Report of an investigation of lifting arrangement failure

ENAK / LOVELETTER

in Sunderland Docks
on 9 May 1997
with loss of one life

Extract from

The Merchant Shipping

(Accident Reporting and Investigation)

Regulations 1994

The fundamental purpose of investigating an accident under these Regulations is to determine its circumstances and the causes with the aim of improving the safety of life at sea and the avoidance of accidents in the future. It is not the purpose to apportion liability, nor, except so far as is necessary to achieve the fundamental purpose, to apportion blame.

GLOSSARY OF ABBREVIATIONS

BST	-	British Summer Time
HSC	-	Health and Safety Commission
IMO	-	International Maritime Organisation
kN	-	Kilonewton
m	-	metre
mm	-	millimetre
MV	-	Motor Vessel
RNLI	-	Royal National Lifeboat Institution
RSJ	-	Rolled Steel Joist (section)
SAR	-	Search and Rescue
SWL	-	Safe Working Load
t	-	tonne
UTC	-	Universal Co-ordinated Time
VHF	-	Very High Frequency (radio)

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Synopsis

The accident occurred at 0930, 9 May 1997, and was notified to the Marine Accident Investigation Branch (MAIB) by the General Manager of The Port of Sunderland at 1200. An investigation began at 1230 that day. MAIB Inspector, Mr J Lee, carried out the investigation.

Two large gantry cranes, each weighing 460t, had been loaded as cargo onto the deck of mv LOVE LETTER by the floating crane ENAK in Sunderland Docks during 8 May 1997. These operations were completed without incident.

A 40.5t lifting frame was in place on each gantry, and these were required to be removed before the departure of mv LOVE LETTER. On 9 May removal of the lifting frame from one of the gantries on the deck of LOVE LETTER started, using both the ENAK and a quayside crane.

During this operation, a pair of brackets, to which lifting shackles and slings had been attached, tore free from the frame allowing it to fall, first to the deck of LOVE LETTER and then partly into the water in the dock. Several of ENAK's crewmen were on the frame at this time. One lost his life and another was injured.

The fundamental cause of the accident was the failure of the brackets on the aft gantry's lifting frame because, although not designed or designated as lifting points, they were used for lifting purposes.

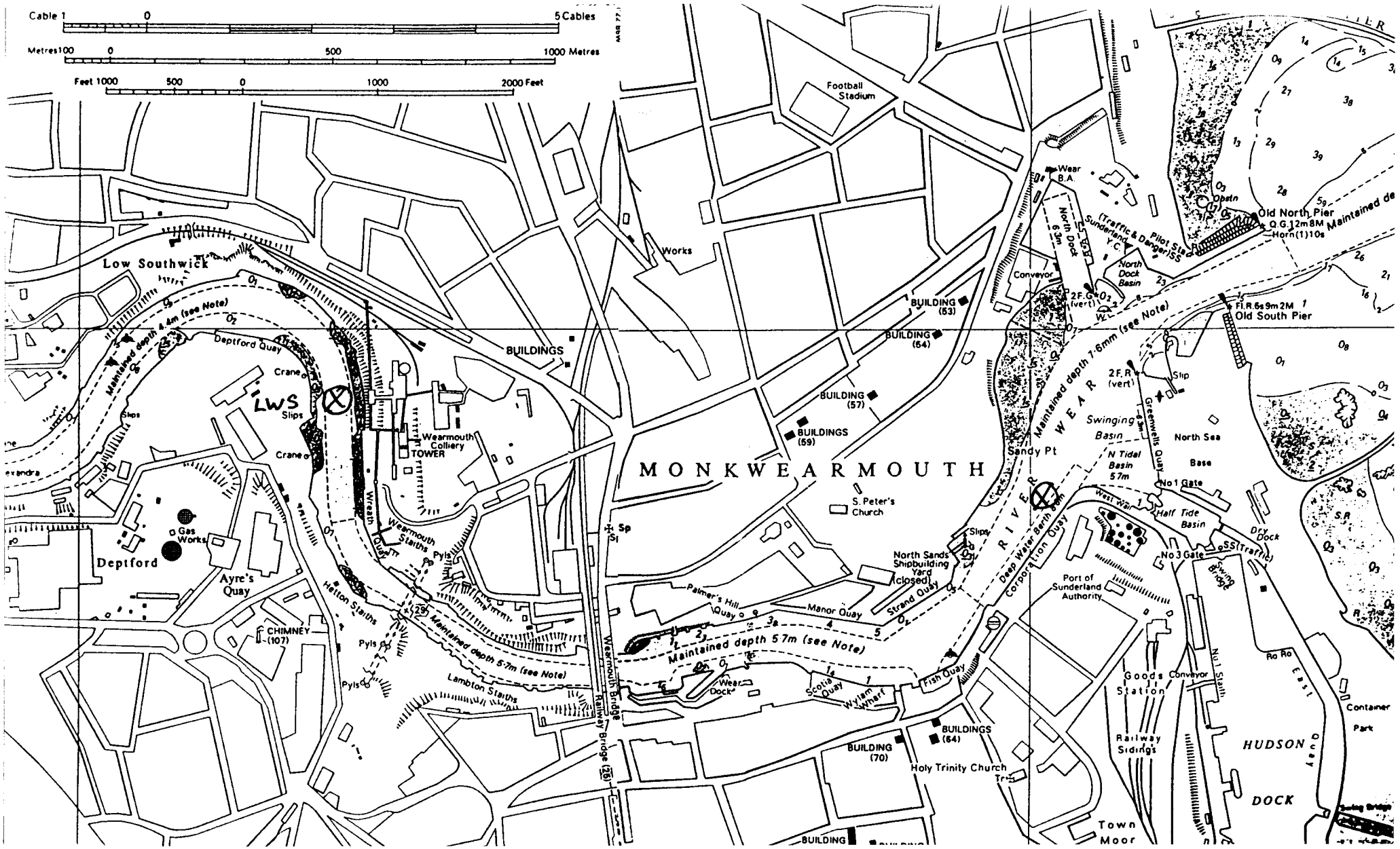
Photograph courtesy of The Sunderland Echo

Heavy Lift Barge 'ENAK' and General Cargo Vessel 'LOVE LETTER'

Particulars of Vessels:

Name	:	LOVE LETTER
Port of Registry	:	Hamburg
IMO Number	:	8609620
Type	:	General Cargo
Gross Tonnage	:	6500
Length Overall	:	114.93 metres
Breadth Overall	:	20.44 metres
Date Built	:	1986
Classification Society	:	Germanischer Lloyd

Name	:	ENAK
Port of Registry	:	Hamburg
IMO Number	:	6826858
Type	:	Salvage, Heavy Lift Barge
Gross Tonnage	:	1701
Length	:	55.17 metres
Breadth	:	25.05 metres
Date Built	:	1967
Classification Society	:	Germanischer Lloyd



THE RIVER WEAR FROM LIEBHERR WORKS, SUNDERLAND, TO CORPORATION QUAY, SUNDERLAND PORT

Figure 1

Section 1 - FACTUAL INFORMATION

1.1 Introduction

Note: throughout this report, all references to port, starboard, forward and aft are made with respect to LOVE LETTER, unless specifically stated otherwise.

Delivery of a series of large gantry cranes to China from the Liebherr Works, Sunderland started during 1995. The gantries were transported in pairs as deck cargo on a sea going vessel. Each gantry weighed 460t with approximate overall dimensions of 19m wide x 31m long x 16m high.

The first stage of the operation was the transport of each pair of gantries along the River Wear to Sunderland Docks from the riverside factory of Liebherr Works, Sunderland. This was performed with each gantry secured to a floating pontoon after being loaded onto the same using the floating crane ENAK. These pontoons were then towed down river using tugs (Figures 1 & 2).

Figure 2

At Sunderland Docks, the gantries were lifted from their pontoons and transferred to the deck of a ship for the sea passage. For lifting purposes each gantry had been fitted with a lifting frame, each having four lifting brackets rated at 125t. The ship was port side alongside the quay, with ENAK working from its starboard side. Owing to the size of the gantries, there was space for only two of them on the deck of the ship; one forward and one aft.

The ship in use at the time of the incident was the mv LOVE LETTER. A sister ship, the mv NIPPON, had been used on four previous occasions. This was the first occasion that LOVE LETTER had loaded gantries of this type. All gantry lifting operations performed as part of this transfer were undertaken by the floating crane, ENAK.

In order to be able to use the gantries' lifting frames for subsequent operations, these frames were to be removed and returned to the Liebherr Works, Sunderland. Once this operation was complete, and the gantries secured to the deck , LOVE LETTER was to commence its passage to China.

1.2 Sequence of Events All times quoted are BST (UTC + 1 hour)

At 1830 on 5 May 1997 MV LOVE LETTER arrived at Sunderland. On 6 May at 1448 the vessel moved to a berth at Corporation Quay, Sunderland Docks, port side alongside.

During 8 May two gantries, from Liebherr Works, Sunderland, were loaded as deck cargo on LOVE LETTER. As a consequence of the asymmetric loading of the gantries LOVE LETTER needed to make adjustments to its distribution of ballast, in order to remain upright, as the weight of each gantry was gradually transferred from the ENAK.

These loading operations were completed at 1700. The lifting frame on each gantry was temporarily left in place, supported from its gantry by pin jointed straps at each corner.

On 9 May 1997 the operation to remove the lifting frame from the aft gantry commenced with ENAK moving from her berth in Sunderland Docks at 0900 and arriving alongside LOVE LETTER at 0915, with her bows on to the starboard side of the ship (Figure 3).

Six crewmen from ENAK boarded LOVE LETTER to rig lifting gear for the frame removal operations.

The driver of the quayside crane was signalled, by a crewman from ENAK, to lift a pair of slings from the deck of LOVE LETTER and position their free ends so that they could be shackled to brackets on the port side of the aft gantry's lifting frame.

Figure 3

Showing Operation of 10 May, that on 9 May was similar

The free lower end of each sling was then shackled to a bracket on the lifting frame. These brackets were not the designated 125t lifting brackets. The crane driver was signalled to hoist sufficiently to remove the slack from the slings.

Compliance with this request proved impossible as a safety cut out on the crane operated, preventing further hoisting. An electrician was called to make an adjustment to the crane's limit stops while the crane driver awaited his arrival.

Two crewmen from ENAK, who were attending the port side of the frame, sat on one of the LOVE LETTER's deck cranes awaiting instructions.

The Master of LOVE LETTER was observing the operation and monitoring the mooring lines of his vessel from the quayside. No adjustment to the vessel's ballast was performed during the frame removal operation.

Two further slings were connected between the port 300t hook of ENAK and two brackets on the starboard side of the lifting frame. These, too, were not the designated 125t lifting brackets. Two crewmen from ENAK were on the starboard side of the frame. Two others, in VHF contact with ENAK, were on the gantry above.

Figure 4

Photograph courtesy of The Sunderland Echo

The Chief Engineer was at the winch controls inside the wheelhouse of ENAK. From his position at the front of the wheelhouse he was able to see the starboard side of the frame and gantry. He was in VHF contact with the crewmen on LOVE LETTER. VHF reception was good.

Instructions were passed to ENAK, by VHF, to take the weight of the starboard side of the frame so that the pins of the support straps could be removed. The pins on the aft straps were removed first.

The two crewmen on the frame then moved forward and removed the pins from the forward support straps. ENAK was then asked to lower that side of the frame by about 30mm. Having completed this task, both men on the starboard side of the frame then started to walk aft along the lifting frame towards an access door in the gantry. Before reaching the door, the forward starboard bracket tore away from the frame, followed, very soon afterwards, by the aft starboard bracket.

As the starboard side of the lifting frame began to drop, the quayside crane experienced a shock as the frame slid to starboard, fell from the support straps and tensioned the slings, resulting in the brackets on the port side of the frame breaking free. The complete frame then fell onto the deck and partially slid over the starboard side of LOVE LETTER into the water of the dock (Figure 4). The time was about 0930.

The two crewmen on the starboard side of the frame were thrown into the water together with ENAK's Chief Officer. One crewman in the water was injured. He was rescued by ENAK's Chief Officer and lifted on board the attending tug. The remaining crewman could not be found immediately.

The Master of LOVE LETTER returned to his vessel and called Sunderland Port on Channel 14 VHF to report the accident. The weight of the fallen frame had given the vessel a list of 6½° to starboard.

SAR operations, involving Police, Fire Brigade and RNLI units, began immediately.

As the lifting frame was seen as a potential hazard to SAR personnel, and to the vessel, it was secured to LOVE LETTER by crewmen from ENAK.

SAR operations continued until 1343 when the body of the missing crewman was recovered.

Following its recovery from the dock, the aft frame was transported to Liebherr Works, Sunderland.

On 10 May 1997 the lifting frame on the forward gantry was removed and also transported to Liebherr Works, Sunderland. The procedure adopted for this operation was similar to that used the previous day, except that the 125t lifting eyes of the frame were used (see Figure 5).

Figure 5

1.3 Loss of Life and Injuries

One crewman from ENAK lost his life and another was injured. No other loss of life or injuries were reported.

1.4 Weather, Sea and Tidal Conditions

During the morning of Friday 9 May 1997, the weather conditions in Sunderland Port were: Westerly wind, force 2, cloudy, dry with good visibility. There was no discernible swell. Conditions during 10 May were similar.

Arrangements were made with Sunderland Port, by the Master of ENAK, for no large vessel to be allowed to make passage past the berth, Corporation Quay, during operations.

Predicted time of High Water at Sunderland on 9 May was 0541 and the following Low Water 1204. Corresponding heights of tide were 5.2m and 0.7m.

1.5 Liebherr-Werk, Nenzing

This company is a large, well established engineering organisation which specialises in the manufacture of large cranes of many types. The company's operations cover many parts of the world with many of its design, management and control functions being exercised centrally from the parent works in Nenzing, Austria.

1.6 Liebherr Works Sunderland

One of the daughter companies of Liebherr-Werk, Nenzing, is Liebherr Works, Sunderland, UK, on the south bank of the River Wear, about 1½ miles upriver from Sunderland Docks.

This Sunderland site had previously been used as a shipbuilding yard and features of its earlier role remain: craneage, river frontage, hard standing etc. However, since the general demise of shipbuilding in the area, the River Wear has, in the absence of regular dredging, suffered from silting so restricting the size of seagoing vessels which can be navigated to the site of the Liebherr Works.

All design, control and major management functions for the Sunderland works are performed from the Austrian headquarters of the company in Nenzing. The seniority, number and authority of the management staff at the Sunderland works is limited.

The two gantries which were loaded on mv LOVE LETTER were manufactured at the Liebherr Works, Sunderland.

1.7 Planning

A formal planning meeting was held at Liebherr Works, Sunderland, on 4 May 1995 to discuss the intended series of gantry loading operations. Parties represented at that meeting were:

Liebherr-Werk, Nenzing
Liebherr Works, Sunderland
Bugsier, owners of ENAK
SAL, Charterer of mv NIPPON & mv LOVE LETTER
Port of Sunderland
Underwriters

A second formal meeting was held at Liebherr Works, Sunderland, on 11 August 1995. The parties represented were:

Liebherr-Werks, Nenzing
Liebherr Works, Sunderland
Bugsier
SAL

In addition to these formal meetings, informal discussions occurred on various unrecorded matters between several parties.

In general, all discussions centred on the task of transferring the gantries from Liebherr Works, Sunderland, to the ship chartered to transport the gantries to China. There is no record of any detailed discussions on the matter of lifting frame removal and how that should be executed.

1.8 Personnel

The Master and crew of LOVE LETTER performed little active role in the loading of the gantries or removal of their lifting frames. Associated activities performed by them during the gantry loading operations were confined to ballasting their ship to maintain it upright and, once loading was complete, to secure the gantries to the deck. They performed no significant tasks during frame removal operations.

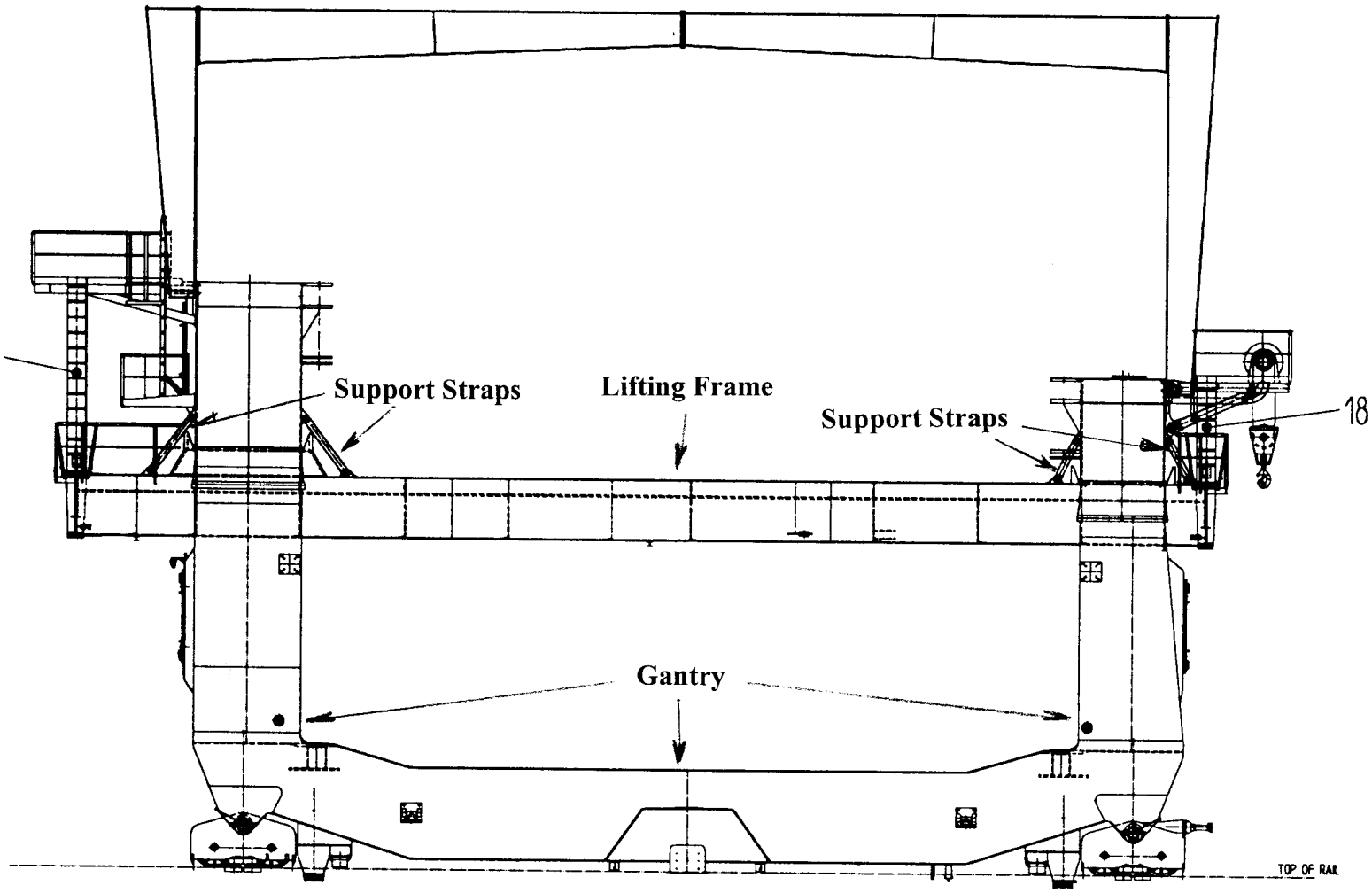
All activities directly associated with loading gantries onto LOVE LETTER were performed by crewmen of the ENAK. This was also the case during the removal of the lifting frames, excepting only for the use of a quayside crane and its driver supplied by Sunderland Port.

1.9 Gantry Lifting Frames

To overcome the need for dedicated lifting points to be built into the gantries, a pair of re-usable lifting frames was constructed. One frame was fitted to each gantry at the Liebherr Works, Sunderland. Once the gantries had been loaded on board ship, the frames were to be removed and returned to Liebherr Works, Sunderland for re-use.

Each lifting frame consists of two major load bearing components in the form of two substantial box section beams, approximately 22 metres length, at each end of which is a 125t lifting bracket. Viewing each frame, while its respective gantry sits on the deck of the ship, these beams run transversely beneath the gantry with their ends extending beyond the sides of the gantry. The 125t lifting brackets are on these protruding portions of the beams (see Figure 6).

Figure 6



END ELEVATION OF GANTRY SHOWING LIFTING FRAME SUPPORT STRAPS

On the upper face of each box section are two contact pads faced with wood. These pads make contact with the under face of the gantry and transmit the lifting forces during gantry lifting operations.

To maintain a predetermined horizontal distance between each of the box section beams, two 12 metre long space frame structures are secured between the box section beams with pin joints (see Figure 7).

When assembled, the box section beams and the space frames form a structure which, in plan, is rectangular. (Figure 8). As the connections between the sides of the rectangle are pin joints, two pin jointed diagonal struts are used to maintain the beams at 90° to the space frames. The total weight of each assembled lifting frame is 40.5t.

The two space frames of each lifting frame are each constructed of two parallel rolled steel sections with welded diagonal bracing. Welded to the top face of the upper section are two brackets. Each pair of these brackets is designed to accommodate, during transport of the lifting frame when dismantled, one of the diagonal struts used to maintain the rectangular geometry of the assembled lifting frame. (Figure 7)

1.10 Modifications to Frames

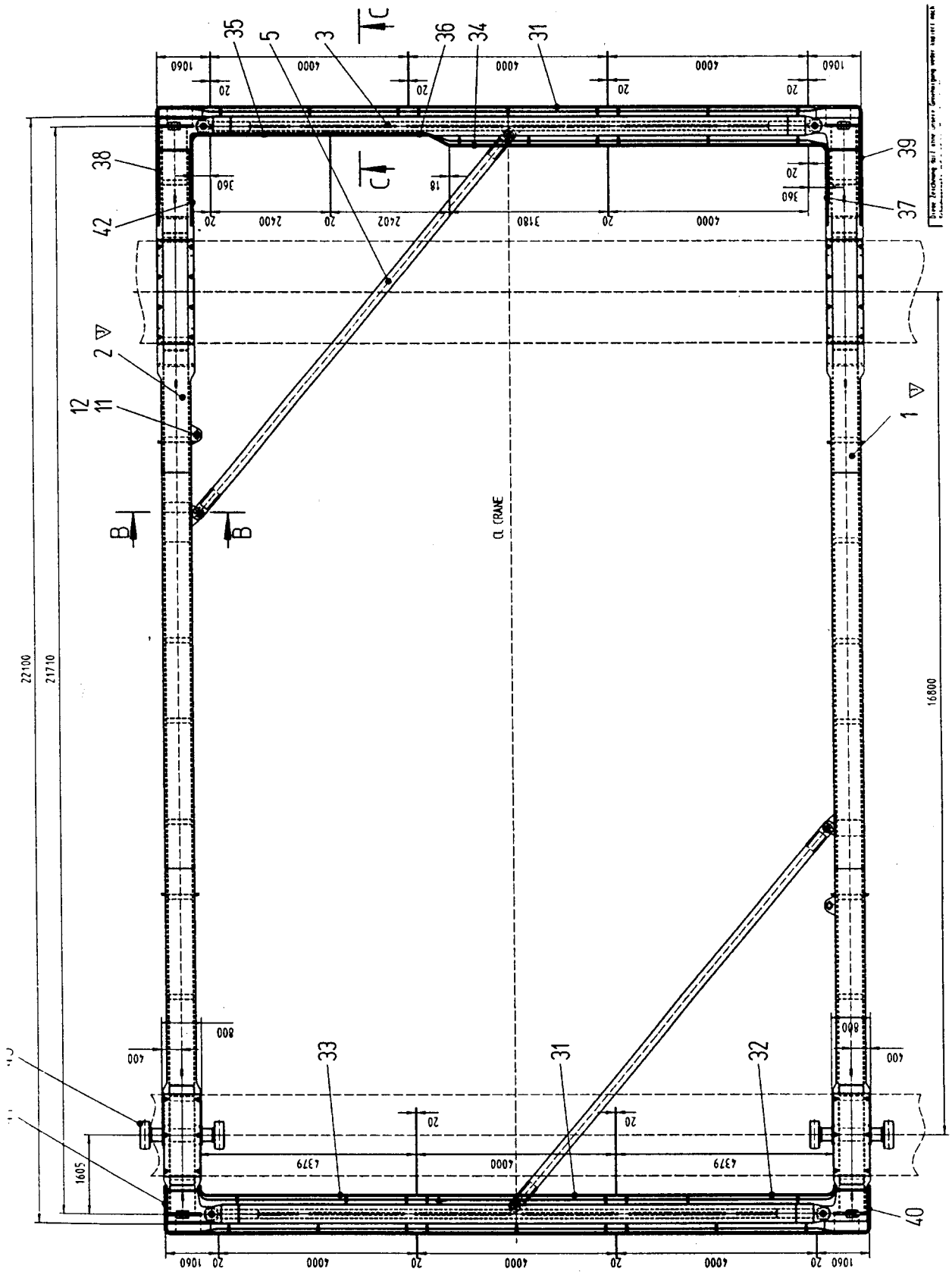
In the early stages of this project, before any gantries had been manufactured, each lifting frame was predicted as having a weight of 25t. Further consideration of the lifting frame's design resulted in the fore and aft space frames being of heavier construction, resulting in each lifting frame having a weight of 40.5t. In this form the frames' lifting brackets were each load tested to 125t; 500t in total.

Another modification, which resulted from the selected floating crane ENAK having limited headroom, was the fitting of securing eyes to each lifting frame and gantry. Between these eyes steel straps were fitted which allowed each frame to remain in place, on the gantry, during transport of the gantry from Leibherr Works, Sunderland to Sunderland Docks by pontoon. The clearances in these eyes, straps and pins are such as to ensure that the lifting frame properly takes the weight of a gantry, without placing load on the straps, and give a vertical clearance of 25mm between gantry and lifting frame when the frame hung from the straps during transport by pontoon (Figure 6).

Two pairs of wheels were added to the box sections to aid the movement of the frame across the hatch cover of the transporting ship, once lowered from the gantry (Figure 8). A walkway was also formed on the upper section by fitting guard-rails to the spacer elements.

After experience gained from the first set of gantry lifting operations, the bores in the 125t lifting brackets were increased in diameter by 4mm to ease the fitting of lifting shackles. This was the only modification performed after the frames were first used.

Figure 8



PLAN OF LIFTING FRAME SHOWING DIAGONAL STRUTS

1.11 Gantry Rigging

A spreader beam, of 500t SWL, was suspended from ENAK's lifting hooks by slings. Use of this spreader beam allowed for two further sets of slings to run from the ends of the beam to the lifting brackets on the gantry lifting frames, without fouling the gantry structure (Figure 9)

This beam was used only when lifting a gantry. It played no part in the removal of the lifting frames.

1.12 Removal of Lifting Frames

After loading the two gantries onto the deck of the ship, the associated lifting frames had to be lowered from beneath the gantries and returned to Liebherr Works, Sunderland. This policy prevented the weight of the frames from having a detrimental effect on the ship's stability and made the frames available for subsequent gantry loading operations in Sunderland.

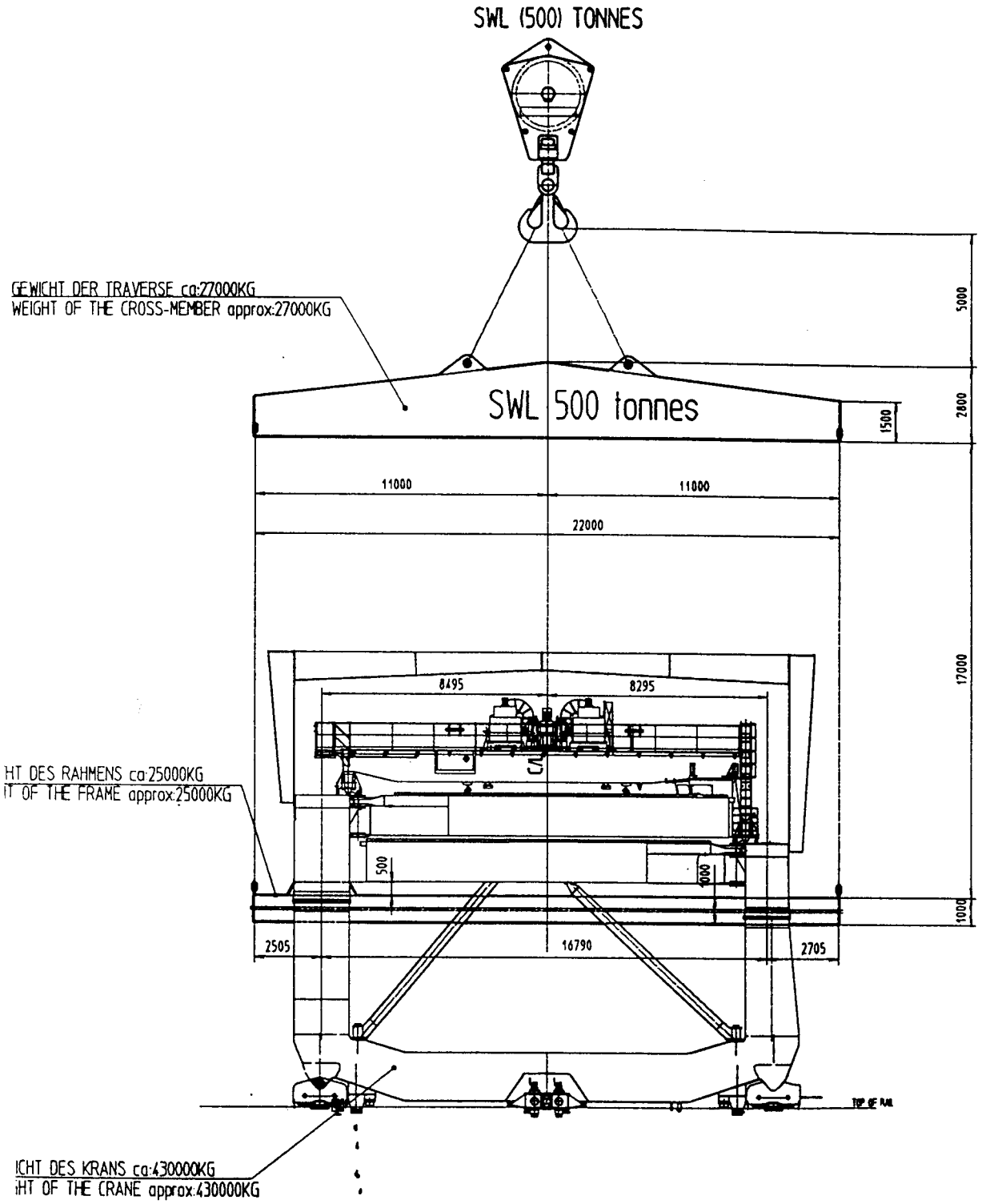
The operation, as initially proposed, required the lifting frame to be lowered as a continuation of the gantry lowering operation (Figure 10). This could not be undertaken by ENAK alone because the height of the jib gave insufficient head room, between the spreader and gantry, to allow the lifting frame to be lowered onto the deck in one continuous operation. To overcome the problem, a modified procedure was adopted which required the lowering of the lifting frame onto the deck using ENAK and a quayside crane in tandem.

To achieve this, the lifting frame was temporarily allowed to hang from the gantry on the supporting straps. Clearances between these straps, their locating pins and the respective eyes of the gantry and frame allowed the frame to come into contact with the gantry, during gantry lifting operations, and hang free when necessary. In this free condition a clearance of 25mm between the upper face of the frame and the under face of the gantry was intended; achieved with suitable pin and strap clearances.

The spreader beam was disconnected from the suspended lifting frame. ENAK moved away from the loading berth and lowered the spreader beam onto a pontoon. ENAK returned to the loading berth for the lifting frame removal operation.

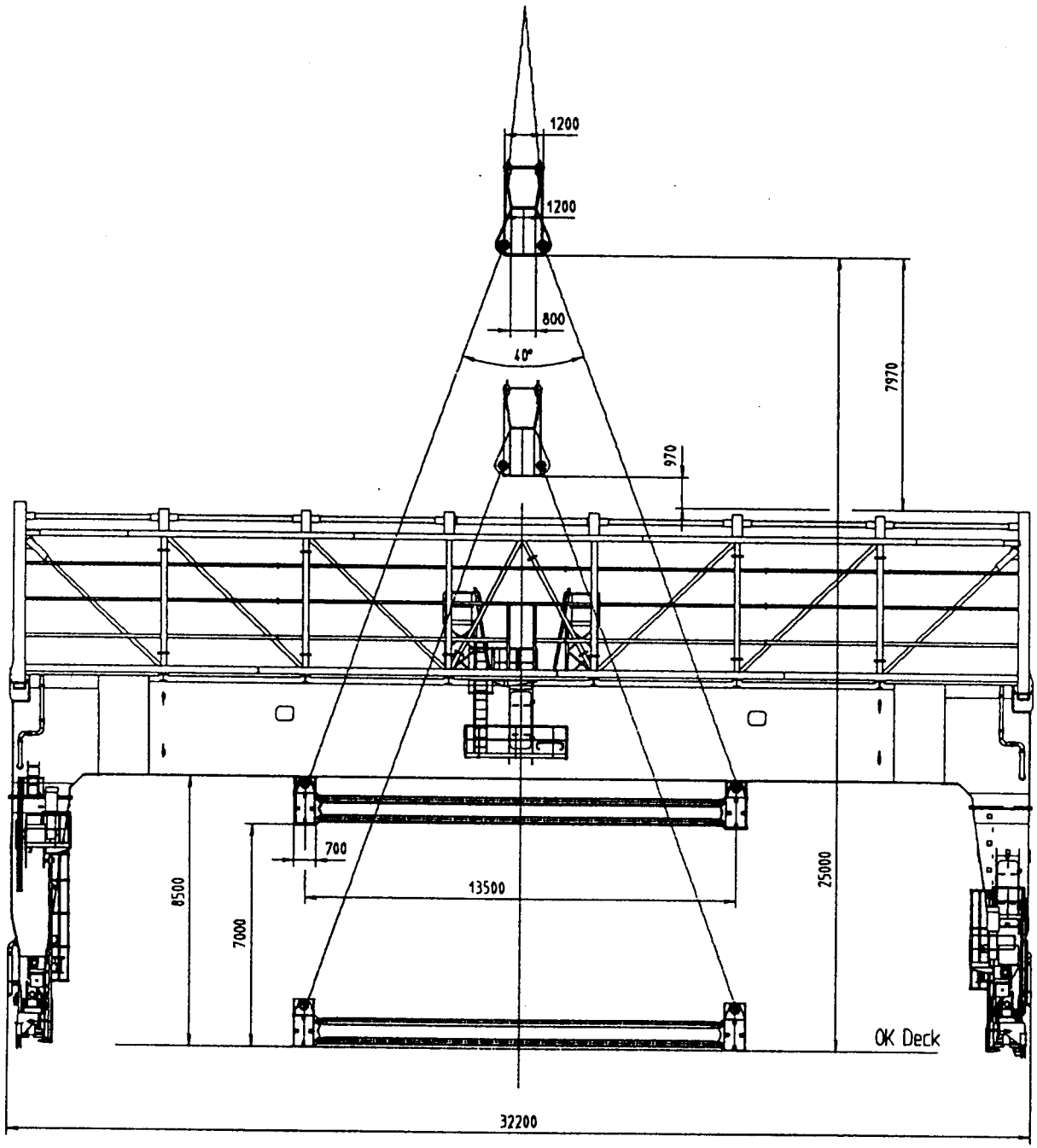
This operation required ENAK to support a portion of the frame's weight at the starboard side of LOVE LETTER with the quayside crane taking the remainder of the weight at the port side.

Figure 9



END ELEVATION OF GANTRY SHOWING LIFTING ARRANGEMENTS AND 500t SPREADER BEAM

Figure 10



SIDE ELEVATION OF GANTRY SHOWING INITIAL PROPOSAL FOR A SINGLE LIFT PROCEDURE FOR LOWERING LIFTING FRAME

Once ENAK and the quayside crane had had slings and shackles rigged to the lifting eyes on the lifting frame, some weight was taken to remove weight from the straps and pins which had previously been supporting the frame. Once sufficient weight was taken, and all pins removed, the frame was lowered to the deck. The quayside crane was released from the frame. Using ENAK, and the sets of wheels on the box sections of the frame, the frame was moved towards the starboard side of the vessel and lifted away by ENAK.

Once clear of the ship, the two lifting frames were dismantled and transported to Liebherr Works, Sunderland, for storage and re-use.

This operation was completed on four occasions in Sunderland Docks, from September 1995 to December 1996, without incident.

1.13 Frame Lifting Points

Each lifting frame is fitted with four designated lifting brackets, one at each end of each box section beam. These brackets were designed and tested for a total SWL of 500tonne; 125tonne each. No markings were made on the frame to indicate the location of the designated lifting points.

During the first set of frame removal operations in September 1995, the weight of each frame was taken on the designated 125tonne lifting brackets (Figure 11).

Figure 11

The strut stowage brackets were used for frame lowering purposes for the fourth set of these operations in December 1996. It is not known which points were used during the operations of March and July 1996.

For the operations of 9 May 1997 the strut stowage brackets were used as lifting points. Following the accident to the aft lifting frame, the forward lifting frame was removed on 10 May 1997, using the 125tonne lifting brackets (Figure 5).

The brackets employed for lowering the aft gantry's lifting frame, on 9 May 1997, were not designed, designated or tested as lifting points. The brackets had no designated safe working load. Referring to these brackets, the term overload may be considered to apply to any load that causes any plastic deformation, or fracture of the material of the brackets, their welds, or material immediately surrounding. The term is applied in this way for the purpose of this report.

1.14 Communications

On-site communications between ENAK and its crewmen on LOVE LETTER were performed by VHF.

Communication between ENAK's crewmen on LOVE LETTER, and the driver of the quayside crane, were performed by hand signals.

A hard-wired telephone between the cab of the quayside crane and the quayside was installed, but not used during these operations.

All members of ENAK's crew spoke German. Of all the persons involved directly with frame lowering operations on 9 May 1997, only the driver of the quayside crane did not speak the language.

1.15 Quayside Crane

The maximum SWL of the quayside crane used on 9 May was 35tonne. The driver of the crane had about six years experience of crane driving since completing his training.

The crane driver had observed the frame lowering operation, and had been briefed, on an informal basis, by other crane drivers who had completed the task before. However, he had not undertaken the operation until 9 May 1997.

1.16 The Floating Crane, ENAK

During operations on board ENAK the Chief Engineer controls the winch from a station at the forward part of the wheelhouse. At this control station are displays for the load sensing system. No reference was made to the load sensors during the frame removal operation of 9 May 1997.

During lifting operations the master's station in the wheelhouse is at the vessel's main control position, which is slightly higher than and further aft of the Chief Engineer's position. The Master has control of all vessel's propulsion, positioning and external communication systems from his station.

ENAK has two pairs of lifting hooks which were used during gantry or frame handling operations, a pair of 300tonne hooks and a pair of 150tonne hooks. On 9 May only one hook was used for lowering the aft frame; this was the 300tonne hook at ENAK's port side.

1.17 MV LOVE LETTER

A notable feature of LOVE LETTER is the mounting of two jib type deck cranes at the port side of its main deck (Figure 3). These cranes prevent the gantries being loaded on the vessel's centre line and cause the gantries' centre of gravity to be about 4m to starboard. This asymmetry requires LOVE LETTER to make ballast adjustments, as the weight of each gantry comes onto the vessel, to remain upright.

No similar ballasting operations are required during frame removal operations.

1.18 Other Lifting Gear

The quayside cranes' slings, used at the port side of the aft lifting frame, were as follows:

Slings: 130mm circumference, SWL marking not found

Shackles: 12tonne SWL

Slings used at the starboard side of the aft lifting frame, by ENAK, had a SWL of 50tonne. The shackles used were not identified.

1.19 Damage to Vessels

MV LOVE LETTER sustained damage to its hatch covers, some adjacent structure and starboard side guard-rails due to impact from the aft lifting frame falling. These items required repair before the vessel was able to proceed to sea.

There was no reported damage to the ENAK.

1.20 Damage to Aft Lifting Frame

The frame was inspected in the assembled condition, as found when recovered from the waters of Sunderland Docks.

The top member of each space frame showed localised damage at the strut stowage brackets.

The damage to the starboard space frame girder consisted of rectangular tears at the strut stowage brackets, which had been torn away, having footprints slightly larger than the base sections of the brackets. The material of the girder's web surrounding these tears was deflected upwards approximately symmetrically (Figure 12).

Figure 12

The damage to the port space frame was very similar, except that the girder web material surrounding the tears was not deflected symmetrically. In each case the material to the port side of the tear was highest (Figure 13).

Figure 13

The material which had been torn from the girder, still welded to the bracket was attached to the base of each bracket (Figure 14).

Other damage consisted of: some bending of each space frame, buckling of the diagonal struts, damage to guard-rails, bending of various minor brackets and impact damage to undersurfaces of box sections and their wheel units.

Figure 14

1.21 Inspection of Forward Frame

The stowage brackets on the fore and aft members showed no signs of damage or deflection. However, the web of the RSJ, to which the brackets were welded, showed permanent deflection near the welds. The magnitude of this deflection was not uniform between the four brackets; the maximum measured deflection being 6mm.

In addition to this deflection, the surfaces of the RSJs' webs showed signs of stress cracking of the paint film in the regions adjacent to the brackets' weld attachments.

1.22 Metallurgical Tests on Failed Brackets

Macroscopic examination of the failed brackets, which had been on ENAK's side of the aft lifting frame or starboard side of LOVE LETTER, showed they had been subjected to overloads on successive occasions, and that failure propagated from the vertical edge of each bracket.

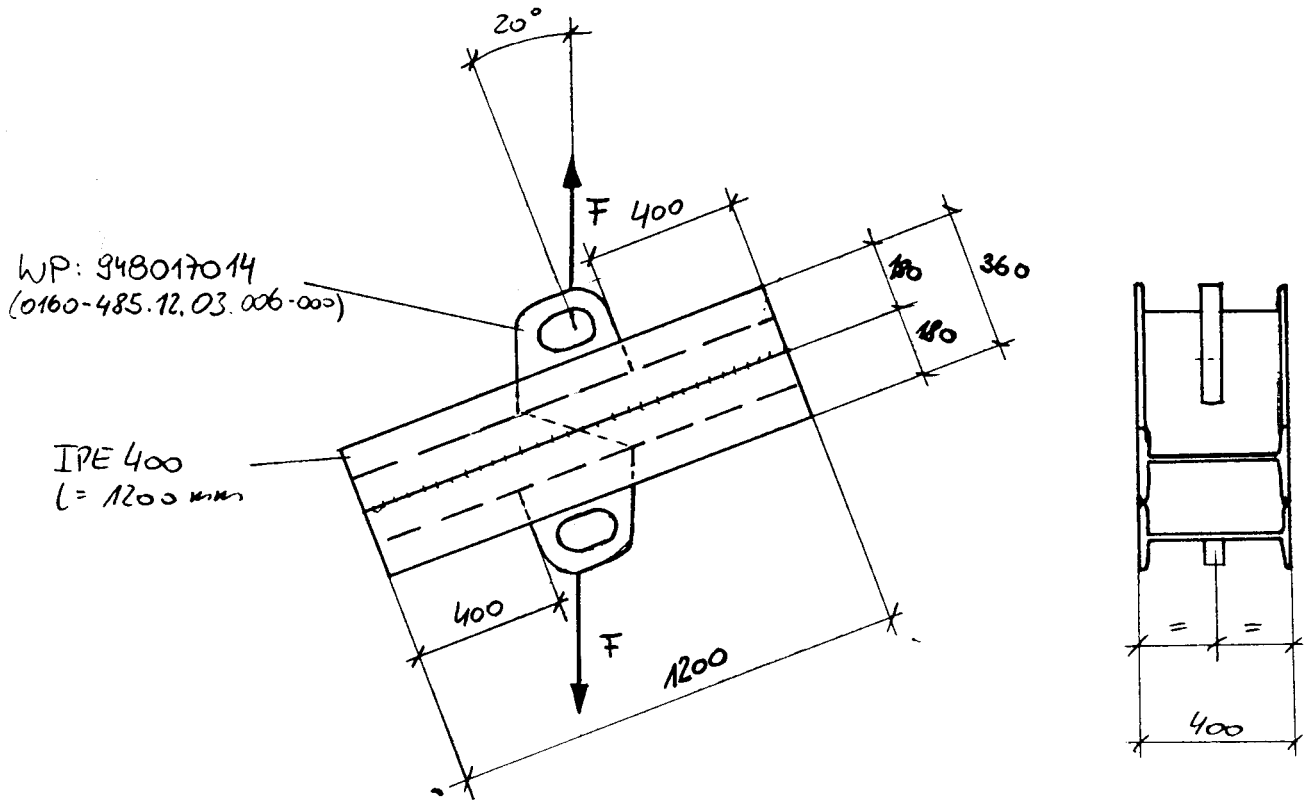
1.23 Tensile Tests on Frame Brackets

A pair of brackets, of similar design, material and manufacture, were subjected to a tensile test at the National Material Testing Station, Stuttgart University. Each bracket was welded to a length of 'I' section girder which were then welded together 'back to back'. Loads applied to each bracket produced a force system similar to that considered to have been applied to the first pair of brackets which failed on 9 May 1997. The applied test forces had a line of action 70° above the axis of the girder sections (Figure 15).

Load was applied to the test component at the rate of 100kN/minute. The test concluded when the test component fractured. The results were:

Breaking Load - 537kN
Load when deformation first observed - 300kN
Fracture behaviour - comparable to original bracket

Figure 15



1.24 Requirements and Guidance

The Merchant Shipping (Hatches and Lifting Plant) Regulations 1988 are applicable to UK ships on matters concerning lifting plant, its marking, testing and use. They place an obligation on a vessel's master and his employer to ensure operations are carried out safely.

Neither LOVE LETTER nor ENAK was UK registered.

For a non-UK ship, these Regulations provide for actions to be taken by the port state, which includes detention, if it does not conform to the standards required of a UK ship by the same regulations. The Regulations do not explicitly require that the vessel's master takes any action to assess the suitability, as lifting gear, of certain items which are part of an item of cargo.

The Docks Regulations 1988 impose obligations on persons, including employers, during all dock operations. These Regulations impose no duty on the master or crew of a ship, or their employer, in relation to plant which remains on board the ship, and any dock operations carried out on the ship solely by the master or crew of the ship.

The Approved Code of Practice associated with The Docks Regulations offers guidance on the requirements of these Regulations. The desirability of maintaining records of operations covering specific cargoes and ships is mentioned in this guidance.

To implement the lifting aspects of the Amending Directive to the Use of Work Equipment Directive (95/63/EC) (AUWED), the lifting requirements of both the Docks Regulations and the Merchant Shipping (Hatches & Lifting Plant) Regulations are under review.

Section 2 - ANALYSIS

2.1 Frame Lowering Operations

During the preliminary planning stages of the total operation in 1995, it was proposed that the gantries' lifting frames should be lowered as part of a continuous lowering operation performed by the floating crane. As such, this part of the operation necessitated the use of the slings and shackles, used for lifting the relevant gantry, attached to the 125tonne lifting eyes of the frame. No opportunity existed for transferring the lifting points from the 125tonne lifting brackets to the strut stowage brackets, or for substituting slings and shackles of a lesser SWL. Had this procedure been followed on 9 May 1997, this accident would have been prevented.

In preparing to lower a lifting frame it was necessary first to lift the frame slightly, to remove load from the support straps to enable pin removal. With ENAK and the quayside crane taking the weight of the lifting frame, any attempt to lift the frame a vertical distance greater than the 25mm clearance between the two parts, could have induced a load in the lifting equipment greater than that due to the frame's weight alone. By lifting a frame a few millimetres, to unload the supporting straps, careful control of the cranes was essential to prevent loss of all clearance between frame and gantry and the application of excessive loads to the lifting gear. Attempting to achieve this degree of control using a floating crane, in anything other than still water, could induce loads of indeterminate magnitude in the lifting gear. It is considered essential that this type of operation should be avoided, unless all lifting gear employed is capable of supporting the maximum weight which could be induced during the worst possible conditions. This requires that all lifting gear and lifting points used by ENAK are capable of taking the maximum likely load. Therefore the use of the four designated 125tonne frame lifting brackets, with similarly rated shackles and slings, is necessary.

Although these comments have centred on the use of ENAK, similar problems are possible when using the quayside crane at the port side of the lifting frame on 9 May. Due to its greater displacement, LOVE LETTER was less likely to be affected by sea conditions, such as swell, than ENAK. Relative vertical movement, of short cyclic period, between the quayside crane and LOVE LETTER was likely to have been small. However, lowering of the water level alongside the quay, caused by fall of tide, could be important at the critical stage of the operation, when the quayside crane had taken the weight of the frame in order to unload the supporting straps. Any significant delay at that stage, could allow the falling tide to reduce the vertical clearance between the frame and the gantry. Once this clearance had been lost, a load of indeterminate magnitude would be applied to the crane. As this frame/gantry clearance is just 25mm, without frequent adjustment of the crane, a falling tide could reduce this clearance to zero in only a few minutes. This procedure therefore could have overloaded the quayside crane and its associated lifting gear. The practice of using the quayside cranes in this fashion should be discontinued.

At 0930 on 9 May the slings on the quayside crane were slack, showing that the above mechanism did not contribute to the accident. However, no formal assessment of the risk associated with this feature of the operation had been made. An assumption was made,

probably unconsciously on the part of many associated with the operations, that the driver of the quayside crane and crew of ENAK were sufficiently experienced to be aware of this danger.

2.2 Failure load on Brackets (1)

It is recorded that the strut stowage brackets were used for lifting purposes during the frame removal operations in December 1996. Visual inspection of these brackets, on the frame used on the forward gantry for the operations in May 1997, showed significant permanent distortion adjacent to the brackets. The brackets were not used for lifting during the operations in May 1997, so distortion must have occurred due to overloading applied during earlier operations. Macroscopic examination of two failed brackets, from the aft lifting frame, indicated they had also been overloaded before the operation which began on 9 May 1997.

Tensile tests, performed at Stuttgart University, attempted to replicate the loading of the brackets at the time of failure on 9 May. Applying load at the angle of the slings used that day, 20^{o} to the vertical, the loading geometry is considered to be a reasonable representation of that applicable at the time. The test results indicate that deformation occurred at a load of about 30tonne; giving a vertical component of this load as 28.2tonne. Failure due to fracture occurred at 54.74tonne; with a vertical component of 51.4 tonne.

With each lifting frame weighing 40.5tonne, the nominal load taken by each of the four brackets would be approximately 10tonne. Comparing this to the weight at which the test bracket failed, 28.2tonne, indicates that a factor of safety was present, if the brackets had been designated as lifting points. This comparison also shows that the brackets had previously been subjected to loads greater than that which would have been imposed by the weight of the frames alone.

The tensile test component, consisting of two lengths of girder and associated brackets 'back to back', was geometrically, materially and qualitatively similar to the items which failed on 9 May. However, the configuration may have given a system which underestimated the load which could have caused failure (Figure 6). The most important difference between the test component and the original frame and bracket system, is the presence of bracing struts, on the underface of the frame's girder. These struts increased the stiffness of the girder. Notwithstanding the possible underestimate of the significant loadings, the tests are considered to have been of great value.

They indicate that load was applied to the brackets, of magnitude greater than the weight of the lifting frame alone, on at least one occasion before the operations in May 1997. The overload must, therefore, have occurred during frame removal operations when the frame was lifted slightly in order to remove weight from the support straps; a problem which may have been aggravated by the limited vertical clearance between frame and gantry.

In future, even if all lifting frame removal operations employ the 125tonne lifting eyes, any potential for generating unquantifiable loadings on any parts of the lifting equipment should be removed. This requires a change in operating procedures.

2.3 Failure load on Brackets (2)

The failure of the two brackets at the starboard side of the aft lifting frame occurred before the port side brackets failed. This order of events on 9 May 1997 is confirmed by several witnesses.

Tensile tests performed on similar brackets indicate that sound components were unlikely to fracture until a load in excess of 500kN (51tonne) was applied. However, the fractured pieces exhibited similar characteristics to the failed brackets on the starboard side of the frame.

A notable characteristic of the tears in the upper section of the starboard space frame, was the symmetrical upward deflection of the material surrounding each tear, indicating that any transverse component of loading was small. Failure was thus due to vertical and longitudinal components of forces.

The strut stowage brackets were used on occasions before 9 May to lower both lifting frames. From the plastic deformation found in the region of the brackets on the forward lifting frame, it is reasonable to assume that similar deformation may have been present around the starboard brackets of the aft frame before the operation commenced on 9 May 1997. Because of this probable loss of load bearing integrity of the starboard brackets on that occasion, they may well have fractured at a load significantly less than the 500kN (51tonne) suggested by the test load.

It is therefore concluded that the starboard brackets fractured due to an applied load, through the lifting slings and shackles. This load was probably in excess of that due to the frame's weight alone. The integrity of the brackets may have been compromised by overloading on previous occasions.

The tears in the upper section of the port space frame, in way of the brackets, had their port edges significantly higher than their starboard edges. This is interpreted as indicating failure being due to a load having a significant transverse component, which the brackets were not designed to withstand.. This load was generated by the frame sliding to starboard while the port side slings and shackles remained attached, after the failure of the starboard brackets. This interpretation is again consistent with witness evidence.

2.4 Planning and Monitoring

Before the first pair of gantries were loaded on board MV NIPPON in September 1995, two formal planning meetings were held on 4 May 1995 and 11 August 1995. Minutes were recorded. Unrecorded informal discussions also took place.

However, it appears that some involved parties were happy to accept that others were sufficiently knowledgeable and skilled, in the type of operation being planned, to warrant minimal interrogation.

This attitude was reinforced on each occasion that a pair of gantries was successfully loaded and their lifting frames removed. After four successful sets of operations, it is probable that most parties viewed the operations as almost routine.

2.5 Weather and Sea Conditions

Relative vertical movements between ENAK and LOVE LETTER, due to swell, has been identified as having the potential to generate a load in the lifting gear, greater than that which could have been caused by the weight of the frame alone.

Reports of sea conditions appear to dismiss the possibility of sufficient swell being present to have caused any difficulty on 9 May 1997.

The possibility of a rapidly falling tide having the potential to cause an overload on the quayside crane has been mentioned. The time of the operation on 9 May coincided with a falling tide. There is no record of this risk having been formally considered during the planning stages. However, there is no evidence to suggest that the slings on the quayside crane were loaded due to this effect.

2.6 Previous Operations

The two lifting frames had been removed from their gantries, using the strut stowage brackets as lifting points, on at least one occasion before the operations of May 1997. The first set of operations in September 1995 used the designated 125tonne lifting eyes.

In the absence of formal records of planning meetings covering this part of the operation, it has proved impossible to identify which of the operations of March or July 1996 was the occasion on which the stowage brackets were first used as lifting points. It has also proved impossible to establish the reasons for the change of lifting points.

Clear, documented operational procedures covering all parts of the operations might, in addition to assisting this investigation, have refreshed the minds of various operators on the importance of those procedures. The task of compiling those procedures might also have caused the inherent dangers of the proposed operations to be identified. The accident might have been avoided as a result.

2.7 Markings

The application of suitable markings at Liebherr Works, Sunderland, might have reduced the chances of this accident occurring. To assist in preventing similar accidents, Liebherr Works Sunderland should be recommended to identify and mark all lifting points, in cases where confusion is possible, and where the consequences of lifting point failure are serious.

At the time of the accident, UK Merchant Shipping Regulations covering the operation did not require the designated lifting points of the gantries' lifting frames to be marked as such.

It is anticipated that the introduction of new UK regulations, which implement the Amending Directive to the Use of Work Equipment Directive (95/63/EC)(AUWED), is likely to require the marking of lifting equipment in a manner which is relevant to this accident. The MCA should be recommended to consider the circumstances of this accident, and the conclusions of this report, when compiling regulations.

2.8 Selection of Lifting Points

A senior member of ENAK's crew had formed the erroneous opinion that the strut stowage brackets had been fitted to the frames for the purpose of lifting and handling the frames. It has proved impossible to identify the foundation of this opinion.

The apparent objective of using the strut stowage brackets as lifting points was to allow the use of lighter shackles and slings, so making their handling simpler. Except for the extreme difficulty of transferring the frames' weight from the support straps to the respective crane, without inducing indeterminate loads on the lifting gear, this would have been an understandable motive.

However, the potential to overload the lifting gear during these operations was not properly recognised. The clearest indicator of this is the use of 12tonne SWL shackles for connecting the slings to the lifting frame. This SWL is about 20% in excess of the nominal weight which would be applied with the frame hanging, freely supported only on the four slings and shackles; a very reasonable margin. However, when the potential for overloading is considered, this margin disappears.

The complete failure of the brackets, particularly of those on the starboard side, demonstrates not only the magnitude of the forces involved, but also the lack of recognition of the potential dangers inherent in the operation.

Section 3 - CONCLUSIONS

3.1 Causes

1. The brackets on the aft gantry's lifting frame failed because, although not designed or designated as lifting points, they were used for lifting purposes.

2. Underlying causes leading to incorrect points being selected as lifting points were:

    i) the absence of suitable markings,

    ii) insufficient planning,

    iii) inadequate assessment of risk, and

    iv) limited monitoring of operations.

3.2 Findings

1) During lifting frame removal operations, at about 0930 on 9 May 1997 at Corporation Quay, Sunderland Docks, the aft frame, of 40.5t, fell onto the deck of MV LOVE LETTER due to failure of the frame's lifting points. (1.2)

2) A load, greater than that due to the weight of the lifting frame, had been applied to the brackets used for lifting, before or on 9 May 1997. (1.22 ,1.23, 2.2)

3) The strut stowage brackets were used as lifting points on the aft lifting frame on 9 May 1997. (1.2)

4) The integrity of the strut stowage brackets was probably affected by overloading during operations performed before 9 May 1997. (2.3)

5) The strut stowage brackets at the starboard side of the frame failed before those on the port side. (2.3)

6) The forces applied to the strut stowage brackets on the starboard side of the frame had no significant transverse components. (2.3)

7) The strut stowage brackets on the port side of the frame failed due to the application of forces having substantial transverse components. (2.3)

8) The strut stowage brackets used for the operation were not designated nor designed as lifting points. (1.13)

9) This type of operation had been completed on four previous occasions, without incident. (1.1)

10) After the operations in 1995 and early 1996, their monitoring became unsatisfactory. (2.4)

11) The forward starboard bracket failed first, followed shortly afterwards by the aft starboard bracket. (1.2)

12) Both brackets on the port side of the frame failed due to the starboard side of the frame falling, resulting in the port side support strap arrangements failing, and applying a sudden oblique loading to the brackets via their slings. (1.2)

13) Both lifting frames in use had been lowered using their strut stowage brackets as lifting points, on at least one previous occasion. (2.2)

14) The designated 125t lifting brackets were not used during the frame removal operation on 9 May 1997. (1.2)

15) Neither the failed brackets nor the designated lifting brackets were marked to indicate their purpose. (1.13)

16) Planning of the operation did not formally cover removal of the frame. (1.7, 2.4)

17) Weather conditions made no significant contribution to the accident. (2.5)

18) Tidal effects had the potential to overload the quayside crane.. (2.1, 2.5)

19) The frame removal procedure had the potential to cause a load to be applied to the lifting equipment, greater than that due to the weight of the frame alone. (2.1)

20) The potential for the operation to generate a load in the lifting gear, greater than the weight of the lifting frame, was not recognised and fully accommodated in the planning. (2.7, 2.1)

Section 4 - RECOMMENDATIONS

The Maritime and Coastguard Agency is recommended to

1. consider requiring lifting points to be identified and marked, particularly in cases where confusion is possible and where the consequences of lifting point failure are serious when compiling Merchant Shipping Regulations, implementing the Amending Directive to the Use of Work Equipment Directive (95/63/EC)(AUWED).

The Manager of Liebherr Works, Sunderland is recommended to

2. consider introducing the practice of identifying and marking all lifting points on equipment being despatched from their works, particularly in cases where confusion is possible and where the consequences of lifting point failure are serious. (2.7)

3. modify the frame removal operation so that loads of indeterminate magnitude cannot be imposed on lifting equipment. (2.2)

The General Manager of the Port of Sunderland is recommended to

4. discontinue the practice of using quayside cranes to assist in the removal of this type of lifting frame, unless the procedures used on 9 May 1997 are changed, to ensure that an overload cannot occur. (2.1)

Section 5 - SUBSEQUENT ACTIONS

5.1 Following the circulation of MAIB's draft report to criticised parties into this accident, The Port of Sunderland has reported that a quayside crane is no longer used in the operation of frame removal.