The Serviceability of Helicopter Passenger Immersion Suits - A Report following the ditching of G-BISO on 2nd May 1984

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INTRODUCTION

On the 2nd of May 1984 a Boeing Vertol 234 Helicopter (G-BISO) ditched in the North Sea following a control malfunction during transit to the Magnus oil field. The ditching took place under relatively calm conditions and the aircraft remained upright on the surface of the sea during evacuation of the 3 crew and 44 passengers. Difficulties were experienced in boarding the life rafts with the result that all but 11 of the passengers ended up in the sea supported on life preservers. Rescue was rapid and there were no fatalities but passengers reported various degrees of leaking into their immersion suits during the period they were in the sea. In view of this BP Petroleum Development Ltd requested assistance from the Institute of Aviation Medicine in assessing the serviceability of the 44 immersion suits used by the survivors of the ditching and another 48 suits of the same type drawn from the pool of suits held by the company for issue to helicopter passengers.

METHODS

Suits

The suits investigated were all of the same type namely Multifab's helicopter passenger survival suits type 505. The suit is made from Gore-tex fabric and is donned via a front entry waterproof zip closure. The suit includes waterproof socks sealed to the suit and worn beneath normal working footwear. Waterproof gloves are permanently attached to the wrists but, for non emergency use, are kept stowed in an enclosure on the forearm the suit being folded back at the wrists to allow the hand to emerge through an un-zipped aperture at the wrist. In an emergency the glove is unstowed and the hand withdrawn into the suit and placed in the glove prior to closing the waterproof zip at the wrist. The head end of the suit includes a hood permanently attached to the suit save for the front area. The latter is closed in an emergency by closing the front entry zip over a flap closure around the neck and then securing a further external flap across the front of the zip

Normal Inspection/Maintenance Arrangements

In submitting the suits for inspection BP Petroleum Development Limited provided the following account of the normal inspection/maintenance arrangements made under contract with the suit handling contractors:

"The suits are visually inspected each time they return to the Wood Group (suit handling contractors) Distribution Centre. Any suits with noted defects are returned to the Wood Group Service Centre for more detailed inspection. With very few exceptions these are then returned to the manufacturer's (Multifabs) local depot. Here, the suits are leak tested prior to and after repairs before being returned to Wood Group.

On a six monthly basis (approx) each suit is taken out of service and sent to the Wood Group Service Centre where it is given a water test. Any defective suits are sent to the manufacturers for testing and repairs as in preceding paragraph.

Wood Group will make a judgement based on the maintenance history, age and general condition of the suit as to whether it is repairable or should be scrapped."

Tests Performed

1. Visual Inspection. Each suit was submitted to a careful visual inspection and all visible defects were noted on an individual suit diagram as shown at Figure 8. Additional notes were recorded on the proforma shown at Figure 11.

2. Leak Tests. Each suit was submitted to a shortened version of the Institute's Bench Test for watertight integrity (Allan. J.R. "A Simple Test of the Watertight Integrity of Immersion Suits." RAF IAM AEG Report No.478 December 1982).

In this test the suit is turned inside out and the zip closures secured before mounting on a specially designed bench which enables the neck opening to be held at a fixed distance (36 cm) above the surface of the bench. This provides acceptable control over the hydrostatic head induced when the suit is filled with water. Most modern suits have openings through wrist seals and these are normally secured at the same level as the neck opening through similar mounting devices. However the suits in this investigation, having integral gloves sealed to the suits and thus fully enclosing the arm, did not require the used of wrist mountings.

Once filled with water the total leakage from the suit was measured for a period of 10 minutes by collecting all water draining from the bench and by mopping up any small leaks over the suit surface with a pre-weighed sponge and re-weighing the sponge at the end of the test. In addition to the overall 10 minute leak rate obtained in this way, all significant individual leaks were recorded on the same suit diagrams as were used for the visual inspection. In a few cases suits were found to have broken zips. Since this made it impossible to leak test them they were submitted only to the visual inspection.

RESULTS

Leak Tests

The results of the bench leak tests are given in Table 1.

10 min leak g	Number of suits SURVIVORS	POOL	TOTAL
<50	1	0	1
51 - 500	12	6	18
501 - 1000	6	7	13
1001 - 2000	10	14	24
2001 - 3000	4	6	10
3001 - 4000	1	3	4
4001 - 5000	2	2	4
> 5000	4	4	8
UNTESTED	4	6	10
TOTAL	44	48	92

TABLE 1. Results of 10 min bench leak test.

Since there is no formal specification of the required performance of these suits it is impossible to state whether the suits did or did not meet a required standard of waterproofness. It is possible only to compare the results achieved in this batch of suits with limits for the bench test set by other authorities and by reference to known capabilities of the best available suits. In this respect the Institute of Aviation Medicine has set a limit of 100 grams as the maximum acceptable leak for a 20 minute bench test which would be equivalent to a 50 gram leak in the present shortened 10 minute test. Though this may appear a low figure it is known to be easily achievable by current manufacturer's techniques. On this basis only one of the 92 suits tested reached the standard. Indeed, only a further 18 suits fell within a limit of 500 grams or 10 times the current RAF limit. At the other end of the scale a total of 26 suits leaked more than 3 litres in 10 minutes. It must be concluded that the majority of the suits would have been of very little value had a longer period of survival, in colder water, been required. As an approximate guide a leak of 1.5 litres results in a loss of 50% of the insulation value of underlying clothing.

This Institute has bench tested several examples of this particular design of survival suit from the same manufacturers and, when new, these have always fallen within the RAF limit for the bench test. It may therefore be further concluded that the failures in the test suits are almost certainly due to inadequate maintenance and/or repair. In respect of overall leak rate there where no significant differences between the survivor's suits and the pool suits.

Visual Inspection

Individual records of the results of visual inspection of each suit have been supplied separately to BP Petroleum Development Ltd. The number of suits in which there were visible defects (that is holes, serious abrasions, burns or defective zips,) was 28 out of 44 suits from the survivors batch and 44 of the 48 suits from the pool batch. Figure 9 shows, for each batch of suits, a breakdown of these visible defects by regions - arm zips, main zips, socks, general suit fabric, gloves, and "all causes". The results of this breakdown indicate no substantial differences in the state of repair of the suits in each of the two batches although the survivors suits were generally in a less poor state of repair than the pool suits. 10 suits had broken main or arm zips, 18 suits had holes or serious wear in the socks, 56 had holes or serious wear in the general suit fabric and 17 had holes or serious wear in the gloves. In the case of socks and gloves these figures include the respective attachment tapes joining the sock or glove to the suit and in the case of the general fabric of the suit this includes defective repair patches such as bond failure.

Typical examples of visible defects are shown in Figures 1 to 7.

Source of leaks

Sites of leakage were noted during the course of each bench test and, as with visible defects, the individual suit records have been passed to BP Petroleum Development Limited. The results of this section of the investigation are summarised in Figure 10, parts 1, 2 and 3.

Leaking valves, which included leaks through the attachment of the valve to the suit were found in 46 suits in the case of arm valves and 72 suits in the case of leg valves. Porous suit fabric, which included pin holes and abrasions led to leaks in 48 suits. Leaks through suit seams were found in 53 suits, leaks through repair patches were found in 27 suits, leaks through seams in the neck area were found in 56 suits, leaks through arm zips were found in 80 suits and leaks through main zips were found in 50 suits. Leaks through the gloves were found in 23 suits and through the attachment of the gloves to the suit at the wrists in 46 suits, leaks in the socks were found in 60 suits and through the sock attachment to the suit at the ankle in 66 suits. Finally 3 suits were leaking through burns.

DISCUSSION

Suit Design

In common with many other designs of immersion suit in current use in the North Sea, the design of the neck closure of the test suits is known to give rather poor water-excluding properties when tested under realistic conditions. The defect of this particular design was notified to BP Petroleum Development Ltd following tests conducted by RAF IAM in November 1982 when a leak rate of 1793 g was found duirng an RAF "23 minute" test (see report at annex A).

From a design point of view it is also clear that the type of valve used on this suit is insufficiently reliable (46 suits had leaking valves) a point that was also made in the report at annex A.

Waterproof zips are never trouble free and require careful maintenance and inspection. The wrist zips on this particular design are not operated routinely by the passengers and were found to be broken in no fewer than 8 suits (4 in each batch). It was also found that the system of glove stowage had exposed the inner layer of the Goretex fabric to particular wear and tear at the wrist openings resulting in serious failure of the fabric (See Figure 1). For these reasons, and because a suit with three zips to close in an emergency is probably incapable of being secured sufficiently quickly, we believe this design feature to be unacceptable.

Although a particular feature of wear and tear at the wrist openings, we found many other examples of wear and tear failure of the inner layer of the suit. We believe the inner layer of the particular variety of Gore-tex used in these suits to be insufficiently robust. Clearly fabric specifications for Gore-tex immersion suits should include clauses specifying the abrasion resistance of both inner and outer layers.

Maintenance inspection and repair

Notwithstanding the design weaknesses noted above, the major source of failures in the test suits is attributable to maintenance inspection, repair and test procedures. The Institute was provided with copies of the suit inspection records obtained from the suit handling contractors and the manufacturer's suit repair records obtained from Messrs Multifabs Ltd. These documents contain simple records of the dates of visual inspection and the dates of return for manufacturer's repair and subsequent return to service. There are brief details of the nature of faults found and repairs undertaken.

The lack of sufficient detail in these records and our lack of detailed knowledge of the precise inspection and testing procedures used by the suit handlers and manufacturers makes it impossible to reach precise conclusions as to the adequacy of the various features of the inspection and maintenance procedures. Nevertheless the overall conclusion that they are collectively inadequate is inescapable.

Perhaps the most significant finding in relation to maintenance was the presence of visible defects in 28 of the 44 'survivor's' suits and 44 of the 48 'pool' suits. In the case of the survivor's suits it is possible, though highly improbable, that the defects all developed between the time of the last visual inspection and the accident. In the case of the 'pool' suits, however, we believe these were drawn from suits already inspected after return to the pool but not yet re-issued. If that is the case then the visible defects found at our inspection must have been present at the time of the last visual inspection which failed to detect them. Our conclusion, though it cannot be proven, is that the same is almost certainly true of the defects found in the survivor's suits.

Failure to detect visible defects during a visual inspection has a number of possible explanations. Either the inspector is insufficiently trained to recognise a defect when he is looking at one or he is being given insufficient time or facilities to make a proper inspection, or he is negligent or careless in his duties. We can reach no conclusion on these possibilities except that there appears to have been a very serious failure.

We now come to the incidence of leaks from defects which could not have been reliably detected by even a meticulous visual inspection. These were present in each of the suits that also had visible defects but since we do not have a technique for separately measuring the leak from each defect we cannot determine how many of these would have led to unacceptable overall leak rates. Of the 16 suits with no visible defects in the survivor's batch, one passed the bench test with a leak rate of 9 grams and 15 failed with leak rates from 141 g to 499 g in 10 minutes. Of the 4 suits in the pool batch with no visible defects, leak rates varied from 219 g to 1523 g. Subjectively we believe that even without the visible defects a large number of suits would have leaked unacceptably. Overall our conclusion from this part of the study is that visual inspections alone are not sufficient to ensure adequate serviceability of immersion suits and that some form of leak testing is required on each suit either before each issue or, at least, upon a regular and frequent basis.

<u>User Care</u>

There were a few signs of careless use by the wearers e.g. cigarette burns, but it was difficult to be sure of the cause of many of the defects.

CONCLUSIONS AND RECOMMENDATIONS

1. Of 44 suits used by survivors from the ditching of G-BISO only one was found to be serviceable when tested at the RAF Institute of Aviation Medicine some 3 weeks after the accident.

2. Of 48 suits drawn from the BP pool of suits none was found to be serviceable.

3. Of the 92 suits in both batches, 72 had visible defects in the form of holes or obvious serious wear and tear. The most likely explanation is that the visual inspections carried out on the last occasion before the suits were withdrawn were ineffective for reasons which cannot be identified with certainty.

4. The very high incidence of leaking from defects which could not be reliably detected by visual inspections suggest the necessity for an adequate regime of leak testing as well as visual inspections.

5. There were a few signs of careless and/or rough handling by the wearers and greater respect for the suits would probably improve the serviceability record and reduce repair costs.

6. There are some design weaknesses in the particular suits that were the subject of this investigation and the water-excluding performance of the suit is considered inadequate for a helicopter passenger immersion suit.

7. It is strongly recommended that both the type of suit in use and the servicing procedures be reviewed in the light of this report.

SUIT : MULTIFABS SURVIVAL (BP 505/L230)

TESTS : Water-exclusion tests only.

IDENTIFICATION : BP 505/L230

BRIEF DESCRIPTION : Single-layer Nomex Gortex suit with front entry 'through neck' zip. Neck closed by main zip over padded collar. Gortex hood attached at sides and rear of neck with large velcro-closed flaps over mouth/neck. Wrists sealed by placing hands in water-proof glove on sleeves and closing water-proof zip. Gloves normally stowed in arm mounted stowages when hands protrude through W/P zip. Fabricated socks permanently attached to legs. Suit has air valves on both legs and shoulders.

STANDARD RAF 23 MIN TEST 1st TEST 7472 g. Left leg valve did not close.
2nd TEST (After correcting leg valve) 1793 g
- mainly through neck 'seal'

RAF IAM BENCH TEST Another severe valve leak this time on (R) leg. Stopped after "reseating" valve. Slight seeps along main zip stitching.

COMMENTS A well made suit but the air valves seem susceptible to failure with disastrous consequences. The neck closure has the advantage of comfort but is insufficiently water-proof in our view. The glove system is ingenious but we feel the possibility of wear and tear damage to the zip must be considered.

5 Oct. 1982

List of Figures

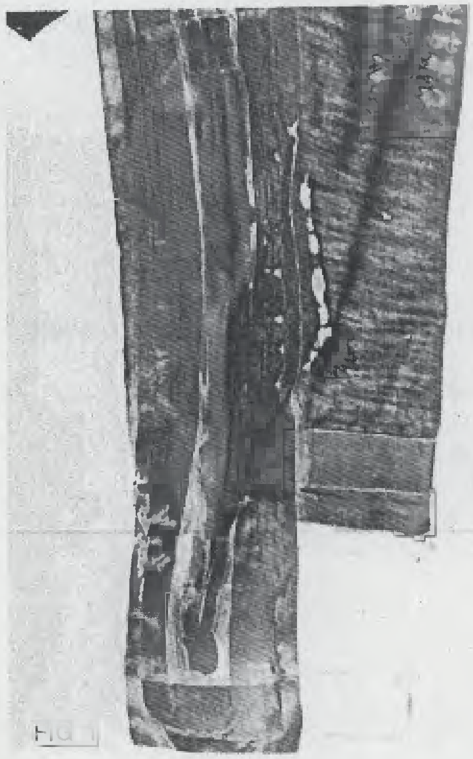


FIG 1

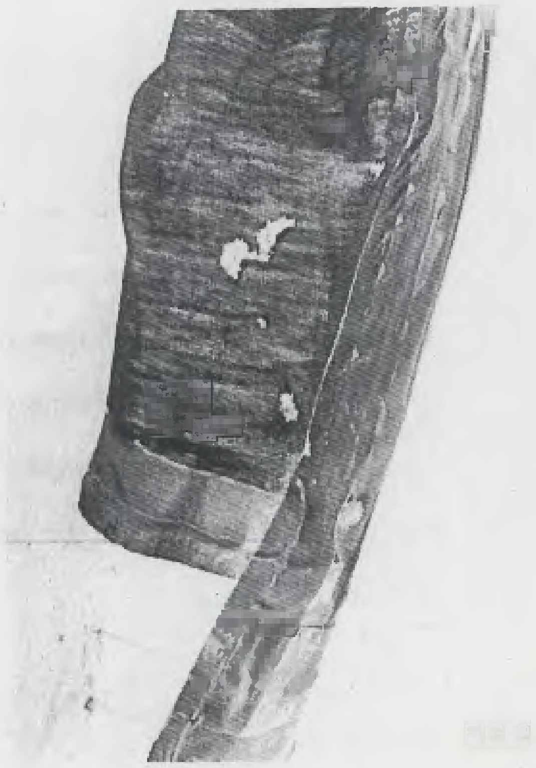


FIG 2

FIG 3

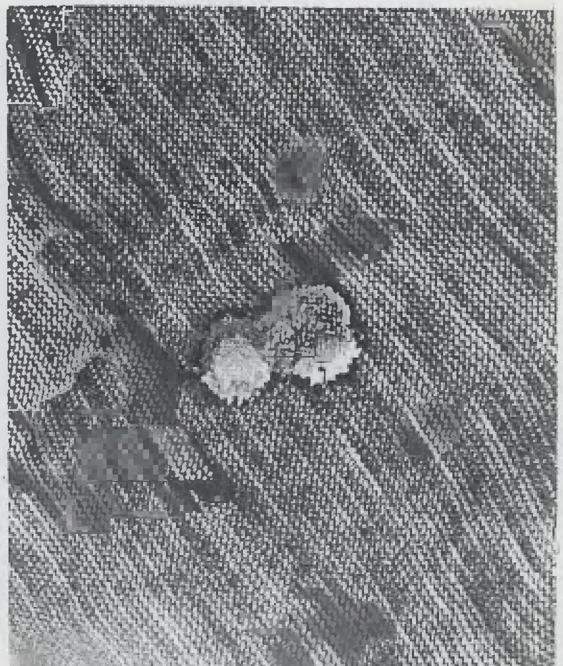


FIG 4

FIG 5

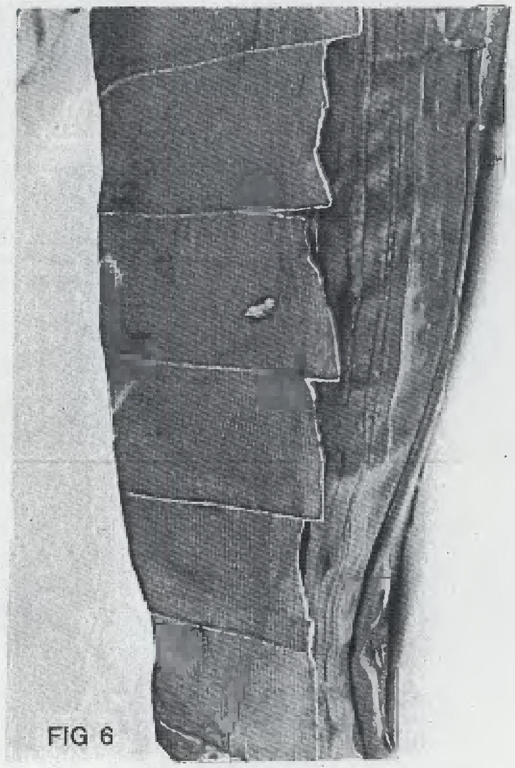


FIG 6

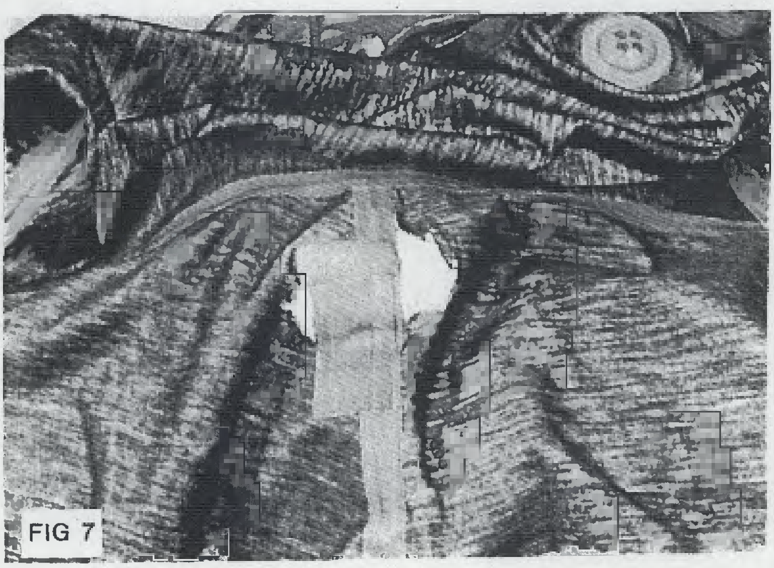
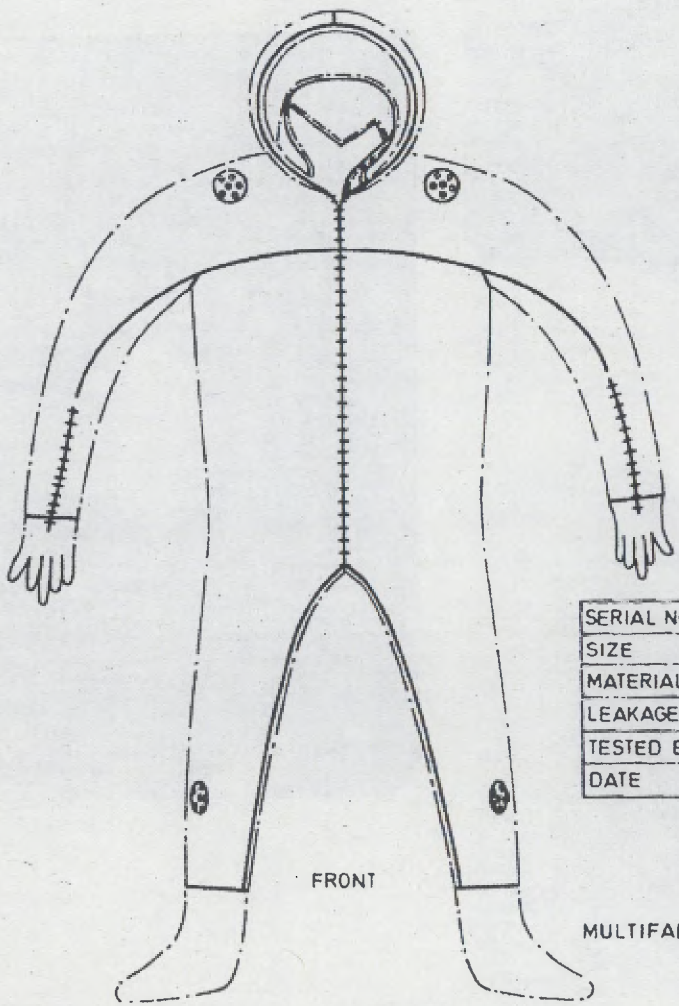
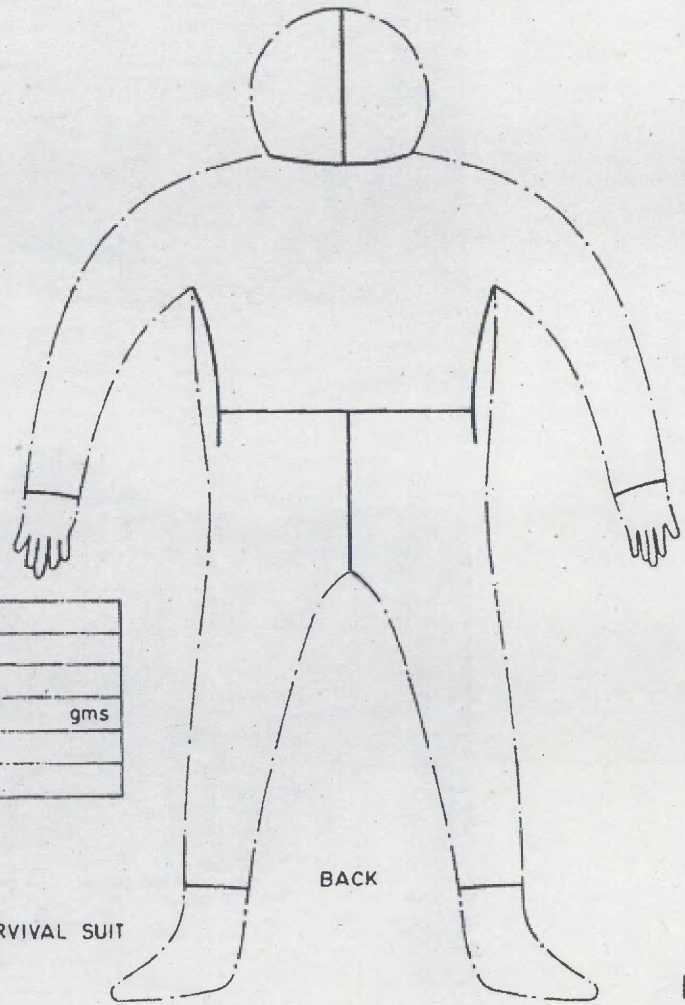


FIG 7



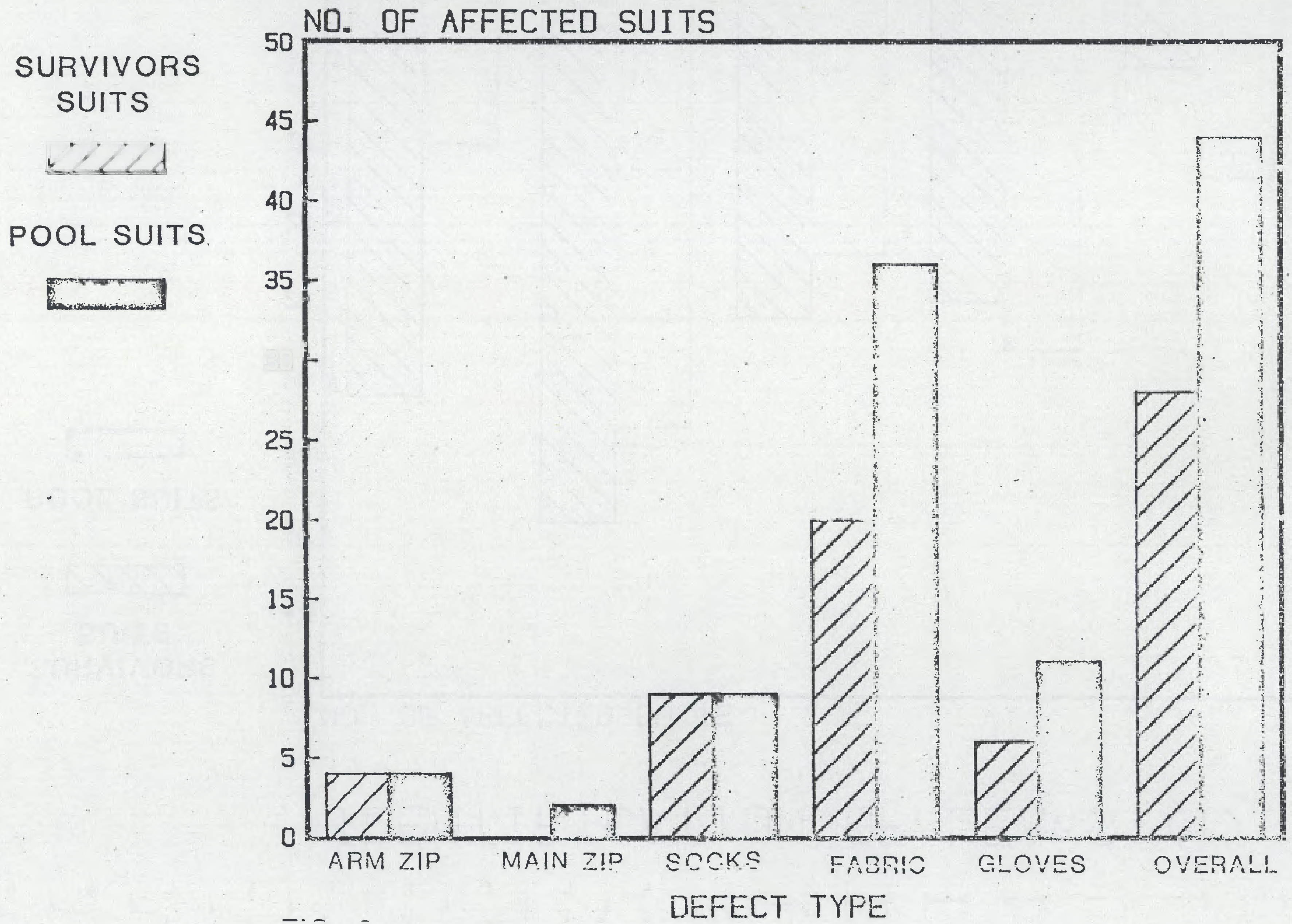
SERIAL No	
SIZE	
MATERIAL	
LEAKAGE	gms
TESTED BY	
DATE	



MULTIFABS SURVIVAL SUIT
(BP)

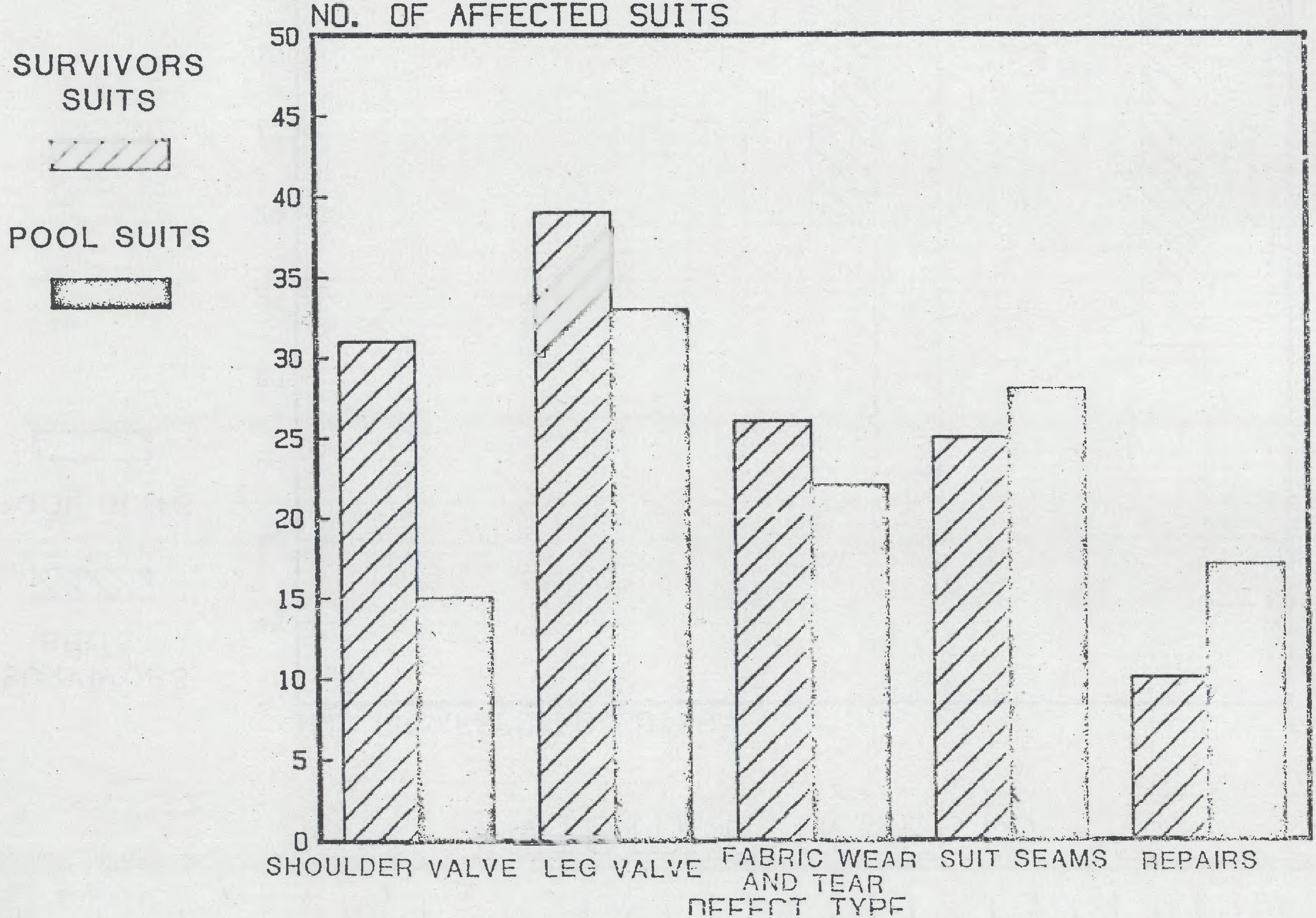
FIG 8

VISIBLE DEFECTS



Commercial in Confidence

IDENTIFICATION OF LEAKS (1)



Commercial in Confidence

IDENTIFICATION OF LEAKS (2)

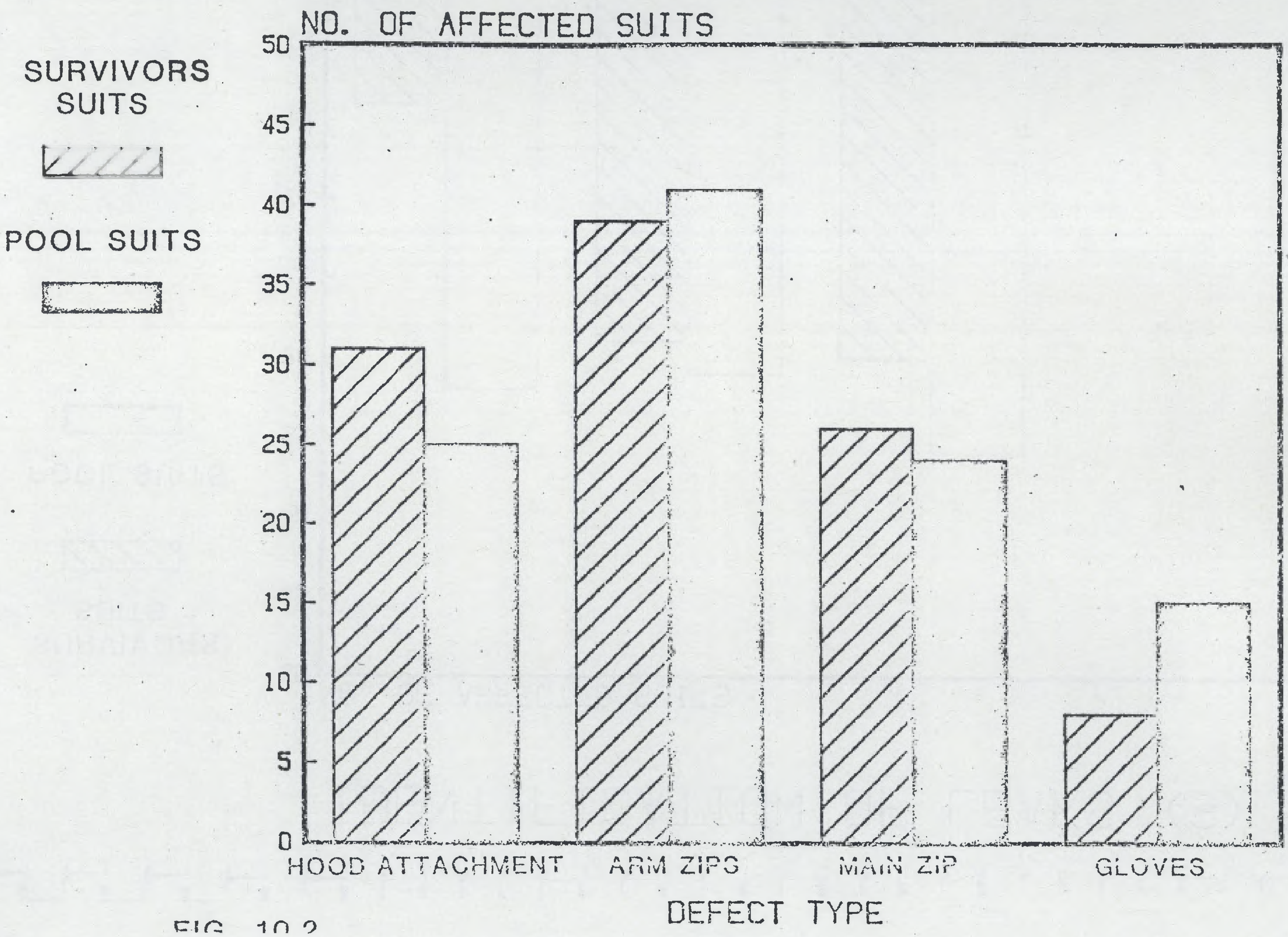


FIG. 10.2

IDENTIFICATION OF LEAKS (3)

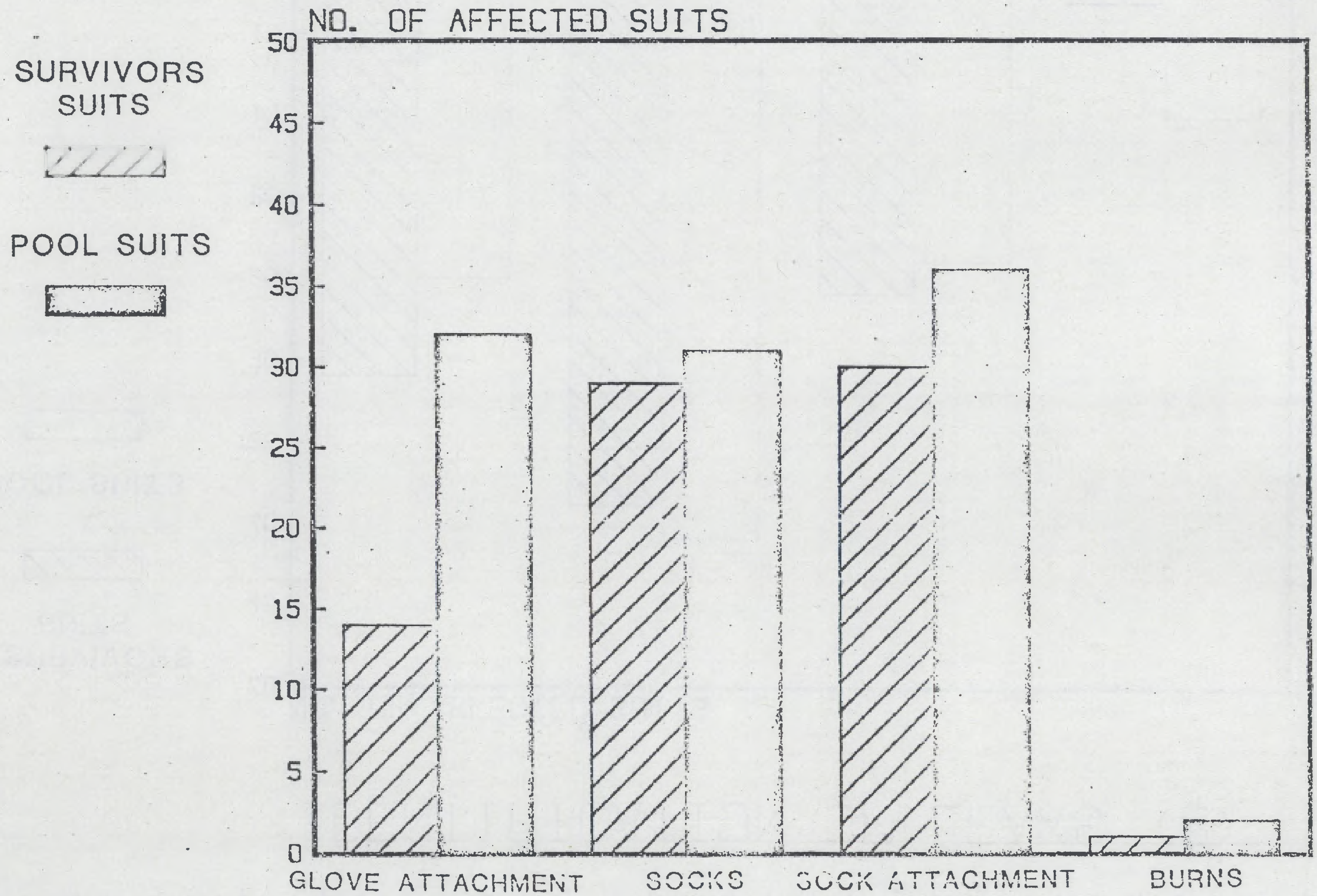


FIG. 11 DEFECT PROFORMA

IDENTIFICATION No. .... SIZE ....

1. EXTERNAL SUIT

GENERAL CONDITION ....

VISIBLE TEARS ....

2. ZIPS

OPERATION ....

ZIP LOOPS INTACT ....

RUBBER SEAL CONDITION ....

3. GLOVES

VISIBLE TEARS ....

WRIST SEAL CONDITION ....

4. SOCKS

VISIBLE TEARS ....

ANKLE SEAL CONDITION ....

5. VALVES

INTACT ....

6. INTERNAL SUIT

NECK FLAP INTACT ....

TAPE SEAL CONDITION ....