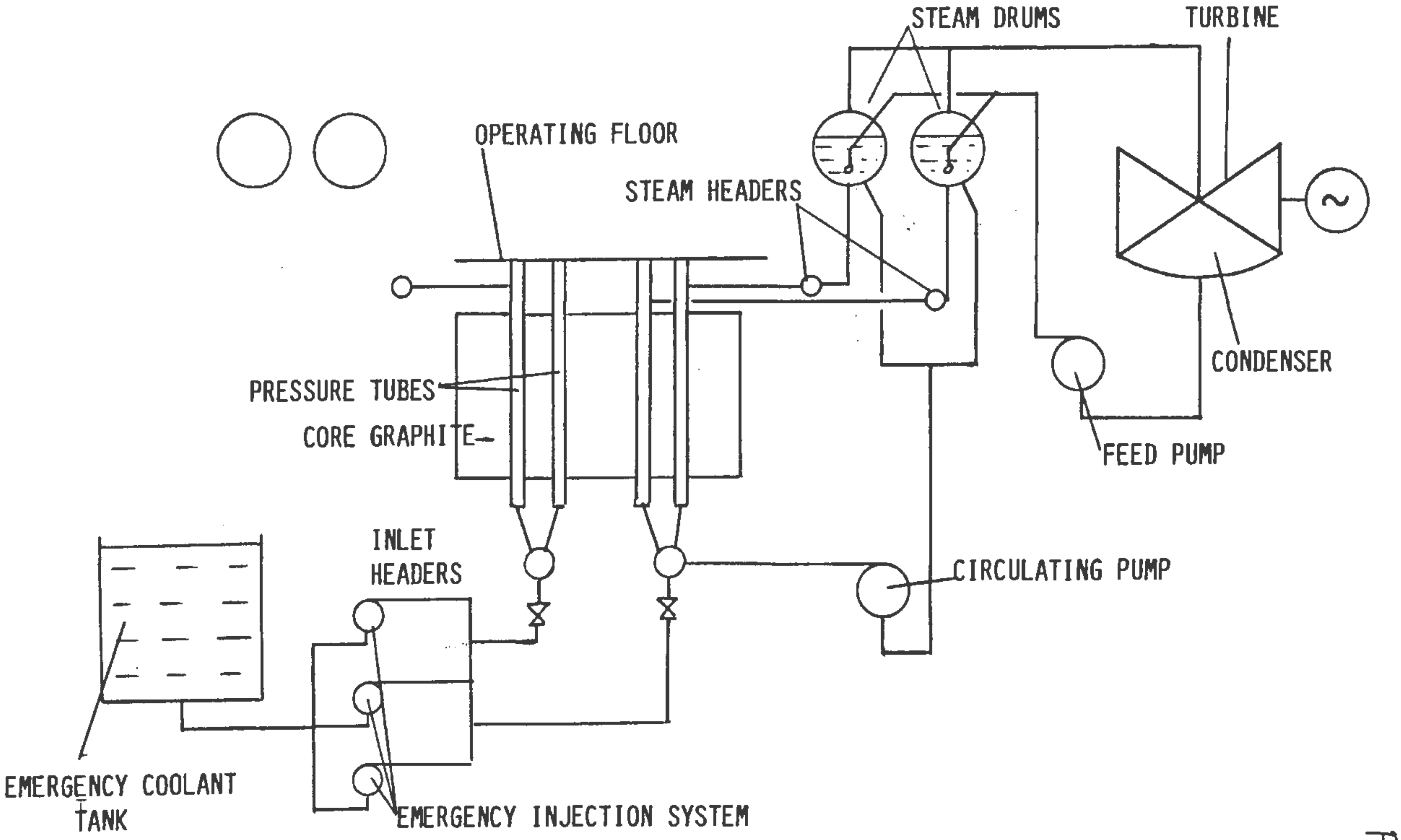
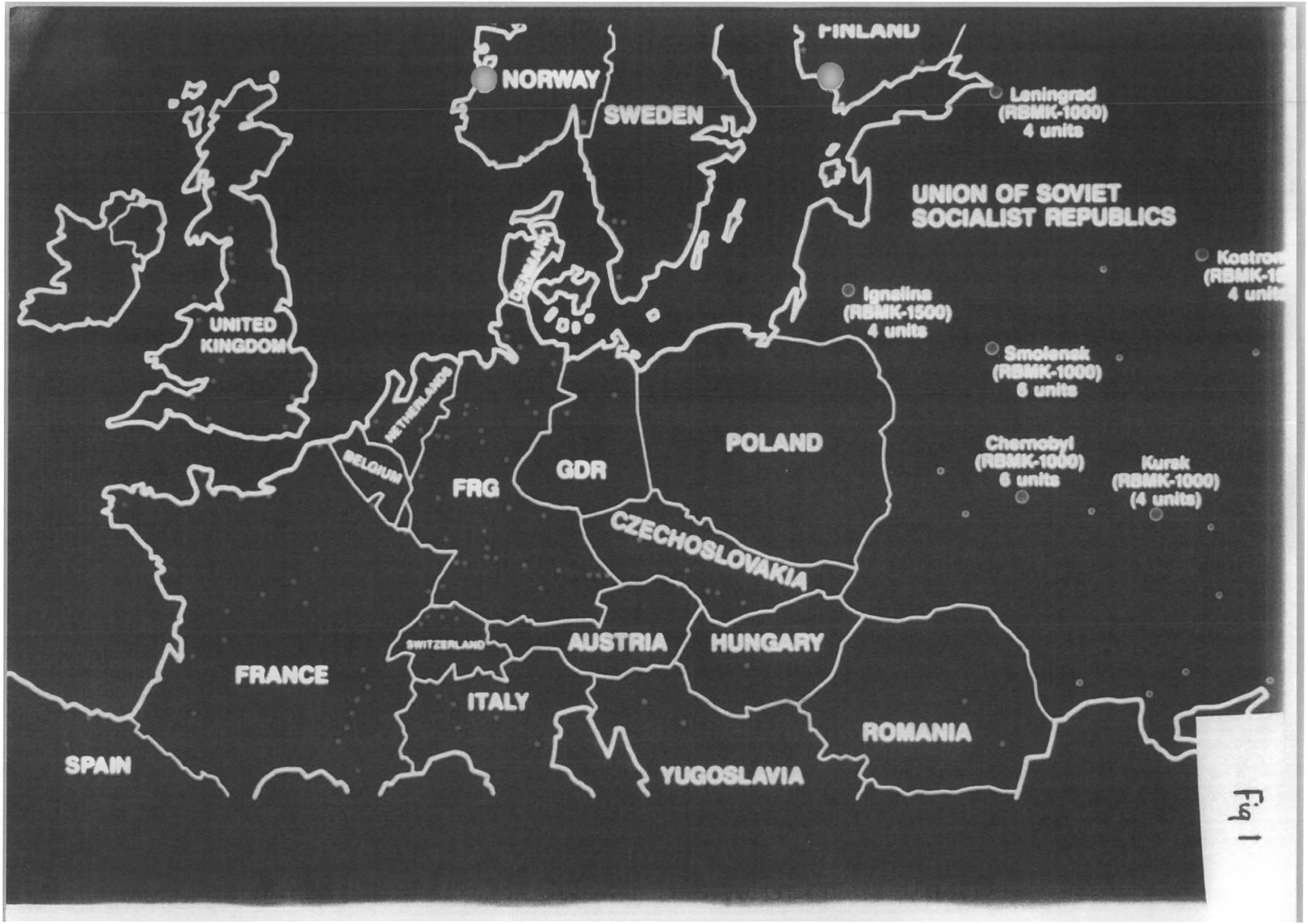


FIG. 11


FINLAND
NORWAY
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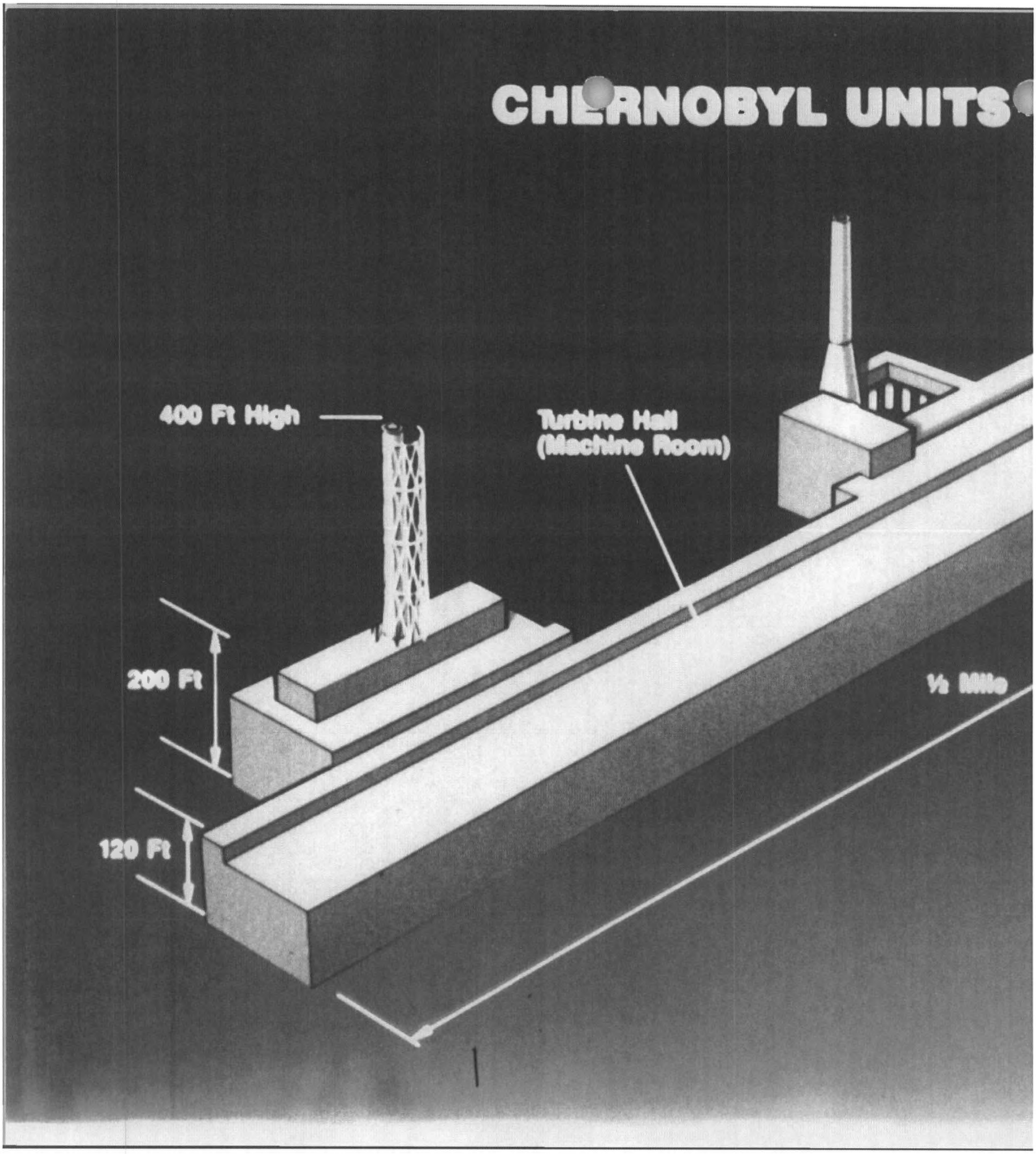
4 units
UNION OF SOVIET
SOCIALIST REPUBLICS
Kostrom
(RBMK-1
4 unit
Ignalina
(RBMK-1500)
4 units
Smolensk
(RBMK-1000)
6 units
Chernobyl
(RBMK-1000)
6 units
Kursk
(RBMK-1000)
(4 units)
UNITED
KINGDOM
DENMARK
NETHERLANDS
BELGIUM
FRG
GDR
POLAND
CZECHOSLOVAKIA
SWITZERLAND
AUSTRIA
HUNGARY
FRANCE
ITALY
SPAIN
ROMANIA
YUGOSLAVIA

Fig 1

CHERNOBYL UNITS



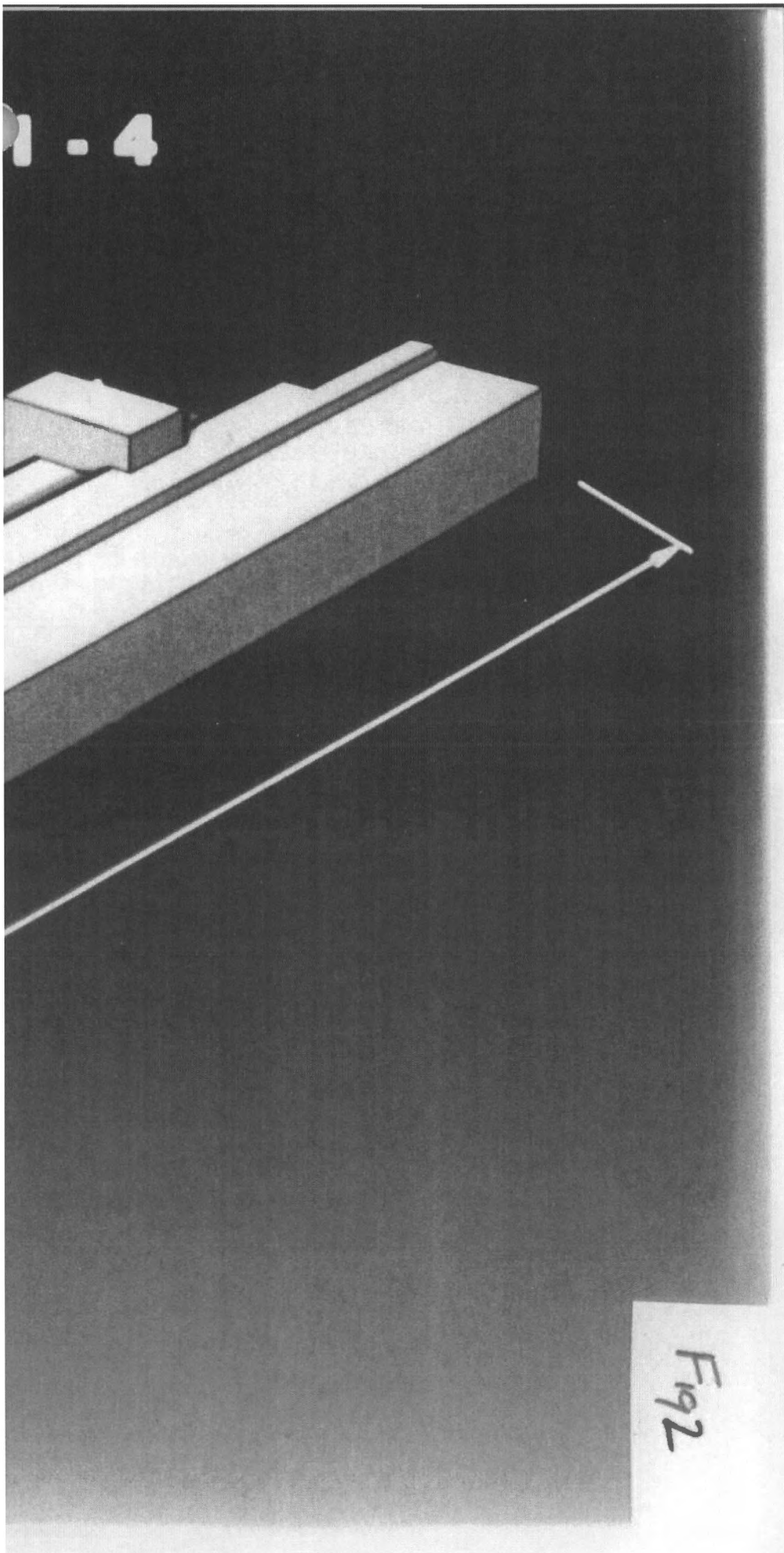


Fig2

CHERNOBYL - 4

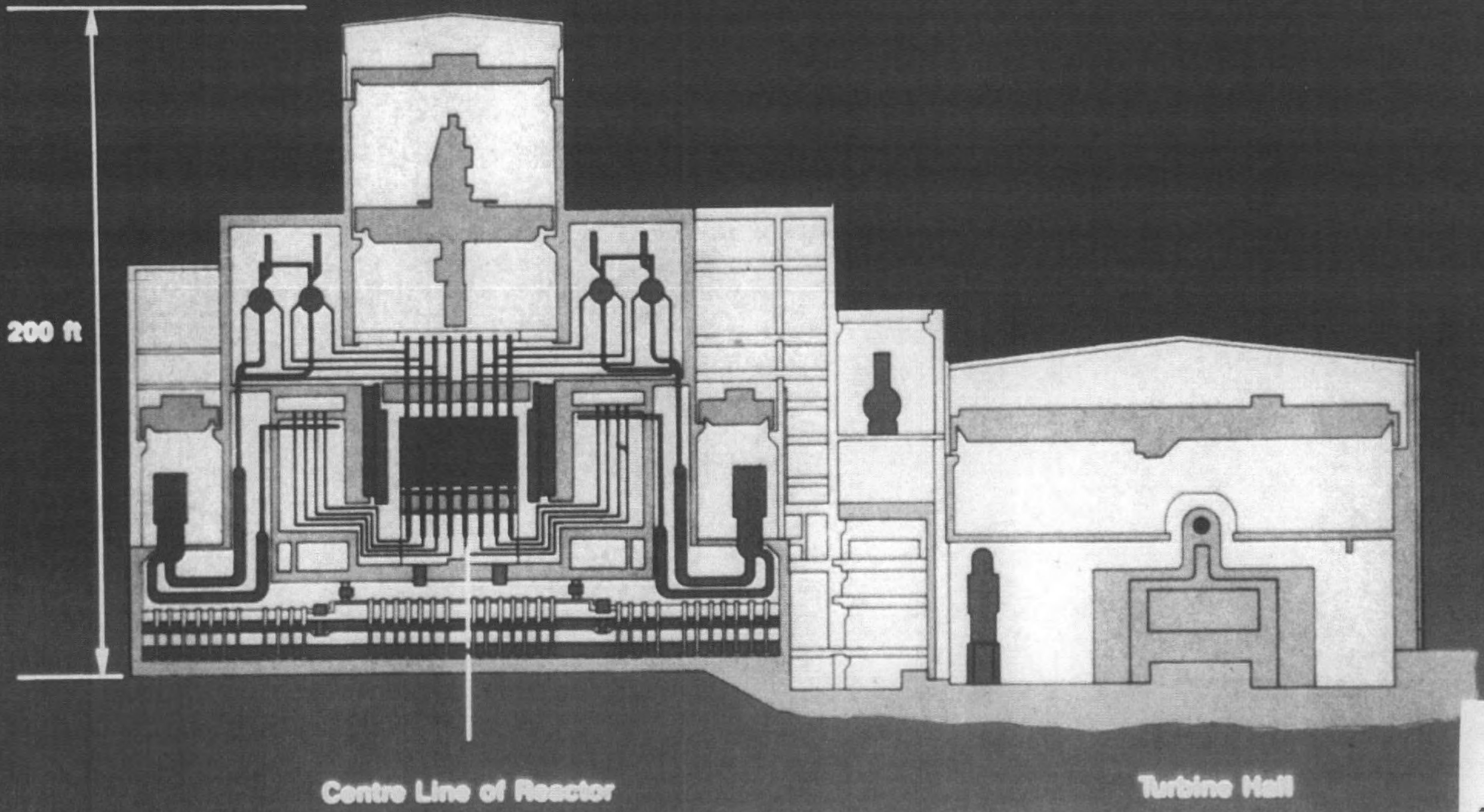


Fig 3

SECTION THROUGH RBMK REACTOR

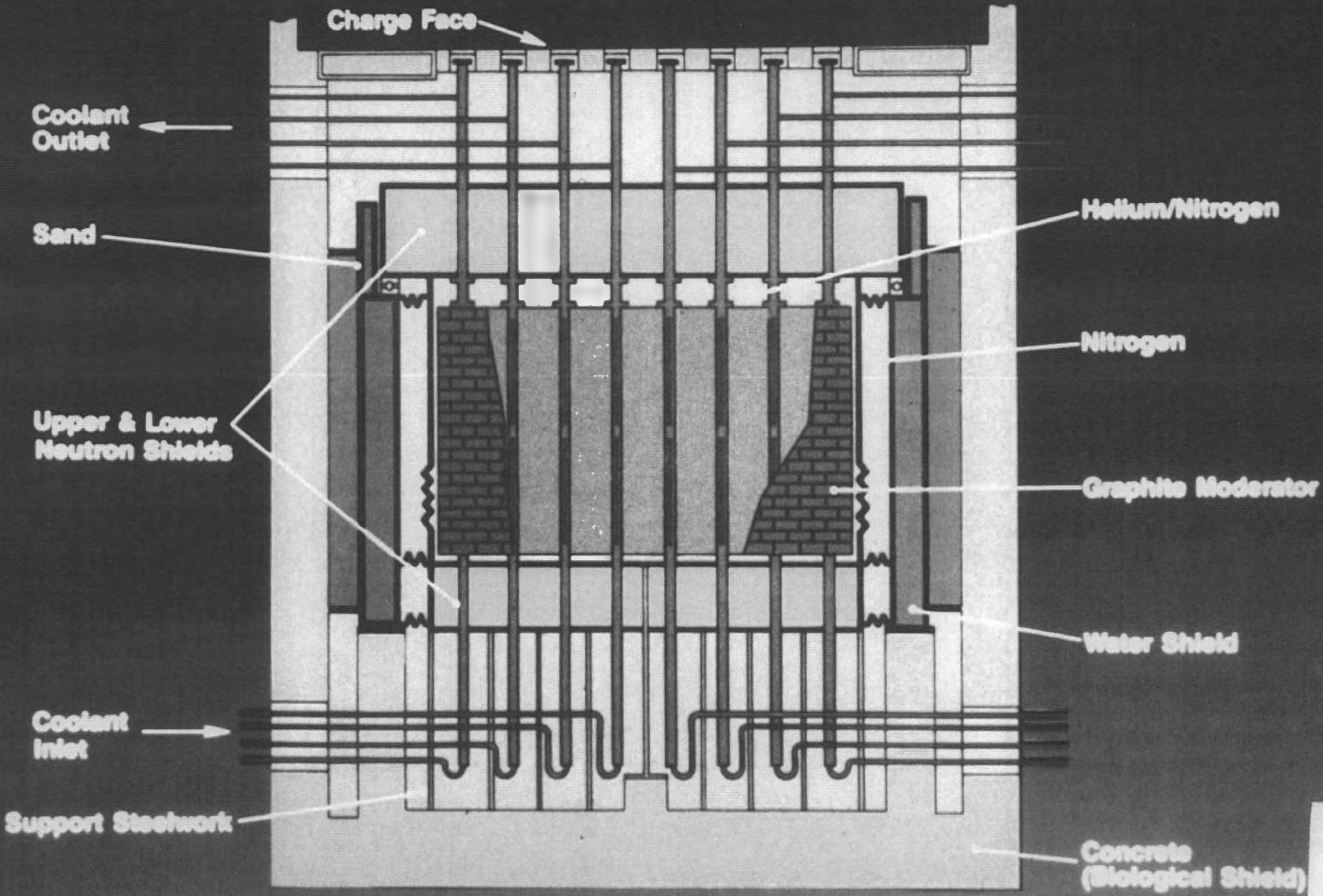


Fig 4

ARRANGEMENT OF PRESSURE TUBES IN REACTOR CORE

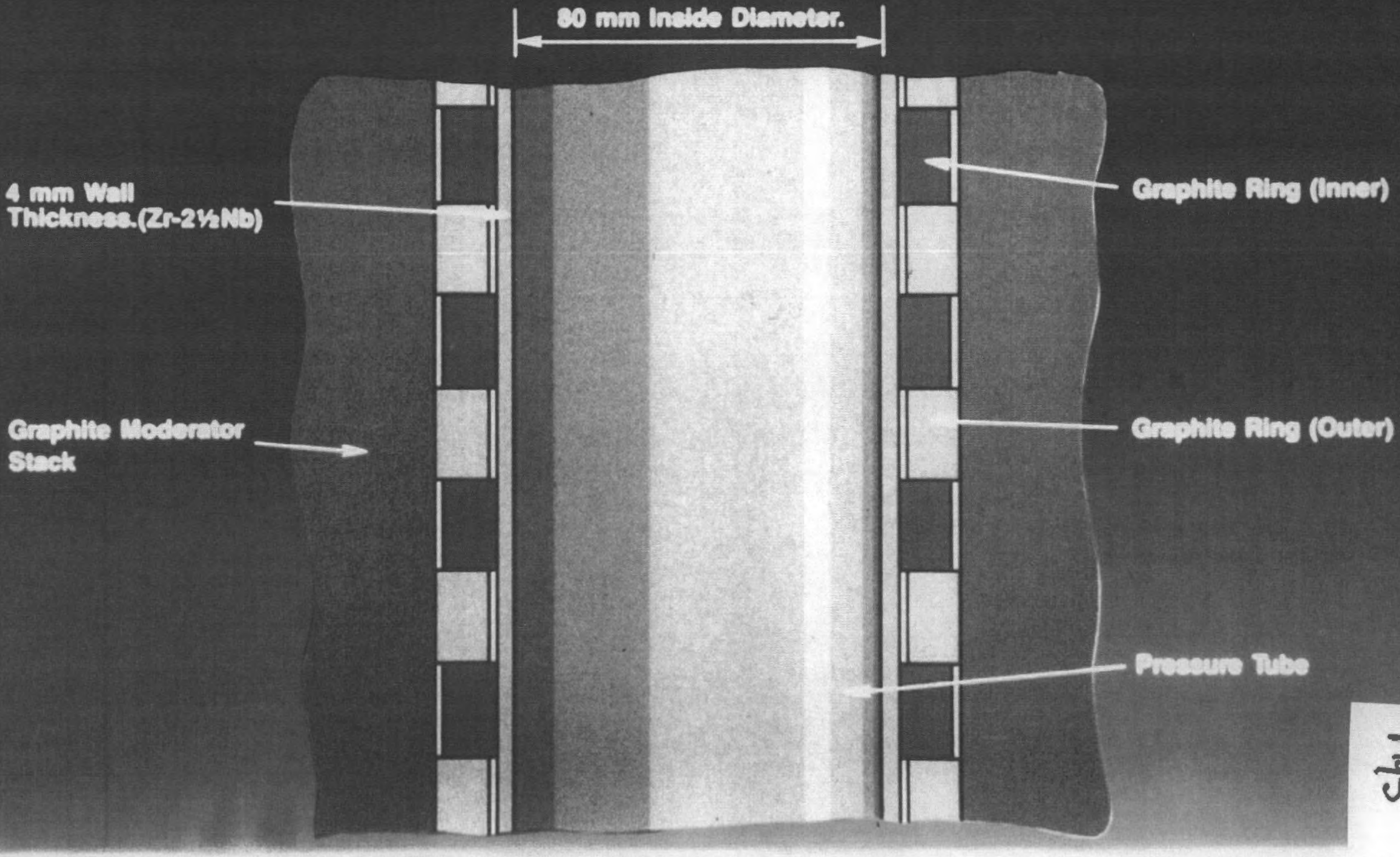
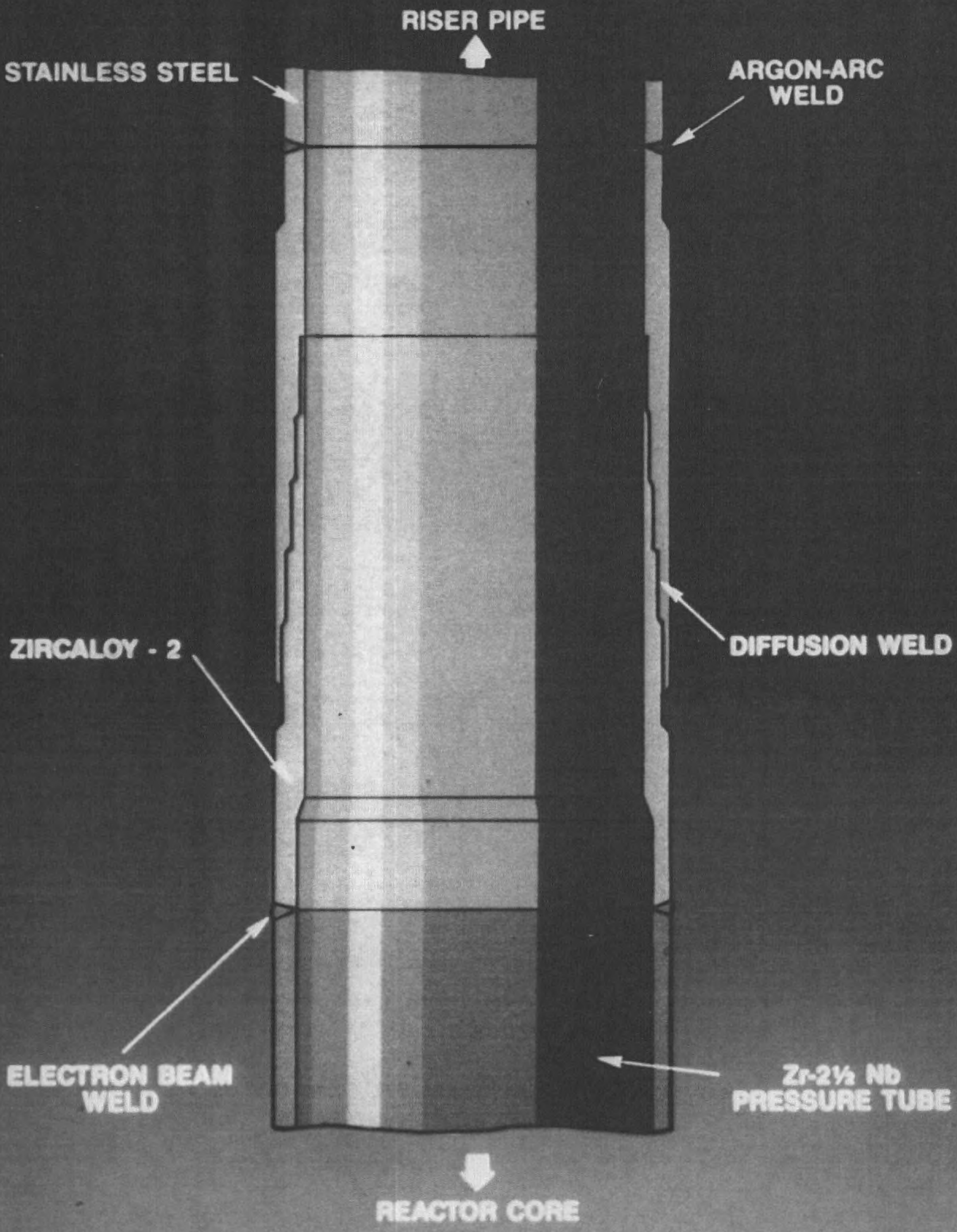


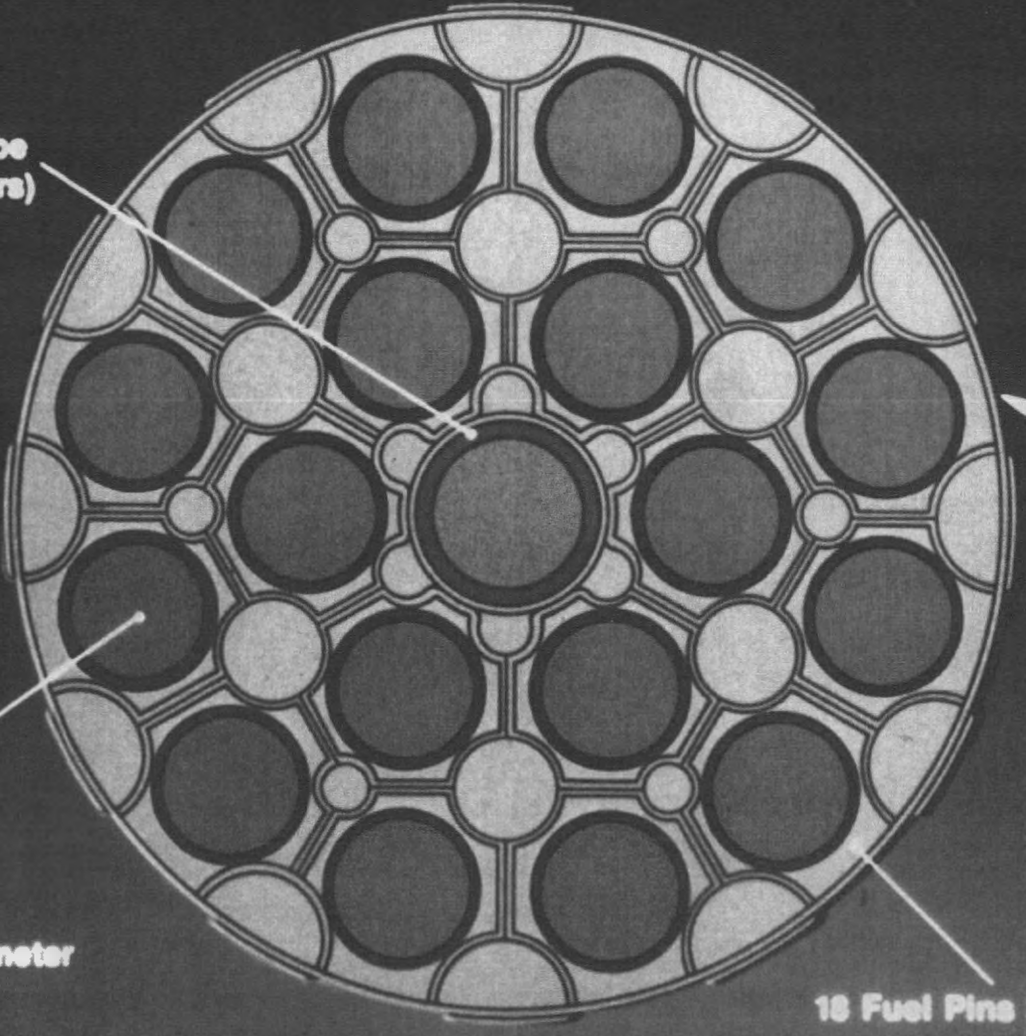
Fig5

FIG. 6

ZIRCONIUM - STEEL JOINT



SECTION OF SPACER GRID & FUEL PINS



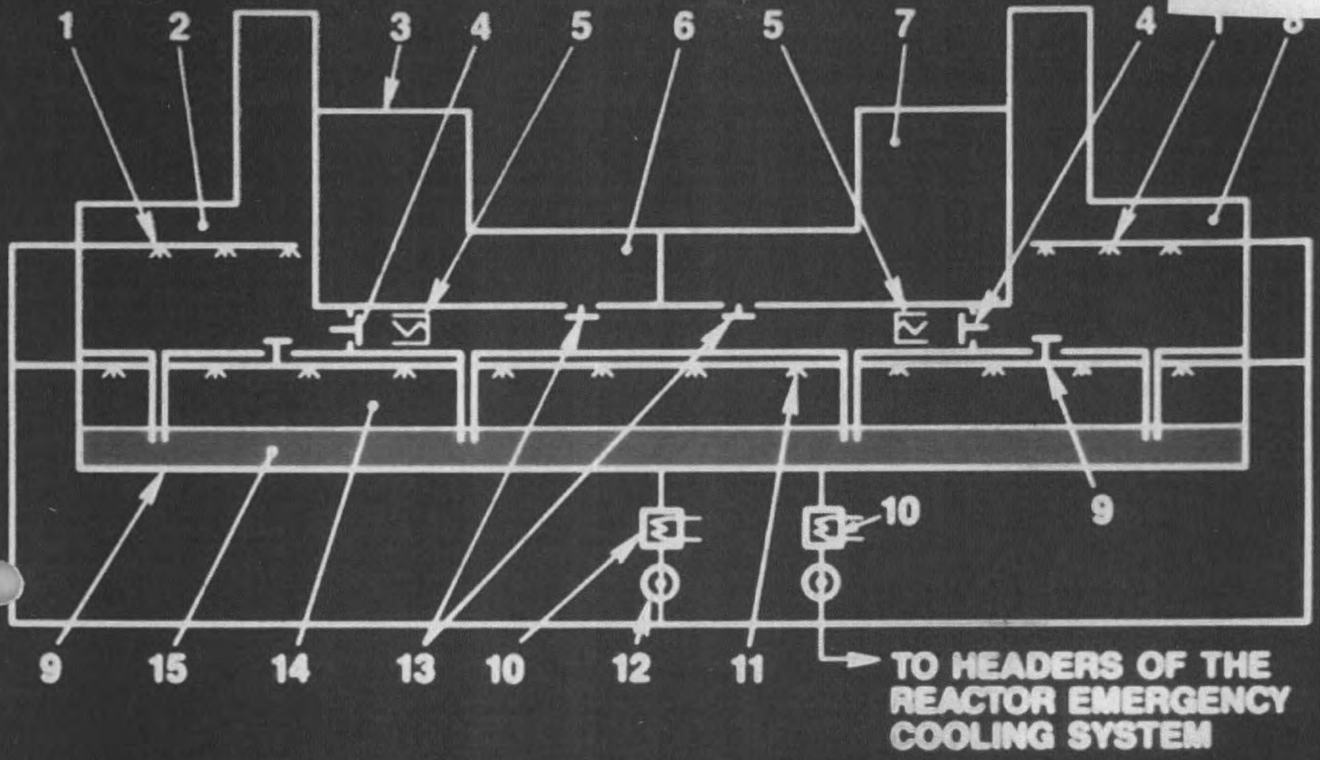
Central Supporting Tube
(With Nuetron Detectors)

Spacer Grid

Uo$_2$ Fuel Pellets
(11·5 mm Dia)
Zr-1½ Nb Cladding
13·6 mm Outside Diameter

18 Fuel Pins 3644 mm Long

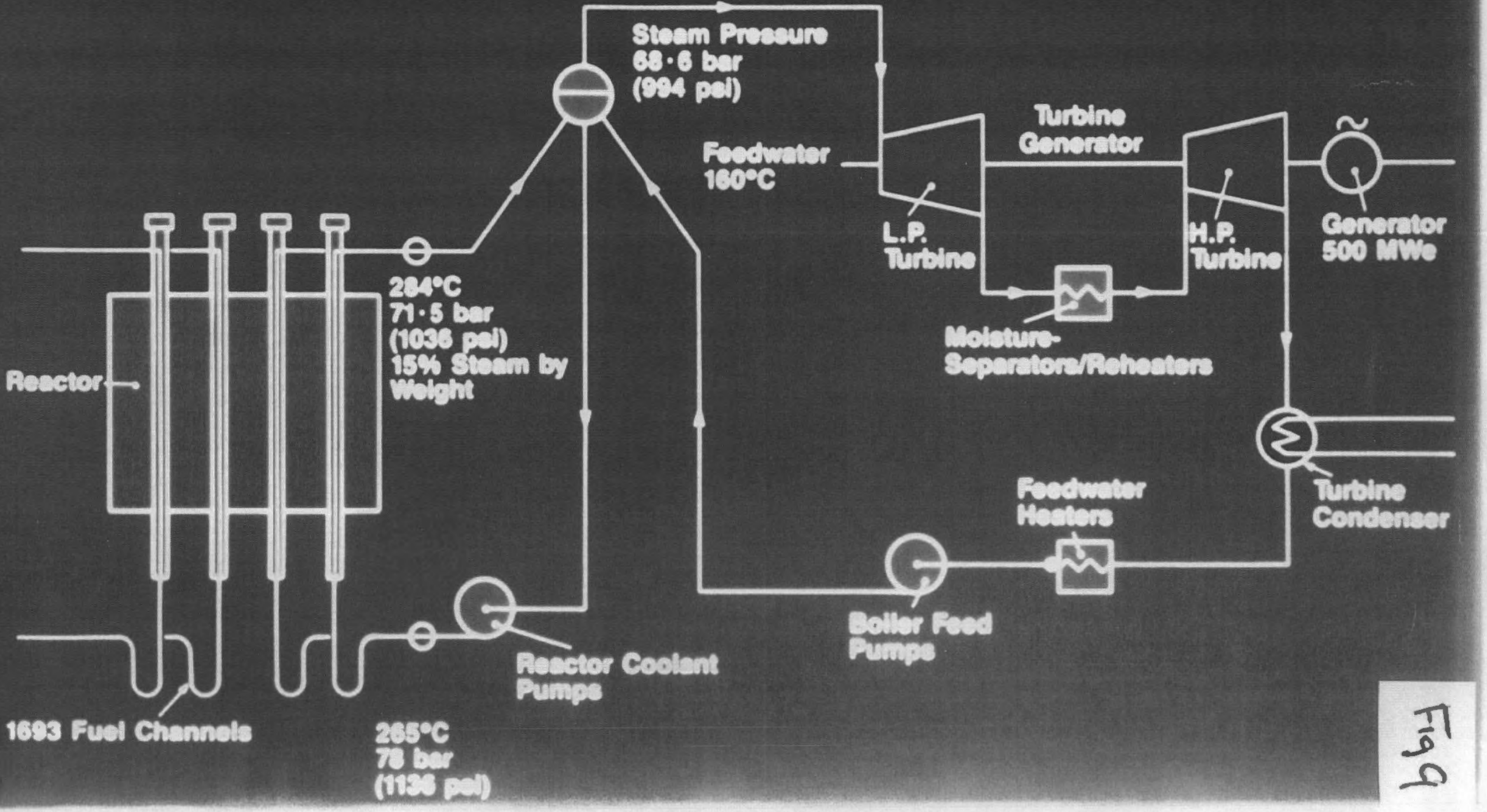
Fig 7



Schematic diagram of the system for retaining and localizing radioactive products in the event of an accident involving an RBMK-1000 type reactor

1, 11 - Sprinklers
2, 8 - Left and right hand halves of the hermetically sealed chambers
3, 7 - Left and right hand halves of the rooms housing the lower water lines
4 - Valve panels in the partitions separating the chambers and the corridors
5 - Surface type condensers
6 - Steam distribution corridor
9 - Relief valves
10 - Heat-exchanger
12 - Pump
13 - Check valves
14 - Air space above sparge pond
15 - Depth to which sparge pond is filled with water
16 - To emergency reactor cooling system collectors.

SCHEMATIC FLOWSHEET OF RBMK POWER PLANT



Steam Pressure
68·6 bar
(994 psi)

Feedwater
160°C

Turbine
Generator

L.P.
Turbine

H.P.
Turbine

Generator
500 MWe

Moisture-
Separators/Reheaters

284°C
71·5 bar
(1036 psi)
15% Steam by
Weight

Reactor

Turbine
Condenser

Feedwater
Heaters

Boiler Feed
Pumps

Reactor Coolant
Pumps

1693 Fuel Channels

265°C
78 bar
(1136 psi)

Fig 9

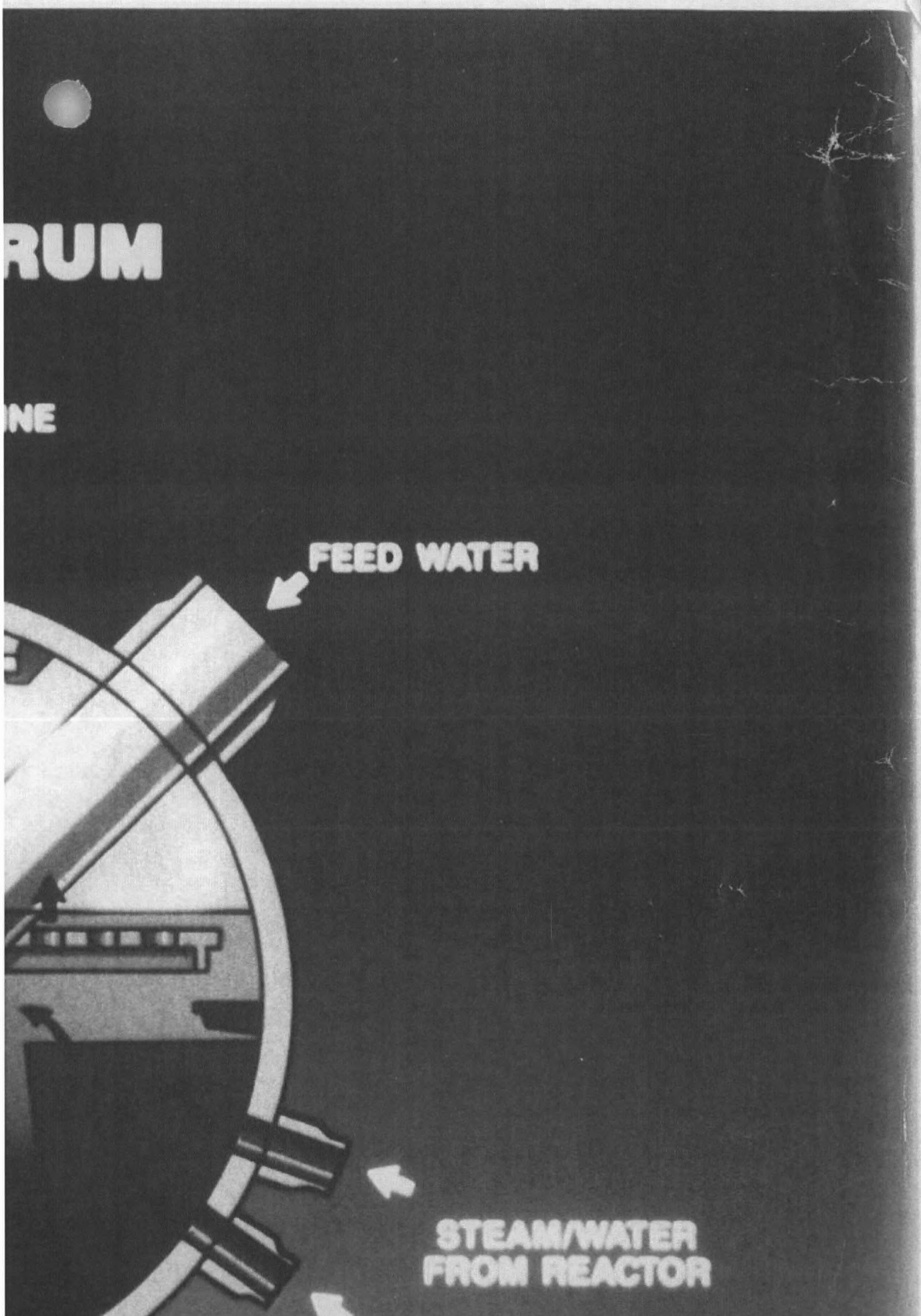
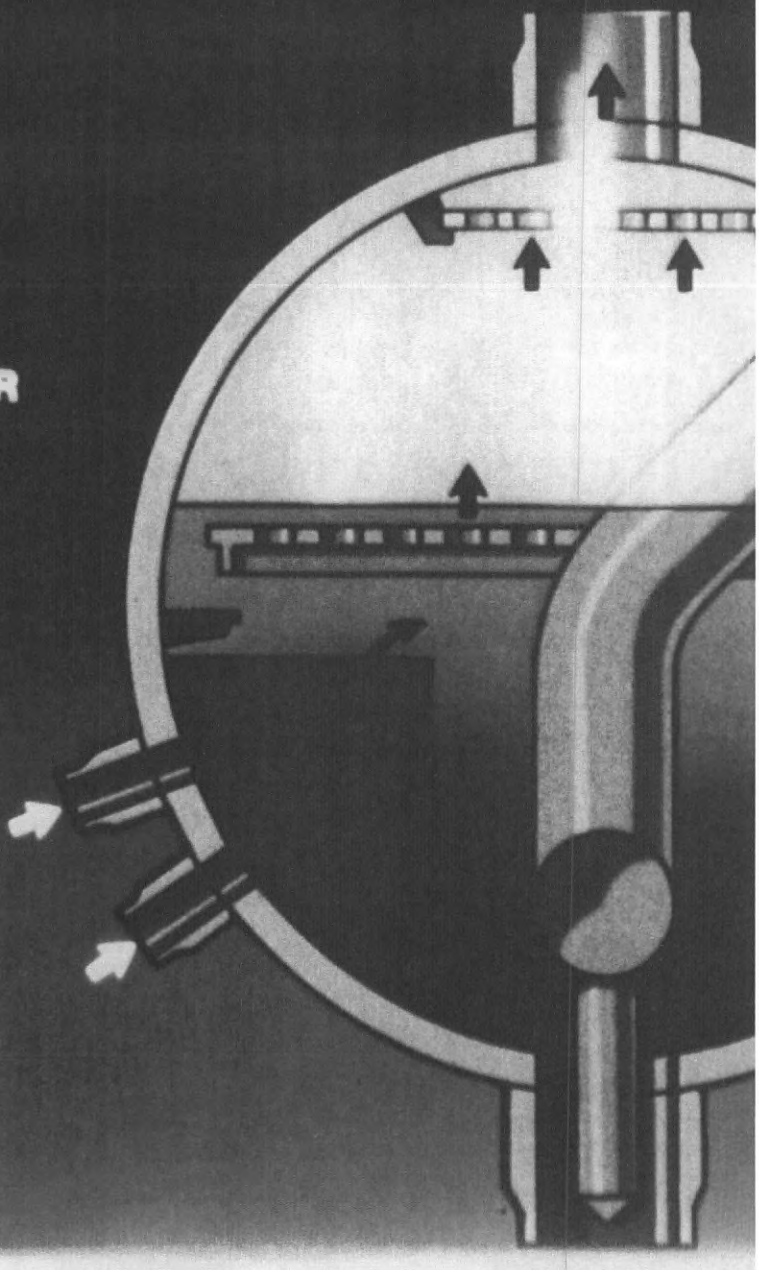


Fig 10

STEAM DI



STEAM TO TURB

8·5 DIAMETER

CHERNOBYL REACTOR SCEMATIC

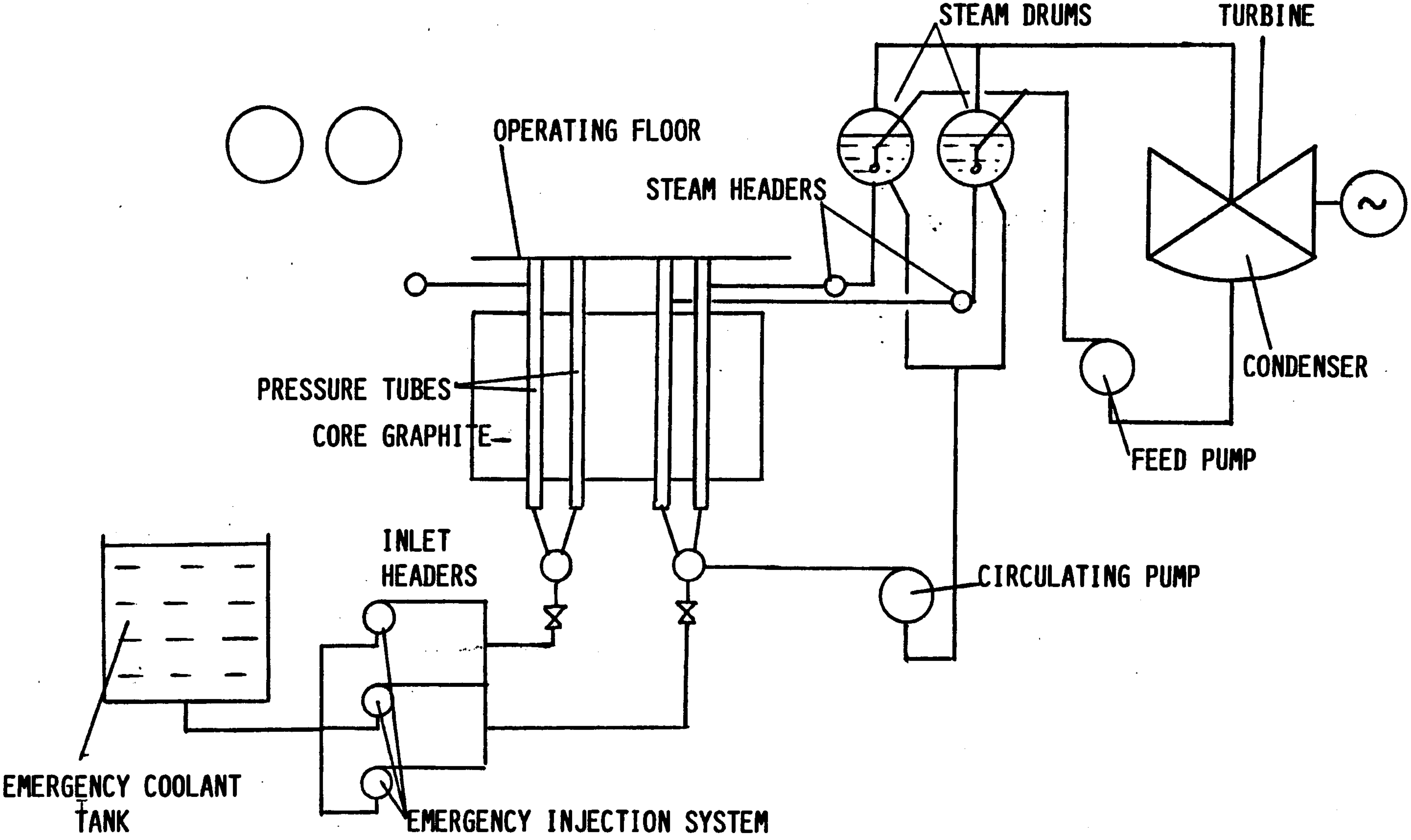


FIG. 11

ГОСУДАРСТВЕННЫЙ КОМИТЕТ
ПО ИСПОЛЬЗОВАНИЮ АТОМНОЙ ЭНЕРГИИ СССР

АВАРИЯ НА ЧЕРНОБЫЛЬСКОЙ АЭС И ЕЕ ПОСЛЕДСТВИЯ

Информация, подготовленная для совещания
экспертов МАГАТЭ

(25—29 августа 1986 г. ВЕНА)

Часть I. Обобщенный материал

WORKING DOCUMENT FOR CHERNOBYL
POST ACCIDENT REVIEW MEETING

NOT FOR PUBLICATION

Август
1986 г.

CONTENTS

PREFACE

The information presented here is based on conclusions of the Government Commission on the causes of the accident at the fourth unit of the Chernobyl' Nuclear Power Station and was prepared by the following experts employed by the USSR State Commission Committee on the Use of Atomic Energy:

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Ministry of Health, the State Committee on Nuclear Safety, the Ministry of Defense, the Main Fire Protection Administration of the Ministry of Internal Affairs and the USSR Academy of Sciences.

INTRODUCTION

An accident occurred at the fourth unit of the Chernobyl' Nuclear Power Station on April 26, 1986, at 1:23 AM with damage to the active zone of the reactor and part of the building in which it was located.

The accident occurred just before stopping of the powerplant for scheduled maintenance during testing of the operating modes of one of the turbogenerators. The power output of the reactor suddenly increased sharply, which led to damage to the reactor and discharging of part of the radioactive products accumulated in the active zone into the atmosphere.

The nuclear reaction in the reactor of the fourth powerplant stopped in the process of the accident. The fire which broke out was extinguished, and operations were begun for containing and eliminating the consequences of the accident.

The population was evacuated from areas immediately adjacent to the area of the nuclear power plant and from a zone with a radius of 30 km around it.

In view of the extreme character of the accident which occurred at Chernobyl', an operations group headed by Prime Minister of the U.S.S.R. N. I. Ryzhkov was organized at the Politburo of the CC CPSU (Central Committee of the Communist Party of the Soviet Union) for coordinating the activity of ministries and other government departments in eliminating the consequences of the accident and rendering aid to the population. A Government Commission was formed and entrusted with studying the causes of the accident and carrying out the necessary emergency and reconstruction measures. The necessary scientific, technical and economic capabilities and resources of the country were provided.

Representatives of MAGATE were invited to the USSR and given the opportunity to familiarize themselves with the state of affairs at the Chernobyl' Nuclear Powerplant and measures for overcoming the accident. They informed the world community about their assessment of the situation.

The governments of a number of countries, many governmental, social and private organizations and individual citizens from various countries of the world appealed to various organizations of the USSR with proposals concerning participation in overcoming the after-effects of the accident. Some of these proposals were accepted.

In the thirty years of its development, nuclear power engineering has occupied an essential place in worldwide power production and, on the whole, has displayed high levels of safety for man and the environment. One cannot imagine the future of the world economy without nuclear power. However, its further development must be accompanied by still greater efforts on the part of science and engineering for ensuring its operational reliability and safety.

The accident at Chernobyl' was the result of coincidences of several events of low probability. The Soviet Union draws the proper conclusions from this accident.

Rejecting nuclear power sources would require a considerable increase in production and combustion of organic fuels. This would steadily increase the risk of human diseases and the loss of water and forests due to the continuous passage of harmful chemical substances into the biosphere.

The development of the world's nuclear power resources brings with it, in addition to gain in the area of the energy supply and the preservation of natural resources, dangers of an international character. These dangers include transfers of radioactivity across borders, especially in large-scale radiation accidents, the problem of the spread of nuclear weapons and the danger of international terrorism, and the specific danger of nuclear installations under conditions of war. All this dictates the fundamental necessity of deep international cooperation in the field of development of nuclear power systems and ensuring of their safety.

Such are the realities.

The saturation of the modern world with potentially dangerous industrial processes, in significantly intensifying the effects of military operations, places the question of the senselessness and unacceptability of war under modern conditions on a new plane.

In a speech on Soviet television on May 14, M. S. Gorbachev stated: "The indisputable lesson of Chernobyl' for us lies in the fact that under conditions of further expansion of the scientific and technical revolution, questions of the reliability of equipment and its safety and questions on discipline, order and organization take on primary importance. The strictest requirements are needed everywhere.

Furthermore, we consider it necessary to move toward a serious deepening of cooperation within the framework of the International Agency on Atomic Energy."

CHAPTER 1. DESCRIPTION OF THE CHERNOBYL' NUCLEAR POWER STATION WITH RBMK-1000 REACTORS

1.1 Design Data

The planned power of the Chernobyl's Power Station (ChAES), was 60MW, and on January 1, 1986, the power of four units of the AES was 4000MW. The third and fourth units belong to the second phase of the ChAES and to the second generation of these Nuclear Power Stations (AES).

1.2 Description of the Reactor Installation (RU) of the Fourth Unit of the ChAES

The basic design features of RBMK reactors are as follows:

1) vertical channels with the fuel and the heat-transfer agent, which permit local reloading of fuel with a working reactor;

2) fuel in the form of bundles of cylindric fuel elements of uranium dioxide in zirconium shell tubes;

3) a graphite moderator between channels;

4) a low-boiling heat-transfer medium in the forced circulation rrcirculation mode (KMPTs) with direct feeding of steam to the turbine.

These design decisions in combination condition all the basic features of the reactor and the AES, both advantages and shortcomings. The advantages include: the absence of reactor vessels, which are awkward to produce on the powerplant maximum capacity and on the production base; the absence of a complex and expensive steam generator; the possibility of continuous reloading of fuel and a good neutron balance; a flexible fuel cycle, which is easily adapted to variations in the fuel market conditions;

the possibility of nuclear superheating of the steam; high thermodynamic reliability of the thermal equipment and viability of the reactor due to the controlling of the flow rate for each channel separately, monitoring of the integrity of the channels, monitoring of the parameters and neutron flux radio activity of the heat-transfer medium of each channel and replacement of damaged channels while running. The shortcomings include: the possibility of the development of a positive void coefficient of reactivity due to the phase change in the heat-transfer agent which determines the transient neutronic behavior; high sensitivity of the neutron field to reactivity disturbances eg Xe of different kinds, necessitating a complex control system for stabilizing the distribution of the release of energy in the active zone; complexity of the inlet-outlet piping system for the heat-transfer agent of each channel; a large amount of thermal energy accumulated in the metal structures, fuel elements and graphite block structure of the reactor; slightly radioactive steam in the turbine.

1000 MWe

The RBMK-1000 reactor with a power of 3200 MW (thermal) (Fig. 1) is equipped with two identical cooling loops; 840 parallel vertical channels with heat-releasing assemblies (TVS) are connected to each loop.

A cooling loop has four main parallel circulation pumps (three working pumps feeding 7000 t/h of water each with a head of about 1.5 MPa, and one back-up pump).

The water in the channels is heated to boiling and partially evaporates. The water-steam mixture with an average steam content of 14% by mass is bled through the top part of the channel and a water-steam line into two horizontal Steam drums gravity separators. The dry steam (with a moisture content less than 0.1%) separated in them passes from each separator at a pressure

7 x 145 psi = 1015 psi

of 7 MPa in two steam lines into two turbines with a power of 500 MW (electrical) each (all eight steam lines of the four separators are jointed by a common "ring"), and the water, after mixing with steam condensate, is fed by 12 down pipes into the intake collector of the main cooling pumps.

Condensate of the steam exhausted from the turbines is returned by feed water pumps through separators into the top part of the down pipes, creating undercooling underheating of the water to the saturation temperature at the main cooling pump inlet.

The reactor as a whole is made up of a set of vertical channels with fuel and the heat-transfer medium built into cylindric apertures of graphite columns, and top and bottom protective plates. A light cylindric housing (casing) encloses the space of the graphite block structure.

The block structure consist of graphite blocks with a square cross section with cylindric apertures along the axis assembled into columns. The block structure rests on the bottom plate, which transmits the weight of the reactor to a concrete shaft.

About 5% of the reactor power is released in the graphite from slowing down of neutrons and absorption of gamma quanta. For reducing the thermal resistance and preventing graphite oxidation, the block structure is filled with a slowly circulating mixture of helium and nitrogen, which serves at the same time for monitoring the integrity of the channels by measuring the humidity and temperature of the gas.

There are spaces under the bottom and over the top plates for placing heat carrier pipes on routes from the separator drums (BS) and distributing collectors to each channel.

A robot - a loading and unloading machine (RZM) - after removal of the appropriate section of the plating and after being moved to the coordinates of the channel links with its head, balances its pressure with the pressure of the channel, unseals the channel, removes the burned-out (fuel elements (TVS) and replaces them with a fresh one, seals the channel, uncouples itself and transports the irradiated TVS to a holding tank. While the RZM is connected to the cavity of the channel (TK), a small flow of pure water passes from it through a thermohydraulic seal into the TK, creating a "barrier" to the penetration of the RZM by hot, radioactive water from the TK

The system for control and protection (SUZ) of the reactor is based on movement of 211 solid absorber rods in specially isolated channels cooled with water of an independent duct. The system provides: automatic adjustment to a specified power level; a rapid reduction of the power level by adjustment to ~~by~~ both rods of automatic regulators (AR) and rods of manual regulators (RR) according to malfunction signals from the basic equipment; emergence interruption of the chain reaction by emergency protection (AZ) rods according to signals of dangerous deviations of the parameters of the unit or malfunctions of the equipment; compensation for reactivity variations in heating up and emergence at power; regulation of the distribution of the release of energy over the action zone.

RBMK reactors are equipped with a large number of independent control systems, which are being moved into the active zone at a rate of 0.4 m/s in functioning of the AZ. The low rate of movement of the control systems is compensated for by the large number of systems.

The SUZ includes subsystems for local automatic control (LAR) and local emergency protection (LAZ). Both operate according to signals of ionization chambers inside the reactor. The LAR automatically stabilizes the fundamental harmonics of radial-azimuthal distribution of the release of energy, while the LAZ provides emergency protection of the reactor against exceeding the specified power of channel cartridges in reactor individual areas. Shortened absorber rods (USP) introduced into the zone from the bottom (24 rods) are included for controlling the power fields along the height of the reactor.

The RBMK-1000 reactor includes the following basic monitoring and control systems in addition to the SUZ: protection

1) a system for physical monitoring of the field of the release of energy along the radius (more than 100 channels) and the height (12 channels) by means of direct charging pickups;

2) a start-up monitoring system (neutron flux monitors, start-up fission chambers);

3) a system for monitoring the water flow rate along each channel with ball flowmeters;

4) a system for monitoring the integrity (KGO) of the fuel elements based on measuring the short-time activity of volatile fission products in water-steam lines (PVK) at the outlet from each channel; the activity is detected sequentially in each channel in appropriate optimum energy ranges ("windows") with a photomultiplier, which is moved from one PVK to another by a special carriage;

5) a system for monitoring the integrity of the channels (KTsTK) by measuring the humidity and the temperature of the gas flowing in the channels.

All the data pass to a computer. The information is given out to the operators in the form of deviation signals, indications (on call) and data of recorders.

The RBMK-1000 power units operate primarily in a base-load mode (at constant power output).

In view of the great power of the unit, a full automatic shut-down of the reactor occurs only if indicators of the power level, pressure or water level in the separator pass beyond acceptable limits, in a case of a general cut-off of electric current, disconnection of two turbogenerators or two main cooling pumps at once, a drop in the feedwater flow rate by a factor of more than 2, or full cross-sectioned rupture of the main outlet pipeof cooling pumps with a diameter of 900 mm. In other cases of equipment failures, only an automatic controlled reduction in power (to a level corresponding to the power of the equipment which has remained in operation) is envisaged.

1.3. Basic Physical Characteristics of the Reactor

The RBMK-1000 nuclear power reactor is a heterogeneous thermal channel reactor, in which uranium dioxide weakly enriched in regard to uranium-235 is used as fuel, graphite is used as moderator and boiling light water is used as the heat-transfer medium. The reactor has the following basic characteristics:

Thermal power	3200 MW	
Fuel enrichment	2.0%	
Uranium mass in a cartridge	114.7 kg	
Number/diameter of fuel elements in TVS	18/13.6 mm	
Depth of fuel burnup	20 MW day/kg	20,000 MWD/Te
Coefficient of non-uniformity of release of energy along the radius	1.48	
Coefficient of non-uniformity of release of energy along the height	1.4	

Calculated maximum power of channel	3,250 kW	
Isotopic composition of unloaded fuel:		
uranium-235	4.5 kg/t	
uranium-236	2.4 kg/t	
plutonium-239	2.6 kg/t	
plutonium-240	1.8 kg/t	
plutonium-241	0.5 kg/t	
Void reactivity coefficient at a working point	2.0×10^{-6}/vol.% steam	(positive)
Fast power reactivity coefficient at a working point	-0.5×10^{-6}/MW	(neg)
Coefficient of expantion fuel temperature coefficient	-1.2×10^{-5} / °C	
Coefficient of expantion graphite temperature coefficient	6×10^{-5}/°C	
Minimum "weight" of rods of SUZ, ΔK	10.5%	Protection
Effectiveness of rods of RR, ΔK	7.5%	
Effect of replacement (on the average) of the burnup TVS with fresh	0.02%	

An important physical characteristic from the point of view of control and safety of the reactor is a value called the operating reactivity margin. The operating reactivity margin means the specific number of SUZ rods plunged into the active zone which are in a region of high differential ficiency. It is determined by recalculation for fully submerged SUZ rods.

The value of the reactivity margin for RBMK-1000 reactors is generally accepted as 30 RR rods. In this case, the rate of introduction of a negative reactivity in functioning of the AZ amounts to 1 "β"/s ("β" is the proportion of delayed neutrons), which is sufficient for compensation for positive reactivity effects.

The character of the dependence of the effective neutron breeding coefficient on the density of the heat-transfer medium in RBMK reactors is determined to a great degree by the presence of absorbers of different kinds in the active zone. In initial charging of the AZ, which includes about 240 boron-containing additional absorbers (DP), dehydration results in a negative reactivity effect.

initial neg void coeff

At the same time, a small increase in the steam content at nominal power with a reactivity margin of 30 rods results in an increase in reactivity ($\approx 2.0 \times 10^{-4}$/vol.% steam).

+ve VC

For a boiling water-graphite reactor, the basic parameters which define its ability to properly operate and safety in the regard to thermal equipment are: the temperature of the fuel elements, the margin before the a crisis of heat transfer occurs, and the graphite temperature.

A set of computer codes which makes it possible to conduct operating calculations on station computers for ensuring plant reliability of thermal equipment of the powerplant in a mode of continuous reloading of fuel at any position of the cut-off and control valves at the inlet to each channel has been developed for RBMK reactors. Thus the possibility of determining the ı sical parameters of the reactor at variable frequency of the adjustment of channel flow rates and different control criteria (based on ~~eighter~~ either outlet steam quality or on the margin of the critical power) and also as a function of the throttling of the active zone is provided.

For defining the fields of the release of energy over the active zone of a reactor, indications of the physical monitoring system, based on measurements of the neutron flow along the radius and height of the active zone taken inside the reactor, are used. In addition to indications of the physical monitoring system, data characterizing the composition of the active zone and the energy generation of each TK, the arrangement of the regulating rods, the distribution of water flow rates along channels of the active zone and readings of gages of the pressure and temperature of the heat-transfer medium re also entered into the station computer. As a result of calculations by the PRIZMA program performed periodically by the computer, the operator receives information on a digital printing device in the form of a cartogram of the active zone, which indicates the type of loading of the active zone, the arrangement of regulation rods, the network the arrangement of pickups inside the reactor, and the distribution of power levels, water flow rates, reserves up to critical powers and reserves up to the maximum acceptable thermal loads on the fuel elements in regard to each fuel channel of the reactor. The station computer also computes the overall thermal power of the reactor, the distribution of flow rates of the steam-water mixture among the separators, the integral generation of power, the steam content at the outlet from each TK and other parameters necessary for monitoring and controlling the installation.

The experience of operation of active RBMK reactors indicates that with the means for monitoring and control available on these reactors, maintaining temperature conditions of the fuel and the graphite and reserves before a crisis of convective heat transfer at an acceptable level causes no difficulties.

1.4. Safety Assurance Systems (Figs. 2 and 3)

1.4.1. Protective Safety Systems

The system for emergency cooling of the reactor (SAOR) is a protective safety system and is intended for providing elimination of the residual release of heat by prompt feeding of the required amount of water into reactor channels in accidents accompanied by disruption of cooling of the active zone.

Such accidents include: ruptures of large-diameter KMPTs pipelines, ruptures of steam lines, and ruptures of feedwater pipelines.

The system for protection against an excess of pressure in the main heat carrier duct is intended for providing an acceptable pressure level in the duct due to removal of steam into a perforated sprayer tank for its condensation.

like pressurizer sprays

suppression pool

The system for protection of the reactor space (RP) is intended for ensuring that an acceptable pressure is not exceeded in the RP in an emergency situation with rupture of one operating channel due to removal of the steam-gas mixture from the RP into the screen of steam-gas discharges of the sprayer tank and then into the sprayer tank with simultaneous extinguishing of the chain reaction with the AZ facilities. The SAOR and the system for cooling the reactor space can be used for introducing the appropriate neutron absorbers (salts of boron and He).

1.4.2 Localizing Safety Systems

The system for localization of accidents (SIA) realized on the fourth unit of the ChAES is intended for localizing radioactive discharges in accidents with unsealing of any pipelines of the reactor cooling duct except the PVK pipelines, the top tracts of the operating channels and that part of the down pipes which is located in the separator drum compartment, and pipelines for steam-gas discharges from the RP.

The main component of the localization system is a system of airtight compartments, including the following compartments of the reactor division:

- tightly packed cells arranged symmetrically in relation to the reactor axis and designed for an excess pressure of 0.45 MPa:

- compartments of separator group collectors (RGK) and bottom water lines (NVK); these compartments do not permit an increase in excess pressure above 0.08 MPa according to the conditions of strength of components of the reactor structure and are designed for this value.

Compartments of tightly packed cells and the steam distributor corridor are connected to the water space of the perforated sprayer condensation device by steam outlet channels.

The cut-off and sealing armature system is intended for providing airtightness of the zone of localization of accidents by cutting off communicating lines connecting the sealed and unsealed compartments.

The bubbling condensation device is intended for condensation of steam formed:

- in the process of an accident with unsealing of the reactor contour;

- in functioning of the main safety valves (GPK);

- in leaks through the GPK in a normal operating mode.

1.4.3. Security Safety Systems

The AES Power Supply

Electric power users at an AES are divided into three groups, depending on the requirements placed on the reliability of the power supply:

1) users who cannot permit interruption of the feed for fractions of a second up to a few seconds under any conditions, including conditions of a total disappearance of alternating current voltage from working and back-up transformers for system needs, and who require the obligatory presence of a power supply after functioning of the reactor AZ;

2) users who can accept a power interruption of tens of seconds up to tens of minutes under the same conditions and require the obligatory presence of a power supply after functioning of the reactor AZ;

3) users who do not require the presence of a power supply in conditions of a disappearance of voltage from working and back-up transformers for system needs and in a normal model of operation of the unit can permit interruption of the supply for the time of transfer from a working to a back-up transformer for system needs.

1.4.4. Controlling Safety Systems

Controlling safety systems are intended for automatic engagement of devices of protective, localizing and security safety systems and for monitoring of their operation.

1.4.5. The Radiation Monitoring System

The AES radiation monitoring system is a component (subsystem) of the AES automated control system and is intended for collection, processing and display of information concerning the radiation situation in compartments of the AES and in the external environment, the condition of operating facilities and ducts, and irradiation doses to personnel in accordance with active norms and legislation.

1.4.6. AES Control Points

Control of the AES is carried on at two levels: station and plant.

All the control systems which ensure safety of the AES are located at the plant level.

1.5. Description of the Area of the Chernobyl' AES and the Areas in Which It is Located

1.5.1. Description of the Region

The Chernobyl' AES is located in the eastern part of a large region known as the Belorussian-Ukrainian Alluvial Plain, on the banks of the Pripyati River, which flows in the Dnepr. This region is characterized by a relatively flat relief with very slight surface slopes in the direction of the river and its tributaries.

The total length of the Pripyati up to its flow into the Dnepr is 748 km; the area of the drainage basin at the AES site is 106 thousand km , and the width is 200-300 m. The average flow speed is 0.4-0.5 m/s, and the average water flow rate over many years is 400 m^3/s.

The water-bearing level, which is used for domestic and drinking water needs of the region in question, lies at a depth of 10-15 m in relation to the current depth of the Pripyati and is separated from Quaternary deposits by clay marls which are relatively impermeable to water.

The region of the Belorussian-Ukrainian Alluvial Plain as a whole is characterized by a low population density (before the beginning of construction of the Chernobyl' AES, the average population density in the region in question was approximately 70 people per km).

At the beginning of 1986, the total population in a 30-kilometer zone around the AES amounted to about 100 thousand people, of whom 49 thousand lived in the city of Pripyati, located west of the three-kilometer sanitary-protection zone of the AES, while 12.5 thousand lived in the regional center, the city of Chernobyl', located 15 km to the southeast of the AES.

1.5.2. Description of the AES Areas and Its Structures

The first phase of the Chernobyl' AES, composed of two power units with RBMK-1000 reactors, was built in the period of 1970-1977, and construction of two power units of a second phase was completed at the same site by the end of 1983.

Construction of another two power units with reactors of the same kind (the third phase of the AES) was begun 1.5 km southeast of this site in 1981.

To the southeast of the AES site, right in the valley of the Pripyati River, a water cooling pond was built with an area of 22 km^2; the pond provides cooling of turbine condensers and other heat exchangers of the first four power units. The normal retaining level of water in the cooling pond was adopted as 3.5 m below the grading mark of the AES site.

Two high-capacity cooling towers (a hydraulic load of 100 thousand m /h each), which can operate parallel with the cooling pond, are being built as part of the third phase of the AES.

To the west and north of the site of the first and second phases of the AES is the area of the construction base and the supply department.

1.5.3. Data on the Number of Personnel at the AES Site During the Accident

There were 176 duty operating personnel and, also, other workers of various shops and repair services at the site of the first and second phases of the Chernobyl' AES on the night of April 25 and 26, 1986.

In addition, 268 construction workers and assemblers were working on the night shift at the site of the third phase of the AES.

1.5.4. Information About the Equipment at the Site Which Operated Together With the Damaged Reactor and About the Equipment Used in the Process of the Overcoming the Accident

Construction of the Chernobyl' AES is carried out in phases, which each consist of two power units and have special water purification systems common to the two units and have special water purification systems common to the two units and auxiliary structures and the industrial site which include:

- storage for liquid and solid radioactive wastes;
- open distributor devices;
- gas equipment;
- back-up diesel generator power plants;
- hydraulic engineering and other structures.

The storage for liquid radioactive wastes, built as part of the second phase of the AES, is intended for collection and temporary storage of liquid radioactive wastes arriving in operation of the third and fourth units and for collection of water from operational flushing and its recovery for reprocessing. Liquid radioactive wastes pass from the main housing by pipelines laid on the bottom level of a scaffold, while the solid radioactive wastes come to the storage by the top corridor of the scaffold by electric trucks.

A nitrogen-oxygen station is intended for satisfying the needs of the third and fourth units of the AES.

The gas equipment is made up of compressor, electrolysis, helium and argon tank equipment intended for providing the third and fourth units of the AES with compressed air, hydrogen, helium and argon. Receivers for storing nitrogen and hydrogen are located in open areas.

A back-up diesel power plant (RDES) is an independent emergency source of electric power for systems important to the safety of each unit. Three diesel generators with a unit power of 5.5 MW were installed on each RDES of the third and fourth units. Intermediate and base diesel fuel depots, pump transfers of fuel, and emergency fuel and oil drainage tanks are included for ensuring operation of the RDES.

The source of the technical water supply for the third and fourth units is the cooling pond.

The water of the circulation pump house, which is unified for the third and fourth units, is fed into a delivery tank, from which it passes by gravity flow into the turbine condensers.

Separate water works of the third and fourth units are included for supplying technical water to important users who require an uninterrupted water supply. A back-up power supply from diesel generators is available for these water works.

All four power units of the first and second phases and auxiliary systems and industrial area facilities involved with their normal operation were working on April 25, 1986.

CHAPTER 2. CHRONOLOGY OF THE DEVELOPMENT OF THE ACCIDENT

The Chernobyl' Powerplant No. 4 was put into operation in December, 1983. By the time of stopping of the plant for a medium repair, which was planned for April 25, 1986, the active zone contained 1659 TVS with an average burnup of 10.3 MW day/kg, 1 DP and 1 unloaded channel. The main part of the TVS (75%) were cartridges of the first loading with a burnup of 12-15 MW day/kg.

Tests of turbogenerator No. 8 in a runout mode with the auxiliary consumption load only internal needs were planned just before stopping. The purpose of these tests was to experimentally verify the possibilities for using mechanical inertia energy of the rotor of a turbogenerator disconnected from steam supply, in order to generate electricity for auxiliary motors what may be required if the turbogenerator is disconnected from an electric grid. This mode is used in one of the subsystems of the high-speed system for emergency cooling of the reactor (SAOR). With the proper order of performance of the tests and additional safety measures, the performance of tests of this kind on a working AES was not prohibited.

Such tests had already been performed previously at this station. It was established at that time that the voltage on the generator busses drops much before the mechanical (inertia) energy of the rotor in running down. In the tests scheduled for April 25, 1986, the use of a special system to control regulator of the magnetic field of the generator, which was to have eliminated this shortcoming, was planned. However, the "Working Program of Tests for Turbogenerator No. 8 of the Chernobyl' AES" in accordance with which the tests were to have been conducted was not prepared and approved in the proper way.

The quality of the program proved low; the section on safety measures included in it was composed purely as a matter of form. (It pointed out only that in the process of tests, all switching is done with the authorization of the station shift director; in case of development of an emergency situation, all personnel must act in accordance with local instructions; and just before the beginning of the tests, the test leader - an electrical engineer, who is not a specialist on reactor installations - briefs the watch on duty.) In addition to the fact that the programs essentially included no additional safety measures, it prescribed disengaging the system for emergency cooling of the reactor. This meant that throughout the period of the tests, i.e., about 4 hours, the safety of the reactor appears to have been lowered significantly.

On the strength of the fact that the proper attention was not devoted to the safety of these tests, the personnel were not ready for them and did not know about the possible dangers. In addition, as one will be able to see from what follows, personnel deviated from carrying out the program, thereby creating the conditions for development of an emergency situation.

The personnel started to reduce the power output of the reactor, which had been operating at nominal parameters, at 1:00 PM on April 25, and at 1:05 PM turbogenerator No. 7 (TG No. 7) was disconnected from the grid at a reactor thermal output of 1600 MW. The electric power supply for the auxiliaries (4 main cooling pumps, 2 feed water pumps) was transferred to the busses of turbogenerator No. 8.

The SAOR was disengaged from the KMPTs at 2:00 PM in accordance with the test program. However, taking the unit out of operation was delayed according to a request from the dispatcher centre. Operation of the plant continued at this time with a disengaged SAOR in violation of the regulations.

The turbogenerator was continued at 11:10 PM. In accordance with the test program, the runout of the generator with a load of the plant auxiliaries was to be conducted at a reactor power of 700-1000 MW (thermal). However, with disengagement of the LAR (Local automatic control) system, which was necessary for operation of the reactor at a low power output, the operator was not able to eliminate the imbalance of the measurement part of the AR (automatic regulator) which developed quickly enough. As a result, the power dropped to a level below 30 MW (thermal). Only by 1:00 AM on April 26, 1986, did the personnel manage to stabilize it at a level of 200 MW (thermal). In connection with the fact that Xe poisoning "contamination" of the reactor continued during this period, further raising of the power was rendered difficult due to the small operating reactivity margin, which was substantially below the required level by this moment.

Nevertheless, it was decided to perform the tests. At 1:03 and 1:07 AM, two more main coding pumps, one from each side were engaged in addition to the six pumps which had been operating, so that after the end of the experiment, in which four pumps were to operate to support the runout mode of operation, four pumps would remain in the forced circulation loop (KTPT) reliable cooling of the active zone.

Since the reactor power and, consequently, the hydraulic resistance of the active zone and the KMPTs were substantially below the planned level and all the eight pumps were in operation, the total flow rate through the reactor increased to (56-58) x 10 m^3/h and the rate in regard to an Individual pump increased to 8000 m^3/h, which is a violation of the operating regulations. Such a mode of operation is prohibited due to danger of interruption of the pump operation and the possibility of development of vibrations of the main feed water lines as a result of cavitation. Connection of the additional pumps and the increase in the water flow rate through the reactor caused by this resulted in a decrease in steam generation a drop in the steam pressure in the separators and changes in other parameters of the reactor. The operators tried to maintain the following basic reactor parameters manually: the steam pressure and the water level in the separators however, they were not able to accomplish this fully. Dips in steam pressure by 0.5-0.6 MPa and dips in the water level below the emergency point were observed in the separators during this period. In order to avoid shutdown of the reactor under such conditions, personnel blocked the emergency protection signals in regard to these parameters.

Meanwhile the reactivity of the reactor continued to drop slowly. At 1:22:30 AM, the operator noticed on the printout of the program for quick evaluation of the reactivity margin reserve that the operating reactivity margin was at a value requiring shutdown of the reactor. Nevertheless, this did not stop the personnel, and the tests began.

At 1:23:04, the shutdown control valves (SRK) of turbogenerator No. 8 were closed. The reactor continued operating at a power of about 200 MW (thermal). The available emergency protection for closing the SRK of the two turbogenerators No. 7 had been disengaged during the afternoon of April 25, 1986) was blocked in order to have the possibility of repeating the test, if the first attempt proved unsuccessful. Thus another departure had been made from the testing program, which did not envisage blocking the emergency protection of the reactor with respect to disengagement of two turbogenerators.

A slow increase in power began some time after beginning of the test.

At 1:23:40 the shift manager of the; plant gave the command to press pushbutton AZ-5, on a signal from which all control rods and emergency protection rods are inserted into the active zone. The rods went down, although impacts were heard, and the operator saw that the absorber rods stopped without reaching the bottom ends. Then he cut off the servodrive couplings, so that the rods fell into the active zone by their own weight.

According to the evidence of witnesses who were outside the fourth plant, two explosions were heard, one after another, at 1:24; some kind of hot fragments and sparks flew up above the fourth plant, some of which fell on the roof of the turbogenerator room and started a fire.

CHAPTER 3. ANALYSIS OF THE PROCESS OF THE DEVELOPMENT OF THE ACCIDENT ON A MATHEMATICAL MODEL

The "Skala" centralized monitoring system (STsK) of the RBMK-1000 reactor includes a program for diagnostic recording of parameters (DREG), according to which several hundred analog and discrete parameters are examined and stored periodically with a specified cycle (the minimum cycle time is 1 s).

In connection with performance of the tests, only those parameters which were important from the point of view of analysis of the results of the tests being performed were recorded with high frequency. Therefore, reconstruction of the process of development of the accident was performed by calculation on a mathematical model of the power unit with the use not only of printouts of the DREG program but also of readings of instruments and the results of questioning of personnel.

An integral mathematical model of a power unit with an RBMK-1000 reactor, realized by computer in real time, was used for providing accelerated analysis of variations and versions of the emergency situation in question. Dependences of reactance on the steam content and movement of the absorber rods were defined according to results of calculations on distributed, including three-dimensional, neutron-physics models.

In calculation reconstruction of the process of development of the accident, it was extremely important to make sure that the mathematical model of the power unit accurately describes the behavior of the reactor and the other equipment and systems under just those conditions making up the situation just before

the breakdown. As already mentioned in the previous section, the reactor was operating in an unstable manner after 1:00 AM on April 26, 1986, and the operators were introducing "disturbances" into the control object practically continuously for stabilizing its parameters. This made it possible to compare actual data recorded with adequate reliability by recording devices to data optained in numerical simulation for quite a large time interval under various effects on the reactor installation. The comparison results proved quite satisfactory, which attests to the adequacy of the mathematical model and the real object.

In order to present the effect of prehistory on the character of development of the accident more clearly, we shall analyze the calculation data beginning from 1:19:00 AM, i.e., 4 minutes before the beginning of the test with rundown of the TB (Fig. 4.). This moment is convenient in that the operator began one of the operations for replenishment of the separator drums (the second since 1:00), which introduced strong disturbances into the regulation object. At this moment, the DREG program recorded the positions of rods of all three AR; i.e., the initial conditions for the calculation were clearly recorded.

The operator began replenishment of the separator drums to avoid allowing a dip in the water level in them. He succeeded in maintaining the level in 30 s, having increased the flow rate of feedwater by a factor of more than 3. The operator apparently decided not only to maintain the water level but to raise it. Therefore, he continued increasing the water flow rate, and it exceeded the original flow rate by a factor of 4 in just about a minute.

As soon as colder water from the separating drums reached the active zone, steam generation decreased noticeably, causing a decrease in the volumetric steam content, which resulted in movement of all the AR rods upward. In about 30 s they emerged at the top ends, and the operator was forced to "help" them with manual control rods, thereby reducing the operating reactance reserve. (This operation was not recorded in the operation log, but it would have been impossible to maintain power at a level of 200 MW without it.) The operator, having moved the manual rods up, achieved recompensation, and one of the groups of AR rods was lowered by 1.8 m.

The decrease in steam generation led to a small pressure decrease. After about a minute, at 1:19:58, a high-speed reduction device (BRU-K), through which steam surpluses were released into the condenser, was closed. This promoted some decrease in the rate at which the pressure was dropping. However, the pressure continued to drop slowly up to the beginning of the test. It changed by more than 0.5 MPa during this period.

A printout of the actual fields of releases of energy and the positions of all the regulation rods was obtained on the "Skala" STsK at 1:22:30. An attempt has been made at "tying together" the calculated and recorded neutron fields by just this moment.

The overall characteristics of the neutron field at this moment were as follows: it was practically arched in a radialazimuthal direction and double-peaked, on the average, in regard to height, with a higher release of energy in the top section of the active zone. Such a field distribution is

quite natural for the situation of the reactor: a depleted active zone, almost all the regulation rods up, a volumetric steam content significantly higher in the top part of the active zone than at the bottom, contamination with ^{135}Xe higher in the central parts of the reactor than in the peripheral parts.

The reactance reserve amounted to a total of 6-8 rods at 1:22:30. This value was at lease two time lower than the minimum acceptable reserve established by technical operating regulations. The reactor was in an unusual, nonregulation condition, and for evaluating the subsequent development of events, it was extremely important to determine the differential efficiency of rods for regulation and emergency protection in real neutron fields and the fission characteristics of the active zone. Numerical analysis indicated high sensitivity of the error in determining the efficiency of the regulation rods to the error in reconstruction of the vertical field of releases of energy. If one takes into account in addition that at such low power levels (about 6-7%), the relative field asurement error is substantially higher than under nominal conditions, the need for analyzing an extremely large number of calculation versions to ascertain the reliability or inaccuracy of some version becomes clear.

The reactor parameters were closest to stable for the time period in question by 1:23, and the tests began. A minute before this, the operator sharply reduced the feedwater flow rate, which occasioned an increase in the water temperature at the inlet to the reactor with a delay equal to the time of passage of the heat-transfer medium from the separator drums to the reactor.

At 1:23:04 the operator closed the SRK of TG No. 8 and began rundown of the turbogenerator. Due to the decrease in the flow rate of steam from the separator drums, its pressure began to increase slightly (at a rate of 6 kPa/s, on the average). The total water flow rate through the reactor began to drop due to the fact that four of the eight GTsN were working off the turbogenerator which was "running down."

The increase in the steam pressure, on the one hand, and the decrease in the water flow rate through the reactor and also in the feedwater supply to the separator drums, on the other, are competing factors which determine the volumetric steam content and, consequently, the power of the reactor. It should be emphasized in particular that in the condition at which the reactor arrived, a small change in the power results in a situation where the volumetric steam content, which directly influences reactance, increase many times more sharply than at nominal power. The competition of these factors led in the final analysis to a power increase. Just this situation could be the cause for pressing button AZ-5.

Pushbutton AZ-5 was pressed at 1:23:40. Insertion of emergency protection rods began. By this time, the AR rods, in partially compensating for the previous increase in power, were already located in the bottom part of the active zone, while the work of personnel with an unacceptably low operating reactance reserve resulted in a situation where practically all the other absorber rods were located in the top section of the active zone.

Under the conditions which had been created, the disruptions permitted by the personnel resulted in a significant decrease in

the efficiency of the emergency protection. The total positive reactance developing in the active zone began to increase. After 3 s the power exceeded 530 MW, and the runaway period came to be much less than 20 s. The positive steam effect of reactance promoted deterioration of the situation. Only the Doppler effect partially compensated for the reactance introduced at this time.

The continuing decrease in the water flow rate through the operating channels of the reactor under conditions of an increase in power led to intense steam formation and then to a crises of convective heat transfer, heating up of the fuel, its disintegration, rapid boiling of the heat-transfer agent, into which particles of disintegrated fuel were falling, a sharp increase in pressure in the operating channels, rupture of the channels and a thermal explosion, which destroyed the reactor and part of the structural components of the building and led to the release of active fission products into the environment.

Disintegration of the fuel was simulated in the mathematical model by a sharp increase in the effective heat-transfer surface area, where the specific release of energy in the fuel exceeded 300 cal/g. At just this time, the pressure in the active zone increased to the extent that a sharp decrease in the water flow rate from the GTsN occurred (the check valves closed). This can be seen clearly both from results obtained on the mathematical model and from measurement results recorded by the DREG program. Rupture of the operating channels alone led to partial reconstruction of the flow rates from the GTsN, although water passed from them into the reactor

space as well as into the surviving channels.

The steam formation and the sharp temperature increase in the active zone created the conditions for steam-zirconium and other exthermic chemical reactions. Witnesses observed their appearance in the form of fireworks of flying hot and glowing fragments.

A mixture of gases containing hydrogen and carbon monoxide capable of thermal explosion in mixing with air oxygen was formed as a result of these reactions. This mixing could occur after unsealing of the reactor space.

CHAPTER 4. CAUSES OF THE ACCIDENT

As the analysis presented above demonstrated, the accident at the fourth unit of the ChAES belongs to the class of accidents involved with introduction of excess reactance. The design of the reaction installation included protection against accidents of this type with consideration for the physical features of the reactor, including the positive steam coefficient of reactance.

The technical protection facilities include systems for control and protection of the reactor against a power excess and a decrease in the runaway period, blocking and protection against malfunctions or switching the equipment and systems of the power unit, and a system for emergency cooling of the reactor.

Strict rules and an order for conducting the operating process at the AES, defined by power unit operating regulations, were also included in addition to the technical protection facilities. Requirements concerning the unacceptability of a decrease in the operating reactance reserve below 30 rods are among the most rules.

In the process of preparing for and conducting tests of a turbogenerator in a rundown mode with a load of system auxiliaries of the unit, the personnel disengaged a number of technical protection devices and violated the important conditions of the operating regulations in the section of safe performance of the operating process.

The table presents a list of the most dangerous violations of operating conditions committed by personnel of the fourth unit of the ChAES.

No.	Violation	Motivation	Results
1	Decrease in the operareactance reserve significantly below the acceptable value	Attempt to get out of "iodine pit"	Emergency protection of reactor proved ineffective
2	Power dip below value envisaged by testing program	Operator error in disengagement of LAR	Reactor proved to be in hard-to-control state
3	Connection of all GTsN to reactor with exceeding of flow rates established by regulations in regard to individual GTsN	Fulfillment of requirements of testing program	Temperature of heat-transfer medium of KMPTs came close to saturation temperature
4	Blocking of reactor protection on signal for shutdown of two TG	Intention to repeat experiment with disengagement of TG if necessary	Loss of possibility of automatic shutdown of reactor
5	Blocking of protection in regard to water level and steam pressure in separator drum	Attempt to conduct tests despite unstable operation of reactor	Protection of reactor in regard to thermal parameters was disengaged
6	Disengagement of system for protection against maximum theoretical failure (disengagement of SAOR)	Attempt to avoid false response of SAOR during performance of testing	Loss of possibility of reducing scale of accident

The basic motive in the behavior of the personnel was the attempt to complete the tests more quickly. Violation of the established order in preparation for and performance of the tests, violation of the testing program itself and carelessness in control of the reactor installation attest to inadequate understanding on the part of the personnel of the features of accomplishment of operating processes in a nuclear reactor and to their loss of a sense of the danger.

The developers of the reactor installation did not envisage the creation of protective safety systems capable of preventing an

accident in the presence of the set of premeditated diversions of technical protection facilities and violations of operating regulations which occurred, since they considered such a set of events impossible.

An extremely improbable combination of procedure violations and operating conditions tolerated by personnel of the power unit thus was the original cause of the accident.

The accident took on catastrophic dimensions in connection with the fact that the reactor was brought by the personnel to a condition so contrary to regulations that the effect of a positive reactance coefficient on the power build-up was intensified significantly.

5. INITIAL MEASURES TO INCREASE NUCLEAR POWER PLANT SAFETY WITH RBMK REACTORS

A decision has been made to reset terminal breakers of control rods on working nuclear power plants with RBMK reactors such that in the outermost position all rods are inserted into the core to a depth of 1.2 m. This measure increases the response efficiency of protection and precludes the possibility of the multiplication properties of the core from increasing in its lower part when the rod moves from the upper end piece. At the same time a number of absorber rods constantly in the core increases to 70 - 80; this reduces the steam void effect of reactivity to an allowable value. is is a temporary measure and in the future it will be replaced by converting RBMK reactors to fuel with initial enrichment 2.4% and placing additional absorbers in the core which ensure that positive coastdown of reactivity not exceed more than one beta for any change in coolant density.

A number of additional signallers of the cavitation reserve of reactor coolant pumps and an automatic system for computing reactivity reserve with output of an emergency reactor shutdown signal when the reserve drops below a given level are being installed. These measures have a somewhat adverse effect on economic indicators of nuclear power plants with RBMK, but guarantee the necessary safety.

In addition to technical measures organizational ones to strengthen plant discipline and increase operating quality are being implemented.

6. PREVENTING DEVELOPMENT OF AN ACCIDENT AND REDUCING ITS CONSEQUENCES

6.1 Fire Fighting on a Nuclear Power Plant

The primary task after a reactor accident was to control the fire.

As a result of explosions in the reactor an ejection of core fragments heated to high temperature onto the rooves of certain buildings of reactor section services, the deaerator, stack and turbine room more than 30 fires were started. Due to damage to individual oil lines, short circuits in electrical cables and intense thermal radiation from the reactor fire foci were formed in the turbine room above TG No. 7, in the reactor room and the partially destroyed compartments adjacent to it.

At one hour 30 minutes, fire fighting units for nuclear power plant protection from the cities of Pripyat' and Chernobyl arrived.

Due to the direct threat of the fire spreading over the cover of the turbine room to the adjacent third unit and its rapid intensification, primary measures were directed at eliminating the fire in this sector. Fires arising within compartments were fought using fire extinguishers and inside stationary fire cranes. By 2 hours 10 minutes most of the fires had been put out on the roof of the turbine room and by 2 hours 30 minutes on the roof of the reactor building. By 0500 the fire had been put out.

6.2 Estimating fuel condition after the accident

The accident led to partial destruction of the reactor core and complete destruction of its cooling system. Under these conditions, the state of the environment in the reactor shaft was determined by the following processes:

- residual heat release of the fuel due to decay of fission products

- heat release due to different chemical reactions taking place in the reactor shaft (hydrogen combustion, graphite and zirconium oxidation, etc.);

- heat discharge from the reactor shaft due to its cooling by flows of atmospheric air through holes formed in sealed (before the accident) shells surrounding the core.

To solve the problem of preventing accident development and limiting its consequences, during the first hours after the accident major efforts were devoted to estimating the fuel state and its possible change as time passed. To do this, the following analyses had to be done:

- estimate possible scales of melting (due to residual heat release) of fuel in the reactor shaft;

- study processes of the interaction of molten fuel with reactor structural materials and reactor shaft materials (metals, concrete and so forth);

- estimate the possibility of melting of construction materials of the reactor and the shaft due to heat release from the fuel.

Initially computations were done to estimate fuel state in the reactor shaft with allowance for leakage of fission products (PD) depending on time since the accident began.

Study of the dynamics of PD discharge from the reactor during the first few days after the accident showed that the fuel temperature change as time passed was nonmonotonic. It can be assumed that there were several stages in the temperature mode of the fuel. The fuel heated up at the instant of explosion. Temperature estimation from the amount of relative leakage (fraction of the isotope discharging from the fuel from its total content in the fuel at a given point in time) of iodine radionuclides showed that the effective temperature of the fuel remaining in the reactor building after the explosion was 1600 - 1800 K. During the next several dozen minutes, fuel temperature dropped due to release of heat to the graphite structure and reactor structures. This led to a drop in leakage of volatile PD from the fuel.

Here it was considered that the amount of PD discharge from the reactor shaft was determined during this time mainly by processes of graphite combustion and associated processes of migration of finely dispersed fuel and PD introduced into the graphite by the accident explosion in the reactor. Subsequently, the temperature of the fuel due to residual heat release began to rise. As a result, leakage of volatile radionuclides (inert gases, iodine, tellurium, cesium) from the fuel increased. With the subsequent temperature increase of the fuel leakage of other so-called nonvolatile radionuclides began. By 4 - 5 May, the effective temperature of the fuel remaining in the reactor unit stabilized and then began to drop.

The results of theoretical analyses of fuel state are shown in Fig. 5 which lists results which characterize residual radionuclide content in the fuel and also the temperature change of the fuel with allowance for leakage of PD from it depending on the time since the accident began.

Computations showed:

- maximum fuel temperature cannot reach its melting point;

- the PD emerges onto the fuel circuits in batches; this can lead only to local heatup on the fuel-environment boundary.

The PD escaping from the fuel fall on structural and other materials surrounding the reactor in the reactor unit according to condensation and precipitation temperatures of the fuel. Here radionuclides of krypton and zenon escape from the reactor unit almost completely, the volatile PD (iodine, cesium) to some extent and the others remain almost entirely within the reactor building.

Thus the energy of the PD is dissipated throughout the volume of the reactor unit.

As the result of these factors melting of the medium surrounding the fuel and fuel movement become of low probability.

6.3. Limiting the Accident Consequences in the Reactor Core

The potential of concentrating part of the molten fuel and establishing conditions for formation of critical mass and a self-containing chain reaction required measures against this danger. In addition, the destroyed reactor was a source of emissions of a large amount of radioactivity into the environment.

Immediately after the accident, an attempt was made to reduce the temperature in the reactor shaft and prevent combustion of the graphite structure using emergency and auxiliary feedwater pumps to supply water to the core space. This attempt was unsuccessful.

Immediately one of two decisions had to be made:

- Localize the focus of the accident by filling the reactor shaft with heat discharging and filtering materials;

- Allow combustion processes in the reactor shaft to end naturally.

The first option was taken since in the second the danger of radioactive damage to considerable areas with the threat to the health of the populations of large cities arose.

A group of specialists in military helicopters began to drop boron compounds, dolomite, sand, clay and lead onto the damaged reactor. From 27 April to 10 May almost 5000 tons of materials were dropped, most from 28 April through 2 May. As a result, the reactor shaft was covered by a layer of loose mass which intensely absorbed aerosol particles. By 6 May, the discharge of radioactivity ceased to be a major factor, having dropped to several hundred and by the end of the month dozens of curies per hour. At the same time, the problem of reducing fuel heatup was solved. To reduce temperature and oxygen concentration nitrogen from a compressor station was sent into the space under the reactor shaft.

By 6 May, the temperature increase in the reactor shaft stopped and began to drop due to formation of a stable convective air flow through the core into the free atmosphere. As insurance against extremely improbable (but possible during the first few days after the accident) failure of the lower tier of structures, it was decided to immediately establish an artificial heat discharge horizon under the building foundation in the form of a flat heat exchanger on a concrete slab. By the end of June the planned work was finished.

Experience showed that the decisions made were primarily the right ones.

From early May the situation had largely stabilized. Destroyed parts of the reactor building were in stable positions. The radiation situation following decay of the short lived isotopes improved. The exposure rate was single roentgens per hour in compartments under the reactor, in the turbine room and control panel compartments. Escape of radioactivity from the unit into the atmosphere was due mainly to wind entrainment of aerosols. The radioactivity of the releases did not exceed dozens of curies per day. Temperature conditions in the reactor shaft were stable. Maximum temperatures of various sections were several hundred degrees C with a steady trend towards dropping at a rate of roughly 0.5 degrees C per day.

The lower slab of the reactor shaft had been preserved and fuel was localized mainly (roughly 96%) in the reactor shaft an in compartments of steam water and lower steam service lines.

6.4 Measures at First-Third Blocks.

The following measures were taken on the first - third blocks after the accident on the fourth block:

- The first and second blocks were shut down at 0113 hours and 0213 hours on 27 April;

- The third block which was closely connected to the damaged fourth block but hardly suffered at all from the explosion was shut down at 0500 hours on 26 April;

- First - third blocks were prepared for prolonged cold shutdown;

- The nuclear power plant equipment following the accident was shifted into the cold reserve state.

The first - third blocks and power plant equipment were checked by on-duty personnel.

Considerable radioactiave contamination of equipment and compartments of the first-third power plant blocks was caused by entry of radioactive substances thorugh the ventilation system which continued to operate for some time after the accident.

Individual sections of the turbine room had major radiation levls since it was contaminated through the destroyed roof of the third block.

A government committee was assigned to organize decontamination and other operations on the first - third units. The objective was to prepare the units for startup and operation.

Decontamination was done using special solutions. Their composition was selected with allowance for the material to be washed (plastic compounds, steel, concrete, various coatings), the nature and level of surface contamination.

After decontamination, gamma radiation levels dropped by a factor of 10-15. Radiation dose rate for compartments of the first and second units in June was 2-10 mR/hr.

Final decontamination and stabilization of the radiation situation on the first - third units can be ensured only after completing decontamination on the nuclear power plant grounds and mothballing the damaged unit.

6.5 Monitoring and Diagnostics of the Condition of the Damaged Unit.

Diagnostic measurements made it possible to solve the following main problems:

- establish reliable monitoring of fuel movement;

- determine contamination scales on terrain adjacent to the power plant;

- estimate scales of damage and carry out dosimetry within the unit, determine the potential for working in undamaged compartments;

- determine distribution of fuel, fission products and others to generate raw data for design of mothballing facilities.

Among primary measurements monitoring of reactor state from the air was set up together with estimations of the radiation situation on the plant and around it. Radiation measurements, photographs of the damaged reactor building and its components in infrared radiation were done from helicopters and the chemical composition of gases discharged from the reactor shaft was analyzed; a number of other measurements were also taken. After it was established that compartments and equipment had survived in the lower part of the reactor building, it became possible to take initial measurements and install emergency monitoring instruments. First measuring instruments to measure neutron flux, gamma radiation dose rate, temperature and thermal flow were set up in the drained pressure suppression pool. Temperature measuring equipment was set up on a redundant basis. Evaluation of the situation in the pressure suppression pool showed the absence of any immediate danger of structures melting through. This confirmed the safe conditions for work to establish a lower protective slab.

The overall measurement strategy was as follows:

- Dosimetric and visual reconnaissance within the damaged unit;

- Radiometric and visual observation from helicopters;

- Measurement of the most important parameters (radioactivity, temperature, air flow) in surviving structures and accessible compartments.

Primary measurement efforts at the initial stage were directed at checking possible movement of fuel downward.

Solution of diagnostic problems became complicated for the following reasons:

- The regular measurement system had completely failed;

- Readings from sensors which may have survived were not accessible to personnel;

- Information on the state of compartments and the radiation situation in them was limited.

At the next stage locations of fuel discharge from the reactor shaft in the building had to be determined and its temperature and heat output conditions estimated.

To solve this problem, traditional dosimetric methods were used, and rviving pipelines for delivering measurement probes were opened. As a result, fuel distribution within the building was largely established.

The temperature in compartments under the reactor did not exceed 45 degrees C beginning in June; this indicated good heat output.

Monitoring and diagnostic methods were refined with allowance for this information.

6.6 Decontamination of the Nuclear Power Plant Site

During the accident radioactive materials were discharged over the plant grounds and fell onto the roof of the turbine room the roof of the third unit, and metal pipe supports.

The grounds of the plant, walls, and rooves of the buildings had considerable contamination due to precipitation of radioactive aerosols and radioacative dust. Contamination of the ground was non-uniform.

To reduce dispersion of radioactive dust on the grounds, roof of the turbine room building and shoulders of roads were treated with different ymerizing solutions to stabilize upper soil layers and preclude dust formation.

To establish conditions for comprehensive decontamination operations, the grounds of the nuclear power plant were divided into individual zones. Decontamination in each zone was done as follows:

- removal of trash and contaminated equipment from the grounds;

- decontamination of rooves and outside building surfaces;

- removal of 5-10 cm of soil and hauling it in containers to the solid waste storage pit of the fifth unit;

- placement of concrete slabs on the ground, if necessary, or clean soil;

- covering slabs and unconcreted grounds with fil forming compounds.

As a result of completed measures, the total gamma background in the area of the first unit was reduced to 20-30 mR/hr. This residual background was due mainly to external sources (damaged unit). This indicates the relative efficiency of decontamination of grounds and buildings.

6.7 Long Term Mothballing of the Fourth Unit

Mothballing of the fourth unit should ensure normal radiation situations on the surrounding territory and in the air as well as prevent escape of radioactivity into the environment.

To mothball the unit the following structures should be erected. (Figs. 6 - 8):

- outside protective walls along the perimeter;
- inside concrete dividers in the turbine room between the third and the fourth units, in unit "V" (Cyrillic alphabetical equivalent our "C"), and in the deaerator along the turbine room and on the side of the barrier near the tank "SAOR";
- metal divider in the turbine room betwen the second and third units;
- protective cover over the turbine room, and in addition the central hall and other reactor compartments should be sealed, the barrier near the tank "SAOR" and compartments of the northern GTsN for mothballing the barrier concreted, and protection established against radiation on the reactor unit side.

The thickness of the protective concrete walls is 1 m and greater depending on designs and the radiation situation.

There are two versions in the ventilation outline:

- open configuration with air purification using aerosol filters and discharge into the atmosphere through the existing pipe of the ventilation center;

- Closed configuration with heat discharge in a heat exchanger located in the upper part of the vented volume, while maintaining a partial vacuum in the building volume which is ensured by exhaust of air from the upper part of the volume and its discharge through filters and pipe into the atmosphere.

The aforementioned operations are carried out as follows.

1. On the grounds adjacent to the unit the surface layer of soilis removed on local sections using a special technique.

2. The grounds are concreted with the surface leveled; this allows self-propelled cranes and other equipment to move easily.

3. The rooves and walls of the building are decontaminated.

Special polymer adhesive pastes of varied compositions are used in areas with high radiation.

4. After the site is cleaned up and concreted metal frames of protective walls are installed and subsequently concreted.

5. As walls are erected work is done to set up the main structures which ensure complete mothballing the the fourth unit.

6.8. Decontamination of the 30-km zone and returning it to economic activity

Major radioactive contamination of areas adjacent to the nuclear power plant made it necessary to make a number of extreme decisions regarding the establishment of controlled zones, evacuation of population, prohibition or limitation on agricultural use of soil and so forth.

A decision was made to introduce three controlled zones: special, 10 and 30 km. Strict dosimetric monitoring of transport was set up and decontamination points deployed in them. On zone boundaries the workers were transported from one mode of transport to others to reduce transfer of radioactive substances.

The radiation situation within the 30-km zone will continue to change, pecially in regions with a high gradient of contamination levels. Radionuclides will be dramatically redistributed over landscape elements according to relief characteristics. The question of re-evacuation of population can be posed only after the radiation situation has stabilized over the entire territory of the contaminated zone: burial of the fourth block, decontamination of the nuclear power plant site, and stabilization of radioactivity in areas with elevated contamination level.

Beginning in June a complex of hydraulic facilities began to be built to protect ground water and surface water in the vicinity of the Chernobyl plant from contamination, including:

- antifiltration wall in the soil along the partial perimeter of the nuclear power plant site and drawdown wells;

- curtain of the coolant pond;

- cutoff drainage curtain on the right bank of the Pripyat';

- intercepting drainage curtain in the southwestern sector of the nuclear power plant;

- drainage water purification facilities.

By this time, based on completed estimates of the situation with regard to contamination of the soil-vegetative cover of the 30-km zone, special agritechnical and decontamination measures were developed and implemented which made it possible to return the contaminated earth to agrocultural use. These measures included: changing the traditional methods of working the soil in this region, use of special compositions to suppress dust formation, changing methods of harvesting and handling the harvest and so forth.

7. Monitoring radioactive contamination of the environment and the health of the population

7.1. Estimating amount, composition and dynamics of fission product release from the damaged reactor.

The following results were used as raw data for this estimate:

- systematic studies of radionuclide composition of aerosol samples collected above the damaged power plant unit from 26 April 1986;

- aerogammaphotography of the nuclear power plant region;

- analysis of precipitation samples;

- systematic data from national weather station measurements.

Discharge of radionuclides outside the damaged block of the Chernobyl plant was a long term process consisting of several stages.

In the first stage dispersed fuel from the damaged reactor was discharged. The radionuclide at this stage of escape corresponded roughly to their composition in the irradiated fuel, but enriched with volatile nuclides of iodine, tellurium, cesium, and inert gases.

In the second stage, from 26 April through 2 May 1986, the magnitude of discharge outside the damaged unit decreased due to measures taken to prevent burning of the graphite and to filter the discharge. During this period radionuclide composition in the discharge was also near their composition in the fuel. At this stage finely dispersed fuel was discharged from the reactor by a flow of hot air and by graphite combustion products.

The third stage of discharge is characterized by rapid increase in the magnitude of fission product escape beyond the reactor unit. In the predominant entrainment of volatile components was observed, in particular, iodine, and then the radionuclide composition again approached their composition in the irradiate fuel (on 6 May 1986).

This was due to heating of the fuel in the core to temperatures exceeding 1700oC by residual heat release. As a result of the temperature dependent migration of fission products and chemical transformations of uranium oxide fission products leaked from the fuel matrix and were entrained in aerosol form on graphite combustion products.

The last, fourth stage which began after 6 May was characterized by a rapid drop in discharge (Table 1). This was the result of special measures which had been taken, formation of higher melting compounds of fission products as a result of their interaction with introduced materials, stabilization andsubsequent drop in fuel temperature.

Nuclide composition of the discharge is shown in Table 2.

In air and precipitation samples fission products were found in the form of individual radionuclides (mainly volatile) and in fuel particle composition. In this case, particles (associates) were found with increased content of individual radionuclides (Cs, Ru, and so forth) formed by migration of fission products in the fuel in materials of the backfill and structures, and sorption on surfaces.

Total discharge of fission products (without radioactive inert gases) was roughly 50 megacuries; this corresponds roughly to 3.5% of the total amount of radionuclides in the reactor at the time of the accident. These data were computed for 6 May 86 with allowance for radioactive decay. Discharge of radioactive materials was essentially completed by this time.

Дата ①	Время после аварии, сут. ②	q, МКи**) ③
26.04	0	12
27.04	1	4,0
28.04	2	3,4
29.04	3	2,6
30.04	4	2.0
01.05	5	2.0
02.05	6	4.0
03.05	7	5,0
04.05	8	7,0
05.05	9	8,0
06.05	10	0,1
09.05	14	~0,01
23.05	28	20.10^{-6}

Table 1. Daily discharge q of radioactive substances into the atmosphere from the damaged unit (without radioactive inert gases*)

Headings: column 1 - date; column 2 - time after accident, days; column 3 - q, megacuries**

* - error in estimating discharge + 50%. It is determined by the error of dosimetric instruments, radiometric measurements of radionuclide composition of air and soil samples, and also by the error caused by averaging precipitation over the area.

** - values of q were computed on 6 May 86 with allowance for radioactive decay (at the time of release 26 Apr 86 activity was 20 - 22 megacuries). See Table 2 for the composition of the discharge.

Table 2. Estimation of radionuclide composition of release from damaged unit of Chernobyl nuclear power plant*.

Column 1 - Nuclide **; columns 2 and 3 - activity of release, megacuries; column 4 - percentage of radioactivity discharged from the reactor by 6 May 86. Column 4, line 1 - possibly up to 100.

① Нуклид**)	Активность выброса, МКи		Доля активности, выброшенной из реактора к 06.05.86, % ④
	26.04.86 ②	06.05.86***) ③	
^{133}Xe	5	45	Возможно, до 100
^{85m}Kr	0.15	—	"
^{85}Kr	—	0,9	"
^{131}I	4,5	7,3	20
^{132}Te	4	1,3	15
^{134}Cs	0,15	0,5	10
^{137}Cs	0,3	1,0	13
^{99}Mo	0,45	3,0	2,3
^{95}Zr	0,45	3,8	3,2
^{103}Ru	0,6	3.2	2,9
^{106}Ru	0,2	1.6	2,9
^{140}Ba	0,5	4.3	5,6
^{141}Ce	0,4	2.8	2.3
^{144}Ce	0,45	2.4	2,8
^{89}Sr	0,25	2.2	4,0
^{90}Sr	0,015	0,22	4,0
^{238}Pu	$0{,}1 \cdot 10^{-3}$	$0{,}8 \cdot 10^{-3}$	3,0
^{239}Pu	$0{,}1 \cdot 10^{-3}$	$0{,}7 \cdot 10^{-3}$	3,0
^{240}Pu	$0{,}2 \cdot 10^{-3}$	$1 \cdot 10^{-3}$	3,0
^{241}Pu	0,02	0,14	3,0
^{242}Pu	$0{,}3 \cdot 10^{-6}$	$2 \cdot 10^{-6}$	3,0
^{242}Cm	$0{,}3 \cdot 10^{-2}$	$2{,}1 \cdot 10^{-2}$	3,0
^{239}Np	2,7	1,2	3,2

* - estimate error + 50%, see remarks to Table 1 for explanation.

** - data are cited for activity of main radionuclides measured in radiometric analyses.

*** - total release by 6 May 86.

The composition of radionuclides in the accident release roughly corresponded to their composition in the fuel of the damaged reactor, differing from it by the increased content of volatile iodine, tellurium, cesium and inert gases.

7.2. Monitoring system

At the time of the accident the regular system of meteorological, radiation and sanitary-hygienic monitoring began to operate according to the emergency plan. As soon as the scale of the accident became clear the monitoring system began to expand by enlisting additional groups of cialists and equipment. During the first few days after the accident primary attention was focused on immediate problems of radiation, sanitary-hygienic and medical-biological monitoring.

At the same time the monitoring system began to expand with consideration of long term problems. Organizations from Goskomgidromet of the USSR, the Ministry of Health of the USSR and union republics, the academies of sciences of the USSR, Ukrainian SSR, Byelorussian SSR, the GKAE of the USSR, Gosagroprom and others were involved in its formation.

Specialized medical facilites in Moscow and Kiev were enlisted to treat irradiated individuals.

Together with formation of the monitoring system a program of radioecological, medical-biological and other scientific problems of estimation and prediction of the effect of ionizing radiation on man, flora and fauna was set up and began to be executed.

The primary tasks of monitoring were:

- estimating the possible level of internal and external irradiation of Chernobyl power plant personnel, the population of the Pripyat' and the 30-km zone;

- estimating possible level of irradiation of the population in a number of regions outside the 30-km zone, with a level of radioactive contamination which could exceed allowable limits;

- development of recommendations for measures to protect population and personnel from irradiation above established limits.

These recommendations include:

- evacuation of population;

- prohibitition of limitation on use of food products with increased content of radioactive substances;

- recommendations for behavior of the population in houses and in open terrain.

To solve these initial problems systematic monitoring of the following was done:

- Gamma radiation level in contamination regions;

- concentration of biologically significant radionuclides in the air and water of reservoirs, in particular those used for drinking water supply;

- density of radioactive contamination of the soil and vegetation and its radionuclide composition;

- content of radioactive substances in food products, in particular iodine-131 in milk;

- radioactive contamination of special clothing, personnel clothing and footwear, transport resources and so forth;

- accumulation of radionuclides in the internal organs of individuals and so forth.

7.3. Main characteristics of radioactive contamination of the atmosphere and locale, possible ecological consequences.

Radioactive contamination of the environment as a result of the accident at Chernobyl unit No. 4 was determined by the dynamics of radioactive release and weather conditions.

The raedioactively contaminated airstream spread initially in the western and northern sectors, during the two or three days following the accident in the northern sector, from 29 April for several days in the southern sector. The contaminated air masses then spread great distances over the territory of the Byelorussian SSR, Ukrainian SSR, and the RSFSR.

On 27 April the height of the stream exceed 1200 m, the radiation level in it at a distance of 5 - 10 km from the accident site was 1000 mR/hr. The stream and radioactive trace which formed were regularly photographed by aircraft of the Goskomgidromet equipped with sampling, roentgenometric, and gammaspectrometric equipment, and in the network of weather stations.

Fission products as well as products of induced activity Np-239 and Cs-134 were detected in the air samples.

The main zones of terrain contamination following the accident formed in the western northwestern and northeastern directions from the power plant, and on a smaller scale in the southern direction. Radiation levels near the nuclear power plant exceeded 100 mR/hr, in the western trace maximum radiation levels 15 days after the accident were 5 mR/hr at a distance of 50 - 60 km from the accident zone (maximum distances), in the north at a distance of 35 - 40 km. In Kiev radiation levels early in May reached 0.5 - 0.8 mR/hr.

In the near zone of the trace plutonium isotopes (their propagation in the locale was insignificant) were identified (in addition to those mentioned above). In this zone fractionation of the isotopes was not significant, but in the far trace radioactive products were greatly riched by isotopes of tellurium, iodines, and cesium.

Integration of contaminated areas made it possible to determine the total activity of precipitated radioactive materials (outside the site). In the zone of near and far precipitation in the European part of the USSR it was roughly 3.5% (see section 7.1) of the total activity of the fission products and activity accumulated in the reactor (in the near trace roughly 1.5 - 2%).

Addition of the activity of radionuclides precipitated in the near trace and determined by taking soil samples yielded a close value, i.e. from 0.8 - 1.9%.

Levels of contamination by plutonium isotopes in the aforemenetioned zones are not decisive from the point of view of decontamination efforts and making economic decisions.

Information on radioactive contamination of rivers and reservoirs was obtained by regular analysis of water samples from the Pripyat', Irpan', and Teterev rivers and the Dneprovsk water supply. Beginning from 26 April 1986 water samples were taken over the entire water area of the Kiev reservoir.

The highest concentrations of iodine-131 were found in the Kiev reservoir on 3 May 1986, i.e. 3 x 10-8 curies per liter. It must be noted that the spatial distribution of radionuclides in the water was characterized by great nonuniformity.

Monitoring of radionuclide content in bottom sediments of reservoirs both inside and outside the 30-km zone was set up from the first few days of the accident. The radionuclide concentration in bottom sediments in isolated sections of the Kiev reservoir adjacent to the accident region during the second 10 days of June was 10-7 - 10-8 curies/kg, in the water 10-10 curies/l.

Irradiation of marine organisms in the Kiev reservoir did not seriously affect the population level. Significant radiation influence on the marine eco system can occur only in the coolant pond of the Chernobyl nuclear power plant.

Water ecosystems which inhabit the cooling pond of the Chernobyl nuclear power plant were exposed to the greatest radiation burdens. For some types of water plants, dose rate of internal irradiation was 10 rad/hr, and near the bottom of the cooling pond the level of external irradiation was 4 rad/hr (at the end of May 1986).

According to estimates of specialists levels of irradiation up to 10-2 rad per day do not noticeably affect ground ~~eolic systems~~ ecosystems. Within the 30-km zone around the Chernobyl nuclear power plant higher irradiation levels were observed in isolated sections contaminated by radioactive fallout. This can lead to a noticeable change in the state of radiosensitive types of plants in these areas.

Irradiation levels outside the 30-km zone the kilometer zone around the Chernobyl nuclear power plant cannot dramatically affect species composition of plant and animal communities.

These results are of a preliminary nature. The study of the consequences of the Chernobyl accident on living organisms and ecosystems continues.

7.4. Irradiation doses to the population in the 30-km zone around the nuclear power plant.

Analysis of radioactive contamination of the environment in this zone made it possible to estimate real and predictable irradiation doses to the population of cities, towns, villages and other population centers.

Based on these estimates decisions were made to evacuate the population of Pripyat' and a number of other population centers. A total of 135,000 individuals were evacuated.

These and other measures made it possible to prevent irradiation of the population above the established limits.

Radiological consequences for the population in the next few decades were estimated. These consequences will be insignificant against a background of natural malignant and genetic diseases.

7.5. Data on irradiation of power plant
and emergency service personnel.
Treatment.

As a result of participation in accident control measures during the first few hours after the accident some individuals from among plant personnel received high doses (greater than 100 ~~ber~~ rem) and also burns from hting fires. First aid was rendered to all those affected. By 0600 hours on 26 April 1986 108 individuals had been hospitalized and during that day another 24 from among those examined. One patient died at 0600 hours on 26 April 1986 from severe burns and one individual from among those working on the damaged unit was not found. His work site may have been in the zone of debris and high activity.

Based on criteria of early diagnosis adopted in the USSR, by the start of the first 36 hours individuals were selected for immediate hospitalization for whom development of acute radiation sickness (OLB) was predicted with greatest probability. Clinical facilities in Kiev near the accident site and a specialized hospital in Moscow were selected for hospitalization in order to provide a maximum amount of assistance and competent analysis of observation results.

During the first two days 129 patients were sent to Moscow. From among them, during the first three days 84 were diagnosed as having OLB of II - IV degree of severity and 27 as having OLB of degree I. In Kiev, 17 individuals were diagnosed as having OLB of degree II - IV, and 55 with OLB of degree I.

Detailed information on methods and results of treating these patients is given in the appendix.

The total number of those who died from burns and OLB among personnel at the beginning of July was 28. Among the population there was no one who had received high doses leading to OLB.

8. Recommendations for increasing the safety of nuclear power engineering.

8.1. Scientific and technical aspects.

A consultation committee for coordination of scientific research in the field of nuclear plant safety approved in 1985 a "list of priority efforts" which is the foundation for planning of experimental and theoretical research on the safety of nuclear power plant engineering in the USSR aimed at more detailed validation of safety requirements, estimation of the actual safety of nuclear facilities and bringing this level for nuclear power plants started before 1975 into agreement with established requirements.

After the accident at the Chernobyl plant a revision and evaluation of the state of experimental and theoretical research on ensuring nuclear power plant safety were done and measures outlined and expand, improve and intensify it.

Theoretical programs for analysis of nuclear power plant safe behavior in all possible transition and accident modes, including those for which it is not design are being improved and the modelling systems and complexes developed.

The search continues to expand on the possibility of building reactors with passive safety systems, so-called reactors with "internally inherent" safety, with cores which cannot fail during any accidents.

Research will be intensified on quantitative-probabilistic analysis of safety, analysis of risk from nuclear power, development of conceptual and methodological principles of optimizing radiation safety and comparing the radiation hazard with other types of hazards from industrial activity.

8.2. Organizational-technical measures

The system of supervision and standard documents which exist in the USSR encompasses all main questions of ensuring nuclear power plant safety and continues to be improved. Under the aegis of Gosatomenergonadzor, a consolidated list and plan for development of rules and regulations in the field of nuclear power which coordinates and directs the activity of all the departments in development and systemization of a corresponding scientific and technical documentation was compiled in 1985 in the USSR.

Comparison of existing Soviet documents on questions of design and operation of nuclear power plants with foreign analogs does not reveal any fundamental differences. Existing standard requirements associated with safety for the most part do not require re-examination. However their practical implementation requires more careful monitoring. Quality of training and re-training of personnel must be raised, monitoring of the quality of equipment, installation, and startup efforts by builders and designers and their responsibility for subsequent efficiency and safety of nuclear power plants in operation must be intensified.

After the accident at the Chernobyl nuclear power plant organizational measures to increase power plant safety were implemented. They can be divided into two stages.

The first stage which was carried out through detailed scientific and technical analysis of the course of the accident from results of initial information from the site relates to working nuclear power plants with RBMK type reactors and includes operational measures in working nuclear power plants with RBMK developed primarily to prevent the conditions which immediately preceded the accident.

The second stage, i.e. measures developed from the results of scientific and technical analysis of the course of the accident, included measures to increase safety of all types in nuclear power plants.

These measures will ensure safe operation of nuclear power plants with RBMK type reactors.

For nuclear power plants with other types of reactors previous measures to increase safety associated mainly with new advances in science and technology, operating experience, capabilities for diagnosis of the condition of metals in piping and equipment, and devices for automatic control of industrial processes are scheduled for implementation.

To increase the level of management and responsibility for the development of nuclear power and improve operation of nuclear power plants an All-Union Ministry of Nuclear Power Engineering was formed.

A host of measures to intensify government supervision of safety in nuclear power has been outlined.

8.3. International measures

The Soviet Union, which contributes its share to international efforts in nuclear power safety and which is guided by the desire to further strengthen international safety, in light of the Chernobyl accident, came forward with initiatives for establishing an international program for safe development of nuclear power and expansion of international cooperation in this area. These suggestions were set forth by the General Secretary of the CC CPSU, M.S. Gorbachev, on 14 May and 9 June 1986.

The international system for safe development of nuclear power is a system of international legal documents, international organizations and structures, and also organizational measures and activities to protect the health of the population and the environment within the framework of peaceful use of nuclear power. Establishment of this system could be supported by international agreements, participation in corresponding international conventions, additional accords, implementation of joint coordinated scientific programs on problems of nuclear safety, exchange of scientific and technical information, and establishment of international data banks and equipment necessary for safety purposes and so forth.

With the direct participation of international organizations funds could be created for rendering immediate assistance, including immediate support with the necessary special medical preparations, dosimetric and diagnostic equipment and instruments, supply of foodstuffs, fodder, and other material aid. A system of operational warning and supply of information in the case of a nuclear power plant accident, in particular one with transnational consequences, must be set up.

Treatment of the problem of material and psychological damage in accident cases also merits attention.

There is another aspect of nuclear safety, the prevention of nuclear terrorism. The extreme importance of the problem derives from this, i.e. development of a reliable system of mesures to prevent nuclear terorism in any of its manifestations.

A major role in establishing the international system for safe development of nuclear power will be played by the MAGATE.

At present it can be noted with satisfaction that initial steps have already been taken to implement suggestions relating to establishment of the international system for safe development of nuclear power. Efforts have begun on preparation for concluding two international conventions "Operation warning of a nuclear accident" and "Assistance in the case of nuclear accidents and radiological emergency situations". Questions of expanding international cooperation, in particular research programs of the MAGATE on nuclear safety are being actively discussed.

Initiatives on establishing an international system for safe development of nuclear power are closely associated with problems of detente and nuclear disarmament. The accident at the Chernobyl nuclear power plant has again demonstrated the danger of uncontrolled nuclear power and highlighted the destructive consequences to which its military use or damage to peaceful nuclear facilities during military operations could lead. In addressing and solving problems of safe use of nuclear power it would be absurd to develop means and methods of its most dangerous and inhuman use at the same time.

9. Development of nuclear power engineering in the USSR

Due to continued development of nuclear power engineering a reduction in the increase of consumption of organic fuel by thermal power plants in the European part of the country is outlined by the energy program of the USSR. The amount of fuel oil in electric power generation should be cut in half. The nuclear power will cover most of the increased consumption of electricity by the national economy. Maximum possible use of nuclear fuel for centralized heating and industrial heat supply and establishment of nuclear-industrial complexes are planned.

The Soviet Union is a pioneer in the use of nuclear power for peaceful purposes. The first nuclear power plant in the world with a pressure tube uranium-graphite reactor has been operating for 32 years. The program for building so-called demonstration power reactors for nuclear power plants with relatively small electrical capacities which implemented at the time made it possible to select the most promising of these for further development and improvement.

The existence of three types and modifications of nuclear reactors which have been adopted in the USSR for building up nuclear power capacities allows great flexibility and reliability of energy supply, and much more complete utilization of nuclear fuel resources; it also matches the characteristics of development of the power machinery construction base to a satisfactory degree.

Nuclear power plants under construction in the USSR use reactors of types VVER, RBMK, and BN. The first two are thermoneutron reactors with cooling water. BN are fast neutrton breeder reactors with sodium coolant currently being built for industrial trials of designs which have been adopted and gradual development of a closed fuel cycle with plutonium fuel on this foundation in the future.

The basis of nuclear power engineering in the USSR is nuclear power plants with VVER and RBMK reactors. Installed capacities in the Soviet Union have reached almost 30 million kilowatts. Soviet nuclear power plants are distinguished by high operational readiness. Utilization factor of installed power in a nuclear power plant has been rather high over the last few years.

According to the "Main trends in economic and social development of the USSR for 1986 - 1990 and through the year 2000" continued development of nuclear power engineering in the European part of the USSR and in the

Urals is planned. In 1985 nuclear power plants generated approximately 170 billion kilowatt hours of electricity and by the year 2000 this will increase by a factor of 5 - 7.

This development will allow nuclear power plants to occupy first place in terms of new capacities in power systems of the European part, having eliminated the construction of new thermal power plants using organic fuel to cover increases in the base part of the load curve.

Development of nuclear sources of heat supply based on high temperature gas cooled reactors is underway in the USSR. Construction of safe plants with these reactors will make it possible to generate high mperature heat for a number of industrial technologies.

The Soviet Union is actively involved in international cooperation in the field of nuclear power engineering and collaborates in agencies and committees of the United Nations, the MAGATE, the MIREK, and others. Nuclear power engineering in the USSR is developing in close cooperation with COMECON countries.

LIST OF ABBREVIATIONS

AZ - emergency protection

AZ-5 - signal to insert all regulating rods and emergency protection rods into the active zone

AN - Academy of Sciences

AR - automatic regulator

AS - nuclear station

AES - nuclear power station

BN - fast breeder reactor

BRU-K - high-speed reduction device

BS - water-steam separating drum

BSSR - Belorussian Soviet Socialist Republic

GKAE - USSR State Committee on the Use of Atomic Energy

Gosagroprom - USSR State Agro-industry Committee

Gosatomenergonadzor - USSR State Committee on Safe Performance of Operations in Atomic Power Engineering

Goskomgidromet - USSR State Committee on Hydrometeorology and Monitoring of the Environment

GPK - main safety valves

sN - main circulation pump

DP - additional absorber

DREG - diagnostic recording of parameters (program)

KGO - monitoring of seal of shells

KMPTs - repeated forced circulation duct

KTsTK - monitoring of the integrity of channel pipes

LAZ - local emergency protection

LAR - local automatic regulation

MAGATE - International Atomic Energy Agency

Minzdrav SSSR - USSR Ministry of Public Health

MIREK - World Energy Congress

NVK - bottom water lines

OLB - acute radiation sickness

OON - United Nations

PVK - steam-water lines

PD - fission products

PEN - electric feeder pump

RBMK - high-power channel reactor

RGK - distribution group collector

RZM - unloading-loading machine

RDES - back-up diesel power plant

RP - reactor space

RR - manual regulator

RSFSR - Russian Soviet Federated Socialist Republic

RU - reactor installation

SAOR - system for emergency cooling of the reactor

SLA - accident localization system

SM SSSR - USSR Council of Ministers

SRK - stopper-regulating valves

SUZ - system for control and protection

SEV - Council for Mutual Economic Aid

TVS - heat-releasing assembly

TG - turbogenerator

TK - operating channel

USP - shortened absorber rods

USSR - Ukrainian Soviet Socialist Republic

ChAES - Chernobyl' Nuclear Power Station

EVM - computer

LIST OF BASIC EQUIPMENT OF THE MAIN HOUSING OF THE AES

Item No.	Equipment or Product	Measurement Units	Unit Mass in Tons	Number per Power Unit
1	graphite lining	set	1850	1
2	"S" system metal components	"	126	1
3	"OR" system metal components	"	280	1
4	"Ye" system metal components	"	450	1
5	"KZh" system metal components	"	79	1
6	"L" system metal components	"	592	1
7	"D" system metal components	"	236	1
8	Water-steam separating drum	item	278	4
9	TsVN-6 Main Circulation Pump	"	67	8
10	GTsN electric motor	"	33	8
11	DU-800 main cut-off gate valve	"	5.7	8
12	intake collector	"	41	2
13	delivery collector	"	46.0	2
14	distribution group collector	"	1.3	44
15	bottom water lines (NVK)	set	400	1
16	steam-water lines (PVK)	"	450	1
17	DU-300 down pipelines	"	16	1
17a	DU-800 pipelines of MPTs duct	"	350	1
18	unloading-loading machine (RZM)	"	450	1
19	central room traveling crane Q 50/10 tf	item	121	1
20	GTsN room traveling crane Q 50/10 tf	"	176	1
21	forced-ventilation fan	"	3.5	30
22	exhaust fan	"	3.5	50

23	organized leak water tank	item	1.4	2
24	organized leak water heat exchanger	"	0.2	2
25	scheduled preventive maintenance vessels	"	25	4
26	metal components and pipelines of accident containment zone	set	270	1
27	NVK compartment check valves	"	2.5	11
28	accident containment system overflow valve	item	2	8
29	accident containment system condensers	"	3.7	36
30	container car	"	146	1
31	crane in UPAK (gas activity reduction system) compartment Q 30/5 tf	"	45	1
	pipelines of carbon steel	set	1170	1
	pipelines of stainless steel	set	760	1
	MACHINE ROOM			
32	K-500-65/3000 turbogenerator set	item	3500	2
33	SPP-500 steam superheater separator	"	15	8
34	low-pressure preheater	"	37.5	4
35	first extraction condenser pump units	"	2.5	6
36	machine room traveling crane Q 125tf	"	211	1
	pipelines of carbon steel	set	3825	1
	pipelines of stainless steel	"	1300	1
37	gas stripper	item	4.5	2

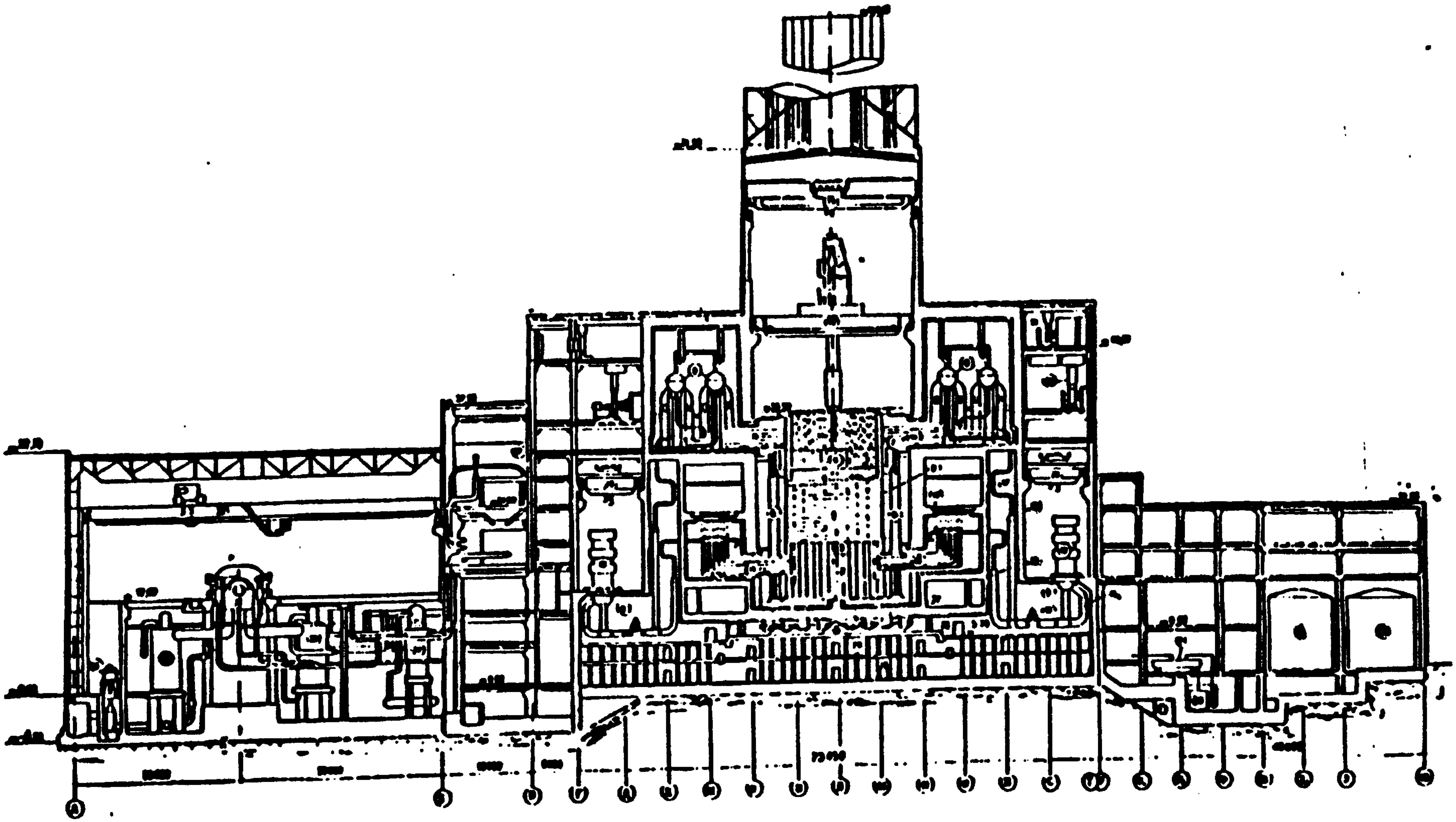


Рис. 1. Разрез по главному корпусу АЭС с РБМК-1000 (с зоной локализации)

Fig. 1. Sections along main housing of AES with RBMK-1000 (with containment zone)

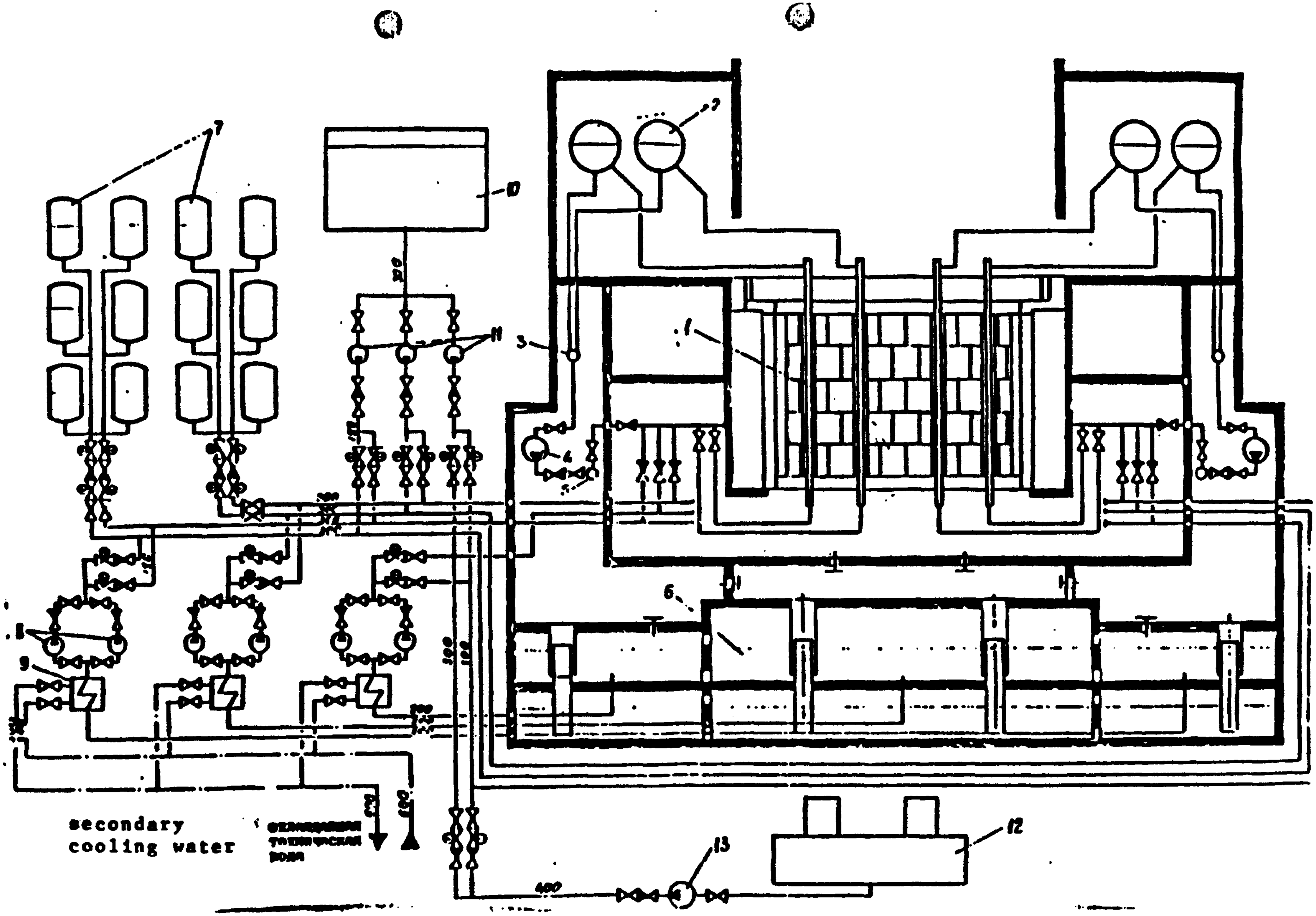


Fig. 2. Schematic diagram of system for emergency cooling of the reactor: 1 - reactor; 2 - steam separators; 3 - suction header; 4 - main circulation pump; 5 - pressure header; 6 - suppression pool; 7 - SAOR vessels; 8 - SAOR pumps for cooling malfunctioning half of reactor; 9 - heat exchanges; 10 - pure coordinate tank; 11 - SAOR pumps for cooling non-malfunctioning

(with containment zone)

РАЗРЕЗ ПО РЕАКТОРНОМУ ОТДЕЛЕНИЮ А С РБМК-1000
(с зоной локализации)

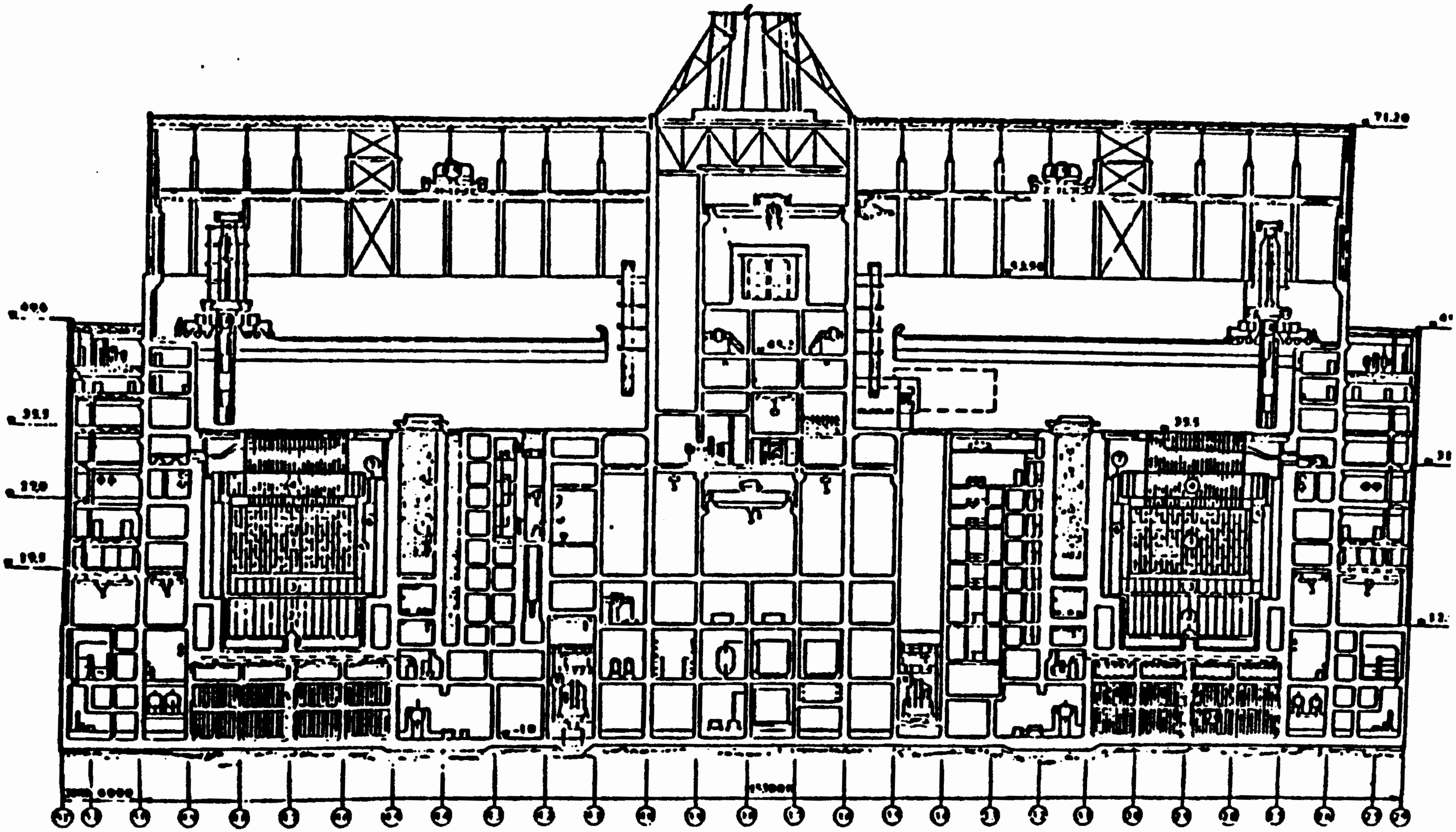


Рис. 3
Fig. 3

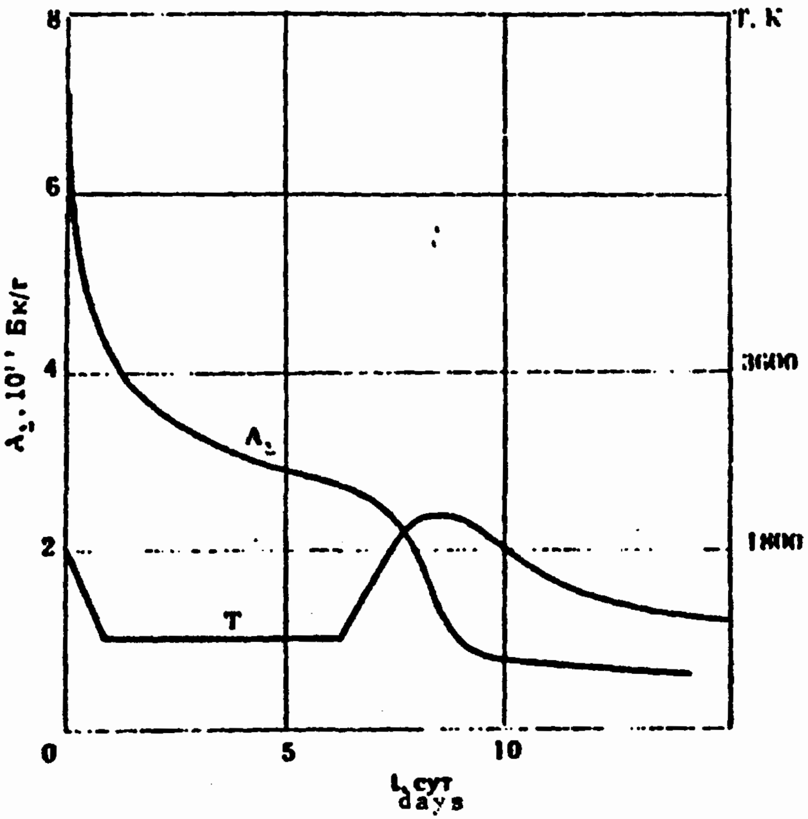


Рис. 5. Изменение активности и температуры топлива по времени

Fig. 5. Variation of fuel activity and temperature in time

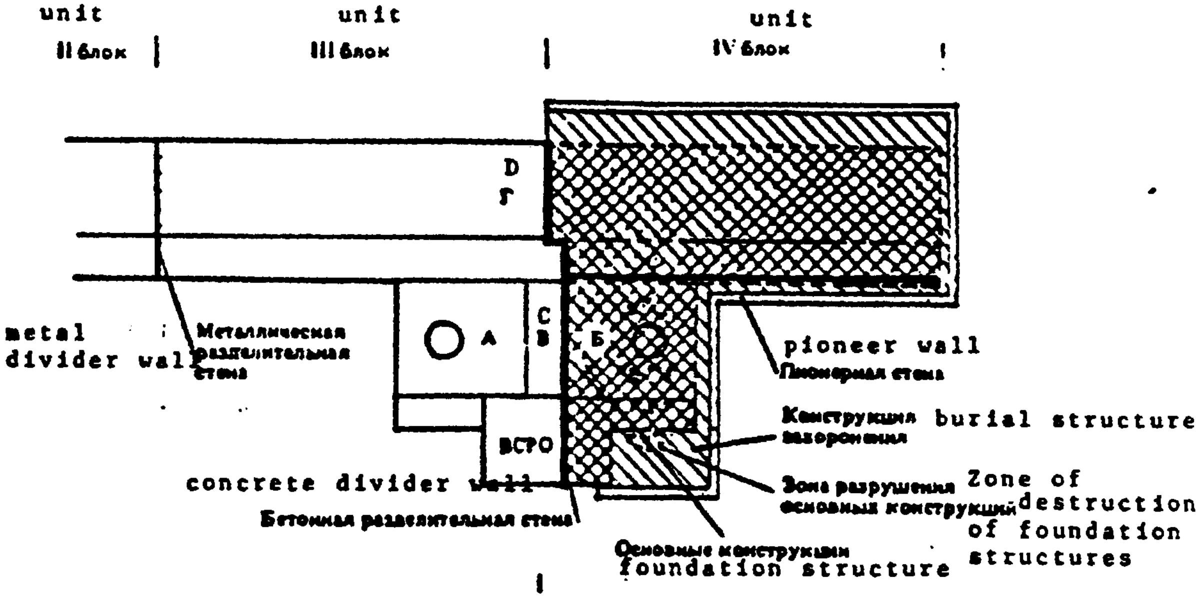


Рис. 6. Схема захоронения энергоблока № 4. Горизонтальный разрез одного из вариантов проекта

Fig. 6 Diagram of burial of power unit No. 4. Horizontal sections of one version of the plan.

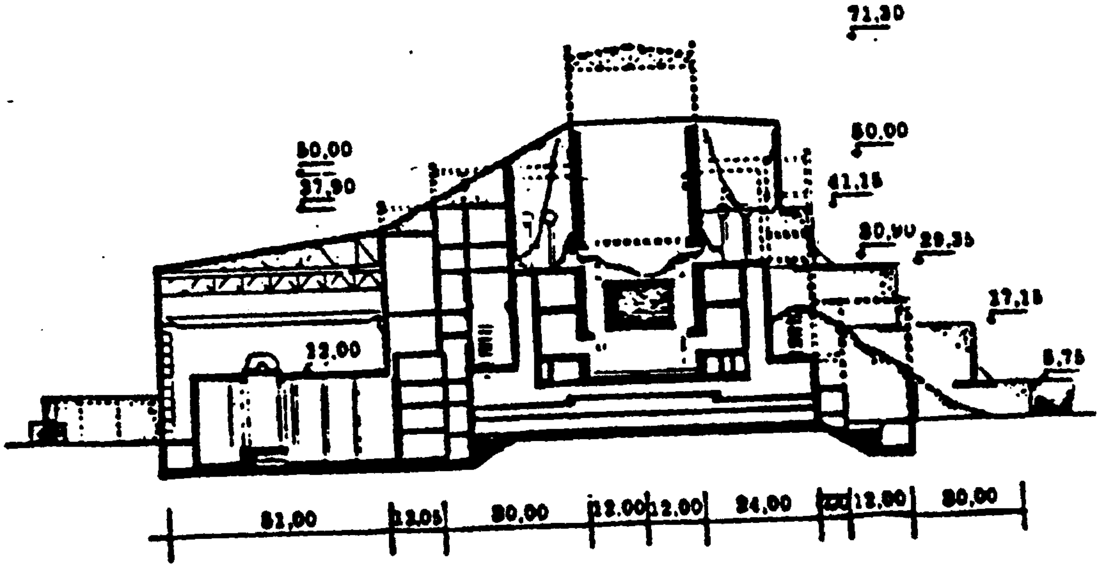


Рис. 7. Схема захоронения энергоблока № 4. Поперечный разрез одного из вариантов проекта

Fig. 7. Diagram of burial of power unit No. 4. Cross section of one version of the plan

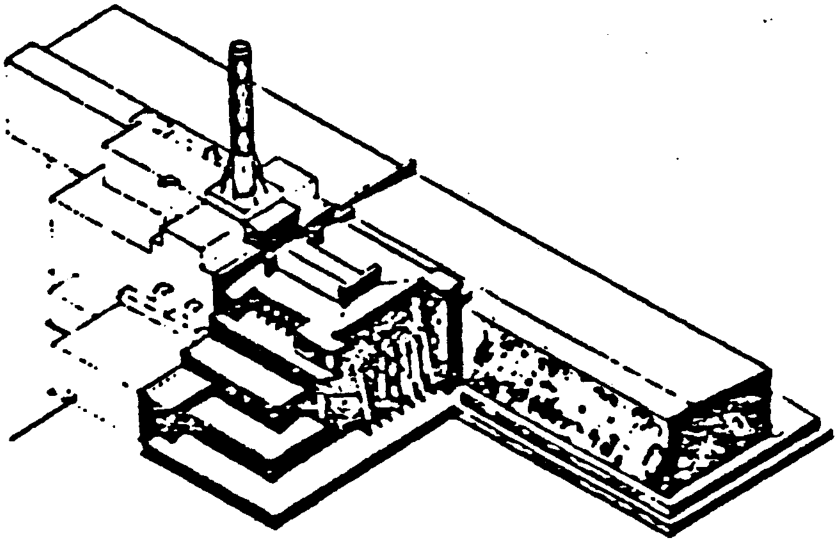


Рис. 8. Схема захоронения энергоблока № 4. Общий вид одного из вариантов проекта

Fig. 8. Diagram of burial of power unit No. 4. Overall view of one version of the plan.

Xerox to
Bonnell
Andy Hall
Bill Nixon
P Clough
I Dunbar
Mr R Hayes
[redacted]
TNM
G Low
J Holmes
D Hicks

CENTRAL ELECTRICITY GENERATING BOARD
Direct Dialling 01-634 7108
Main Exchange number 01-634-5111

Sudbury House
15 Newgate Street
London EC1A 7AU

Dr JH Gittus/ Mr BC Carpenter

Please find the Russian accident summary report. Please note that this is an unauthorised draft received from US sources and should be treated with discretion.

WITH COMPLIMENTS

A.W. Clarke

RP 3032

John,

I felt that you would want this with you.

I have sent a copy of the full version in Russian to Hough in the translations office at Risley. Meanwhile CEGB are plugging on with translating it themselves. So we seem to have as many belt and braces arrangements as we can.

Barry Carpenter.

IAEA POST ACCIDENT REVIEW MEETING ON THE CHERNOBYL ACCIDENT
25-29 AUGUST 1986

Distribution

Mr H J [redacted]
Dr M R Hayns
Dr F R Allen
Dr W Nixon
Mr M Egan
Dr P N Clough
Dr I Dunbar
Dr A N Hall
Dr S F Hall
Mr P Bonell

Dr B O Wade AERE
Dr D Hicks AERE
Mr D Levey LHQ

IAEA POST ACCIDENT REVIEW MEETING ON THE CHERNOBYL ACCIDENT, 25-29 AUGUST 1986

REPORT BY DR JOHN H GITTUS (UKAEA)

P3/7

Monday, 25 August, Plenary Sessions
10.00 to 11.00 hours: Opening of the meeting

The audience was divided between two rooms, one being provided with closed circuit television. The meeting commenced at 10.00 am, many TV crews being present for the first speech.

Blix, Director General of the IAEA, opening the meeting, said the results would be transmitted to the IAEA Board before its September meeting. He drew parallels with the Agency's response to the accident at Three Mile Island. Already, following the Chernobyl accident, at the Agency there had been formulated schemes for international accident notification and emergency response. These were to be formally adopted in September. We would not be asked to endorse any resolutions. A factual report to the IAEA Board of Governors on the outcome of the meeting would be prepared by the Secretariat and INSAG (the International Nuclear Safety Advisory Group) in the week following the meeting.

Rometsch, Chairman of the meeting, spoke next. The meeting had three objectives as he saw it:

(1) To understand the lessons of Chernobyl

(2) To apply them, where relevant, in our own countries

(3) To assist future international collaboration on nuclear safety.

Legasov, head of the USSR delegation, then addressed the meeting. Construction of nuclear power plant was receiving priority in the USSR since without it they would be "unable to master" the next stage in the development of their society. The Chernobyl incident was a disaster. On a world scale it was leading to a re-evaluation of the part to be played in future by nuclear power. In the USSR since the accident there had been an intensive development of accident-prevention measures and a parallel analysis of the nature and effects of the accident itself. The work continues. The USSR would be entirely open to suggestions about decontamination and other methods of limiting the impact of the Chernobyl accident. They would like to open up discussions on all possible ways of improving the reliability of nuclear installations, of reducing risk and of mitigating the damage done should another accident occur. He listed the many eminent USSR engineers and medical specialists who were present at the meeting, indicating their direct involvement with the practical response to the accident. His own work, apart from Chernobyl related responsibilities, was on the development of the High Temperature Reactor at the Kurchatov Institute.

PH/7

11.00 to 13.00 hours: Overview of the Accident

Legasov now presented a video of the sequence of events in the Chernobyl accident. The reactor power had been teetering on the brink of dangerous thermal hydraulic and neutronic instabilities because the operators had turned off vital safety systems and had too few absorber rods in the core. When they diverted steam from the turbine this was the last straw. The reactor power rocketed up, steam pressure burst the reactor and the overheated fuel then gave off many millions of curies of radioactivity. Within a day or so the 100,000 or so people living up to 30 km away were evacuated.

He went on to describe the RBMK reactor. This has a graphite moderator pierced by holes or channels, lined with zirconium-niobium tubes and containing the uranium dioxide fuel. Water in the channels is boiled by the fuel. This produces the steam needed to drive the turbo-alternators and it also keeps the fuel from overheating, by continuously removing the heat generated by nuclear fission. The rate of heat-generation is controlled by inserting or withdrawing neutron-absorbing rods. There are pumps to pump water into the bottom of the channels and it boils as it rises up the channels. A mixture of hot water and steam emerges from the top and passes through pipes to steam-separators. Here the steam collects above the water and is led by pipes to the turbines whilst the water is drawn off and pumped back through the channels to be boiled again. The steam from the turbines is condensed and it, too, is pumped back through the channels, completing the cycle.

Legasov summarised the conditions of coolant flow, level, temperature or steam-content which could, if allowed to persist, lead to an accident and which therefore normally automatically trigger a "trip" or cessation of heat-generation due to fission. If there are fewer than 15 neutron control rods inserted in the reactor then the rules require it to be tripped by the operators. They judged that the probability of the operators failing to trip it in such a case was lower than the probability of failure of a purely automatic trip system. In the event it was precisely this error that the operators made. They had fewer than 15 rods but did not trip the reactor, leaving it critical and poised on a knife-edge.

Legasov went on to describe the safety systems which take the heat away should an accident commence: the emergency core cooling systems. Then he described the containment philosophy: the steam separators, the pumps and the pipes leading to and from the channels are separately contained, each in its own concrete cell or box. Tubes from each cell are immersed in a "bubbling pool" and the pressure in the cell is [illegible] by bubbling should a pump, a separator or a pipe burst. by bubbling should a pump, a separator or a pipe burst

Monday, 25 August.
15.00 to 18.00 hours: Overview of the Accident
(continued)

In the afternoon Legasov continued, now concentrating in greater detail upon the reasons for the accident and its progress. Although he followed quite closely the written report which participants had been given he added several important points. In particular he said that the operators felt that they were under extreme pressure to complete the planned experiment that night since they knew that it would be a full year before they would have another chance. It was "a tremendous psychological mistake" on the part of the designers of the RBMK reactor that they did not foresee that additional protective systems would be needed in the core in order to trip the reactor and keep it cool even if (as occurred in the Chernobyl accident):

(a) the operators deliberately switched off the standard protection systems and in addition

(b) (completely disobeyed the safety rules concerned with the minimum number of control rods which must be inserted.

This, he said, was the case against the RBMK designers: "Now, with hindsight we can see that it could have been prevented, in a very easy way using technical means" (by which he meant engineered safety features, not written rules). He illustrated what had happened by means of an analogy. It was, he said, as if the pilot of a passenger 'plane suddenly started testing the 'plane in flight: opening and closing the doors and switching off safety systems. He went on to criticise the Soviet nuclear community in these terms: "We have started later than other specialists to think about the need to protect against this kind of human stupidity and it is our fault".

As for the detailed progress of the accident: this is involved. In essence what Legasov says happened was as follows:

The operators tried to power the coolant pumps using electricity from a "free-wheeling" turbo-alternator. As the alternator slowed down, so of course did the pumps which it was driving and so the amount of steam being produced increased. It was this that triggered the accident. The operators tried to insert the control rods but the rods were mostly so far out of the core (only 6 were inserted instead of the minimum of 30 required by the rules) that long before the rods could have shut the reactor down it had run away, the power rocketing up. The steam, now produced in vast quantities, burst the pressure tubes. [illegible] The uranium dioxide pellets disintegrated with a further explosive generation of steam which blew the top cover (pile-cap) off the reactor and exposed the hot fuel to the air. Hydrogen and carbon monoxide were produced by the oxidation (in steam and air) of graphite and zirconium. These gases burned or exploded in the air. Volatile and gaseous radionuclides were freely evolved into the air by the overheated fuel.

None of this would have happened had the operators, (by switching off vital safety systems and ignoring the rule about the minimum number of inserted control rods) not allowed the reactor just prior to the experiment to be poised on the threshold of just such a reactivity-excursion.

PG 17

Development and Consequences of the Accident

The attention of the IAEA meeting now turned to the immediate consequences of the accident. Legasov continued the presentation, following the written report once more.

The initial release of radioactivity missed the adjacent town of Pripyat. Evacuation was delayed, but Legasov defended this saying that they were initially safer where they were. Indeed those in stone houses were forbidden to leave since the masonry sheltered them from radiation. However, the graphite fire, the increase in graphite temperature and the continued release of activity soon made evacuation of Pripyat vital. It was accomplished in 2½ hours.

The amount of radioactivity released was greatest on the first and ninth days following the accident. The second peak occurred when decay heat and fire had raised the core to its maximum temperature of 2000°C. The graphite fire resulted in the production of a radioactive aerosol which went up into the atmosphere. It was to stifle the graphite fire and stop the escape of the aerosol that 5000 tons of sand, boron carbide and lead were dropped onto the exposed face of the reactor from helicopters. The boron carbide was to prevent fission from restarting locally. The lead was to absorb heat, absorb radionuclides and shield the helicopters from gamma radiation. The sand and clay were to act as aerosol filters. By 6 May the release of activity had ceased, or virtually so, the rise in temperature having been reversed by natural convection of air and by creating a forced flow of cold nitrogen through the core.

No more than 3½ percent of the activity (excluding the noble gases) was released from the core: less than fifty megacuries.

Temperature measurements in and around the reactor core could not be made except with simple devices such as thermionic valve amplifiers or materials of known melting point. The radiation fields rendered semiconductor instruments unreliable. With the exception of the reactor vault itself, radiation fields have now fallen from thousands of Roentgens per hour (the maximum recorded) to no more than one or two R per hour.

Release from the reactor is now down to tenths of curies per day, as an aerosol. Temperatures are now below 300°C in the core. A priority task was to shut down Units 1, 2 and 3 following the accident. Units 1 and 2 have been decontaminated and by the year end will be back in operation, the operators rehoused. As for Unit 3: a review is in progress and may permit it to be brought back into use.

The social losses comprise 203 seriously injured, 31 dead, collective doses of 9 million manrem in 1986 and 29 million over the next 50 years. Decontamination of the surrounding land should enable limited economic use to recommence eventually.

The speaker now turned his attention to safety requirements before and after the Chernobyl accident. Beforehand it was permissible for some control rods to be completely withdrawn: now none may be less than 1.2 meters into the core. The minimum number of fully-inserted rods must now be eighty: it was thirty. In the future the fuel enrichment will be raised from 2.0% to 2.4% which coupled with the greater amount of control rods permanently in the core will offset the positive void coefficient which was one of the principal design shortcomings. Finally, the reactor protection systems will be more highly automated so as to place less reliance on the operators.

Some RBMK reactors are still operating and others will be brought back into operation following these changes. More training is to be given to their operators.

The presentation ended to loud and prolonged applause at 6.0 pm. It had been a marathon performance, both open and frank.

P7/7

Mr. [redacted]

<NII> SNAPE

P. 1

BY DEX. 13.05 HRS THURSDAY

NUCLEAR OPERATIONS SUPPORT GROUP

TO: Dr J H Gittus - AEA

FROM: K G Steele - NOSG

21st August 1986

cc MRH

Jean,
Please circulate
to Senior o Barnwood
Staff for information
MPH
20/8/86

CHERNOBYL - RUSSIAN ACCIDENT REPORT

The attached brief simple technical note has been prepared from an initial digest of the Russian Report. It concentrates on the perceived reasons for the experiment with the turbogenerator, and the sequence of events during the test, leading to the accident.

K G Steele

K G Steele

c.c. Board Members
CIMRG Members

*1ST OF 4 PAGES

/KGS

20-08-86

Chernobyl Accident

Simplified Interpretation of Soviet's Reported Accident Sequence

Background information

Large power systems operate on a principle of siting power stations at economically and technically acceptable sites, feeding electricity into a grid system to major areas of demand. The power station sites are not necessarily at or near to the points of supply demand - which are probably more numerous than the number of power stations.

Continuity of supply to the consumer is a major aim of any electricity utility and to accommodate plant breakdowns, or transmission line failures, the generating plant running and connected to the system is not all fully loaded and hence has a margin of "spinning reserve" to take over generating capacity lost by breakdown. Similarly the transmission lines do have routes which have spare capacity to take over from the line which fails.

Notwithstanding the above, there are severe conditions for example a lightning storm over a large area which could cause fragmentation of the transmission system into pockets. These pockets if not supported by sufficient generating capacity would be "blacked out". Another result could be the disconnection of a power station from the transmission system leaving it supplying its own load, and no other, that is only if the fault did not cause its generators to automatically shut down.

A desirable feature of a modern power station then becomes its ability to accept an instantaneous reduction in its total output down to house load without the transient causing the plant to trip automatically. If the plant does trip during the transient, nuclear power stations would have still available an essential electrical supply system fed from diesel or gas turbine generators to maintain safe shut down conditions.

Scope of Test

Although the test at Chernobyl Unit 4 was the initiator of the accident its purpose has not been explicitly stated by the Russians. It is perceived to be concerned with the capability of the turbogenerator in a running down mode to supply (for a short interval) some power station auxiliary plant. Broadly speaking the testing conditions were to be:-

Reactor at about 25% power with one of its two associated turbine shut down, the other supplying the grid and part of the units auxiliaries. The remaining auxiliary plant was fed from the grid.

The running turbine was to be disconnected from the grid and its steam inlet-valves shut, but with part of the unit auxiliaries still being supplied whilst running down.

It was hoped that the reactor would continue at power accepting the transient in steam demand, with some of its circulating and feed pumps being driven by the running down turbogenerator, with the other pumps being fed from the grid.

The test procedure was not authorised by the proper authority, the safety aspects had not been thought through, and departures from the procedure were allowed during the test as well as violations of the operating rules.

/...

Design features relevant to accident

In order to understand the sequence of events leading to the accident, it is necessary to consider some aspects of the RBMK design.

The Fuel is enriched uranium dioxide, clad in zirconium, a metal which does not absorb neutrons necessary for the chain reaction. The fuel is contained in fuel channels (zircalloy tubes) with water coolant. Steam produced from heating the water flowing in the fuel channels is collected in steam/water separators and led directly to the turbine, the water separated being returned to the inlet of the fuel channels.

To replace the water taken away as steam, feed water is introduced to the separators.

In a thermal reactor, e.g. BWR PWR, AGR, RBMK a moderator is required to reduce the energy of neutrons released in fission so that they can effectively cause the next fission in the chain reaction. The moderator can be water, or graphite, or a mixture of the two as in the RBMK reactor. In the RBMK reactor the fuel channels are led through graphite blocks, these not being part of the steam/water circuit, but surrounded by an inert gas atmosphere. Water as water and water as steam produce different moderating results. In the RBMK reactors a change from water to steam tends to produce a power increase and vice versa. The technical jargon is a "positive void coefficient of reactivity". This is an undesirable design feature which Western Designers go to some lengths to avoid.

A reduction in power also produces a higher level of Xenon, a decayed fission product which absorbs neutrons. The chain reaction will slowly die away unless sustained by control rod withdrawal. On an RBMK reactor, the capability of the control rods is not sufficient to keep the reactor critical if the reactor power falls to a low level for more than an hour or so. In such circumstances, the operators simply have to wait for 1-2 days until the Xenon has decayed away.

Sequence of events

The sequence of the events leading to the accident were as follows; on the 25th April 1986 Chernobyl Unit 4 was reduced to about 50% power and one of the two turbogenerators was shut down. The reactor and running turbine auxiliaries were now being supplied partly from the one running turbine and partly from the grid. As it was envisaged that the test would cause some disturbances to the water level in the steam water separators, a low level condition of which would initiate emergency cooling water injection, the operation of emergency cooling was inhibited late on the evening of the 25th April, and some hours later, power was reduced to 25% for the commencement of the test. Difficulty was experienced in regulating the reactor, and contrary to requirements the operator took over manual control. Stabilised conditions were eventually obtained at 7% power and contrary to the experiment procedure it was decided to start the test.

At 0107 on the 26th April in the belief of obtaining a potentially safe condition on the reactor at the end of the test the standby fuel channel circulating pumps were put into operation, making 8 pumps operational; and producing a flow which infringed the operating rules. The effect of this was to destablise steam/water separator steam pressure and water level. Contrary to operating rules the operator then rendered inoperable the reactor trip capability from these parameters being outside limits. Because of the large water flow in the fuel channels, steam produced in terms of voidage was minimal, but the entire reactor coolant was only just below its boiling point.

/...

Due to the time delay from initial power reduction Xenon had built up and the control rod configuration was such that operating rules required the unit to be shut down. In spite of this, it was decided to continue with the test.

At 01.23 hrs the valves controlling steam flow to the turbine were shut with the reactor power at about 7%. Normally the shutting of both turbine steam valves would have tripped the reactor. However, this safety function had also been negated. Water flow now reduced from the pumps that are connected to the running down turbine and the steam pressure increased. The net effect was an increasing steam voidage in the channel which in turn led to power increasing at an accelerating rate.

The operator initiated a manual shut down, because by this time all of the automatic trip parameters that could have responded had been negated. However, some absorbers did not reach the fully inserted position. A manual shut down would drive the control rods in the core. Servodrive clutches were disengaged to cause the absorbers to fall into the core under their own weight. However, dry out had already occurred in fuel channels leading to fuel clad rupture, fuel channel coolant pressure increase, fuel channel rupture, and a thermal explosion that destroyed the reactor and part of the structural components of the building.

The steam formation together with the sharp temperature increase led to steam - zirconium reactions and the production of hydrogen gas. The hydrogen was then able to escape through the breach and to mix with air providing an explosive mixture. This reaction was observed as fireworks of flying hot and glowing fragments.

....

BURROUGHS DEX3500

9691
19 AUG 1986

BRITISH EMBASSY
3100 Massachusetts Avenue NW Washington DC 20008
Telex Domestic USA 89-2370/89-2384
Telex International 64224(WUI)/440015(ITT)
Telephone (202) 462-1340

Your reference

Our reference

Date
18 August 1986

IMMEDIATE

GRS Pl. circulate quickly to SRD and other interested. 19/8

For Mr W McMillan, AEA London

I attach the Atomic Industrial Forum "Infowire" on the Soviet report on the Chernobyl accident, as requested.

Regards.

Copies to: Dr Gittus
Mr Nicholson
Dr Llewelyn
Mr Levey
Mr Carpenter
Press Office
Mr Peters / Mr Somers
Mr Corner BNF
19/8

Deirdre Watson (Ms)
Senior UKAEA Liaison Officer

5 pages following ....

UKAEA

PRODROME B.HSH

ATTN: JOHN FRANCE
FIRST SECRETARY
AUGUST 17, 1986 4:00 PM EDT

TO ALL INFOWIRE SUBSCRIBERS (86-92):

SUBJECT: SOVIET REPORT ON CHERNOBYL

THERE IS NO HARD DATA CONCERNING THE CATASTROPHIC ACCIDENT AT THE NUMBER FOUR CHERNOBYL REACTOR, BECAUSE THE SKALA INFORMATION SYSTEM AT THE REACTOR WAS SWITCHED OVER TO RECORD ONLY DATA FROM THE COAST-DOWN TEST WHICH LED TO THE ACCIDENT, ACCORDING TO A REPORT SUBMITTED TO THE INTERNATIONAL ATOMIC ENERGY AGENCY BY THE STATE COMMITTEE FOR THE USE OF ATOMIC ENERGY OF THE USSR. THE INFORMATION SYSTEM CAN ACCOMMODATE ONLY 400-500 PARAMETERS, INSUFFICIENT TO RECORD BOTH NORMAL REACTOR OPERATING DATA AND DATA FROM THE TEST.

AS A RESULT, SOVIET OFFICIALS HAVE HAD TO RESORT TO USING A MATHEMATICAL MODEL OF THE RBMK-1000 ALONG WITH INSTRUMENT READINGS AND INFORMATION PROVIDED BY OPERATING PERSONNEL TO RECONSTRUCT THE ACCIDENT.

THE REPORT, TITLED THE ACCIDENT AT THE CHERNOBYL ATOMIC ENERGY STATION AND ITS CONSEQUENCES, CONSISTS OF A 67-PAGE SUMMARY AND SEVERAL TECHNICAL APPENDICES. AT FIRST GLANCE IT APPEARS TO BE COMPLETE AND FRANK AND CONTAINS A GREAT AMOUNT OF DETAILS ABOUT THE RBMK-1000 AND ITS OPERATION.

AN OFFICIAL TRANSLATION OF THE DOCUMENT INTO ENGLISH WAS UNDERWAY OVER THE WEEKEND, AND IS EXPECTED TO BE AVAILABLE AUGUST 18. IN THE MEANTIME WE ARE ABLE TO PROVIDE THE FOLLOWING INFORMATION FROM THE REPORT:

-- OPERATOR ERROR IS GIVEN TOP BILLING AS A CAUSE OF THE ACCIDENT. CONTAINED IN THE REPORT IS A TABLE LISTING SAFETY VIOLATIONS, THE MOTIVATION FOR EACH, AND THE RESULT. HIGHLIGHTED AS THE FUNDAMENTAL MOTIVATION FOR THE VIOLATIONS IS AN ALLEGED DESIRE BY WORKERS TO GET THE TEST OVER WITH.

-- DESPITE THE EMPHASIS ON OPERATOR ERROR, THERE IS A STRONG UNDERCURRENT OF DISSATISFACTION WITH THE WAY IN WHICH THE RULES WERE PRESENTED TO SHIFT PERSONNEL. APPARENTLY IT WAS ASSUMED THAT MANY SAFETY PROCEDURES WOULD BE FOLLOWED BY SHIFT SUPERVISORS, BUT THERE WAS CONSIDERABLE QUESTION AS TO WHETHER THEY WERE PROPERLY WRITTEN DOWN.

-- IT APPEARS THAT EMERGENCY SYSTEMS INVOLVING TURBOGENERATORS NUMBER SEVEN AND EIGHT, WHICH WERE ASSOCIATED WITH CHERNOYBL UNIT FOUR, WERE BOTH TURNED OFF IN VIOLATION OF OPERATING RULES. THE SYSTEM INVOLVING NUMBER EIGHT WAS SUPPOSED TO BE TURNED OFF IN CONNECTION WITH THE TEST. HOWEVER, WORKERS ALSO SHUT OFF NUMBER SEVEN'S SYSTEM BECAUSE THEY INTENDED TO SHIFT THE TEST TO THAT GENERATOR IF THEY DID NOT RECEIVE SATISFACTORY DATA FROM THE FIRST TEST. THEIR AIM WAS ALLEGEDLY TO SAVE TIME.

-- THERE WERE CONSIDERABLE DATA THAT INDICATED THE TEST SHOULD HAVE BEEN BROUGHT TO A SPEEDY HALT AT SEVERAL POINTS, BUT THESE WERE IGNORED FOR REASONS NOT EXPLAINED. FOR INSTANCE, DATA SEEMED TO INDICATE A SEVERE IMBALANCE IN THE REACTOR'S OPERATION AT LOW POWER. BUT BY THE TIME THE SHIFT LEADER GAVE THE ORDER TO HIT BUTTON A2-5, WHICH PRESUMABLY WAS TO SCRAM THE REACTOR, THE CONTROL RODS FAILED TO SEAT AND THERE WAS A SHARP REPORT FROM THE REGION OF THE REACTOR.

-- ATTEMPTING TO SEAT THE RODS, THE OPERATOR THEN CUT OFF THE SERVOMECHANISM POWER SUPPLY, IN ORDER TO PERMIT THE RODS TO DESCEND OF THEIR OWN WEIGHT. TWENTY SECONDS LATER EYEWITNESSES REPORTED TWO EXPLOSIONS FOLLOWED BY FLYING HOT FRAGMENTS AND SPARKS WITHIN THE REACTOR BUILDING. SOME OF THE HOT MATERIALS LANDED ON THE ROOF AND STARTED A FIRE.

-- DESPITE THE EMPHASIS ON OPERATOR ERROR THERE IS A SECTION IN THE REPORT DEVOTED TO QUICK TECHNICAL FIXES PLANNED FOR THE RBMK-1000. THESE INCLUDE LENGTHENING THE CONTROL RODS TO 1.2 METERS (WE ARE UNCERTAIN OF THEIR PRESENT LENGTH)/ INCREASING THE NUMBER OF CONTROL RODS TO 70 OR 80 (AT PRESENT THERE ARE ABOUT 50)/ RAISING THE FUEL ENRICHMENT TO 2.4 PERCENT FROM THE PRESENT TWO PERCENT/ INSTALLING ADDITIONAL SIGNAL MECHANISMS AND SENSORS IN THE CONTROL ROOM/ AND INCREASING PUMP CAPACITY.

OF PARTICULAR INTEREST IN CONNECTION WITH THE PLANNED FIXES IS THE COMMENT BY THE REPORT'S AUTHORS THAT THESE MEASURES WILL DEGRADE THE ECONOMICS OF THE RBMK BUT WILL GUARANTEE NECESSARY SAFETY.

IN ADDITION, THE FOLLOWING SENTENCES APPEAR IN THE REPORT'S FOREW[illegible]. IT IS IMPOSSIBLE TO IMAGING THE FUTURE WORLD ECONOMY WITHOUT NUCLEAR ENERGY. NEVERTHELESS, ITS FUTURE MUST BE ACCOMPANIED BY YET LARGER INPUTS OF SCIENCE AND TECHNOLOGY TO ENSURE ITS RELIABILITY AND SAFE EXPLOITATION.

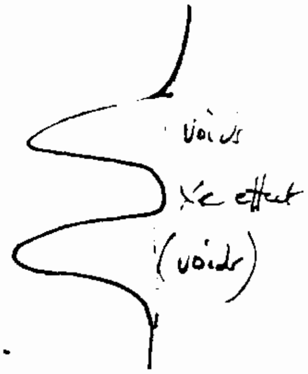
FOLLOWING IS AN UNOFFICIAL TRANSLATION OF THE SEQUENCE OF EVENTS OF THE CHERNOBYL ACCIDENT:

CHANNELS FUELED OF WHICH SEVENTY-FIVE PERCENT WAS FROM THE FIRST FUEL LOADING AT BURNUP OF TWELVE TO FIFTEEN MWD/KG. THE REACTOR STATUS ALSO INCLUDED ONE CHANNEL ABSORBER, ONE CHANNEL EMPTY, AVERAGE BURNUP OF 10.3 MWD/KG.

SAFETY PROCEDURES USED IN THE TEST WERE UNREVIEWED AND FORMALISTIC. THE TEST WAS INTENDED TO USE TURBINE ROTOR KINETIC ENERGY TO DRIVE EMERGENCY SYSTEMS INCLUDING FEED WATER AND RECIRCULATION PUMPS, WITH PLANT DISCONNECTED FROM ELECTRICAL GRID.

Normally driven by Grid or DIESELS.

1.00 pm the previous day	APRIL 25, AT 1300	BEGIN RAMP DOWN FROM FULL POWER 3500 MWth DISCONNECT TURBINE GENERATORS FROM GRID AT 1600 HOURS (50PERCENT) SUPPLY RECIRCULATION PUMPS FROM TURBINE GENERATORS BUS A.	So lots of FP
	1400 HOURS	① BLOCK OUT EMERGENCY CORE COOLING SYSTEM (DISCONNECT)	Otherwise would come on automatically
	2310 HOURS	POWER AT 700 - 1000 MWT (22 - 31PERCENT)	
Safety systems disconnected		② TURNED OFF LOCAL CONTROL SYSTEM, OPERATOR THEN COULD NOT BALANCE TURBINE GENERATOR SUPPLY AND DEMAND, AS POWER DROPPED 30 MWT (ABOUT 5PERCENT OF CURRENT VALUE)	
	APRIL 26, 0100	POWER STABALIZED AT 200 MW(E) (6PERCENT) 6% UNDER MANUAL CONTROL. XENON BUILDING, CAUSING COOLANT DENSITY DECREASE/ OPERATOR MUST THEREFORE USE ZONAL CONTROL/ LEADS TO POWER DEPRESSION AT CORE CENTER, I.E. TWO-HUMPED AZIMUTHAL POWER DISTRIBUTION.	= voiding
	0103 TO 0107	STARTUP TWO STANDBY RECIRCULATION PUMPS/ ALL EIGHT PUMPING TOTAL CORE FLOW OF 57,000 CUBIC METERS PER HOUR	all from Own Generator.
		③ DIFFICULTY CONTROLLING STEAM SEPARATOR (Drum) LEVELS/ OPERATOR BLOCKS EMERGENCY PROTECTION SIGNALS (PROBABLY LEVEL, FLOW AND TEMPERATURE LIMITS) INCREASES FEEDWATER ABOUT FOUR TIMES INITIAL VALUE. THIS CAUSES LOW CORE INLET TEMPERATURE, REDUCED OUTLET QUALITY. THEREFORE, POWER DISTRIBUTION UNUSUALLY HIGH IN UPPER CORE. SIMULTANEOUSLY, SYSTEM PRESSURE DROPS AND CONTROL RODS RAISE FOR THIRTY SECONDS TO UPPER CONTACT WHERE OPERATOR TAKES MANUAL CONTROL TO STOP THEM	~~filling up~~ emptying automatically



operator.

[Juggling with cooling and power generation with three Safety systems disconnected

4

HOWEVER, DUE TO XENON BUILDUP, REACTIVITY MARGIN IS ONLY SIX TO EIGHT CONTROL RODS VERSUS FIFTEEN MINIMUM ALLOWABLE. SHOULD HAVE SHUT DOWN. ANALYSIS SAYS HIGHEST POSITIVE VOID EFFECT.

High +ve void

0120 BEGIN EXPERIMENT (ED. NOTE: IN FACE OF ABOVE DIFFICULTIESX) BYPASS TURBINE AND CLOSE ALL CONDENSER PUMP VALVES.

ie recirculation

← now electricity from running-down turbine

PRESSURE RISES AT A RATE OF SIX K PA/S BY TOTAL OF 0.5 MPA (73 PSI). TURBINE GENERATORS NOW POWERING PUMPS WITH KINETIC ENERGY ONLY.

Not abstracting energy to power turbine

FLOW DROPS. as pumps ran down with running down turbine

NET EFFECT OF PRESSURE RISE AND FLOW DROP IS INCREASED VOID, THEN POWER RISE. RISE

more voids ∴ stagnant boiling in channel.

0123 OPERATOR PUSHES SCRAM BUTTON, CALLING FOR AZ5 RODS. BANGING NOISES HEARD, RODS DO NOT BOTTOM. POWER RISES TO 530 MW(T) (17PERCENT) WITH PERIOD UNDER 20S.

-- POSITIVE VOID EXACERBATES POWER RISE WITH INADEQUATE COMPENSATION FROM DOPPLER EFFECT.

-- FLOW DROPS (DUE TO INCREASED CHANNEL PRESSURE DROP AND TURBINES RUNNING DOWN FASTER THAN EXPECTED).

-- CRITICAL HEAT FLUX (BURNOUT) CONDITIONS IN SEVERAL CHANNELS.

-- FUEL OVERHEATS.

-- 3[illegible] CALORIES/GM ENERGY DEPOSITION CAUSE SOME FUEL TO BURST, CAUSI[illegible] STEAM EXPLOSIONS.

-- SOME FUEL CHANNELS BURST.

UPPER SHIELD BLOWN OPEN, REACTOR HALL BUILDING BLOWN OPEN.

-- FUELING MACHINE JUMPS UP AND DOWN, FALLS ON REACTOR FACE RUPTURES MORE CHANNELS.

-- FLOW REVERSES, CHECK VALVES CLOSE, PUMPS STILL PUMPING CAUSE RETURN IN FLOW TO BOTH UNRUPTURED CHANNELS AND RUPTURED CHANNELS, HENCE INTO OPEN REACTOR FACE.

-- REACTION OF WATER WITH HOT ZIRCALOY AND HOT GRAPHITE PRODUCES HYDROGEN, CARBON MONOXIDE AND HEAT.

-- BURNING, FRAGMENTING, SCATTERING OF MATERIALS OCCURS.

-- EXPLOSIONS RESULT FROM CONTACT OF HYDROGEN AND CARBON MONOXIDE WITH AIR.

FOR E LATEST TAPE RECORDING OF INFORMATION, CALL 301-652-1078.

TO CONTACT AN AIF STAFFER OUTSIDE OF WORKING HOURS, CALL 301-986-1535.

ATOMIC INDUSTRIAL FORUM
NNNN
AUG 17 1986 17:19
VIA CCI NYC
◇

PRODROME R WSH

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NUCLEAR OPERATIONS SUPPORT GROUP

NO/AWC

18th August 1986

To: All on attached list

From: A.W. Clarke

Please find the attached list of principal contact numbers for use during the Vienna Conference on Chernobyl.

Note that some numbers are ex-directory and should not therefore be made generally available.

There are still a few blanks which will be filled in during the course of this week.

for A.W. Clarke

cc HJT
WN
ME
PNC
ANH
SFH
GM
PB
ID

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NAME	OFFICE HOURS	OUT OF OFFICE HOURS
Mr. A.W. Clarke (NOSG)	Tele: 01 634 7108/6278 Dex: 01 634 6973	Tele: Bedford (0234) 58859 Dex: Bedford (0234) 58859
Mr. K.G. Steele (NOSG)	Tele: 01 634 6182/5214 Dex: (1) 01 634 6973 (2) 01 634 6628	Tele: 0679 4645
Dr. J.E. Gore (BNL)	Tele: 0453 810451 Ex. 114 Dex: 0453 812529	Tele: Tetbury (0666) 52925
Mary Willcox (GDCD)	Tele: 045265 2123 Dex: 045265 2776	Tele: Cheltenham (0242) 820846
Mr. J. Collier (Information only)	Tele: 045265 2000 Dex: 045265 2003	
Mr. Mike Green (DIPA)	Tele: 01 634 5719 Dex: 01 634 6628	Tele: 01 278 6516
Mr. J. Corner (BNF)	Tele: 01 930 6888/9 Telex: 264476	Tele: Tunbridge Wells (0892) 41092
Mr. R.R. Marshall (NNC Booths Hall)	Tele: 0565 3800 Dex: 0565 54672 Telex: 666000	Tele: Wilmslow (0625) 523774
Dr. T. Margerison (NEIG)	Tele: 01 828 0116 Dex: 01 828 0110	Tele: 01 341 0435
Mrs Price (NEIG)	Tele: 01 828 0116	Tele: 01 305 0846
(PMT)	Tele: Dex: Telex:	Tele:
Mr. P. Woods (NII)	Tele: 01 211 5907 Dex: 01 834 5370 Telex: Energy London 918777	Tele: 01 642 2663

NAME	OFFICE HOURS	OUT OF OFFICE HOURS
<u>SRD</u>	Tele: 0925 31244 Dex: 0925 76 3936 Telex: 629301	
Dr. F.R. Allen (General Policy)	Tele: Extension 7245	Tele: 0925 76 5017
Mr. H.J. Teague (Int Matters - especially NEA)	Tele: Extension 7226	Tele: 051 424 2984
Dr. W. Nixon (Atmospheric Dispersion)	Tele: Extension 7284	Tele: 0925 810592
Mr. M. Egan (Atmospheric Dispersion)	Tele: Extension 7373	
Dr. P.N. Clough Mr. I. Dunbar (Fission Product Release/ Composition)	Tele: Extension 7238 Tele: Extension 7365	Tele: Lymm 4209
Mr. A.N. Hall Mr. S.F. Hall (Accident sequence interpretation & phenomenology)	Tele: Extension 7270 Tele: Extension 7313	Tele: 0925 76 5017 Tele: 051 727 1238
Mr. G. Meggitt Radiological Protection)	Tele: Extension 7224	Tele: Lymm 5076
Mr. P. Bonell (General Inquiries)	Tele: Extension 1390	061 · 928 · 1105
Mr. D. Levey (Overseas Relations)	Tele: 01 930 5454 Ex. 200	Tele: 01 301 3507

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NAME	OFFICE HOURS	OUT OF OFFICE HOURS
Dr. R. Clarke (NRPB)	Tele: 0235 831600 Dex: 0235 833891 Telex: 837124	No out of hours contact
Mrs J. Nowak (Main contact) (D of Environment) Dr. Feates (D of Environment) (25/8/86 & 30/8/86)	Tele: 01 212 4242/5663 Dex: 01 212 8707	Tele: 01 553 1888 Radiopage - 0893 372 772 Tele: 0491 39276 Radiopage - Message No. 4856896 Tele Bureau - 0345 333111 - From London 840 7000
Mr. A.J. Daniels (Dept of Energy) Mr. P. Agrell	Tele: 01 211 6683 Dex: 01 834 3771 Tele: 01 211 5008	Tele: 01 337 1104 Tele: 0732 451840
(MAFF)	Tele: Dex: Telex:	Tele:
Mr. D.N. Woolf NFL)	Tele: 0925 835496 Dex: 0925 817625 Telex: 627581	Tele: 0925 755097 Duty Sergeant 0925 31244 (Ex 3780) for radiopage contact
Mr. M. Hurp Mr. C. Clarke (UKAEA London)	Tele: 01 930 5454 X 319/539 Tele: 01 930 5454 X 520/539 Dex: 01 930 5454 X 274	Dex: 01 930 7461 Tele: 01 5454 Duty Sergeant/Police (Leave Message)
Dr. Pexton (SSEB) Mr. Currie (if Dr. Pexton not available)	Tele: 041 637 7177 Dex: 041 637 4583 Telex: 777703 Tele: 041 637 7177	Tele: 041 427 4327 Tele: 0786 72104

URGENT FAX

To:
Mr A M Allen LHQ
Mr R N Simeone
Mr R L R Nicholson
Mr M A W Baker
Mr A W Hills
Mr F Chadwick
Mr W MacMillan
Mr R N James
Mr B C Carpenter

Mr J Bretherton Dept of Energy

Dr T N Marsham Risley
Dr B L Eyre Risley
Mr A D Evans Risley
Mr J R Askew Risely
Dr G G E Low Harwell
Dr D Hicks Harwell
Dr J E R Holmes Winfrith
Mr C W Blumfield Dounreay

Mr H J Teague SRD
Dr M R Hayns
Dr R S Peckover
Dr F R Allen
Dr G M Ballard

From: Dr J H Gittus, SRD

THE RUSSIAN CHERNOBYL REPORT

An English summary became available yesterday, in advance of next week's meeting in Vienna.

It shows that the operators were to blame. They had, without permission, "switched-off" the automatic reactor trip system and the emergency core-cooling water system together with other safety provisions. This information supplies the "missing link": hitherto we had been unable to fathom why the safety systems had failed to prevent the accident.

The operators wanted to find out whether the reactor coolant pumps and other systems could be adequately powered by the main turbo-alternator when the latter was free-wheeling to a standstill. The coolant pumps, in the event, were not able to keep the reactor cool under the circumstances. It did not trip, since the operators had inhibited this safety provision and the emergency cooling did not operate since the operators inhibited this, too.

Accordingly it overheated, the resultant high steam pressure burst the pressure-tubes and the flimsy containment; radionuclides, evaporating from the by now uncooled fuel, escaped. Both the zircaloy and the graphite were partially oxidized by air and steam and the hydrogen and carbon monoxide so produced burned in the air.

The amount of activity released went through its second peak when a week after the accident the fuel temperature reached its highest value. The fuel did not melt but nevertheless released all the noble gases and three percent of the other radionuclides which it contained (over ten million curies).

Apart from laying the blame on the operators, the main technical short-coming highlighted by the Russians is the positive void coefficient. They say that they intend to minimise this by raising the fuel enrichment and increasing the worth of the absorbers permanently located in the core.

20 August 1986

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IMMEDIATE

X-6

HD / NED

Mr Goodall

Mr Daunt

Mr Daniels, D/Energy

Mr Gittus, UKAEA
15.8

RC cc HD
MRH

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TELNO 2085
OF 122200Z AUG 86
INFO IMMEDIATE BONN, PARIS, UKMIS VIENNA, MOSCOW

WESTERN CONSULTATIONS BEFORE IAEA POST-CHERNOBYL MEETING

1. FOLLOWING YOUR TELNO.1420 COUNSELLOR (ENERGY) AND FIRST SECRETARY (ATOMIC) ATTENDED THE MEETING AT THE STATE DEPARTMENT TODAY.

2. DR CLAUS GEST ATTENDED FROM THE FEDERAL GERMAN ENVIRONMENT MINISTRY. IN ADDITION TO THE UK, FRANCE AND CANADA WERE REPRESENTED BY EMBASSIES. AMBASSADOR KENNEDY DID NOT ATTEND AND THE MEETING WAS CHAIRED BY CONGDON OF THE STATE DEPARTMENT. DENTON OF NRC AND BRUSH OF USDOE ALSO ATTENDED.

3. DR THEMIS SPEIS (NRC) REPORTED WHAT DR SEMINOV, DEPUTY CHAIRMAN OF THE USSR COMMITTEE FOR THE UTILISATION OF ATOMIC ENERGY, HAD TOLD HIM AND AMBASSADOR KENNEDY DURING A RECENT VISIT TO MOSCOW. SEMINOV HAD SAID THAT THE CHERNOBYL NO.4 REACTOR HAD BEEN SHUT DOWN TO 7 PERCENT POWER FOR MAINTENANCE AND THE STAFF WERE PREPARING TO DO AN EXPERIMENT. HE HAD LAID GREAT STRESS ON THE EXPERIMENT'S BEING POORLY PLANNED, POORLY DESIGNED AND POORLY EXECUTED. SHORT CUTS HAD BEEN TAKEN. THE EXPERIMENT WAS DESIGNED TO TEST WHETHER THE INERTIA OF THE TURBINE COULD BE USED TO GENERATE POWER FOR SAFETY SYSTEMS FOR SHORT PERIODS. SHORTLY AFTER THE EXPERIMENT BEGAN THE REACTOR WENT INTO AN EXCURSION. AT THIS POINT THE REACTOR WAS IN THE WORST POSSIBLE CONFIGURATION FROM THE POINT OF VIEW OF MANIFESTING ITS POSITIVE VOID COEFFICIENT.

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8. THERE WAS A DISCUSSION OF WESTERN OBJECTIVES AT THE IAEA MEETING. ALL PARTIES AGREED THAT THE OBJECTIVES MUST BE TO OBTAIN THE FULLEST POSSIBLE FACTUAL AND TECHNICAL REPORT FROM THE SOVIETS, TO KEEP THE MEETING NON-POLITICAL, AND TO AVOID ANYTHING WHICH WOULD MAKE THE SOVIETS FEEL THAT THEY WERE ON TRIAL. AS FAR AS POSSIBLE THE DRAWING OF CONCLUSIONS SHOULD BE LEFT UNTIL AFTER THE MEETING.

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10. THERE WAS ALSO A DISCUSSION OF THE HANDLING OF THE PRESS. THE US REPORTED THAT THE IAEA HAD ALREADY ANNOUNCED THE INTENTION TO INVITE ACCREDITED PRESS TO THE FIRST AND LAST DAYS OF THE MEETING. THE GENERAL VIEW WAS THAT IT WOULD BE UNREALISTIC TO CHALLENGE THIS. ALTHOUGH SOME MISLEADING REPORTS WOULD NO DOUBT RESULT, THE WORST THING OF ALL WOULD BE FOR CLAIMS TO BE MADE THAT INFORMATION WAS BEING WITHHELD. THE US DELEGATION INTENDS TO BE AVAILABLE TO THE PRESS ON A REGULAR BASIS. THEY WILL ATTEMPT TO COORDINATE THEIR RESPONSES AND TO AVOID AS FAR AS POSSIBLE DRAWING CONCLUSIONS ON POLICY IMPLICATIONS OR ON THE SOVIET PERFORMANCE. THERE WILL ALSO BE A QUOTE DAMAGE CONTROL TEAM UNQUOTE FROM THE US NUCLEAR INDUSTRY IN VIENNA TO DEAL WITH SPECIFIC POINTS THAT MAY ARISE RELATING TO US NUCLEAR PLANT.

11. ON DELEGATION SIZES, THE US PLAN TO HAVE 17, CANADIANS 9, AND THE GERMANS 14. NOBODY SEEMED CLEAR WHAT THE LIMITS ARE.

12. ALL PARTIES EXPRESSED WILLINGNESS TO CONSULT DURING THE VIENNA MEETINGS. THE FRENCH DID NOT RAISE THEIR IDEA OF A FURTHER CONSULTATION MEETING IN ADVANCE. THE AMERICANS WERE WILLING TO ATTEND A DINNER ON 24 AUGUST, THOUGH THEY DID NOT WANT TO BE THE HOSTS. COUNSELLOR

IN ADVANCE. THE AMERICANS WERE WILLING TO ATTEND A DINNER ON 24 AUGUST, THOUGH THEY DID NOT WANT TO BE THE HOSTS. COUNSELLOR (ENERGY) EXPLAINED THE WILLINGNESS OF THE UK TO ATTEND AT ABOUT 8:30 PM OR LATER. IT SEEMS LIKELY THAT THE GERMAN DELEGATION WILL HOST SUCH A DINNER FOR A SMALL NUMBER OF LEADING PEOPLE FROM WESTERN DELEGATIONS. THE US DELEGATION WILL BE CONTACTABLE THROUGHOUT THE MEETINGS AT THE HILTON HOTEL, WHERE THEY WILL HAVE CONFERENCE FACILITIES. THEY SUGGESTED SPECIFICALLY THAT SENIOR MEMBERS OF WESTERN DELEGATIONS MIGHT MEET ON THE WEDNESDAY MORNING (27 AUGUST) WHILE TECHNICAL EXPERTS ARE PREPARING QUESTIONS.

13. PLEASE ADVANCE TO DANIELS, DEPARTMENT OF ENERGY, AND GITTUS, UKAEA.

JENKINS

YYYY

ORWBAN 5532
NNNN

JHG
15.8

GRS 900

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FM WASHINGTON
TO IMMEDIATE FCO
TELNO 2085
OF 122200Z AUG 86
INFO IMMEDIATE BONN, PARIS, UKMIS VIENNA, MOSCOW

cc H[redacted]
MRW

WESTERN CONSULTATIONS BEFORE IAEA POST-CHERNOBYL MEETING

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8. THERE WAS A DISCUSSION OF WESTERN OBJECTIVES AT THE IAEA MEETING. ALL PARTIES AGREED THAT THE OBJECTIVES MUST BE TO OBTAIN THE FULLEST POSSIBLE FACTUAL AND TECHNICAL REPORT FROM THE SOVIETS, TO KEEP THE MEETING NON-POLITICAL, AND TO AVOID ANYTHING WHICH WOULD MAKE THE SOVIETS FEEL THAT THEY WERE ON TRIAL. AS FAR AS POSSIBLE THE DRAWING OF CONCLUSIONS SHOULD BE LEFT UNTIL AFTER THE MEETING.

9. OTHER POINTS RAISED BY THE US BUT NOT PURSUED AT THE MEETING WERE (A) IS THERE A NEED FOR FOLLOW-UP EXPERT MEETINGS AFTER THE CHERNOBYL PRESENTATIONS BUT BEFORE THE GENERAL COUNCIL, (B) THE NEED TO OBTAIN SOVIET DATE ON EPIDEMIOLOGICAL EFFECTS, (C) THE FORM OF THE DOCUMENT THAT THE IAEA INTEND TO PREPARE AS A RESULT OF THE CHERNOBYL PRESENTATIONS.

10. THERE WAS ALSO A DISCUSSION OF THE HANDLING OF THE PRESS. THE US REPORTED THAT THE IAEA HAD ALREADY ANNOUNCED THE INTENTION TO INVITE ACCREDITED PRESS TO THE FIRST AND LAST DAYS OF THE MEETING. THE GENERAL VIEW WAS THAT IT WOULD BE UNREALISTIC TO CHALLENGE THIS. ALTHOUGH SOME MISLEADING REPORTS WOULD NO DOUBT RESULT, THE WORST THING OF ALL WOULD BE FOR CLAIMS TO BE MADE THAT INFORMATION WAS BEING WITHHELD. THE US DELEGATION INTENDS TO BE AVAILABLE TO THE PRESS ON A REGULAR BASIS. THEY WILL ATTEMPT TO COORDINATE THEIR RESPONSES AND TO AVOID AS FAR AS POSSIBLE DRAWING CONCLUSIONS ON POLICY IMPLICATIONS OR ON THE SOVIET PERFORMANCE. THERE WILL ALSO BE A QUOTE DAMAGE CONTROL TEAM UNQUOTE FROM THE US NUCLEAR INDUSTRY IN VIENNA TO DEAL WITH SPECIFIC POINTS THAT MAY ARISE RELATING TO US NUCLEAR PLANT.

11. ON DELEGATION SIZES, THE US PLAN TO HAVE 17, CANADIANS 9, AND THE GERMANS 14. NOBODY SEEMED CLEAR WHAT THE LIMITS ARE.

12. ALL PARTIES EXPRESSED WILLINGNESS TO CONSULT DURING THE VIENNA MEETINGS. THE FRENCH DID NOT RAISE THEIR IDEA OF A FURTHER CONSULTATION MEETING IN ADVANCE. THE AMERICANS WERE WILLING TO ATTEND A DINNER ON 24 AUGUST, THOUGH THEY DID NOT WANT TO BE THE HOSTS. COUNSELLOR (ENERGY) EXPLAINED THE WILLINGNESS OF THE UK TO ATTEND AT ABOUT 8:30 PM OR LATER. IT SEEMS LIKELY

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/THAT

THAT THE GERMAN DELEGATION WILL HOST SUCH A DINNER FOR A SMALL NUMBER OF LEADING PEOPLE FROM WESTERN DELEGATIONS. THE US DELEGATION WILL BE CONTACTABLE THROUGHOUT THE MEETINGS AT THE HILTON HOTEL, WHERE THEY WILL HAVE CONFERENCE FACILITIES. THEY SUGGESTED SPECIFICALLY THAT SENIOR MEMBERS OF WESTERN DELEGATIONS MIGHT MEET ON THE WEDNESDAY MORNIN G (27 AUGUST) WHILE TECHNICAL EXPERTS ARE PREPARING QUESTIONS.

13. PLEASE ADVANCE TO DANIELS, DEPARTMENT OF ENERGY, AND GITTUS, UKAEA.

JENKINS

YYYY

ORWBAN 5532

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AND TO DESKBY 070900Z DEPT OF ENERGY
INFO ROUTINE UKREP BRUSSELS, MOSCOW

cc M R Hayne
H J. T[illegible]

DEPT OF ENERGY FOR AE DIVISION
MY TELNO 154 (NOT TO ALL): IAEA: DRAFT CONVENTIONS

SUMMARY

1. LITTLE CHANCE OF CONCLUSION THIS WEEK. PROBABLE THAT WORK WILL FINISH ON TUESDAY 12 AUGUST. BULK OF AGREEMENT ON MUTUAL ASSISTANCE HAS BEEN PROVISIONALLY ADOPTED AT FIRST READING IN PLENARY. MAIN POINT OUTSTANDING IS THE SCOPE ISSUE.

DETAIL

2. AGREEMENT ON THE SCOPE OF THE NOTIFICATION CONVENTION AWAITS NEW INSTRUCTIONS FOR THE SOVIET DELEGATION. AT PRESENT THE RUSSIANS CAN ONLY AGREE TO CIVIL NUCLEAR INSTALLATIONS BEING COVERED. THE AMERICANS CAN AGREE TO CIVIL AND MILITARY INSTALLATIONS AND REACTORS (INCLUDING SUBMARINES BY IMPLICATION). ALL OTHERS, INCLUDING UK, FRANCE AND CHINA, AGREE TO ANY NUCLEAR ACCIDENT OR RADIOLOGICAL EMERGENCY, BY IMPLICATION INCLUDING NOT ONLY MILITARY INSTALLATIONS AND SUBMARINES BUT ALSO WEAPONS. THE MOST LIKELY COMPROMISE WOULD BE TO ADOPT THE FULL SCOPE WORDING WITH THE US AND SOVIET UNION MAKING DECLARATIONS TO THE EFFECT THAT THEY DID NOT INTERPRET THIS AS COVERING WEAPONS.

3. ANY SUCH COMPROMISE SOLUTION WOULD NEED CAREFUL CONSIDERATION TO ENSURE THAT WE AVOIDED A SITUATION WHEREBY, SAY, THE UK HAD AN OBLIGATION TO NOTIFY OTHER STATES IF A BRITISH NUCLEAR WEAPON WERE INVOLVED IN AN ACCIDENT WHEREAS THE US DID NOT HAVE THAT OBLIGATION EVEN IF SUCH AN ACCIDENT OCCURRED ON BRITISH TERRITORY.

4. NO SERIOUS WORK HAS BEEN DONE ON A COMPROMISE AS ALL CONCERNED ARE WAITING FOR A CHANGE IN THE SOVIET POSITION. THE SOVIET DELEGATION SAY THAT THEIR HOPED FOR NEW INSTRUCTIONS MUST BE APPROVED BY THE POLITBURO WHICH SHOULD MEET LATER THIS WEEK. THEY DO NOT EXPECT TO RECEIVE THEIR NEW INSTRUCTIONS BEFORE THE AFTERNOON OF 8 AUGUST. TO ALLOW TIME TO PREPARE A COMPROMISE AND TO CLEAR IT WITH CAPITALS THIS MEANS THAT IT IS UNLIKELY THAT WORK ON THE CONVENTIONS WILL BE COMPLETED BEFORE TUESDAY OF NEXT WEEK.

5. A PLENARY SESSION ON 6 AUGUST CONSIDERED THE INCOMPLETE TEXT OF THE MUTUAL ASSISTANCE CONVENTION AS AGREED BY WORKING GROUP B. SOME ARTICLES WERE REFERRED TO THE LEGAL WORKING GROUP FOR CLARIFICATION OR TO ENSURE CONSISTENCY WITH THE CONVENTION ON NOTIFICATION. ON THE WHOLE NO POINTS OF SUBSTANCE IN THIS CONVENTION ARE LEFT OUTSTANDING WITH THE EXCEPTION OF:

(A) ARTICLE 5 (FUNCTION OF THE AGENCY). THIS WAS GIVEN PRELIMINARY AGREEMENT BY THE UK DELEGATION BECAUSE, INTER ALIA, THE ARTICLE ONLY REQUESTS THE IAEA TO CARRY OUT VARIOUS ACTIVITIES. THE LEGAL WORKING GROUP HAVE BEEN ASKED TO EXAMINE THE USE OF THE WORD QUOTE REQUESTS UNQUOTE WHICH SOME THINK TOO WEAK AND OTHERS THINK INAPPROPRIATE. I REMINDED THE PLENARY THAT THE MATTER WAS ONE OF SUBSTANCE AND IMPORTANCE TO US AND THAT UK AGREEMENT TO ARTICLE 5 WAS DEPENDENT

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/UPON.

UPON THE MAINTENANCE OF THE WORD QUOTE REQUESTS UNQUOTE.

(B) ARTICLE 12 (ENTRY INTO FORCE). THE CHAIRMAN OF THE LEGAL WORKING GROUP PROPOSED AN AMENDMENT TO THE FIRST PARAGRAPH SO THAT THE FIRST LINE WOULD READ QUOTE THIS AGREEMENT SHALL BE OPEN FOR SIGNATURE BY ALL STATES AND BY NAMIBIA REPRESENTED BY THE UN COOUNCIL FOR NAMIBIA ... UNQUOTE. THE LAST TEN WORDS WERE PROPOSED TO MAKE IT POSSIBLE FOR NAMIBIA (AS REPRESENTED ETC), WHICH IS ALREADY A MEMBER OF THE IAEA, TO HAVE THE RIGHT AS OTHER IAEA MEMBERS TO SIGN THE CONVENTION. AFTER CONSULTATION WITH SOUTHERN AFRICAN DEPARTMENT I EXPRESSED A UK OBJECTION TO THIS AMENDMENT BUT SAID THAT I WOULD NOT PRESS THE OBJECTION TO THE POINT OF BREAKING CONSENSUS. NO OTHER OBJECTIONS WERE MADE. I WAS THANKED FOR NOT PRESSING THE MATTER BY MY NIGERIAN COLLEAGUE. I ALSO TOOK THE OPPORTUNITY OF REMINDING PLENARY THAT ARTICLE 12 IS STILL INCOMPLETE AND THAT DISCUSSIONS ARE CONTINUING ON THE BEST WORDING TO PERMIT THE ADHERENCE TO THE CONVENTION OF THE EUROPEAN COMMUNITY. ON THIS POINT THE ONLY OBJECTIONS COME FROM ARGENTINA AND MOSCOW. THEY HAVE NO OBJECTION TO EC ADHERENCE BUT WISH TO PREVENT ADHERENCE BY OPANAL (THE ORGANISATION ESTABLISHED BY THE TREATY OF TLATELOLCO). SUITABLE WORDING SHOULD EMERGE WITHIN THE NEXT DAY OR SO.

6. WORK CONTINUES IN ALL THREE WORKING GROUPS AND THE EXTRA TIME PROVIDED BY THE SOVIET DELAY SHOULD, IN FACT, PROVE USEFUL AND PREVENT A LAST MINUTE RUSH.

7. TODAY'S PLENARY AGREED UNANIMOUSLY THAT BOTH TEXTS, HITHERTO CALLED QUOTE AGREEMENTS UNQUOTE SHOULD IN FUTURE BE CALLED QUOTE CONVENTIONS UNQUOTE.

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DEPT OF ENERGY: FOR AE DIVISION
MY TELNO 158: IAEA: DRAFT CONVENTIONS

SUMMARY

1. THE TARGET FOR COMPLETION HAS NOW BEEN SET AS TUESDAY 12 AUGUST. WORK CONTINUES ON POLISHING POINTS OF DETAIL BUT OUTSTANDING MATTERS OF SUBSTANCE ARE NOT LIKELY TO BE TACKLED UNTIL NEXT WEEK.

DETAIL

2. AT A MEETING OF HEADS OF DELEGATIONS ON 7 AUGUST THE CHAIRMAN SAID THAT THE BUREAU HAD CONCLUDED THAT IT WAS NO LONGER REALISTIC TO ATTEMPT TO CONCLUDE WORK ON THE TWO CONVENTIONS BY 8 OR EVEN 9 AUGUST. HE THEREFORE PROPOSED THAT THE WEEKEND BE TAKEN AS A BREAK, WITH TIME FOR REFLECTION AND CONSULTATION OF CAPITALS, AND THAT THE TARGET SHOULD BE CONCLUSION ON TUESDAY 12 AUGUST, IF NECESSARY AFTER A NIGHT SESSION.

3. CANADA AND INDIA (BOTH FOR PERSONAL REASONS) ARGUED THAT WORK SHOULD CONTINUE THROUGH 9 AUGUST AND THE TARGET FOR COMPLETION SHOULD BE 11 AUGUST. HOWEVER, THEY JOINED THE MAJORITY IN AGREEING WITH THE CHAIRMAN.

4. NO PROGRESS ON THE QUESTION OF SCOPE. ALL STILL DEPENDS ON THE RUSSIANS.

5. THE QUESTION OF TRIGGERING A NOTIFICATION HAS NOT YET BEEN SETTLED. THE US, SOVIET UNION, CHINA, FRANCE, INDIA AND THE UK WISH TO RETAIN THE IDEA IN THE ORIGINAL AGENCY DRAFT THAT NOTIFICATION SHOULD BE TRIGGERED BY AN EVENT OF TRANSBOUNDARY SIGNIFICANCE. THE REMAINING EC MEMBERS AND SCANDINAVIANS WISH TO SET A TRIGGER OF PURELY NATIONAL SIGNIFICANCE, AND ITALY IN PARTICULAR IS SEEKING A

VERY

VERY LOW TRIGGER POINT. DISCUSSIONS CONTINUE AND IT IS LIKELY THAT A SOLUTION TO THIS PROBLEM WILL BE TIED TO A SOLUTION OF THE SCOPE QUESTION.

6. OTHERWISE, WORKING GROUPS CONTINUE TO TIDY THE TEXTS AND TO RESOLVE LESSER PROBLEMS.

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AND TO PRIORITY DEPT OF ENERGY
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FOR DEPT OF ENERGY: AE DIVISION
MY TELNO 163: IAEA: DRAFT CONVENTIONS

SUMMARY

1. A US/SOVIET FORMULA ON SCOPE IS NOW UNDER DISCUSSION. PROBLEMS WITH TRIGGER ARE LESSENING. EC ADHERENCE HAS BEEN ACCEPTED. COMPLETION ON 12 AUGUST IS POSSIBLE BUT A FURTHER DELAY SEEMS LIKELY.

DETAIL

2. THE SOVIET DELEGATION RECEIVED THEIR LONG AWAITED INSTRUCTIONS ON 8 AUGUST. THEY AND THE AMERICANS ARE NOW READY TO ACCEPT A FORMULA ON SCOPE WHICH WOULD COVER CIVIL AND MILITARY INSTALLATIONS AND REACTORS AND WHICH THEY STATE WOULD COVER SUBMARINES AND SATELLITES. THE FORMULA ONLY EXCLUDES WEAPONS BUT THEY SAY THAT IN PRACTICE THEIR GOVERNMENT WOULD ALSO NOTIFY IN THE EVENT OF AN ACCIDENT CONCERNING WEAPONS.

3. THEIR FORMULA (AN EARLY VERSION OF WHICH WAS SENT BY FAX ON 8 AUGUST) HAS SOME TECHNICAL DEFICIENCIES (LISTED IN MESSAGE SENT BY FAX TO FCO AND DEPARTMENT OF ENERGY ON 11 AUGUST). NONETHELESS IT OFFERS A CONSIDERABLE ADVANCE OVER THE EARLIER SOVIET POSITION. AT PRESENT INDIA, ARGENTINA AND FRANCE ARE COMPLAINING THAT THE FORMULA IS INSUFFICIENT. I HAVE BEEN ASKED BY MY SOVIET COLLEAGUE AND BY MY NETHERLANDS COLLEAGUE (ALSO CHAIRMAN OF THE DRAFTING MEETING) NOT ONLY TO SUPPORT THE FORMULA BUT TO ENCOURAGE OTHERS TO DO SO. I HAVE SAID THAT I EXPECT TO BE ABLE TO GIVE THE FORMULA UK SUPPORT, ESPECIALLY IF IT IS AMENDED TO MEET SOME OF THE TECHNICAL DEFICIENCIES BUT I HAVE SAID THAT I THINK IT UNLIKELY THAT WE COULD BE ACTIVE IN ENCOURAGING OTHERS TO SUPPORT IT.

4. THE TRIGGER QUESTION HAS NOT BEEN FORMALLY RESOLVED. ON 8 AUGUST THE ITALIAN DELEGATION MADE AN EMOTIONAL STATEMENT TO THE EFFECT THAT ALTHOUGH ITALY WOULD NOT BLOCK A CONSENSUS, SHE WOULD HAVE TO MAKE A STATEMENT AT THE CONCLUSION OF THE MEETING STATING THAT ANY AGREEMENT ON TRIGGER OTHER THAN THE EXTREME FORMULATION THAT SHE FAVOURS WOULD MEAN THAT ITALY COULD NOT SIGN THE CONVENTION. MY NETHERLANDS COLLEAGUE HAS ASSURED ME THAT IN THE INTEREST OF SECURING FINAL AGREEMENT HIS DELEGATION WILL NOW DROP ITS PROPOSAL FOR A NATIONAL TRIGGER AND WILL ENCOURAGE THE OTHERS TO DO THE SAME. HE

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SUGGESTED THAT THE UK APPROACH THE ITALIAN GOVERNMENT IN ROME AND, AS PRESIDENCY, SEEK ITALIAN ADHERENCE TO A COMMUNITY POSITION. I REMINDED HIM THAT A COMMUNITY MEETING ON 8 AUGUST HAD REVEALED A COMPLETE RANGE OF POSITIONS BETWEEN ITALY AT ONE EXTREME AND THE UK AND FRANCE AT THE OTHER. I SAID THAT I COULD NOT, AT PRESENT, SEE ANY COMMUNITY POSITION TO WHICH ITALY COULD BE ENCOURAGED TO ADHERE.

5. PLENARY ON 8 AUGUST GAVE PRELIMINARY APPROVAL TO MOST OF THE TEXT OF THE NOTIFICATION CONVENTION AND TO LEGAL CLAUSES COMMON TO BOTH CONVENTIONS. OF MOST SIGNIFICANCE WAS AGREEMENT ON A TEXT WHICH WILL ENABLE THE EUROPEAN COMMUNITY TO SIGN THE CONVENTION (TEXT SENT BY FAX TO FCO AND UKREP BRUSSELS).

6. THE US/SOVIET FORMULA WILL ONLY BE CIRCULATED, FORMALLY, ON 11 AUGUST. UK DELEGATION HAS BEEN IN CONTACT WITH THE AMERICANS OVER THE WEEKEND AND WILL CONTINUE TO DISCUSS WITH THEM POSSIBLE IMPROVEMENTS. OTHER DELEGATIONS, SEEING THE FORMULA FOR THE FIRST TIME, WILL NEED TO SEEK INSTRUCTIONS. THE MEETING MAY WELL, THEREFORE, HAVE TO EXTEND INTO WEDNESDAY 13 AUGUST.

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PERSONAL

29 July 1986

Mr A M Allen
Chairman
11 Charles II Street
LONDON
SW1Y 4QP

Dear Chairman

NOTES ON THE DINNER WITH MR GOODLAD

Mr Simeone asked me to put down my recollections. The Minister had been briefed by Manley and Morphet on the four issues which were selected for discussion at the Chairmen's meeting which preceeded the dinner: Magnox, Emergency Plans, Regulation, Public Perception. Dealing with each in turn:

Magnox

Miller said that SSEB will probably not be able to afford to continue buying electricity from BNFL's Chapelcross reactors. As Morphet remarked, if BNFL then closed the reactors down on economic grounds the public will suspect they actually closed them because Chernobyl has made them think the reactors are unsafe. We will then be under increased pressure to close the other Magnox reactors in the country. Miller surprised me when he said that the NII would not press for Magnox to be shown to meet current safety standards. "Judgement" would come into it, he said. Later on the same tack we had WM's indictment of an NII Inspector whose over-zealous attitude on pressure component integrity, seismic issues and quality assurance (the three top ssues) was a major obstacle to the acceptance by NII of CEGB's long-term safety review submissions. WM and DM were both angling for a relaxation of NII attitudes here.

Private discussions have increased my conviction that neither SSEB nor CEGB would rue the closure of the early Magnox stations, which are seen as having given a good return. However, BNFL's investment plans presume, I imagine, that Magnox-reprocessing will suffer no such set-backs.

Emergency Plans

Morphet made the important point: increasing the evacuation radius in response to Chernobyl will confirm the public in its view that we are lying when we imply that "Chernobyl cannot appen here", (WM has been widely quoted as saying just that).

The UKAEA is going to upgrade its Site Emergency Plans, particularly to help our reactor operators to control an accident and stop it escalating. The French have their "U" and "H" procedures which do just that and in my view the UK industry must follow suit: "exploring the French approach", we would say, and the public, not being involved would not be so alarmed.

All agreed that it would be very difficult to increase the evacuation distance in our tight little island. Far better to learn how to stifle severe accidents at their inception by developing these accident-management techniques and training our operators to use them. The UKAEA can set the example here.

Regulation

The main concern was BNFL's agreement, effectively binding on all of us, to spend these "grossly disproportionate " sums on safety. One would have thought that the way forward would be to agree what is meant numerically by gross disproportion (ten-fold for example?) and preferably to agree this via the scientific press and not in a Court of Law. NRPB could be approached by BNFL to help with this. NRPB are the fount of contemporary cost-benefit guidance. Christopher Harding might like to link this with the Halsbury Scale which is receiving so much attention at the moment and could ask the question: what can we afford to spend in order to move one step down the Halsbury Scale? He might like to invite Dunster to answer this or help to answer it.

Public Perception

Nothing very innovative emerged. It was correctly stated that the NEIG initiatives are slow to take off. Miller complained that things were no better than they had been twelve years ago despite all our publicity and efforts at public education. Privately, Flowers and I agreed afterwards that it was only the said efforts that had maintained public acceptability at its present "50/50" level and that had we done less we would be considerably worse off.

Yours sincerely

pp JH Gittus/JE

J H GITTUS

cc Mr R N Simeone, LHQ

CL

PERSONAL

MEMORANDUM

To MR A M ALLEN

Your Ref.
Our Ref.
Tel Ext. 7206

Subject MEETING OF INDUSTRY CHAIRMEN, 28.7.86.

These are my brief impressions of the meeting which you, Mr Simeone and I attended.

Firstly, I wondered (as I mentioned to you afterwards) whether Manley and Harding had agreed before the meeting to try and persuade Walter Marshall to shorten the letter drastically and concentrate only on two or three issues which were obviously related to Chernobyl.

Walter extricated himself by not agreeing to give special emphasis to selected items in the letter and suggesting instead that we emphasised selected items at the dinner later.

On Magnox nothing particular struck me but on AGR, as expected, the SSEB were very sensitive and suspicious. I was surprised that they agreed to the section concerned with vented containments and offload refuelling. Ted Pugh was also very sensitive here and reflected on the NNC's real concern about their future workload when he asked that the CEGB should say in the letter that they might order an AGR for construction in 1988

Walter capitulated rather easily to your demand to delete all reference to fast reactors: it raises the question, "Why is the fast reactor the only topic not mentioned", and no doubt we shall have to address that question quite soon. It is for consideration whether the Authority unilaterally advises the Department on the relevance or otherwise of Chernobyl to the Authority's fast reactor programme: a letter from you on this?

The major campaign just being launched by the Royal Society has probably been prompted by the CEGB, I guess. Certainly they are funding the Watt Committee exercise with which Peter Jones and Frank Allen from the Authority are involved.

The discussion on the "regulation" referred to the concession which has been made by BNFL. They have said that they are prepared to spend money on safety "in gross disproportion to the benefits achieved" (or words to that effect). It is the phrase "gross disproportion" which SSEB and CEGB find so unhelpful: the pass sold.

pp JH Gittus JE

J H GITTUS

28 July 1986

cc Mr R N Simeone

Cha - Chairmen [illegible] [illegible]) ([illegible])

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SAX (in confidence) & not for further distribution

JHG.

CENTRAL ELECTRICITY GENERATING BOARD
Sudbury House, 15 Newgate Street, London EC1A 7AU. Telephone 01-634 5111

From the Chairman
The Lord Marshall of Goring Kt, CBE, FRS

DE [illegible]

CONFIDENTIAL

Mr. Alastair Goodlad, MP
Parliamentary Under-Secretary of State
Department of Energy
Thames House South
Millbank
London SW1P 4QJ

28 July 1986

Dear Minister,

The other Chairmen of the Nuclear Industry and I have had a wide ranging discussion about the nuclear issues facing the UK and would like to advise you of our thinking. We applaud the Secretary of State's speech of 26 June 1986 which reflects the unanimous view of the industry on the importance of nuclear power in the UK.

Considering first the Magnox stations, may we remind you that there are a total of 26 reactors operating in the UK with a total net capability of 4159MW. In addition, there are single reactor stations of the UK design in operation in Italy at Latina and in Japan at Tokai Mura.

Electricite de France still operate 4 Magnox reactors in France and one reactor at Vandellos in North Spain. All of these reactors are subject to a comprehensive safety review after about 20 years operation and the various Licences will each need to satisfy their respective licencing Authorities that continued operation is satisfactory in the light of modern practices and standards. Before the accident at Chernobyl, the conduct of the Long Term Safety Reviews in the UK was being raised in some quarters as a matter of public concern. The Chernobyl accident has been used by those opposed to the continued operation of Magnox stations in the UK to whip up concerns amongst the general population; a task that has been made that much easier because of some superficial (and misleading) similarities in features between Magnox and RMBK reactors.

The pressures in Italy have been much greater however, and there is still the real possibility that the Italian Government will decide to "sacrifice" Latina in an attempt at reducing pressure on the remaining nuclear programme. The matter is likely to come to a head at a Conference the Government is arranging to review the nuclear issue in November or December.

The Japanese are nervous but not under any great pressures; the French are relaxed but have expressed a wish to discuss Magnox safety issues with us.

The safety of the Magnox stations on a day to day basis is not in question; a position that is fully supported by the NII. However, there are genuine technical issues to be addressed in relation to the longer term operation of Magnox stations. The NII's requirement that we should make comparisons with modern safety criteria applied to the very latest stations has identified 3 principle areas where detailed technical debate is ongoing between Licencees and the NII. These are the integrity of the steel reactor pressure vessels, the seismic capability of the plants and the extent to which full numerical risk analysis techniques should be applied. Matters are complicated still further by the fact that the current safety cases for individual stations are not identical. It is most important that this technical debate which is fundamental to the Licencing Process in the UK should be allowed to run its course to the conclusions that either the owners or the NII may reach without being prejudiced by public fears or perceptions.

To summarise, the Magnox issues are complex. The operation and safety assessment strategy, the approach to public responses and publication of safety cases adopted by one Licencee will restrict freedom of action of the other Licencees. We recognise the importance of providing you with coherent UK advice which takes account of possible external influences and we have therefore arranged to reinforce the existing Magnox Technical Group. A list of the revised tasks of this Group is appended at Attachment 1. We have agreed that an industry meeting, at Chairman level will be held, if these Magnox discussions suggest one is needed.

It is important to remember that these Long Term Reviews are the business of the operators not something imposed by the NII. It is therefore important that the main effort on these Reviews should come from the operators and the main justification in public for the continued operation of the Magnox stations should also come from the operators. The NII response to these Reviews need not be elaborate nor definitive, although to the public it must carry conviction and to the operators it is an important supplement to the regular NII licensing process which takes place at least once every two years. Unfortunately the public impression is that these Reviews are something of vital importance which determine whether the NII will permit the continued operation of the Magnox stations or not. Clearly we need to explain the philosophy of our regulatory system much more carefully and we the operators need to pay much greater attention to the presentational aspects of Magnox safety to the public.

The AGR position is more straightforward. All parties agree upon the overriding need to obtain maximum output from the operating stations as soon as possible. An important part of this exercise is the establishment of on-load refuelling at the highest achievable power levels on all AGR's. There is still much work to be done before the performance of newly commissioned AGR's at Dungeness B, Hartlepool and Heysham I reaches a satisfactory position. Following on from the Long Term Magnox Safety Reviews we may possibly have need to look again at the early AGR's to come closer to the Heysham 2 safety philosophy.

As to a future AGR, the difference in policy between CEGB and SSEB is well known. There is good co-operation between the two Boards with joint funding of NNC work aimed at preserving the AGR option at least into the next decade.

/ ...

Particular aspects that are being examined by NNC as a matter of high priority are:-

(i) A dry, rather than wet, spent fuel route at the reactor.

(ii) A larger buffer store (to permit discharge of a large part of the core to facilitate major repairs).

(iii) Some form of vented containment which could reduce the consequences of unlikely accidents.

(iv) The feasibility and economics of an AGR refuelled predominantly off-load. This Study is requested by CEGB because this might simultaneously avoid the complications of on-load refuelling and simplify the safety case sufficiently to be economically attractive. But those attractions have to be weighed against acknowledged benefits of on-load refuelling to see, on balance, if the present AGR concept is best.

CEGB judges that it would not be in a position to order a further AGR for some time. This is because, in the light of experience gained to date, it is CEGB's view that further optimisation of the balance between safety and economics would be prudent and a Public Inquiry, of whatever sort, would postpone start of construction to 1990 at the earliest.

The SSEB take the view that a next AGR should be based on Heysham II/Torness whilst taking into account possible benefits from (i) to (iii) above, and that main construction could start in mid 1988 if an Inquiry could be avoided.

Turning to the question of waste management, there is little that has not already been said. NIREX have the responsibility for developing waste disposal sites and they must be allowed to get on with the job. NIREX are also exploring the "sea disposal" option which you will appreciate is a sensitive issue. The Industry is continuing its investigations for a central dry store for irradiated AGR fuel.

On the PWR front, CEGB recognises that Chernobyl will raise additional questions which must be addressed. Up to the present moment there is nothing about the Chernobyl accident which would make us wish to change the design of Sizewell B. It is implicit in the Sizewell B risk assessment that some further improvements might be gained if the containment was vented or the concrete base mat cooled. We shall naturally look further into these options following Chernobyl, but we know that the gain, if gain there is, will be a reduction from a level of risk which is already satisfactorily low. In the Sizewell B risk assessment we had already considered cases in which the containment is fractured and those in which the base mat melts.

/ ...

An important issue brought into focus by the Chernobyl accident is the adequacy of current Emergency Planning arrangements and the public perception of these Plans. As with the Magnox safety issue, we think it important that you are provided with a coherent view. Here too we are reinforcing existing collaboration arrangements to ensure that the consistency of emergency planning arrangements across all UK nuclear establishments operated by CEGB, SSEB, BNFL and UKAEA are systematically evaluated and that views on the need for change in the light of Chernobyl are co-ordinated. Attachment 2 gives the tasks allocated to the relevant Working Group. We shall of course take advantage of the work of the Civil Contingency Unit and as individual managements will need to keep in close touch with NII thinking as it evolves.

The Industry as a whole has become very concerned about escalating regulatory demands on our operations. We do of course accept the need for a safety philosophy which demands of us constant vigilance and constant escalation of our proof of safety, but that is quite different to the demands to reduce actual emissions from levels which are already unimportant to levels which are trivial and where the demands upon us are more related to the popular perception of risk than the actual risk.

Our final topic is the difficult one of public acceptance of nuclear power. We are pleased that you are taking a personal interest in this matter. Government support for nuclear power is vital at the present time. As you are aware the Nuclear Energy Information Group (NEIG) is active in the presentation of information to Trade Unions, Political Parties, and is developing long term information programmes. The Group also analyses public opinion through public attitude surveys. BNFL are currently involved in an advertising campaign encouraging the public to come and see for themselves the Company's operations at Sellafield. As you know the CEGB will be launching a local advertising campaign to provide information to local communities about the operation of nuclear establishments as an important way of informing the public about different apects of nuclear power. We also recognise the need to be seen to be open about all aspects of our operation although this may be uncomfortable at times. There is also a pressing need to tackle public concern and ignorance about radiation and its effects, particularly at low levels of exposure, and we are considering how best to do this. We recognise the importance of gaining third party support since nowadays we fear that CEGB and even NII spokesmen have no more credibility in the minds of the public than the most extreme anti-nuclear spokesmen. We have received a number of unsolicited letters of support from academics and on an individual basis, we have been encouraging academics and industrialists to take opportunities to present the facts about nuclear power as they see them. The Royal Society is about to launch a major campaign to improve the general public's appreciation of science and to improve the public's perception of risk. The Royal Society will be seeking financial support from the nuclear industry as well as other industries for their new "high visibility" effort. The Watt Committee which represents all the scientific and engineering institutions in the energy field are also anxious to take on a "higher visibility" role by providing a panel of "third party spokesmen" on all energy matters, particularly nuclear matters. We are therefore encouraging the Royal Society and the Watt Committee to co-ordinate their activities closely and probably one will conentrate on scientific and the other on engineering matters. There are a few other groups that might wish to promote the need for the nuclear power option but we do not expect rapid results. The most pressing need is to educate people to the fact that living is all about putting relative risks in perspective and that nuclear power ought to be at the bottom of the list of risks.

From within the Industry, we are examining how we can best implement the open information policy both in terms of reporting and publiation of incidents and in terms of making technical information more widely available. It goes without saying that we are happy to defend the technical competence of our staff to anyone. We must however find a way of doing this without adversely affecting the businesses that we are charged to run.

We are in lively discussion with the Department of Energy and the Department of the Environment about the classification and publication level for incidents down to the most trivial kind. We hope that, in this way, we can implement the Government's commitment to an open information policy but not simultaneously give grossly exaggerated weight to what are, in reality, unimportant events. We also hope to develop a "Halsbury Scale" as an impartial way of signalling to the public the qualitative importance of each event.

We are looking forward to discussing these issues and any others that you may wish to raise with us on 28 July.

Yours sincerely,

ATTACHMENT 1

Magnox Technical Liaison Group

(Chairman: Dr B Edmondson, CEGB)

Revised Tasks

1. To encourage consistency of approach to safety aspects of UK Magnox Stations.

2. To examine in this context the progress of Long Term Safety Reviews.

3. To examine options for similar harmonisation with Magnox plant operators overseas.

4. To identify problems, both specific and of general policy purport, stemming from Magnox plant safety issues.

5. To respond to options for public dissemination of information on Magnox plant safety.

6. To encourage a consistent approach to public responses on particular Magnox plant safety issues.

7. To co-ordinate use of resources to these ends.

8. To resolve such problems as lie within the competence of the Group, referring others for resolution.

9. To Report regularly on progress, and urgently as the need arises, to Senior Management of the CEGB, SSEB and BNFL.

ATTACHMENT 2

CHERNOBYL - TASKS RELATING TO REVIEW OF UK NUCLEAR SITE EMERGENCY PLANS

Mr R R Matthews was requested to carry out a review of UK Emergency Plans for Nuclear Sites with the following terms of reference:-

"In co-operation with appropriate representatives of the organisations concerned to examine the Nuclear Site Emergency Plans of the CEGB, SSEB, BNFL and UKAEA with the following objectives:

1. To encourage consistent principles and practices embodied in the Emergency Plans.
2. Where any significant difference may be identified to bring it to the attention of the organisation concerned, with the intent that all interested parties should have available an explanation for use in public discussion and debate.
3. To collect views on the possible need to modify or amplify the Plans as a consequence of information and data derived from the Chernobyl accident.
4. To Report regularly on progress, and urgently as the need arises, to Senior Management of the CEGB, SSEB, BNFL and UKAEA.

28-7

NUCLEAR OPERATIONS SUPPORT GROUP

CEGB IN CONFIDENCE

NO/KGS

[illegible]

24th July 1986

cc JHG.

cegb Chem,
SWH

To:
A Allen, Chairman, UKAEA
F R Gibbs, Chairman, NNC
C Harding, Chairman, BNFL
D Miller, Chairman, SSEB
J C C Stewart, Chairman, BNF

cc R S [illegible]

From: K G Steele - NOSG

Meeting of Nuclear Industry Chairmen with Mr Goodlad

You will be aware that an initial draft of a letter from yourselves to Mr Goodlad was circulated to your representatives who attend the Chernobyl Incident Management Review Group. I enclose a revised draft which has been circulated as the basis of the comments received. It is proposed that this should be discussed at 2.00pm Monday 28th July.

KG Steele

c.c.
Lord Marshall
Mr H E Bolter, BNFL
Mr R Pilling, BNFL
Dr A Pexton, SSEB
Dr D Hicks, AEA, Harwell
Dr J Gittus, AEA Culcheth
Mr B Carpenter, AEA London
Mr D Smith, NNC

Executive Members
Mr G Hadley
Mr J G Collier
Mr P N Vey
Dr B Edmondson
Dr J K Wright
Mr R R Matthews
Mr F E Bonner
Mr B Hampton, D of E
Miss B Beebee/Mr P Haslam

DRAFT LETTER TO MR GOODLAD

Dear Minister,

We have had a wide ranging discussion about the nuclear issues facing the UK and would like to advise you of our thinking.

Considering first the Magnox stations, may we remind you that there are a total of 26 reactors operating in the UK with a total net capability of 4159MW. In addition, there are single reactor stations of the UK design in operation in Italy at Latina and in Japan at Tokai Mura.

Electricite de France still operate 4 Magnox reactors in France and one reactor at Vandellos in North Spain. All of these reactors are subject to a comprehensive safety review after about 20 years operation and the various Licences will each need to satisfy their respective licencing Authorities that continued operation is satisfactory in the light of modern practices and standards. Before the accident at Chernobyl, the conduct of the Long Term Safety Reviews in the UK was being raised in some quarters as a matter of public concern. The Chernobyl accident has been used by those opposed to the continued operation of Magnox stations in the UK to whip up concerns amongst the general population; a task that has been made that much easier because of the superficial design similarities between Magnox and RMBK reactors.

The pressures in Italy have been much greater however, and there is still the real possibility that the Italian Government will decide to "sacrifice" Latina in an attempt at reducing pressure on the remaining nuclear programme. The matter is likely to come to a head at a Conference the Government is arranging to review the nuclear issue in November or December.

The Japanese are nervous but not under any great pressures; the French are relaxed but have expressed a wish to discuss Magnox safety issues with us.

/...

The safety of the Magnox stations on a day to day basis is not in question; a position that is fully supported by the NII. However, there are genuine technical issues to be addressed in relation to the longer term operation of Magnox stations. The NII's requirement that we should make comparisons with modern safety criteria applied to the very latest stations has identified 3 principle areas where detailed technical debate is ongoing between Licencees and the NII. These are the integrity of the steel reactor pressure vessels, the seismic capability of the plants and the extent to which full numerical risk analysis techniques should be applied. Matters are complicated still further by the fact that the current safety cases for individual stations are not identical. It is most important that this technical debate which is fundamental to the Licencing Process in the UK should be allowed to run its course without prejudice to the conclusions that either the owners or the NII may reach.

To summarise, the Magnox issues are complex. The operation and safety assessment strategy, the approach to public responses and publication of safety cases adopted by one Licencee will restrict freedom of action of the other Licencees. We recognise the importance of providing you with coherent UK advice which takes account of possible external influences and we have therefore arranged to reinforce the existing Magnox Technical Group. A list of the revised tasks of this Group is appended at Attachment 1. In the natural course of his responsibilities Edmondson will be reporting regularly to Lord Marshall and we have agreed that an industry meeting, at Chairman level will be held, if these Magnox discussions suggest one is needed.

The AGR position is more straightforward. All parties agree upon the overriding need to obtain maximum output from the operating stations as soon as possible. An important part of this exercise is the establishment of on-load refuelling at the highest achievable power levels on all AGR's. There is still much work to be done before the performance of newly commissioned AGR's at Dungeness B, Hartlepool and Heysham I reaches a satisfactory position. We may possibly have to backfit the early AGR's to come closer to the Heysham 2 safety philosophy. The NII have already raised this issue with SSEB.

As to a future AGR, the difference in policy between CEGB and SSEB is well known. However, at a technical level, there is good co-operation between the two Boards with joint funding of NNC work aimed at preserving the AGR option at least into the next decade.

Particular aspects that are being examined by NNC as a matter of high priority are:-

(i) A dry, rather than wet, spent fuel route.

(ii) A larger buffer store (to permit major repairs).

(iii) Some form of vented containment which could reduce the consequences of unlikely accidents.

(iv) The feasibility and economics of an AGR refuelled predominantly off-load.

CEGB judges that it would not be in a position to order a further AGR for some time. This is because, in the light of experience gained to date, it is CEGB's view that further optimisation of the balance between safety and economics would be prudent.

The SSEB take the view that a next AGR should be based on Heysham II/Torness whilst taking into account possible benefits from (i) to (iii) above, and that main construction could start in mid 1988.

/...

The interest worldwide in the early development of Fast Reactors is diminishing at present. The West Germans are in considerable difficulty over siting and it seems most unlikely that they will be able to participate actively in a European collaboration venture in the foreseeable future. US Secretary of State Hetherington has stated publicly that the development of fusion power is higher up his priority list than the development of the Fast Reactor. The responsibility for fast reactor development in the UK lies clearly with UKAEA but, as you know, CEGB and SSEB have been providing limited financial support as an eventual interested customers. However, the key to future UK participation lies in a European reprocessing facility at Dounreay. CEGB have indicated quite firmly to EdF that the siting of the reprocessing facility at Dounreay is a necessary condition for the injection of CEGB funding into the next European reactor under international collaboration. Work is in hand to provide a firmer basis for fast reactor fuel cycle and construction costs. The position will be kept under review by the joint national and international bodies which are in various stages of evolution.

ossible alternative paragraph proposed by the UKAEA.

"Progress in fast breeder development in Europe has been encouraging in terms of both safety and economics and the collaborative arrangements envisaged in the Memoranda of Understanding between Governments seem capable of providing the benefits hoped for at the time of the Government's 1983 policy review.

There has, however, been a delay in agreement between West Germany and France on the next demonstration project. Although some German utilities appear to be keen to proceed, there are political problems which make full German participation less certain. Together with the Department's officials, we are participating in efforts to resolve this problem. The responsibility for fast breeder development at this stage, in advance of firm projects, lies primarily with the AEA, but the generating boards, BNFL and NNC are continuing in appropriate areas. An early objective must be for us to seek to have the European Demonstration Reprocessing Plant at Dounreay and the public inquiry on this appears to be progressing satisfactorily. For the present, it is believed that the current policy should be maintained, with our continuing to participate fully in the co-operative European programme and seeking to have all the greements signed and fully implemented as soon as possible, though this may need to be reviewed in the light of developments in West Germany."

Turning to the question of waste management, there is little that has not already been said. NIREX have the responsibility for developing waste disposal sites and they must be allowed to get on with the job. NIREX are also exploring the "sea disposal" option which you will appreciate is a sensitive issue. Because of the importance of fuel cycle costs to total generation costs, there is a need for greater liaison between BNFL and the Generating Boards and it is proposed to extend the Terms of Reference of an existing waste management working party to cover "the back end of the fuel cycle" in total.

/...

On the PWR front, CEGB recognises that Chernobyl will raise additional questions which must be addressed. CEGB is preparing a report to be available shortly which will review the possible implications of Chernobyl for the Sizewell B design. Among other things, up to the present moment there is nothing about the Chernobyl accident which would make us wish to change the design of Sizewell B. It is implicit in the Sizewell B risk assessment that some further improvements might be gained if the containment was vented or the concrete base mat cooled. We shall naturally look further into these options following Chernobyl, but we know that the gain, if gain there is, will be a reduction to a level of risk which is already satisfactorily low. In the Sizewell B risk-assessment we had already considered cases in which the containment is fractured by internal assaults and those in which the base mat melts.

An important issue brought into focus by the Chernobyl accident is the adequacy of current Emergency Planning arrangements and the public perception of these Plans. As with the Magnox safety issue, we think it important that you are provided with a coherent view. Here too we are reinforcing existing collaboration arrangements to ensure that the consistency of emergency planning arrangements across all UK nuclear establishments operated by CEGB, SSEB, BNFL and UKAEA systematically evaluated and that views on the need for change in the light of Chernobyl are co-ordinated. Attachment 2 gives the additional tasks allocated to the relevant Working Group.

Our final topic is the difficult one of public acceptance of nuclear power. The Nuclear Energy Information Group (NEIG) is active in the presentation of information (e.g. to Political Party Conferences) and in the analysis of opinion formers through the media of public opinion polls. BNFL are currently in the middle of a major "pro Sellafield" advertising campaign. We reached the view that NEIG was setting about its job in a competent way and we saw no obvious gaps in its work. We recognise the importance of gaining third party support since nowadays we fear that CEGB and even NII spokesmen have no more credibility in the minds of the public than the most extreme anti-nuclear spokesmen. We have received a number of unsolicited letters of support from academics and on an individual basis, we have been encouraging academics and industrialists to take opportunities to present the facts about nuclear power as they see them. There are a few other groups that might wish to promote the need for the nuclear power option but we do not expect rapid results. The most pressing need is to ducate people to the fact that living is all about putting relative tasks in erspective and that nuclear power ought to be at the bottom of the list of risks.

From within the Industry, we are examining how we can best implement the open information policy both in terms of reporting and publiation of incidents and in terms of making technical information more widely available. It goes without saying that we are happy to defend the technical competence of our staff to anyone. We must however find a way of doing this without adversely affecting the businesses that we are charged to run.

We are looking forward to discussing these issues and any others that you may wish to raise with us on 28th July.

Yours sincerely,

ATTACHMENT 1

Magnox Coordination Group

Magnox ~~Technical~~ ~~Liaison~~ Group

(Chairman: Dr B Edmondson, CEGB)

Terms of Ref.

Revised Tasks

1. To encourage consistency of approach to safety aspects of UK Magnox Stations.

2. To examine in this context the progress of Long Term Safety Reviews.

3. To examine options for similar harmonisation with Magnox plant operators overseas.

4. To identify problems, both specific and of general policy purport, stemming from Magnox plant safety issues.

5. To ~~pursue~~ advise on options for public dissemination of information on Magnox plant safety.

6. To encourage a consistent approach to public responses on particular Magnox plant safety issues.

7. To co-ordinate use of resources to these ends.

8. To resolve such problems as lie within the competence of the Group, referring others for resolution.

9. To Report regularly on progress, and urgently as the need arises, to Senior Management of the CEGB, SSEB and BNFL.

ATTACHMENT 2

CHERNOBYL - ADDITIONAL TASKS RELATING TO REVIEW OF UK NUCLEAR SITE EMERGENCY PLANS

Mr R R Matthews was requested to carry out a review of UK Emergency Plans for Nuclear Sites with the following terms of reference:-

"In co-operation with appropriate representatives of the organisations concerned to examine the Nuclear Site Emergency Plans of the CEGB, SSEB, BNFL and UKAEA with the following objectives:

1. To encourage consistent principles and practices embodied in the Emergency Plans.

2. Where any significant difference may be identified to bring it to the attention of the organisation concerned, with the intent that all interested parties should have available an explanation for use in public discussion and debate.

3. To collect views on the possible need to modify or amplify the Plans as a consequence of information and data derived from the Chernobyl accident.

4. To Report regularly on progress, and urgently as the need arises, to Senior Management of the CEGB, SSEB and BNFL.

Chairman

Arithmetic Scale of Nuclear Accidents

Following our discussion, the arithmetic scale would be measured in man. Sieverts. One hundred man. Sieverts causes one late cancer death if received by a large population.

Figures for accidents are then:

Chernobyl	3,000,000
Windscale Fire	3,300
Three Mile Island	70
Sellafield release	0.64

J Gittus

24th July 1986

United Kingdom Atomic Energy Authority

11 Charles II Street
London SW1Y 4QP

Telephone: 01-930 6262

Chairman.

A "Richter scale" for accidents to Nuclear Installations. J. Gittus 24 Jy 86

Having thought about this I conclude that the scale to use is $\log_{10}$ (man. Rem).

SRD colleagues agree. The scale runs approximately from zero to 10:

~~Accident~~ Sellafield release (Nov 1983) : 1.8 - 0.2
Three Mile Island accident : 3.8 1.8
Windscale reactor fire : 5.5 3.5
Chernobyl accident : 8.5 6.5

Meeting of Nuclear Industry Chairmen with Mr. Goodlad, 28 July

Briefing Points

At the meeting of Chairmen on 28th July prior to the dinner with Mr. Goodlad, a draft letter to Mr. Goodlad will be considered covering a broad look at the situation of the nuclear industry following the Chernobyl accident. There are also draft terms of reference for Working Parties both to be chaired by the CEGB - one to review the position on Magnox reactors and the other on emergency planning. The drafts are generally satisfactory although the initial CEGB draft of the comments on the fast reactor to Mr. Goodlad was most inappropriate.

Magnox Reactor

2. From Lord Marshall's comments, it seems that the CEGB have strong reasons for thinking that the Italians are likely to close down Latina.

3. At the recent meeting of Lord Marshall's Chernobyl Implications Review Group, the SSEB indicated that they were unlikely to make a robust case for continuing the operation of Hunterston A (should the safety of Magnox come under heavy attack) if its sacrifice seemed to be necessary in order to strengthen the position of Torness in particular and AGR technology generally.

4. The NII are in the process of carrying out the Long Term Safety Reviews (the so called "20 year review") of the safety of Magnox reactors. Reports on Bradwell and Berkeley are expected before the report on Hunterston.

5. Within the CEGB it has been mooted that the future of Magnox could be subject to either the "domino theory" (if you close one reactor down because you are not sure of continued safety you will be asked to close

them all) or the "sacrifice theory" (say that you've looked at all of the reactors and most are absolutely fine but you have decided on balance to close two down).

6. It has to be recognised that a decision to close down a Magnox station (because although it continues to be safe in the short term, it needs money spent for the longer term which it will not be economic to find) could have an effect on the SGHWR. Pressure could be set up to close the SGHWR on the basis that it is a redundant reactor system nearly 20 years old which shares some similarities with the Chernobyl reactors, unfair though such a line would be.

7. The proposal that a technical group should be set up under Dr. Edmondson to keep the position on Magnox reactors closely under review seems to be sensible. It would be as well for the Authority to be represented to keep an eye open for unwelcome developments.

8. No comments seem to be necessary on the passage on Magnox in the draft letter to Mr. Goodlad.

AGR

9. The draft letter to Mr. Goodlad indicates the current CEGB thinking that to keep the AGR option open it is sensible for the Board to consider with NNC what a new CEGB AGR would look like - whether features such as off-load refuelling, vented containment and dry spent fuel storage would produce obvious attractions in terms of safety benefits. Presumably SSEB may be unhappy with this and may wish to stress the advantages of current AGR designs.

Fast Reactors

10. The line taken on the fast reactor in CEGB's first draft letter to Mr. Goodlad was far too negative in tone and Dr. Marsham has suggested that the subject should preferably be omitted from the letter, as the implications of Chernobyl for the fast reactor are far from clear. An alternative draft has been proposed should it be decided, on balance, that the letter would be incomplete without reference to the fast reactor.

Emergency Planning

11. It is undeniable that the Chernobyl accident will have increased public awareness of the need to demonstrate, both nationally and internationally, that arrangements exist to deal with large-scale emergencies. International action has already started. Currently there is an IAEA meeting in Vienna to draft two conventions - one dealing with early warning arrangements by which the stricken country can inform others through the IAEA of an accident big enough to have trans-boundary effects, the other a mutual assistance agreement by which people and equipment could be provided through an international clearing arrangement.

12. The CEGB have said that they intend to make their Site Emergency Handbooks available publicly. The Authority are preparing versions of the Handbooks for Dounreay, Harwell and Winfrith, omitting necessarily confidential information like telephone numbers, for the same purpose.

13. It is necessary that the industry should meet together to discuss a number of important aspects, including:

- how to answer demands to know what considerations have been given to the technical capability of dealing with an accident bigger than a design base reference accident;

- is there, in reality, regional machinery in place for dealing with disasters, including large-scale evacuation, provision of health services, provision of food and water from other safer regions;

- what is actually known about the problems of decontaminating large areas of land;

- do central Government arrangements need modification - is the current philosophy of appointing a Government Technical Adviser the right approach and is his role clear;

- is there a broadly consistent approach to emergency arrangements within the industry.

14. The recommendation to form a Working Party chaired by Mr. Matthews seems to be a necessary step forward. Care must be taken by non-CEGB representatives to avoid proposals being made in a style which suits the CEGB's circumstances but not particularly anyone else's. The Working Party will also need to be aware of areas in which it may not be possible to make firm proposals without an indication of policy from Government Departments.

Public Acceptance

15. The draft letter to Mr. Goodlad refers to the joint industry programme carried out by the Nuclear Energy Information Group, directed by Dr. Margerison. It also refers to the need to encourage independent groups to express some support for nuclear power. Lord Marshall has some hopes in respect of the Watt Committee on Energy, a registered charity supported by some 80 professional institutions. The Watt Committee has formed a safety study group to consider issues arising from the Chernobyl accident. The first meeting was attended by Dr. Allen, SRD and Professor Jones.

Incident Reporting

16. Ministers have held discussions with industry Chairmen about:

(i) more rigorous criteria describing incidents to be reported to Ministers within 24 hours;

(ii) a policy of publicising more minor incidents, perhaps in regular bulletins from nuclear establishments covering a range of subjects of general interest.

The matter is still under discussion, primarily because of problems in covering the (different) needs identified by both the Department of Energy and the Department of the Environment.

Post Chernobyl Authority Studies

17. Areas to be covered in Authority studies designed to consider implications of the Chernobyl accident are:

(1) Analysis of the accident to consider the lessons relevant to other types of reactor and any relevant to the operation of reactors in general;

(2) the potential impact in the UK of reactor accidents overseas;

(3) Accident consequences, in respect of likely health effects;

(4) A study of the concept of intrinsically safe reactors - incorporating naturally safe design elements (eg. the fact that a reactor relying on water both as a coolant and as a moderator will shut down on severe coolant loss) with engineered safety barriers.

18. The analysis of "lessons learned" will lead to a re-examination of the safety case for DIDO, PLUTO, the SGHWR and the PFR. Hopefully much more will be learnt about what happened at Chernobyl at IAEA Post Accident Review at the end of August, although it has become known through diplomatic circles that the Russians would prefer the conference to deal more widely with accidents rather than confine it to Chernobyl. This would undoubtedly reduce its value.

BC/22/7/86

John

Richter Scale

✓

I like this

1 chest X-ray $\approx \frac{1}{10}$ mSv (see attached)

Ergo natural background $\approx$ 20 chest X-rays

This puts 1 chest X-ray per year in perspective.

This has close similarities with Charlie Clements catastrophe index for defining the risk from the plant, which was concerned with deaths rather than Sieverts. Sieverts is better for nuclear accident because it short circuits the need to make the equivalence

either ~ 5 Sv $\equiv$ 1 early death

or ~ 100 Sv $=$ 1 late death

You still have a free parameter – the "zero" of the system. Personally I would go for

$$\log_{10}\left(\frac{\text{man Sv}}{100}\right) \approx \log_{10}(\text{no of cancers})$$

so a negative number meant less than 1 cancer, positive numbers meant cancers. Thus Chernobyl would be 4.5

As against this Force 8 on the Beaufort scale means a gale, and earthquakes leading to deaths are around 6 to 8 on the Richter scale so that people may be already calibrated that way.

Another argument in favour of your "zero" is that

$$1\ \mathrm{Sv}/\mathrm{yr} \approx 10^{-2}/\mathrm{yr} \text{ chance of death by cancer}$$

Since we live 3 score years & 10 , our natural chance of death from all causes , in ignorance, $\approx 10^{-2}/\mathrm{yr}$. Hence your zero corresponds (?) to peoples gut reaction. Most people only care about the chance of something happening in their lifetime

I discussed this sort of thing with Clements when I queried his "zero".

Richard P.

London 73 (RLRN)
552.

4.00pm Prof Jones Office.

§6. It complex .. cost §7 Sophistication ~~or~~ later ... economic
smaller reactor less efficient in economic terms; say
WILL BE MORE EXPENSIVE, although intrinsic will offset some
economic costs.

§13 Concept ~~not ignored~~ has a place in the main stream

Child's Play §10 + §11 an apparently intrinsic safety
feature .. apparently not always

IN CONFIDENCE

MEMORANDUM

To Dr J H Gittus, Director, SRD

Your Ref.
Our Ref.
Tel Ext. 7226/1336

Subject "RICHTER SCALE" FOR NUCLEAR ACCIDENTS

1. The first point, and most fundamental, is the appropriateness of a logarithmic scale for comparison of accidents. Most technical people will feel, intuitively, that this is a "natural" type of scale to use. Probably the only logical reason for it is convenience in representing a wide range of possible consequences, analogous to using logarithmic rather than lineargraph paper. Note that there is a difference with certain logarithmic scales like decibels where the logarithmic nature can be linked to the nature of physiological response. Use of a logarithmic scale will attract the criticism that it is a piece of whitewashing to reduce the size of the numbers at the top. Nevertheless, on balance, I think such a scale could be defended for the reasons given earlier. The analogy with the original Richter Scale of course can also be invoked. ✓

2. Having decided on the form of the scale, what of the arbitrary zero? Intuitively, one feels this should have some recognisable significance. As proposed, zero corresponds to 1 man Sievert which would be 100 rems for an individual. I have used this in the past as a convenient "round number" boundary between immediate effects and stochastic ones. As such it represents the limit where calculations on loss of life expectancy are appropriate whatever the size of the population. (The smallest population is one). Are there alternative zeros that could be chosen? One possibility would be the average background radiation received in a year which would give a scale of log man Sieverts + 3: or one could take the ICRP limit for the general public which would give log man Sieverts + 2.3. All these are arbitrary and on balance I would prefer to leave it as you have proposed. +2 chosen ✓

3. On a point of detail, I think your definition of the Sievert is actually the definition of the Gray. The Sievert recognises that not all energy is equally damaging and derives itself from the Gray by using the relative biological effectiveness (RBE) to multiply the absorbed dose in Gray. Since the RBE for most of the radiation we are concerned with is 1, the Gray and Sievert are for most applications identical. ✓

4. Another small point relates to the dose which will cause immediate death. This depends on the constitution of the patient and on the counter-measures invoked to help him. It might be better to stick to the LD50 dose (ie that dose which gives a 50% probability of early death). ✓

Betty Chadwick
for H J TEAGUE

23 July 1986

cc Dr F R Allen
Dr G M Ballard
Dr M R Hayns
Dr R S Peckover
Dr P Clough
Dr W Nixon

Your Ref.
Our Ref. T.3
Tel Ext.

MEMORANDUM

To Dr J H Gittus, Director, SRD

Subject "RICHTER SCALE" FOR NUCLEAR ACCIDENTS

One important distinction you are making in your paper on a "Richter Scale" for nuclear accidents is that the scale should be a property of the consequences of the accident, not a property of the accident itself. This is clearly different from the Richter scale for earthquakes where the scale reflects the severity of the earth tremor not the consequences that resulted from that event. Thus a large earthquake may h [illegible] from zero to many thousands of deaths depending on where it occurs with respect to centres of population, coal mines, etc but the size of the event and thus the scale value would be constant. By analogy a nuclear plant accident has a potentially large range of accident consequences depending on the detail of the event, eg. weather, population, etc, even if the size of the event (measured say in curies (becquerels) released) is the same. However, the scale will measure the consequence not the size of the event, in contrast to the earthquake case. Following this point it clearly is then important to distinguish between events with immediate consequences, ie. deaths and those with delayed consequences (Lord Marshall's point about "big nuclear accidents"). This could be done in the way you suggest in your paper by explicitly stating the number of deaths. I think this is the way that probably has most impact. However, one could consider modifying the consequence scale by say a ratio which reflects the proportion of early deaths to delayed deaths. ✓

G. Ballard

G M Ballard
SRD

22 July 1986

RICHTER SCALE OF ACCIDENTS

Attached is the graph of the proposed accident scale for the instances mentioned in your draft paper. The values quoted there are essentially correct, viz:

Accident	Delayed cancer Facilities	man-Sv	Log_{10} (man-Sv)	+2
Chernobyl	30,000 (1)	3×10^6	6.48	8.48
Windscale Fire	33 (2)	3300	3.52	5.52
TMI-2	0.7 (3)	70	1.84	3.84
Sellafield Discharge		0.64 (4)	-0.19	1.81

Notes

1. SRD estimate for USSR and Western Europe is ~20,000. This figure includes allowance for more remote regions.

2. M J Crick and G S Linsley. NRPB R135 Addendum (Sept 1983).

3. Staff Reports to the President's Commission on the Accident at TMI~~-2~~. Reports of the Public Health and Safety Task Force (OCT 1974).

4. Estimate by S Nicholson based on discharge of 45 T Bq of the 103/106 plus some Zr + Nb activity in November 1983.

Other comments on the draft:

Top of page 3 - The energy dose unit ✓ quoted (1J into 1 kg) is the Gray (equivalent to 100 Rad).

The Sievert (≡ 100 Rem/ takes into account biological effectiveness also. ✓

Bottom of Page 3 - 1 man-Sv is a collective dose - therefore cannot be compared with an individual smoking cigarettes. ✓

If an individual receives 1 Sv, this is equivalent in increased cancer risk to him smoking 5 cigarettes ✓

1 chest x-ray ≡ 0.1 mSv ✓

Page 4 - Early deaths. It is worth noting that the 28 admitted early deaths at Chernobyl were mainly recovery workers - not members of the public - as far as we know. ✓

PETER CLOUGH/W NIXON

22 July 1986

J719

IN CONFIDENCE

MEMORANDUM

DECLASSIFIED

To SEE BELOW

Ref.
Our Ref.
Tel Ext. 7206

Subject A "RICHTER SCALE" FOR ACCIDENTS TO NUCLEAR INSTALLATIONS BRIEF FOR THE CHAIRMAN BY J H GITTUS

The attached paper is for immediate comment to me please (and checking of numbers quoted).

Mr Allen has asked me for this brief and would like us not to mention it to others outside SRD at present please.

I believe that to calculate the number of man Sieverts we would use CRAC (or our marine dispersion code) with the NRPB de minimis dose as a cut-off.

pp J H Gittus

J H GITTUS

22 July 1986

TO: MR H J TEAGUE away
DR M R HAYNS
DR R S PECKOVER replied
DR F R ALLEN replied
MR G M BALLARD
DR W NIXON
DR P CLOUGH

PS A typed version of the attached is being prepared.

FR Allen ✓ Sievert definition ✓ 75 kg individual ✓
5 cigs/week

JHG.
revision

A "~~[illegible]~~ "SCALE" FOR ACCIDENTS TO NUCLEAR INSTALLATIONS

Brief for the Chairman

By Dr J H Gittus 24 July 1986.

Recommendation

~~One [illegible]~~

The scale suggested in this Brief is one in which the severity of the accident is measured in terms of ~~the logarithm (to the base ten) of~~ the number of Man ~~Sieverts~~ Sievert ~~Rem~~ of radiation calculated to be produced by the accident, ie

man.Sv ~~$\log_{10}$ (man.Sv Rem)/2~~ ~~$\log_{10}$(100 x man.Sv)~~

On this scale the Chernobyl accident rates ~~6~~8.5. ~~One would say "the Chernobyl accident, which has killed 28 people, rates 6 8.5 on The Scale". Similarly "The Sellafield accident in which activity was released to the sea, killed no-one: it rates 0.5 1.8 on The Scale".~~ ~~(does it)?~~

Or, in ~~[illegible]~~ old units, $\log_{10}$ (~~man.Sv x 100~~)

$\log_{10}$ (man.Rem)

Other Scales dismissed

a) Curies released

A Scale could be based on the number of curies accidently released from the nuclear installation. The drawback is that one curie from plutonium does not produce the same damage as one curie from cobalt. The proper unit to measure damage to living things is the Sievert. It takes account of the different between plutonium and cobalt (and all other radioactive substances, too).

b) Sieverts measures damage to living things.

The Sievert ~~is defined as that amount of radiation that delivers 1 Joule to 1 kilogram of tissue~~. We could calculate, therefore, how many Sieverts a person ~~of standard mass (say 75 kilograms)~~ would receive if situated at a fixed distance from the nuclear installation. For example he might be at the site boundary. However,

a) On the site boundary to the North-West of Chernobyl he would have received much less radiation than a man 10 kilometers further away, we calculate. This is because the radioactive "fumes" rose to a height of over 300 meters above the reactor on the rising hot air from the fire before being caught by the wind and blown up country. Accordingly, the fumes 'skipped' the site boundary and did not begin to fall to the ground until they were some distance downwind.

In other imaginable accidents this effect would be less marked or absent altogether.

b) On the site boundary to the South-East of Chernobyl he would have received even less radiation. This is because the wind was blowing the fumes away from him.

If we are to use Sieverts as the Scale we shall also have to say what height the fumes ascended and what the meteorological conditions were. Four numbers at the very least (Sieverts, height, wind-speed and direction) are needed, whereas for ~~The~~ a practical Scale we must only have a single number. The number to use is the Man Sievert:

The Man Sievert selected

Given:

a) The number of curies of plutonium, colbalt, iodine and any other radioactive substance released.

b) The energy (height) of release.

c) The meteorological conditions.

We can calculate (given the population-distribution round the installation) w~~W~~hat will be the total number of man·Sieverts attributable to the accident.

The Scale is now couched in terms of a single number. ~~Moreover, real (and imagined) accidents produce a number of man Sieverts whose logarithm varies from 0 to 725 (or thereabouts).~~ 10

This is a similar range to the Richter Scale and so it has a ring of familiarity.

Equivalent indices of harm

One hundred man Sieverts shared between some thousands of people will cause one of their number to die from a resultant cancer, some 10 to 40 years later.

If a man receives a Sievert the harm ~~One man~~ ~~Sievert~~ is equivalent to 5 cigarettes a week in terms of the increase in cancer deaths which it produces.

(~~One chest x-ray is equal to~~ ~~x man Sieverts (what is x please)?~~ ~~One ten thousandth of a Sievert.~~)

"Early" deaths

Some people close to the installation may die early. That is to say within days or weeks of the accident. Twenty-eight such early deaths occurred at Chernobyl. ~~Two early deaths occurred~~

~~in the accident to the USA reactor SL.I~~ A Dose~~s~~ of more than 4½ Sieverts to an individual person cause~~s~~ early death.

Form of words to use

There is no straightforward relationship between the number of early deaths and the number of man‹Sieverts and so one would quote both figures. Here are four examples of the form of words which one would use:

1) "The Windscale reactor ~~accident~~ fire measured ~~[illegible]~~ 5 on The Scale. No-one died in the accident (ie there were no early deaths").
   3,300

2) "The Chernobyl reactor accident in April 1986 measured ~~[illegible]~~ 5 on The Scale. Twenty-eight people died in the accident or shortly afterwards".
   3,000,000

3) "The accident in November 1983 which released activity from Sellafield measured ~~0.5~~ on The Scale. No-one was killed in the accident" ~~[illegible]~~ 0·64

4) "The accident at Three Mile Island measured ~~2.5~~ on The Scale. No-one was killed in the accident although their were two deaths due to road accidents in the evacuation which ensured".
   ~~28~~ 70

5) " The ~~release of plutonium inside the building at on the nuclear site core measured registered~~ accident involving a less than unity on The Scale" (this is the form of words to use for values in public statements between zero and unity.)

6) " The accident ~~at~~ in the nuclear ~~laboratory~~, involving a small release of radioactivity, did not register on The Scale" (this is the form of words to use in public statements for ~~values~~ values below zero) ~~but believe this is what is the form of word~~ They ~~are~~ correspond to ~~less than~~ one man-Rem) ~~and are insignificant to~~

O

I have spoken to NRPB and MAFF to clarify some of the points.

1 ACTION LEVELS

The 1,000 Bq/kg action level was taken from the recommendations of Article 31 Group of Experts and was proposed for a wide range of foodstuffs based on the ICRP's 1mSv/year dose limit. It is to be contrasted with the Derived Limit recommended by NRPB which comes out at 9,000 Bq/kg for the isotope mix relevant, ie Cs134 and Cs137. Thus the NRPB level would correspond to 5mSv from a years consumption at fairly extreme rates. A factor in deciding on the 1,000 Bq/kg action level in the UK was to ensure some harmony with what is going on in the rest of Europe and thereby protecting trade. The 600 Bq/kg figure quoted in the press is a number adopted by the CEC essentially for imports from the Eastern Block and imposed on all foodstuffs except milk and those intended for babies.

2 PERSISTENCE OF ACTIVITY

First of all on pasture. The opinion of both NRPB and MAFF is that by far the most important pathway is ingestion of activity directly deposited on pasture. This is washed off into the ground with a half life of about 14 days. It is also diluted on the pasture by the growth of grass. I mentioned in my previous note that sheep consume quantities of soil and that there is uptake of activity by the roots of plants. Neither of these pathways are really significant because the caesium becomes fixed to particles of clay in the soil. This is then not easily absorbed into the sheep's body and is not easily absorbed by the roots of plants. The conclusion is therefore that the available activity decays with a half life of a few weeks.

Persistence of activity in sheep. Since the NRPB published their report DL7 they have reconsidered the model used there for sheep. The persistence of activity in muscles with a half life of 120 days now seems an over-estimate. They now think about a month. MAFF have suggested that the appropraite figures are: for full grown sheep 50 days and for lambs 20-30 days.

3 VALUE OF THE BAN

The ban of 21 days is expected to roughly halve the levels of activity in lambs. The existing time period appears to have been the balance of consideration of the biological half life etc and of the fact that the Minister can authorise a ban of up to 28 days without it needing to be discussed in the Commons.

A further reason for imposing the ban was that it will give MAFF enough time to do further monitoring and establish more closely the existing areas of greatest concentration.

The value of removing lambs from grazing, thus eliminating intake of Cs137 etc, seems to have been considered but, given the relatively short persistence time on pasture, there is little value in this compared with simply leaving them to graze normally. I understand that most of the lambs which were in the areas of highest deposition would not be slaughtered until August or September, so the contamination would be down by a factor of about 4 anyway

4 CONSEQUENCES

The NRPB level of 9000 Bq/kg is set on the basis of a 10 year old eating 20kg of lamb per year. This consumption rate is an extreme value; a more representative one would be 5kg/yr. If this more reasonable value is taken then consumption for one year of lamb contaminated at the UK action level of 1000 Bq/kg would lead to a dose of about 0.15 mSv. To reach this kind of level a person would have to deep freeze some of the most contaminated lamb around now and eat it for the rest of the year. Natural background is about 2mSv/year.

Dr Gittus Took Note 13-8

Chernobyl file

EXTRACT FROM NPWSC MINS.
JULY '86

ITEM IV - THE USSR CHERNOBYL INCIDENT (NPWS 7/86)

9. MR TEAGUE introduced the paper by remarking that although the information which it contained about the reactor and its design features was well founded, the events and accident sequences were necessarily highly conjectural until more reliable information emerged from the USSR. He described the reactor as typical of a large class of Russian reactors of which important features were (i) its large size, (ii) spatial instabilities, (iii) complex control system and (iv) on load refuelling. In consequence, of the 1700 channels, nearly 1/10 contained control rods. The reactor at times in its life had a positive void coefficient. The graphite was cooled by conduction and gas convection with Nitrogen and Helium mixture adjusted to maintain temperature levels. Some of the graphite could reach temperatures as high as 760°C.

10. The Russians were alive to the safety issues and had paid very considerable attention to such matters as emergency core cooling, effect of breaches in coolant pipes and employed a multi-compartment containment system of which the suppression pool beneath the reactor was a part. One design basis accident was single tube failure. The core box was then protected by a bursting disc discharging to the pressure suppression pool.

13. The best information on the accident had been obtained through the Nuclear Energy Agency of OECD. Its Committee on severe accidents had been able to "back-track" from information received from its members in the early phases to a possible source term. The reported information emphasised (i) an explosion occurred without warning with the reactor operating at 7% of full power followed by a power rise over 10 seconds to 50% during which the top of the core blew off and (ii) an intense fire with 100 ft flames ensued. MR TEAGUE conjectured that the most likely origin was an instability of flux pattern leading to a local power excursion. The ensuing rapid power transient caused overheating and a rapid increase in steam quality leading eventually to dry out and overheating in a number of fuel channels. Reaction between the steam and zirconium produced hydrogen and more heat and led to multiple tube failure,sufficient to cause top of core to lift off exposing tubes with fuel. The scale of the failure was too great for the pressure suppression system to cope with. Because this reactor has more zirconium than in a PWR, the potential exists for production of large quantities of hydrogen. The damage could admit air to a hot graphite stack which could ignite.

14. This situation appears to have released 1-10% of core inventory within the first few days with subsequent release continuing over several days while the fire continued. The mix of fission products seen was consistent with the reactor not being critical at power. The estimate of total release of volatiles was 20%, but a large proportion of the core has been affected.

15. MR TEAGUE saw few direct implications for the Naval programme, especially since Naval PWRs had strong leak tight containments which could not be bypassed. UKAEA, BNFL and the Electricity Boards see one major outcome, simply as greater public awareness of the potential consequences of severe accidents and therefore are considering fuller publication of accident plans. The fact that effects were felt at very long range came as a surprise, although it did not appear that any local population exceeded the whole body ERLs. The USSR accident arrangements were severely criticised and inevitably this casts doubt on those within the UK. The view is that more information will need to be made publicly available. The fact that a severe fire occurred, aggravated the initial response and posed questions about the means of fire fighting in a radioactive/high radiation environment. Of the lessons learned, see para 6ix of the report, he emphasised the need to develop accident management by studying possible sequences of events and actions. The evidence from Chernobyl suggests that the operators were slow to diagnose what was wrong.

16. MR DUNSTER was assured that,where ERLs were referred to in the paper,they corresponded to the lower values. DR MARSHAM

regarded the paper as an expression of view from SRD. UKAEA as a whole did not subscribe to all of its assertions. He queried whether any of the graphite would exceed 500°C at 7% power. The figure of 700°C might be reached after full power operation towards end of life and he could not imagine temperatures exceeding 400°C if the reactor had only been at low power. DR MARSHAM pointed out that spatial instabilities and a positive void coefficient could be dealt with by appropriate design of the control system and were not inherently dangerous. The vital question was, "why did the means of controlling then not work?". He felt that the nub of the matter did not lie with the intrinsic properties of the reactor. Despite many problems, the fact that it proved possible to derive a source term and predict fission product composition had been an enormous success story. It showed that the major consequence factors of the incident were understood despite the fact that it had not been possible to validate the answers. He took strong exception to the suggestion in para 6viii that Chernobyl could be likened to learning nuclear safety technology by making mistakes.

17. MR GITTUS argued that the mere listing of technical features which were possible contributory factors did not necessarily imply that they were the cause of the accident. An increase in reactivity may have been sparked off by failure of absorbers. It could not have occurred spontaneously. The Russians started to build reactors of this type in 1954 and were building a 600 MW version by 1958. They had a vast fund of experience - something must have triggered a sequence of events which culminated in the accident. DR MARSHAM repeated his view that the methods for controlling reactivity are known - why did they not work?

18. MR GITTUS regarded paragraph 6viii as expressing a public perception. In the eyes of the public, having had an accident, they will find it difficult to believe that the nuclear industry is not operating this way. MR TEAGUE agreed and reminded the Committee that SL1, SPERT and TMI could be adduced to support this perception. DR MARSHAM pointed out that paragraph 6viii did not explicitly associate the remarks with a public perception of the situation and he still regarded it as unfortunately expressed.

19. MR TEAGUE added that at an IAEA meeting during late August, the Russians had promised to provide further particulars. He regarded the statement that none of the papers on the cause of the accident would be available in advance of the meeting as an indication that they were unlikely to be very forthcoming. THE CHAIRMAN deduced that if the Russians were continuing to operate similar reactors at full power they must either know the cause and are able to attribute the accident to a known error or they are being foolhardy. He could not accept the latter and thought the most likely cause was human error.

20. MR DUNSTER commented on the uncertainties associated with the source term, the changing wind directions during the release and the complex and uncertain analyses. The Russian ERLs were ten times those of the UK. He understood the need to evacuate was based on the dose from material on the ground and did not pay heed to the dose from inhalation during passage of the cloud. He suspected that there were places where the UK lower ERL would have been exceeded and where no action had been taken. MR TEAGUE reminded the Committee that the release had occurred at a high level. MR DUNSTER queried whether there had been an inversion layer at any time. He was sceptical of the somewhat cosy view expressed in the paper. It could be over simplified and therefore misleading. The UK would be unwise to accept unquestionly what the Russians say or publish about the effectiveness of the measures taken to protect people. Their perception of what was an acceptable risk may differ from that of the West.

21. PROFESSOR FARMER commented that it would only be acceptable to the Russian Government to shut down a reactor type if the power supply network could cope. He instanced situations where the Russian practice with pipes containing liquid sodium was not in accord with UK. He supported Dr Marsham's view that the situation would not necessarily be improved by doubling the amount of safety work, nor would all accident possibilities be covered. He advocated preparedness for all contingencies including evacuation and action to minimise possible thyroid doses.

22. MR DUNSTER emphasised that one lesson MOD should pay heed to, was driven firmly home to NRPB by Chernobyl. There was a strong case for having a pool of quantitative information available to the public to be drawn on by a wide range of bodies. Each Public Authority, each Government Department, each Local Council expects to have immediate detailed monitoring and other information specific to its area on tap. He thought it would be essential in the next few years to establish this type of information, where it should be held and to whom issued.

23. DR PANTON referred to the CCU(N) meetings which are coordinating the reassessments forced on all Departments by recent activities. The aim was to report by October 1986 and to have re-examined all accident response arrangements. MOD was represented and CSA with other Chief Scientists were also looking at aspects of the aftermath. Failure of the third IAEA forum to generate a complete picture will create pressure for further diplomatic/political action in parallel with international protocol such as through IAEA which would have implications for MOD. In answer to THE CHAIRMAN, DR PANTON said this action had not spawned any new committees. DR MARTIN, DHSS, supported the view that there was a need to keep the public informed - Chernobyl had shown that even the term

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"reassurance" was taken by some people to imply that real harm had occurred, not that the levels were trivial. THE CHAIRMAN agreed that some people did not want to be reassured. He felt that a major difficulty was that Ministers would be subject to a whole range of new problems despite attempts by officials to rehearse by way of accident exercises. In MOD this could easily lead to a real security problem. In MR DUNSTER's opinion the media had behaved responsibly and had not indulged in scaremongering. MR GITTUS thought this was because, when they did so, their switchboard was jammed; nevertheless they were the source of most of the hard information.

STAFF IN CONFIDENCE

CHAIRMAN'S LETTER ON CHERNOBYL : 10 JULY 1986

Defensive Brief on Paragraph 10

Exposure of individuals to very high doses and dose rates of radiation (more than 5 sieverts, say, within a short space of time) is likely to cause serious illness within a period of a few days or weeks and/or death. Very much lower doses and dose rates, operating in a completely different way, may increase the probability of developing delayed effects such as leukaemia and cancers.

For the purposes of estimating the total risk of such delayed effects in populations exposed to low doses, it is generally assumed that risk is proportional to dose, without threshold (the "linear hypothesis"): in other words, there is no difference in total risk between one individual receiving one very high dose, an individual receiving the same total dose over a period of may years, and a population receiving the same total dose shared between them in very small amounts. On this basis, the International Commission on Radiological Protection estimate from studies of survivors receiving low doses from the atomic bombs, and from analyses of the health of patients exposed to substantial programmes of irradiation in hospitals, that the toal risk of fatal radiation-induced cancers is about 1.25 x 10^{-2} Sv^{-1}. This is the direct basis of the numerical analysis in para 10 and 11.

The radiological protection system recommended by the ICRP, which is the basis of UK practice, has as its aim the limitation of occupational risk from exposure to radiation to levels comparable to those experienced by workers in "safe" industries: this is taken to be an individual risk of death in any one year, from occupational causes of 1 in 10000. The system of occupational dose limitation has three components:

(a) no practice shall be adopted unless its introduction produces a positive net benefit;

(b) all exposures shall be kept as low as reasonably achievable, economic and social factors being taken into account;

(c) the dose equivalent to individuals shall not exceed the limits recommended for the appropriate circumstances by the Commission.

For protection against delayed effects such as cancers, the current ICRP limit is 50 mSv per year. Use of this limit, in conjunction with principles (a) and (b) above, leads in practice to the average exposure to radiation workers being only about a tenth of the limit, ie 5 mSv per year. Combination of this average exposure with the risk factor above leads to an average individual risk of 6.25×10^{-5} per year, or 1/16,000; or, in other words, to a risk comparable to that in "safe" industries. Mortality studies among radiation workers, including Authority employees, suggest that the risk in practice is at least as low as this.

The ICRP themselves acknowledge that the linear hypothesis underlying these calculations may well over-state the risk from very small doses, particularly when these are calculated by extrapolation from irradiation involving higher doses delivered at higher dose rates: "in these cases, it is likely that the frequency of effects per unit dose will be lower following exposure to low doses, or to doses delivered at low dose rates." Many radiobiologists believe that the body has active repair mechanisms which can operate at low doses, and that the basic risk, for gamma rays at least, requires two or more coincident events to produce damage. On these assumptions, the same total dose of radiation will have less effect at low dose rates than at high rates. While these beliefs are being tested, at present regulations maintain the cautious approach.

The Authority's response to requests for reassurance on radiation risk from employees with high total lifetime doses, or their Staff or TU Side representatives, should:

(a) admit frankly that on any reasonable assumption employees with higher lifetime doses will run a slightly greater risk that those with lower doses

(b) point out that even on the strict application of the linear hypothesis to the ICRP's total risk factor the absolute level of risk is very low.

(c) stress particularly the probable conservatism of the linear hypothesis, quoting specifically the ICRP comment above.

The Recommendations of the ICRP

1. The International Commission on Radiological Protection was established by the Second International Congress of Radiology in 1928, and is widely regarded as the appropriate body to provide international guidance on standards affecting the whole field of radiological protection. The Commission's policy is to formulate the fundamental principles upon which appropriate radiation protection measures can be based; its basic recommendations, first published in 1928, have been reviewed and revised as required in the light of increasing knowledge and experience. The Commission is essentially different from other international bodies concerned with the effects and control of radiation in that its members are not national or Government delegates. Its authority is therefore directly related to the standing of ICRP members among their scientific peers.

2. The most recent recommendations of the ICRP (1977 and 1980) set out three major principles underlying its system of dose limitation:

(i) Justification - no practice involving the use of ionising radiation shall be adopted unless its introduction is judged to produce a net positive benefit.

(ii) Optimisation - all exposures to ionising radiation shall be kept as low as reasonably achievable, economic and social factors being taken into account.

(iii) Limitation - the dose to individuals shall not exceed the limits recommended by ICRP.

The system of dose limitation is formulated in terms of an "effective dose equivalent", measured in sieverts (Sv). This unit expresses the biological risk from radiation on the same basis for all types of exposure so that the risk can be limited to the same level whether it arises from ingestion or inhalation of radioactive materials or from external radiation, and irrespective of the type of radiation or its spatial distribution among the tissues of the body. The dose equivalent is derived by modifying the absorbed dose (in Gy) by a quality factor; Table 1 shows the values of the quality factor for different types of radiation:

Table 1

X-rays, gamma rays and electrons	1
Neutrons, protons and singly-charged particles of rest mass greater than one atomic mass unit of unknown energy	10
Alpha particles and multiply charged particles (and particles of unknown charge) of unknown energy	20
Thermal neutrons	2.3

3. To ensure protection against non-stochastic effects the ICRP recommend for workers an annual effective dose-equivalent limit for any tissue of 0.5 Sv. The exception to this is the lens of the eye in which opacities may be produced by irradiation. For this particular tissue the limit is 0.15 Sv. If these limits are observed then it is unlikely that, over a working lifetime, the threshold for non-stochastic effects will be reached. For stochastic effects, which by definition have no threshold, the ICRP has derived its estimation of risks in terms of dose-equivalent. These, for induction of fatal cancers in certain organs, and for hereditary risks* are shown in Table 2.

Table 2

Organ or tissue	Risk factor (Sv^{-1})	Effect
Red bone marrow	2×10^{-3}	Leukaemia mortality
Bone	5×10^{-4}	Bone cancer mortality
Lung	2×10^{-3}	Lung cancer mortality
Thyroid	5×10^{-4}	Thyroid cancer mortality
Breast	2.5×10^{-3}	Breast cancer mortality
All other tissue	5×10^{-3}	Cancer mortality
Any other single tissue	1×10^{-3}	Cancer mortality
Uniform whole-body irradiation	10^{-2}	Cancer mortality
Uniform whole-body irradiation	4×10^{-3}	Hereditary effects within first 2 generations

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* It should be noted that no hereditary effects have been detected in humans, either in bomb survivors or in medical cohorts. The estimates are formed by cautious extrapolation from animal experiments and may be regarded as plausible upper limits.

Using these estimations of risk there can then be derived a dose-equivalent of uniform whole-body irradiation which if not exceeded will place workers in the same category of average mortality risk, i.e. 10^{-4}, as workers in other safe industries. The ICRP has recommended that this be limited annually to 50 mSv.

4. The dose limitation system is also based on the principle that the risk should be equal whether the whole body is irradiated uniformly or non-uniformly. If the latter, then a weighting factor is used to reflect the risk of irradiation to certain tissues (see Table 3). This takes account of the radiosensitivity of various tissues and the proportional risks of irradiation. The annual dose-equivalent in any tissue must be multiplied by its weighting factor, and the sum of such separate dose-equivalents should never be greater than the limit for uniform whole-body irradiation of 50 mSv. For such tissues the limit for non-stochastic effects must also, of course, apply. For the thyroid gland, for example, the stochastic dose-equivalent limit obtained by dividing the limit of 50 mSv by the thyroid weighting factor 0.03 would give an implied dose-equivalent of 1.7 Sv. This however exceeds the non-stochastic limit of 0.5 Sv which must be the overriding constraint.

Table 3

Tissue	Weighting Factor (W_T)
Gonads	0.25
Breast	0.15
Red bone marrow	0.12
Lung	0.12
Thyroid	0.03
Bone surfaces	0.03
Remainder	0.30

5. The Recommendations of the Commission cover in great detail the limitation of ingestion or inhalation of particular radionuclides so that the primary recommended limits are met. For occupational exposure to radioactive materials the Commission believes that the time over which the dose equivalent should be integrated is a working life of 50 years. The total dose equivalent in any tissue over the 50 years after intake of a radionuclide into the body is termed the Committed Dose Equivalent. The annual limit on intake (ALI) of a radionuclide is a secondary limit designed to meet the basic limits for occupational exposure recommended by the Commission and is derived from the stochastic and non-stochastic limits such that the ALI is the greatest value of the annual intake which satisfies both of the following conditions:

(a) the sum of the committed dose equivalents to a particular tissue (taking account of the relevant tissue weighting factor) is less than 50 mSv,

(b) the total committed dose equivalent is less than 0.5 Sv,

Finally, for convenience, the Commission recommends values of derived air concentration (DAC). The DAC for any radionuclide is defined as that concentration in air which, if breathed for a working year of 2000 h under conditions of "light activity", would result in the ALI by inhalation.

8294

File No. 29.7

Mr M A W Baker

cc SAG

ccs: Chairman
Mr Simeone
Dr Lomer
Dr Gittus ✓
Dr Pearce

Note to Staff about Chernobyl: Defensive Brief

You may be interested to see the final version of the Defensive Briefing on Paragraph 10 of the Annex to the Chairman's letter of 10th July. This has been prepared by Dr Pearce in the light of comments in particular from Dr Lomer. I have sent out this final version to Senior Administrators.

E Hollis

Employee Relations Branch
28th July 1986

F

SAX (in confidence) & not for further distribution:

JHG.

CENTRAL ELECTRICITY GENERATING BOARD

Sudbury House, 15 Newgate Street, London EC1A 7AU. Telephone 01-634 5111

From the Chairman
The Lord Marshall of Goring Kt CBE FRS

CONFIDENTIAL

Mr. Alastair Goodlad, MP
Parliamentary Under-Secretary of State
Department of Energy
Thames House South
Millbank
London SW1P 4QJ

28 July 1986

Dear Minister,

The other Chairmen of the Nuclear Industry and I have had a wide ranging discussion about the nuclear issues facing the UK and would like to advise you of our thinking. We applaud the Secretary of State's speech of 26 June 1986 which reflects the unanimous view of the industry on the importance of nuclear power in the UK.

Considering first the Magnox stations, may we remind you that there are a total of 26 reactors operating in the UK with a total net capability of 4159MW. In addition, there are single reactor stations of the UK design in operation in Italy at Latina and in Japan at Tokai Mura.

Electricite de France still operate 4 Magnox reactors in France and one reactor at Vandellos in North Spain. All of these reactors are subject to a comprehensive safety review after about 20 years operation and the various Licences will each need to satisfy their respective licencing Authorities that continued operation is satisfactory in the light of modern practices and standards. Before the accident at Chernobyl, the conduct of the Long Term Safety Reviews in the UK was being raised in some quarters as a matter of public concern. The Chernobyl accident has been used by those opposed to the continued operation of Magnox stations in the UK to whip up concerns amongst the general population; a task that has been made that much easier because of some superficial (and misleading) similarities in features between Magnox and RMBK reactors.

The pressures in Italy have been much greater however, and there is still the real possibility that the Italian Government will decide to "sacrifice" Latina in an attempt at reducing pressure on the remaining nuclear programme. The matter is likely to come to a head at a Conference the Government is arranging to review the nuclear issue in November or December.

The Japanese are nervous but not under any great pressures; the French are relaxed but have expressed a wish to discuss Magnox safety issues with us.

The safety of the Magnox stations on a day to day basis is not in question; a position that is fully supported by the NII. However, there are genuine technical issues to be addressed in relation to the longer term operation of Magnox stations. The NII's requirement that we should make comparisons with modern safety criteria applied to the very latest stations has identified 3 principle areas where detailed technical debate is ongoing between Licencees and the NII. These are the integrity of the steel reactor pressure vessels, the seismic capability of the plants and the extent to which full numerical risk analysis techniques should be applied. Matters are complicated still further by the fact that the current safety cases for individual stations are not identical. It is most important that this technical debate which is fundamental to the Licencing Process in the UK should be allowed to run its course to the conclusions that either the owners or the NII may reach without being prejudiced by public fears or perceptions.

To summarise, the Magnox issues are complex. The operation and safety assessment strategy, the approach to public responses and publication of safety cases adopted by one Licencee will restrict freedom of action of the other Licencees. We recognise the importance of providing you with coherent UK advice which takes account of possible external influences and we have therefore arranged to reinforce the existing Magnox Technical Group. A list of the revised tasks of this Group is appended at Attachment 1. We have agreed that an industry meeting, at Chairman level will be held, if these Magnox discussions suggest one is needed.

It is important to remember that these Long Term Reviews are the business of the operators not something imposed by the NII. It is therefore important that the main effort on these Reviews should come from the operators and the main justification in public for the continued operation of the Magnox stations should also come from the operators. The NII response to these Reviews need not be elaborate nor definitive, although to the public it must carry conviction and to the operators it is an important supplement to the regular NII licensing process which takes place at least once every two years. Unfortunately the public impression is that these Reviews are something of vital importance which determine whether the NII will permit the continued operation of the Magnox stations or not. Clearly we need to explain the philosophy of our regulatory system much more carefully and we the operators need to pay much greater attention to the presentational aspects of Magnox safety to the public.

The AGR position is more straightforward. All parties agree upon the overriding need to obtain maximum output from the operating stations as soon as possible. An important part of this exercise is the establishment of on-load refuelling at the highest achievable power levels on all AGR's. There is still much work to be done before the performance of newly commissioned AGR's at Dungeness B, Hartlepool and Heysham I reaches a satisfactory position. Following on from the Long Term Magnox Safety Reviews we may possibly have need to look again at the early AGR's to come closer to the Heysham 2 safety philosophy.

As to a future AGR, the difference in policy between CEGB and SSEB is well known. There is good co-operation between the two Boards with joint funding of NNC work aimed at preserving the AGR option at least into the next decade.

/ ...

Particular aspects that are being examined by NNC as a matter of high priority are:-

(i) A dry, rather than wet, spent fuel route at the reactor.

(ii) A larger buffer store (to permit discharge of a large part of the core to facilitate major repairs).

(iii) Some form of vented containment which could reduce the consequences of unlikely accidents.

(iv) The feasibility and economics of an AGR refuelled predominantly off-load. This Study is requested by CEGB because this might simultaneously avoid the complications of on-load refuelling and simplify the safety case sufficiently to be economically attractive. But those attractions have to be weighed against acknowledged benefits of on-load refuelling to see, on balance, if the present AGR concept is best.

CEGB judges that it would not be in a position to order a further AGR for some time. This is because, in the light of experience gained to date, it is CEGB's view that further optimisation of the balance between safety and economics would be prudent and a Public Inquiry, of whatever sort, would postpone start of construction to 1990 at the earliest.

The SSEB take the view that a next AGR should be based on Heysham II/Torness whilst taking into account possible benefits from (i) to (iii) above, and that main construction could start in mid 1988 if an Inquiry could be avoided.

Turning to the question of waste management, there is little that has not already been said. NIREX have the responsibility for developing waste disposal sites and they must be allowed to get on with the job. NIREX are also exploring the "sea disposal" option which you will appreciate is a sensitive issue. The Industry is continuing its investigations for a central dry store for irradiated AGR fuel.

On the PWR front, CEGB recognises that Chernobyl will raise additional questions which must be addressed. Up to the present moment there is nothing about the Chernobyl accident which would make us wish to change the design of Sizewell B. It is implicit in the Sizewell B risk assessment that some further improvements might be gained if the containment was vented or the concrete base mat cooled. We shall naturally look further into these options following Chernobyl, but we know that the gain, if gain there is, will be a reduction from a level of risk which is already satisfactorily low. In the Sizewell B risk assessment we had already considered cases in which the containment is fractured and those in which the base mat melts.

/ ...

An important issue brought into focus by the Chernobyl accident is the adequacy of current Emergency Planning arrangements and the public perception of these Plans. As with the Magnox safety issue, we think it important that you are provided with a coherent view. Here too we are reinforcing existing collaboration arrangements to ensure that the consistency of emergency planning arrangements across all UK nuclear establishments operated by CEGB, SSEB, BNFL and UKAEA are systematically evaluated and that views on the need for change in the light of Chernobyl are co-ordinated. Attachment 2 gives the tasks allocated to the relevant Working Group. We shall of course take advantage of the work of the Civil Contingency Unit and as individual managements will need to keep in close touch with NII thinking as it evolves.

The Industry as a whole has become very concerned about escalating regulatory demands on our operations. We do of course accept the need for a safety philosophy which demands of us constant vigilance and constant escalation of our proof of safety, but that is quite different to the demands to reduce actual emissions from levels which are already unimportant to levels which are trivial and where the demands upon us are more related to the popular perception of risk than the actual risk.

Our final topic is the difficult one of public acceptance of nuclear power. We are pleased that you are taking a personal interest in this matter. Government support for nuclear power is vital at the present time. As you are aware the Nuclear Energy Information Group (NEIG) is active in the presentation of information to Trade Unions, Political Parties, and is developing long term information programmes. The Group also analyses public opinion through public attitude surveys. BNFL are currently involved in an advertising campaign encouraging the public to come and see for themselves the Company's operations at Sellafield. As you know the CEGB will be launching a local advertising campaign to provide information to local communities about the operation of nuclear establishments as an important way of informing the public about different apects of nuclear power. We also recognise the need to be seen to be open about all aspects of our operation although this may be uncomfortable at times. There is also a pressing need to tackle public concern and ignorance about radiation and its effects, particularly at low levels of exposure, and we are considering how best to do this. We recognise the importance of gaining third party support since nowadays we fear that CEGB and even NII spokesmen have no more credibility in the minds of the public than the most extreme anti-nuclear spokesmen. We have received a number of unsolicited letters of support from academics and on an individual basis, we have been encouraging academics and industrialists to take opportunities to present the facts about nuclear power as they see them. The Royal Society is about to launch a major campaign to improve the general public's appreciation of science and to improve the public's perception of risk. The Royal Society will be seeking financial support from the nuclear industry as well as other industries for their new "high visibility" effort. The Watt Committee which represents all the scientific and engineering institutions in the energy field are also anxious to take on a "higher visibility" role by providing a panel of "third party spokesmen" on all energy matters, particularly nuclear matters. We are therefore encouraging the Royal Society and the Watt Committee to co-ordinate their activities closely and probably one will conentrate on scientific and the other on engineering matters. There are a few other groups that might wish to promote the need for the nuclear power option but we do not expect rapid results. The most pressing need is to educate people to the fact that living is all about putting relative risks in perspective and that nuclear power ought to be at the bottom of the list of risks.

From within the Industry, we are examining how we can best implement the open information policy both in terms of reporting and publiation of incidents and in terms of making technical information more widely available. It goes without saying that we are happy to defend the technical competence of our staff to anyone. We must however find a way of doing this without adversely affecting the businesses that we are charged to run.

We are in lively discussion with the Department of Energy and the Department of the Environment about the classification and publication level for incidents down to the most trivial kind. We hope that, in this way, we can implement the Government's commitment to an open information policy but not simultaneously give grossly exaggerated weight to what are, in reality, unimportant events. We also hope to develop a "Halsbury Scale" as an impartial way of signalling to the public the qualitative importance of each event.

We are looking forward to discussing these issues and any others that you may wish to raise with us on 28 July.

Yours sincerely,

ATTACHMENT 1

Magnox Technical Liaison Group

(Chairman: Dr B Edmondson, CEGB)

Revised Tasks

1. To encourage consistency of approach to safety aspects of UK Magnox Stations.

2. To examine in this context the progress of Long Term Safety Reviews.

3. To examine options for similar harmonisation with Magnox plant operators overseas.

4. To identify problems, both specific and of general policy purport, stemming from Magnox plant safety issues.

5. To respond to options for public dissemination of information on Magnox plant safety.

6. To encourage a consistent approach to public responses on particular Magnox plant safety issues.

7. To co-ordinate use of resources to these ends.

8. To resolve such problems as lie within the competence of the Group, referring others for resolution.

9. To Report regularly on progress, and urgently as the need arises, to Senior Management of the CEGB, SSEB and BNFL.

ATTACHMENT 2

CHERNOBYL - TASKS RELATING TO REVIEW OF UK NUCLEAR SITE EMERGENCY PLANS

Mr R R Matthews was requested to carry out a review of UK Emergency Plans for Nuclear Sites with the following terms of reference:-

"In co-operation with appropriate representatives of the organisations concerned to examine the Nuclear Site Emergency Plans of the CEGB, SSEB, BNFL and UKAEA with the following objectives:

1. To encourage consistent principles and practices embodied in the Emergency Plans.
2. Where any significant difference may be identified to bring it to the attention of the organisation concerned, with the intent that all interested parties should have available an explanation for use in public discussion and debate.
3. To collect views on the possible need to modify or amplify the Plans as a consequence of information and data derived from the Chernobyl accident.
4. To Report regularly on progress, and urgently as the need arises, to Senior Management of the CEGB, SSEB, BNFL and UKAEA.

MEMORANDUM

Your Ref.
Our Ref.
Tel Ext. 1390

To Dr F R Allen, SRD

Subject WESTINGHOUSE PRESENTATION ON THE CHERNOBYL ACCIDENT

The W presentation at Booths Hall was organised by John Appleby, PMT, and A C Hall, PPP. It was attended by the CEGB; HSD, PMT, NDA, GDCD and BNL; also NNC and SRD.

SRD attendees were F Abbey, P N Clough, W Nixon, A N Hall and P G Bonell.

Notes of the presentation are attached.

PG Bonell.

P G Bonell

22 July 1986

Enc

Copies to:

Dr J H Gittus
Prof H J Teague
Dr M R Hayns
Dr R S Peckover
Mr F Abbey
Dr P N Clough
Dr A N Hall
Mr W Nixon
Dr M L Brown
Mr R N H McMillan
Mr E Bevitt
Mr R Clasper
Mr R F Cox
Mr K M Leigh

W PRESENTATION AT BOOTHS HALL, KNUTSFORD, ON THE CHERNOBYL ACCIDENT

The Westinghouse presentation, on Tuesday 15 July 1986, at NNC Knutsford, stated the aims of their programme for the Chernobyl reactor accident, which was to:

- Understand RBMK-1000 plant design, operation and safety case
- Compare RBMK-1000 with PWR technology
- Understand Chernobyl accident
- Investigate lessons learned

W said that technical information on the RBMK reactor design and operation was limited for Chernobyl units 3 and 4, but they had available to them several individuals with first-hand knowledge of the Soviet design and operational philosophy. W were using their own resources on:

- Reactor design and operational procedures
- System analysis and integration capability
- Lessons learned from TMI-2
- Severe accident methodology

They also had interaction with the USNRC and USDOE technical staff.

The general description of the reactor was taken as read and only those parts W felt needed careful discussion in making their technical points were described in any detail.

In the lengthy free exchange of views between those present on core physics and the thermal hydraulics of the reactor, it was obvious that the views of the meeting on what had caused the accident at Chernobyl were not in any way fixed. W admitted that they had not done many calculations but rather more literature surveys. On the other hand, SRD and the CEGB's BNL had done, and were continuing to do, a fair amount of calculation on the physics and thermal hydraulics of the reactor. Winfrith have been associated with these calculations but they were not present at the discussion.

The meeting also discussed the likelihood of a steam explosion or zirconium pressure tube failure as alternative links in the accident chain. There were differences in views between the UK and W which were not resolved. These points are enlarged on in Annex 1 by A N Hall.

The meeting agenda included a discussion of the RBMK safety case for which little information was available.

Source terms and accident consequences were summarised by SRD with questions from the meeting.

W summarised the specific RBMK characteristics which may have influenced the severity of the Chernobyl accident. These included:

- Operating margins
- Reactor coolant flow control
- Positive moderator coefficients
- Shutdown system design/operation
- Emergency systems actuation/operation
- Containment
- Accident design margins

Some specific features of the RBMK which appeared not to have worked and therefore played no mitigating role in the Chernobyl accident severity were:

- ECC system design
- ECC system may not have been actuated
- Containment did not include reactor core
- Suppression pool
- Hydrogen mitigation system did not appear to work

W concluded that the RBMK design has a very narrow acceptable operating region:

- Depends on continuous positive operation action to remain within acceptable limits
- Deviations can result in 'fast' transients

The RBMK design does not have recoverability strength:

- Design based on prevention rather than mitigation
- Only designed for limited range of accidents

W said the Chernobyl accident had not made much impact in the US in comparison with its impact on Europe. This was probably because the US population was not directly affected and also because of general anti-Russian feeling in the US. W said that the specific lessons learned from the Chernobyl accident with potential impact on LWR safety were limited to:

- Containment performance for severe accidents
- Hydrogen burning potential

- Emergency planning

- Effect of operator action

Most of the lessons learned from Chernobyl are already addressed by post-TMI-2 upgrades to plant.

W said that they had information that historically there had been 3 core damage accidents to the RBMK system in 80 reactor years:

- one major release

- two limited release

Extrapolating (with no improvements) with 19 units operating:

C D Probability = 0.5/R-year (one per 2 years)

C M Probability = 0.2/R-year (one per 5 years)

The CEGB Sizewell 'B' PMT presented their views on how Chernobyl would affect Sizewell 'B' PWR.

The Inspector's report was expected in October, together with NII approval.

The PMT thought that questions may be asked by the Inspector of the relevance of Chernobyl to Sizewell 'B'.

In view of the Chernobyl accident, the PMT had set themselves the task of reviewing likely questions on:

- Emergency planning review

- A look at reactivity results - fast transient, inherent characteristics, operator action, moderator coefficients, pellet clad interaction, boron faults.

They expected to review containments features such as filter vents and other ideas. The containment by-pass leading to loss-of-coolant would be re-examined ('V' sequence - SG tube rupture, etc).

With aircraft crash there were small margins.

Hydrogen explosions would be re-examined. The use of H_2 in the volume control tank and gases to radwaste plant using H_2 will be looked at.

Operator error was already being addressed in detail and this would continue.

Operator recovery actions will be examined.

The consequences of beyond the design basis accidents need further examination. What can we do if they occur?

W suggested that the PMT starts by reviewing its Degraded Core PRA.

W overheads of their presentation are available.

P G Bonell

16 July 1986

ANNEX 1

Taken from Section 2 of the draft AEX paper 'Restart of operation of the Winfrith Reactor', by Dr J H Gittus, 18 July 1986.

Finally, fuel overheating could have occurred because the delay in actuation of the engineered safeguards exceeded the time required for a significant fuel temperature rise in the particular accident that occurred. It is important that core cooling be established rapidly. If core cooling were delayed, the core could dry out and fuel temperatures could rise to those at which substantial oxidation of the zircaloy fuel clad could occur (over 1000 C). If supplies of water were then supplied to the dried out fuel, the zirconium oxidation might be stoked by the supply of water and the heat released could accelerate core damage to fuel meltdown, rather than bring about quenching of the hot material. Hydrogen would also be produced by this reaction.

Following fuel overheating, core damage could propagate in a number of ways. Steam explosions could occur if fuel melted and mixed with water. Alternatively, the pressure tubes might rise to high temperatures, be weakened and fail, releasing steam and hydrogen into the graphite moderator as suggested by Westinghouse.

For fuel to reach high temperatures and melt, fuel channels would have to dry out. Steam explosions could not therefore occur unless liquid coolant re-entered the dried-out channels. Thus, there would have to be water remaining in other parts of the pressure circuit that could re-enter the channel at some stage, or emergency injection to the channel would have to occur to reflood it. If fuel melting occurred as a result of a reactivity transient, then although water would be forced out of the channels by the increase in heat transfer, the pumps would restore the flow as the transient subsided. The general geometry of a long tube containing molten material is reminiscent of some of the configurations which have been used in experiments to promote such interactions (eg a "shock tube"). The resultant explosion might displace the stand-pipe closure expelling steam, hydrogen and molten material into the reactor hall. The hydrogen might ignite and in addition if the interaction involved unoxidised Zr, expelled particles of this could burn rapidly. In thermal explosions involving molten Aℓ, chemical explosions involving the rapid oxidation of finely divided Aℓ are often observed. The combination of steam pressure, hydrogen and Zr burning would probably collapse the relatively light reactor hall, causing the overhead crane to fall as reported.

A difficulty in interpreting the in-core explosion as a steam explosion arises if, as appears likely, the circuit pressure were close to its normal value of about 7 MPa at the time of the explosion. Various studies have concluded that a steam explosion is difficult to trigger at high pressures (>1 MPa). There is, however, evidence that a steam explosion occurred during a reactivity transient in an in-pile experiment at EG&G Idaho at a pressure of 6.4 MPa, so a steam explosion in the Chernobyl reactor at normal operating pressure is a possibility. Furthermore, if pressure tube failure occurred during the melting transient the resulting depressurisation would reduce the local system pressure.

For pressure tubes to rise in temperature and weaken as suggested by Westinghouse, either the rate of heat generation in the fuel following channel dry out would have to be not much greater than that in normal operation or the fuel would have to melt and relocate prior to pressure tube failure so as to come into contact with the pressure tubes and create hot spots. In normal operation, the maximum graphite temperature is 550C and the temperature close to the pressure tubes approaches the coolant temperature (the maximum graphite design temperature of 750C is not reached in normal operation). As Chernobyl Unit 4 had been at low power for a couple of hours prior to the accident, the graphite and pressure tube temperatures would probably have been in the range 300-400C. The integrity of the pressure tubes would be in doubt once they reached a temperature of about 700C. Following channel dryout, heat would be transferred from the fuel to the pressure tube walls mainly by thermal radiation. Simple scoping calculations indicate that if heat were generated in the fuel at three times the normal operation rate, the fuel would have risen in temperature to the clad melting point (1850C) by the time the pressure tube wall had reached 700C. These temperatures would be reached at about 17s after a step increase of power and dryout, so could occur within the 20-25s required for full insertion of control/shutdown rods. For higher powers, fuel melting would occur before pressure tube failure, perhaps leading to pressure tube failure by fuel relocation and contact with the pressure tube. For lower powers, pressure tube failure could occur before fuel melting, but only if the delay before reactor shutdown exceeded the already long period of 20-25s believed to be required for full insertion of the control/shutdown rods.

If the pressure tubes weakened and failed due to high temperatures, steam and hydrogen generated by oxidation of zirconium would be rapidly released into the graphite moderator. A vessel surrounds the moderator, but it and its bursting disks are only believed to be capable of coping with a single tube failure. Thus failure of several pressure tubes might fail this vessel and disrupt the core, perhaps giving the appearance of an explosion. Of course, water would flow from the steam drums into the breached pressure tubes and steam explosions might occur in this case also. The hydrogen released could also cause an explosion if it mixed with air, but the graphite moderator of the Chernobyl reactor was inerted with a helium/nitrogen mixture and the core was surrounded by a nitrogen blanket, so an in-core hydrogen explosion could not have occurred unless the inerting systems had failed.

In either the case of steam-explosions occurring in-core or the case of pressure tubes failing through high temperature weakening, hydrogen would be released into the reactor building and reactor hall. There it would mix with air and be ignited by hot fuel debris ejected with it from the core, causing the reported hydrogen explosion(s) and the structural damage seen in photographs.

Breach of a fuel channel would probably prevent cooling of the fuel in that channel and damage inlet pipework, leading to a loss of coolant. As the coolant system on RBMK 1000 reactors is divided into two separate loops however, only one loop might suffer a loss of coolant accident if the initial damage were sufficiently localised. If only one loop were breached, the core might be treated as three separate regions: the initial damaged region, which might not be coolable even if ECCS water were available; the rest of that circuit, which would undergo a loss of coolant accident with long term failure of ECCS; the other circuit, which would undergo an intact circuit fault with long term loss of feed. The different regions would have different thermal time constants and in such a situation, the damaged region of the core could grow and release volatile fission products over an extended period of time. In the case of Chernobyl Unit 4, the decay heat would have been augmented by heat released by burning zirconium and graphite in air and this would have accelerated the propagation of core damage.

Containment of fission products released from pressure circuit

Reactors in which the coolant becomes significantly contaminated with radioactive materials during normal operation are provided with secondary containment structures so that a radiological hazard would not arise in the case of a large loss of coolant accident. These secondary containment structures are designed to withstand the pressurization resulting from a large loss of coolant accident and in the case of large modern PWRs, they are also assessed to be capable of withstanding the hydrogen burns that might follow core degradation and oxidation of zirconium fuel clad by steam. Indeed, a hydrogen burn did occur in the secondary containment building at Three Mile Island, but the containment remained intact. It is therefore clear that secondary containment structures can significantly reduce the consequences of beyond design basis accidents by either preventing or mitigating releases of fission products to the environment.

CHERNOBYL UNITS 1 - 4

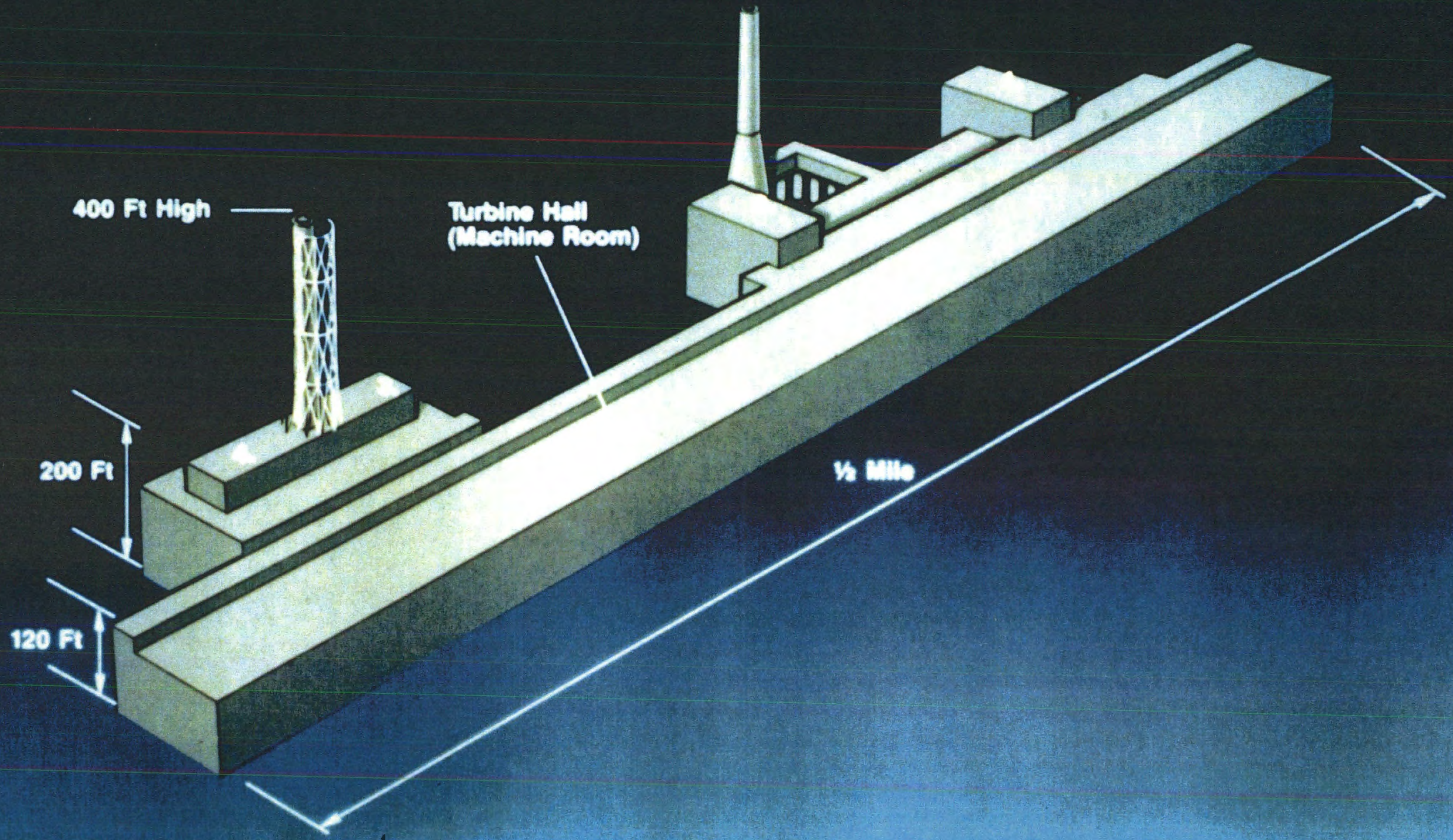
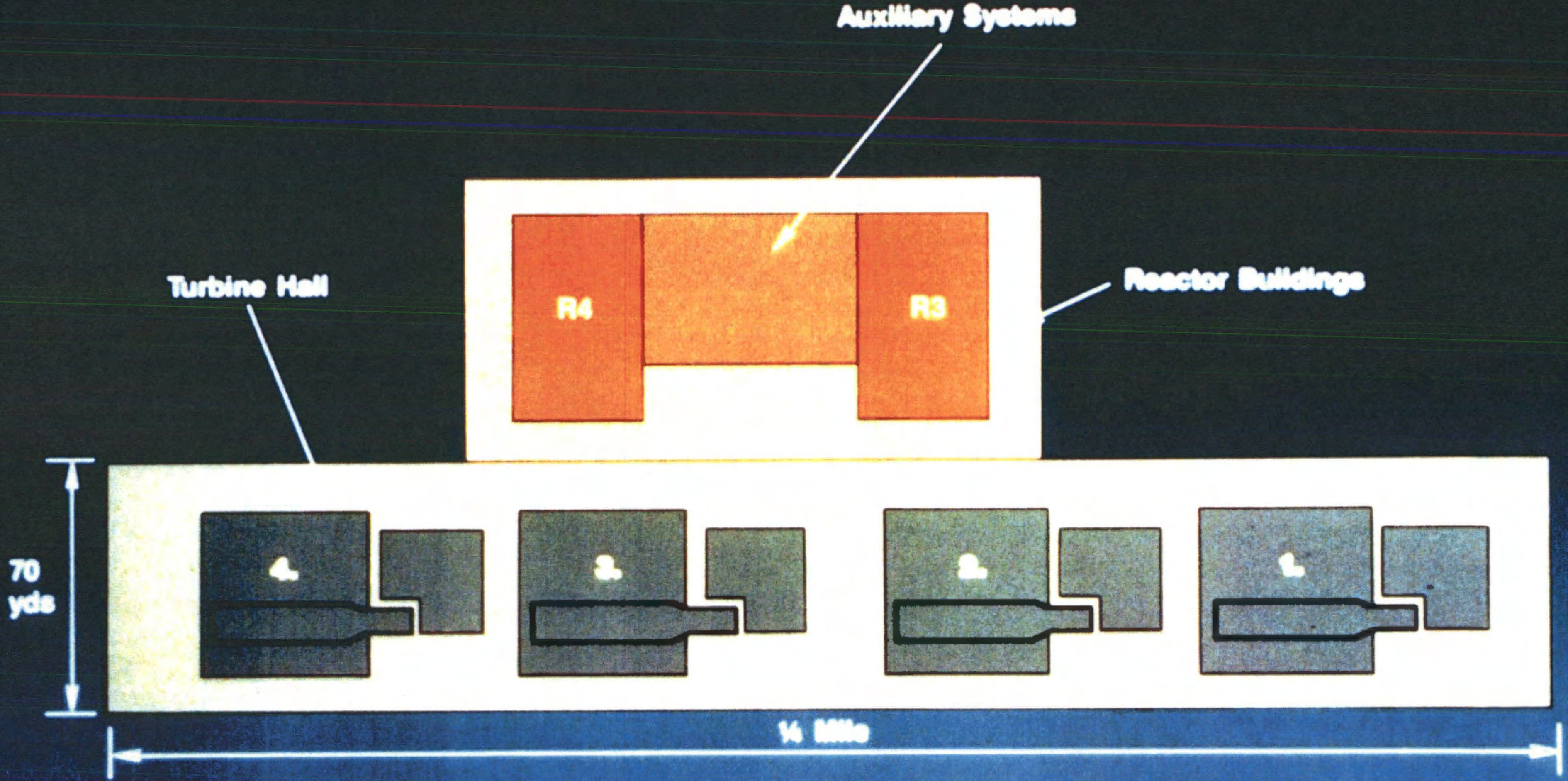


FIG 2

PLAN OF CHERNOBYL 3 AND 4



F. 3

CHERNOBYL - 4

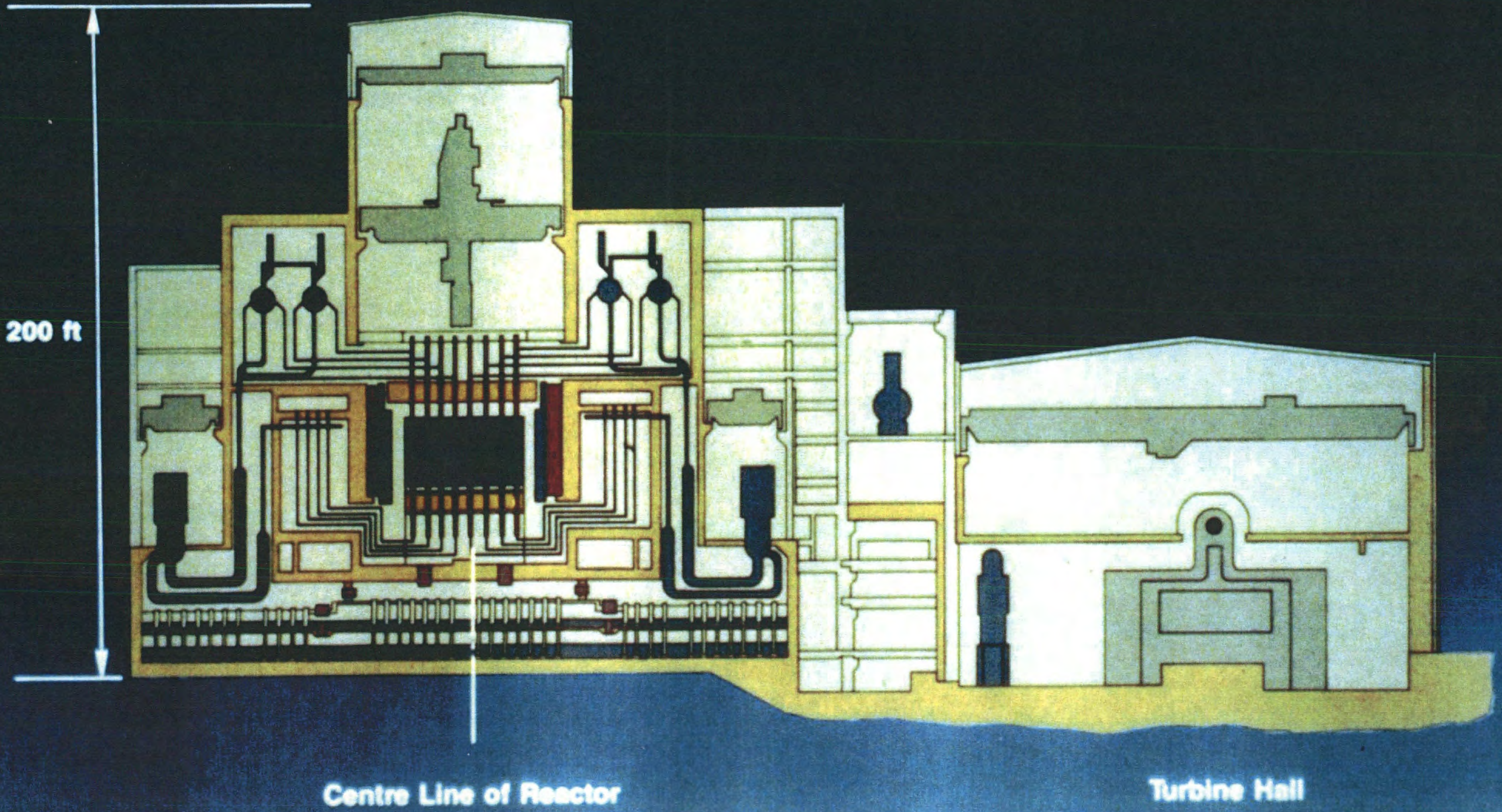


FIG. 4

SECTION THROUGH RBMK REACTOR

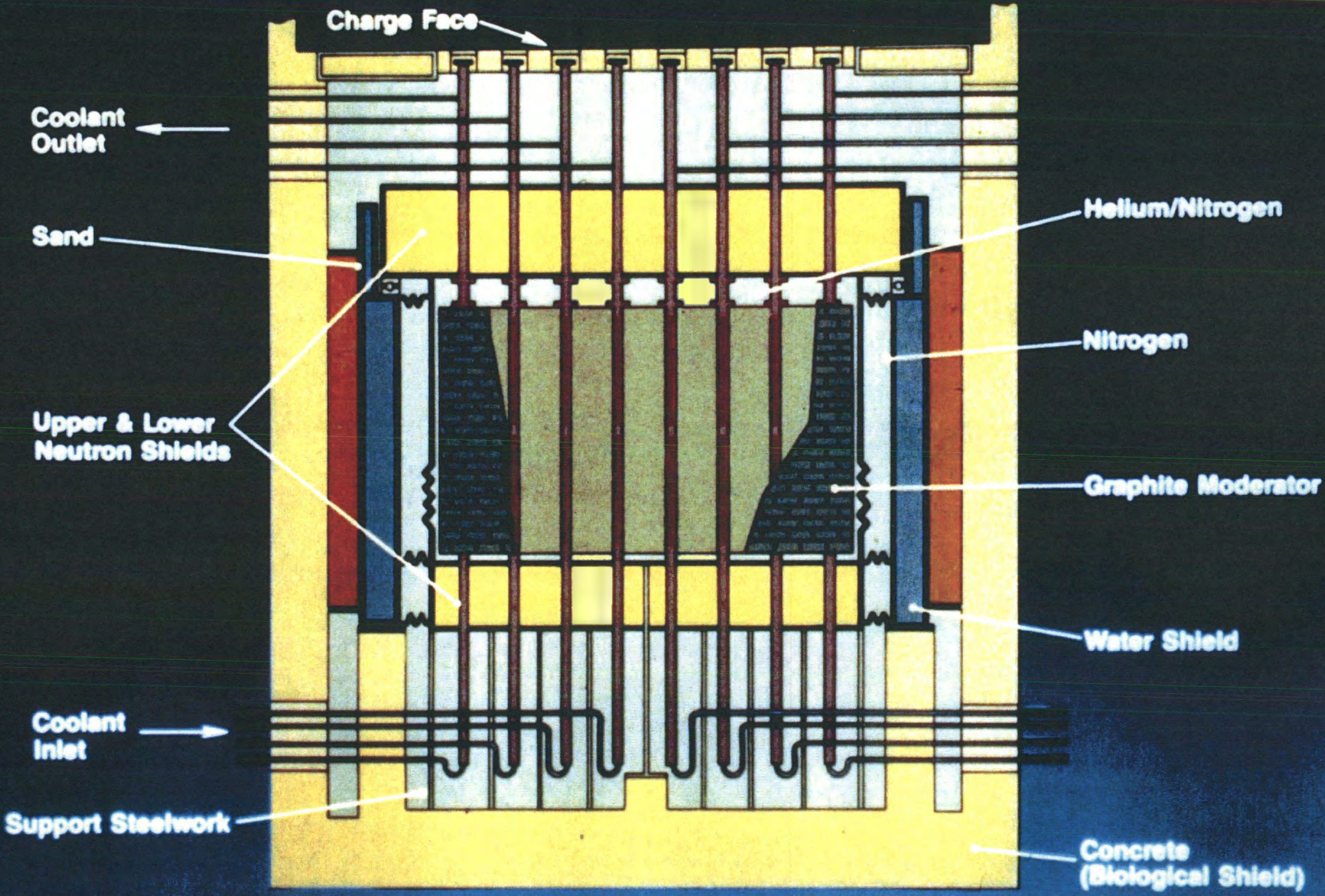
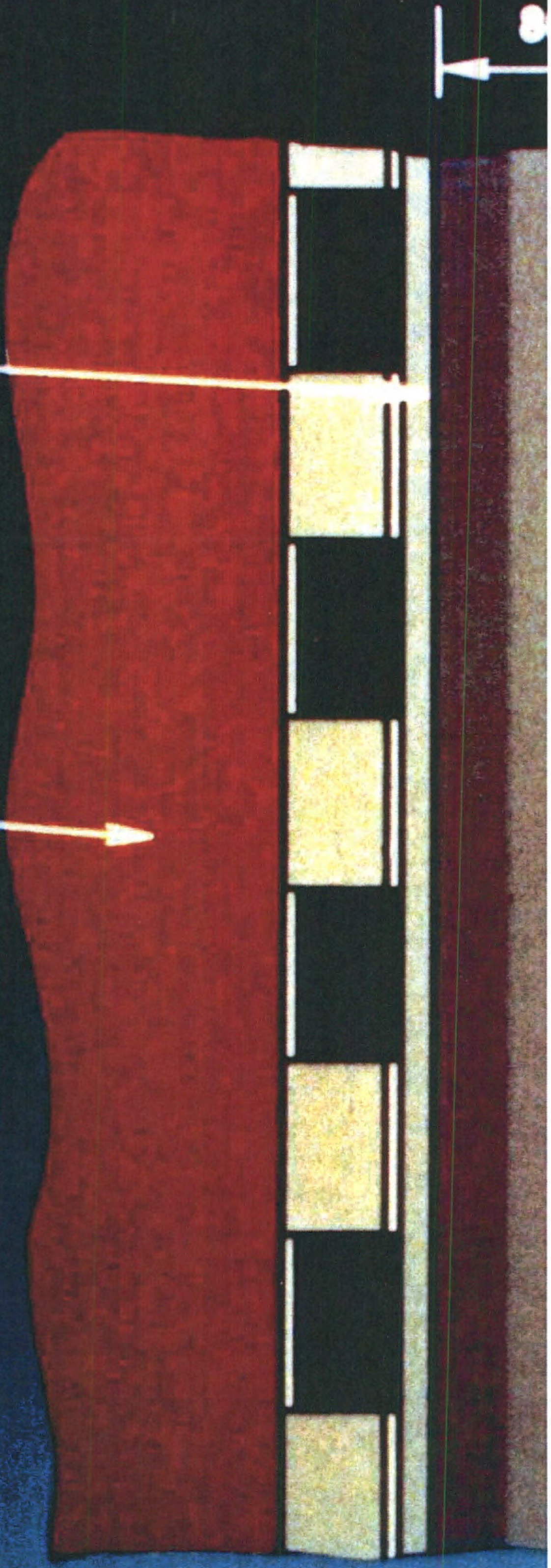


FIG 5

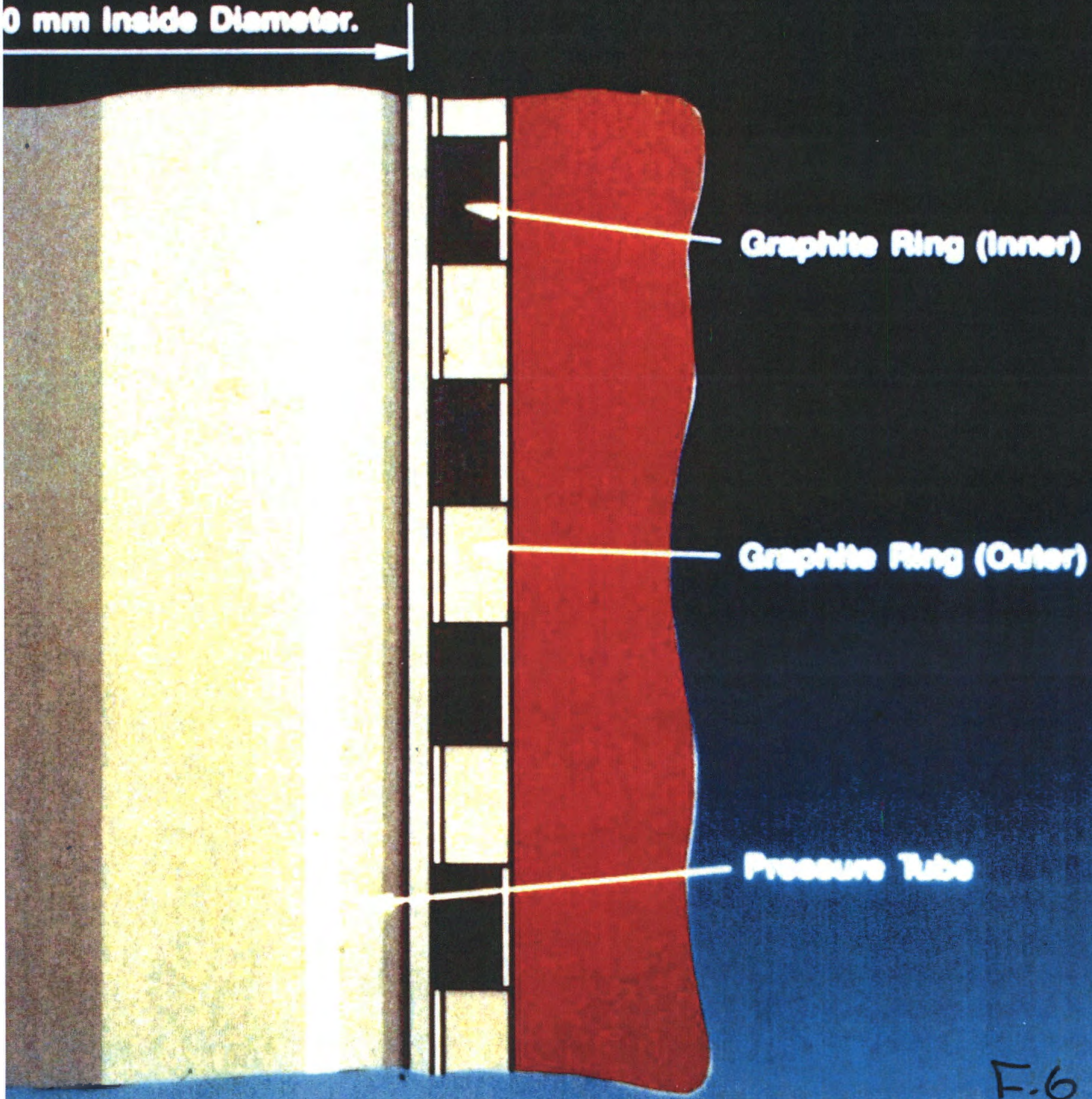
ARRANGE
TUBES I



4 mm Wall
Thickness.(Zr-2½Nb)

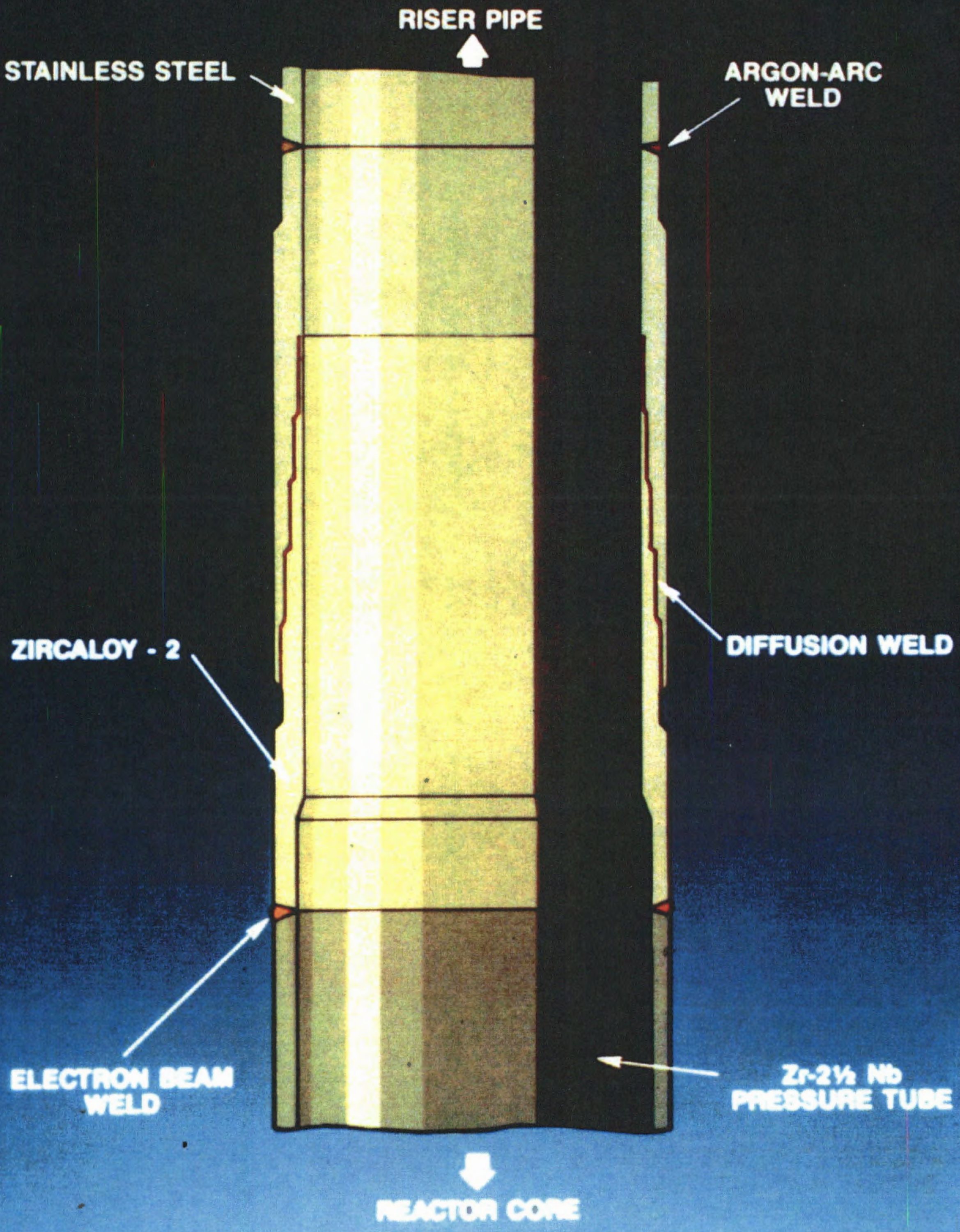
Graphite Moderator
Stack

MENT OF PRESSURE
N REACTOR CORE



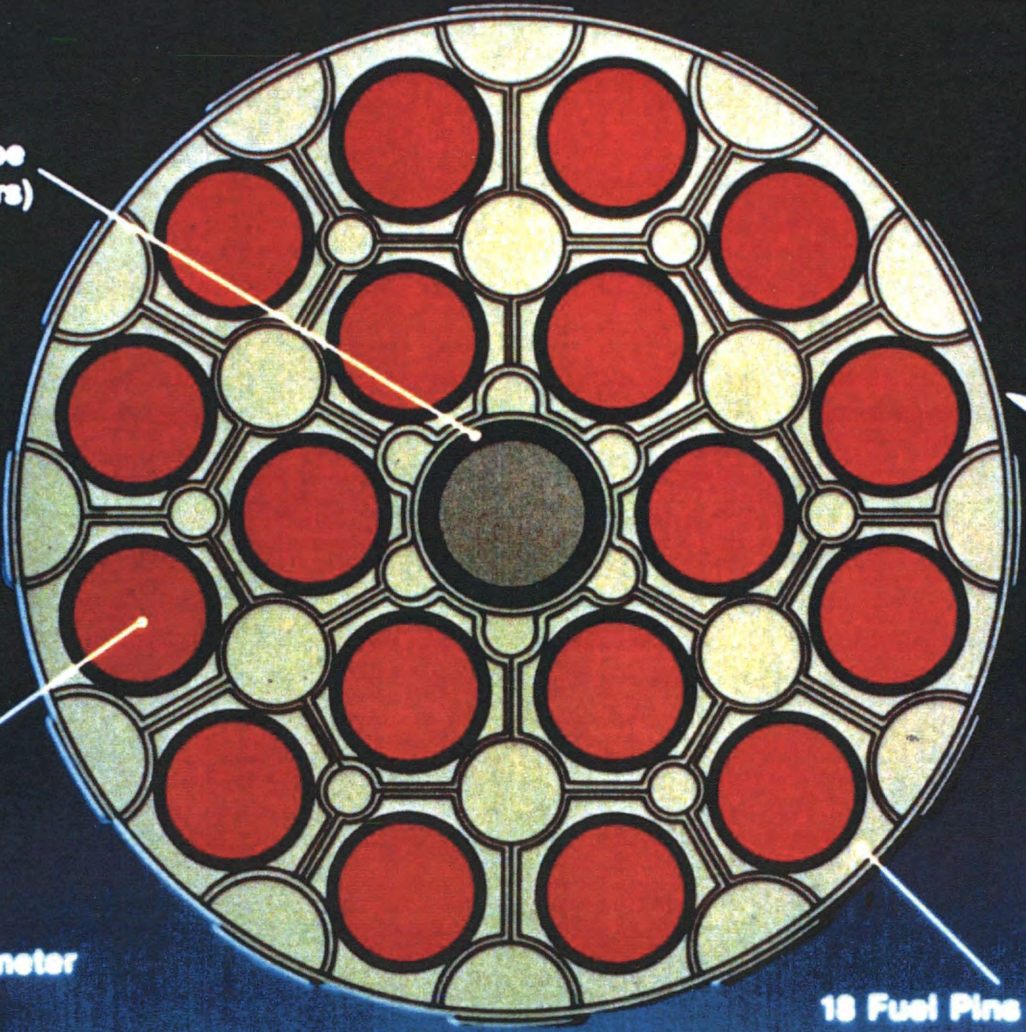
F.6

ZIRCONIUM - STEEL JOINT



F7

SECTION OF SPACER GRID & FUEL PINS



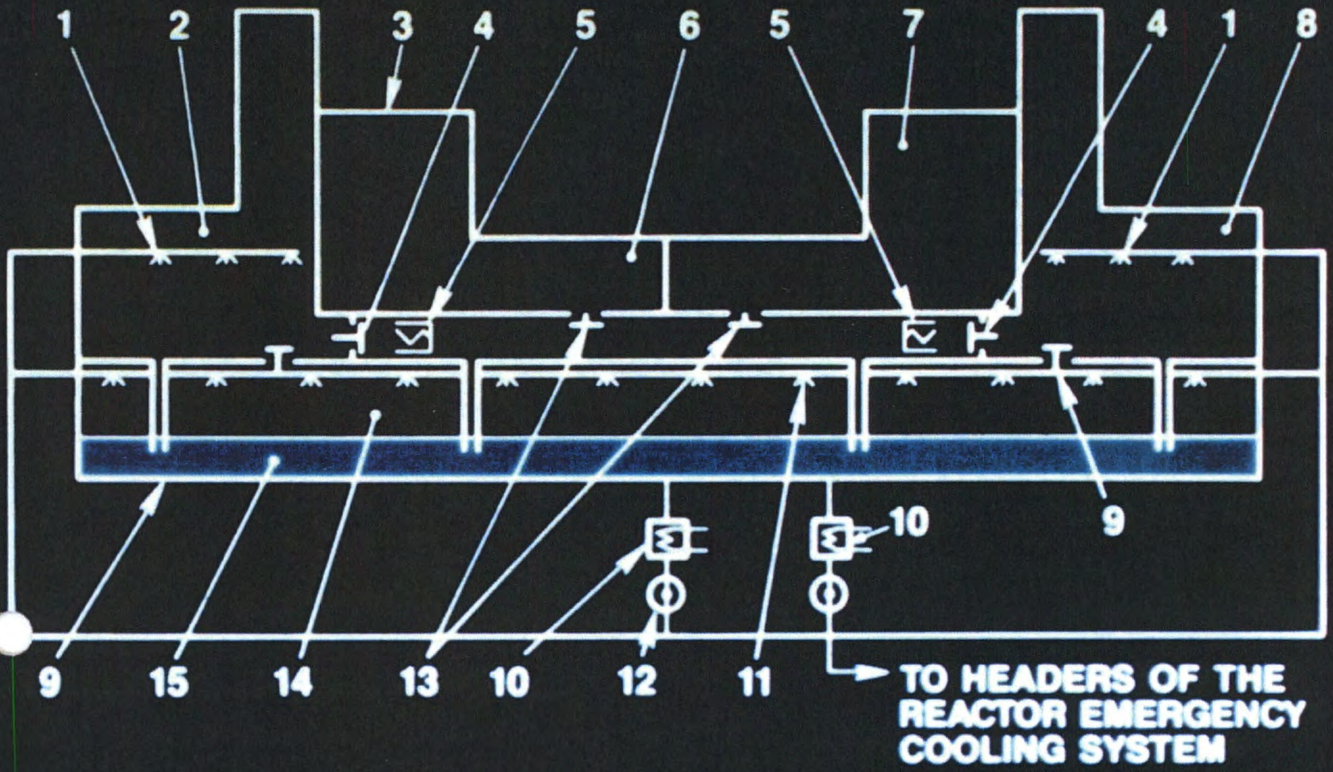
Central Supporting Tube
(With Nuetron Detectors)

Spacer Grid

Uo_2 Fuel Pellets
(11·5 mm Dia)
Zr-1½ Nb Cladding
13·6 mm Outside Diameter

18 Fuel Pins 3644 mm Long

FIG 8

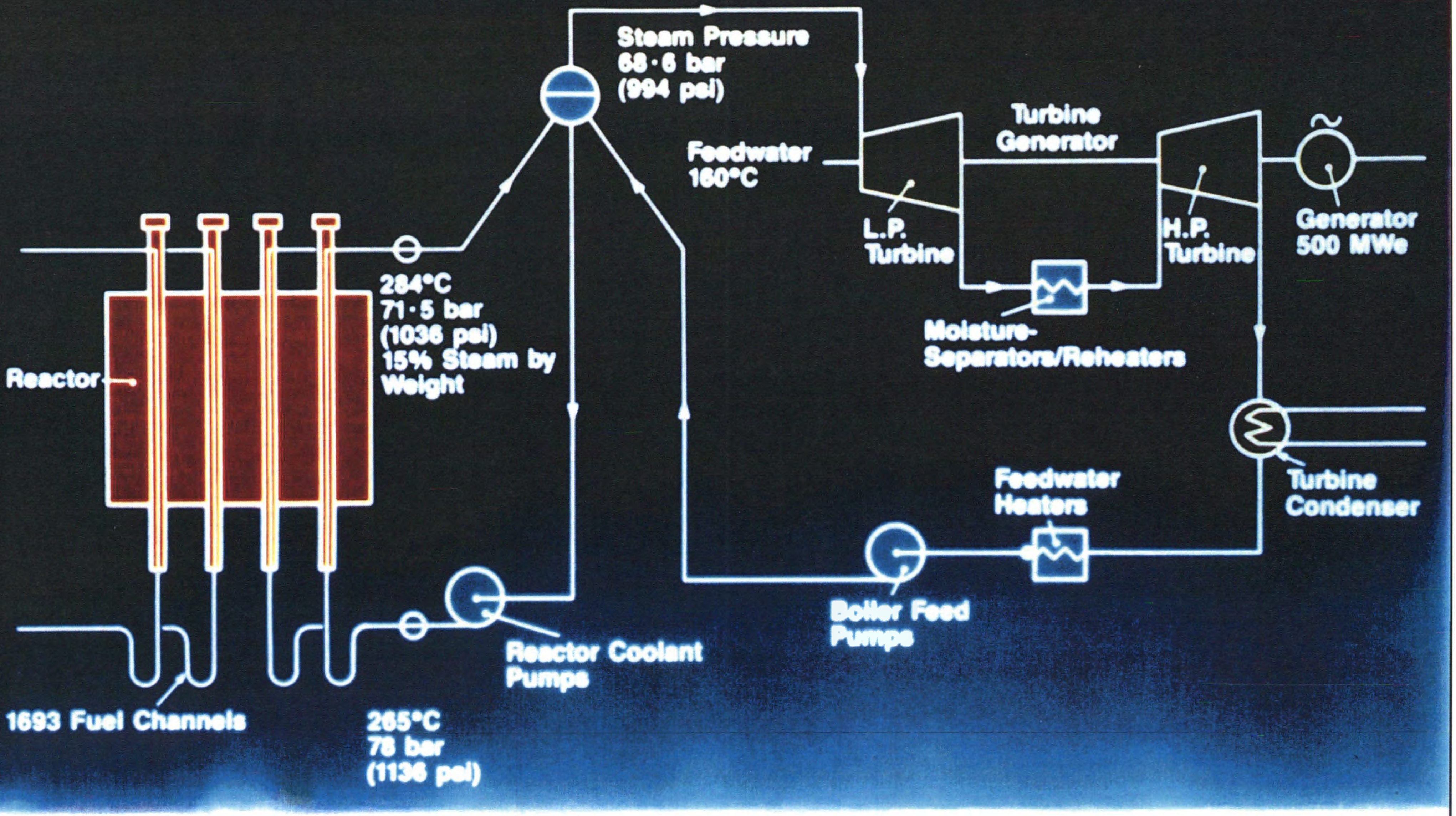


Schematic diagram of the system for retaining and localizing radioactive products in the event of an accident involving an RBMK-1000 type reactor

1, 11 - Sprinklers
2, 8 - Left and right hand halves of the hermetically sealed chambers
3, 7 - Left and right hand halves of the rooms housing the lower water lines
4 - Valve panels in the partitions separating the chambers and the corridors
5 - Surface type condensers
6 - Steam distribution corridor
9 - Relief valves
10 - Heat-exchanger
12 - Pump
13 - Check valves
14 - Air space above sparge pond
15 - Depth to which sparge pond is filled with water
16 - To emergency reactor cooling system collectors.

F.9

SCHEMATIC FLOWSHEET OF RBMK POWER PLANT



Steam Pressure
68·6 bar
(994 psi)

Feedwater
160°C

Turbine
Generator

L.P.
Turbine

H.P.
Turbine

Generator
500 MWe

Moisture-
Separators/Reheaters

Reactor

284°C
71·5 bar
(1036 psi)
15% Steam by
Weight

Turbine
Condenser

Feedwater
Heaters

Boiler Feed
Pumps

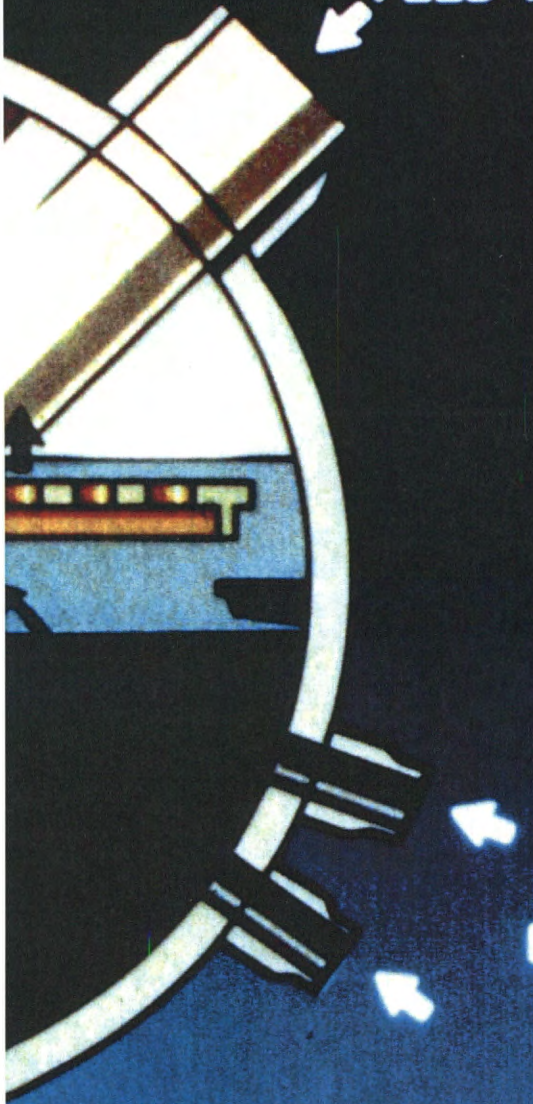
Reactor Coolant
Pumps

1693 Fuel Channels

265°C
78 bar
(1136 psi)

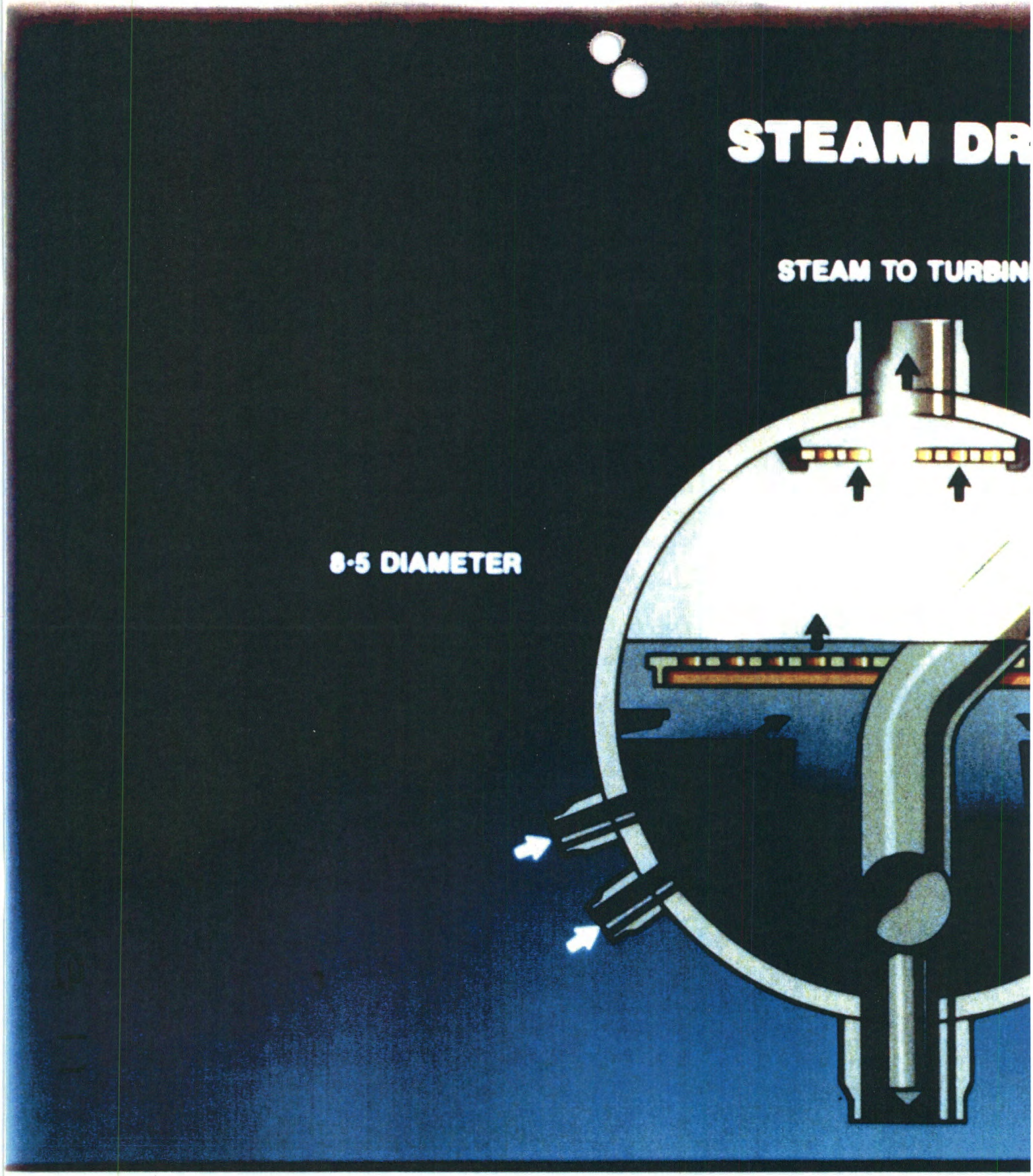
RUM

E



FEED WATER

STEAM/WATER
FROM REACTOR



STEAM DR

CHERNOBYL REACTOR SCEMATIC

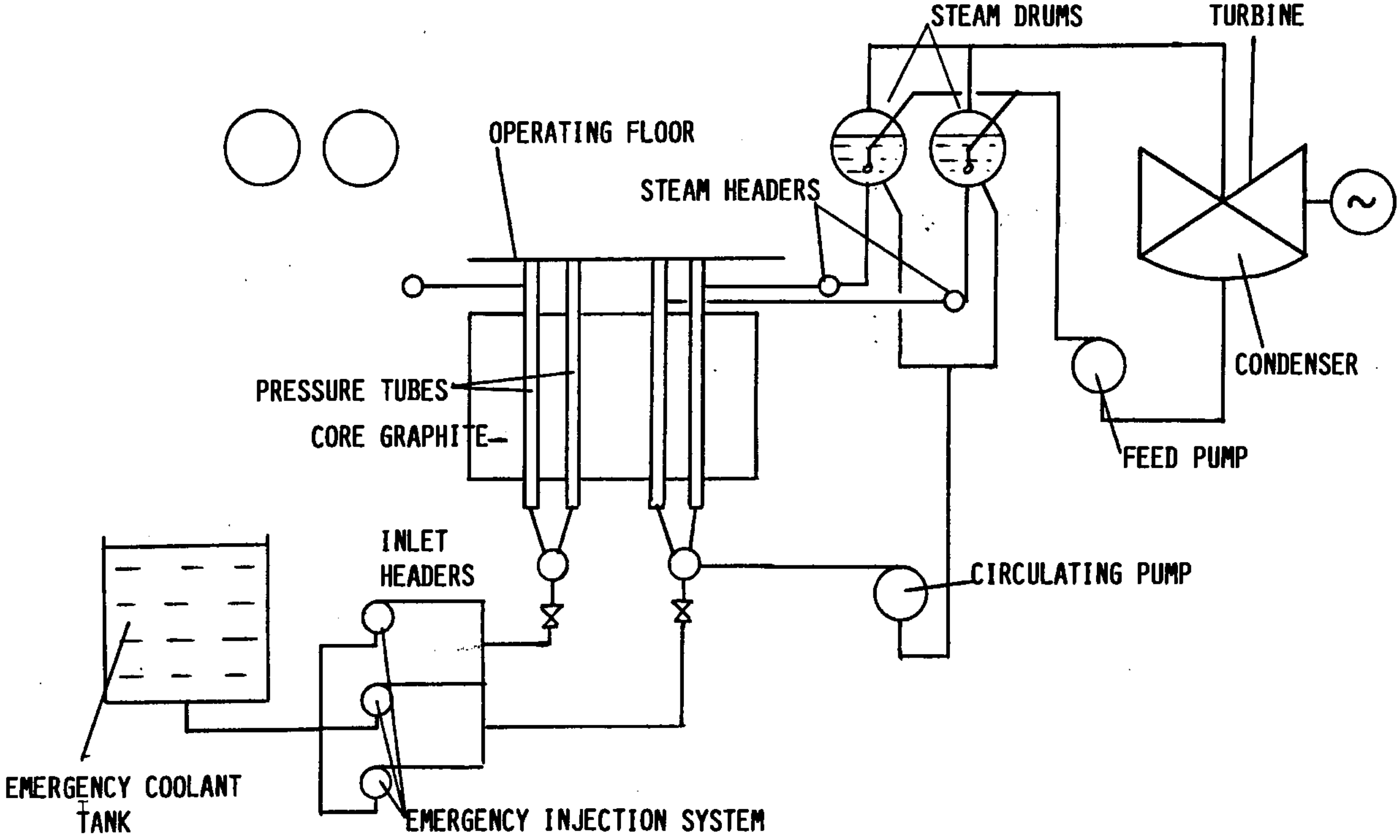


FIG. 12

SECTION 3: DEGRADED CORE ACCIDENTS: WHAT MAY HAVE HAPPENED AT CHERNOBYL

Information on the events at Chernobyl is at present incomplete, so a definitive description of the accident cannot yet be given. The methodology of degraded core analysis has been developed over many years however, and this provides a framework for the assimilation of such information on the accident at Chernobyl as has been made available. It has been found that an effective method for analysing hypothetical degraded core accidents is to break the accident sequences down into a number of separate steps. These steps would ideally be completely independent of one another: in practice they are not, but they usually are sufficiently independent to make the division into steps worthwhile. Generally four steps are considered, these being:

accident initiation;
cessation of nuclear fission by reactor shutdown;
provision of cooling to avoid core degradation;
containment of fission products released from pressure circuit.

The accident at Chernobyl may be considered within this general framework.

Accident initiation

The first step in a hypothetical accident is the initiation of the accident. An event occurs that causes an imbalance between the heat generated in the reactor core and the heat removed from the core by the primary coolant. There are many ways in which such an imbalance could arise. It could arise from a loss of primary coolant through a break in the primary circuit pressure boundary causing a reduction of coolant pressure, voiding and ultimately uncovering of the core. It could also arise with an intact primary circuit boundary, however. Intact circuit faults could include an increase of reactor power, a reduction of coolant flow through the core or, in the case of reactors with indirect steam cycles, a reduction of heat transfer from the primary to the secondary coolant.

In the case of Chernobyl, President Gorbachev referred to an 'increase of capacity' in his statement on Soviet television, which could indicate an increase of the power of the reactor from its reported initial 'hot shutdown' value of 6-7% of full power prior to the accident. A reactivity transient could be a plausible initiator of the Chernobyl accident as it appears that to optimise fuel burnup in RBMK 1000 reactors, the Russians are prepared to allow them to operate with a small positive void coefficient. As an increase of reactor power would increase the voiding in a fuel channel, positive feedback would reinforce rather than counter the rise in power. Operation under these conditions would not be permitted in the West and indeed reactors at Gentilly and Marviken were closed down when they exhibited such behaviour. Furthermore, the large volume of the RBMK 1000 cores allows local regions to become supercritical and causes the reactors to suffer various radial and axial power instabilities that have to be actively suppressed by automatic local area controllers. Failure of a local area controller could therefore lead to a local power excursion.

It should be noted however, that although a reactivity transient could be caused by an incident such as control rod withdrawal or failure of a local area controller, it might also possibly be a result of a loss of coolant accident initially affecting a localised region of the core and causing a reactivity transient through the positive void coefficient. In this case, the breach causing the loss of coolant would be regarded as the initiating event.

Cessation of nuclear fission by reactor shutdown

The second step in a hypothetical accident is the shutdown of the fission reactions in the core. This action, known as either reactor trip or scram, is the first of a series of safeguards provided to prevent accident progression to core degradation. It causes the rate of heat generation in the core to fall to less than 5% of the normal operation value within a minute of shutdown and should place the heat generation rate well within the capability of the coolant to accept heat from the core. If the reactor were not shutdown, the accident would develop into an "anticipated transient without trip (ATWT)", which would severely load the primary circuit pressure boundary. For the accident at Three Mile Island and apparently for the Chernobyl accident however, the reactors were shutdown successfully. Although the Germans have speculated that a recriticality occurred at Chernobyl, radionuclide distributions measured in various European countries have not shown the later peaks of short-lived radionuclides that would have been produced by this. Unless a recriticality occurred so soon after the initial events that the second peak of short-lived radionuclides could not be distinguished from the first release, a recriticality appears to have been unlikely.

Provision of cooling to avoid core degradation

Having shutdown the fission reactions in the core, the third step is to establish and maintain core cooling. This is necessary because about 7% of the energy liberated by nuclear fission is not released immediately, but is released over an extended period of time as the fission products decay. The decay heating rate in a shutdown reactor core is quite substantial, being about 120 MW one minute after trip and about 40 MW after an hour for a 1000 MW (e) reactor. To ensure that effective core cooling is established and maintained in such circumstances, engineered safeguards are provided that supply emergency cooling water to the core. These consist of passive systems, such as accumulators that rely on a pressure difference between an accumulator and the primary circuit to inject water into the primary circuit, and actively pumped systems. In the case of modern pressurized water reactors such as Sizewell 'B', provision is made for the emergency core cooling systems (ECCS) to draw condensate from sumps in the secondary containment building once the primary source of water, the refuelling tank, has been depleted. This enables the ECCS to operate almost indefinitely provided cooling of the secondary containment building is maintained.

It is important that core cooling be established rapidly however. If core cooling were delayed, the core could dry out and fuel temperatures could rise to those at which substantial oxidation of the zircaloy fuel clad could occur (over 1000 C). If supplies of water were then supplied to the dried out fuel, the zirconium oxidation might be stoked by the supply of water and the heat released could accelerate core damage to fuel meltdown, rather than bring about quenching of the hot material. If molten fuel were to come into contact with water, steam explosions might occur, which would cause further damage to the core and might present a threat to the pressure circuit boundary, either directly by loading it impulsively, or indirectly by fragmenting core debris into fine particles that could form an uncoolable debris bed. In addition, the hydrogen generated by oxidation of zirconium in steam could burn if it escaped from the pressure circuit and mixed with air.

It is also important to maintain core cooling once it is established. If this were not done, the core materials would dry out and melt at a later stage of the accident. For this reason, the ECCS of modern PWRs are able to operate in a coolant recirculating mode as noted above.

The Germans have speculated that at Chernobyl, failure of an inlet header supplying 40 pressure tubes was the accident initiator. In this case, a localised region of the core might have been uncoolable from the beginning of the accident, although reverse coolant flow through the tubes connected to the broken header might have provided cooling, at least initially. There are also reports that an explosion or explosions occurred within the reactor vault at the start of the accident. This suggests that the fuel must have overheated very rapidly to provide the initial conditions required by steam explosions or hydrogen explosions, so effective cooling could not have been established sufficiently rapidly, if at all.

The graphite moderator of the Chernobyl reactor was inerted with a helium/nitrogen mixture and the core was surrounded by a nitrogen blanket, so an in-core hydrogen explosion could not have occurred unless the inerting systems had failed. Steam explosions could occur in the pressure tubes however, if the fuel dried out and melted and then water re-entered the tubes. Such steam explosions could breach pipework and disrupt the pile cap, ejecting steam, hydrogen and fuel materials into the reactor hall. There, the hydrogen and zirconium alloy fuel clad could mix with air and burn, causing the structural damage seen in photographs. Air would then have access to the core and zirconium and graphite remaining in the core could then burn.

It has been reported that the initial explosions caused the 200 Te overhead crane in the reactor hall to fall onto the pile cap causing further damage to the core and breaking pipework that would have allowed ECCS accumulators to discharge water into the pressure tubes. The pumped ECCS are believed to supply water to the inlet headers in the lower regions of the reactor building however, so some core cooling might have been available initially.

An explosion in a fuel channel would probably prevent cooling of the fuel in that channel and damage inlet pipework, leading to a loss of coolant. As the coolant system on RBMK 1000 reactors is divided into two separate loops however, only one loop might suffer a loss of coolant accident if the initial damage were sufficiently localised. If only one loop were breached, the core might be treated as three separate regions: the initial damaged region, which might not be coolable even if ECCS water were available; the rest of that circuit, which would undergo a loss of coolant accident with long term failure of ECCS; the other circuit, which would undergo an intact circuit fault with long term loss of feed. The different regions would have different thermal time constants and in such a situation, the damaged region of the core could grow and release volatile fission products over an extended period of time. This would, however, depend on the extent to which the pipes of the two loops were interlaced in the reactor core.

Containment of fission products released from pressure circuit

Reactors in which the coolant becomes significantly contaminated with radioactive materials during normal operation are provided with secondary containment structures so that a radiological hazard would not arise in the case of a large loss of coolant accident. These secondary containment structures are designed to withstand the pressurization resulting from a large loss of coolant accident and in the case of large modern PWRs such as Sizewell 'B', they are also assessed to be capable of withstanding the hydrogen burns that might follow core degradation and oxidation of zirconium fuel clad by steam. Indeed, a hydrogen burn did occur in the secondary containment building at Three Mile Island, but the containment remained intact. Dr Gittus, in his Proof of Evidence (P16) to the Sizewell Inquiry, noted the contribution that secondary containment structures would make towards mitigating the consequences of beyond design basis accidents by reducing the frequency of an uncontrolled release of fission products to a value almost two orders of magnitude smaller than the already low core melt frequency. Even in the few cases where the containment was predicted to fail, the assessment was that for the majority of such cases, failure would not occur until several hours after the start of the accident, which would allow physical and chemical phenomena mitigating the release time to develop.

The strength of the building around the Chernobyl reactor core is uncertain to us, however. Some cell walls are reported to be capable of withstanding a pressure of 4 bar but it is not clear if these completely surround the core. In any case, the containment does not appear to have contained a missile shield of the type installed over PWRs and so would not have been protected against missiles from a steam explosion in a fuel channel. Once the pipework above the core had been breached and the pilecap disrupted, hydrogen and fuel rod materials would have been ejected into the relatively light reactor hall where they would have burned and caused structural damage. It appears that at Chernobyl, containment was breached shortly after the start of the accident and although sand, dolomite and other materials were dumped onto the reactor to mitigate releases, a significant quantity of volatile fission products escaped nonetheless.

A further consequence of containment failure would be that water initially inside the containment building would be lost as steam through the breach and so even if the ECCS were designed to switch to a recirculating mode once the primary source of water were depleted, it would eventually fail and the core temperatures generally would then rise.

SECTION 4: SOURCE TERMS

The source term (or to give it its full name, the radiological source term to the environment) for an accident is that information from the study of the in-plant progression of the accident which is carried forward into the calculation of the dispersion of material through the environment and the consequential health effects. The source term has several components:

a the amounts of the various radionuclides released to the environment, expressed as fractions of the initial core inventories (these can be converted into activities released given the activity inventories);

b the height and the energy of the release (these affect the height to which the plume rises and hence the distance the material is transported);

c time scales, such as the time and duration of the release and the warning time that a release is imminent.

Source terms are routinely calculated in safety studies for hypothetical reactor accidents. Those calculated for the Sizewell B Safety Study are exemplified in Table 4.1, which gives release fractions for the classes of fission product containing the most volatile elements: the noble gases, iodine, and caesium and rubidium. Four broad categories of accident are considered on this table:

Release Category A

Accidents of the severest type in which the containment fails or is bypassed by a leaking pipe at the moment when the core becomes completely molten. A substantial amount of highly active, volatile radionuclides will then be released to the environment.

Release Category B

Degraded Core accidents in which the containment fails some hours after the core melts: the release of radionuclides would be substantial although radioactive decay would have reduced their activity whilst dissolution, plate-out and aerosol sedimentation would have resulted in much retention.

Release Category C

All degraded core accidents in which the containment leaks or is penetrated below ground level but does not fail above ground.

Release Category D

In this category we might place all degraded core accidents in which the containment does not fail, but may nevertheless leak at the design-rate. The release of activity is then only small.

Normally, when dealing with hypothetical accidents, one calculates first the accident phenomenology, then the source term and finally the environmental consequences, each calculation using information from the previous one. At present with the Chernobyl accident we know too little about the initial conditions to follow this route. Instead we have to work backwards from the amount of material found in the environment to an estimated source term (which can then also be used as further information on the nature of the accident progression). In this backward calculation important assumptions have to be made as to how the various materials are transported through the environment.

In the preliminary assessment of the Chernobyl source term (carried out by Dr P N Clough) the data used were those from the Netherlands, Sweden, Denmark, Finland and Hungary, collected over the period from 28 April to 4 May. Only information on the relative amounts of the different nuclides has been used, with no regard for the absolute magnitudes of the activity. A reasonably consistent pattern of relative release fractions has been built up at the various measurement sites; this is given on table 4.2, where it is compared with the inventory initially in the core, as predicted by the FISPIN code. FISPIN calculations were done for various burn-up assumptions. The figures on the table are for a one year burn-up, consistent with the Cs137/Cs134 ratio of around 2.0 found at all the measuring points.

The pattern of radionuclide releases, as shown on table 4.2, gives some indications as to the conditions in the core while the releases were occurring. For example the tellurium seems to have been released in the same proportions as the iodine and caesium. Tellurium vapour is expected to react with any zirconium available and thereby be retained. The absence of such retention suggests that the zirconium in the region of fission product release was being rapidly oxidized. The high release of ruthenium relative to the other non-volatile elements is a further indication of highly oxidizing conditions in the degrading core region. This is consistent with the idea that there was air ingress to the core, and that a large-scale fire in the graphite moderator was a feature of the accident.

Table 4.2 says nothing about the absolute magnitude of radionuclide releases. Initial SRD estimates from measurements in Scandinavia put the release of volatile fission products in the <u>initial stages</u> of the accident at a few percent of the core inventory. The Imperial College group, using data from all over Europe, inferred a release period of 3 - 4 days and a total release <u>over the whole period</u> of around 20% of the iodine inventory. The fact that similar nuclide ratios were observed at widely separated sites suggests that the core degradation started locally and then propagated outwards, with the release mechanisms being similar at all times. The above release estimates are therefore not inconsistent, and place the release somewhere between the categories A and B on Table 4.1.

TABLE 4.1

FRACTIONS OF RADIOISOTOPES CALCULATED TO BE RELEASED ('SOURCE TERMS')

Category	Equivalent Crude Category	Xe - Kr	I	Cs - Rb
UK - 1	A	0.9	0.7	0.5
UK - 5	B	1.0	0.06	0.3
UK - 10	C	0.006	0.00002	0.00001
UK - 12	D	0.05	0.000008	0.000001

TABLE 4.2

RELATIVE RELEASE FRACTIONS FROM CHERNOBYL BASED ON MEASUREMENTS AT DISTANT SITES

Element	Isotope	$t_{1/2}$	Inventory per fuel channel, Bq*	Relative Release Fraction
Cs	137	30y	8.82(13)	1.0
	134	2.06y	4.87(13)	
I	131	8.04d	1.9 (15)	0.2-0.3
	132	2.30h	2.83(15)	
	133	20.8h	4.17(15)	
Te	132	78.2h	2.77(15)	0.3-0.5
Ba	140	12.7d	3.71(15)	0.02-0.03
La	140	40.3h	3.76(15)	<0.005**
Ru	103	39.4d	2.67(15)	0.03-0.07
	106	368d	4.0 (14)	
Ce	141	32.5d	3.54(15)	<0.005
	144	285d	1.84(15)	
Nb	95	35.1d	3.6 (15)	<0.005
Np	239	2.36d	3.86(16)	0.001-0.07

* Multiply by 1693 for whole core inventory.

** Based on only one measurement which distinguished La140 from Ba140.

SECTION 5: ENVIRONMENTAL CONSEQUENCES

Atmospheric Dispersion Across Europe of Material Released from Chernobyl

Increased activity levels were first reported on 28th April from environmental monitoring stations in Finland and Sweden, where external dose rates in certain locations exceeded normal background levels by a factor of ten or more. On succeeding days elevated radioactivity concentrations were detected throughout Europe until almost complete coverage had been achieved by 3rd May. Based upon reported measurements conveyed through international bodies (IAEA, WHO and NEA), complemented by calculations using the UKAEA consequence code CRACUK on the CRAY computer at Harwell, it has been possible to assemble a picture of the pattern of dispersion of the material released from the core of the damaged reactor, as it affected western Europe. The progression of this pattern with time is illustrated in Figures 1 to 6. There is a marked patchiness in the environmental measurements from different countries owing to wet deposition during periods of rainfall. Such large variations in observed deposition levels over relatively short distances are not shown in the Figures, which represent the general distribution of contamination via the measured values for external exposure rate.

In the initial stages, activity was transported in a north-westerly direction from Chernobyl over the Soviet Union and north east Poland, crossing the Baltic Sea into Scandinavia. By the end of the 26th April, however, the meteorological situation had developed such that the plume, on release, began to follow a more westerly trajectory than was taken initially, passing over the continental mainland and across West Germany so that, by 30th April, it was over parts of France (Figure 3). A component of this part of the release passed over the United Kingdom on 2nd May. The changing weather patterns over the western Soviet Union than led to relatively light and variable winds in the vicinity of the accident site. Material released in the final days of April therefore tended to begin to be transported towards the East before circulating more locally and passing towards the Balkans and south east Europe.

In addition to the very wide dispersion brought about by the changing meteorology over the several days during which emissions from the damaged plant took place, it seems likely that material was distributed over a considerable range of elevation, owing to the energy associated with the release. Strong directional shear in the wind over the depth of the atmospheric boundary layer, in which transport occurs, would lead to further lateral dispersion of the plume for activity discharged at a given time during the release. Material transported at very high altitudes (> 1km) appears to have been responsible for the subsequent observations of elevated activity levels in countries bordering the Pacific Ocean.

Dosimetric Assessment for Western Europe

Using data provided by agencies responsible for radiological protection in various countries, it is possible to obtain estimates for the dosimetric impact of the release on W Europe. Dosimetric pathways contributing to individual exposure include the inhalation of activity from the plume, exposure to external radiation from deposited activity and ingestion of contaminated foodstuffs. In comparison with these, other modes of exposure for the population of western Europe make much smaller contributions to overall dose levels. For the inhalation pathway an estimate is made of the average integrated concentration of airborne activity over each country. Similarly for external exposure, which, over a period of decades following the initial deposition, will predominantly arise from irradiation due to decay of radioisotopes of Caesium, it is possible to make an estimate of the total dose delivered over 50 years, averaging throughout each country. In both cases the averaging procedure is weighted where necessary according to the distribution of population. By means of appropriate conversion factors, a translation from activity levels to mean individual dose can then be obtained.

Contamination in foodstuffs arises via a number of pathways. Leafy green vegetables act as efficient collectors for airborne aerosols. Dairy cattle and other livestock were able to consume both contaminated rainwater and grass, yielding concentrations of radioactive isotopes of Iodine and Caesium in farm supplies. In general, throughout Western Europe, however, levels of activity in milk supplied by dairies (the most significant pathway for exposure via foodstuffs) rarely approached values necessitating protective action. More recently, caesium in some slaughtered lambs from parts of the UK has been measured to be greater than the appropriate action levels.

Consumption of grass by these animals in those areas of the country affected by rainfall during passage of the plume, and their relatively light overall body weight, has led to such elevated concentrations. The overall contribution of meat to the total collective dose estimated from figures for environmental activity concentrations remains to be assessed fully, but is likely to be of second order importance in comparison with that from milk and vegetables. In the calculations reported here, UK food consumption rates were assumed for all of Europe.

In Table 1, the results of a dosimetric analysis for Western Europe are presented, summarising the total collective dose commitment estimated for each country. As a rough guide, the contribution from inhalation is, at most, a few percent while that from ingestion is something over 50%, the remainder being due to external irradiation.

It is instructive to compare these figures with background exposure levels. For example, in the United Kingdom, the average individual dose rate from background radiation is 2 mSv yr^{-1}, resulting in an annual collective dose of approximately 10^5 manSv. The total dose commitment over the next 50 years resulting from the increased radiation levels due to the Chernobyl accident is therefore equivalent to about one or two months at normal background dose rates.

TABLE 1

Estimated Collective Effective Dose Equivalent Commitment for W European Countries Arising from Chernobyl Releases

Country	Collective dose (man Sv)		
	Internal exposure (inhalation + ingestion)	External exposure	TOTAL
Austria	6.2×10^3	4.4×10^3	1.1×10^4
Belgium	4.6×10^3	2.3×10^3	6.9×10^3
Denmark	5.0×10^1	1.0×10^2	1.5×10^2
Finland	4.0×10^3	1.8×10^3	5.8×10^3
France	2.8×10^3	2.7×10^3	5.5×10^3
W Germany	4.9×10^4	3.6×10^4	8.5×10^4
Greece	1.1×10^3	7.8×10^2	1.9×10^3
Ireland	2.8×10^2	2.4×10^2	5.2×10^2
Italy	8.0×10^3	1.2×10^4	2.0×10^4
Netherlands	6.6×10^3	3.3×10^3	1.0×10^4
Norway	9.0×10^3	6.2×10^2	1.5×10^3
Portugal	$< 5.0 \times 10^2$	$< 5.0 \times 10^2$	$< 1 \times 10^3$
Spain	$< 1.9 \times 10^3$	$< 1.9 \times 10^3$	$< 3.8 \times 10^3$
Sweden	2.8×10^3	1.8×10^3	4.6×10^3
Switzerland	2.3×10^3	9.1×10^2	3.2×10^3
UK	4.6×10^3	3.9×10^3	8.5×10^3

Notes

1. Figures 1 to 6 indicate the estimated variation of external exposure rate throughout Europe in the days following the accident (see Key 1 for units and notation). The figures show the general distribution, ie they do not include local variations due to, eg heavy rainfall. They also represent an interpretation of available measurements around Europe - some interpolation was necessary.

2. Dose levels in Figures 1 to 6 stabilised and then decreased.

KEY TO FIGS 1 TO 6

KEY:

	INCREASE GIVEN AS MULTIPLES OF BACKGROUND DOSE RATE
▨	10^{-2} – 1
■	1 – 5
■	5 – 10
□	10 – 20
■	20 – 40
■	40 – 100
■	> 100

□	NO DETECTABLE RISE IN DOSE RATE

KEY 1

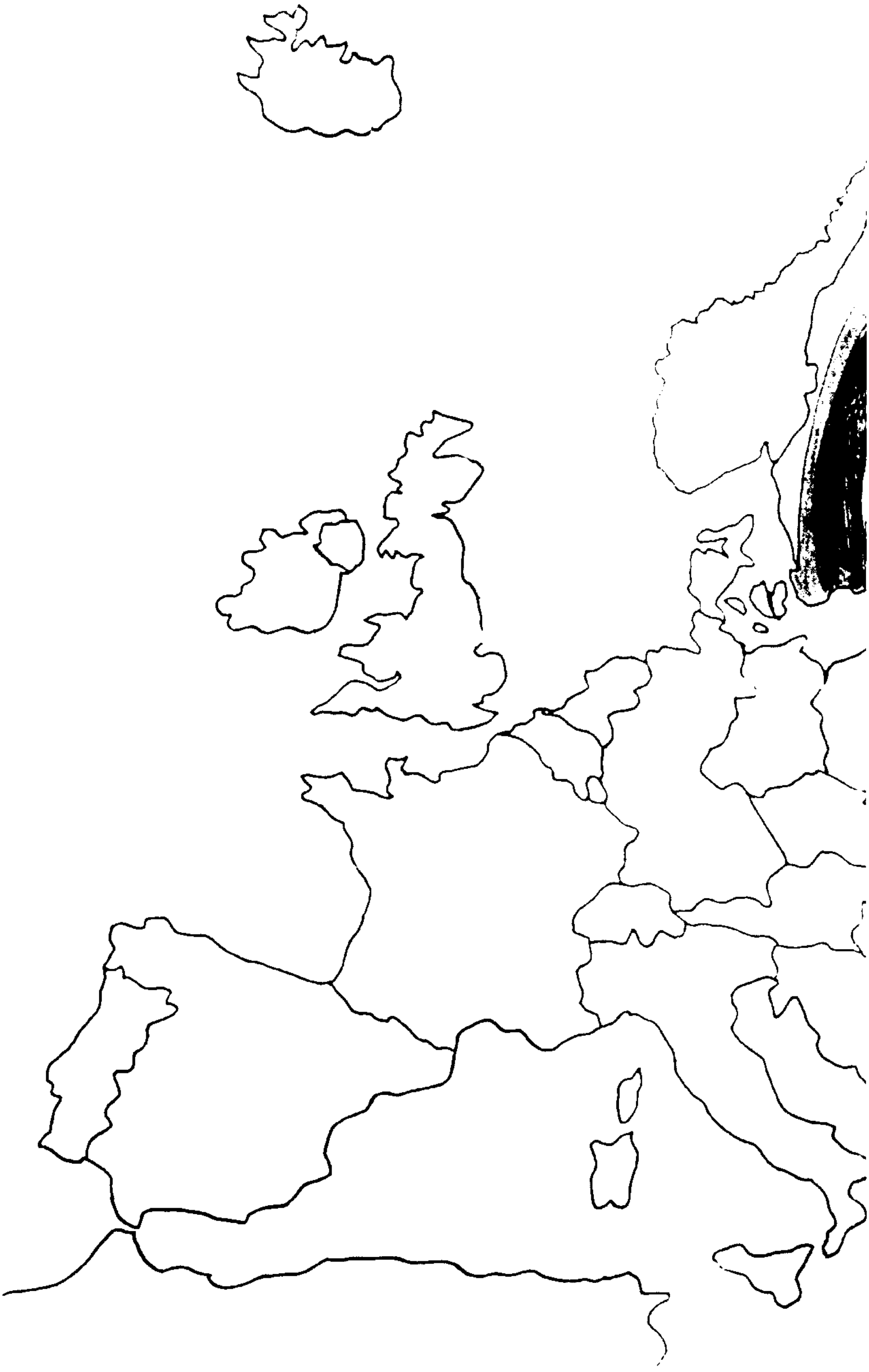


FIG 1

29 APRIL 1986

FIG 2

29 APRIL 1986

FIG 3

30 APRIL 1986

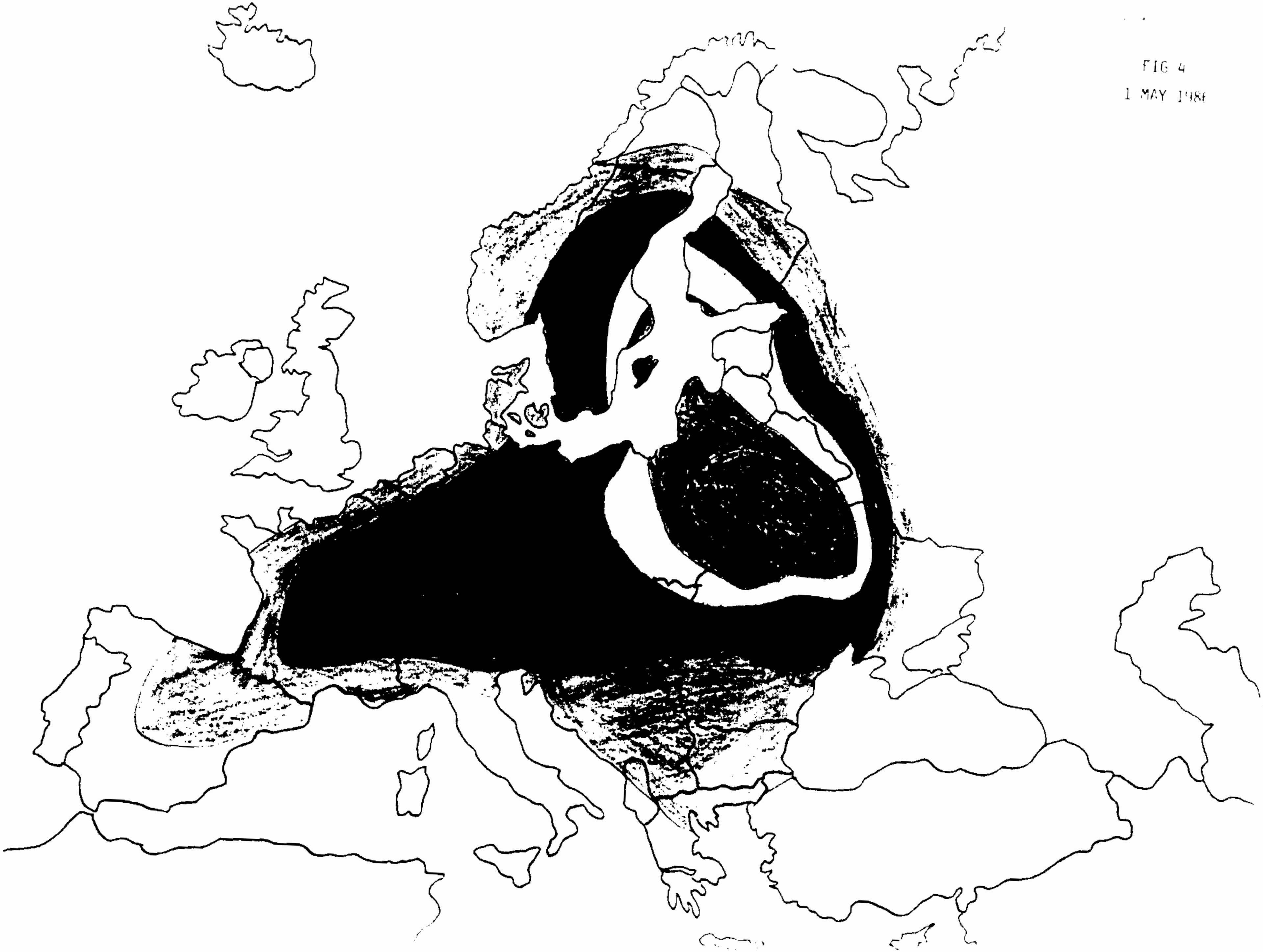
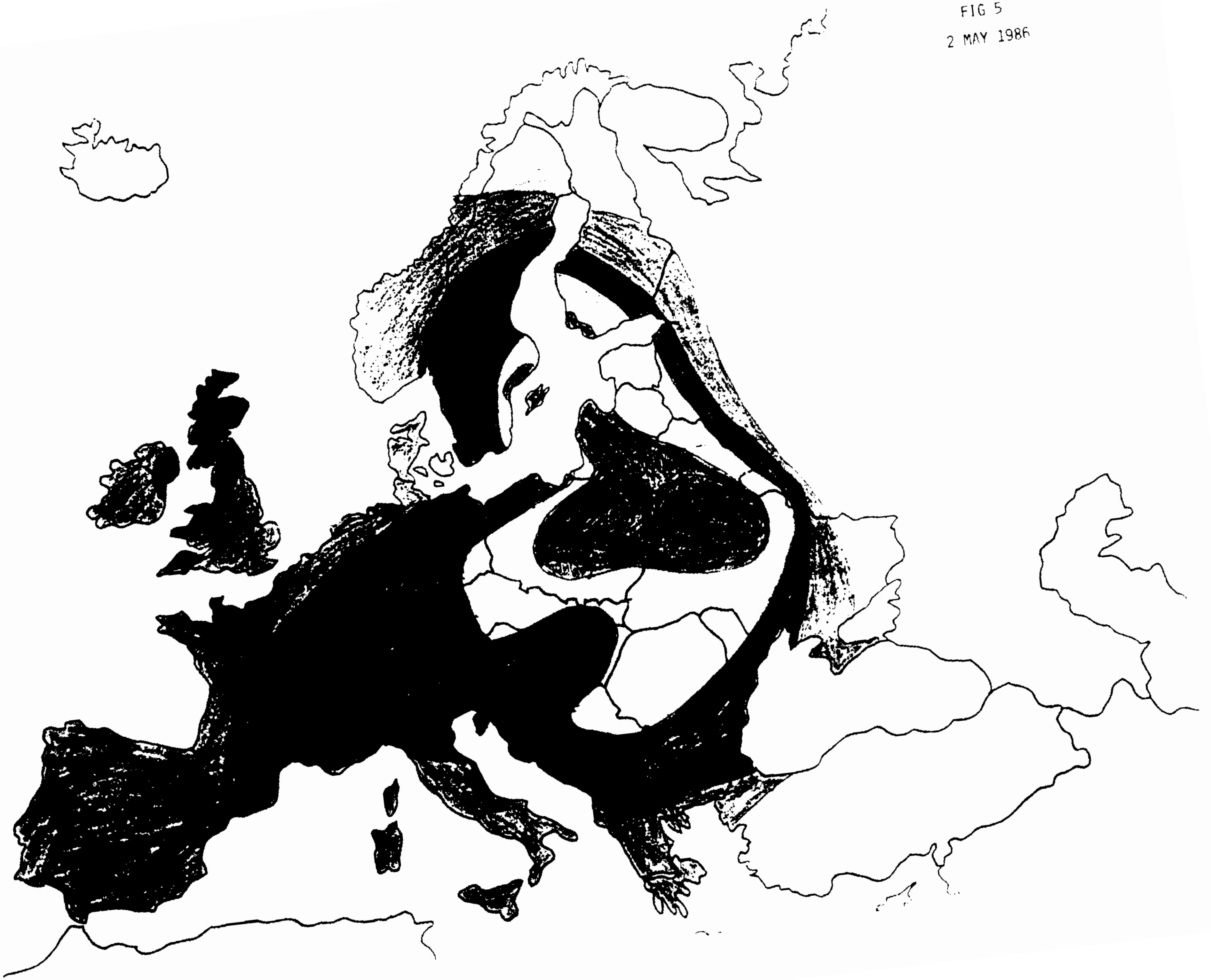


FIG 4

1 MAY 1986

FIG 5

2 MAY 1986



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Mr. Chadwick

c.c. Mr. Simeone
Mr. Nicholson
Dr. Llewelyn
Mr. Preston
Dr. J. H. Gittus, SRD ✓
Dr. M. R. Hayns, SRD

Chernobyl - European Council, 26th - 27th June

In commenting on French preparations on the European Summit meeting, the Embassy in Paris report that both the Elysee and the Prime Minister's Office (Matignon) expect Chernobyl to be a major item for discussion.

2. Both the Elysee and the Matignon are firmly opposed to enlarging Community competence in nuclear safety and international control. They share the UK Government view that the IAEA is the proper agency for these matters. The Embassy detected a difference over the tactical handling of Chancellor Kohl's proposal for an international conference on nuclear safety, with the Elysee saying that the President was "not against" an international conference and the Matignon declaring that the French Government disliked the proposal. On substance, however, both offices insisted on the importance of preventing an anti-nuclear climate from establishing itself on a permanent basis in fora dealing with virtually every Community activity, including agriculture, the environment, etc. They saw this as being particularly dangerous for the UK and France because sentiment against nuclear energy could easily be mobilised against nuclear weapons. President Mitterand had warned Chancellor Kohl of the dangers of allowing discussion on nuclear matters to range widely within the Community. It would be useful to en gage in joint studies and to work for harmonisation on such innocuous aspects as research, health protection measures and the provision of information to the public.

3. Soundings in Brussels indicate that the Belgians are looking to the French to lead off any attempt to push the Council into adopting positions which would encourage the anti-nuclear lobby. However, it seems likely that the Belgian delegation may take the opportunity to advocate the rejuvenation of Euratom and a stronger role for the Commission.

D. M. Levey

Overseas Relations Branch
27th June, 1986.

CONFIDENTIAL

H J Teague

24 June 1986 AEX(86)50

ATOMIC ENERGY EXECUTIVE

THE CHERNOBYL ACCIDENT AND ITS CONSEQUENCES

Note by R N Simeone

At its meeting on 29 May the Executive requested Dr Gittus to produce a paper on the Chernobyl accident and its consequences. Such a paper is attached.

AEX(86)50
ANNEX

THE CHERNOBYL ACCIDENT AND ITS CONSEQUENCES

John H Gittus

SUMMARY

The USSR has a large and expanding nuclear power programme. It is regarded as essential to the economy and currently provides about 15% of USSR power production. It is based upon two main types of reactors, the (RBMK) pressure tube reactors and pressurized water reactors (PWRs).

The reactors at Chernobyl are 1000 MW(e) graphite-moderated pressure tube boiling water reactors with a direct cycle to two 500 MW turbines. They contain fuel rods consisting of UO_2 pellets with a zirconium alloy clad, which are arranged in bundles in vertical pressure tubes passing through the graphite moderator. The core is physically large (diameter about 12m) and requires a complex control and protection system. The pressure circuit consists of two separate loops and the core is provided with emergency cooling by passive accumulators and pumped emergency core cooling systems. Inert gas blankets are provided for the graphite moderator and some cells in the reactor building and these are protected against overpressure by bursting disks and a pressure suppression pool. The reactors are not housed in buildings equivalent to the secondary containment of a large modern PWR, but the reactor pressure circuit is enclosed within a system of several strong cells.

A definitive description of the accident cannot yet be given as our information on the events is incomplete. The established methodology of degraded core analysis provides a framework for assimilating the available information however, and the accident at Chernobyl may be considered within this framework. Accident progression may be considered in four steps: accident initiation; cessation of nuclear fission by reactor shutdown; provision of cooling to avoid core degradation; containment of fission products released from the pressure circuit.

Accident initiation is an event that causes an imbalance between the heat generated in the core and the removal of heat from the core by the coolant. There is an indication that the accident at Chernobyl involved a reactivity transient, but it is not yet certain that this was the initiating event.

The second step is the shutdown of nuclear fission in the core. This step appears to have been successful at Chernobyl, although there has been speculation that a recriticality occurred. Core cooling must then be provided to avoid core degradation. This clearly was not successful at Chernobyl and it appears that core degradation occurred very rapidly after accident initiation, for it is reported that explosions occurred shortly after the start of the accident. These were probably steam explosions and/or hydrogen explosions, both of which would require fuel materials to reach high temperatures beforehand.

Finally, fission products released from the pressure circuit should be contained. This also was not successful at Chernobyl. The amounts of radioactive materials released in an accident, together with certain characteristics of that release, are collectively referred to as the source term for the accident. Source terms are routinely calculated for hypothetical accidents in safety studies. In the Sizewell B study for example, source terms were calculated for accidents ranging from those with containments remaining completely intact at all times to those where the containment is breached or bypassed even before the core damage begins. Too little is known at present for an ab initio source term calculation to be carried out for Chernobyl, but based on measurements of material deposited across Europe, it has been estimated that between 10 and 30 percent of the inventory of volatile fission products was released over a period of 1-4 days.

A picture of the dispersion of radioactive material from Chernobyl across western Europe has been assembled, based on reported measurements conveyed through international bodies (IAEA, WHO and NEA) and complemented by calculations using the UKAEA consequence code CRACUK on the CRAY computer at Harwell. Wet deposition during periods of rainfall caused a marked patchiness in the environmental measurements from different countries.

Initially, activity was transported in a north-westerly direction from Chernobyl into Scandinavia, but by the end of the 26th April, a more westerly trajectory was followed. A component of this release passed over the United Kingdom on the 2nd May. In the final days of April, light and variable winds in the vicinity of Chernobyl tended to circulate the activity before eventually transporting it towards south east Europe. It seems likely that the activity was distributed over a considerable range of elevation.

Estimates have been made of the dosimetric impact of the release on western Europe. The main dosimetric pathways contributing to individual exposure are inhalation of activity from the plume, exposure to external radiation from deposited activity and ingestion of contaminated foodstuffs. It is estimated that ingestion will contribute something over 50% to the total dose commitment in most European countries, with the contribution from inhalation being at most a few percent. The total dose commitment in the United Kingdom over the next 50 years resulting from the increased radiation levels due to the Chernobyl accident is estimated to be equivalent to about one or two months at normal background dose rates.

CONTENTS

SECTION 1: USSR POWER REACTOR PROGRAMME

The nuclear power programme in the USSR is provided by two main types of reactors, the (RBMK) pressure tube reactors and the (PWR's) pressurised water reactors.

Pressure tube reactors of the RBMK type have been operating in the USSR since 1954 with a small 5 MW unit, with development to 600 MW's in 1958, expanding to units of 1000 MW's and 1500 MW capacity. Table 1 shows the large RBMK units now in service and also under construction in the USSR.

The USSR also has a large PWR programme which currently produces 44% of their nuclear power but will by 1991 produce 61%, Tables 2 and 3. Nuclear power is essential to the USSR economy and it presently forms about 15% of their power production with 26 GW's. The USSR have under construction 36 GW's up to 1991 of both RPMK units and PWR's which will give 62 GW's of nuclear power (Fig 1).

TABLE 1
Large RBMK Units in Service and Under Construction in USSR

Status at 31.12.85	Station	Unit output MWe (net)	No of units	Commercial operation
In Service	Leningrad	950	4	1974 - 1981
	Kursk	950	3	1976 - 1983
	Chernobylsk	950	4	1978 - 1984
	Smolensk	950	2	1983 - 1985
	Ignalinsk	1450	1	1984 -
Under Construction	Kursk	950	1	1986 -
	Ignalinsk	1450	1	1986 -
	Chernobyslk	950	2	1987 - 1989
	Smolensk	950	2	1988 - 1989
	Kostroma	1450	2	1988 - 1989

TABLE 2
PWR Units in Service in USSR

Status at 31.12.85	Station	Unit output MWe (net)	No of units	Commercial operation
In Service	Novo Voronezh	265	1	1964 -
		338	1	1970 -
		410	2	1972 - 73
		953	1	1981 -
	Kola	440	4	1973/75-1982/84
	Armenia	370	2	1976 - 1980
	Rovno	420	2	1981 - 1982
	Nikolaiev	953	2	1984 - 1985
	Kalinin	953	2	1984 - 1985
	Bala Kovo	953	1	1985 -
	Zaporozhe	953	1	1985 -

TABLE 3
PWR Units Under Construction in USSR

Status at 31.12.85	Station	Unit output MWe (net)	No of units	Commercial operation
Under Construction	Zaporozhe	953	5	1986 - 1991
	Khmelnitski	953	4	1986 - 1990
	Nikolaiev	953	2	1987 - 1989
	Aktash	953	2	1987 -
	Tatar	953	1	1987 -
	Volgodonsk	953	4	1987 - 1990
	Rovno	953	2	1988 - 1990
	Bashkir	953	2	1988 - 1989
	Odessa	953	2	1988 - 1990
	Balakovo	953	2	1989 - 1990
	Nizhinekamsk	953	1	1989 -


NLAND
NORWAY
SWEDEN
Leningrad
(RBMK-1000)
4 units
UNION OF SOVIET
SOCIALIST REPUBLICS
Kostrom
(RBMK-15
4 unit
Ignalina
(RBMK-1500)
4 units
Smolensk
(RBMK-1000)
6 units
Chernobyl
(RBMK-1000)
6 units
Kursk
(RBMK-1000)
(4 units)
UNITED
KINGDOM
NETHERLANDS
BELGIUM
FRG
GDR
POLAND
CZECHOSLOVAKIA
SWITZERLAND
AUSTRIA
HUNGARY
FRANCE
ITALY
ROMANIA
SPAIN
YUGOSLAVIA

SECTION 2: DESCRIPTION OF RBMK REACTOR

The basis of a nuclear station containing RBMK reactor units is provided by 2 units of electrical power of 1000 MW each, Figs 1,2,3 and 4. Each unit is a reactor of a graphite-moderated pressure tube, boiling water type, with direct cycle to 2 x 500 MW turbines. The reactor fuel is contained inside pressure tubes, which are located in the graphite vertical columns. The reactor water passes through the pressure tubes and starts to boil. The steam leaves the pressure tubes as a 2-phase mixture with a void content of 15%, is directed to steam drums, and is then transferred to the turbines. Tables 1, 2 and 3 give reactor and fuel specification.

The reactor has a multi-compartment containment system. The containment round the graphite moderator and the multi-containment boxes round the reactor coolant loops are protected from overpressure by bursting discs which vent into the suppression pool. It has a complex control and protection system involving sector control and stabilising equipment. The reactor physics is complex; under some conditions the reactor may have a positive void coefficient (although the power coefficient is still negative). The positive void coefficient would cause coupling and feedback between thermal hydraulics and reactor power. The ECCS system includes both accumulator injection and pump injection.

Reactor Vault

The graphite structure forming the core and reflector is supported on a welded metal structure. There is concrete shielding 3m thick above the core and 2m thick below the core. Water tanks provide the inner radial biological shielding and there is an annulus filled with special sand between these water tanks and the outer concrete of the reactor vault. The space immediately round the graphite core is sealed and contains a helium/nitrogen mixture (40% He/60% N2), (Fig 5).

The space outside the inner volume is filled with nitrogen at 22mm WG. If the pressure tube should burst and increase the pressure in the gas space, there are special bursting discs which are designed to relieve pressure at 1.8 kgf per square cm (26.5 lb per sq in).

The heat generated in the moderator (approx 160 MW 5%) is transferred to the fuel channels by conduction and radiation via 'piston ring' type graphite rings, one mounted tightly on the fuel channel and the other fitting tightly in the graphite column (Fig 6). The maximum temperature in the graphite stack is 700 degrees C.

Fuel Channels

The RBMK-1000 graphite-channel boiling-water reactor has 1693 fuel channels (FC) arranged in vertical holes in the graphite stack. Each channel has a body of tubular construction within which is located a fuel stringer.

The coolant is boiling light water circulating in the vertical zirconium channels which pass through the graphite moderator.

The part of the pressure tube inside the moderator is made of a zirconium alloy and has the form of a tube 88mm in diameter with a wall thickness of 4mm. The upper and lower ends of the zirconium 2.5 Nb alloy tubes have extensions made of alloy steel which are connected by special transition pieces (Fig 7).

The Fuel

Each of the 1693 channels contains 2 fuel sub-assemblies held together by a central supporting rod and suspended from a plug in the upper duct (Fig 8). The sub-assemblies are each 3.5m long and are made up of 18 fuel pins (called elements by the Russians) spaced by 10 stainless steel cellular spacer lattices. The fuel pins are of 1.8% enriched uranium dioxide pellets in a zirconium-niobium (Zr + 1% Nb) cladding 13.6 mm od and 0.9 mm thick. The inner space of the fuel pin is filled with an argon-helium mixture.

Reactor Control System

The large size and high power of the reactor requires special features to allow efficient and safe operation of the reactor. These include:

- The control system which regulates the total power of the reactor and its average neutron flux from the far sub-critical state to normal operating level.

- The start-up apparatus to enable the reactor power to be controlled from 10% of power to -10% of the nominal level.

- Further increase in power is controlled by the automatic protection regulator operating over the reactor power range 0.1% to 5%.

- Two automatic controllers are provided over the power range 5% to 100%.

Protection against power excursions for the reactor as a whole and also locally are provided by emergency signal measuring against set points.

The rate of power increase and power distribution on the periphery of the reactor are also monitored.

Data processing equipment calculates the power of all fuel assemblies from detector signals and from calculated reactor physics data to allow comparison.

Containment

The RBMK plants do not have a housing which would be equivalent to a full-size containment. Instead the reactor coolant system is surrounded by several boxes. Each box usually contains one coolant loop. Moderate coolant leakages to the boxes can be led to a condensing system, suppression pool, or condensed with a spray system. Bursting discs are provided to the boxes to prevent an inadmissible increase in pressure in the containment box. Leakage through the pressure tube wall into the graphite containment is also vented via a bursting disc into the suppression pool (Fig 9).

Control Rods

The control rod channels are cooled by a separate water cooling circuit. They are divided by function, as follows:

a 89 manually operated rods

b 12 automatically operated rods for power variation c 57 emergency shutdown rods

d 21 shortened absorber rods. These, and the manual rods, are used for controlling the power distribution in the reactor.

The power distribution control, radial profile control, power-level control and safety rods consist of 6 elements and have an overall length of 6170mm, while the axial profile control rods consist of 3 elements and have an overall length of 3050mm.

Refuelling

The RBMK reactors are designed to be refuelled at full load. Fig 4 illustrates a refuelling machine operating from a gantry running the full length of the common refuelling machine hall.

The Coolant System

The coolant circuit is shown in Fig 10. It consists of 2 parallel loops each of which cools half of the reactor (It has been stated that alternate tubes from the 2 loops feed to the two halves of the core, an arrangement that seems likely). Water at 270 degrees C enters the bottom of each fuel channel individually through a 53.5mm diameter pipe. On leaving the top of the fuel channel the steam water mixture is passed via an individual 72mm pipe to a drum separator. Each loop has 2 drum separators linked by steam and water connectors. The drums are made of carbon steel lined with stainless steel (Fig 11). Saturated steam at 284 degrees C, 70 kgf/sq cm is passed to a general collector supplied by both loops from which it enters 2 x 500 MW turbines. Condensate from the turbine is returned to the drum separators by electric pumps.

Shutdown Heat Removal

In common with all large nuclear reactors the residual power production in the core when the reactor has been shut down is fairly substantial. For example, after a day it is 0.4% of the nominal power (Nnom), ie 12.8 MW. After 30 days, this falls to 0.12% Nnom and then remains virtually constant for a long time. This makes it clear why it is not permissible to drain the core even after shutdown. Therefore, in conducting servicing on the forced multiple circulation loop (FMCL), it is necessary to organise core cooling.

Emergency Feed and Cooling System

Safety of the installation with complete stoppage of feed water fed into the power units is achieved by switching off the reactor by the emergency safeguarding system according to a signal for decreasing the flow rate below 50% of the instantaneous value. In this regime, the input of water into the circulation loop by emergency feed pumps constitutes approximately 20% of the nominal value; they are switched on 10-20 seconds following cessation of feed water inflow.

The water from the emergency reactor cooling system is input to each distributing group collector, and in order to avoid its loss through the rupture section in the head collector non-reverse valves are provided at the inlet to the distributing group collector. The emergency reactor cooling system consists of 2 sub-systems: a main sub-system with a hydro-accumulation unit and a sub-system with prolonged cooling with special pumps and water storage in tanks, see Fig 12.

Investigations have shown that for any rupture of pipelines up to maximum diameter (900mm), due to the rapid action and capacity of the emergency reactor cooling system, there is an acceptable temperature regime for the fuel elements.

TABLE 1

General Specification

Thermal power, MW	3140
Electrical power (at generator terminals), MW	1000
Core diameter, m	11.8
Core height, m	7
Lattice pitch, mm	250 x 250
Number of channels in lattice	2044
made up of:	
- fuel channels	1693
- control and safety system channels	195
- reflector cooling channels	156
Number of channels outside lattice	18
made up of:	
- temperature channels	17
- gas sampling channels	1
Constant uranium dioxide charge, t	204
Uranium, enrichment, %	1.8
Mean power of fuel channel, kW	1850
Power of most highly loaded channel, kW	2700
Coolant flow, t/hour	37.5 x (10 to the 3)
Mean bulk steam content	0.15
Saturated steam temperature, deg C	284
Coolant temperature at fuel channel inlet, deg C	270
Saturated steam pressure in drum separators, kgf/cm sq	70
Feedwater temperature, deg C	160
Maximum graphite temperature, deg C	700
Burn-up MWD/kg uranium	18.5

TABLE 1 Continued

Mean channel power rating MW/te	15.4 (cf 13.6 at HYB)
Peak channel power rating MW/te	22.4 (cf 17.4 at HYB)
Coolant circuit	Two parallel loops, 4 pumps per loop. Coolant enters the fuel channels from below (supplied by individual feeder pipes) and the steam-water mixture from the top of the channels passes along individual riser pipes to steam drums (2 drums per loop). The coolant pressure at the steam drums is 68.6 bar (994lb/sq in). Feedwater temperature is 160 degree C.
Refuelling	On load, up to 5 channels/ 24 hours.
Turbine generators	2x500MWe capacity each at the generator terminals.
Reactor building	(See Fig 4) the reactor core is in a concrete vault and the main primary circuit components (piping, pumps, steam drums) are in separate cells with concrete biological shielding round them. In the bottom of the reactor building is a 'bubbler pond' (suppression pool) into which steam can be discharged if it cannot be passed to the turbine condenser.

TABLE 2

Characteristics of RBMK-1000 Fuel Sub-Assembly and Fuel Element

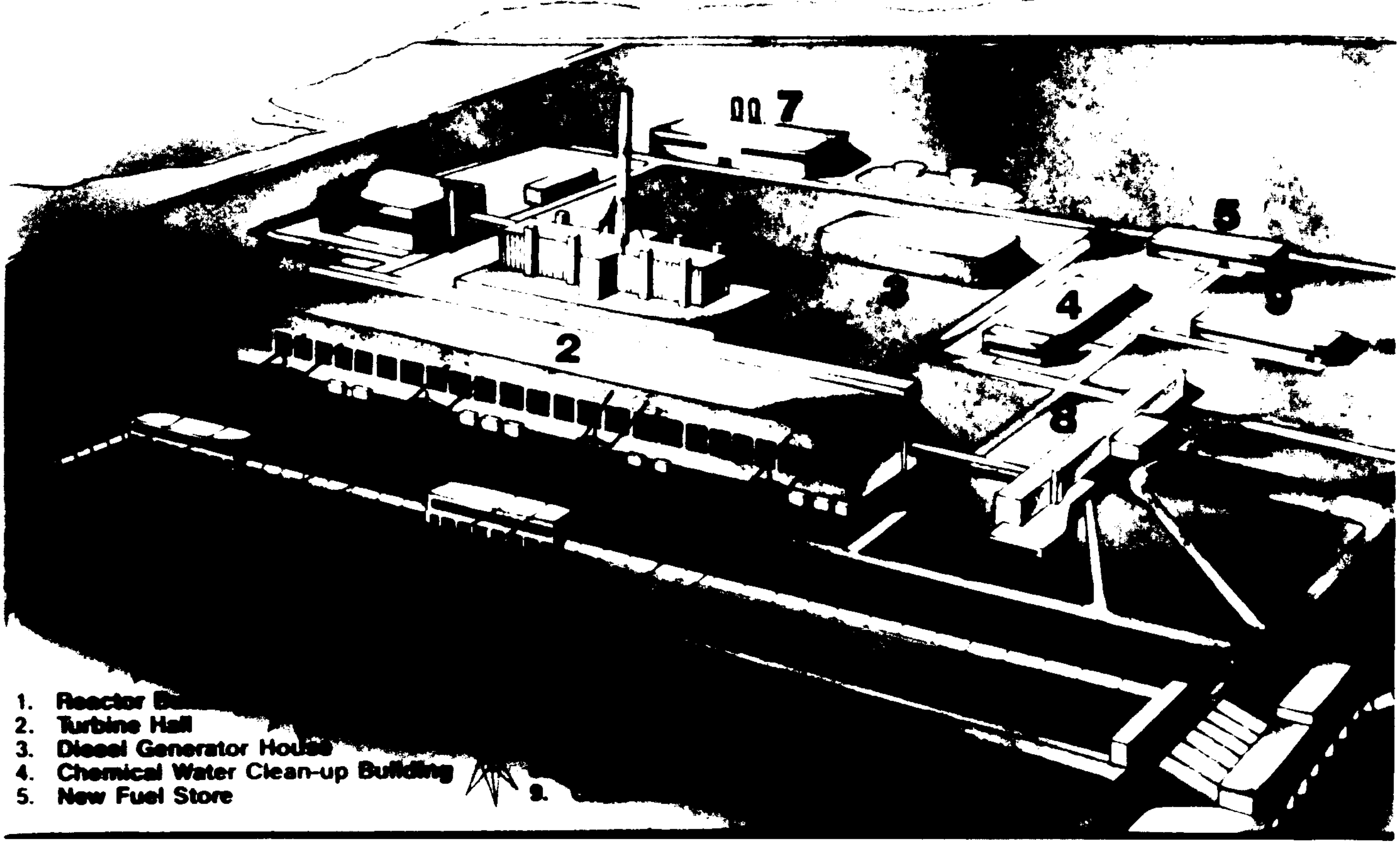
Distribution of fuel elements in fuel sub-assembly	2 rows of 6 and 12
Spacer grid	Stainless steel cellular type
Supporting central rod	Zr alloy with 2.5% Nb
Length of fuel element	3644 mm
Weight of uranium dioxide (mean)	3.59 kg
Length of fuel column	3430 mm
Volume of gas collector	17.4 cubic cm
Filler gas	Helium at 1 atm
Fuel element cladding	Zr alloy with 1% Nb in fully annealed condition
External diameter of cladding	13.6 mm
Wall thickness of cladding (min)	0.825 mm
Diametral gap between fuel and cladding	0.18-0.38 mm
Fuel enrichment	1.8%
Fuel density	> or = 10.3 g/cubic cm
Height of fuel pellet	12.0 mm
Diameter of fuel pellet	11.52 mm
Volume of indentation on pellet	3%

TABLE 3

Thermal Parameters of RBMK-1000 Fuel Sub-Assembly and Fuel Element

Maximum power of fuel channel	3000 KW
Coolant pressure - at inlet	80 kgf/square cm
- at outlet	73 kgf/square cm
Coolant temperature - at inlet	265 degrees C
- at outlet	284 degrees C
Maximum steam content	27 wt.%
Maximum velocity of steam-water mixture	20 m/sec
Rate of flow of coolant through fuel at maximum power	21,200 kg/hour
Maximum thermal flux from surface of element	83 W/square cm
Maximum linear thermal power	350 W/cm
Maximum fuel temperature	1800 degrees C
Mean burn-up	19,500 MWD/t uranium
Duration of operation of fuel element at rated power	1190 days

GENERAL VIEW OF SMOLENSK - 1 & 2 RBMK POWER PLANT



1. Reactor B
2. Turbine Hall
3. Diesel Generator House
4. Chemical Water Clean-up Building
5. New Fuel Store

9.

No comment

+ Naval
(i.e. late pm)

MEMORANDUM

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Subject CHERNOBYL ACCIDENT

The attached is a paper that Professor H J Teague intends presenting to the NPWSC at the next meeting on 2 July 1986. Your comments would be welcome and should be addressed to Professor Teague.

An early response would also be appreciated.

P G Bonell

17 June 1986

Enc

Copies to:

Dr M L Brown
Mr E Bevitt
Mr R Clasper
Mr R F Cox
Mr K M Leigh
Mr R N H McMillan
Mr M A King

THE CHERNOBYL ACCIDENT

1. Introduction

Pressure tube reactors have been operating in the USSR since 1954 with a small 5 MW unit, with developments to 600 MW in 1958, expanding to units of 1000 MW and 1500 MW capacity (Table 1). The 4 units at Chernobyl, each of 1000 MW(e) gross, became operational during the 1978-1984 period with unit 4, in which the accident occurred, operational for about 18 months.

Historically, information about the Russian RBMK reactor units was made available to the UKAEA during the 1970s, when the then Prime Minister, Harold Wilson, set up a scientific exchange agreement with the USSR which focussed on the RBMK units and our own SGHWR, both pressure tube reactors. A series of visits took place between the USSR and the UK and technical information was exchanged on a wide range of design and safety topics.

The information given in these papers and the information exchanges have allowed the UKAEA to react quickly following the accident. Also, SRD's contacts with overseas safety organisations provided much authoritative information on activity levels measured in various nearby countries. The paucity of information relating to the actual accident only allowed conjecture on the cause of the accident but the availability of the technical information, and the dissemination of the radioactive sampling data received from various countries, has allowed an estimate to be made of the extent of the escape of the volatile fission products, and from this a scenario can be postulated about the likely effects of the accident on the core, and also to the long-term effects on ground contamination.

2. Description of RBMK Reactor

The basis of a nuclear station containing RBMK reactor units is provided by 2 units of electrical power of 1000 MW each,Figs 2 and 3. Each unit is a reactor of a graphite-moderated pressure tube, boiling water type, with direct cycle to 2 x 500 MW turbines. The reactor fuel is contained inside pressure tubes, which are located in the graphite vertical columns. The reactor water passes through the pressure tubes and starts to boil. The steam leaves the pressure tubes as a 2-phase mixture with a void content of 15%, is directed to steam drums, and is then transferred to the turbines. Thirteen units containing RBMK-1000 reactors are now operating: 4 at Leningrad nuclear power station, 4 at Chernobyl, 3 at Kursk, 2 at Smolensk, and one unit containing an RBMK-1500 at the Ignala nuclear power station.

The reactor involved in the incident at Chernobyl is the most recently constructed fourth reactor, ie the second half of the second station. This is thought to be part of the same series and thus similar to the Smolensk reactor.

The reactor has a multi-compartment containment system. The containment of the reactor core has a pressure capability which is not known in the UK at present but may be relatively low. It is protected by a system of bursting discs with a suppression pool. It has a complex control and protection system involving sector control and stabilising equipment. The reactor physics is complex; under some conditions the reactor may have a positive void coefficient (although the power coefficient is still negative). The negative void coefficient would cause coupling and feedback between thermal hydraulics and reactor power. The ECCS system includes both accumulator injection and pumped injection.

A more detailed description of the reactor vault, together with the fuel details and the method of reactor control, is given in Appendix 1 which also describes the shutdown heat removal, the emergency feed and cooling system.

3. The Course of the Accident

Information relating to the actual sequence of events at Chernobyl has been sparse and often contradictory. Whilst some consistent features are now emerging, the full picture is still unclear. Appendix 2 discusses currently available information and indicates a possible sequence of events. Definite conclusions must await clarification of the true cause. However, design features have been identified which may have contributed to the accident including:

- Possible operation with positive void coefficient.
- Relatively weak containment of red-hot, reactive graphite.
- Complex control and stabilising system.
- Possible human error.
- Proximity of red-hot graphite, zirconium, high pressure steam and water.

4. Preliminary Conclusions about the Source Term

In the early stages of the accident, it was most important to establish any likely danger to the UK public, both at home and overseas, from the released reactor fission products. Although there was little information about the radiation levels in the immediate vicinity of the Chernobyl plant itself, radionuclide sampling data from a variety of points in Western Europe (and limited data from Eastern Europe) were made available to SRD through personal telephone and telex communication. A trickle of information about the origins of the accident and damage state of the reactor came from the USSR, through the IAEA and public media. The extrapolation of radionuclide sampling data to a source term was more likely to provide a consistent picture of the accident than working from an imagined reactor damage state towards a source term. Information on radionuclides sampling have continued to be received from all over the world. SRD contacts with other national experts such as CEGB, NRPB, NNC and the experts within the UKAEA, have allowed opinions to be formed and advice given to UK governmental departments. A task force was set up by the CEGB with AEA participation to co-ordinate the effort and information began to flow to industry through a CEGB newsletter on the Chernobyl accident. Discussion of views on this data has also been possible through personal contacts between colleagues on the international committees of the Senior Group of Experts on Severe Accidents.

An early statement on the emission of radionuclides made by SRD indicated that much of the available evidence, including Soviet bulletins, pointed to the release of radioactivity from the damaged reactor having taken place over a number of days. The variation of weather patterns over this period complicated greatly the interpretation of measurements of radionuclide concentrations since the plume of released material will have experienced numerous changes in atmospheric conditions.

The current 'best estimates' of the release magnitude are based upon earlier recordings obtained from Scandinavia (for the period 28 April to 4 May 1986), together with the thyroid uptake of radio-iodine measured for the students returning to the UK from Minsk. After making suitable weather and released material concentration assumptions, the activity release corresponded to a few percent of the inventory of volatile fission products. It is not clear whether this represents a few percent from each channel or a near total release from a few percent of the channel; the latter may be the more likely if the initiator was a local power increase.

A fairly consistent picture of the relative release fractions of different fission products emerges from which the following conclusion can be drawn:

(a) The Cs137/CS134 ratio is everywhere consistent at about 2.0, corresponding to an average fuel burn-up of one year to 500 days.

(b) Measurements over a period extending over one week after the accident initiation on 26 April, after half-life corrections, all point to the same shut-down inventory, ie there was no significant continuing reactivity in the core generating short-lived fission products after 26 April. This confirms what the USSR have stated.

5. Evacuation

It has been possible to deduce the evacuation requirements having already determined the source term. At present, the contamination is largely due to caesium with a half-life (including the effects of migration into the earth) of about 30 years. Earlier on the activity was due to many other radionuclides but these will by now have decayed to low levels.

The following points can be noted:

Virtually no member of the public would exceed the Whole Body ERL.

Evacuation might be expected out to 30 km based on the thyroid ERL. This seems consistent with the exclusion zone stated by the USSR. The issue of stable iodine may be expected outside the 30 km radius as has been reported.Taking the dose rate levels corresponding to the 0.5 rem/year (5 mSv/yr) limit for the public as the criterion, those evacuated from the 30 km radius could not be allowed back within a year.

These predictions are consistent with the known facts.

6. Implications

Little detail is known of the incident at the plant so it is difficult to draw detailed conclusions at this stage. Appendix 2 sets out the information that is available on the course of the accident and it explores possible accident initiators.

The United Kingdom's likely concerns will include any implication of the accident related to containment and perhaps operator error issues. It is not clear what the capability of the RBMK-1000 containment system is. However, doubts have been raised in several quarters as to its adequacy in view of the large release of activity. Similarly, whilst details of the cause of the accident are still not available, human error has been mentioned as a possible contributor. Both these topics may be read across to other reactor systems.

The major concern is likely to be in the area of emergency response. Public awareness of the potential consequences of severe accidents is now extremely high and reassurance on emergency preparedness seems necessary. The UKAEA is reviewing its position with regard to published emergency plans with a view to releasing more detailed documents. Similar steps are believed to be under consideration in the CEGB.

Finally, it seems clear that there will be a continuing trend towards greater publication of information on incidents and on safety in general. The CEGB are considering publication of a generic review of Magnox reactor safety similar to that already published on the AGR. Within the AEA, consideration is being given to preparation of various documents in layman's language covering the safety of reactors and other related safety topics. Whilst all of these may not come to fruition there is a clear movement towards more public information being provided and in less technical language.

APPENDIX 1

REACTOR VAULT

The graphite structure forming the core and reflector is supported on a welded metal structure. There is concrete shielding 3 m thick above the core and 2 m thick below the core. Water tanks provide the inner radial biological shielding and there is an annulus filled with special sand between these water tanks and the outer concrete of the reactor vault. The space immediately round the graphite core is sealed and contains a helium/nitrogen mixture (40% He/60% N2).

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The RBMK-1000 graphite-channel boiling-water reactor has 1693 fuel channels (FC) arranged in vertical holes in the graphite stack. Each channel has a body of tubular construction within which is located a fuel stringer.

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(c) 57 emergency shutdown rods.

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The power distribution control, radial profile control, power-level control and safety rods consist of 6 elements and have an overall length of 6170 mm, while the axial profile control rods consist of 3 elements and have an overall length of 3050 mm.

REFUELLING

The RBMK reactors are designed to be refuelled at full load. Fig 3 illustrates a refuelling machine operating from a gantry running the full length of the common fuelling machine hall.

THE COOLANT SYSTEM

The coolant circuit is shown in Fig 4. It consists of 2 parallel loops each of which cools half of the reactor. Water at 270 degrees C enters the bottom of each fuel channel individually through a 53.5 mm diameter pipe. On leaving the top of the fuel channel the steam water mixture is passed via an individual 72 mm pipe to a drum separator. Each loop has 2 drum separators linked by steam and water connectors. The drums are made of carbon steel lined with stainless steel. Saturated steam at 284 degrees C, 70 kgf/sq cm is passed to a general collector suplied by both loops from which it enters 2 x 500 MW turbines. Condensate from the turbine is returned to the drum separators by electric pumps.

SHUTDOWN HEAT REMOVAL

The residual power production in the core when the reactor has been shut down is fairly substantial. For example, after a day it is 0.4% of the nominal power (Nnom), ie 12.8 MW. After 30 days, this falls to 0.12% Nnom and then remains virtually constant for a long time. This makes it clear why it is not permissible to drain the core even after shutdown. Therefore, in conducting servicing on the forced multiple circulation loop (FMCL), it is necessary to organise core cooling.

EMERGENCY FEED AND COOLING SYSTEM

Safety of the installation with complete stoppage of feed water fed into the power units is achieved by switching off the reactor by the emergency safeguarding system according to a signal for decreasing the flow rate below 50% of the instantaneous value. In this regime, the input of water into the circulation loop by emergency feed pumps constitutes approximately 20% of the nominal value; they are switched on 10-20 seconds following cessation of feed water inflow.

The water from the emergency reactor cooling system is input to each distributing group collector, and in order to avoid its loss through the rupture section in the head collector non-reverse valves are provided at the inlet to the distributing group collector. The emergency reactor cooling system consists of 2 sub-systems: a main sub-system with a hydro-accumulation unit and a sub-system with prolonged cooling with special pumps and water storage in tanks.

Investigations have shown that for any rupture of pipelines up to maximum diameter, due to the rapid action and capacity of the emergency reactor cooling system, there is an acceptable temperature regime for the fuel elements.

APPENDIX 2

Information Available on the Course of the Accident

The information on the accident at Chernobyl has tended to be contradictory and has been confused by possibly misleading reports put out by interested parties, which have, in effect, been largely speculation. The "hard" facts are that the reactor building has been destroyed by fire and/or explosion, a core/graphite fire ensued and a significant quantity of the fission product inventory has been released. Reports available from the IAEA team which visited the area as well as Tass and Pravda are starting to paint a more consistent picture. A more detailed chronology of events is being built up but this assessment is largely based on the following.

The "initial" incident appears to have been an explosion or explosions which occurred at 1.23 am on Saturday, 26 April. This resulted in a fire in the reactor building, which may have spread to the turbine hall roof. Blix and Rosen (IAEA) have reported that the event occurred when the reactor was at low power (200 MW th), which is normal for a routine short-term shutdown, and that all pumps were running at the time. Rosen stated that he had seen control room data which supported the theory that the reactor had been at full power prior to the "shutdown". The shutdown itself was said to be uneventful until the accident occurred, this appeared to be a spontaneous event. It was reported that there was an explosion which "took the roof off the reactor" and caused the 300 te overhead crane to fall into the reactor causing further damage. At some time prior to the explosion, the power of the reactor suddenly surged from 6% to 50% in 10 seconds. Soviet scientists are still analysing the data but believe they are close to identifying the cause of the explosion. They are confident that the accident originated inside the reactor and was not a consequence of an event from outside. It has also been reported that the design of the Chernobyl reactor has been reviewed and no design flaw has been identified. However, operating procedures are being reviewed at similar plants and stringent alert procedures are being adopted. This strongly suggests an element of operator error.

Under normal conditions, none of the materials in the core have the potential to cause explosions. For an explosion to occur, either chemical reactions must reduce water to produce hydrogen, which can then explode if it mixed with air, or fuel rod materials must melt and then mix with liquid water to provide the initial conditions for a steam explosion or steam spike. In either case, this would require greatly elevated core temperatures as significant reduction of water by either the zirconium cladding or the graphite moderator requires temperatures of 1000 C or above and large-scale melting of the fuel cladding could not occur until a temperature of 1850 degrees C was reached (though some local fuel liquefaction might occur at temperatures above 1300 degrees C). For such temperatures to be attained either the coolant supply to a fuel channel would have to be reduced or departure from nucleate boiling would have to occur. The latter could result from an overpower transient, a reduction of coolant pressure or some combination of the two. Indeed, as the core appears to have a negative coolant density coefficient of reactivity, an overpower transient could arise as a direct result of a fall in pressure increasing the void fraction of the coolant.

Overheating of fuel, however, does not by itself provide the necessary conditions for an explosion. As already noted, to produce a hydrogen explosion the gases produced by the reduction of water must mix with air to produce an explosive mixture, and to produce a steam explosion molten materials and water must be intermixed.

POSSIBLE INITIATORS AND SOME REACTOR PHYSICS STUDIES

So far, the discussion has concentrated on the course of the accident following the explosion. The question arises as to what caused the explosion in the first place? Some are initiators in themselves (eg turbine failure or steam drum failure) but the others require the production of either molten material or hydrogen. There may be many ways to postulate this happening but to remain undetected (or ignored if operator error is postulated) a local fault seems the most likely. These may be under-cooling or over-power faults.

Some exploratory calculations of the reactor physics have been made by the Authority (AEEW) and these scoping calculations are aimed at throwing light on:

(a) Minimum size of a critical zone.

(b) Magnitude of reactivity coefficients especially in relation to the reported negative void coefficient.

(c) The dynamics of a reactor with a positive void coefficient.

MINIMUM CRITICAL SIZE

Fresh fuel with an enrichment of 1.8% U235 has a k of around 1.3. It is known that Chernobyl is fuelled with 2% U235. The minimum critical size is clearly very small. An uncontrolled area of about 40 channels would be critical at normal operating conditions. Control rods are inserted in positions on the same lattice as the fuel on a 1-in-8 grid.

REACTIVITY COEFFICIENTS

On the basis of a single reflected lattice cell calculation, the void coefficient is strongly positive. It decreases with irradiation. This is unrealistic since in practice there will be sufficient leakage to give a just critical condition. This can be represented either by peripheral absorber or by an energy independent critical buckling. Neither of these gives an accurate representation of the spatial and energy dependence of the leakage but they do give a sufficiently accurate approximation to the general nature of the situation.

For fresh fuel under these conditions the void coefficient is negative. However, at an irradiation in the region of 8,000 MWd/t, rough calculations show it becoming positive. This must be close to the irradiation of Chernobyl 4. It has been stated by the Russians, however, (Romanesco, Risley seminar 1977) that the void coefficient would stay slightly negative. It would appear that the position is at best borderline and could well depend on details of reactor operation, such as how much installed reactivity is retained through onload refuelling. The Doppler coefficient is negative and the power coefficient is probably negative but small at this irradiation. It is quite possible that the power coefficient becomes positive at higher irradiation.

The core is initially loaded with absorbers to take up some of the excess reactivity. It is operated with onload refuelling and therefore with little excess reactivity at equilibrium. Details of the method of achieving the transition are unknown. The equilibrium situation is a low local leakage situation over a region of a few channels and is therefore likely to be a situation with a positive void coefficient.

KINETICS

Some point kinetic calculations have been carried out to look at some possible scenarios. It is known that the reactor was at a low power of 200 MW thermal. One of the papers (Kuznetsov, Risley seminar 1977) states that at powers below 150 MW(E) the primary flow is throttled back from 42,000 t/hr to 6,000-7,000 m^3/hr or about 4,500 t/hr. This is apparently a cut-back to about of normal flow. It is stated that the reason for this throttling of the pump outlet is to prevent cavitation. Other papers state that full flow is 700 m^3 /hr - there is therefore some confusion and it could be that the throttling is intended to maintain a more or less constant flow. In the argument that follows, we will assume that the throttling does reduce flow to about 1/10 of normal flow.

It would require a reactivity step of 0.3% to achieve 50% power in 5 sec. It has been stated in the reports that 50% power was achieved. It has also stated that it takes 20 secs to drive the control rods in. It is clear therefore that a smaller reactivity step could achieve 50% power before trip.

What would be the consequence of 50% power with 10% of full flow? At full flow and 100% power, the exit steam quality is 15%. AT 50% power and 10% flow the exit quality would be around 75% corresponding to a void fraction of nearly 100%. There would thus be very high voidage in much of the channel. Using the calculated positive void fraction, this could be worth as much as 1% in reactivity. There is thus clearly the potential for a runaway situation starting with a very small reactivity insertion. An attempt is being made to extend the point reactivity calculation to model the resulting positive void feedbacks.

At such a high voidage, there would certainly be a dryout situation. A simple and approximate calculation suggests that a 1,000 degrees C temperature rise at 50% power would require about 40 secs. This would raise the temperature to 1,300 degrees C and approach onset of the zirconium water reaction.

On the face of it, the control system should have shut the reactor down in time to prevent this. Even with a 20 sec response time, it should have been able to respond. However, if the 50% power reading was a reactor average condition, it could well be that a group of channels were at higher power and reached 1,300 degrees C in a time comparable with the rod insertion time. At this point, further heating and hydrogen production could proceed without continuing nuclear power. If steam or hydrogen pressure built up to the extent that it flowed backwards in the feeder pipes, it could well have passed to the inlet of another channel and led to a propagation of the incident.

CONCLUSIONS ON LIKELY ACCIDENT

The above scenario still requires an initiating event. The Observer in a front page cover article on 25 May states that control rod experiments were being carried out. This may provide the last link in a plausible chain of events:

(a) Control rod withdrawals being carried out.

(b) Positive void coefficient leads to accelerating reactivity transient.

(c) Low standby flow leads to dryout and rapid temperature rise.

(d) Control rod insertion time too slow to stop the transient in time.

(e) Zirconium and steam reaction leads to hydrogen production, possible propagation and pressure tube rupture.

In general it can be said that various sequences can be postulated which fit the known facts. The propagation of an undetected local fault or local criticality seem the strongest possibilities, particularly the latter in view of the increase in power. Propagation of these events could be either via steam or hydrogen "explosions", with the former being more probably in reactor and the latter affecting out-of-reactor plant.

TABLE . 1

LARGE RBMK UNITS IN SERVICE AND UNDER CONSTRUCTION

Status at 31.12.85	Station	Unit Output MWe (net)	No of units	Commercial operation
In Service	Leningrad	1000	4	1974-1981
	Kursk	1000	3	1976-1983
	Chernobyl	1000	4	1978-1984
	Smolensk	1000	2	1983-1985
	Ignala	1500	1	1984
Under Construction	Kursk	1000	1	1986
	Ignala	1500	1	1986
	Chernobyl	1000	2	1987-1989
	Smolensk	1000	2	1988-1989
	Kostroma	1500	2	1988-1989

Figure 1 shows the location of these stations in the USSR.

TABLE 2.

GENERAL SPECIFICATION

Thermal power, MW	3140
Electrical power (at generator terminals), MW	1000
Core diameter, m	11.8
Core height, m	7
Lattice pitch, mm	250 x 250
Number of channels in lattice	2044
made up of:	
- fuel channels	1693
- control and safety system channels	195
- reflector cooling channels	156
Number of channels outside lattice	18
made up of:	
- temperature channels	17
- gas sampling channels	1
Constant uranium dioxide charge, t	204
Uranium enrichment, %	1.8
Mean power of fuel channel, kW	1850
Power of most highly loaded channel, kW	2700
Coolant flow, t/hour	37.5 x (10 to the 3)
Mean bulk steam content	0.15
Saturated steam temperature, deg C	284
Coolant temperature at fuel channel inlet, deg C	270
Saturated steam pressure in drum separators, kgf/cm sq	70
Feedwater temperature, deg C	160
Maximum graphite temperature, deg C	700
Burn-up MWD/kg uranium	18.5
Mean channel power rating MW/te	15.4 (cf 13.6 at HYB)
Peak channel power rating MW/te	22.4 (cf 17.4 at HYB)

TABLE 2 contined

Coolant Circuit	-	Two parallel loops, 4 pumps per loop. Coolant enters the fuel channels from below (supplied by individual feeder pipes) and the steam-water mixture from the top of the channels passes along individual riser pipes to steam drums (2 drums per loop) The coolant pressure at the steam drums is 68.6 bar (994lb/sq in). Feedwater temperature is 160 degree C.
Refuelling	-	On load, up to 5 channels/ 24 hours.
Turbine generators	-	2x500MWe capacity each at the generator terminals.
Reactor building	-	(See Fig 2) The reactor core is in a concrete vault and the main primary circuit components (piping, pumps, steam drums) are in separate cells with concrete biological shielding round them. In the bottom of the reactor building is a 'bubbler pond' (suppression pool) into which steam can be discharged if it cannot be passed to the turbine condenser.

TABLE 3

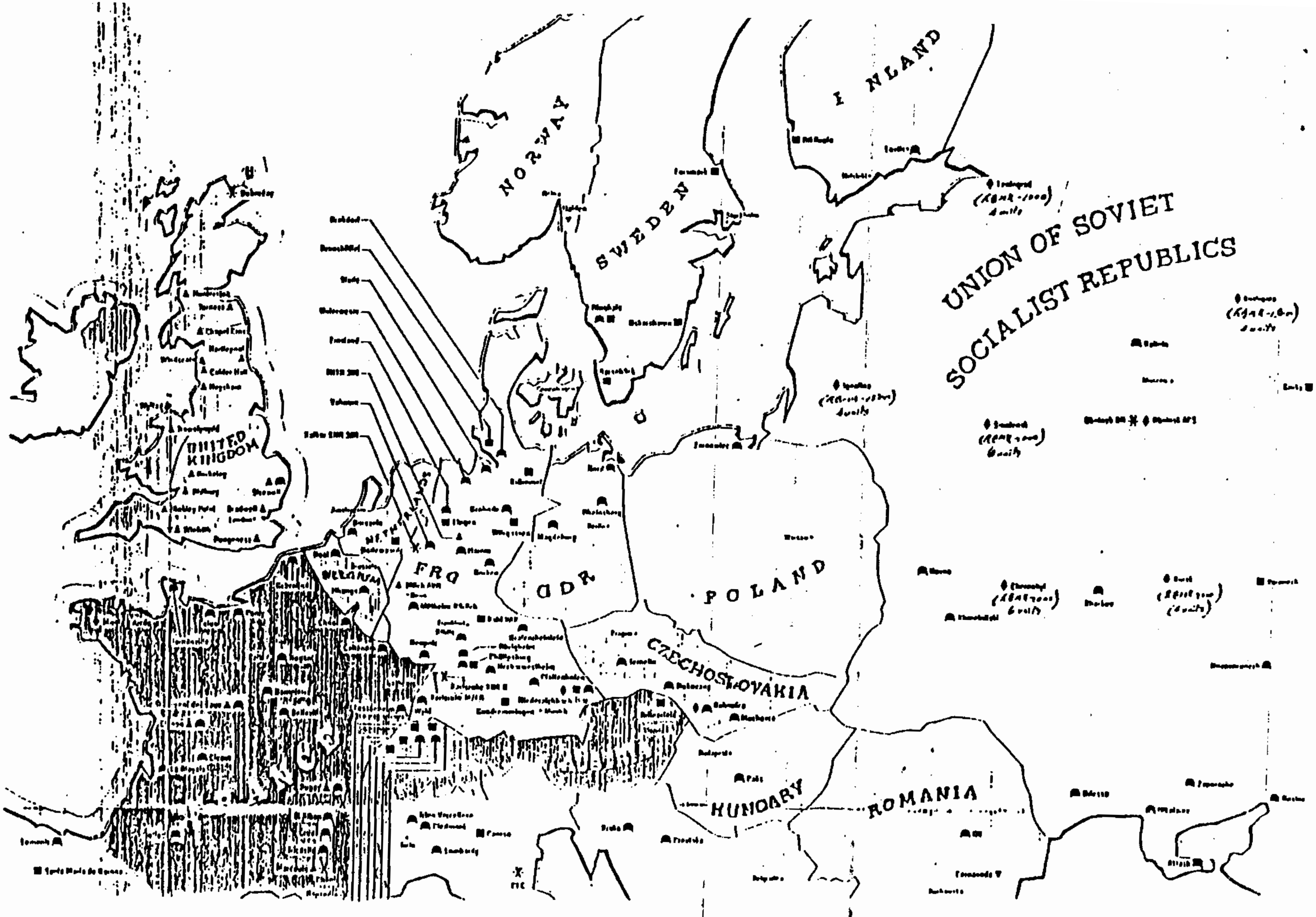
CHARACTERISTICS OF RBMK-1000 FUEL SUB-ASSEMBLY AND FUEL ELEMENT

Distribution of fuel elements in fuel sub-assembly	2 rows of 6 and 12
Spacer grid	Stainless steel cellular type
Supporting central rod	Zr alloy with 2.5% Nb
Length of fuel element	3644 mm
Weight of uranium dioxide (mean)	3.59 kg
Length of fuel column	3430 mm
Volume of gas collector	17.4 cubic cm
Filler gas	Helium at 1 atm
Fuel element cladding	Zr alloy with 1% Nb in fully annealed condition
External diameter of cladding	13.6 mm
Wall thickness of cladding (min)	0.825 mm
Diametral gap between fuel and cladding	0.18-0.38 mm
Fuel enrichment	1.8%
Fuel density	> or = 10.3 g/cubic cm
Height of fuel pellet	12.0 mm
Diameter of fuel pellet	11.52 mm
Volume of indentation on pellet	3%

TABLE 4

THERMAL PARAMETERS OF RBMK-1000 FUEL SUB-ASSEMBLY AND FUEL ELEMENT

Maximum power of fuel channel		3000 KW
Coolant pressure	- at inlet	80 kgf/square cm
	- at outlet	73 kgf/square cm
Coolant temperature	- at inlet	265 degrees C
	- at outlet	284 degrees C
Maximum steam content		27 wt.%
Maximum velocity of steam-water mixture		20 m/sec
Rate of flow of coolant through fuel at maximum power		21,200 kg/hour
Maximum thermal flux from surface of element		83 W/square cm
Maximum linear thermal power		350 W/cm
Maximum fuel temperature		1800 degrees C
Mean burn-up		19,500 MWD/t uranium
Duration of operation of fuel element at rated power		1190 days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SOCIALIST REPUBLICS
UNITED KINGDOM
FRG
GDR
POLAND
CZECHOSLOVAKIA
HUNGARY
ROMANIA
Magdeburg

Fig. 1

KURSK-1 & 2

Fig 2

A. & B - Reactors

C - Auxillary systems

D - Turbine Hall

E - Deaerator mounting

F - Repair service compartment

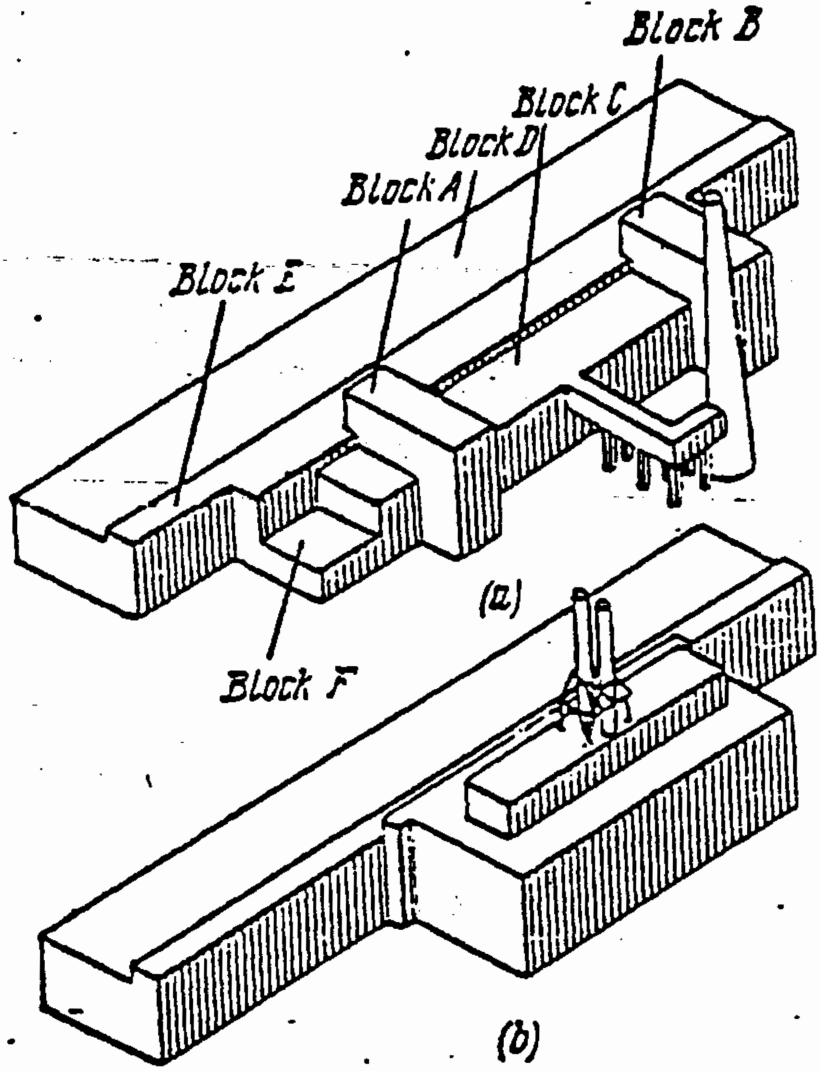


Fig. 2 Layout of the first stages at (a) Kursk and (b) Smolensk

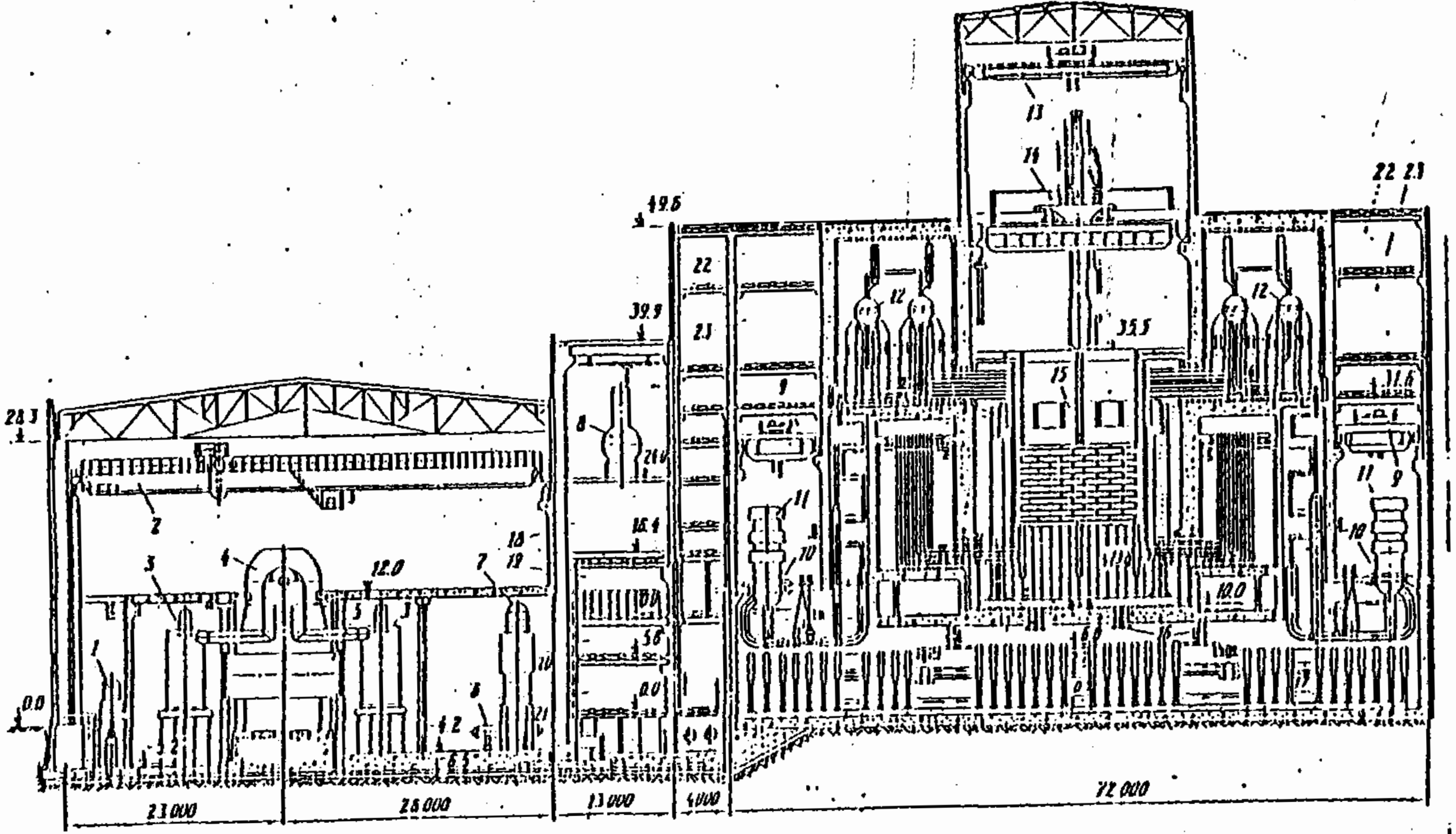
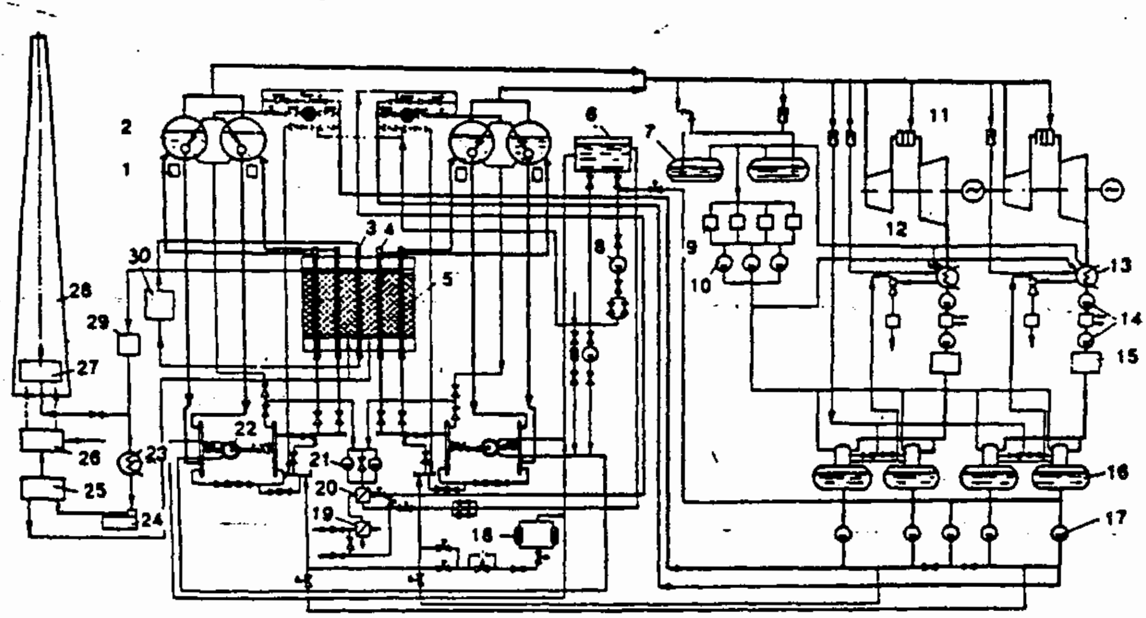


Fig. .3 Cross-sectional view of the main building at Smolensk

3—first-stage condensate pump; 7—125/20-t overhead travelling crane; 8—separator-steam superheater; 1—K-500-65/3000 steam turbine; 2—condenser; 4—additional cooler; 5—low-pressure heater; 6—deaerator; 9—50/10 t overhead travelling crane; 10—main circulating pump; 11—electric motor of main circulating pump; 12—drum separator; 13—50/10 t remotely controlled overhead travelling crane; 14—refuelling mechanism; 15—RBMK-1000 reactor; 16—accident containment valves; 17—bubbler pond; 18—pipe aisle; 19—modular control board; 20—location beneath control board room; 21—house switchgear locations; 22—exhaust ventilation plant locations; 23—plenum ventilation plant locations

Fig 3

Fig 4



1	Cladding failure detection system	16	De-aerator
2	Steam separator	17	Electric feedpumps
3	Monitoring channel	18	Pressurizers of emergency cooling system
4	Fuel channel	19	Aftercoolers
5	Reactor	20	Regenerators
6	Emergency feed-water tank	21	After-heat removal hose
7	Spurging tank	22	Main circulating pump
8	Emergency cooling pump	23	Gas circuit condenser
9	Condensers	24	Compressor
10	Condensate pumps	25	Helium cleaning plant
11	Separator and superheater	26	Buffer gasholder
12	Turboalternator	27	Wet gasholder
13	Condenser	28	Ventilation stack
14	Condensate pumps	29	Fuel channel failure detection system
15	Low-pressure preheaters (five in series)	30	Pumps and heat exchangers of control rod system

Fig. 10 Schematic of RBMK–1000 generating unit

Fig 5

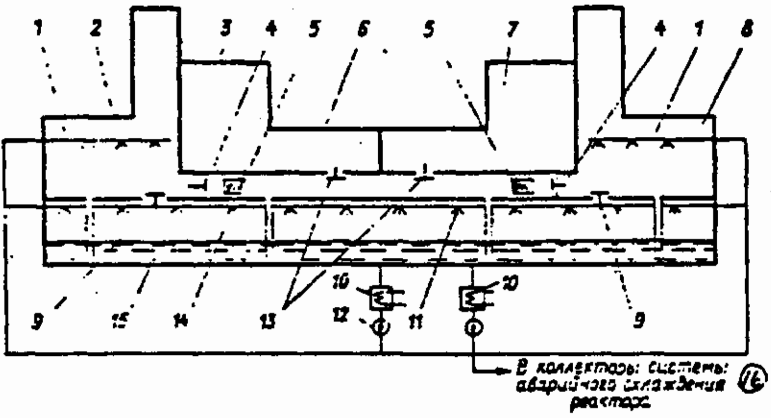


Fig. 5 Schematic diagram of the system for retaining and localizing radioactive products in the event of an accident involving an RBMK-1000 type reactor

1, 11 - sprinklers

2, 8 - left and right hand halves of the hermetically sealed chambers

3, 7 - left and right hand halves of the rooms housing the lower water lines

4 - valve panels in the partitions separating the chambers and the corridors

5 - surface type condensers

6 - steam distribtion corridor

9 - relief valves

10 - heat-exchanger

12 - pump

13 - check valves

14 - air space above sparge pond

15 - depth to which sparge pond is filled with water

16 - To emergency reactor cooling system collectors.

Fig 6

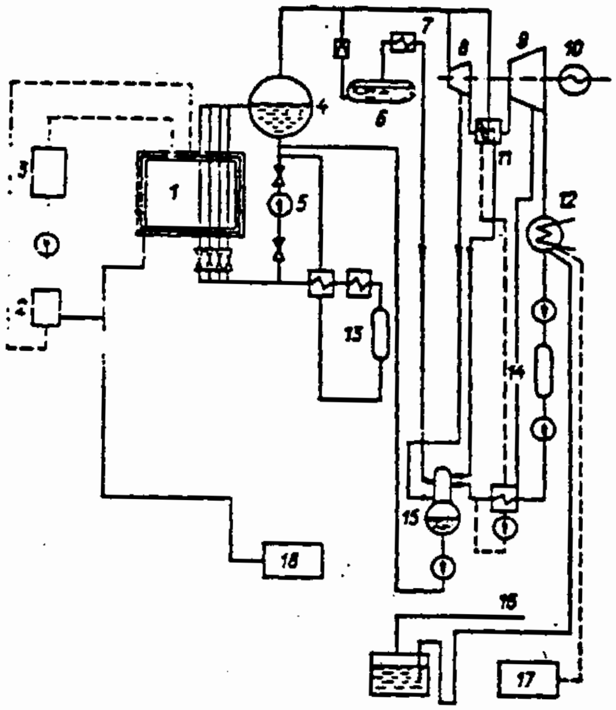


Fig. 6 Schematic flow diagram of a generating unit at an RBMK-1000 type nuclear power station

1. Reactor
2. Helium purification plant
3. System for monitoring the moisture in the reactor graphite blocks
4. Drum-separator
5. Main circulating pump
6. Sparger
7. Process condenser
8. Part of h.p. turbine
9. Part of l.p. turbine
10. Power generator
11. Separator-steam superheater
12. Main turbine condenser
13. Filter
14. Condensate polishing unit
15. Deaerator
16. Chemically treated make-up water
17. Gas cleaning plant
18. Nitrogen plant

Fig 7.

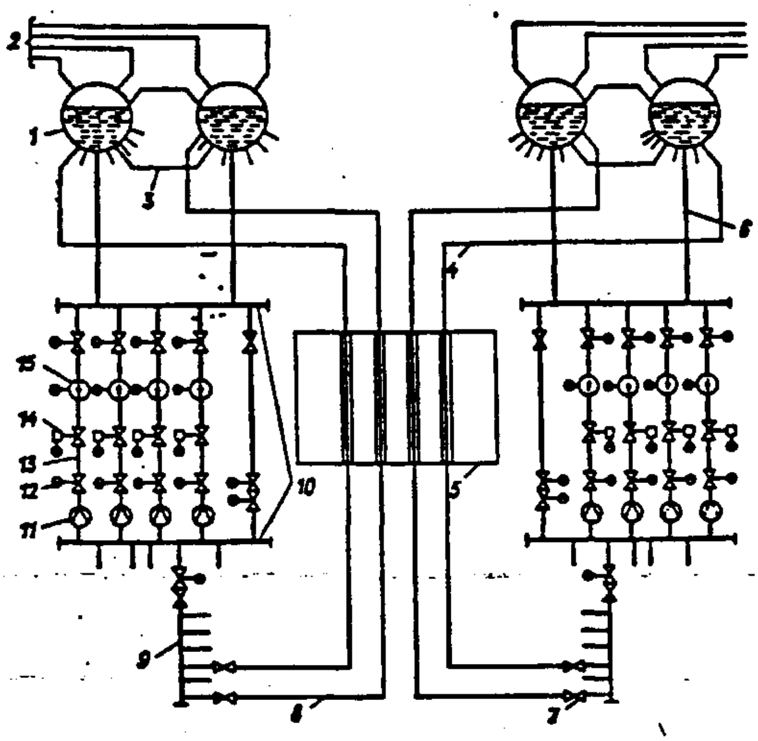
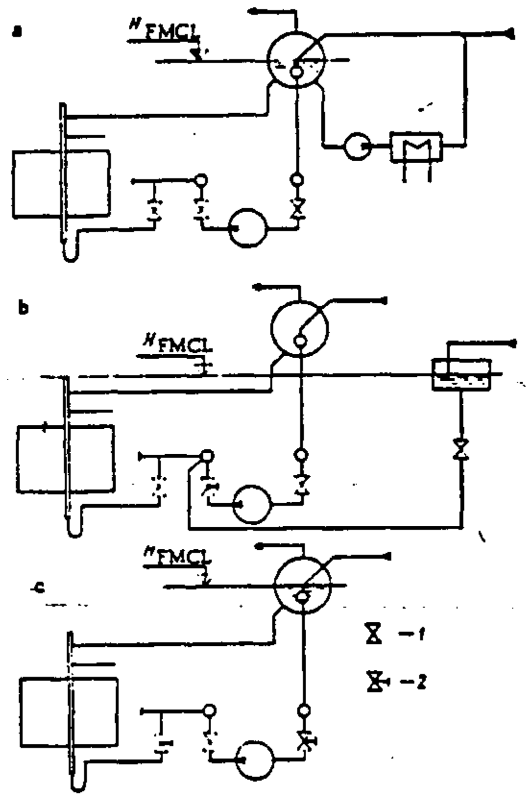


Fig. 7 Diagram of multiple forced circulation loop of an RBMK-1000 type reactor

1. Drum-separator
2. Steam to turbine
3. Compensation line
4. Steam-water lines (76 x 4 mm, n = 1693)
5. Reactor
6. Downcomers (nom. dia. 300, n = 48)
7. Control valve
8. Lower water lines (57 x 3.5 mm, n = 1693)
9. Group distribution manifold (nom. dia. 300, n = 44)
10. Suction and pressure headers (nom. dia. 1000, n = 4)
11. Check valve
12. Main shut-off valve
13. Connecting pipes (nom. dia. 800, n = 10)
14. Throttle valve

Fig 8

Figure 8



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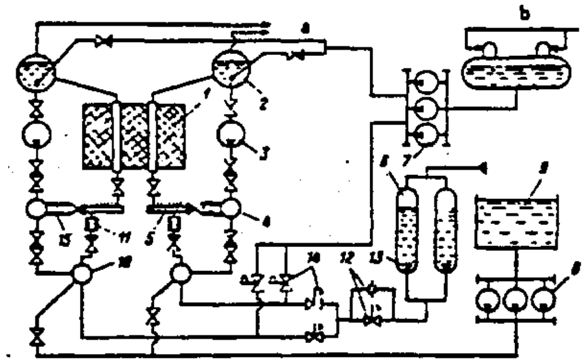

Header

Essential scheme for circulation loop and ECS: 1) reactor; 2) separator; 3) MCP; 4) pressurized collector; 5) DGC; 6) hydraulic accumulation unit in ECS; 7) feed pump; 8) ECS pumps; 9) water stock in condensation device; 10) ECS collector; 11) restriction nozzle; 12) intermediate throttling link; 13) cutoff float valve; 14) fast ECS valve; 15) DGC insert; a) steam to turbines; b) condensate return.

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Telephone: 01-930 5454

Overseas Relations Branch

Our Ref: UR.2 (F.1)
JA.2

17th June, 1986.

Dr. M. R. Hayns,
U.K. Atomic Energy Authority,
Safety and Reliability Directorate,
Wigshaw Lane,
Culcheth,
Warrington, WA3 4NE,
Cheshire.

Dear Mike

Chernobyl - Impact on Japan

My contact at the Japanese Embassy has sent me a copy of a preliminary report on the impact of the accident on Japan and the measures taken by the Japanese Government. The Japanese would appreciate similar information from the UK. Is there anything available with which I could reciprocate?

Yours sincerely,

D. M. Levey

c.c. Dr. T. N. Marsham, Northern Division
Dr. G. Low, Harwell
Dr. W. M. Lomer, Culham
Dr. J. Holmes, Winfrith
Dr. J. H. Gittus, SRD
Dr. D. A. Hicks, WRPD, Harwell
Dr. G. I. W. Llewelyn, LHQ
Mr. F. Chadwick, LHQ
Mr. C. W. Blumfield, DNE
Mr. W. M. McMillan, ISB, LHQ.

Enclosure.

IMPACTS OF SOVIET NUCLEAR ACCIDENT ON JAPAN AND MEASURES TAKEN BY THE JAPANESE GOVERNMENT

1. Impacts on Japan

(1) A very minute amount of radioactivity that is not significant to pose any health risk was detected from some of the Japanese who returned to Japan on May 1 from Mogilev, about 300 km to the north of Chernobyl Nuclear Power Plant and of the Japanese tourists who returned on May 5 from Kiev and neighborhood.

(2) Radioactive substance (Iodine 131) presumably originating from the above accident was first detected on May 3. It has since been detected nationwide in Japan, but the quantity is not significant to pose any health risk.

2. Measures taken by the Japanese Government

(1) Measures against radioactivity

a. Science and Technology Agency instructed the intensification of radioactivity monitoring by 32 prefectures on April 29.

b. Enlarged meeting of representative secretariat members of the Radioactivity

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Countermeasures Headquarter (presided by the Minister of State for Science and Technology) was held on April 30, and it was agreed to intensify the radioactivity monitoring regime and announced the advisory measures for the time being. (See Attachment 7)

c. The plenary meeting of the Radioactivity Countermeasures Headquarter was held on May 4, and decided to intensify the radioactivity monitoring activities and decided matters of precaution in the immediate Future. (See Attachment 8)

d. Secretariat members meeting of the Radioactivity Countermeasures Headquarter was held on May 13, and it was agreed upon that the current intensified activities of radioactivity monitoring should be continued. (See Attachment 9)

e. Meeting of representative secretariat members of Radioactivity Countermeasures Headquarter was held on May 17, and future monitoring of radioactivity in Japan concerning the Soviet nuclear accident was discussed. (See Attachment 10)

f. Meeting of representative secretariat members of Radioactivity Countermeasures Headquarter was held on May 22, and it was decided that the future radioactivity monitoring in Japan should be directed to grasping environmental radioactive level and a long-term accumulating tendency of radioactivity correctly. (See Attachment 11)

(2) Investigation of accidents

a. Nuclear Safety Commission held an extraordinary meeting on April 30 and released a statement in the form of an informal talk of the Chairman on the establishment of special investigation committee on the accident, desire for related information to be released by Soviet authorities. (See Attachment 12)

b. Nuclear Safety Commission established on May 13 the Special Investigation Committee on the Soviet Nuclear Plant Accident. (See Attachment 12)

c. The first meeting of the Special Investigation Committee was held on May 16. (See Attachment 13)

(3) Actions by the diet

Resolutions were adopted in the plenary session and Standing Committee on Science and Technology of the House of Representatives and the plenary session and Special Committee on Science and Technology of the House of Councilors. (See Attachment 14, 15)

(4) Other measures

a. Measures for Japanese residents overseas

(i) Radioactivity analysis was carried out on May 3 for the environmental samples, such as food stuff, sent from the Japanese Embassy in Moscow. (A minute quantity of Iodine 131 was detected, but it was not significant from health risk.)

Similar analysis were carried out again on May 8 for additional food stuff sent from the Japanese Embassy in Moscow. (Iodine 131 of 1,300 pCi/liter and other nuclides were detected from cow's milk.)

(ii) Specialists were despatched to the Soviet Union and Eastern European countries for advice on health of Japanese residents.

A specialist of radiological protection: leaving on May 3 to Warsaw and Stockholm

A specialist of health physics: leaving on May 4 to Moscow and Leningrad.

b. Measures for home-coming travelers

Medical examination was started on May 2 by the National Institute of Radiological Sciences for the home-coming travelers from the Soviet Union. Examination was also started on May 13 by Kyoto University Hospital and Hamamatsu Medical College Hospital.

c. Measures for imported foods

Necessary monitoring for imported foods is being carried out by the Ministry of Health and Welfare based on informations from the countries concerned, so as to prevent import of food contaminated by radioactive substance.

d. Measures for travelers abroad

Special attentions are being called for travelers to the regions of suspected contamination by radioactivity by the Ministry of Transportation in cooperation with Ministry of Foreign Affairs.

Attachment 1:

Detection of I-131

Max. Value as of 17:00 May 23, 1986

Radiation Countermeasure Headquarters

	Location	Rain pCi/ℓ	Tapped Water pCi/ℓ	Air-borne Dust pCi/m²	Milk pCi/ℓ	Vegetables pCi/kg raw	Others pCi/kg raw
1	Hokkaido	467	33	-	280.4	-	4477
2	Aomori Pref.	2150	N.D.	-	N.D.	-	-
3	Akita Pref.	5100	25	-	103	-	-
4	Iwate Pref.	-	-	Sig.	-	-	-
5	Miyagi Pref.	260	N.D.	13.6	320	2230	-
6	Fukushima Pref.	8320	N.D.	4.3	298	5720	-
7	Gunma Pref.	920	-	-	-	-	-
8	Ibaraki Pref.	1987	17	7.5	390	10300	5700
9	Saitama Pref.	31	N.D.	-	98.9	-	-
10	Chiba Pref.	13300	32	5.4	32	4800	10000
11	Tokyo	9300	-	12.0	-	-	-
12	Kanagawa Pref.	5400	N.D.	22	160	9000	3800
13	Shizuoka Pref.	2300	4.3	0.90	96	-	-
14	Niigata Pref.	2000	36	12	220	3000	-
15	Toyama Pref.	1840	N.D.	8.3	-	-	-
16	Ishikawa Pref.	1304	13	12.3	24.1	-	-
17	Fukui Pref.	2391	N.D.	22.5	240	3300	16000
18	Shiga Pref.	210	4	3	-	-	-
19	Kyoto	990	N.D.	8.3	160	-	-
20	Okayama Pref.	4800	44	6.2	Sig.	8100	4400
21	Shimane Pref.	8923	22	7.9	677.7	3.6	5990

	Location	Rain pCi/ℓ	Tapped Water pCi/ℓ	Air-borne Dust pCi/m²	Milk pCi/ℓ	Vegetables pCi/kg raw	Others pCi/kg raw
22	Ehime Pref.	680	N.D.	4.1	N.D.	-	-
23	Fukuoka Pref.	Sig.	N.D.	2.4	216	-	D
24	Saga Pref.	1870	N.D.	6.0	29.1	-	649
25	Nagasaki Pref.	D	N.D.	0.6	3.4	-	-
26	Kumamoto Pref.	-	-	-	116.5	900	-
27	Kagoshima Pref.	375	N.D.	19.7	86.4	N.D.	-
28	Okinawa Pref.	115	N.D.	1.0	33.2	-	3638

29 Solitary Islands (pCi/ℓ)

Miyake-jima : Rain water 160 (Tokyo)
Hachijo-jima : Rainwater 340 (Tokyo)
Tsushima : Rainwater N.D. (Nagasaki Pref.)
Hukue-jima : Reservoir N.D. (Nagasaki Pref.)

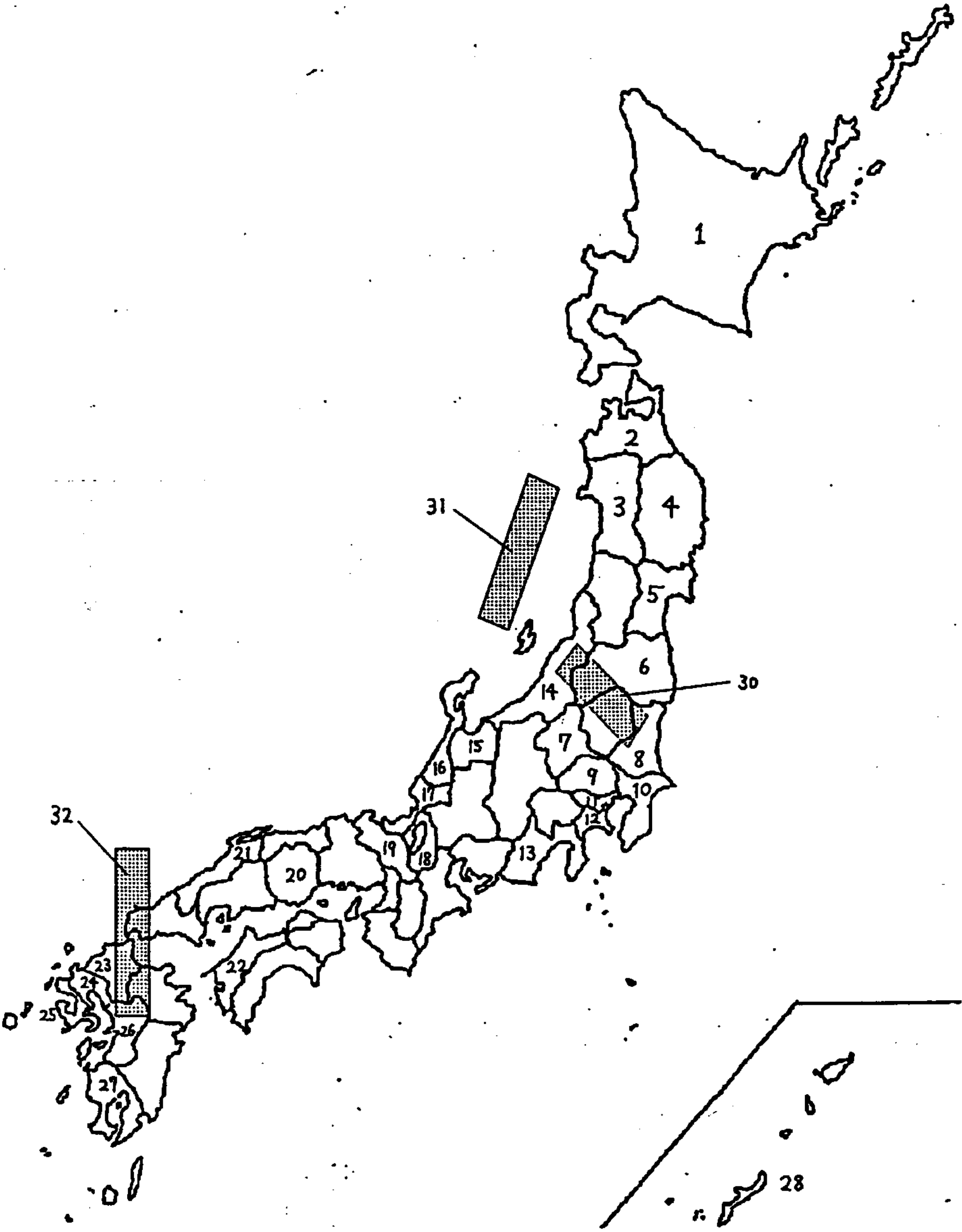
30 Defense Agency (high altitude air of the central Japan)
0.21 pCi/m² about 10000m height

31 Defense Agency (high altitude air of the northern Japan)
0.59 pCi/m² about 10000m height

32 Defense Agency (high altitude air of the western Japan)
0.24 pCi/m² about 10000m height

"Tap water" includes samples from city water reservoir
: "Milk" includes
unprocessed milk, market milk
D : Detected
N.D. : Not detected
Sig. : Significant
- : (No quantitative data)

(Rounded to one decimal place)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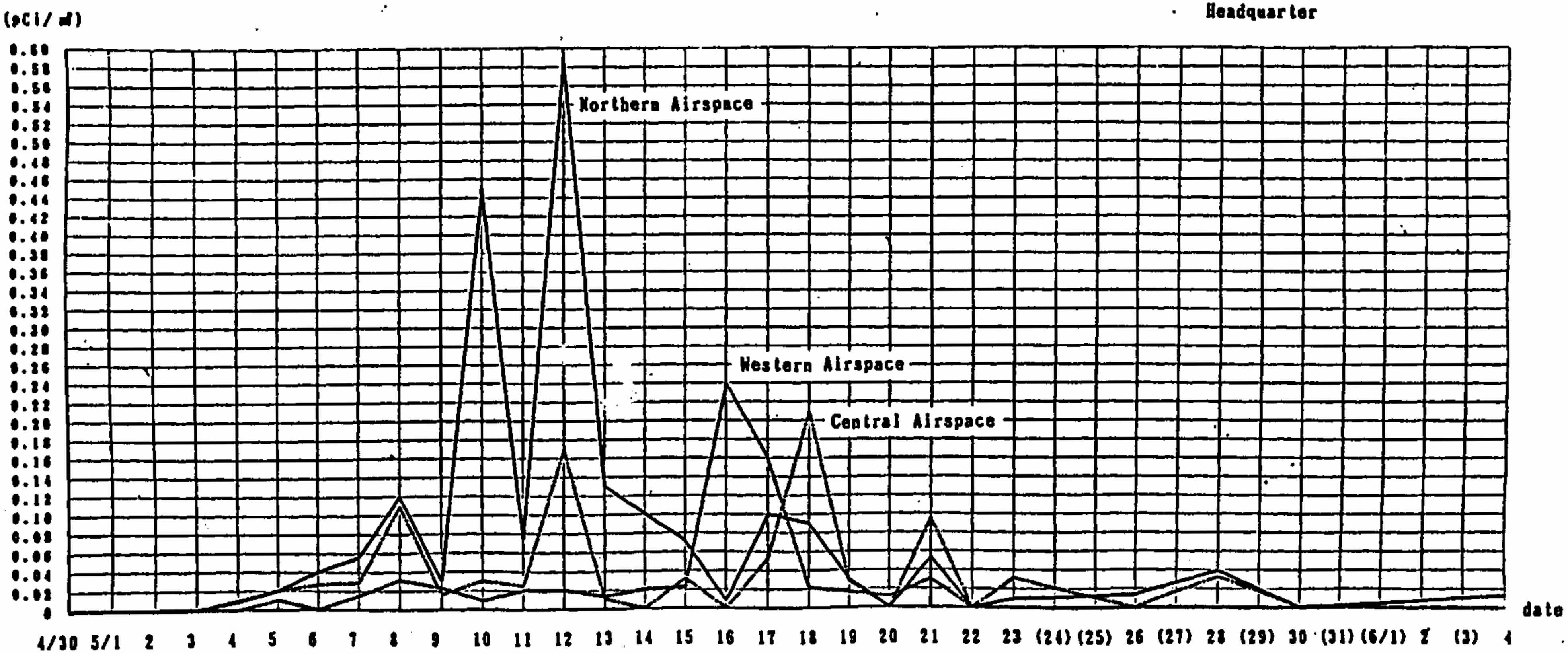
(Attachment 2)

Iodine 131 Concentration in High Altitude Airborne Dust in Three Airspace (Defence Agency)

June.4,1986
Radioactivity Countermeasures
Headquarter



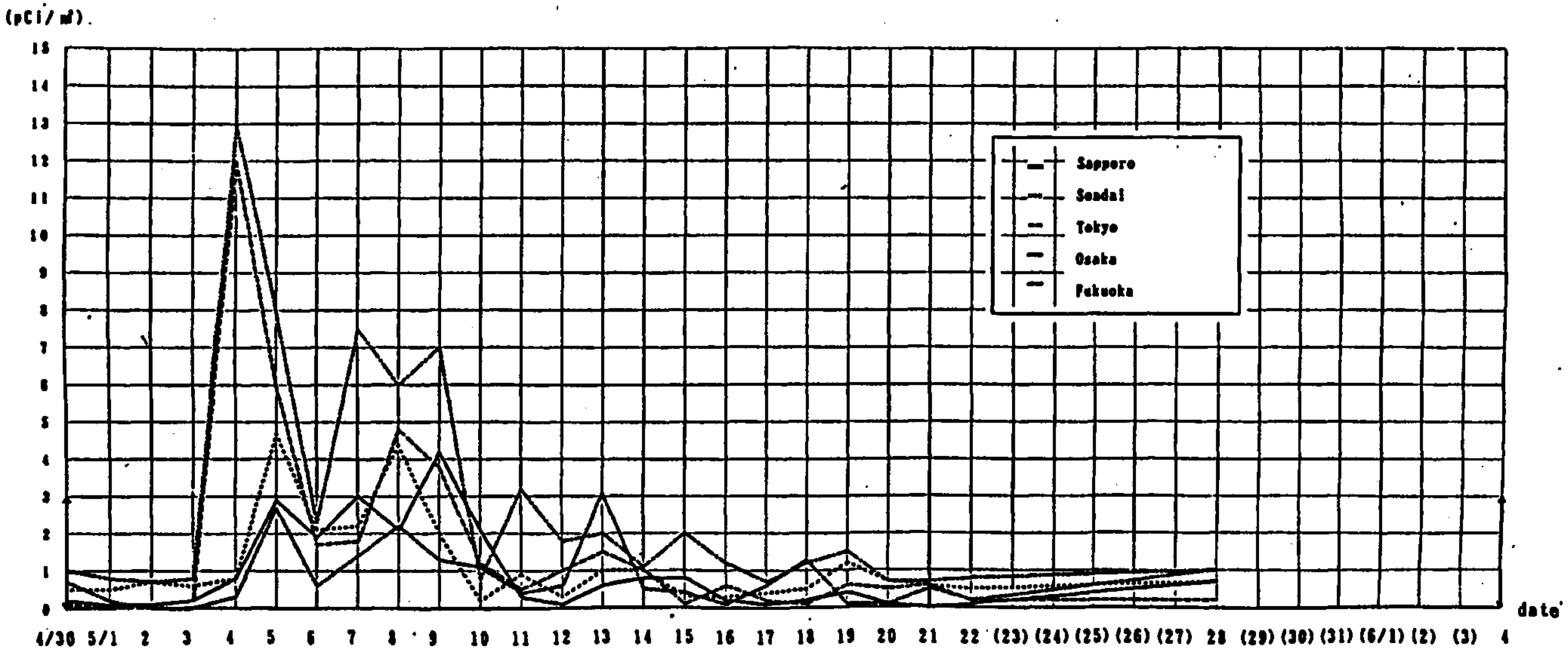
May 14 Northern Airspace
May 19 Western Airspace
] not measured

(Attachment 3)

Total Beta Activity in Airborne Dust in Five District Meteorological Observatories

(Meteorological Agency)

June.4,1986
Radioactivity Countermeasures
Headquarter



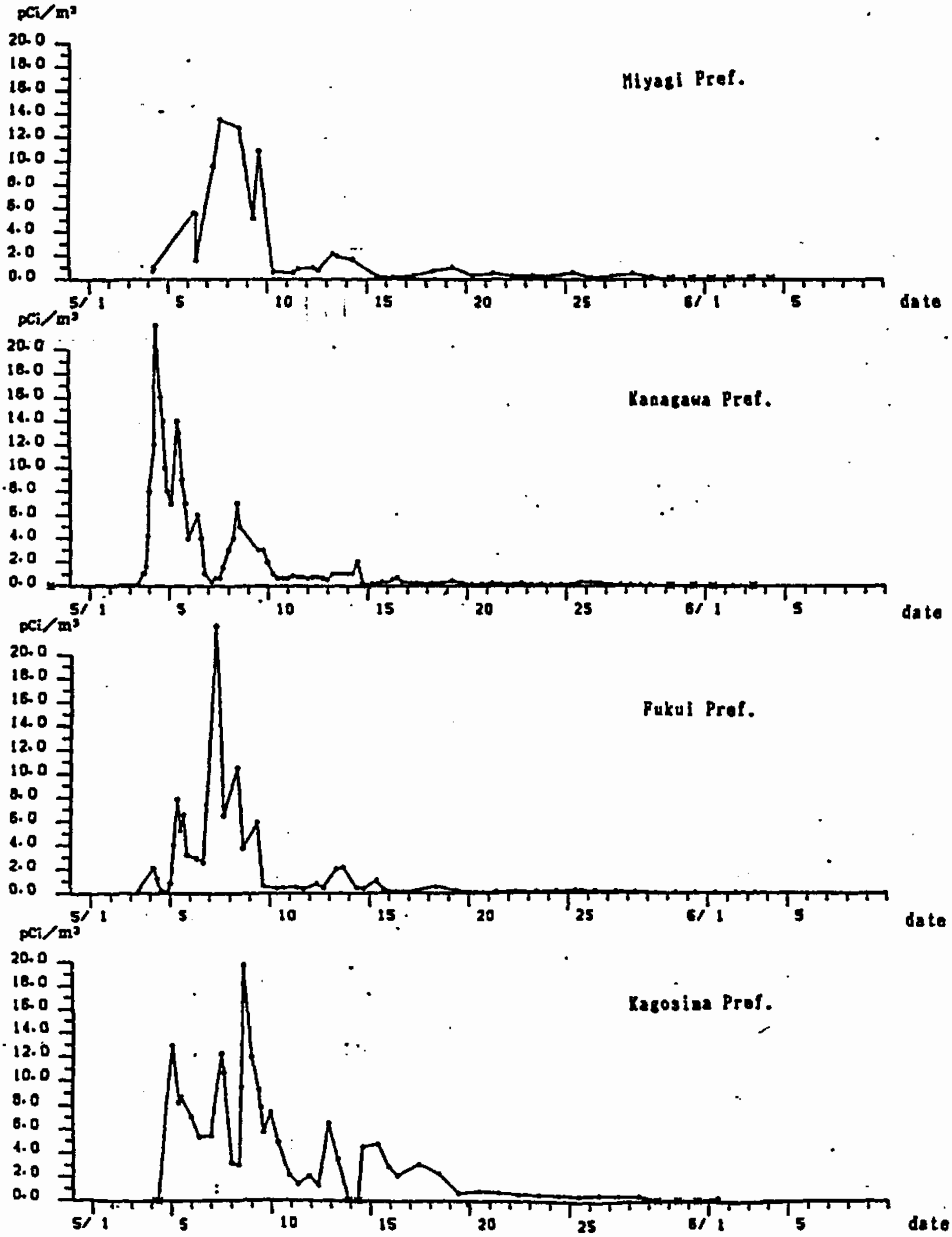
April 1984 ~ March 1985
Max.value 3.0
Min.value 0.0

(Attachment 4)

Iodine 131 Concentration in Airborne Dust

(Science and Technology Agency)

June.4.1986
Radioactivity Countermeasures
Headquarter

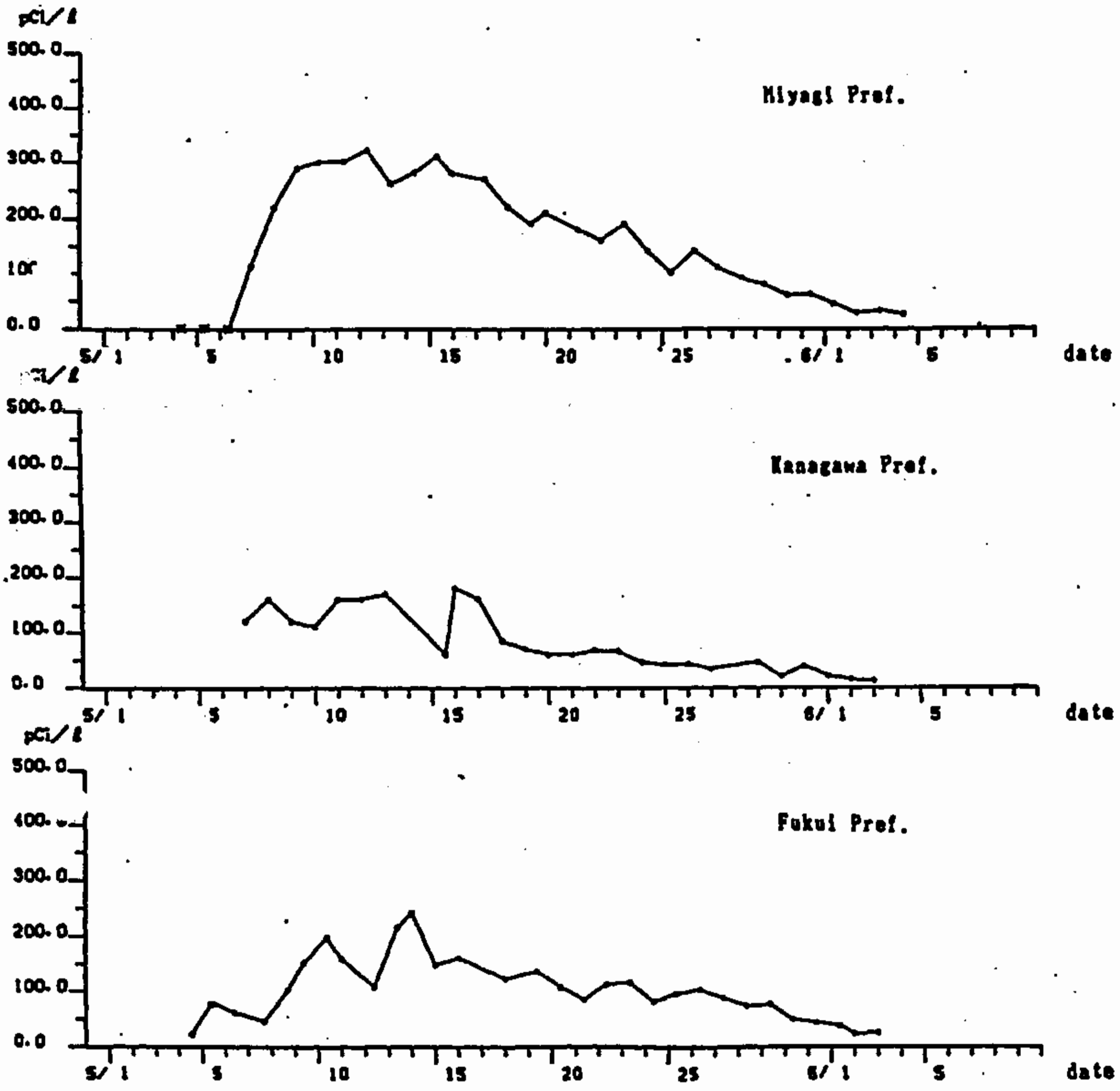


(Attachment 5)

Iodine 131 Concentration in Raw Milk

(Science and Technology Agency)

June.4.1986
Radioactivity Countermeasures
Headquarter



(Attachment 6)

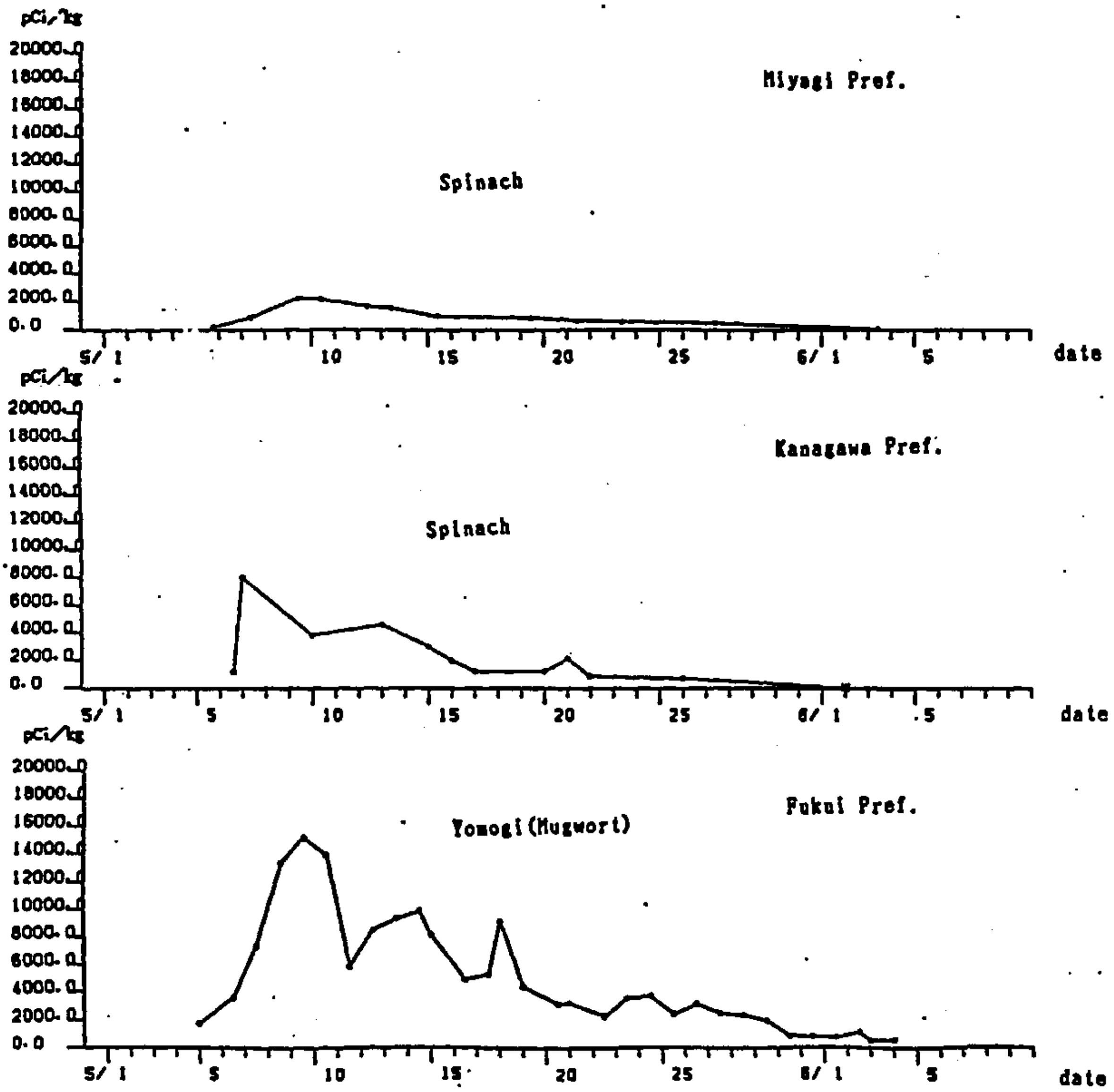
Iodine 131 Concentration in Leafy Vegetables

(Science and Technology Agency)

June.4.1986

Radioactivity Countermeasures

Headquarter



(Attachment 6-2)

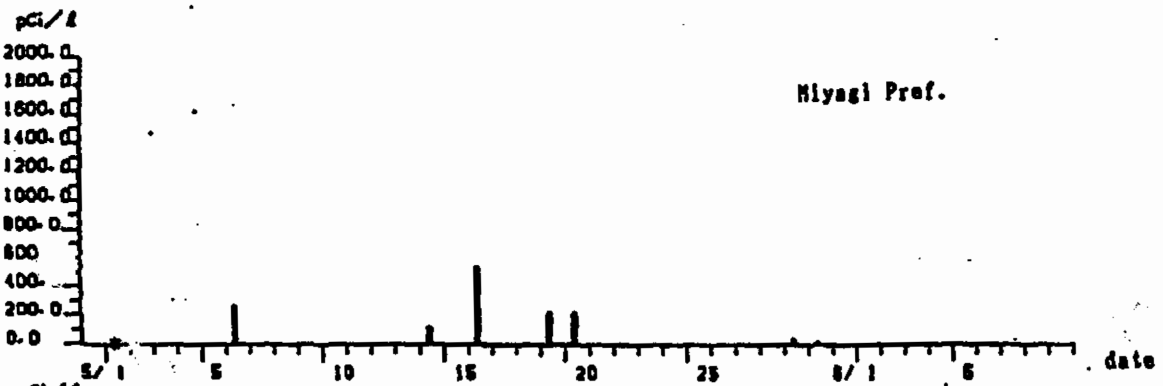
Iodine 131 Concentration in Rain Water

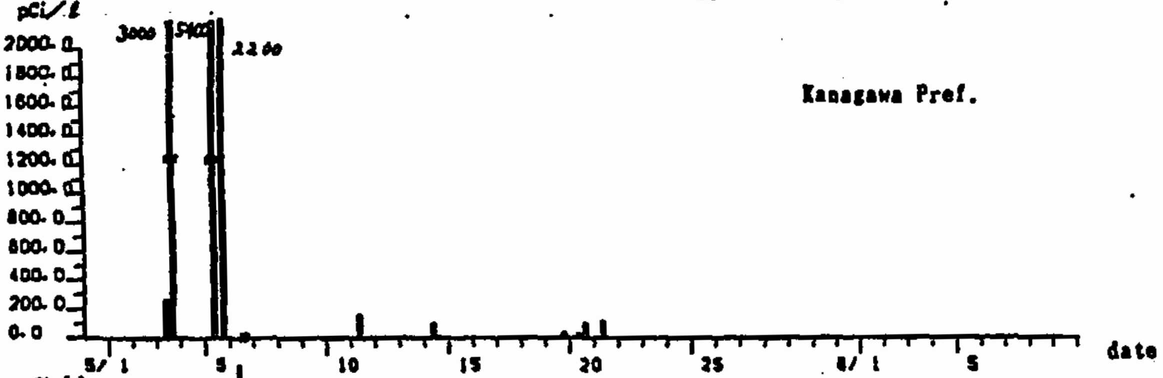
(Science and Technology Agency)

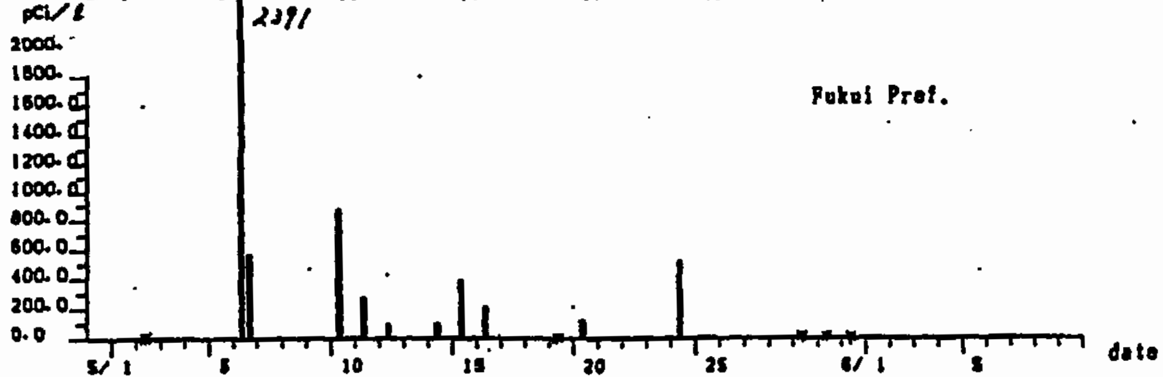
June.4.1986

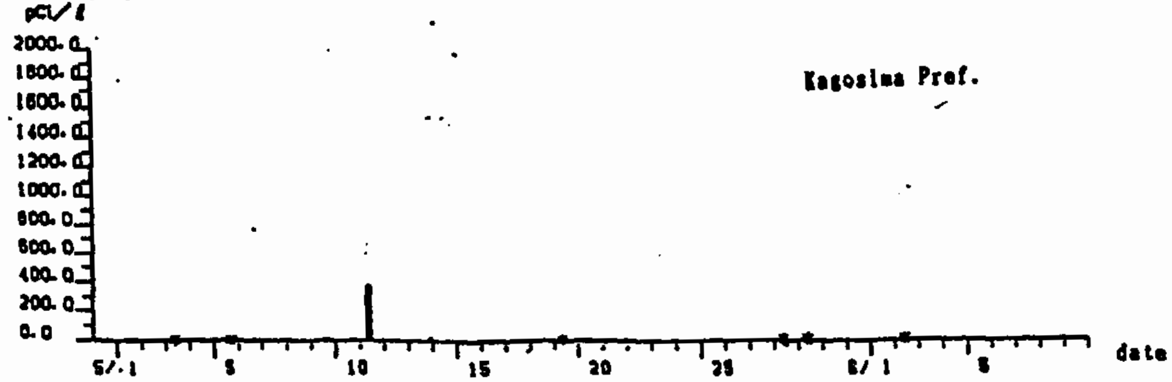
Radioactivity Countermeasures

Headquarter







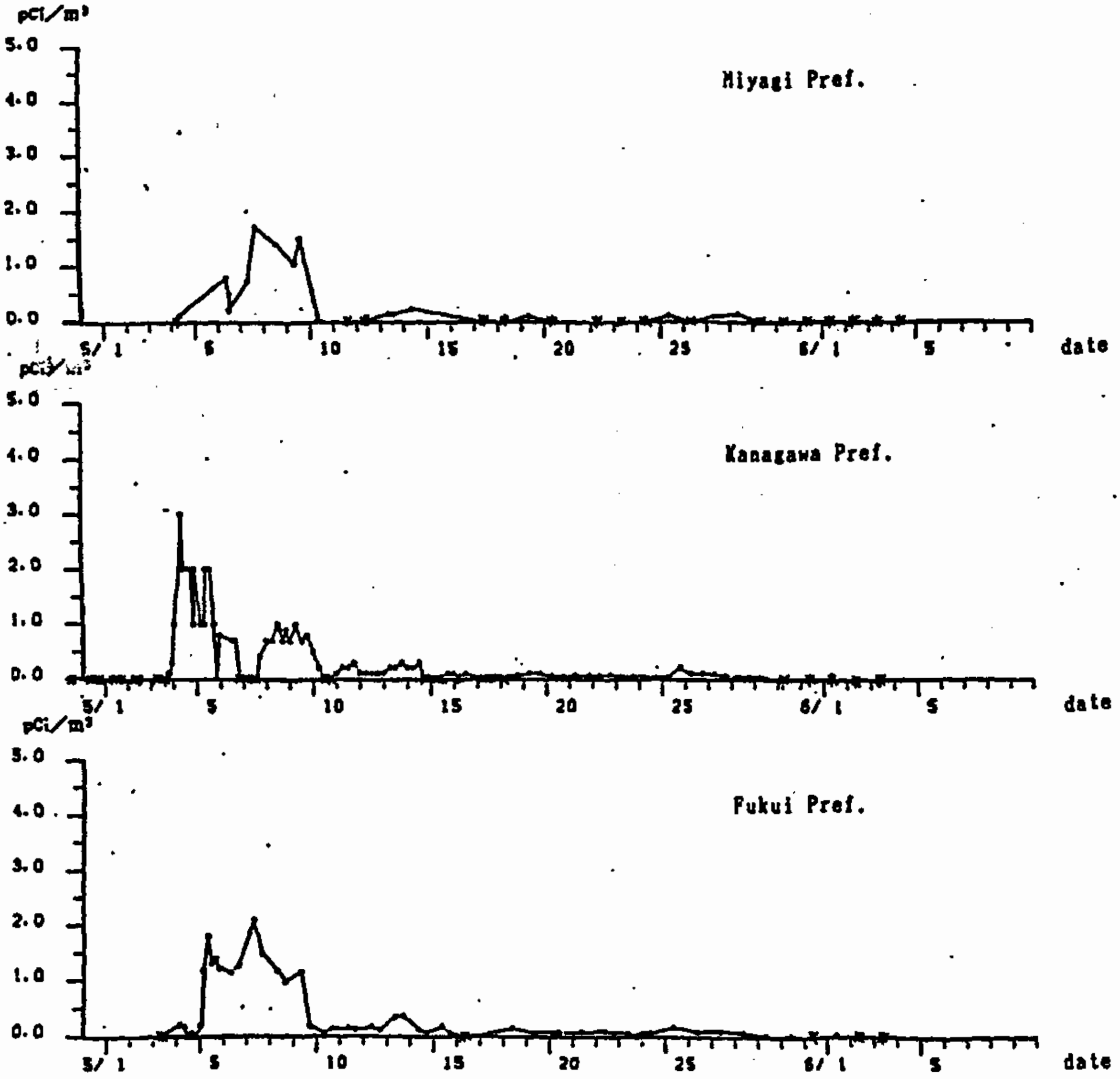


(Attachment 6-3)

Cesium 137 Concentration in Airborne Dust

(Science and Technology Agency)

June.4.1986
Radioactivity Countermeasures
Headquarter



Attachment 7:

Understanding at the Enlarged Meeting of Representative Secretariat Members of Radioactivity Countermeasures Headquarter

April 30, 1986

Practically no impacts on Japan can be anticipated due to the radioactive nuclides discharged into the environment from Chernobyl Nuclear Power Plant in the Soviet Union as a result of the accident because of the large distance (about 8,000 to 9,000 km). Following measures have been already taken in Japan.

(1) The Science and Technology Agency has intensified activities of radioactivity monitoring network in 32 prefectures and environmental monitoring around nuclear power plants.

(2) The Meteorological Agency has also intensified radioactivity observation activities by district meteorological observatories in 13 districts, local observatories and other weather stations.

However, considering the fact that the accident concerned is estimated to be of a very large scale, the present enlarged meeting has decided to take the following actions so as to assure cautious measures against radioactivity.

1. The Science and Technology Agency shall ensure (1) daily measurements of spacial radiation in the 32 prefectures, with gross beta-measurements for rain water and fallout dust as required, and (2) continue to intensify monitoring activities of environmental radioactivity around nuclear power plants.
2. The Defence Agency shall take samples and conduct radioactivity measurements of floating dust in the high altitude atmosphere.
3. The Meteorological Agency shall (1) continue to intensify monitoring activities of radioactivity in 13 district meteorological observatories, local observatories, and weather stations, and (2) conduct investigation and analysis of the atmospheric current reaching Japan from Kiev District in Soviet Union.
4. The Ministry of Foreign Affairs shall continue to strengthen collection of information concerning the accident at Chernobyl Nuclear Power Plant.

Attachment 8:

Japanese Measures against Radioactivity as a Result of Accident in Chernobyl Nuclear Power Plant in the Soviet Union

Radioactivity Countermeasures Headquarter,
May 4, 1986

1. Background Information

(1) Enlarged meeting of representative secretariat members of Radioactivity Countermeasures Headquarter was held on April 30, concerning the accident at Chernobyl Nuclear Power Plant in the Soviet Union, and it was agreed to intensify the radiation monitoring activities by the ministries and agencies concerned. Constant measurements of radioactivity for high altitude-floating dust, floating dust near the ground surface, rain water, and the spacial radiation have been carried out accordingly.

(2) No impacts had been recognized that could be attributed to the accident in the plant before the Saturday evening of May 3, but Iodine 131 was detected by nuclide analysis of floating dust near ground surface and rain water collected on and after May 3 as follows:

(Note) Iodine 131 decays with a half-life of 8 days, but it is apt to concentrate in a thyloid if it is taken in.

- Floating Dust near the Ground

(1) Kanagawa Prefectural public health laboratory

Result of investigation	Date of sampling	
0.1 pCi/m^2	May 3	11:30 ∿ 13:30
1 pCi/m^2	"	16:15 ∿ 18:17
1 pCi/m^2	"	18:20 ∿ 20:20
4.2 pCi/m^2	"	22:40 ∿ 0:40

(2) Tokyo Metropolitan Isotope Research Center

Result of investigation	Date of sampling	
Detected but no quantitative analysis	May 3	12:00 ∿ 14:00 thereafter

- Rain Water

(1) Japan Chemical Analysis Center

Result of investigation	Date of sampling	
4000 pCi/ℓ (7400 pCi/m^2)	May 3	9:00 ∿ 22:30

(2) Tokyo Metropolitan Isotope Research Center

Result of investigation	Date of sampling
1700 pCi/ℓ (8700 pCi/m^2)	May 2, 12:00 ∿ May 3, 19:00

(3) Kanagawa Prefectural public health laboratory

Result of investigation	Date of sampling	
263 pCi/ℓ (800 pCi/m^2)	May 3	9:00 ∿ 16:00

(Note) Figure in ( ) shows the amount of fallout.

2. Future Measures

(1) Intensification of radiation monitoring activities

In view of the detection of Iodine 131 in a considerable amount, the existing activities of radiation monitoring shall be intensified further so as to investigate the influence of released radioactivity.

① Nuclide analysis shall be promptly carried out for rain water, service water, floating dust, by Japan Atomic Energy Research Institute, Power Reactor and

Nuclear Fuel Development Corporation and prefectural governments that have equipments for nuclide analysis.

② Nuclide analysis shall be carried out for the floating dust in high altitude atmosphere.

③ The temporarily intensified activities of radiation monitoring of high altitude atmospheric current and those in the meteorological observatories and weather stations shall be continued.

(2) Matters of attention for the time being

① The level of radioactivity in rain water detected yesterday in Chiba is such that the permissible dose activity cannot be reached unless taking 2.2 liter of the rain water concerned daily for half a year; thus the drinking of collected rain water is harmless at the moment. However, it is desirable to filter rain water through a layer of charcoal if it is to be taken directly.

② There is no concern about service water, well water, or cow's milk.

③ Leaf vegetables also pose no problems, but it is desirable to wash enough before consumption for the sake of precaution.

④ There is no problem in other daily activities such as washing clothes, drying them in open air and getting wet by rain.

(3) Future measures

Based on the result of radiation monitoring in the future, meetings of Radioactivity Countermeasure Headquarter shall be held as appropriate, and necessary measures shall be discussed.

Attachment 9:

Understanding at the Meeting of the Representative Secretariat Members of Radioactivity Countermeasure Headquarter

May 13, 1986

With regard to the accident in Chernobyl Nuclear Power Plant in the Soviet Union, enlarged meeting of representative secretariat members of Radioactivity Countermeasure Headquarter was held on April 30, and it was agreed to intensify radiation monitoring activities by the ministries and agencies concerned. Further, the plenary meeting of Radioactivity Countermeasure Headquarter was held on May 4, to further intensify radiation monitoring activities so as to investigate the impacts of radioactivity released. The result of investigation to date shows that there is no ill health effects of radioactivity in our country at the moment.

In order to ensure our measures against radioactivity we reviewed the information on the radiation monitoring activities by other countries, and it was decided that the following measures shall be continued.

1. Radioactivity Monitoring Activities

While extending the current radiation monitoring activities,

(1) Radioactivity measurements by Science and Technology Agency for the samples of rainwater taken by The Maritime Safety Agency and the Ministry of Health and Welfare in solitary islands shall be continued for the time being.

(2) Radioactivity measurements shall be carried out by The Ministry of Education in cooperation with universities in those prefectures where no radiation monitoring had been conducted.

2. Measures for Imported Foods

The Ministry of Health and Welfare shall further intensify necessary monitoring activities on imported foods, based on informations from those countries concerned, from the viewpoint that importation of food contaminated by radioactivity be prevented.

3. Measures for Travelers Abroad

The Ministry of Transport shall take necessary actions, in cooperation with the Ministry of Foreign Affairs, for example calling attention of travelers to the regions of suspected contamination by radioactivity.

Attachment 10:

Domestic Radiation Monitoring Activities Concerning the Soviet Nuclear Plant Accident

Radioactivity Countermeasures Headquarter,
Representative Secretariat Meeting
May 17, 1986

It can be concluded that the existing countermeasures against radiation in our country need not be altered, judging from the official announcement by the Soviet Government on the status of the reactor after the accident and the results of monitoring of radioactivity level in our country. Therefore, radiation monitoring on Sunday of May 18 shall be conducted as follows:

The following sampling actions shall be conducted.

(1) Rainwater and cow's milk

Samples of rainwater and cow's milk shall be taken, but measurements of radioactivity shall be carried out on later date as required.

(2) Floating dust, leaf vegetables, service water, etc.

No sampling of them required.

However, some monitoring organizations that are responsible for obtaining data continuously and in a wide region shall continue radiation monitoring activities as ever.

Attachment 11:

Domestic Radiation Monitoring Activities Concerning the Soviet Nuclear Plant Accident

Radioactivity Countermeasures Headquarter,
Representative Secretariat Meeting
May 22, 1986

Radiation monitoring activities have been conducted based on the May 4 decision and other actions of Radioactivity Countermeasure Headquarter in cooperation with ministries, agencies, and local governments concerned.

The environmental radioactivity level in Japan shows a gradual declining tendency in general since the middle of May, according to the results of the domestic radiation monitoring. Taking this into consideration together with the information such as official announcement by the Soviet Government on the current status of the reactor after accident, it may be concluded that environmental radioactivity in Japan will not pose any special problem from the viewpoint of environmental safety.

Based on the above circumstances, radiation monitoring activities on and after Friday, May 23 shall be conducted as follows for the time being so that the environmental radioactivity level and long-term accumulation tendency be properly grasped.

1. Nuclide Analysis

(1) Samples shall be taken and analyzed for the following items three times a week (Monday, Wednesday, and Friday) except some monitoring organizations responsible for collecting continuous and wide-region data, that shall take samples every day and analyze them as appropriate.

① Rain water
② Service water
③ Cow's milk
④ Floating dust (including high altitude atmospheric floating dust)

(2) Leaf vegetables shall be sampled and analyzed once a week (on Monday).

(3) The marine lives, seawater, and sea bottom soil that have been the object for monitoring in the case of N-test fallout, shall be sampled and analyzed as appropriate in order to provide data for a comprehensive appraisal in the future.

2. Gross Beta Measurements (Floating Dust and Rain Water) and Spacial Radiation Monitoring

   Monitoring by normal activities

3. Periodical monitoring of fallout shall be carried out by moving up the date.

Attachment 12:

On the Accident at Chernobyl Nuclear Power Plant in Soviet Union

(Tentative Translation)

Informal Talk by the Chairman of
Nuclear Safety Commission
April 30, 1986

1. The details of the accident at Chernobyl Nuclear Power Plant in Soviet Union as to its cause, sequence and current status are not clear yet, because sufficient information are not yet published by the Soviet authorities. However, the radioactive substances discharged from the power plant concerned is considered to pose no ill health effect on the Japanese people due to the considerable distance from the place of the accident to Japan and other factors.

2. As for Japanese nuclear power plants, much effort has been exerted to maintain their safety and reliability reflecting the experiences of accidents and troubles in nuclear power plants at home and abroad, including one at TMI Nuclear Power Plant in USA. The troubled reactor in Chernobyl Nuclear

Power Plant is of a type of graphite-moderating light water-cooling, developed originally by the Soviet Union, and its structure is different from those in Japan. However, our commission will endeavor to obtain related information and examine whether or not there will be matters to be reflected in securing safety in the development and utilization of nuclear power and in nuclear safety regulations in Japan. For this purpose it has been decided to establish in our commission on Special Investigating Committee on Soviet Nuclear Plant Accident.

3. Our commission strongly hope, in view of the significance of the accident concerned, that Soviet authorities will release detailed information on the accident successively.

Attachment 13:

Establishment of Special Investigating Committee on Soviet Nuclear Plant Accident

Nuclear Safety Commission

May 13, 1986

1. Object of Establishment

In order to investigate and deliberate such matters as the cause and impacts of the accident at Chernobyl Nuclear Power Plant in the Soviet Union, Special Investigating Committee on Soviet Nuclear Plant Accident (hereafter called "Committee") is established in Nuclear Safety Commission.

2. Committee Mandates

The "Committee" shall investigate and deliberate on the following matters:

(1) Investigation of the accident at Chernobyl Nuclear Power Plant

(2) Discussion on matters to be reflected in the measures for securing nuclear safety in Japan, in conjunction with the accident at Chernobyl Nuclear Power Plant

(3) Other important matters with regard to the accident at Chernobyl Nuclear Power Plant

3. Organization

The members of the "Committee" shall be selected from among the members of the Committee on Examination of Reactor Safety and the Committee on Examination of Nuclear Fuel Safety, as well as members of various Special Committees in Nuclear Safety Commission.

4. Management

Articles 2 to 10 of Management Regulations of Special Committees of Nuclear Safety Commission (decided by Nuclear Safety Commission on October 25, 1978) shall be applied for management of the "Committee".

MENBER OF SPECIAL INVESTIGATING COMMITTEE ON SOVIET NUCLEAR PLANT ACCIDENT

MAY. 13. 1986

NAME	OCCUPATION
MR. MICHIO AKEBI	DIRECTOR, REACTOR DEVELOPMENT COODINATION DIVISION , PNC
DR. MICHIO ISHIKAWA	DIRECTOR, DEPARTMENT OF JPDR, TOKAI RESEARCH ESTABLISHMENT, JAERI
MR. RYUSHI ICHIKAWA	DIRECTOR, DIVISION OF ENVIRONMENTAL HEALTH, NATIONAL INSTITUTE OF RADIOLOGICAL SCIENCES
MR. KAZUHIKO IMAI	GENERAL MANAGER, BESINESS DEPARTMENT, JAPAN RADIATION SAFETY TECHNOLOGY CENTER
DR. TATUO OKU	HEAD, MATERIALS STRENGTH LABORATORY, DEPARTMENT OF HIGH TEMPERATURE ENGINEERING, TOKAI RESEARCH ESTABLISHMENT, JAERI
[illegible] KAZUO SATO	DIRECTOR, DEPARTMENT OF REACTOR SAFETY RESEARCH, TOKAI RESEARCH ESTABLISHMENT, JAERI
MR. MASAYOSHI SHIBA	DEPUTY DIRECTOR GENERAL, JAPAN INSTITUTE OF NUCLEAR SAFETY, NUCLEAR POWER ENGINEERING TEST CENTER
DR. TODASU TAKEKOSHI	RESEARCH ADVISOR, CENTRAL RESEARCH INSTITUTE OF ELECTRIC POWER INDUSTRY
DR. TOYOZO TERASHIMA	DEPUTY DIRECTOR GENERAL, NATIONAL INSTITUTE OF RADIOLOGICAL SCIENCES
PROF. YASUMASA TOGOH	TOKYO UNIVERSITY
DR. MASAO NOZAWA	EXECUTIVE DIRECTOR, JAERI
PROF. NAOHIRO HIRAKAWA	TOHOKU UNIVERSITY
PROF. YOHICHI FUJIIE	NAGOYA UNIVERSITY
D' ICHIRO MIYANAGA	EXECUTIVE DIRECTOR, JAERI
MR. ATUYOSHI MORISHIMA	ADVISORY SCIENTIST, JAERI
MR. HAJIME YAMANOUCHI	DEPUTY SENIOR DIRECTOR, REACTOR CONSTRUCION AND OPERATION IN CHARGE OF ATR, PNC
DR. TOMOAKI YOSIKAWA	CHIEF OF THIRD RESEARCH LABORATORY, APPLIED METEOROLOGY RESEARCH DIVISION, METEOROLOGICAL RESEARCH INSTITUTE, JAPAN METEOROLOGICAL AGENCY

JAERI : JAPAN ATOMIC ENERGY RESEARCH INSTITUTE
PNC : POWER REACTOR AND NUCLEAR FUEL DEVELOPMENT COORPORATION

Attachment 14:

Resolution on the Accident at Chernobyl Nuclear Power Plant in the Soviet Union

Resolution in the plenary session of
the House of Representatives

May 8, 1986

The accident that happened at Chernobyl Nuclear Power Plant in the Soviet Union towards the end of April has aroused strong impacts to the countries across the world, including Japan. Therefore, be it be resolved that the government shall promptly take proper actions as follows in cooperation with countries concerned:

1. To work upon the Soviet Union for prompt release of such information with regard to current status and causes of the accident.

2. To make efforts for the investigation of the causes of the accident and analysis of data with international cooperation centering around International Atomic Energy Agency, so as to fully reflect them on the safety assurance and safety regulation in Japan.

3. To take prudent and sufficient countermeasures against the radioactivity released from the accident.

(The above resolution was adopted in accordance with the similar resolution made by Standing Committee on Science and Technology of the House of Representatives on May 2, 1986.)

Attachment 15:

Resolution on the Accident at
Chernobyl Nuclear Power Plant in
the Soviet Union

Resolution in the plenary session of
the House of Councilors
May 9, 1986

The accident that happened at Chernobyl Nuclear Power Plant in the Soviet Union towards the end of April has aroused strong shock impacts to the countries across the world, including Japan. Therefore, be it be resolved that the government shall promptly take proper actions as follows in cooperation with countries concerned:

1. To request the Soviet Union for prompt release and provision of informations concerning the current status and the causes of the accident.

2. To make efforts for the investigation of the causes of the accident and analysis of data centering around International Atomic Energy Agency, and to discuss international responsive actions in the event of similar accident so that they can be realized in an early date.

3. To make any lessons learned from the accident fully reflected on the safety assurance and safety regulations of the nuclear power plants in Japan and to take prudent and sufficient countermeasures against radioactivity, for example intensifying environmental radioactivity monitoring system.

(The above resolution was adopted in accordance with the similar resolution made by Special Committee on the Science and Technology of the House of Councilors on May 7, 1986.)

MEMORANDUM

Your Ref.
Our Ref.
Tel Ext.

To See below

Subject USNRC STATEMENT ON CHERNOBYL IMPACT

I attach a copy of a statement on the impact of Chernobyl on the USA, which was made by the Chairman on the USNRC to the Congress Sub-Committee on Energy Conservation and Power on 22 May.

This was given to us by Dr José Cortez, USNRC Office of Nuclear Regulatory Research, when he visited Winfrith for the annual UKAEA/USNRC Agreement meeting at Winfrith on 9/10 June 1986.

N W Davies
Overseas Relations
Risley

17 June 1986

Distribution

Dr J H Gittus, SRD
Mr H Teague, SRD
Dr M R Hayns, SRD
Dr D Hicks, AERE
Mr J Fell, AEEW
Mr R J Haslam, RNE

9.6

cc DCI [illegible]

Nuclear Power: Energy of Today and Tomorrow

The Lord Marshall of Goring

It was my original intention to review the status of nuclear power worldwide as it stands today and predict its future development in the years to come. I had, of course, planned to give some special attention to the position in the UK but, in the main, I had thought to give a philosophical review from a policy point of view looking at the world as a whole.

I have decided that that should remain the format of my talk but since I originally planned it we have had the nuclear disaster at Chernobyl. Therefore, although the plan remains the same, the content is entirely different. In effect, I want to make a first attempt to answer the questions, where does nuclear power go now? Can nuclear power recover from the terrible set-back presented to it by Chernobyl or must we now anticipate the fading away of nuclear power throughout the world? In my opinion, we can and will recover from the set-back which Chernobyl has given us. Indeed, we must recover from that set-back. But of course different countries will cope with it on different timescales. Some countries, like France, are likely to continue to expand their dependence on nuclear power. They have programmes so well established, and so well accepted by their people, that Chernobyl is almost a minor perturbation. We therefore all look forward to nuclear power going from strength to strength in that country. Let us be thankful to the French for setting us such an example.

For other countries, Chernobyl is likely to produce a longer term set-back for the advancement of nuclear power and, of course, most countries by definition will find themselves between these two extreme positions. I do not propose to discuss in any detail the reaction of any individual country to the Chernobyl disaster. I could not do that authoritatively. I can only speak authoritatively for my own country where the position is confused.

However, before I begin my main presentation, there are three things I would like to say to our Russian colleagues and the Russian people and I hope you will join with me in this.

First, I would like to express my sincere sympathy to the Russian people, particularly the residents of the Ukraine, who have suffered the direct consequences of this accident. They have received some radiation, for some that has been fatal, for others it will be fatal, they have been moved from their homes, and their lives have been significantly disrupted by the civil nuclear industry. We are most sincerely sorry for that and we send them our utmost sympathy.

Secondly, I think all of us who are professionals in the nuclear business have been struck with the bravery and dedication of the operating engineers, firemen and men on the spot once the accident had occurred. Russia has many brave men - many of them now in hospital - and the whole world, not just us in this room, owe them our grateful thanks for the strenuous and vigorous efforts they made to control the accident once it had occurred. We will all want to learn lessons from this unfortunate event. It should not have happened, we will want to find out why it did happen. We should suspend judgement on that until the facts are known. But, judging from present information, we shall be full of praise for the recovery operation itself.

Thirdly, I would like to make an appeal to the Russian authorities. Inadvertently a large number of the Russian population have received a radiation dose large enough to produce statistically significant results on the long-term health hazards of radiation. It is vitally important that the trauma of this event should be turned to whatever advantage can be found and we now inadvertently and sadly have an opportunity to add to our knowledge about the long-term health hazards of radiation. I therefore appeal to the Russian authorities to conduct the most stringent and scientific investigations into the health effects of the Chernobyl accident over the next three or four decades and, if possible, I urge that that study be done on an international basis so as to produce the maximum possible confidence in the future application of the results. Of course in some ways it may sound cynical to regard the affected people as just part of a large scale experimental test but I hope my remarks will not be interpreted that way. It is unethical to expose people to radiation unnecessarily but, given that it has happened, it is proper, professional and scientific to learn what we can from the accident.

That said, how does Chernobyl change the world nuclear scene? In some ways nothing has changed at all but, in a profound sense, everything has changed. From a professional point of view we can point out that the Russian reactor at Chernobyl was of a type not used in the West. Therefore, in detail, an accident on the Chernobyl reactor provides no significant technical information about reactor systems in the West. Indeed, we can go further. Our knowledge of the Russian reactor, though sparse, is sufficient to persuade us that it could not easily, if at all, get an operating licence in an established nuclear country in the West. Certainly I believe that to be the case in the UK where safety has to be proved from our own direct knowledge and experience elsewhere cannot be part of a safety argument. From a technical and engineering point of view, therefore, it is entirely valid to say that the Russian incident is not likely to affect nuclear power in our countries at all. If a Russian airliner crashed, we would not immediately ground all Boeing jumbo jets. We would see the event as relevent, but not directly relevant, to the airline industry and aircraft construction industry of the Western world. Because of the technical differences between the Russian reactor and our own reactors, whether built in America, Canada, Japan, France, Germany or the UK, exactly the same comment can be made. I do not think we will learn from this event anything concerning reactor design or safety assessment which we did not know already. We have already had the trauma of Three Mile Island. That did teach us some lessons. I do not think Chernobyl will have such direct technical relevance. But of course, as professional engineers, that broad judgement will not prevent us from doing our homework properly. When we do know the details of the Chernobyl accident, we will all wish to review what lessons can be learnt and what technical lessons should be absorbed by us in the West from this event. We will, therefore, learn what we can. I am simply anticipating that, technically, we will not learn a great deal.

In contrast, I think we will learn a great deal from studying the handling of the emergency itself, particularly the evacuation of people. We will learn also from the evidence upon the dispersal of the radioactive cloud. Certainly, therefore, we should review our emergency planning in the light of the lessons learnt from Chernobyl. But those lessons will be institutional and organisational rather than technical. We can also learn much about tackling big accidents and the resources required and how these can be marshalled. Finally, as I have remarked before, we can learn a great deal of scientific interest and radiological interest by studying the radiological consequences of the accident over the coming decades.

However, all that is a matter of detail, not of principle, and therefore, as I said earlier, there is a real sense in which the events at Chernobyl have changed nothing here in the West. But that, I fear, is only a narrow technical appreciation of very little relevance to the problems facing the nuclear industry today because, although nothing technical has changed, for nuclear power everything else has changed. Everything else has changed because for the public, our politicians and our Governments the public perception of nuclear power has changed and changed dramatically for the worse. Chernobyl has been the centre of worldwide attention for many weeks. The public have been shocked by the widespread effects of Chernobyl. They are appalled that an accident 1,000 miles away in the Ukraine can have effects in the quiet countryside of an English village. We all of us live in a democracy. We can do nothing without the acceptance of the public, we can do nothing without the approval of public opinion and we are in severe risk of losing that as a result of the shock which Chernobyl has given to people worldwide. What then should the nuclear industry worldwide do? What are our prospects in the future? When will we recover from this set-back and what should we do to help that recovery?

To attempt to answer those questions I feel obliged to go back to first principles. Do we really need nuclear power and when will the public realise that most forcibly in the future? To start at the beginning, do we need nuclear power? May I remind you that world supplies of oil and gas are not finite. The number of new large oilfields being discovered has declined. Some of the oilfields in the North Sea have already passed their peak production rate. Whatever in detail the consumption of oil may be in future years, it will be an increasingly scarce commodity by the year 2030; scarce either because of physical shortage or price. Much the same can be said of gas. Let us suppose by the year 2030 the world's production of coal has multiplied by a vast factor of five in order to replace the world's dependence on oil and gas. Then even with that vastly increased coal extraction rate, we will have only enough energy, shared out equally throughout the world, to give each person the present day energy consumption of say a Mexican peasant. I do not think that would be acceptable in any industrialised country. Therefore, on this timescale of half a century or so, we must plan either to keep the third world and the developing countries short of energy and in poverty - so that we in the West can retain a disproportionate share of the world's energy or we must introduce a major new energy source. I reject the first option as unethical, energy supplies to the third world must increase and those countries must be given the chance to catch up with us. We therefore must introduce a new energy source. The only plausible new energy source is nuclear power and fission nuclear power at that.

In my opinion, the attractions of fusion nuclear power are almost entirely illusory. In the developed countries of the world the hydro power opportunities are largely exploited already, the alternative energy sources are simply inadequate to support civilised life as we know it. We do therefore need nuclear power. We need thermal fission reactors first and then we need fast breeder reactors. I remain convinced of that fact not because it is constantly reiterated by myself and my nuclear colleagues but because I have tried to find an alternative for the future and I cannot find it.

However, if we do need nuclear power and we do need fission nuclear power, when will the general public realise that? Not today and not worldwide because oil once again is cheap and Chernobyl has frightened people. Of course some countries have innate, special advantages which should enable them to maintain a policy of nuclear expansion. As I mentioned earlier, France is very special but it has four natural advantages in support of nuclear power. Let me review them for you. France has no oil, no gas and no coal. It has no choice except to have a successful nuclear programme so, of course, it has one. I think Japan is in a very similar position to France but, in contrast, my own country has plenty of oil, too much gas and a long-term supply of coal. These are important factors affecting public perception of the necessity of nuclear power and their perception of the necessity of nuclear power influences their acceptance of the risks of nuclear power.

But the price of oil will not stay low for long. Stripper wells in America are closing down daily, exploitation of the North Sea has had a significant set-back and oil companies worldwide are stretching out their exploration and development programmes. At a rough guess, by 1990 America could once again import as much oil as it produces itself. The low oil prices will stimulate the world economy and the law of the marketplace will operate once again to force up the price of oil. In the 1990's, therefore further expansion of nuclear power will be seen to be the right thing to do even if that does not become apparent before then. Therefore, in my opinion, although Chernobyl is a vast set-back to nuclear power, some countries will survive that set-back with their plans undisturbed and those that do change course now as a result of Chernobyl will renew their interest in nuclear power in the early 1990's which, after all, is not far away.

What must we do in preparation for that time? What must we the nuclear industry do to win back public confidence? What must we do to persuade the public that nuclear power is the cleanest, safest form of energy known to mankind? (That is factually correct despite Chernobyl.)
We must set about the process of educating the public and

explaining ourselves to the public with the same dedication and professionalism that we normally apply only to our engineering. It will not be satisfactory for the world to turn back to nuclear power in the 1990s regarding it, in President Carter's words, as the energy source of last resort. They will then be accepting it as a necessity despite their fear of it. That simply is not good enough. We must do better. The public must accept back nuclear power because they understand it, because they understand that it is not risk free but because it has the smallest risks of any energy source known to man. Let me review what we must do and let me review for you how the nuclear industry has failed in its communication with the public in the past and how that failure has affected public reaction to the Chernobyl disaster.

I will make my points by way of example. First, we know that the risks of nuclear power are the risks of radiation and the risks of radiation are the risks of inducing cancer. We have a well developed science of radiological protection to consider this subject. In my view, it is somewhat over developed. We describe radiation in terms of curies, becherels, rads, rems, sieverts, grays and by the milli, micro and pico versions of those units. I am myself a rads and rems man. I cannot understand the other units and if I cannot understand them, how can I expect the public to do so. How can we have the arrogance of changing notation and changing notation to inappropriately sized units in an area where it is vital that we communicate properly with the public? That is where we as an international community have failed.

Second, even if we do get our nomenclature correct, how are we to explain the risk to the public that, in the main, finds risks and numerical assessments difficult to assimilate. This is a subject I have addressed in previous years and I have recommended that we, the industry, make a direct analogy between radiation dose and cigarette smoking. The analogy is very simple. A once-off dose of one rem is equivalent to regular cigarette smoking of 1/20 of a cigarette per week. Let us define the smoking of 1/20 of a cigarette per week as a unit of health hazard. Let us express risks of radiation in those units. There is no good reason why we do not do that. We have simply not thought it important enough in the past. We ignore this point at our peril.

Let me give you an example of how this choice of language affects public perception. When the radioactive cloud from Chernobyl drifted across Scandinavia and the United Kingdom, the reaction of the authorities and the public in both countries seemed to be broadly the same. When the public were told the radiation rate was so many times above background or normal levels, they thought that was very serious. Ten times normal sounds very bad, although, of course, we know that that radiation level for a short period of time is not very serious. When the Government authorities told the British public that they need take no special safety measures, except not to drink rainwater, the public were not reassured - they thought it exposed Government complacency. When experts estimated that the radiation would cause some tens of extra cancer deaths in the United Kingdom over the next forty years, the public were terrified. When I commented that the risk was equivalent to smoking one or two cigarettes in a lifetime, it sounded so reassuring that the public concluded it was incorrect. All these statements were correct, they could all be reconciled one to the other. Collectively in Britain, we did not do that very well. We must do better in the future.

Let me give you a second example. We are all used to comparing radiation doses to the natural background radiation and we do that partly because it is convenient, partly because it is proper and partly because we think the public will find that reassuring. However, to the public, the phrase "natural background radiation" is very friendly and not something to be frightened about because it is "natural". In contrast to that, the radioactivity we produce is "nuclear waste" or "nuclear pollution". That sounds very bad. It does not sound "natural" at all and the public find it difficult to accept that our radioactivity is no different in kind from natural radioactivity. This contrast is even more important today when the public distinguishes between natural food, which it regards as healthy, and processed foods, which it regards as junk.

We must get over to the public that they live in a radioactive world. Everything is radioactive - their houses are radioactive, their gardens are radioactive, our bodies are radioactive, and unless the general public understands that, and understands that instinctively, not just part of an intellectual exercise, we will always find the acceptance of nuclear power to be very difficult. In my own country, in the United Kingdom, I like to point out that an average Englishman's garden occupies one tenth of an acre and, by digging down one metre in that average small garden, we can extract 6 kilogrammes of thorium, 2 kilogrammes of uranium and 7 thousand kilogrammes of potassium, all of which are radioactive. In a sense, all that is radioactive waste, not our radioactive waste, but the residue left over when God created this planet.

Unless the public understands that they are continually surrounded by that radioactive material and that they are bathed in radiation from it, then they will not see the risks of nuclear power in perspective. I must therefore appeal to all of you at this conference here today. We talk to ourselves too much and to the general public not very effectively. We must do better and if we do not do better, we do not deserve to establish nuclear power in its proper place in the coming decades.

When the dreadful chemical disaster occurred at Bhophal in India, the world did not clamour for the closure of all chemical plants, but following Chernobyl, in many countries they are clamouring for the closure of nuclear plants. The public do see nuclear risks as different, they do see them as more frightening. That is not actually the case, we all know that the chemical industry, general industry and coal mining are all more dangerous than nuclear plants despite Chernobyl, but we communicate with the public so badly, they do not appreciate that.

If we calculate fatalities in the world's coal industry and the world's civil nuclear power industry, even if we start the clock on 27 April, the day of the Chernobyl accident, then already the coal industry is way ahead on fatal accidents to mankind. That will remain the case whatever the long term consequences of Chernobyl, but there is no value at all to our knowing that if the public do not appreciate it. If the public do not understand the nuclear industry, it is not their fault, it is our fault. The main lesson we will learn from Chernobyl is that we need to communicate with the public more effectively than we have ever done in the past. From now on, I want to see every nuclear conference with a session entitled "Communicating with the Public", and let us not talk amongst ourselves about how to do it, let us actually get out and communicate with the public effectively. That is our task for the future. In my opinion, the future of nuclear power will depend more on that than on any technical factor or technical improvement we can make, important though those are.

Thus, Chernobyl presents the world's nuclear industry with a set-back, a challenge and an opportunity. For the first time, the public have a real interest to understand risk and radiation exposures. Let us do a good job of putting this accident into a proper perspective of industrial events and let us trust to the public's common sense to accept nuclear power despite the trauma and emotion of this sad event.

J H Gittus
5978

COMMISSION OF THE EUROPEAN COMMUNITIES

Copy to Dr Lomer.
HMC.
Item hold for next STC.

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Outline communication

from the Commission to the Council

on the consequences of the Chernobyl accident

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I. INTRODUCTION

1. The accident that occurred in the nuclear reactor at Chernobyl has shown that the operation of nuclear power plants involves responsibilities of international magnitude. An event that took place more than 1000 km from the nearest Member State has had considerable repercussions on a sizeable proportion of the population of the Community. This demonstrates more clearly than ever that the Community must involve itself in nuclear safety and that suitable action must be taken at Community level.

Although it is still too early to be able to evaluate fully all the consequences of this accident, it is a matter of urgency for the Community to adopt an initial set of internal measures and measures within the framework of its external relations based on the lessons that it can already learn from that accident.

2. The task of the public authorities is first of all to ensure that, where industrial-scale installations in general are concerned, adequate precautions are taken in order to reduce the risk of accidents to a minimum, in particular the risk of accidents capable of affecting the health and safety of the public; secondly, they must take steps to ensure that, if accidents still do occur - which can never be entirely ruled out - proper measures are taken to limit their consequences as far as possible. In the nuclear field, the probability that major accidents

will have consequences at international level is high, since radioactive substances can travel and spread within the atmosphere. Nuclear safety and radiation protection must hence be considered as matters of priority for international cooperation at world level, particularly within the framework of the IAEA. Prospects for such cooperation have improved considerably since the Chernobyl accident. The Community, for its part, must encourage this development as far as possible.

3. Action by the IAEA is not, however, sufficient in itself. The action has to be supplemented by measures at Community level. The Community has acquired a considerable wealth of experience with and knowledge of both nuclear safety and radiation protection, in particular through research conducted in the context of Community programmes.

Even before the Chernobyl accident occurred, the Commission was proposing that this knowledge be exploited to improve the protection of workers, of the public and of the environment against ionizing radiation.

4. In addition to the possibilities for cooperation on a world and Community level, the Community should also explore channels for initiatives to be taken in a wider European context.

5. The emotional reaction of the public in Europe and throughout the world to the Chernobyl accident - which is eloquently reflected in the numerous official comments made at the highest level of responsibility - is evidence of the acute political sensitivity of the present situation and emphasizes the urgency of the action to be taken. Such action is all the more necessary in view of the fact that nuclear power is now an essential component of the Community's energy balance. It accounts for one-third of electricity production and makes it possible to save the equivalent of 100 million tonnes of oil each year. The situation created by the Chernobyl accident therefore calls for particularly careful and thorough consideration.

6. Meeting in Tokyo only several days after the Chernobyl accident, the Heads of State or Government of the seven main industrialized countries and the representatives of the European Community, after affirming that "nuclear energy is and, properly managed, will continue to be an increasingly widely used source of energy" stated in particular:

"We welcome and encourage the work of the IAEA in seeking to improve international cooperation on the safety of nuclear installations, the handling of nuclear accidents and of their consequences and the provision of mutual emergency assistance. Moving forward from the relevant IAEA guidelines, we urge the early elaboration of an international convention committing the parties to report and exchange information in the event of nuclear emergencies or accidents. This should be done with the least possible delay."

7. On behalf of his Government, Mr Tindemans, the Belgian Minister for External Relations, informed Mr Delors, President of the Commission, of the need to consider action in the field of nuclear safety and requested the Commission to make proposals concerning the definition of objective safety criteria which would have to be applied to the design of nuclear power stations. In addition, plans for typical emergencies would have to be drawn up within the Community and should cover ways and means of rapid mutual assistance between Member States. Furthermore, closer cooperation between Member States in relation to measures restricting intra-Community trade was proving to be necessary. Finally, where the provision of information was concerned, the Chernobyl accident had brought to light serious deficiencies which would have to be put right as soon as possible.

8. For his part, Mr Kohl, the German Federal Chancellor, issued an invitation to the Heads of State or Government of countries which possess nuclear power stations or are in the process of constructing them and to the competent international organizations, suggesting that a conference be held for the purpose of examining all measures that should be taken to ensure that nuclear installations are operated with a maximum of safety and that accidental releases of radioactive substances can be prevented. He also expressed the opinion that improvements in these fields are possible and necessary.

9. The Irish Government, moreover, has pointed out to the Commission that, in its view, short- medium- and long-term action should be undertaken with regard to rapid information on, and mutual assistance in the event of, an accident and that:

- the technological safety standards applicable to nuclear power stations within the Community should be more closely scrutinized;
- stricter radiation protection standards should be laid down.

Finally, priority should according to the Irish government, be accorded to setting up a Community inspectorate for nuclear safety and radiation protection.

10. At its meeting on 12 May 1986, the Council of Ministers, after confirming that the Member States had undertaken to communicate to the Commission uniform data concerning the evolution of radioactivity within their territories and the health measures applicable at national level, requested the Commission to prepare as soon as possible proposals for supplementing, on the basis of the relevant provisions of the Euratom Treaty, the basic standards for the protection of public health and to propose to the Council a procedure for coping with such emergency situations in the future. On 30 May, the Council of Ministers reiterated its invitation to the Commission to expand the basic standard to take account of the dangers inherent in the contamination of products.

11. At an informal meeting in Brussels held on 12 May 1986, the Ministers for Foreign Affairs requested, in the light of the abovementioned communication from Mr Tindemans, the Commission to put forward proposals relating to the definition of objective safety criteria for nuclear power stations. It was also agreed that the Commission should put forward proposals for the drawing-up of emergency plans, which, in particular, would have to enable the Member States to provide mutual aid rapidly in the event of a serious nuclear accident. They also

agreed that, within the framework of the IAEA, the Twelve should work towards making the Directives concerning the exchange of information binding, which could be achieved in the form of an international convention.

The Ministers also considered that it would be necessary to determine whether, at the Vienna Conference on the follow-up to the Conference on Security and Cooperation in Europe, it would be possible to give greater substance to the provisions of "basket" 2 of the Helsinki Final Act on the environment.

12. At its plenary session last May, the European Parliament passed two resolutions convering all the concerns arising from the Chernobyl accident and requesting, inter alia, that the radioactivity limit values applicable to foodstuffs for human consumption be established uniformly by the Member States at a level which would unquestionably guarantee that such foodstuffs were harmless to human health and that these limit values would be applicable both to foodstuffs produced within the Community and to imported foodstuffs.

Parliament also requested the Member States and the Commission:

- to arrive at a common position with a view to negotiating rapidly international standards which would make it binding to report any accidents immediately to the IAEA;

- to set up effective inspection systems at international level.

It also requested the Commission to report on the circumstances of the accident and on its consequences for public health within the Community and for the environment in the medium and long term.

Finally, it called upon the Member States to adopt common standards for the design, operation and safety of nuclear power stations, the decommissioning of any obsolete power stations, the transport and disposal of nuclear waste and the effective supervision of such operations by the IAEA.

13. On 21 May 1986, the Board of Governors of the IAEA requested that:

- a meeting of experts be held in three months to examine in detail the causes of, and the sequence of events during, the Chernobyl accident;

- groups of experts be set up

  . to transform into international conventions the IAEA guidelines on rapid information and mutual assistance in the event of accidents;

  . to evaluate additional measures to be taken to improve cooperation in the field of nuclear safety, including the improvement of standards;

- an intergovernmental conference be held in order to study all the problems that arise in the field of nuclear safety.

14. In a letter sent on 2 June 1986, Mr Poniatowski, Chairman of the European Parliament Committee on Energy, Research and Technology, informed the President of the Commission of the initial conclusions to be drawn from the Chernobyl accident and from the emergency debate held by the European Parliament. The questions dealt with are weighty and varied. The Commission has not yet been able to examine them thoroughly, but it will do so and reply as soon as possible.

15. In the light of the above, and in the desire to protect workers, the public and the environment, the Commission has started discussions on the action to be taken at Community level to pursue the development of a coherent policy in this field.

Such action, which takes account of the lessons learnt from the Chernobyl accident and the specific nature of the problems encountered, will be taken in the following areas according to an appropriate timetable:

A. Health protection
B. Plant safety and operational safety
C. Emergency procedures
D. International action
E. Research.

Some of the measures described are also intended to make up for deficiencies in the information given to the public, both on a preventive basis and in the event of a crisis. The need for information is making itself felt not only at national level, but also in the European context, where it is necessary in particular to ensure consistency.

The Commission will take any other appropriate action, also in the context of other international organizations, that is likely to contribute to the provision of adequate information to the public.

II. BASIS FOR COMMON ACTION

16. In order to cope with the suddenness of the repercussions of the Chernobyl accident - notably with regard to the functioning of the "common market", and above all in the foodstuffs sector - Community action has been based on the EEC Treaty.

In order to deal with certain aspects of the action to be taken, further use should be made of the provisions of the EEC Treaty and of the secondary legislation deriving therefrom to protect the environment and consumers.

7. However, examination of the means of Community action should be based, primarily on the Euratom Treaty.

The Euratom Treaty was concluded by the founding Heads of State who declared themselves:

"Resolved to create the conditions necessary for the development of a powerful nuclear industry which will provide extensive energy resources, lead to the modernization of technical processes and contribute, through its many other applications, to the prosperity of their peoples."

Article 1 of the Treaty stipulates:

"It shall be the task of the Community to contribute to the raising of the standard of living in the Member States and to the development of relations with the other countries by creating the conditions necessary for the speedy establishment and growth of nuclear industries."

In order to enable the Community to accomplish this task, the Treaty lays down "provisions for the encouragement of progress in the field of nuclear energy" (Title Two).

18. Among these provisions, particular importance is attached to those relating to health and safety (Chapter III), on the grounds that they constitute an essential precondition for the exploitation of this form of energy, whether on an experimental or economic scale. From the health and safety angle, the characteristic feature of nuclear energy is the emission of ionizing radiations. However, these radiations are also caused by economic and social activities not connected with the production of energy (e.g., radiology). Furthermore, radiation also exists spontaneously in nature. The environment is subjected - to a certain extent - to ionizing radiations: natural radioactivity (varying from one place to another) and cosmic radiation. It should be borne in mind that in normal operating conditions, the amount of radiation emitted by nuclear facilities constitutes only a few percent of the average level of natural background radiation. This is why institutional provisions relating exclusively to the scientific and industrial exploitation of nuclear energy have not been laid down so much so that Chapter III of the Euratom Treaty deals with the protection of health against all forms of ionizing radiations, irrespective of their sources and origins.

Accordingly, this chapter contains all the provisions necessary to achieve this "Community objective" which, according to Article 2(b), is to "establish uniform safety standards to protect the health of workers and of the general public and ensure that they are applied".

19. As regards the international aspects of the measures to be taken, it should be pointed out that Article 2(h) of the Euratom Treaty stipulates that the Community should establish with other countries and international organizations such relations as will foster progress in the peaceful uses of nuclear energy. In addition, an entire chapter of the Treaty (Chapter X) is devoted to international relations.

20. Lastly, should the abovementioned provisions prove inadequate, recourse could be had to Article 203,[1] which is the Euratom equivalent of Article 235 of the EEC Treaty.

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[1] "If action by the Community should prove necessary to attain one of the objectives of the Community and this Treaty has not provided the necessary powers, the Council shall, acting unanimously on a proposal from the Commission and after consulting the Assembly, take the appropriate measures."

III. ACTION AREAS

A. Health protection

21. A thorough assessment must first be made of the extent to which Chapter III of the Euratom Treaty, referred to in point 21 above, is being implemented. This assessment had already begun, on request, long before the Chernobyl accident, in particular within the European Parliament and, on a specific point, by the Luxembourg government, on 20 February 1986.

22. It will first of all be necessary to decide whether or not there is a case for changing the basic standards for protection against the dangers of radiation, which were drawn up in 1959 and have been revised periodically (most recently in 1984) to take account of technical and scientific progress.

23. Leaving aside this basic question, other provisions of Chapter III must also be reviewed:

- the establishment by the Member States of laws, regulations and administrative provisions to ensure compliance with the basic standards and communication to the Commission thereof (Article 33);

- radioactivity-monitoring facilities and communication of data on radioactivity levels (Articles 35 and 36);

- procedures for examining plans for the disposal of radioactive waste (Article 37).

24. In the light of the events immediately following the Chernobyl accident, it is clear that the Commission, in consultation with the Member States, must take the necessary steps to accelerate, standardize and automate the collection of data on radioactivity levels (Article 36) and to exploit and publish regularly the results.

25. The Commission will be transmitting a comprehensive communication on the problems of implementing Chapter III of the Euratom Treaty and on possible solutions by the end of July 1986.

26. Immediately after the accident when radioactivity had been dispersed in the atmosphere, the Community was faced with the problem of contaminated foodstuffs. It was able to take a number of emergency measures with regard to the relevant trade arrangements. No other measures were taken, however, because it proved impossible to reach an agreement. These difficulties indicated the need to establish "tolerance limits for radioactive contamination"[2] in advance of any incident, so as to avoid controversy in the event of an emergency. Such limits would apply equally to all domestic production and imported products.

27. The Commission has already gone some way towards drawing up a proposal aimed at setting tolerance limits for the radioactive contamination of goods. It will draw upon all of the scientific expertise available and will concentrate its efforts on this proposal in order to complete it as quickly as possible and to take full account of the Councils' request, the arrangements deriving from which expire at the end of September 1986.

B. Intrinsic and operating safety of installations

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[2] This expression denotes the permissible upper contamination limit. The expression "maximum tolerance" has also been used for this purpose in certain Council documents.

28. From the technological point of view, the safety of an installation depends on its ability to confine radioactivity adequately, whether under accident conditions or during normal operation; the Chernobyl accident has highlighted the problem of safety in nuclear power stations. Other types of installation and/or operation must also be considered, as must packages of radioactive materials (most of which contain the products used in industrial radiography and radiopharmaceuticals) and radioactive-waste repositories.

29. The ultimate objective as regards the intrinsic and operating safety of nuclear installations is to ensure the protection of man and the environment.
This is achieved, on the one hand, by appropriate measures to confine the sources of radiation and, on the other, by ensuring the integrity of the containments.

30. According to the basic standards, protection is based on the principle that all exposure to ionizing radiations must be kept "at a level that is as low as reasonably achievable" (ALARA) and also on the obligation to limit the individual doses sustained by exposed workers and by the population at large.
In practice, exposed workers undergo individual and collective monitoring as a means of objectively assuring that the dose limits have not been exceeded. As far as the general public is concerned, individual monitoring is not possible. (This explains, in part, why the individual dose limits for the public are lower than the dose limits for workers.)

31. In the area of non-nuclear activities and for dangers other than ionizing radiation, limits have also been set for exposure of the population and of the environment to pollutants (concentrations in the air and water).

However, for the purposes of defining emission standards applicable to certain types of industry and specific pollutants, the recent directives[3] have also placed more stress on use of the concept of the best available technology not involving excessive costs.

At present there is no compulsory Community standard limiting radioactive emissions into the air and water.

The Commission is looking into the question of whether the emission standards concept should be applied to nuclear installations, in the knowledge that in any case the basic standards will remain in force. It will inform the Council and Parliament of the outcome and submit proposals, where appropriate.

32. In a nuclear reactor, the fission products generated in the fuel constitute the principal source of ionizing radiations and these must be effectively isolated from the biosphere in all circumstances. The conditions that have to be satisfied by the various elements that contribute to this containment (e.g., the fuel cladding and the primary-circuit envelope) represent the installation safety criteria. Just as the articles of a directive express the intentions of the legislator, so too do these criteria set out the specific safety objectives.

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[3] Directive 84/360/EEC on the combating of air pollution from industrial plants (OJ L 188, 16.7.1984); Directive 76/464/EEC on pollution caused by certain dangerous substances discharged into the aquatic environment of the Community (OJ L 129, 18.5.1976) and directives derived therefrom (82/176/EEC; 83/513/EEC; 84/156/EEC; 84/491/EEC).

For example, mandatory criteria reflect the need for structures and components to withstand the effects of earthquakes. In this example, one of the criteria relates to determination of the reference earthquakes (which depend on the location of the installation) to be used in evaluating the stresses on structures and components. The application of (that is to say, compliance with) these criteria is based on detailed standards which are to the criteria what implementing regulations are to Directives. In the example given, the design and construction standards stipulate the calculation methods and fabrication methods. The standards used must be approved by the contracting parties and the safety authorities. They can be adapted to technological progress.

33. In each State, the criteria and standards constitute a coherent set of rules. This set of rules varies from one State to another. Such heterogeneity in a regulatory context gives rise to the de facto walling-off of certain national markets, so that the Community has to take steps both to approximate the regulations and to achieve the nuclear "common market".

34. This course of action is beset by serious difficulties arising from the complexity of the problem to be solved, but it can be facilitated by two favourable factors.

The first of these is that the safety criteria, even though they are strict and precise, are essentially of a general nature and in consequence lend themselves to approximation.

The second derives from the fact that the nuclear reactor market tends to centre on light-water reactors (LWRs), to which may be added in the long term liquid-metal-cooled fast reactors (LMFBRs). The light-water reactors are based on a common design and, although they were developed independently in certain Member States, the European models are closely related to one another. It should hence not be an impossible task to approximate the safety criteria for such reactors within the Community with the ultimate objective of harmonizing them. As regards fast reactors, they are being developed in Europe - on the basis of one and the same concept - through close cooperation between the Member States and firms which are particularly interested. This means that it should be all the easier to lay down criteria and standards jointly.

35. In view of this situation, the Community should accord priority to seeking a consensus among the Member States concerned with regard to the harmonization of safety criteria. Such harmonization would facilitate development of the common market and would at the same time allay public concern. The consensus thus obtained would be formalized at a later stage of the action, which is also important in this context. This course of action in successive stages was adopted in the past in implementation of the Council Resolution of 22 July 1975 on the technologic problems of nuclear safety (OJ No C 185, 14.8.1975). In that resolution, the Council, while recognizing the prerogatives and responsibilities of the competent national authorities in this field:

- recognized that the national authorities themselves, the nuclear energy producers and the constructors would be able to benefit from a harmonized approach to safety criteria at Community level;

- stressed that the problems of nuclear safety extend beyond the frontiers not only of Member States, but of the Community as a whole, and that it is incumbent on the Commission to act as a catalyst for initiatives to be taken on a broader international plane;

- agreed to the course of action in stages[4] in respect of the progressive

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[4] Listing and comparing the safety requirements and criteria applied; drawing up a balance-sheet of similarities and dissimilarities; formulating recommendations pursuant to the second indent of Article 124 of the Euratom Treaty; where appropriate, submitting to the Council the most suitable draft Community provisions.

harmonization of national safety criteria.

36. Only some of the actions called for in that resolution have so far been taken owing to the complexity of the problems. The Commission expects that the willingness recently shown by the Member States to increase international cooperation will also extend to achieving significant progress in the harmonization of safety criteria.

In July 1986, the Commission will report to the Council and Parliament on the status of application of the Council resolution of 22 July 1975, on the problems involved in the harmonization of safety criteria and on the actions to be taken.

37. Under the basic Euratom standards, the nuclear industry is already required to comply with provisions concerning certain preventive measures designed to reduce accident risks, such as notification of the characteristics of nuclear facilities and of emergency plans. On the other hand, there are no existing Community provisions concerning the prior information of the public.

38. Other industrial activities, particularly those in which certain particularly dangerous substances are or can be used, are also the subject of preventive measures designed to limit the risks of major accidents (Directive 82/501/EEC of 26 June 1982, OJ L 230, 5.8.1982).

These measures require in particular that persons who may be affected by a major accident shall receive adequate advance information concerning the action to be taken in the event of such an accident.

The Commission will examine whether the provisions of the Euratom basic standards which cover these preventive measures are correctly applied and sufficient for the protection and information of the public. It will inform the Council of the results of its activities before the end of 1986.

39. Some of the information gathered by national authorities concerning incidents in nuclear power plants is notified - on a voluntary basis - at international level under the OECD and IAEA Incident Reporting Systems - IRS). This exchange of information is intended to enable the authorities responsible for safety to analyse the events which are of the greatest significance from that standpoint.

In the context of the European Reliability Data System (ERDS), the Commission (JRC) has created a data bank for the storage and analysis of information on incidents occurring in nuclear installations. This bank is intended to increase collective knowledge of the technological aspects of anomalies in such plants. The JRC also acts as an operating agent for the IRS system in the OECD area by storing, processing and analysing the system information.

The Commission considers that the international exchange and the joint analysis of information on incidents in nuclear installations should be made more effective and that a compulsory Community reporting system should be adopted. The Commission will send the Council a proposal on this matter before the end of 1986.

40. As regards safety in transit, following the accident involving the freighter Mont Louis the Commission studied all the problems involved in the transport of dangerous and toxic substances and wastes, including radioactive materials.

Before the end of 1986, the Commission intends to send the Council a proposal designed to make the application of the provisions of the international agreements on the transport of dangerous substances[5] obligatory with regard to domestic and international transport.

As regards radioactive materials, which constitute a category of dangerous materials, it is planned that they should be subject, for all transport both within and between Member States, to a uniform set of provisions based on the IAEA recommendations "Regulation of the transport of radioactive materials" (Safety collection No 6, 1985 edition).

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[5] Road - Economic Commission for Europe, ADR Agreement
Rail - Office of International Rail Transport, RID Regulations
Sea - International Maritime Organization, IMDG Code, etc.
Air - International Civil Aviation Organization, Technical Instructions
Inland Waterways - Central Rhine Commission, ADNR Agreement

41. The Commission also intends to examine the possibility of recommending that the Member States should harmonize certain measures covering the training and information of staff responsible for the transport of radioactive materials.

42. As regards the disposal of radioactive waste, implementation of the Community plan of action 1980-92) is proceeding satisfactorily. It covers the following points:

- continuous analysis of the situation with a view to the adoption of the necessary solutions;

- examination at Community level of measures which could ensure the long-term or permanent storage of radioactive waste under optimum conditions;

- consultation on practices concerning the management of waste, the quality and properties of conditioned waste and the conditions governing the disposal of waste;

- the continuity of Community research and development work during the plan;

- the provision of regular information for the public.

Pursuant to this plan of action, an initial report covering analysis of the existing situation and the prospects for the management of radioactive waste in the Community (COM(83) 262) was sent to the Council in 1983. It is proposed to send an update of this report, which is currently being prepared, to the Council before the end of 1986.

43. Furthermore, as is the case with all types of waste, the disposal of radioactive waste at sea is subject to the provisions of the London Dumping Convention. The Convention prohibits the dumping of certain dangerous wastes, particularly high-activity wastes, and provides for an

authorization system to cover the disposal of other wastes. Although all the Member States, with the exception of Luxembourg, are parties to this Convention, the Commission as such is not.

In recent years, the disposal of radioactive waste at sea has given rise to an extremely heated debate within the framework of the London Dumping Convention and, in practice, this method has not been used for the last three years.

As it has already pointed out in its Communication to the Council concerning new directions in environmental policy (COM(86)76 final, 19.2.1986), the Commission intends to submit proposals before the end of 1986 with a view to the participation of the Community as such in the London Dumping Convention.

C. Emergency procedures

44. The Chernobyl accident has demonstrated the need to exchange information on any radioactive hazards very quickly and, for this purpose, to have available at all times data enabling such information to be sent, received and used. An international Convention will be negotiated and signed - then ratified - under the aegis of the IAEA. This will oblige the contracting parties to report and exchange information in the event of a radioactive alert or accident. This Convention will draw upon an IAEA document entitled: "Guidelines on reportable events, integrated planning and information exchange in a transboundary release of radioactive materials" (INFCIRC/321) which sets out in sufficient detail the measures to be taken in any given instance.

45. Although many of the countries concerned are anxious that the new Convention should be concluded at an early date, the negotiating and above all ratification procedures will take some time.

For rapid action within the Community, an interim system should be set up. At regional level, the time required for implementation should be much shorter. Another aim of this system would be to guarantee in each Community country a single source of verified and authenticated information which would be able to meet the information requirements of the public, consumers and the media and thus avoid discrepancies in both the facts and their interpretation, the effects of which are always adverse.

46. A proposal for a regulation on an interim Community system for the rapid provision of information on nuclear accidents will be sent by the Commission to the Council before the end of July 1986.

47. The Chernobyl accident has also demonstrated the usefulness of an international system of mutual assistance, although this does not preclude the possibility of additional bilateral agreements. An international convention will be negotiated. It will be based on the IAEA document entitled: "Guidelines for mutual emergency assistance arrangements in connection with a nuclear accident or radiological emergency" (INFCIRC/310 of January 1984).

48. However, these guidelines, in contrast to those on rapid information in the event of an accident as referred to in 46 above, do not go into close detail. The Commission therefore feels that, in this area, the Community should not merely anticipate the future international system to be set up, but should be more ambitious and take full advantage

of the firm links already existing between its Member States. Moreover, the very advanced stage of nuclear development reached within the Community should enable it to take the lead in the provision of mutual assistance in emergencies.

49. This is nevertheless a complex field in which the national responsibility certainly outweighs that of the Community.

The Commission therefore intends to conduct a number of consultations before laying a proposal before the Council on the implementation of a Community system for mutual assistance in emergencies. Consequently this proposal cannot be ready before the end of the year.

D. International action

50. Apart from the activities that can justifiably be carried out in the Community both because of its purpose and aims, and because of the speed and effectiveness sought, the appropriate international framework is provided by the International Atomic Energy Agency (IAEA) which is in the process of strengthening its cooperative links with other international bodies concerned by some of the consequences of the Chernobyl accident (WHO, WMO, UNEP and UNSCEAR).[6]

51. The legal framework for the cooperative and consultative relations between the Community (Euratom) and the IAEA is defined by a general agreement (of 1 December 1975) enabling the Community as such to be represented within the Agency's sectors of activity other than safeguards, where specific cooperation is in force.

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[6] World Health Organisation; World Meteorological Organization; United Nations Environment Program; United Nations Scientific Committee on Effects of Atomic Radiations.

52. Where its spheres of influence are directly or indirectly involved, the Community will have to be a party to the international conventions, the negotiation of which has recently been decided upon by the Board of Governors of the IAEA (see paragraphs 46-51). There is a major precedent in this area. This is the "International Convention on the physical protection of nuclear materials" which was also signed under the aegis of the IAEA.

53. Other topics which might be covered by worldwide arrangements in which the Community and its Member States should be associated, are: third-party liability in the event of a nuclear accident, the Incident Reporting System already referred to in paragraph 39 of this communication, safety criteria and the monitoring of radioactivity, accompanied by the application of uniform standards governing the measurement of radiation levels.

54. Moreover, the Community and its Member States will be involved in the evaluation of the Chernobyl accident within the IAEA. This work is of supreme importance. It will help the Commission when it reports to Parliament on the circumstances surrounding the accident, on its repercussions on public health within the Community and on its medium and long-term effects on the environment.

55. Finally, the Commission will back Chancellor Kohl's initiative regarding the holding of an intergovernmental conference on all matters relating to nuclear safety.

56. The Commission will take all appropriate steps to enable the Community to take part in international discussions on the basis of common positions or negotiating briefs.

57. Alongside the possibilities for Community and worldwide cooperation, the Community must exploit all existing or future frameworks for bilateral or multilateral cooperation.

E. Research

58. Nearly all the measures that have been identified in the foregoing depend to a large extent on knowledge and know-how derived from past and present Community research programmes. Certain specific problems posed by Chernobyl make it necessary to adapt Community research programmes in hand. In particular, greater emphasis will have to be placed on certain research topics (for example, the improvement of risk evaluation methodologies, the study of major accidents and of the ways and means of limiting the consequences thereof, and the further development of certain research projects on radiation protection). The Commission will put forward appropriate proposals at a later stage; the necessary resources will have to be devoted to such action.

8076
10-6

MEMORANDUM

To Dr J H Gittus, Director, SRD

Your Ref.
Our Ref.
Tel Ext. 1229

Subject CHERNOBYL INFORMATION FROM THE IAEA

At the IAEA Technical Committee Meeting on Thermal Reactor Safety Research in Vienna, 4-6 June 1986, copies of the following papers (which are attached), were circulated:

1. Address by the representative of the USSR to the Board of Governors of the IAEA on the first item of the Agenda: "Information about the accident at Chernobyl, its consequences and measures initiated". (At a meeting held on 22 May 1986.)

2. Speech by Mr Gorbachev - handed to the Director General by Ambassador Khlestov on 3 June 1986. (Translated from Russian, 86-11479.)

There was no official Russian representative at the meeting, and no more positive information about the accident was available.

R N H McMillan

9 June 1986

Encs

<u>Copies to</u>:

Dr M R Hayns
Dr F R Allen
Mr M A H G Alderson
Mr P G Bonell

05/20/86

Translated from Russian

ADDRESS BY THE REPRESENTATIVE OF THE USSR TO THE BOARD OF GOVERNORS OF THE IAEA ON THE FIRST ITEM OF THE AGENDA: "INFORMATION ABOUT THE ACCIDENT AT CHERNOBYL', ITS CONSEQUENCES AND MEASURES INITIATED". [Meeting on 22 MAY 1986]

Mr. Chairman,

First of all I would like to express our deep gratitude to all those who have shown sympathy and understanding in connection with the events at the Chernobyl' nuclear power station. We also highly appreciate the constructive approach to the accident at the Chernobyl' nuclear power plant adopted by the IAEA and by Dr. Hans Blix, its Director General.

As we are aware, the rapid progress in science and technology brings not only benefits for mankind. Man's exploration of the poles and outer space and the harnessing of atomic energy must inevitably involve tragic losses. We have been reminded of this once again by the accident at the Chernobyl' nuclear power plant, where for the first time we have had to face the formidable force of nuclear energy when it gets out of control.

In order to make clearer the technical details which I am going to talk about, it would be useful to recall briefly the main features of the Chernobyl' reactors.

The branch of nuclear power engineering entailing the use of uranium-graphite channel (pressure-tube) reactors cooled with normal water is a traditional one in our country and has a long history. It was indeed this type of reactor that was used in the world's first demonstration nuclear power facility set in operation at Obninsk more than 30 years ago. The design principles adopted at that time were retained in the subsequent experimental-industrial units of the Byeloyarsk nuclear power plant, the long and successful operation of which confirmed the viability of the channel-type design for uranium-graphite reactors and made it possible to move on to the construction of series-produced reactors of high power.

FACILITY

The first of the series of RBMK-1000 reactors was put into operation at the Leningrad nuclear power station in 1973, hence to date we have had more than 10 years of experience in operating reactors of this type. The RBMK-1000 (uranium-graphite boiling-water high-power reactor) has a thermal capacity of 3200 MW and is cooled by boiling water using a single circuit system; the fuel is low-enriched (~2%) uranium dioxide and the moderator is graphite. The mean burnup of the fuel is 18 500 MW-d/t, and the stationary uranium fuel load is 180 t. The water flow rate through the reactor is 37 500 t/h; the steam temperature at the turbine inlet is 280°C, and the pressure is 65 atm.

The coolant circuit consists of two parallel loops, each of which contains two drum separators, four circulation pumps, a pipe system (mean diameter 300 mm; maximum diameter 900 mm) and 22 distributing group pressure headers, which feed the reactors' channels. Saturated steam is pumped through 8 steampipes 400 mm in diameter to two turbines each with an output of 500 MW.

To monitor the power and control the reactor use is made of lateral ionization chambers, while the system for monitoring the power density vertically and radially in the reactor employs neutron detectors mounted in some of the fuel channels as well as in the channels containing measuring detectors of the reactor control and protection system. The leaktightness of the fuel elements is continuously checked by measuring the activity of the steam-water mixture in the pipes at the inlet to the separators by means of scintillation gamma detectors.

The control and protection system contains 180 independent absorbers combined into sets with autonomous detectors.

A feature of this particular reactor is the absence of a thick-walled high-pressure vessel. The graphite masonry is contained in a thin-walled leak-tight casing, while the fuel assemblies are located in channels made of a zirconium alloy which takes the pressure.

In principle, the design of channel reactors is characterized by high reliability as compared with reactors of the pressure vessel type, in which the thick-walled high-pressure vessel is one of the most critical elements from the standpoint of safety.

In the channel reactor disruption of the integrity of the individual fuel channels does not in principle present any grave danger. The practice of replacing the channels has confirmed that this operation is quite normal in nature.

The reactor facility possesses an emergency core cooling system, which includes passive and active subsystems with the necessary redundant equipment. The system ensures reliable cooling of the reactor in the event of the maximum design-base accident, which is taken to be an instantaneous transverse rupture of the pressure header of the main circulation pumps 900 mm in diameter.

To stop steam and fission products escaping in the event that the pipes and working channels of the reactor lose their leaktightness, provision is made for the principal components of the reactor unit to be contained in hermetically sealed compartments calculated to withstand an excess pressure of 4.5 kg/cm^2. These compartments serve the same function as the protective envelope (containment) of PWR reactors. All releases during design-base accidents are localized in these compartments, while the steam condenses in a special pressurizer relief tank connected to the hermetically sealed compartment system.

The passive subsystem of the emergency core cooling system contains two sets of tanks holding 200 m^3 of water. This reserve is guaranteed to be enough to remove the heat from the core within the first three minutes from the moment the accident is initiated.

The active subsystem contains five sets of pumps for feeding water to the core after the water tanks have emptied. All the active subsystem pumps are powered by backup diesel generators located on site. The reserves of water for the active subsystem are adequate to ensure a supply of water to the reactor lasting virtually any amount of time.

ACCIDENT

It now transpires that the accident developed at the power station in the following manner. At 0123 hours and 40 seconds on 26 April an emergency occurred in the fourth unit of the Chernobyl' nuclear power station during the scheduled shutdown of the unit while at a power level of seven per cent. The reactor power suddenly increased and there began intensive evaporation of the cooling water and considerable formation of steam. The ensuing reaction between the steam and the zirconium led to the formation of hydrogen, which then exploded. The explosion caused a fire, and the reactor building together with the equipment in it, the reactor itself and the core were extensively damaged, causing the release of fission products beyond the site. During the accident the chain reaction ceased.

The fire brigade which arrived soon after succeeded in putting out the fire at the fourth unit and prevented the roof of the machine room from catching fire.

The three remaining units were shut down and returned to a sub-critical state; they are now being cooled. Two persons died as a direct result of the explosion, one through burns and the other through injuries suffered from collapsing structures.

The release of radioactivity rose to a height of approximately 1 km. The level of activity in the release was principally determined by short-lived isotopes. The bulk of it was accounted for by iodine-131 (50%).

In the light of the events a Commission was set up by the Council of Ministers of the USSR to take action to eliminate the consequances of the accident and to ascertain the causes of it. The Commission consisted of prominent scientists, administrators and specialists from ministries and departments. The Commission was headed by B.E. Shcherbina, Deputy Chairman of the Council of Ministers of the USSR. Within literally a few hours the members of the Commission were at the scene of the accident. From the very outset the Commission realized that its main task, after ensuring people's safety, was to commence emergency work on the reactor so as to reduce the release of radioactivity to a minimum. In view of the exceptional and dangerous nature of the accident, a group headed by N.I. Ryzhkov, Chairman of the Council of Ministers of the USSR, was set up within the Politburo of the Central Committee of the CPSU to deal immediately with the problem.

In effect, all the work is being conducted on a round-the-clock basis. The scientific, technical and economic resources of the entire country have been brought into action. Operating in the area of the accident are organizations belonging to many of the union ministries and agencies under the supervision of ministers, prominent scientists and specialists, units of the Soviet army and departments of the Ministry of Internal Affairs.

It is too early yet to draw final conclusions about the causes of the accident. All aspects of the matter - design, technology and operation - are being closely scrutinized by the Government Commission. When the investigation into the causes of the accident has been completed, all the necessary conclusions will be drawn and measures will be taken to prevent anything of the sort ever happening again.

The main aim of the emergency operations was, first, to minimize the release of fission products from the reactor and, second, to cool the core of the shutdown reactor, in which heat had been released for a considerable time on account of the radioactivity of the fission products. To deal with the first problem a protective covering of sand, clay, boron, dolomite, limestone and lead was placed over the core with the aid of helicopters. The top of the reactor was covered with a layer of more than 4000 tons of this protective material. By 13 May the reactor had to all intents and purposes stopped releasing fission products into the atmosphere. In view of the fact that the bulk of the fuel was inside the reactor, there was fear of the core melting on account of the residual heat referred to above. It can now be said that this problem has been overcome. The core temperature dropped first to 300-400°C, and then to 200-250°C. This was made possible, among other things, by intensive cooling of the bottom of the reactor with nitrogen which at the same time ensured an inert atmosphere there.

When the main problems of the first stage (cessation of the fission product release and drop in temperature) had been dealt with, attention was focused on decontaminating the territory and constructing a concrete containment (sarcophagus) for final burial of the reactor. To guarantee the insulation of the ground below the reactor floor, work is in progress to insert additional concrete protection beneath the reactor - under the foundations on which it stands.

A tunnel is being made under the reactor and will be used to construct underground what is in effect a concrete cooler in the sense that there will be radiators with a suitable cooling system mounted into the concrete.

The power station precinct has been banked up and protective adaptations have been made to prevent any rain from washing the radioactive substances present on the site itself into the river.

The power station precinct and surrounding areas are undergoing decontamination. Various methods are being used for this purpose, including polymer materials. When these are applied to a surface or to the ground they form a film which binds the radioactive substances and prevents them from being washed away; later on this film can be removed and destroyed. Several million square meters of contaminated land have already been treated in this way. The most difficult part of the work still ahead is that on the collapsed structures and rubble.

In worldwide practice, such difficult technical and engineering problems as those which are successfully being solved by the Soviet scientists and specialists at the Chernobyl' nuclear power station have never before been encountered. The experience gained will be of great value.

At units 1, 2 and 3 which have been shut down, a permanent watch is being kept by specialists numbering about 150 altogether. Units 1 and 2 could be put back into operation at any time.

Post-accident

In the situation that followed the accident, the necessary measures were taken for the proper protection of the population. Mass evacuation was carried out on 27 April, women and children being evacuated first. The inhabitants of the power station settlement were evacuated within a few hours, and then, when it became clear that there was a potential hazard to the health of people in the surrounding area, they also were moved into safe areas. Several 10 000 people were evacuated from Chernobyl' and other places within the 30 km zone. Potassium iodide tablets were administered as a prophylactic measure. All this work required a maximum of rapid, organized and efficient action. The radiation levels in the power station zone and the adjacent areas, although appreciably reduced, still remain hazardous to human health.

At the time of the accident, as has already been said, two men were killed. So far, 299 people have been hospitalized - diagnosed as having radiation sickness of varying degrees. Fifteen of these have died, and 35 who received high doses of radiation remain in critical condition. The fire brigade personnel suffered most heavily. Nineteen bone-marrow transplants were carried out. In order to give all possible help, the best scientific and medical people in the country and specialized hospitals in Moscow and other cities were called on to assist. Foreign medical experts have been helping alongside the Soviet doctors. The patients who have received doses hazardous to their health do not include any inhabitants of the nearby villages, although they were all thoroughly examined.

[illegible]

In the area surrounding the accident zone, the radiation level reached values of 10-15 milliroentgen per hour. By now the radiation levels have declined sharply. The value measured at a meteorological station located 60 km from the nuclear power station was 0.17 milliroentgen per hour on 20 May. Measurements carried out at meteorological stations along the western frontier of the Soviet Union show that the radiation levels are within normal limits. Isotopic analysis of the composition of the radioactive fallout is being performed. Samples from the accident area contain barium, lanthanum-140, ruthenium-103, caesium-137, iodine-132, tellurium-132, strontium-89, strontium-90, and yttrium-91. As has already been pointed out, most of the fallout is accounted for by short-lived elements.

Surveys of the radioactivity level in the water reservoir in the Kiev region, which are carried out regularly, show that it has remained normal and does not pose a health hazard.

The weather services are keeping the radiological situation in the soil, water and atmosphere under constant observation.

The current situation on the territory of the USSR is as follows: outside the 30 km zone around the Chernobyl' nuclear power station, the main radiological factors affecting the population of the Ukrainian, Byelorussian and Moldavian Soviet Socialist Republics and of the various districts of the Russian Soviet Federal Socialist Republic whose territories have received radioactive fallout, are external gamma-irradiation and the ingestion of iodine-131 with food products, but in quantities that do not constitute a risk to the population.

Various lots of milk with an iodine-131 content in excess of these norms have been passed on for processing into products which can be stored for one or two months.

As regards vegetables, fruit and cereals to be harvested in the mid-summer and autumn, there are no grounds for supposing that they will be found to be contaminated with radioactive iodine-131.

Daily reports on the radiological situation around Chernobyl' and along the western frontiers of the Soviet Union are being sent to the IAEA.

A certain amount of activity was carried beyond the frontiers of the USSR in north-westerly, westerly and, later, south-westerly directions.

In a number of European countries, influenced by the sometimes false and usually tendentious mass media reports concerning the scale of the accident at the Chernobyl' nuclear power station, the population showed great anxiety with regard to possible effects of the accident on their health and on the environment. In this connection it is worth recalling the conclusions and recommendations of a special experts' meeting convened by the WHO Regional Office for Europe at the instance of the Director General of WHO, and the official reports by a number of national services, including some published by the IAEA, which bear witness to the fact that the radioactivity level in those countries did not constitute a health hazard to the population.

A serious situation was produced by the accident. It was necessary to evaluate it quickly and competently, and as soon as reliable initial information had been obtained, it was sent through diplomatic channels to the governments of foreign countries and to the IAEA. The IAEA Secretariat and the USSR Mission maintained constant liaison with regard to questions relating to the accident. The Soviet side expressed its willingness to co-operate with the Agency in all matters of interest to the IAEA. Information about the accident was published in the Agency's press releases. In addition, the Soviet Government invited the IAEA Director General, Mr. Hans Blix, to come to the Soviet Union and to see for himself the situation following the accident at the Chernobyl' nuclear power station and to discuss ways of increasing the safety of nuclear power by broader international co-operation and an enhancement of the IAEA's role in this area.

IAEA

During their stay in the USSR, Mr. Blix and the IAEA officials accompanying him, Mr. L. Konstantinov and Mr. M. Rosen, had meetings with the Deputy Chairman of the Council of Ministers and Chairman of the Government Commission, Mr. Boris E. Shcherbina, and with ministers, responsible officials and experts, and also visited the area of the Chernobyl' nuclear power station, where they received additional information about the situation on the site and the measures taken to eliminate the consequences of the accident. During this visit it was agreed that the radiological situation near Chernobyl' and on the western frontiers of the Soviet Union would be reported to the IAEA each day for transmission by the Agency to the respective national bodies dealing with radiation safety.

Pursuant to this agreement, the USSR commenced regular transmissions of data on 9 May 1986.

The information is transmitted daily by telex and includes data from seven different meteorological stations. The first of these, Oster, is located 60 km from Chernobyl'. The six other stations lie along the western boundary of the USSR. They include Leningrad, Riga and Vilnyus in the Baltic region, Brest (on the Polish border, 52° northern latitude), and two stations - at Rakhov and Kishinev - further south near the Hungarian and Romanian borders. Thus, practically all sections of the USSR's western boundary across which radioactive substances could be carried into the territory of neighbouring European States are covered.

The daily reports include the following data as agreed with the IAEA:

1. Radiation dose rate (in milliroentgen per hour);
2. Air temperature (°C);
3. Dew point (°C);
4. Wind direction;
5. Wind speed (m/s);
6. Nature of atmospheric precipitation.

Data on the natural background levels were also officially reported to the IAEA so that they could be taken into account in analysing the daily reports on the radiological situation.

During the period which has elapsed since the beginning of regular data transmissions to the IAEA, the radiological situation near the nuclear power station has gradually improved. According to data from the station at Oster, the dose rate characterizing the radioactivity level has fallen from 0.33-0.36 milliroentgen per hour to 0.17 as recorded yesterday.

In the north-western areas along the USSR's frontier no significant increases in the radioactivity level above natural background values have been recorded. The dose rate values measured there are mostly at background level: 0.01 milliroentgen per hour.

In the west, in the region of Brest, the situation is approaching normal as well. Yesterday the dose rate there was also at the normal background level. Some increase over the natural background has remained until recently in the south-western regions (Rakhov 0.025, Kishinev 0.03-0.04 milliroentgen per hour), apparently because of the atmospheric situation, with weak winds and no precipitation.

On the whole, the radiological and meteorological data sent to the IAEA make it possible to a significant extent to evaluate and forecast the radiological situation for most of Central and Western Europe. The WHO also has expressed an interest in receiving these data. As of 15 May 1986, the Soviet Union has been sending duplicates of the information described above to WHO.

Madam Chairman,

I have given the Board of Governors a brief preliminary report on the accident at the Chernobyl' nuclear power station, its consequences and the measures for dealing with them. As stated in the communiqué on the results of the Director General's visit to the USSR, the Soviet side has expressed its willingness to provide, as it becomes available, information about the accident for discussion at an experts' meeting on nuclear safety; this will assist IAEA Member States in learning from the experience gained with a view to further improving the safety of nuclear power.

Our proposals on this question, as formulated in the statement by the General Secretary of the Central Committee of the Communist Party of the Soviet Union, Mr. Gorbachev, will be presented by my delegation when we discuss the next item on the Agenda.

86-11479
Translated from Russian

SPEECH BY Mr. GORBACHEV

handed to the Director General by Ambassador Khlestov
on 3 June 1986

In my television speech on 14 May I discussed the main conclusions which we believe must be drawn from the Chernobyl' accident. Today I should like to share with you some further thoughts on this subject.

It is quite clear that, on a practical level, we must, without delay, embark on the establishment of an international regime of safe nuclear power development. Such a regime would be aimed at reducing to an absolute minimum the possibility of peaceful atoms causing harm to people. Ensuring reliable and safe nuclear power development must become a universal international obligation of all States severally and collectively.

First steps in this direction - some involving the IAEA - have already been taken. Various States are putting forward suggestions and proposals which we are studying carefully.

I should like to stress right away that we do not claim to have ready solutions. World-wide, a total of 152 nuclear power plant emergencies involving the release of radioactivity have occurred so far. Thus, a number of States already have experience in this field on the basis of which we can and must develop an international nuclear safety regime.

Of course, the first thing that is required is a system of operational notification in the case of accidents and malfunctions at nuclear power plants when they are accompanied by the release of radioactivity. A question which is related to such a notification system is that of obtaining data on possible fluctuations in natural background radioactivity levels.

Many States do not have the means and resources to deal with an emergency on their own. That is why we think an important component of an international regime of safe nuclear power development must be a well-designed international mechanism for the swift provision of mutual assistance when dangerous situations arise. Such a mechanism might also involve the IAEA and the World Health Organization (WHO). States on whose territory an accident has occurred should be assisted by other States in the elimination of the accident consequences if they request such assistance.

Another question which must be considered is that of the form in international law which an agreement relating to a notification system and assistance mechanism might take. One idea is that the obligations of States in this respect could be laid down in a special international convention or conventions. The Soviet side is now considering all these questions and preparing proposals on this matter, taking into account the suggestions of other States.

Several States which agree with this solution to the problem have proposed that even before such a convention is concluded, in June this year, a decision should be taken to establish as soon as possible, within the framework of the IAEA, a system of notification in the event of nuclear accidents. Well, why not, the sooner we can take the appropriate measures, even if they are only preliminary and provisional, the better.

At the same time, the main task, in our view, is to take precautions to prevent an accident from happening. This purpose would be served if information on the causes of the accident could be provided to the IAEA within the tightest possible time limits. Such information would be studied by the appropriate experts with a view to helping IAEA Member States to benefit from the experience gained so as to increase further the safety of nuclear power.

It will be necessary, however, to go further - to elaborate within the IAEA recommendations on nuclear power plant safety questions and to strengthen national and, where appropriate, international verification of compliance with them in all States. It might also be possible to organize, under the auspices of the IAEA, some form of co-operation between the leading countries in nuclear power on the development of a new generation of economic and reliable reactors with enhanced operational safety as compared with existing reactors.

It should also be borne in mind that sufficient attention has not been given at the international level to the question of material, moral and psychological damage in the event of accidents at nuclear power plants and other nuclear installations. We believe that this matter should be set to rights and that attempts at using nuclear accidents to heighten tension and mistrust in relations between States should be prevented.

I consider, moreover, that the problem of standardizing the permissible levels of radiation in force in the various countries deserves attention in many respects.

Nor should we neglect such aspects of nuclear security as the prevention of nuclear terrorism. The fact that damage has intentionally been caused to installations of the nuclear industry in the West must of necessity give rise to concern. For example, between 1974 and 1984 thirty-two such cases were recorded in the United States. Between 1966 and 1977, ten attacks were carried out against different nuclear installations in Europe. The insufficiency of measures to prevent the misappropriation of highly enriched fissionable material is also attracting attention. This is not by any means an exhaustive list of the opportunities open to terrorists. In the light of all this, it has become apparent that there is a need to develop a reliable system of measures to prevent nuclear terrorism in all its manifestations.

In order to set up an international regime of safe nuclear power development, use could be made of what is already available for the purpose in the framework of various international organizations, such as the IAEA, the World Health Organization, UNEP, the World Meteorological Organization and also the United Nations. All these aspects need to be placed on a firm foundation of broad international co-operation.

Clearly, the chief link in such a system will be the IAEA. The role and capabilities of the Agency should therefore be expanded. For this, an increase in its financial and material resources will obviously be necessary. The problem could be solved, for example, by the assignment to special purposes of mandatory contributions from interested Agency Member States. Consideration should also be given to the establishment within the IAEA of a special fund for the provision of emergency assistance to countries requiring it in the event of a nuclear accident.

I have already stated on 14 May that, in order for this whole group of questions to be discussed, a high-level special international conference should be held in Vienna under the auspices of the IAEA.

I should now like to inform you of the practical measures which we intend to take to improve the work of the USSR State Committee on the Monitoring of the Safe Operation of Nuclear Power, which was set up a few years ago. We intend to intensify its links with the relevant international organizations and also with the corresponding national bodies with a view to exchanging experience on the monitoring of safe nuclear power development.

I should also like to say that we are carrying out a comprehensive analysis of the state of nuclear power and that additional measures to enhance the safety of nuclear power plant operation are being developed and will be implemented, with account being taken of the conclusions derived from the accident at the Chernobyl' nuclear power plant.

Let me emphasize once again that the lessons to be learned from this accident should serve mankind as a whole. What happened at Chernobyl' has been an ominous reminder of the awesome forces that the energy of the atom can command. If an accident at a peaceful nuclear power plant can turn into a disaster we need only imagine the tragic consequences for the whole of mankind that would attend the use of nuclear weapons - existing, as they do, specifically for purposes of destruction and annihilation.

The space age, the nuclear era, required fresh political reflection and new policies on the part of the leaders of all countries of the world. These very demanding objectives are being met by the programme which we have put forward for the total abolition of nuclear weapons and for the establishment of a comprehensive system of international safety and security.

From the moment at which nuclear weapons first arrived on the scene, the best minds have been pondering how to drive the nuclear demon back. Meanwhile, however, the nuclear arms race has become more intensive. So where is the key, the missing link with which the nuclear problem can be solved? A first practical step towards nuclear disarmament could be the cessation of nuclear tests. We attach particular importance to this measure because, at the same time as being highly effective, it is simple to carry out in practice. All that is required is that nuclear tests should not be conducted - subject to verification, of course. Such a measure must finally become a reality of international life.

Having extended its unilateral moratorium on nuclear explosions, the Soviet Union has refrained from carrying them out for the best part of a year. We believe that this long period of time should be more than enough for the Americans to weigh up all aspects of the matter and to meet us half-way so that nuclear testing can be stopped on a bilateral basis.

In view of the urgency of putting an end to nuclear tests, I have again confirmed my proposal to President Reagan that we should meet without delay and agree to ban nuclear tests.

Both these tasks - ensuring the safety of the peaceful use of atomic energy and freeing our planet of nuclear weapons - require broad international co-operation and the united efforts of all States, in particular the nuclear States, international organizations and elements of society which are interested in establishing a comprehensive and reliable international system of safety and security. This is a task for all States collectively and individually. We call upon you to make your contribution to this important cause on which the future of human civilization depends.

NOTE TO THE FILE

At his request Ambassador Khlestov was received by the Director General on 3 June 1986. The Ambassador, who was accompanied by Messrs Belov and Rogov, transmitted the enclosed personal message from the Secretary-General of the CPSU, Mr. Mikhail Gorbachov. An identical message had been addressed to the Secretary-General of the United Nations, the President of the USA and the Director General of UNEP.

Ambassador Khlestov pointed out that the message not only confirmed the support of the Soviet Union for a number of measures which were endorsed by the extraordinary session of the Board, such as international conventions on an early warning system and on emergency assistance, a post-accident analysis and an expanded nuclear safety programme in the IAEA.

The message also suggests a number of other measures as well as the discussion of other problem areas:

- Minimum safety standards and possible international control thereof;
- International co-operation for the development of new types of inherently safe reactors;
- International unified standards for permitted radiation levels;
- Physical protection of nuclear material and installations against terrorism;
- A special fund for emergency assistance.

Ambassador Khlestov underlined that the IAEA must be the focal point of all these international co-operative efforts. He also repeated the strong support from the USSR for the convening of an international conference on nuclear safety policy. In this context the USSR would prefer a specially convoked conference or an Extraordinary Session of the General Conference. It was felt that an ordinary but extended General Conference would have too little visibility as a response to worldwide public concern.

J. Molander
1986-06-04

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6 June 1986

Mr P Agrell
Department of Energy
Thames House South
Millbank
London

Dear Peter

CHERNOBYL; A FURTHER SET OF QUESTIONS

Thank you for your letter of 3 June containing responses which you had obtained from your own sources to questions which I had given to Tony Daniels prior to his recent visit. I have now discussed this matter with several colleagues using Mr Fisher's note as my source of information and we have come up with the following, rather extensive, list of questions which we would appreciate you putting to whatever source you have available. I realise that many of these questions may be difficult, if not impossible, to answer at this time but the shape of the entire questions would tell any technical respondent some of the basic thinking we have been doing on the nature of the accident. I will try to indicate which questions I suspect may be difficult to answer.

Questions on the Reactor System

1. Were the Nitrogen inerting systems operating at the time of the accident? In particular, we are interested in the Nitrogen blanketing outside the core region, not the Helium\Nitrogen mixture which is used in the graphite volume itself.

2. Would the region between the upper shield and the pile cap normally have been inerted? As a corollary, and following from question one, if it is normally inerted was it indeed inerted at the time of the accident?

3. What is the design coolant pressure when the reactor is at 7% power? This is a straightforward factual question, we have just not been able to extract from our information, this particular piece of data.

SRD United Kingdom
Atomic Energy Authority

4. Was the coolant flow rate the same as during normal full-power operation or reduced for low power operation?

5. Is it possible to know what instruments were available to measure core temperatures and reactivity? We are particularly concerned about the details of the Chernobyl reactor in particular because it is possible that changes were made from the original Leningrad and Solensk designs which could be very important in trying to determine the level of information from readings which may have been available. A corollary of this is whether the instruments were actually available at the time of the accident rather than as a matter of design intent.

Questions on Initiating Events

1. We are told that the reactor went to 50% over power. Was the reactivity transient localised or widespread? For example, does the 50% refer to the overall core power, during which the entire core suffered a reactivity insertion, or does it correspond to a 50% increase in total power localised in a few channels.

2. What was the cause of the transient? This, of course, is the crucial question and may be the one which we will have most difficulty providing the answers to.

3. The unauthorised experiments which have now been reported in the Observer involve control rod movement. This was reported in the newspaper but has not been confirmed in the information which you managed to get for us last time.

4. We are told that the refuelling machine fell into the reactor core. Is there any way of being able to establish whether this was because the supporting structure failed or whether it was displaced by a steam or hydrogen explosion in the internal volume with the refuelling machine itself?

5. My previous question concerning the availability of AC power was not answered. It is important to know if and when AC power was lost.

6. We are told that operations were in action on the pile cap at the time of the accident. Is there any possibility of knowing what these operations were? Were they connected with these unauthorised experiments or something else?

Questions Concerning Immediate Consequences of the Accident

1. Did the pumped emergency core cooling system to pipes below the core operate? This depends on the availability of AC power.

2. Was cooling maintained in any fuel channels after the explosions?

3. What was the condition of the pile cap following these explosions? Had it collapsed onto the core, was the graphite moderator exposed? These may be very difficult questions to answer.

4. Did the initial explosions eject either fuel elements or control rods or any other radioactive material from the core at that time?

5. Did the safety relief valves on the pressure circuit lift, and if so when?

6. Related to the above. Was there, at any stage in the accident, a blow down to the pressure suppression pools?

7. Photographs that we have of the turbine hall roof show that the damage could have been caused by fire or by masonry falling on it from the reactor hall. Is there any possible means of telling which (or even both) of these mechanisms was responsible for the damage?

8. We are told that the walls of the reactor containment are intact, is it possible to know whether the walls of the steam drum cells were breached by the event? This is to try and establish whether hydrogen could have built up, not only in the reactor hall itself, or in the above core structure but in the cells containing the primary circuit pipework and that this was the locality of the hydrogen explosion.

9. Is the design requirement for the electrical circuits to be fire resistant? Do their regulations require segregation of emergency safeguards equipment control systems?

Questions on Subsequent Events

1. Our calculations would indicate that at some point, possibly after a week or more, heat would have to be removed from the core following the initial events, even with the nuclear chain reactor shut down. How was core cooling established following the initial events? Reports of cooling with Nitrogen gas would require the injection of the order of tons per minute in order to provide cooling. This would seem to be a very stringent requirement. If Nitrogen was used, where was the hot Nitrogen being rejected to since the top of the reactor core had been covered by the sand\boron\lead\limestone mixture?

2. We are told that falling core temperatures were measured some 2 weeks into the accident, is there any way of knowing where abouts in the core such temperature variations were measured?

3. Is the cooling system, which we are told is being installed, being put there to arrest melting of the building foundations, ie. to stop the core melting through the concrete basemat, or to relieve the heat burden on the system being used to freeze the groundwater? We really want to know whether they are trying to guard against a future "China Syndrome" or not.

4. Was the water which was drained from the suppression pools active? This is related to the earlier question on whether there was blowdown into the suppression pools. If there was no blowdown and it was active, then it would mean that core debris must have penetrated the reactor cavity concrete floor.

5. Did the operations to smother the pile cap divert gas flows from the core through the suppression pools? By piling on sand and other materials they have clearly blocked off a normal cooling route and if the material had been diverted through the suppression pools then considerable mitigation of the possible fission product release might have been expected later in the accident sequence.

Questions Concerning the Present Condition of the Plant

1. Are current measurements available of:

    a. Core temperatures
    b. Temperature\radiation levels in the suppression pool area beneath the reactor

2. Is there any way of knowing the present location of most of the fuel debris? I suspect that the Russians will not know the answer of this question, either now or even in the next months or even years.

3. Is there any evidence at all which would indicate that the fuel debris is still in a molten state? This evidence would be either measured temperatures or some hint that radioactivity is still being volatalised out of the core.

4. Related to the question above concerning the suppression pool, is there any evidence that the fuel debris has actually penetrated the floor of the reactor vault?

5. Is there any evidence that non-condensible gases such as carbon monoxide or carbon dioxide are seeping from the reactor cavity? These gases are produced by core debris\concrete attack and would indicate that the core debris has reached the concrete floor of the reactor cavity and could be gradually melting its way into it.

6. At this particular location, how far beneath the reactor basemat is the water table?

7. Do we have any indication as to the nature of the ground beneath the reactor, ie. the soil type, thickness, rock type, thickness, etc?

8. Is there any indication that there has been structural collapse in the reactor vessel\core region? Any recent collapse would indicate that core debris has penetrated to, and attacked, supports for the reactor cavity and perhaps even the foundations of the reactor.

I realise that this is an extensive list of questions, some are more detailed than others and some indeed are only put in to make a complete set because the likelihood of getting an answer is low.

Yours sincerely

Michael R Hayns

M R Hayns

cc Dr J H Gittus ✓
   Dr G I W Llewelyn

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5 June 1986

Sir Peter Hirsch
Isaac Wolfson Professor of Metallurgy
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Dear ~~Sir Peter~~ Peter

Please find enclosed the briefing material which I promised you to provide background to your lecture which you will be giving in Liverpool next week. The briefing material consists mainly of relatively brief summaries of what we know or can summise about what caused the accident, how the accident progressed and the nature of the consequences of the dispersed radioactivity. This information has been gleaned from a large number of sources, some of these are more trustworthy than others and it is almost impossible to provide, in a simple way, a method for separating the wheat from the chaff. I must emphasise that we are still in a state of speculation concerning the precise nature of the causes of the accident and some aspects of the mitigating measures taken by the Russians during its course. We are resisting the temptation to make early statements concerning our view of what happened. Having looked at this material in detail the only point of which I have some concern is the statement (which I have left in the briefing material) which says that we believe that some, possibly unauthorised, experiments were going on at the time of the accident. I have left this in but I am unsure at to its status. I am concerned that this information is not generally available and I would please ask you to treat its further dispersion with caution.†

We are currently looking to the promised international conference at which the Russians will give the West all the information that they have on the accident and its sequence, or so they claim, as a milestone which we must pass before we can give any sort of definitive interpretation of the events that led up to the accident. This is a line being taken increasingly by several countries and provides a reasonable response if people press for details which we just do not have available at this time.

† I have now established that this was printed in the Observer!
So much for "sensitive" information!

I hope this material is of use to you and that your lecture goes well.

Yours sincerely

Mike

M R Hayns
Head, Nuclear Safety
Technolgy Branch and
Overseas Relations

cc Dr J H Gittus, SRD✓

1. What is the Collective Dose to the UK from Chernobyl?

As a result of exposure in the first year after the accident, the collective dose to the UK will be a few thousand manSv. As a result of exposure in the 50 years following the accident, the total collective dose will be $\sim 10^4$ manSv. This means that, assuming a linear dose-risk relationship for cancer fatalities with a risk factor of 10^{-2} Sv^{-1}, as a result of Chernobyl, we might expect $\sim$ 100 cancers in the UK over the next 50 years or so. This is not entirely consistent with the figure of a few tens of cancers suggested by John Dunster of the NRPB shortly after the accident occurred. However, the figure of $\sim 10^4$ manSv has been agreed with the NRPB and they are aware of the point.

2. How does the UK Collective Dose from Chernobyl Compare with that from Background?

The average dose rate from background is $\sim 2 \times 10^{-3}$ Sv yr^{-1}, This results in an annual collective dose of $\sim 10^5$ manSv in the UK, which may be compared with the few thousand manSv in the first year from Chernobyl. Equally well, the 50 year collective dose from background is $\sim 5 \times 10^6$ manSv, which may be compared with 10^4 manSv from Chernobyl. Either way, the background dose is significantly greater.

3. How does the UK Collective Dose from Chernobyl Compare with that from Weapons Testing?

Currently, the dose rate from weapons testing is $\sim 10^{-5}$ Sv yr^{-1}. This results in an annual collective dose to the UK of $\sim$500 manSv. If it is assumed that this dose rate applies for 50 yr (it was greater ten years ago and will be less in years to come), the 50 yr collective dose to the UK is $\sim 2.5 \times 10^4$ manSv. On the basis of these figures, it can be seen that the effect of Chernobyl is roughly comparable to that from weapons fallout.

4. How do the Risks from Chernobyl Compare with that from Smoking?

According to Sir Walter Marshall et al (AERE R10532 - "Big Nuclear Accidents"), "if a person is exposed continuously to radiation at a level of d rem yr^{-1} from birth, it is equivalent to a compulsory cigarette smoking pattern which builds up from zero at the age of 10 to approximately 2d per week at age 40". It is not easy to put Chernobyl in this context, since the dose rate from the accident will not remain constant in succeeding years. However, according to the NRPB (Fry et al, letter to Nature, vol 321, May 1986), the estimated dose in the first year following the accident to a one year old child is 50μSv in the south of the UK and 900μSv in the north. If we take the upper figure (900μSv 0.09 rem) and very conservatively assume that the same dose is received in subsequent years, then the parameter d from Marshall et all becomes 0.09, and the number of cigarettes per week at age 40 is $\sim$0.2. Based on this, the risks from Chernobyl are minute in comparison with the risks from smoking. We have to re-emphasise that these figures are very rough indeed; the cigarette smoking analogy is particularly difficult to use in comparison with an accidental (ie. one-off) release.

SH/CHERNB

THE CHERNOBYL ACCIDENT

1 The Reactor

The reactor is sited 70 miles north of Kiev and 400 miles south-west of Moscow.

The reactor is a light water cooled, graphite moderated pressure tube type generating 1000MW(e).

The reactor and primary pipework are contained in a modular concrete containment with design pressure of 4bars. The operating floor and refuelling machine are in a lightweight steel and concrete building.

2 Probable accident sequence

The accident occured at 1.23am on Saturday 26 April when the reactor was in a hot shutdown state at 7% power.

The most likely accident sequence is that there was a reactivity insertion, possibly linked with experiments being performed on the reactor at the time.

Channel voiding, fuel clad melting, hydrogen production and possibly steam explosion followed.

A steam explosion or hydrogen explosion caused damage to the operating floor and reactor hall walls. The collapse of the latter caused collapse of the reactor hall roof, refuelling machine and bridge crane which caused further damage to the operating floor.

Air ingress to the core led to a large scale graphite fire.

3 Radiological effects

Initially, radioactive material was transported at high altitude towards Scandinavia.

Later, material was transported over most of Europe at lower altitudes leading to contamination in rainwater of many thousands of Becquerels per litre of I131 in several countries and the presence of I131 in milk. In general, the levels of I131 in milk in Western Europe did not necessitate protective action.

Activity was first recorded in the UK on May 2, some six days after the accident.

So far, some 25 people have died as a direct result of the accident; most from the effects of radiation. All of these people were either employed at the plant or were involved in emergency work.

Total long term health effects are likely to be of the order of 10,000 cancer deaths in the USSR, 1,000 in Europe as a whole and 100 in the UK (3 per year over a 30 year period). This latter number should be compared with 600 cancer deaths per year from background radiation and 144,000 cancer deaths per year from other causes.

Some 200,000 people have been evacuated from the immediate vicinity of the reactor and from areas of high activity up to 100 miles away.

4 Recovery Measures

5,000 tonnes of sand, boron, lead and limestone have been dropped onto the reactor by helicopter to control the graphite fire and filter the release to the environment.

The suppression pool under the reactor has been emptied of water and filled with concrete to support the weight of material dropped on the core and to inhibit melt-through.

The ground around the plant has been frozen to prevent movement of ground water and embankments have been built along the river Pripyat to prevent contamination of water supplies.

It is planned to encase the reactor completely in concrete.

SF Hall
05/06/86
SRD

SH/CHERN1

1 DESCRIPTION OF CHERNOBYL REACTORS

The Chernobyl site, 70 miles north of Kiev and 400 miles south-west of Moscow, has four 1000MW(e) reactors of the RBMK ("High power, pressure tube reactor") type which came on line between 1978 and 1984. Units 1 and 2 share one reactor building and units 3 and 4 another. The accident involved unit 4 and has had some effect on unit 3 because of shared reactor hall, refuelling machine and some services.

These reactors consist of vertical pressure tubes, containing the fuel elements, inserted into holes in a stack of interconnected graphite bricks which serve as moderator.

The graphite stack is contained in an inerted vessel, filled with a mixture of helium and nitrogen, at atmospheric pressure.

The fuel channels meet the operating floor in refuelling heads and a charge machine runs on an overhead bridge within the reactor hall to give on-load refuelling capability.

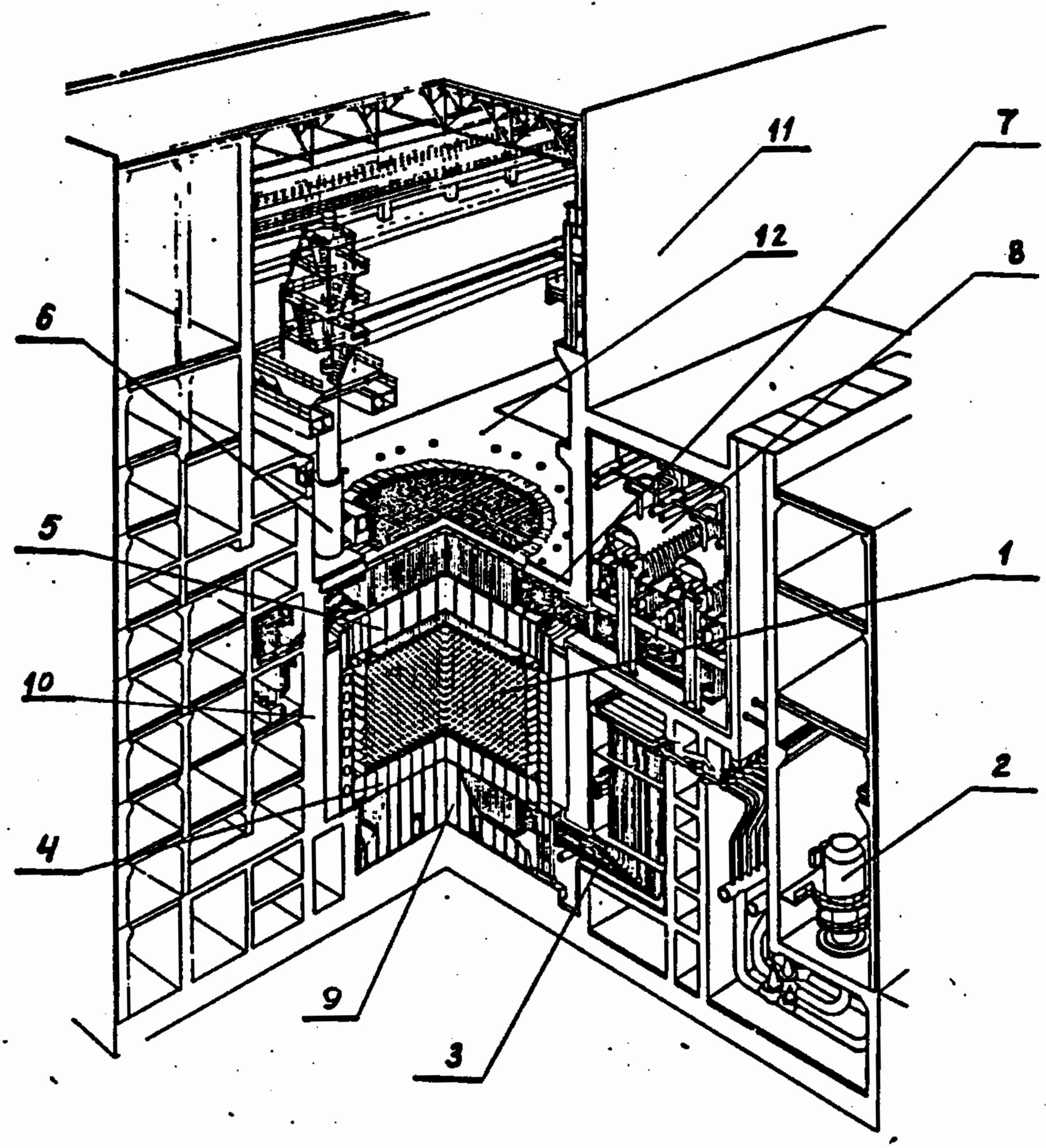
The Chernobyl reactors have a once-through coolant system with two parallel loops comprising 1661 pressure tubes. The core is roughly cylindrical with effective diameter 12.2m and height 7m, and the pressure tubes are on a square lattice of 250mm pitch. The pressure tubes are made of zirconium-niobium alloy with wall thickness 4mm and diameter 88mm. The coolant leaves the core region as saturated steam at 7MPa and passes to separators before going directly to 500MW turbines.

The fuel elements contain 18 pins of UO_2 ,enriched to about 2% and with an average linear rating of 15kW/m and maximum linear rating of 21kW/m, clad in zirconium-niobium alloy cans of outside diameter 13.5mm, 0.9mm wall thickness and filled with an argon-helium mixture. Each fuel element is 3.5m long and there are two in each channel. The fuel has a design burn-up of 22.3 GWd/tonne.

Control of the reactor is achieved by means of 221 control rods with CRDM's beneath the reactor core. The control rod channels have a separate water cooling circuit.

The emergency cooling system comprises an emergency feedwater tank with a pump discahrging directly into the inlet headers beneath the reactor core. This system is designed to deal with a break in a main coolant pipe. In the event of loss of power the reactor is capable of natural circulation.

The reactor and primary pipework are contained in a concrete modular containment with design presure of 4 bars. Under the reactor is a pressure suppression pool conected to the containment by bursting disks. This system, along with the ECCS is designed to cope with a break in one of the 900mm steam headers. The reactor hall is covered by a lightweight concrete and steel building.



Layout of RBMK-1000 Reactor

1 - Core; 2 - Circulation pumps; 3 - Inlet lines to pressure tubes; 4 - Lower core support structure; 5 - Upper biological shield; 6 - Refuelling machine; 7 - Steam/water outlet lines; 8 - Drum separators; 9 - Pressure suppression pool; 10 - Concrete containment; 11 - Reactor hall; 12 - Operating floor.

2. POSSIBLE PROGRESSION OF ACCIDENT SEQUENCE

The "initial" event appears to have been an explosion or explosions that occurred at 1.23 am on Saturday 26 April. This resulted in a fire in the reactor building, which may have spread to the turbine hall roof. The IAEA experts who visited Chernobyl have reported that at the start of the accident, there was an explosion in the reactor vault. Subsequently, the refuelling machine and overhead crane fell onto the reactor causing further damage. The event occurred when the reactor was at low power (7%), said to be normal for a routine short-term shutdown. It had been at full power a few hours prior to this.

More recently, Gorbachev has made a statement on Soviet television that has been interpreted as indicating a power increase initiated the accident. It has also been reported that an unauthorised experiment was in progress at the time of the accident, possibly involving control rods.

Under normal conditions, none of the materials in the core have the potential to cause explosions. For an explosion to occur, either chemical reactions must reduce water to produce hydrogen, which could then explode if mixed with air, or fuel rod materials must melt and then mix with liquid water to provide the initial conditions for a steam explosion or steam spike. Either case would require greatly elevated core temperatures. For such temperatures to be attained, either the coolant supply to a fuel channel would have to be reduced or there would have to be an overpower transient, or some combination of the two.

The graphite moderator of the Chernobyl reactor was inerted by a He/N_2 mixture which was in turn surrounded by a nitrogen blanket prior to the accident, so failures of these blanketing systems would have had to occur to allow air access to the core if a chemical explosion occurred.

A steam explosion could not arise unless liquid coolant re-entered the channel. Thus, there would have to be water remaining in other parts of the primary circuit that could re-enter the channel at some stage, or emergency injection to the channel would have to occur to reflood it. If fuel melting occurred as a result of a reactivity transient, then although water would be forced out of the channels by the increase in heat transfer, the pumps would restore the flow as the transient subsided. The resultant explosion might displace the stand-pipe closure expelling steam, hydrogen and molten material into the reactor hall. The combination of steam pressure, hydrogen and Zr burning would probably collapse the relatively light reactor hall. The accident would then develop as a LOCA with the containment bypassed.

If the initial explosion in the reactor vault were a hydrogen explosion, breach of the pressure circuit would have been a necessity to allow the hydrogen to mix with air.

Following a breach the ECCS would be activated. Part of the core might have been uncoolable because of explosion damage. However, the rest of the core would be cooled, provided the breach did not exceed the ECCS capacity, although the water would gradually be lost through the breach. Normally for breaches inside the containment the ECCS water would run back into the pressure suppression pool from whence it could be recirculated. However, for a breach outside the containment this water would be lost and eventually the ECCS pumps would be starved of supplies and the core would uncover and melt.

Molten fuel debris would fall down the pressure tubes, which pass through the shield beneath the reactor, and would collect on the floor of the reactor vault. The molten debris would attack and melt-through the floor into the pressure suppression pools beneath. Steam explosions could then have occurred if there was water in the pools, but it has been reported that the Russians drained these pools. The debris would eventually melt through the foundations of the building and might form a pool of maximum radius about 19m after about a year before finally resolidifying.

At present, the most likely possible accident sequence appears to be one in which a local reactivity transient leading to a rise to 50% full power over 10 seconds caused dry-out of a few fuel channels and fuel melting. This might have resulted from withdrawal of control rods, failure of a bottom entry control rod, or a dropped fuel stringer and was possibly related to the experiments reported to be in progress. In this type of reactor at low power there is the possibility that neutronic instabilities will occur because of the positive void coefficient. Under these circumstances a reactivity insertion could rapidly become uncontrollable.

As the fuel temperature increased the zirconium cladding of the fuel would react with steam to produce hydrogen. Molten fuel might mix with water remaining in the bottom of the fuel channel or on reflood to cause a steam explosion. Steam explosion(s) could have disrupted the pile cap and ejected fragments of zirconium and hydrogen into the reactor hall and adjoining cells. (There is a suggestion that a steam explosion might have occured in a fuel channel connected to the refuelling machine.) The zirconium and hydrogen would have burned or exploded in the air and caused the structural damage to the building seen in photographs. Subsequent loss of coolant from the pressure circuit caused that fuel not melted in the initial event to heat up and melt in the following days. Air ingress into the now exposed graphite caused a graphite fire. It should be recognised however, that it will probably be a long time before the full facts of the accident are known and until such time, discussions of the accident sequence will be mainly speculation.

3. DISPERSION OF ACTIVITY AND RADIOLOGICAL CONSEQUENCES

The meteorological conditions prevailing at the time of the accident and over the succeeding 24 hours or so were responsible for the transport of released activity in an almost direct trajectory towards Scandinavia. Material initially injected at very high altitudes in the early stages of the accident appears to have led to the first reported measurements of increased activity levels, following rainfall in central Finland on 27 April. It is likely that material transported in this manner at relatively high wind velocities was responsible for the subsequent radiation levels detected in countries bordering the pacific Ocean.

Radioactive material transported at lower altitudes in the atmosphere was probably responsible for the majority of the contamination reported in Europe. Increased radiation levels were reported from Sweden on 28 April, due to activity release at or soon after the accident on the 26th. The release of radioactivity from the damaged core appears to have extended over several days. After some 24 hours, the plume began to follow a more westerly trajectory than that taken initially, passing over the continental mainland, across West Germany and into France. A component of this section of the release reached the United Kingdom on 2 May. The developing meteorology over the western Soviet Union then led to relatively light and variable winds in the vicinity of the accident site. Activity released in the final days of April therefore tended to begin to be transported towards the East before circulating more locally and passing towards the Balkans and south east Europe.

Reflecting this picture of plume dispersion, increased levels of radiation had been detected throughout almost all of Europe by 2 May. Considerable effort has been made by international bodies such as WHO to obtain a consistent survey of contamination. Nevertheless, data collected by national monitoring networks is directed primarily towards radiological protection within individual countries, and an overall view of the consequences is progressing relatively slowly.

Notable variation in levels of contamination arising from the deposition of material from the plume has been reported in all countries, due to the selective removal by 'washout' during periods of rainfall, which extend over only relatively small areas. The efficiency of this removal process led many countries to introduce recommendations for limiting the consumption of fresh rainwater by members of the public. Contamination of rainwater by I131 ran to many thousands of Becquerels per litre in a number of countries. Rainfall in the north west of the United Kingdom was particularly heavy in comparison with the rest of the country in early May, leading to the widely-reported increased levels of contamination in those parts of the country.

Dairy cattle being fed from pasture were able to consume both contaminated rainwater and grass, such that I131 became present in milk supplies. In general throughout Western Europe, however, levels in milk supplied by dairies rarely approached values necessitating protective action.

A number of countries have reported measurements of the relative proportions of different radionuclides within the plume. By comparing these with the relative quantities of activity assumed to be present within the reactor core at the time of the accident, it has been estimated that roughly equal fractions of Iodine and Caesium were released, with smaller amounts of other radionuclides, including Ru103, Ru106, Te132, La140, Ba140 and Np239. A considerable proportion of the released iodine appears to have remained in the vapour phase (or, less likely, in a desorbable form on particulate material), which led to an initial underestimation of the contribution to airborne activity levels.

Numerous teams have attempted to use these environmental concentration data to infer conclusions regarding the magnitude of the release, arriving at as many results from different modelling techniques. The situation is complicated enormously the long time scale over which the release took place and the likely reduction in source strength with time, together with the developing meteorological conditions. However, SRD, NRPB and a team at Imperial College, London appear to be in broad agreement with the tentative initial conclusion that some 5% of the initial inventory of core volatiles (Iodine and Caesium) was transported towards Scandinavia, with approximately 20% released overall.

The overall health impact of the accident for the Soviet Union and the remainder of Europe remains to be assessed fully. Soviet authorities have reported that some 300 people were flown to Moscow for hospital treatment, including bone marrow transplants. Approximately 25 of these have died to date, two of whom were fatally injured at the time of the accident, the remainder apparently due to radiation effects. All those taken to Moscow appear to have been involved in the teams dealing with the accident on site; eg firemen and plant personnel. No early deaths have been reported among members of the public away from the reactor site. Firemen who fought the original fire at the plant are said to have received doses as high as 10 Gy (1000 rad) - early health effects such as nausea might normally be expected above 0.5 Gy, death above 2 Gy. In addition to the reported fatal illnesses and injuries arising from bone marrow dysfunction and acute gastrointestinal syndrome, it may be expected that directly attributable disease and deaths will arise in the coming months from high radiation doses to the lungs, or any combination of these.

Once the scale of the release had become known, rapid evacuation from an area within a 30 km radius of the plant appears to have been achieved. According to SRD's calculations for the assumed release, this seems to be in line with the area which might be subject to ERL - based countermeasures; alternatively the area may reflect existing civil defence plans. Nevertheless, it has recently become apparent that further evacuation has taken place outside this zone to the north of the plant. It is quite possible that rainfall in this region in the first few days following the accident, when the plume was still travelling in a northerly direction, may have brought about local dose levels as high as those within the 30km zone.

In the longer term, it is likely that some cancers appearing in the next few decades among the exposed population will arise as a result of the accident. However, the numbers of fatalities involved are likely to be so small that they will be undetectable against the normal incidence of such effects. Based upon monitoring data, and making interpolations where such information is sparse, it has been estimated that about 100 fatal cancers in the UK in the next 50 years will be due to Chernobyl, with about 1000 in Western Europe. Computer estimates based upon the 20% volatile release discussed above predict about 10,000 fatal cancers in the Soviet Union. The figure of 100 cancer deaths for the UK might be compared instructively with the 600/year from background radiation which would be predicted under the same assumptions regarding the risk from low level irradiation, and approximately 144,000 cancer deaths per year from all other causes.

SH/CHERN4

4 STATE OF PLANT AND RECOVERY MEASURES

Photographs published in the press show severe dammage to the reactor building resuting from the effects of fire and explosion. Concrete rubble from the reactor building end walls and probably from the steam drum cells is strewn on the ground and turbine hall roof. The lightweight reactor hall roof has completely collapsed as has the refuelling machine bridge. Both of these latter two structures are normally supported by the concrete walls of the steam drum cells and it is probable that one of the initial explosions occured inside the containment and resulted in the collapse of these walls. It has been reported that the collapse of the refuelling machine caused extensive damage to the operating floor and this contributed largely to the graphite fire.

Damage to the core is a matter of speculation but it is clear that the has been large scale melting and oxidation of cladding and pressure tube materials and posssibly of the fuel itself. A large amount of the graphite has been burned.

On the second day of the accident helicopters began dropping sand, lead and boron on top of the core in an attempt to control the fire and radiation release. The total amount of material used is reported to be 5000 tonnes.

Fire appliances were used to pump out the suppression pool under the reactor and concrete is being poured in to form a base for the encasement of the reactor. This work was neccessary partly to support the weight of the materials dropped onto the top of the reactor. This base has some form of cooling built into it. The eventual aim of this work is to encase the reactor completely in a cooled concrete vault.

The ground around the reactor has been frozen to prevent ground water movement and embankments have been built along the Pripyat river to prevent the contamination of water supplies.

✓cc MR Hayne (Σ)

File No. ....

Miss M S Caraffi

cc Mr M [illegible] 3 JUN 1986
Dr J H Gittus, SRD - by fax✓

ji

Implications of Chernobyl for the Authority

I have the following comments on the draft letter to Mr Morphet circulated with your minute of 2 June:

Paragraph 3

I understand that this refers to a point made by Mr Blumfield at EDC. He was presumably referring to the report of the CCU(N) Working Party. It is not realistic to expect this (a Cabinet Office paper) to be published. However, a booklet was published at the time and I would replace this paragraph in your draft with the following:

> "The publication of the Handbooks could lead to additional interest in central Government arrangements and responsibilities in regard to civil nuclear emergencies. Following the report of the CCU (N) Working Party, HSE published, in 1982, a booklet "Emergency plans for civil nuclear installations" which was available from HMSO. There may be a requirement for an updated or expanded version of this to be published."

Paragraph 4

Replace "We shall also be sending" with "We have sent".

Delete from after "level 3 exercises" to the end of that sentence and replace by "(ie those testing both local and national procedures) because of the need to allocate such exercises centrally among nuclear operators but we have let the NII know that we would be happy to include Authority establishments in the programme for holding level 3 exercises".

B C Carpenter

AHSS
3 June 1986

A NOTE FROM THE CENTRAL ELECTRICITY GENERATING BOARD

CHERNOBYL NUCLEAR ACCIDENT

1. There is intense public interest and concern about the Chernobyl nuclear accident - its cause, its effects in the Soviet Union, its effects in the United Kingdom, its implications for UK reactors and its implications for the future of nuclear power worldwide. Many of these points of concern cannot be answered at this moment, because we know so little of what has actually happened at Chernobyl. Obviously, the British nuclear industry is following events with great concern and the purpose of this note is simply to record what limited comments it seems possible to make at this point in time.

2. We know that a Chernobyl there were four pressure tube reactors of a Soviet design already operational and two under construction. The first two reactors are reasonably well separated but the third and fourth reactors are housed close together in a single building. The fifth and sixth reactors are not yet operating. The Soviets have told us that it is reactor 4, the most recent, that has had the accident and they have now closed down the other three reactors, that is the first two and reactor 3 which is in the same building as reactor 4. We have no information about the initiating event which caused the trouble in the first place other than the information released by the Soviet Union or the IAEA. We do not know whether fire was the initiating event or the consequence of the initiating event. Discussion about that is not much better than speculation and guesswork. However, we do know something about the reactor design and its safety characteristics, which is relevant and certainly is helpful in understanding the speculations made about the accident sequence. Therefore, what we know about the Soviet reactor design is set out in the next section.

Reactor Design

3. The technical description of the Soviet reactor is a boiling-water, pressure-tube, graphite-moderated reactor. There is nothing like it anywhere in the Western world in civil nuclear power. It has close similarities in principle to the reactors first used in the Soviet Union to produce plutonium for the weapons programme. They also were cooled with water, were pressure-tube reactors and were moderated by graphite. As its name implies, the Soviet reactor has some similarities with the American BWR (use of boiling water in a direct cycle), the CANDU reactor (use of pressure-tubes) and our own gas-cooled reactors (use of graphite as moderator). The reactor it least resembles is the PWR proposed for Sizewell (PWR has indirect cycle, no boiling, a pressure vessel and water as a moderator). Its safety characteristics are unique and it is best to describe it as a hybrid not like any civil reactor operational in the Western world.

4. However, there are some superficial similarities between the Soviet reactor and the British design of a pressure-tube reactor called the Steam Generating Heavy Water-moderated Reactor (they both are direct cycle reactors and have a similar layout of the primary circuit). This is a reactor that was never built on a commercial scale (a small prototype has been constructed and operated by the UKAEA in Winfrith in Dorset). The comparison of the two reactor designs is instructive.

5. The technical description of the SGHW reactor is a boiling-water, pressure-tube, heavy water moderated reactor. The circuit diagram in the Soviet reactor and the SGHW reactor are superficially similar except for the use of a graphite moderator in the Soviet design and heavy water in the British design. In the 1970's the Government of the day made a decision to build the SGHWR subject to detailed design and safety studies. As part of that work the Nuclear Power Company (NPC), now the NNC, consulted a number of countries involved in the development of pressure tube reactor concepts. In particular, a visit was made by the British Nuclear Forum in 1975 to the Soviet Union. Following that visit, the Nuclear Power Company produced a report on the Soviet reactor comparing its features to those of the SGHWR. The report is now somewhat out of date having been published ten years ago in March 1976. Nevertheless, it demonstrates conclusively that the British nuclear reactor designers had important technical reservations about the Soviet design at that time and in view of the public interest in the Chernobyl accident, NNC has decided to make that report public to serve as background information to the on-going debate. That 1976 report highlighted a number of deficiencies of the design as related to UK safety licensing criteria. These include:

i) the lack of a direct in-core spray emergency core cooling system (as used on the SGHWR) and considered necessary to cool the fuel in the case of possible stagnation accidents;

ii) the lack of a full containment for a water cooled reactor (the commercial SGHWR was designed with a full pre-stressed concrete containment);

iii) the mechanical instability of the graphite core particularly the possibility of loads coming onto the pressure tubes due to earthquakes or due to dimensional changes in the graphite due to irradiation effects;

iv) insufficient protection against the failure of a pressure-tube, in particular the structural geometry of the graphite core might not be retained in the event of a pressure-tube rupture due to insufficient venting of the excess steam pressure in the gaps between the bricks;

v) the reactor has a positive void coefficient that is if the water coolant is lost and the fuel channel is filled with steam the neutron population increases. Insufficient shutdown margin was provided for in the Soviet design compared with UK criteria. The possiblility of zonal instabilities and local criticality in the core was noted.

vi) no back-up to the control rods for reactivity shutdown is provided.

vii) the high temperature of the graphite core (700°C) as noted. NPC undertook an analyis of the graphite temperatures throughout the life of the reactor and noted that under some assumptions they could increase to beyond 1000°C at end of life. These temperatures were considered excessively high.

6. The 1976 NPC report relates to the particular reactors installed at Leningrad. There is little doubt that the reactors at Chernobyl do incorporate a number of improvements in design including a pressure suppression containment pool beneath the reactor and an improved emergency core cooling system. However, the other basic features of the design remain the same.

7. Broadly speaking, the designers of that day decided that we could learn little from the Soviet Union about pressure-tube reactors because their safety thinking was so different from our own. Work therefore proceeded using our own ideas on the development of the design of the SGHWR until late 1976. The SGHWR has a number of major advantages over the Soviet graphite reactor. In particular the moderator is heavy water, contained in a separate tank (calandria) and kept cool (70°C) by a separate cooling system. Other features which represent improvements over the Soviet design have been identified above viz. in core spray emergency cooling system, full containment, negative void coefficients.

8. Nevertheless, as the work progressed it became clear that the cost of the reactor was escalating rapidly due to the need to meet the very stringent UK safety licensing criteria. For that reason the Atomic Energy Authority advised the Government of the day that it was not possible simultaneously to satisfy British safety rules and produce economic nuclear power using a pressure-tube reactor in this country. That same report recommended to the Government that there were two reactor concepts which could simultaneously meet British safety rules and be economic. They were the AGR's and PWR's. That remains the position today - subject to the results of the Sizewell Inquiry. This exercise from the past, 1975 and 1976, demonstrates that the Soviet reactor concept did not meet British safety rules and the very much better concept of heavy water moderated pressure tube reactor could meet the UK safety rules but only at the sacrifice of economics.

9. Consequences for our own Reactors

Despite the unique hybrid design of the Soviet reactor we are most anxious to learn what we can from the Chernobyl accident. We are not expecting to learn a great deal about reactor design or construction. We are, however, hoping to learn some useful lessons concerning reactor operation and by comparing and contrasting Soviet practice with our own plans for dealing with nuclear emergencies. However, that obviously depends upon free access to Soviet experience. We must hope that that becomes available in due course.

13 May 1986

Issued by Department of Information and Public Affairs
Central Electricity Generating Board
Sudbury House, 15 Newgate Street, London, EC1A 7AU

The Accident at Chernobyl - The Containment Issue

(Brief issued by Lord Marshall - 12 May 1986)

The nuclear accident at Chernobyl has understandably led the public to ask questions about the safety of our own reactors. One major issue is containment. In the accident at the Three Mile Island nuclear power station, Pennsylvania, USA, there was a partial core meltdown, but there was no significant harm to the public because virtually all the radioactivity was retained inside the containment building when the primary pressure boundary was breached. The Chernobyl reactor accident on the other hand has led to a large release of radioactivity and does not have similar containment. People, therefore, naturally ask what containment do we have on our own Magnox and advanced gas cooled reactors? This note compares the containment features of different types of reactor systems. We hope that this will reassure the public about the safety of our own reactors.

Unfortunately the word "containment" can have either a general or a specific meaning depending on reactor type or national habit - the objective of all safety devices in a reactor is to "contain" the radioactivity. To avoid confusion we shall refer to physical boundaries or buildings as "barriers".

All nuclear fuel is enclosed inside sealed cans, often referred to as the fuel cladding. These cans are the first barrier against the escape of radioactivity and are common to all reactor types.

The fuel together with the other components of the reactor core and the primary coolant, whether it be gas or water, are enclosed within a primary pressure circuit, which provides the second "barrier" to the escape of radioactivity. In a light water reactor like the PWR or BWR, this second barrier is provided by the pressure vessel and the main coolant circuit, made of extremely thick, tough steel. In the early Magnox reactors the pressure vessel is also made of steel. Although not so thick because the gas pressure in a Magnox reactor is only modest compared to a light water reactor we are nevertheless confident that it too will not fail catastrophically. In the later Magnox reactors and in all the Advanced Gas Cooled reactors, a concrete pressure vessel is used. Sometimes in the UK this second barrier is colloquially referred to as "primary containment".

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For all the reactor systems mentioned above, the pressure vessel "contains" the pressure of the system. In practice, this barrier cannot be complete, it cannot be a totally closed cylinder or sphere, otherwise there would be no way to get the coolant, either water or gas, in and out. There must be pipes penetrating this barrier so the heat can be removed, so the control rods can get in and out and so that instruments can be inserted and taken out.

The golden rule of safety in the Western world is that we must be pessimistic and assume Murphy's law applies to all pipes breaching a steel pressure vessel or a concrete vessel. That is, we assume that they can fail completely and we must then prove that no harm comes to the public nevertheless. Sometimes it is also necessary to protect the public by providing a third barrier, the "containment building". This is a large sealed building surrounding the reactor, the primary circuit, and all the pipes and apparatus connected to it. Sometimes, depending on the nature of the technology, it is not necessary to provide that third barrier because of the precautions we take to ensure that significant radioactivity does not escape in the first place from the first or second barriers.

In the Western world, for water reactors like the PWR or the boiling water reactor, where there is a breach in the primary boundary for whatever reason, steam will escape from the primary circuit. That steam will be radioactive because water borne corrosion products are irradiated in the reactor core, and there are sometimes failed fuel elements in the reactor. That steam must be contained so that the radioactivity is not released into the environment. For this reason all water cooled reactors must have a third barrier in the form of a containment building. In the event of such an accident, the steam trapped inside the containment building is automatically sprayed with cold water and thereby condensed back into water.

In our gas cooled reactors the situation is very different. Again, our safety rules insist upon Murphy's law, namely, we assume a breach in the primary circuit and that therefore the CO_2 gas will escape through the hole. However, the gas escaping from the gas cooled reactors is relatively free of radioactivity.

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The reason is that radioactive corrosion products are not readily transported by the gas, and great care is taken to ensure that no fuel with damaged cladding remains in the reactor.

Gas cooled reactors also behave very differently from water reactors in the event of a loss of coolant accident. In gas cooled reactors the gas will simply stream out and the pressure inside the primary circuit will steadily drop, but nothing much else will happen. Gas cannot change suddenly into something else as water can change into steam. Consequently, the environment of the fuel elements changes relatively slowly and there are numerous devices which ensure that we can keep the coolant circulating past the fuel. In those circumstances, we know that leakage of radioactivity from the fuel, if any, into the coolant will only occur to a limited degree and the coolant will remain relatively clean.

Therefore, in these accidents, in contrast to the water reactors, there is no harm in releasing the CO_2 gas directly to the environment and there is no necessity to provide a containment building.

For both water and gas cooled reactors we can imagine even larger accidents. The worst credible accident in the UK system might require an evacuation of the public from within a radius of about 1½ miles.

The discussion given earlier should make clear the essential task of the primary circuit to hold the coolant <u>in</u>. In gas cooled reactors it serves a second equally important role, to keep air <u>out</u> and thus prevent graphite fires.

We can also look at how these general principles apply to pressure tube reactors. The principle of a pressure tube reactor is that the second barrier will not be provided by a steel pressure vessel or a concrete pressure vessel, but by a stout pressure tube. The pressure tube therefore surrounds either a single fuel element or small number of fuel elements and is then connected up to steel pipes and steam drums. The Canadians in their safety assessments assume that a failure in the primary circuit can occur, and they put their entire primary circuit inside a containment building which can withstand the failure so that, in broad principles, their safety arguments are somewhat similar to those for light water reactors, though, of course, they are different in points of detail.

In the RBMK reactors in the Soviet Union they use pressure tubes, water cooling and a graphite moderator, a very different concept from any commercial plant in the West.

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We do not know in detail the safety principles followed in designing that reactor but from fundamental principles this design needs a "barrier" with a unique function. This barrier need not be robust enough to contain the primary pressure (that is done by the pressure tubes) but it needs to have sufficient strength to "contain" the pressure if a tube fails (as the Canadians do) and to surround the graphite to prevent the air getting in. It is this unique "barrier" which appears to have failed at Chernobyl - because it did have a graphite fire and therefore air did get in. In UK reactors this second function (preventing air getting in) is achieved automatically by the robustness of the primary circuit (i.e. second barrier).

We must avoid jumping to hasty conclusions and we must learn what we can from this unfortunate accident, but present evidence suggests that it would be wiser to have a graphite moderator cooled and contained within the primary circuit rather than have a graphite moderator hot, outside the primary circuit and contained only within a weaker containment building.

The provision of a "containment building" or the use of graphite as a moderator - has no intrinsic value or importance at all as an isolated fact. Neither is the choice of water or gas as a coolant itself an important fact. What is essential is that each reactor concept is provided consistently with whatever the technology demands.

12 May 1986

Issued by:

Department of Information and Public Affairs
Central Electricity Generating Board
Sudbury House
15 Newgate Street
London EC1A 7AU

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Note for the Record

Telephone conversation with Bob Cairns of the Australian High Commission, London

Bob Cairns rang enquiring after documents that he had been told we had produced on the damaged state in the Chernobyl reactor. This information had been passed to him from the OECD delegation in Paris and he specifically mentioned the fact that Professor Teague's name was known to them. There was no suggestion that Mr Teague had told them about this document. I indicated that I knew of no such document, certainly that the Authority had produced, and would have been very surprised indeed if such a document existed within the UK nuclear industry. I advised him to telephone Brian Edmondson's office, that is in particular the group of the CEGB running the CEGB newsletter and the information service on Chernobyl. In addition, after checking with the CEA, it proved possible to pass to Cairns the document that CEA have produced in French on their view of the Chernobyl accident. All this happened over two telephone conversations. Eventually Cairns responded that he had had much success with the CEGB and that with the additional information from the French document, he appeared very satisfied indeed that he was able to satisfy the requests from his home office for information.

M R Hayns
SRD

cc Dr G I W Llewelyn
Mr M Preston
Dr J H Gittus

4 June 1986

Pl. keep with
Chernobyl material.

File No. ....

HJT
3408
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TO ALL SENIOR STAFF IN CENTRAL SERVICES

The Working Party set up by Lord Marshall to examine the issues raised by the Chernobyl accident, on which the Authority is represented by Dr. Gittus and Dr. Hicks, has produced the attached papers. The EDC this week agreed that the papers should be circulated to all Senior Staff in the Authority with discretion to pass them on to those of their staff who need to be aware of the information in them. The CEGB are making the documents freely available.

2. The EDC felt that the papers were not in themselves adequate for UKAEA purposes as briefing material for staff who might need to appear at public debates etc. and each site is producing briefing notes regarding the safety characteristics of its own reactor system as fuller defensive briefing. Copies of that briefing will be sent to the Information Services Branch in London Headquarters.

3. Please circulate the attached documents to those of your staff who would find it helpful to see them.

Mark Baker

M. A. W. BAKER

23rd May 1986

Cy: Ross
Kelber
G. Marcus
Cortez
Goller/Conti
B. Morris/Conti
Arlotto/Shao
Ernst/Burdick
File (O&M-OCM)

DRAFT

MAY 20 1986

Cy: Denton
Minogue
Taylor
Heltemes
Shea
G Cunningham

COMMITTEE ON ENERGY AND COMMERCE
SUBCOMMITTEE ON ENERGY CONSERVATION AND POWER

STATEMENT OF THE NUCLEAR REGULATORY COMMISSION
PRESENTED BY NUNZIO J. PALLADINO, CHAIRMAN
U.S. NUCLEAR REGULATORY COMMISSION

MAY 22, 1986

MR. CHAIRMAN, AT YOUR REQUEST, THE COMMISSION APPEARS BEFORE THE SUBCOMMITTEE TODAY TO DISCUSS THE POTENTIAL IMPACT OF THE SOVIET ACCIDENT AT CHERNOBYL ON THE LEVEL OF SAFETY OF THE U.S. COMMERCIAL NUCLEAR POWER INDUSTRY AND THE ADEQUACY OF THE NRC PROGRAMS TO ASSURE PUBLIC HEALTH AND SAFETY. WE HAVE NOT YET BEEN PROVIDED WITH INFORMATION RELATED TO THE CAUSE OF THE ACCIDENT. HOWEVER, MEASUREMENTS OF RADIOACTIVITY OUTSIDE OF THE SOVIET UNION HAVE BEEN USED TO ESTIMATE THE SEVERITY OF THE ACCIDENT. WE HOPE THAT THE SOVIET UNION WILL PROVIDE DETAILS ON THE CAUSE AND CONSEQUENCES OF THE ACCIDENT DURING THE NEXT SEVERAL MONTHS.

AS YOU KNOW, DETAILS REGARDING THE ACCIDENT ARE SKETCHY. HOWEVER, THE AVAILABLE EVIDENCE INDICATES THAT THE ACCIDENT WAS SERIOUS. MY FELLOW COMMISSIONERS AND I WOULD LIKE TO EXPRESS OUR

CONDOLENCES TO THOSE SOVIET CITIZENS, AND OTHERS, WHO HAVE BEEN OR MIGHT BE IMPACTED BECAUSE OF THE ACCIDENT AT CHERNOBYL. IT IS OBVIOUSLY A MATTER OF DEEP CONCERN TO US ALL WHEN TRAGEDIES OCCUR.

THE WHITE HOUSE ESTABLISHED AN INTERAGENCY TASK FORCE TO MONITOR THE HEALTH, SAFETY AND ENVIRONMENTAL CONSEQUENCES OF THE CHERNOBYL ACCIDENT ON THE UNITED STATES. THE TASK FORCE WAS CHAIRED BY LEE THOMAS, ADMINISTRATOR OF THE U.S. ENVIRONMENTAL PROTECTION AGENCY. MEMBERS REPRESENTED VARIOUS FEDERAL AGENCIES, INCLUDING THE NUCLEAR REGULATORY COMMISSION (NRC). THE NRC REPRESENTATIVE WAS MR. HAROLD DENTON, DIRECTOR, OFFICE OF NUCLEAR REACTOR REGULATION. I REGRET THAT MR. DENTON COULD NOT BE WITH US TODAY. HE IS PARTICIPATING IN AN IAEA MEETING IN VIENNA RELATED TO CHERNOBYL.

AN NRC INCIDENT TRACKING TEAM WAS ESTABLISHED ON MAY 1, 1986 TO COLLECT INFORMATION AND REVIEW THE EFFECTS OF THE CHERNOBYL INCIDENT IN SUPPORT OF EPA. THE PURPOSE OF THE EFFORT WAS TO OBTAIN AN UNDERSTANDING OF THE REACTOR ACCIDENT AND THE RADIOLOGICAL SOURCE TERM IN ORDER TO ASSIST EPA IN ASSESSING ITS IMPACT ON THE UNITED STATES.

AS YOU ARE AWARE, MR. CHAIRMAN, WE HAD A SERIOUS ACCIDENT IN THE UNITED STATES AT THE THREE MILE ISLAND UNIT 2 FACILITY. OUR STUDY OF THAT ACCIDENT IDENTIFIED EXTENSIVE CHANGES THAT THE COMMISSION CONCLUDED WERE NECESSARY TO IMPROVE THE SAFETY OF NUCLEAR PLANTS

Cy: Ross
Kelber
G. Marcus
Cortez
Goller/Conti
B. Morris/Conti
Arlotto/Shao
Ernst/Burdick
File (O&M-OCM)

DRAFT

MAY 20 1986

Cy: Denton
Minogue
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Shea
G Cunningham

COMMITTEE ON ENERGY AND COMMERCE
SUBCOMMITTEE ON ENERGY CONSERVATION AND POWER

STATEMENT OF THE NUCLEAR REGULATORY COMMISSION
PRESENTED BY NUNZIO J. PALLADINO, CHAIRMAN
U.S. NUCLEAR REGULATORY COMMISSION

MAY 22, 1986

Mr. Chairman, at your request, the Commission appears before the Subcommittee today to discuss the potential impact of the Soviet accident at Chernobyl on the level of safety of the U.S. commercial nuclear power industry and the adequacy of the NRC programs to assure public health and safety. We have not yet been provided with information related to the cause of the accident. However, measurements of radioactivity outside of the Soviet Union have been used to estimate the severity of the accident. We hope that the Soviet Union will provide details on the cause and consequences of the accident during the next several months.

As you know, details regarding the accident are sketchy. However, the available evidence indicates that the accident was serious. My fellow Commissioners and I would like to express our

IN THE UNITED STATES. BECAUSE OF THE SIGNIFICANT DIFFERENCES BETWEEN THE COMMERCIAL NUCLEAR PLANTS IN OPERATION IN THE UNITED STATES AND THE CHERNOBYL NUCLEAR FACILITY IN THE SOVIET UNION, IT IS DIFFICULT TO IDENTIFY AT THIS TIME ANY LESSONS TO BE LEARNED FROM THIS ACCIDENT THAT MIGHT BE APPLICABLE TO THE PLANTS WE REGULATE.

WE, OF COURSE, WE WILL MAKE EVERY EFFORT TO LEARN WHAT WE CAN FROM THE SOVIETS, BUT UNTIL WE HAVE SUFFICIENT INFORMATION, IT IS PREMATURE TO SPECULATE WHETHER ANY CHANGES IN UNITED STATES' COMMERCIAL PLANTS ARE WARRANTED. I HAVE ASKED THE EXECUTIVE DIRECTOR FOR OPERATIONS (EDO) TO APPOINT A GROUP OF OUR SENIOR SCIENTISTS AND ENGINEERS TO CONTINUE THE STUDY OF THE ACCIDENT AND RECOMMEND TO THE COMMISSION ANY ACTION THAT MIGHT BE NEEDED FOR THE U.S. REGULATORY PROGRAM.

WE WOULD NOW LIKE TO COMMENT ON THE ITEMS YOU SPECIFICALLY REQUESTED THAT OUR TESTIMONY ADDRESS.

I HAVE ALREADY ADDRESSED THE ACTIONS WHICH THE NRC HAS TAKEN TO DATE IN RESPONSE TO THE CHERNOBYL ACCIDENT. AS PREVIOUSLY STATED, THERE ARE SUBSTANTIAL DESIGN DIFFERENCES BETWEEN COMMERCIAL REACTORS IN THE UNITED STATES AND THE CHERNOBYL REACTOR. SOME OF THESE DIFFERENCES INCLUDE A REACTOR ENCLOSURE PHILOSOPHY THAT APPEARS SIGNIFICANTLY DIFFERENT FROM THE CONTAINMENT PHILOSOPHY

EMBODIED IN WESTERN-STYLE PLANT DESIGNS AND A CORE DESIGN THAT CONTAINS APPROXIMATELY 1700 TONS OF GRAPHITE COMPARED WITH NONE IN U.S. COMMERCIAL LIGHT WATER REACTORS. WE HAVE ALSO IDENTIFIED MANY OTHER DESIGN DIFFERENCES THAT THE STAFF IS PREPARED TO DISCUSS. THE SIGNIFICANCE OF THESE FUNDAMENTAL DESIGN DIFFERENCES IS THAT THE NATURE OF ACCIDENT INITIATING EVENTS, AND THE WAY THEY COULD EVOLVE IN A PLANT LIKE CHERNOBYL, AS WELL AS THE NATURE OF THE CONSEQUENCES, ARE VERY DIFFERENT FROM U.S. DESIGNS. FOR EXAMPLE, RELEASE OF RADIOACTIVE MATERIAL TO THE ATMOSPHERE AS A RESULT OF A LARGE GRAPHITE FIRE IS NOT AN ACCIDENT THAT NEEDS TO BE CONSIDERED FOR LIGHT WATER REACTORS.

BECAUSE OF THESE PRONOUNCED DESIGN DIFFERENCES, COMBINED WITH OUR LACK OF ANY DETAILED INFORMATION CONCERNING THE CAUSE OF THE EVENT, IT IS PREMATURE TO DRAW CONCLUSIONS REGARDING ANY REGULATORY CHANGES THAT SHOULD BE TAKEN BY THE COMMISSION AT THIS TIME. WE HAVE NOT LEARNED ANYTHING TO DATE FROM THE CHERNOBYL ACCIDENT THAT WOULD LEAD US TO CONCLUDE THAT U.S. DESIGNED REACTORS ARE UNSAFE.

IN THE AFTERMATH OF TMI, AND AFTER EXTENSIVE EVALUATIONS AND DELIBERATIONS, THE COMMISSION PROMULGATED ITS SEVERE ACCIDENT POLICY IN 1985. ON THE BASIS OF CURRENTLY AVAILABLE INFORMATION, THE COMMISSION CONCLUDED THAT EXISTING PLANTS POSE NO UNDUE RISK TO PUBLIC HEALTH AND SAFETY AND SAW NO BASIS FOR IMMEDIATE ACTION

ON GENERIC RULEMAKING OR OTHER REGULATORY CHANGES BECAUSE OF SEVERE ACCIDENT RISK. HOWEVER, SHOULD SIGNIFICANT NEW SAFETY INFORMATION BECOME AVAILABLE, FROM WHATEVER SOURCE, TO QUESTION THE CONCLUSION OF "NO UNDUE RISK," THEN THE TECHNICAL ISSUES THUS IDENTIFIED WOULD BE RESOLVED BY THE NRC UNDER ITS BACKFIT POLICY AND OTHER EXISTING PROCEDURES, INCLUDING THE POSSIBILITY OF GENERIC RULEMAKING WHERE THIS IS JUSTIFIABLE.

TO IMPLEMENT THIS POLICY, WE WILL BE ASKING THE OWNERS OF OPERATING NUCLEAR PLANTS IN THE U.S. TO PERFORM A SYSTEMATIC EVALUATION OF THEIR PLANT'S DESIGN TO SEARCH FOR WHAT WE CALL "SEVERE ACCIDENT VULNERABILITIES." THE INDUSTRY HAS RESPONDED TO THE SEVERE ACCIDENT POLICY AND HAS SET UP AN INDUSTRY-WIDE GROUP, KNOWN AS IDCOR, TO DEVELOP THE METHODOLOGY TO BE USED IN THIS EVALUATION, AND TO PROVIDE OVERALL INDUSTRY COORDINATION. TO DATE THEY HAVE ANALYZED FOUR REFERENCE PLANTS AND DEVELOPED A METHODOLOGY FOR THE EXAMINATION OF INDIVIDUAL PLANTS. THIS METHODOLOGY IS CURRENTLY UNDER STAFF REVIEW. THE NRC STRONGLY SUPPORTS THE IDCOR EFFORT AND UNDERSCORES THE NEED FOR THIS PROGRAM TO GO FORWARD RAPIDLY.

I WOULD LIKE TO NOTE THAT THERE IS ONE NRC-LICENSED COMMERCIAL NUCLEAR POWER PLANT IN THE U.S., THE FORT ST. VRAIN PLANT IN COLORADO, THAT HAS A GAS-COOLED, GRAPHITE MODERATED REACTOR. IN VIEW OF THE SOVIET REACTOR ACCIDENT AT CHERNOBYL, THE STAFF reexamined the original licensing bases for the Fort St. Vrain facility. Our review revisited both the design features of Fort St. Vrain and the accident analyses done at the time of licensing. We also requested that the licensee examine certain beyond-design basis events, in order to understand the implications of such events.

In licensing Fort ST. Vrain, the staff examined a number of accident scenarios considered credible for this type of reactor, including events involving multiple failures. The staff found then and has reaffirmed that the consequences of these accidents are within the Commission's limits set forth in 10 CFR Part 100. Additionally, the licensee was requested by the staff to examine the consequences of rapid oxidation of the graphite core, although a credible mechanism for such an event could not be identified. The offsite doses resulting from such a postulated event were calculated to be within the 10 CFR Part 100 limits at the Low Population Zone boundary.

Based upon its evaluations, the staff has determined that no additional action needs to be taken to ensure that the health and safety of the public is adequately protected during continued operation of the Fort St. Vrain reactor.

You also asked what the most significant unresolved safety problems at U.S. reactors are. Let me preface my remarks by stating that it is the Commission's firm belief that all operating reactors in the U.S. today are operating at a level of safety that ensures that the health and safety of the public is adequately protected. The issues, or problems, before the Commission today have been codified, as I am sure you are aware, as either Unresolved Safety Issues (USI's) or Generic Safety Issues.

Of the Unresolved Safety Issues pending final resolution, the three most significant and highest priority are: (1) USI A-44, "Station Blackout", (2) USI A-45, "Shutdown Decay Heat Removal Requirements", and (3) USI A-47, "Safety Implications of Control Systems". A proposed rule for Station Blackout has been issued for comment; Shutdown Decay Heat Removal has been addressed technically but final resolution pends Commission action on Station Blackout; and Safety Implications of Control Systems is scheduled for Commission review this fall.

In addition to USI's, there are Generic Safety Issues. These issues are categorized as either HIGH, MEDIUM, or LOW priority, depending upon their safety significance. There are a number of high priority issues for which resolution has not been reached. However, the list of such generic safety issues is a living list with issues being added and closed out on a continuing basis.

BOTH THE UNRESOLVED SAFETY ISSUES, AS WELL AS THE GENERIC SAFETY ISSUES, PRIMARILY ADDRESS TECHNICAL AREAS WHICH THE COMMISSION BELIEVES ARE BEING TREATED ADEQUATELY AND APPROPRIATELY IN THE REGULATORY PROCESS, BUT HAVE A RESIDUAL UNCERTAINTY ASSOCIATED WITH THEM THAT IS LARGER THAN DESIRABLE. THUS, OUR EFFORTS ON THESE ISSUES ARE EITHER TO REDUCE THESE UNCERTAINTIES TO CONFIRM OUR ORIGINAL JUDGMENTS, OR TO CONSIDER THE IMPOSITION OF COMPENSATING FEATURES, FOR EXAMPLE, BACKFITS, TO ACHIEVE THE NECESSARY LEVEL OF CONFIDENCE.

YOU ASKED WHAT ARE THE PROBABILITIES AND CONSEQUENCES OF A SEVERE REACTOR ACCIDENT IN THE U.S. DUE TO THE WIDE VARIABILITY OF NUCLEAR PLANT DESIGNS AND NUCLEAR PLANT SITES IN THE U.S., IT IS NOT POSSIBLE TO PROVIDE YOU WITH A PRECISE ANSWER FOR EACH AND EVERY PLANT.

AS STATED IN THE SUPPLEMENTAL MATERIAL PROVIDED BY THE NRC FOR THE APRIL 17, 1985 HEARING BEFORE THE SUBCOMMITTEE, THERE ARE REASONS TO SUSPECT THAT THE ASSUMED VALUE OF 10^{-4} PER REACTOR YEAR MIGHT BE CONSERVATIVE. INDEED, MORE RECENT ANALYSES APPEAR TO BEAR THIS OUT. RECENTLY, THE OFFICE OF NUCLEAR REGULATORY RESEARCH HAS BEEN REBASELINING THE RISKS FROM FIVE REFERENCE PLANTS USING UP-TO-DATE PLANT INFORMATION AND PRA TECHNIQUES TO ESTIMATE THE MEAN VALUE OF THE FREQUENCY OF SEVERE CORE DAMAGE ACCIDENTS DUE TO INTERNAL accident indicators. These results will be published in September as draft NUREG-1150.

In this process, the staff is looking into the effect of changes in the recent past which have been incorporated in the reference plants; these include not only post-TMI mandated changes but other refinements identified in PRA analysis to improve reliability. Preliminary work so far indicates that improvements have lowered the severe core damage frequency from internal events to levels as low as 1×10^{-5} per reactor year. Even in these plants not all of the potentially practical reliability improvements have been made.

To understand the potential industry-wide significance of this reliability improvement process, which is still going on, one might postulate that these interim values represent industry averages for reactors of these types. In this case the industry average severe core damage frequency would become about 6×10^{-5} per reactor year, and the likelihood of a severe core damage accident occurring in the next 20 years in a population of 100 plants would be 0.12, or one chance in 8. The NRC staff believes that such reductions in severe core damage frequency can indeed be achieved or even improved further, by full implementation of the TMI fixes and aggressive implementation of the Commission's severe accident policy statement.

I SHOULD NOTE THAT SEVERE CORE DAMAGE IS THE STATE THAT IS QUANTIFIED IN PRAs, AND IT IS DEFINED AS THE SITUATION WHERE THERE IS INSUFFICIENT CORE COOLING TO MAINTAIN FUEL INTEGRITY. HOWEVER, SEVERE CORE DAMAGE MIGHT NOT PROCEED TO EXTENSIVE MELTING AND PENETRATION OF THE REACTOR PRESSURE VESSEL, AS EXEMPLIFIED BY THE TMI-2 ACCIDENT. WE CANNOT AT PRESENT QUANTIFY THE DISTINCTION BETWEEN SEVERE CORE DAMAGE AND A "CORE MELT" THAT PENETRATES THE VESSEL.

FINALLY, YOU ASKED TO BE BROUGHT UP TO DATE REGARDING THE RADIOLOGICAL CONSEQUENCES OF THE CHERNOBYL MELTDOWN. AS I AM SURE YOU ARE AWARE, THE SOVIET UNION HAS REPORTED THAT 299 PEOPLE WERE HOSPITALIZED AS A RESULT OF RADIATION RELEASED DURING THE ACCIDENT. THEY HAVE REPORTED 13 PEOPLE HAVE DIED TO DATE. THE MOST SEVERE RADIOLOGICAL CONSEQUENCES OCCURRED IN THE SOVIET UNION. ELEVATED LEVELS OF RADIOACTIVITY WERE REPORTED ESSENTIALLY WORLD-WIDE. LEVELS MEASURED AT SOME LOCATIONS IN THE UNITED STATES WERE ELEVATED, WHICH WITH ONE EXCEPTION THE FDA HAS FOUND TO BE BELOW LEVELS AT WHICH PRECAUTIONARY MEASURES WOULD BE INSTITUTED.

WE HAVEN'T HAD THE TIME TO PROVIDE WRITTEN RESPONSES TO THE MANY QUESTIONS YOU ASKED IN YOUR LETTER OF INVITATION, MR. CHAIRMAN. HOWEVER, WE WILL PROVIDE THOSE RESPONSES AS SOON AS POSSIBLE.

WE HAVE WITH US TODAY STAFF MEMBERS WHO WORKED ON THE CHERNOBYL INCIDENT TRACKING TEAM, AS WELL AS OTHER STAFF MEMBERS. THEY ARE PREPARED TO FURTHER DISCUSS THE ACCIDENT AT THIS TIME AND TO HELP RESPOND TO YOUR QUESTIONS.