Report of the investigation of

two lifting wire failures

on starboard Fast Rescue Craft davit

of safety stand-by vessel

Dea Fighter

on 13 May and 16 July 1999

Marine Accident Investigation Branch
First Floor, Carlton House
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Southampton
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Report No 39/2000

Extract from

The Merchant Shipping

(Accident Reporting and Investigation)

Regulations 1999

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.

CONTENTS

Annex A Geometry of davit head.

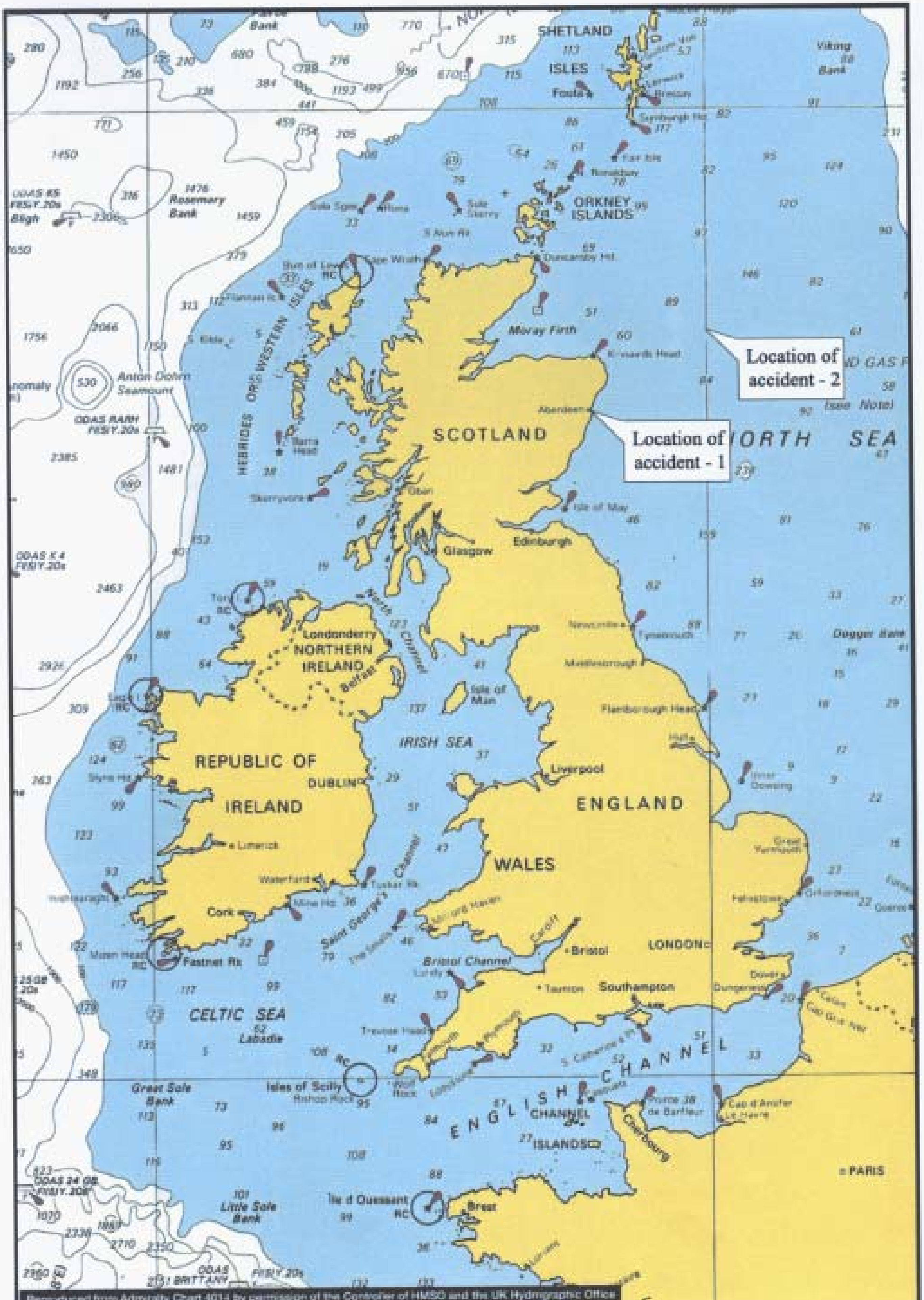
Annex B Calculation of relative movement of wire and tele-leg and effect on wire load when swinging out davit. Correct sheave fitted.

Annex C Calculation of relative movement of wire and tele-leg and effect on wire load when swinging out davit. Undersize sheave fitted.

Annex D Calculation of relative movement of wire and tele-leg and theoretical effect on wire load when swinging out davit. Wire slipped and running on sheave pin.

GLOSSARY OF ABBREVIATIONS

BST	-	British summer time
°C	-	Degrees centigrade
DoT	-	Department of Transport
FoS	-	Factor of safety
FRC	-	Fast rescue craft
HSE	-	Health and Safety Executive
IACS	-	International Association of Classification Societies
ICS	-	International Chamber of Shipping
ITF	-	International Transport Federation
m	-	metre
MCA	-	Maritime and Coastguard Agency
mm	-	millimetre
SOLAS	-	Safety of life at sea (convention)
SWL	-	Safe working load
UKOOA	-	United Kingdom Offshore Operators Association
UTC	-	Universal co-ordinated time



SHETLAND ISLES
ORKNEY ISLANDS
Moray Firth
Aberdeen
Location of accident - 2
Location of accident - 1
NORTH SEA
SCOTLAND
HEBRIDES OR WESTERN ISLES
Oban
Glasgow
Edinburgh
Isle of May
Londonderry
NORTHERN IRELAND
Belfast
North Channel
Isle of Man
IRISH SEA
REPUBLIC OF IRELAND
DUBLIN
Limerick
Waterford
Cork
Fastnet Rk
Liverpool
ENGLAND
WALES
Bristol
Bristol Channel
LONDON
Southampton
Saint George's Channel
CELTIC SEA
Isles of Scilly
ENGLISH CHANNEL
CHANNEL ISLANDS
Cherbourg
Brest
PARIS
Dogger Bank
Great Sole Bank
Little Sole Bank
Rosemary Bank
Anton Dohrn Seamount
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SYNOPSIS

Dea Fighter is a safety stand-by vessel operated in the North Sea with a crew of 12. She is equipped with two davit launched fast rescue craft (FRC).

During 1999 the lifting wire of the starboard FRC davit failed twice. Once on 13 May when in Aberdeen Harbour, and again on 16 July when on station at an offshore installation. FRC occupants were injured. On each occasion the wire failed about 1m from the FRC's lifting eye.

The owners of *Dea Fighter* carried out their own investigations into the causes of the failures. As the results were inconclusive, the Marine Accident Investigation Branch (MAIB) began its own investigation on 17 September 1999.

Shortly before the first failure, an undersized top sheave was fitted to the davit arm. Apart from changing the wire geometry, this allowed the wire to be displaced from the sheave's groove and become trapped between the sheave and sideplate boss of the arm. Excessive bending of the wire also resulted. When swinging out the FRC, with the telescopic arm fully compressed, the change of wire geometry caused the wire to be grossly overloaded.

A combination of gross tensile overload, excessive local bending and crushing caused the wires to fail. The mechanism of failure was similar on each occasion.

The Maritime and Coastguard Agency (MCA) is recommended to publish standards for the FRC launching systems on board safety stand-by vessels.

It is also advised to publish advice in its system of Marine Guidance Notes, Code of Safe Working Practices for Merchant Seamen, and Instructions to Surveyors, on the importance of using replacement parts on davits and lifting gear which are to manufacturer's specifications.

The owners of *Dea Fighter* are recommended to modify their davit operator training and on-board instructions to suit the amendments made by the davit's manufacturer, Caley Ocean Systems. They are also recommended to introduce management procedures which will ensure that replacement parts for davits comply with manufacturer's specifications.

The International Association of Classification Societies (IACS), International Chamber of Shipping (ICS) and the International Transport Federation (ITF) are recommended to disseminate the lessons learned from this investigation to their members.

SECTION I - FACTUAL INFORMATION

1.1 PARTICULARS OF VESSEL AND INCIDENTS

Name	:	*Dea Fighter*
Port of registry	:	Aberdeen
Type	:	Safety stand-by vessel
Official number	:	702743
Registered length	:	53.17m
Gross tonnage	:	1022
Date and place built	:	1973, Netherlands
Construction	:	Steel
Crew	:	12
Owners	:	Nomis Shipping Ltd. 186 Albert Quay Aberdeen AB11 5QA
Position of incidents	:	Aberdeen Harbour (1) Buchan Alpha Offshore Installation (2)
Times and dates	:	1909, 13 May 1999 (1) 0748, 16 July 1999 (2)
Damage	:	None
Casualties	:	One injured (1) Two injured (2)

Note: All times quoted are UTC (BST - 1hour)

Starboard side of *Dea Fighter* showing Fast Rescue Craft, davit and wheelhouse

1.2 INTRODUCTION

Dea Fighter's FRC are launched and recovered with single arm davits. On two occasions within three months the wire rope of the starboard davit failed while launching the FRC. There were injuries to those on board the FRC.

1.3 NARRATIVE

Incident 1

Dea Fighter was at her berth in Aberdeen Harbour on 13 May 1999. A mechanic and a crewman boarded the starboard FRC at 1905 to change its quick release hook.

With the vessel's mate at the davit's controls the FRC's davit was swung out. Before the FRC was lowered, the lifting wire parted, allowing the FRC to fall about 3m to the water.

The mechanic, who had been standing in the FRC, was thrown down and suffered injuries to his right shoulder, arm and legs.

The mate hit the button of the man-overboard alarm and organised heaving lines. Medical assistance was also summoned.

Once the FRC was brought alongside the vessel's recovery area, the injured mechanic was taken to the vessel's own hospital. After examination by ambulance paramedics he was transferred to hospital ashore.

A new wire was fitted to the davit.

Incident 2

While *Dea Fighter* was at sea on 16 July 1999, off the Buchan Alpha oil installation, the starboard FRC was being launched for a crew exercise at 0825. Three crewmen were on board and the mate was at the davit's controls. Wind was south-west, force 3, with a slight sea and swell. Conditions were dry and cloudy with good visibility.

Normal launching procedures were followed until the davit arm was fully swung out. Before lowering began, the lifting wire parted, causing the FRC to fall to the water. Two of the crewmen suffered what were reported as slight injuries to their legs. The third man reported no injury.

The FRC was recovered and, following an inspection of the davit, a new wire was fitted.

The master introduced modified boarding procedures in the event of the FRC being required in an emergency.

1.4 FRC AND DAVIT ARRANGEMENTS (Figures 1 & 2)

Dea Fighter's two FRCs are located port and starboard, just aft of the wheelhouse, on hydraulically-operated luffing davits of 3.5 tonnes safe working load (SWL). Power supply for launching and recovery is from a hydraulic power unit on the aft deck, just inboard of the port funnel. This unit is started and stopped at a panel in the aft part of the wheelhouse, within sight of the davits.

The davit control stations are at the aft end of the wheelhouse deck; one station port and one starboard. Mounted on a small panel at guardrail height are three control levers arranged so the operator faces aft, giving him a good view of the respective davit and FRC. Each set of control levers serves the three basic davit operations: luffing, hoisting/lowering and auto-tensioning.

The single arm of each davit is rigid and pivots about its lower end under the control of a double-acting hydraulic ram. Mounted on the lower part of the arms is the hydraulic hoisting/lowering winch.

Also mounted on the lower part of each arm is a cradle for the stowage of the FRC. The cradle swings with the arm.

A single wire rope runs from the winch's drum over three sheaves, fixed to the arm, and then through a pendulation head before terminating in a lifting ring that attaches to the FRC's lifting hook. The manufacturer's material specification for the top sheave is *Nylatron*, a non-metallic material. The sheaves run on stainless steel pins and plain bearings.

A swivel connection within its length gives the pendulation arm limited freedom to swing in the fore and aft plane. This motion is damped by two hydraulic cylinders.

The pendulation head is suspended from a pair of swivel bearings mounted on the davit head by a telescopic element or tele-leg. These bearings allow the pendulation arm to swing in the port to starboard plane. This motion is damped by two hydraulic cylinders. The tele-leg contains no spring, either internal or external, and once fully compressed offers a positive stop.

At the lower end of the pendulation arm is a docking cradle, which guides and locates the FRC's lifting frame during recovery.

1.5 DAVIT WINCH

The davit's hydraulic system operates at a maximum pressure of 240bar. This corresponds to a theoretical maximum hauling and stall load of 4.9 tonnes. Actual loads are slightly less.

The winch's brake is applied automatically when the hoist/lower control lever is put to 'stop'. Acting alone the brake has the capability of withstanding a winch load between 1.5 and 2.5 times SWL, depending on brake pad condition.

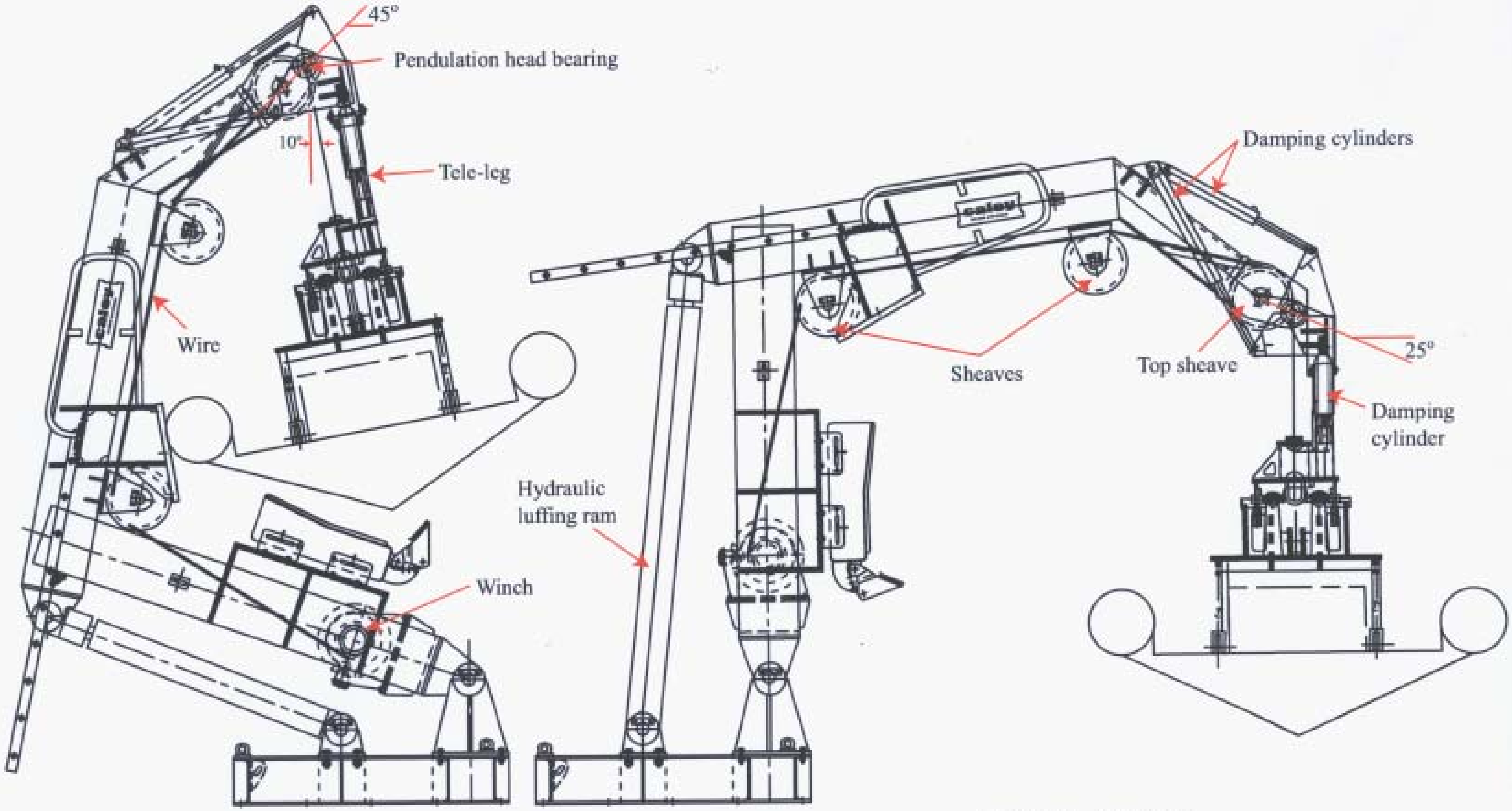


Figure 1A -Stowed

Figure 1B - Swung out

General arrangement of davit

Figure 1

Figure 2

View of starboard davit from its control station (centre foreground)

1.6 FRC LAUNCHING OPERATIONS

At sea, FRC launching and recovery operations are normally carried out with the mother vessel making way at a recommended speed of between two and four knots.

In the stowed position the FRCs are secured to their cradles with gripes. Once the gripes are clear, the FRC is hoisted slightly to clear the stowage cradle. This movement usually fully compresses the tele-leg.

A towing line, or painter, is attached between the bows of the FRC and the mother ship.

The davit is then fully swung out, through an angle of about 70°, the luffing control put to 'stop' and the winch control to 'lower'. With the FRC waterborne, its crew release the lifting hook before releasing the towing line.

Recovery is a reversal of these operations. The FRC approaches the mother vessel and its towing line is attached before connecting the lifting hook. The 'auto-tensioning' mode of the winch is selected until wave conditions are suitable to begin hoisting. Hoisting continues until the FRC's lifting frame is fully engaged with the pendulation head and the tele-leg compressed, usually fully. The davit arm is swung fully inboard, the FRC lowered slightly into its cradle and the gripes secured.

Once the FRC is stowed and fully secured, tension is removed from the lifting wire allowing the docking head to partially disengage from the FRC's lifting frame.

1.7 CREW TRAINING

Under normal circumstances only designated crewmembers are allowed to operate the davits' controls. Before becoming designated operators, crewmen are instructed in davit and launching/recovery operations. They must then demonstrate their proficiency.

Crew training and assessment is carried out by more experienced crewmembers who, in turn, were trained and assessed by their predecessors.

1.8 OPERATING INSTRUCTIONS

Copies of davit manufacturer's operating instruction, current at the time of installation, are carried on board *Dea Fighter.* These emphasise the importance of operator training, checking wires and running gear.

Any mention of compressing the davit's tele-legs during launching or recovery of FRCs, places no limit on the amount of compression.

1.9 FRC MAINTENANCE HISTORY

Until the 13 May davit wire failure, a single mechanic generally undertook FRC maintenance. He was injured during that incident. No records are available to show what work was done.

1.10 DAVIT HISTORY

The general design of this type of 3.5 tonnes SWL davit was introduced by Caley Ocean Systems in 1993. The two davits installed on *Dea Fighter* were manufactured in March 1995.

On-board routine davit maintenance such as lubrication, was recorded, and these records indicate the work was performed regularly.

Wire rope renewals were recorded in the vessel's logbook. Wire ropes were recorded as changed at regular intervals; sometimes after little more than three or four months in service.

During February 1999 a shore-based engineering contractor renewed the top sheave on the starboard davit. The original sheave was of '*Nylatron*' and 420mm overall diameter. The replacement sheave was steel and 280mm overall diameter.

1.11 DAVIT WIRE HISTORIES

The vessel's crew renewed the wire on the starboard davit at sea on 31 March 1999. The test certificate associated with this wire recorded a proof load of 10.125 tonnes and a SWL of 4.05 tonnes with a Factor of Safety (FoS) of 6:1.

The wire was renewed again on 13 May following the failure during Incident 1. This wire failed during the 16 July incident. The test certificate recorded a proof load of 8.75 tonnes and a SWL of 3.5 tonnes, also with an FoS of 6:1.

1.12 DAVIT STATUS

The davits were fitted to *Dea Fighter* to handle FRCs when she performed her duties as a safety stand-by vessel.

In 1992 the davit's basic design was submitted to The Marine Directorate of The Department of Transport (now Department of the Environment, Transport and the Regions) to obtain type approval. Following inspection of the design and witnessing of tests, a Certificate of Inspection and Test was issued on 22 March 1993. This certificate declared that the specimen examined and tested was acceptable for the purposes of *The Merchant Shipping (Lifesaving Appliances) Regulations 1986 (incorporating the SOLAS 74 convention 1983 Chapter III Amendments, and its equivalence accepted by UK).*

In 1991 the Health and Safety Executive (HSE) and Department of Transport (DoT) published a revised version of the *Code for the Assessment of the Suitability of Stand-by Vessels*. This Code was in effect when the FRC davits were installed on *Dea Fighter.*

That code was superseded in November 1997 by *Guidelines for Survey of Vessels Standing by Offshore Installations* published by UK Offshore Operators Association (UKOOA).

Neither code had statutory force. Both contained guidelines, recommendations and the standards required of a vessel operating within the offshore industry.

In the joint HSE and DoT Code, in force when the davits were installed, an FRC's launching system was required to comply with a standard not less than that required by the *Merchant Shipping (Lifesaving Appliances) Regulations 1986.*

The later UKOOA publication states in Section 5.3.2: *Each FRC should be capable of being launched while the stand-by vessel is making way and provided with its own launching system of a standard acceptable to the MCA (Maritime and Coastguard Agency.* MCA publish no guidance on the standard which is acceptable.

1.13 METALLURGICAL TESTS

In an effort to establish the cause of the wires' failures, the vessel's owners commissioned metallurgical tests on each of the failed wires. A summary of these results is:

Wire which failed 13 May

Wire length was 18m, with a diameter of 16mm. One end was fitted with a hard eye, the other was fused and tapered. The wire had failed approximately 1m from the hard eye.

A general examination showed the wire was in good condition, with little evidence of corrosion. The internal strands were well lubricated.

The fracture surfaces of several of the wire's strands were examined. The surfaces were relatively flat and essentially perpendicular to the wire axis, with little ductility or necking evident.

Hardness tests were also performed on wire material both close to, and remotely from, the fracture faces. Wire material close to the fractured ends was significantly harder than wire remote from the fractures.

As a result of these inspections and tests, it was concluded that the wire had been heated to 700°C. This heating had changed the wire's structure locally, making it susceptible to hydrogen-induced cracking/embrittlement, by which it had failed.

Wire which failed 16 July

This was a wire of 16mm diameter and had failed about 1m from the end fitted with a hard eye. The general condition of the remainder of the wire was good, with little evidence of damage by wear or otherwise. The line, including the internal strands, was well lubricated.

At the fracture, wire had necked and had some exhibited 'cup and cone' features.

Hardness tests gave values typical of a cold drawn wire.

As a result it was concluded that this wire had failed due to tensile overload.

Further metallurgical tests

In order to pursue MAIB's investigation into these accidents, the same metallurgical laboratory was commissioned to carry out further tests on the wires.

The metallurgist's written report on these further tests was not available when MAIB compiled its report on these two incidents. However, the inspector was given a brief verbal report, and has based his conclusions on this.

The essence of the metallurgist's verbal report indicated that during the initial tests performed on the first wire to fail, samples of wire strands were taken from two areas. Some were taken at the area of failure and some from a region where the wire had been fused and crimped.

A labelling error caused the sample taken from the crimped area to be recorded as coming from the area of failure. These were the strands that were tested and reported on during the initial metallurgical tests on the first wire to fail.

Because the process used for fusing and crimping requires the application of heat, it would be expected that wire strands taken from this region would show metallurgical signs of the process. Owing to the labelling error, these signs were incorrectly attributed to the region of the wire's failure.

When the first wire was re-examined in the area it had failed, no evidence of heating was displayed. It was concluded that it had failed for the same reason as the second; tensile overload.

SECTION II - ANALYSIS

2.1 REVIEW OF THE TWO FAILURES

Both wire failures occurred during the launching of an FRC, when the davit arm had been swung out, but the lowering had not yet begun.

There are other details of the davit's operation and geometry that might be considered to have contributed to the failures. They were, however, factors that were present during all, or most, of the launching operations undertaken during several years of service. This history of safe operation causes this analysis to be largely concentrated on the possible effects of having an undersized sheave fitted to the head of this type of davit.

2.2 DESIGN CRITERIA

When the davits were installed on board *Dea Fighter*, they were required to comply with the standards set out in *Assessment of the suitability of stand-by vessels attending offshore installations. The Merchant Shipping (Lifesaving Appliances) Regulations 1986* were quoted as minimum standards. This publication was withdrawn in November 1997.

The replacement publication is *Survey of Vessels Standing by Offshore Installations,* by UKOOA. FRC launch and recovery systems are mentioned in this publication, but it contains no explicit standards of the type set out in earlier documents. This publication does not make it clear whether FRC davits are required to comply with the standards of lifesaving appliances (LSA), only that they should be 'of a standard acceptable to the MCA'.

The MCA publishes no acceptable standards for these systems. This could cause confusion, uncertainty and inconsistency within the industry. The MCA should issue clear standards, which industry accepts.

2.3 METALLURGICAL EXAMINATIONS

Tests performed following the first wire failure, suggested that local heating was a factor in the failure. Efforts were initially made to identify how, when and why such heating could have occurred. These efforts were unsuccessful.

However, further examination showed that these results were incorrect and that both wires failed due to tensile overload.

2.4 WIRE BREAKING LOAD

Although of similar diameter, 16mm, the two wires which failed had slightly different SWLs assigned at 4.05 and 3.5 tonnes. Each was quoted at a FoS of 6:1 indicating breaking loads of 24.3 and 21 tonnes respectively.

These figures are for wires in new condition. Inspections of the wires at the subsequent metallurgical examinations, showed both to be in good condition and well lubricated. In the absence of any features indicating a significant deterioration in the wires' general condition after fitting, the tensile breaking loads are assumed to be as for a new wire.

2.5 WINCH LOADS

The winch's hauling capacity is related to the hydraulic system pressure. A pressure of 240bar, the normal hydraulic pressure, corresponds to a theoretical hauling load of about 4.9 tonnes. A practical figure is rather lower due to the effects of frictional losses. The maximum figure is significantly less than the breaking load of either of the two failed wire ropes.

When the winch is stopped, its brake is applied automatically. The expected holding capacity of the brake is between 1.5 and 2.5 SWL (5.25 and 8.75 tonnes), depending on the condition of the friction surfaces.

These figures for hauling and braking capacity indicate that, even with these loads applied together and summated, the winch is unable to resist a load equal to the breaking load of the wires. It would be expected to slip.

At loads corresponding to the properties of new wires, the winch could not have generated sufficient load to produce a tensile overload failure. Neither could the winch have withstood the application of such loads without rotation, or slip.

2.6 EFFECTS OF OPERATION ON WIRE LOADING

If an FRC is launched or recovered with the tele-leg of the davit only partially compressed, the wire loading will be the sum of the FRC's gross weight, plus the tele-leg's weight. This will be comfortably within the system's SWL of 3.5 tonnes. This will be true, even with an undersized top sheave fitted.

However, if launching is performed with the tele-leg fully compressed before the davit starts its swing out, the load in the wire will initially be that which is induced by the winch.

As the davit arm is swung out, this wire load can be increased by the tele-leg attempting to stretch the wire slightly. This effect will exist to a limited degree even with the correct size top sheave fitted. However, the smaller the sheave below designed diameter, the greater this stretching effect will be.

If the designed geometry of the davit head and top sheave is maintained, the induced extra load is kept within design limits, and is considered by the manufacturers to be normal. Departure from this geometry, due to an undersize top sheave, has the potential to induce wire loads greater than design value.

2.7 NORMAL WIRE LOADING

With the davit's arm in the inboard position and the weight of the FRC just taken by the wire, both the tele-leg and the length of wire between the top sheave and the FRC's hook will be about 10° from the vertical **(see Figure 1A)**.

In swinging out to the extreme outboard position, the davit arm will rotate about 70°. However, because of their initial inclination of 10°, the tele-leg and the wire from the FRC's hook will rotate only 60° relative to the davit arm **(see Figure 1B)**.

This relative motion has two results **(Annex A & B)**. Firstly, the 60° rotation of the top sheave causes wire to be unwound from the sheave over a 60° arc. This effectively increases the length of wire leading from the sheave to the FRC's hook. Secondly, the support bearing of the tele-leg, by also following a similar 60° arc, is lowered relative to the sheave axis.

The ends of the wire and tele-leg are effectively connected and, if the length of wire unwound from the sheave equals the lowering of the tele-leg bearing, there is no tendency for these ends to separate.

However, these two dimensions do not exactly match.

When a correctly dimensioned wire of 16mm and top sheave of 350mm are fitted to the davit, the amount of wire unwrapped from the top sheave when swinging out the davit, will be about 191.6mm. The corresponding relative downward movement of the tele-leg bearing will be about 203.2mm. This gives a net relative movement of 11.6mm at the connection between the wire's end and tele-leg. However, as these two points are intended to remain in contact there is no relative movement, and the difference has to be accommodated in other ways.

If the swinging out operation begins with the tele-leg only slightly compressed, this difference is easily accommodated by the tele-leg compressing a few extra millimetres.

Conversely, if the operation begins with the tele-leg fully compressed, the difference must be accommodated by a combination of wire stretching and compression of elastic components in the tele-leg system; particularly the rubber landing pads between the docking collar and the FRC's lifting frame.

The limiting, or maximum extra load induced in the wire by this effect may be estimated by neglecting any elasticity of the tele-leg system, and assuming that the total 11.6mm difference is taken by the wire stretching. This will induce a strain, corresponding stress and load of about 2.7 tonnes in the wire over and above that present when the swinging out operation began. This figure may be reduced by the elasticity of the system, giving an estimated resultant wire stretch between 5mm and 7mm. This corresponds to wire loads of 1.162 tonnes and 1.627 tonnes, if it is assumed that wire stretch is uniformly distributed over its length between winch and tele-leg.

This load would be superimposed on any winch-induced load generated when hauling, until the tele-leg is fully compressed in the inboard position. If the winch is hauled in to its theoretical capacity of 4.9 tonnes before swinging out the davit arm, a maximum wire load of 7.6 tonnes (the motor's hauling capacity of 4.9 + 2.7) would be induced. More probably, the load would be less than this figure due to the system's elasticity. Again, even the maximum possible load is very much less than the breaking load of the wire.

When a Factor of Safety of 6 (which is the figure for a davit required to comply with SOLAS standards) is applied to the wires, this load exceeds the SWL of each of the failed wires on *Dea Fighter*. It should also be noted that even when only the minimum wire stretch of 5mm is taken as applicable, the sum of the initial winch load (4.9 tonnes) plus the effect of the induced strain (1.162 tonnes) produces a load of 6.062 tonnes. This exceeds the SWL assigned to the two wires that failed (4.05 and 3.5 tonnes).

2.8 POTENTIAL WIRE LOADING WITH UNDERSIZE TOP SHEAVE

With the undersized top sheave fitted, a similar loading mechanism is present, but the magnitude of the potential loading is greater **(Annex A & C)**.

When the davit swings outboard, the tele-leg bearing will still move down by approximately 203mm. However, with a sheave having an effective diameter of 262mm, only about 145.56mm of wire will pay off the sheave as it rotates through 60°.

There is then a difference of 57.64mm to be accommodated. Again assuming all of this difference is taken by the wire stretching uniformly between winch and tele-leg, the corresponding wire load will be approximately 13.4 tonnes.

This load is less than the breaking load of a wire in good condition, but is greater than the winch could be expected to withstand without slip.

The undersized sheave results in an overload being generated in the wire. Although repeated loading of this magnitude might reduce the working life of the wire, the load would be insufficient to cause failure. Further, it would most probably result in the winch slipping slightly, itself having the effect of reducing the wire's loading.

2.9 OTHER CONSEQUENCES OF FITTING AN UNDERSIZE TOP SHEAVE

In addition to the mechanism mentioned above, there are other potential problems generated when undersized wire sheaves are fitted to lifting gear.

A smaller diameter sheave may have a correspondingly shallow groove. This increases the chances of the wire slipping from the groove. This type of failure is particularly likely as the sheave is the last one before the hook, and the hook can swing.

A sheave that is narrower than specification offers increased clearance between its flanks and any adjacent sideplates of the davit arm. This may give enough room for the wire to slip between sheave and sideplates. The wire will almost certainly be damaged and the lifting gear is, at least temporarily, out of service. Several effects are possible:

- After slipping from the sheave, the wire is then supported by the sheave's bearing pin or centre boss. These, relative to the sheave, are very small in diameter and, if the wire is under tension, will have a similar tensile load magnification effect as using a sheave having a diameter which is too small.

- Running over the pin, the wire will be subjected to far greater bending effects than when running on a sheave.

- With the wire resting on the sheave's non-rotating pin, large friction forces may be generated between a loaded wire and the pin. This can produce a large difference in wire force either side of the pin.

- The limited side clearance between the bosses on sheave and sideplate provides a space in which the wire can be trapped.

The smaller the sheave diameter, the greater the bending effect on the wire as it passes over the sheave. Bending may affect the fatigue life of the wire and the greater the bending, the shorter the fatigue life. Premature failure requiring wire replacement is the likely result.

A groove which is too narrow for the wire diameter can lead to the wire being pinched. Although this may not generate an immediate danger, the rope's working life can be reduced due to the resulting wear.

Because the smaller sheave altered the run of wire between top and second sheave, this allowed the wire to foul the davit's structure, causing wear of both the structure and the wire.

The fitting of an undersized top sheave on *Dea Fighter* indicates a lack of appreciation of some of the fundamentals of lifting equipment. Such a fitting poses several potential dangers, many of which should be common knowledge to maintainers and repairers of lifting gear.

2.10 FRC STOWING PROCEDURE

Following recovery of an FRC, it is normal procedure on *Dea Fighter* to secure the FRC in its cradle and allow the davit's wire to slacken. The degree of wire slack is not known, and cannot be easily monitored, but is sufficient to allow the docking head on tele-leg to partially disengage from FRC lifting frame. The amount of slack wire generated is unlikely to be consistent between recovery operations, but has been recorded as being sufficient to allow the wire to ride over the sides of an undersized top sheave **(see Figure 3)**.

Figure 3

View of slack wire, clear of undersized top sheave

This practice has little significance when the correct size top sheave is fitted. However, the smaller sheave fitted is sufficiently narrow to allow the wire to drop from sheave's groove when slack is removed during the next launching operation. The wire may then be unable to regain its proper position on the sheave until the FRC is next recovered, and even then would probably require manual assistance.

The combination of this stowing procedure, and undersized top sheave, gives a mechanism for the wire to slip from the top sheave and into the gap between the bosses of the sheave and sideplate while launching an FRC. The wire may then be trapped at this point.

2.11 EFFECTS OF TRAPPED WIRE

There are several potential consequences of trapping the wire between the top sheave and its sideplate:

- The wire attempts to run over the comparatively small diameter of the sheave pin (60mm), so inducing large local bending stresses
- This small diameter replicates, and even amplifies, the load inducing effects of running the wire over a small diameter top sheave
- The wire is prevented from sliding easily by wire spread, crushing and squeezing between the boss of the sheeve and sideplate
- The wire will be weakened at this point by crushing and squeezing
- Wire load at the lifting eye will not be fully transmitted back to the winch.

The net result would be a mechanism which:

1. Overloads the wire if the tele-leg has insufficient compression
2. Weakens the wire at the point where it passes over the top sheave's axis, about 1m from the lifting eye, and
3. Prevents an overload from being transmitted to the winch to cause slip and reduction in wire load.

2.12 CAUSES OF WIRE FAILURES ON *DEA FIGHTER*

With the undersized top sheave fitted to the davit, launching an FRC with the davit's tele-leg fully compressed has the potential to overload the davit wire because of the stretch induced in the wire.

If this stretch is approximately evenly distributed along the length of wire off the winch drum, just over 6m, the stress induced is much less than the breaking stress of a wire in good condition. Although the working life of the wire might be reduced, no immediate failure is likely.

With the wire running on the sheave pin, of 60mm diameter, the amount of wire stretch is potentially much increased to 163.41mm **(Annex A & D)**.

Should all of this stretch be distributed over the length of wire between the winch and the lifting eye, the potential load is about 37.9tonne. This is clearly impossible as this load significantly exceeds the wire's breaking load. The wire would fail before this load was reached.

However, the large but indeterminate trapping force on the wire would be expected to prevent easy movement of the wire over the pin, and produce a tendency for concentrating the stretch into the 1m length between davit head and lifting eye. Also, forces sufficient to cause the winch to slip might not be transmitted beyond the pin. As a result, winch slip is not an essential symptom of the failures. None was reported during either failure.

During the two launching operations, wire slack was taken up by hoisting the winch. However, the wire had slipped from the top sheave and was trapped in the gap between sheave and sideplate bosses, effectively attempting to run on the pin. As the davit arm swung out, the adverse wire geometry at the davit head generated an increasing load and corresponding stretch in the wire. Because the wire was trapped beside the top sheave, insufficient of this stretch, or overload, was transmitted to the winch to cause it to slip.

The wire was also weakened at the trapped point due to crushing, squeezing and bending, about 1m from the lifting eye, and the overload reached a value where it was enough to cause a local tensile failure.

It is this mechanism that is considered to have caused both wire failures.

The gross tensile overload in the wires might have been prevented only if sufficient compression remained in the tele-leg before the davit arm was swung out, ie greater than 163.41mm. However, owing to the localised bending and crushing of the wires on the sheave pin, failure would still have been highly likely, although not necessarily during the first operation under these conditions.

2.13 OPERATING PROCEDURES

The practice of fully compressing tele-legs on this type of davit during launch and recovery of FRCs is common on vessels operating in the offshore industry.

Although the practice has the potential to overload the davits' wires beyond their SWL, even when fitted with correctly dimensioned components, the degree of overload is most unlikely to be sufficient to cause or significantly contribute to a catastrophic failure.

Consideration of the primary function of these davits suggests a reason for the development of this practice. It is a requirement that a stand-by vessel's FRC responds to a casualty in the water within time limits which are dependent on whether the vessel is on 'close standby' or not. These standards can require an FRC to be in a position to recover the first casualty within 4 minutes of the alarm sounding.

These time limits clearly place an emphasis on speed of launching, rather than sympathetic handling of the davit and its machinery. When a stand-by vessel is launching an FRC to recover casualties, this urgency is understandable, even commendable. However, the practice is likely to spill over into all FRC launching operations, with consequent reductions in the working lives of load bearing components, particularly wires and lifting hooks. Increased levels of maintenance are then required. Following davit manufacturer's most recent recommendations on operating procedures may have the benefit of reducing some of these maintenance requirements.

2.14 OPERATING INSTRUCTIONS AND TRAINING

The tele-legs are important flexible elements in the davits, capable of limiting shock and tensile wire loadings. The manufacturers have clearly stated in their instructions for recently built units, the conditions under which the legs should not be fully compressed.

The davit operating instructions on board *Dea Fighter* imply that full compression of the tele-legs during launching and recovery is acceptable. Such practice effectively disables these units. Their shock absorbing properties are lost, together with their ability to prevent wires being loaded beyond the SWL.

This implication should be removed by amending the on-board instructions to reflect the manufacturer's latest advice.

2.15 MAINTENANCE AND MANAGEMENT

A number of indications suggest that the requirement for extra maintenance was recognised, at least to some degree. The history of regular wire replacement, routine lubrication and general condition of the davits' supports this view. However, this recognition did not extend to understanding the likely implications of departing from the manufacturer's specifications for the top sheave. The owners should, therefore, introduce management procedures to ensure that replacement parts of davit systems comply with original equipment specifications.

With their potential for generating excessive load in the wire, some of the implications of an undersized sheave on the davit head geometry require an intimate understanding of this particular davit's design. But awareness of the general dangers alone should be enough to discourage the fitting of an undersize top sheave.

Had some of the fundamental principles associated with the maintenance of lifting gear been understood and applied, the undersized sheave would probably not have been fitted to *Dea Fighter*, and the two wire failures would have been avoided.

The owners of *Dea Fighter* appointed a local engineering contractor to carry out repairs, namely, fitting a new top sheave. It is common to expect a reasonable level of expertise from contractors who claim proficiency in specialised areas of work. However, a vessel's owner must take responsibility for any work done and, to that end, his management system needs to be capable of ensuring work is performed to his requirements. In this instance, the vessel's managers had not identified the fitting of an incorrect component to a safety critical system.

The owners should make any modification necessary to ensure their vessel management system is able to perform the function of specifying and auditing the supply and installation of components to safety critical systems.

Many users of this type of davit might overlook the significance of the change in top sheave diameter. Therefore, the importance of using replacement parts which comply with manufacturer's specification should be emphasised to the industry.

With regard to lifting equipment and their *Code of Safe Working Practices for Merchant Seamen, Instructions to Surveyors* and *Marine Guidance Notices*, the MCA should consider including advice on the importance of using replacement parts which comply with the specification of manufacturers of the original equipment.

The lessons from this investigation should also be distributed to international bodies associated with shipping safety.

SECTION III - CONCLUSIONS

3.1 FINDINGS

1. The lifting wire on the starboard FRC davit of *Dea Fighter* failed on two occasions during 1999. Once on 13 May, when in Aberdeen Harbour, and once on 16 July, with the vessel on station at an offshore installation. [1.3]

2. Shortly before the first incident, the top sheave of the davit was replaced by an item having incorrect dimensions. It was too small in diameter, and not of manufacturer's recommended material. [1.10]

3. Except for the fitting of an incorrect top sheave, davit maintenance was satisfactory. [1.10, 1.11]

4. On each occasion the wire failed about 1m from the FRC's lifting eye, coincident with the davit's top sheave. [1.13]

5. Both lifting wires were in good condition before their failures. [1.11, 2.4]

6. Both wires failed due to tensile overload. [1.13, 2.3]

7. The davit's winch could not have generated sufficient load in the wires to cause simple tensile failure. [2.5]

8. The winch could not have withstood a wire load sufficient to cause simple tensile failure without slipping. [2.5]

9. Normal launching procedures resulted in the davit's tele-leg being fully compressed. This has the potential to increase the load in the lifting wire beyond the weight of the rescue boat plus its crew. [2.6, 2.7]

10. Normal launching procedures, with a correctly dimensioned top sheave, did not generate a sufficient overload to cause the wires' failures. [2.6, 2.7]

11. Normal launching procedures, with correctly dimensioned top sheave but with the tele-leg fully compressed, have the potential to induce wire loads exceeding their SWL. [2.7, 2.13]

12. The wire geometry was upset by the use of the undersized top sheave. [2.9]

13. Wire loading can be amplified when using an undersized top sheave. [2.8]

14. Normal FRC recovery and stowing procedures allow the lifting wire to slacken. [2.10]

15. Prior to the attempted launchings on 13 May and 1 July, the slack wire slipped between the top sheave and a sideplate, where it was trapped. [2.10]

16. Wire failure was caused by the trapped wire being overstrained as the davit was swung out. [2.11, 2.12]

17. Additional local effects of bending and crushing caused the failure to occur where the wire passed over the top sheave's pin. [2.11, 2.12]

18. Failure might not have occurred on these occasions if the tele-leg had not been fully compressed before the davit was swung out. However, eventual wire damage was likely due to bending and crushing. [2.12]

19. On-board instructions implied that operating the davit with the tele-leg fully compressed was acceptable. [2.14]

20. The MCA publishes no standards against which FRC davit systems should be assessed. [2.2]

3.2 CAUSES

Immediate causes

The davit wires failed due to overloads generated by the consequences of the wires having slipped from the top sheave and becoming trapped in the adjacent space. [2.12]

The wire slipped from the sheave because the sheave's diameter was significantly less than the manufacturer's specification. [2.12]

Underlying causes

A lack of understanding of the general principles and dangers associated with fitting undersized wire sheaves to lifting plant. [2.9, 2.15]

The lack of a vessel management system able to identify the fitting of a safety related component that significantly deviated from the manufacturer's specification. [2.15]

SECTION IV - RECOMMENDATIONS

The Maritime and Coastguard Agency is recommended to:

1. Publish standards for the FRC launching systems on board safety stand-by vessels [2.2]

2. Include advice on the importance of using replacement parts on lifting equipment which comply with equipment manufacturer's specification in:

Code of Safe Working Practices for Merchant Seamen
A Marine Guidance Notice
Instructions to Surveyors [2.15]

The owners of *Dea Fighter* are recommended to:

3. Modify their davit operator training and on-board instructions to suit the amendments made by Caley Ocean Systems to their instructions for the operation of these davits. [2.14]

4. Introduce management procedures to ensure that replacement parts of davit systems comply with original equipment specifications. [2.15]

The International Association of Classification Societies (IACS), International Chamber of Shipping (ICS) and the International Transport Federation (ITF) are recommended to:

5. Make the lessons from this investigation known to their members. [2.15]

Marine Accident Investigation Branch
December 2000

ANNEX A

Geometry of davit head

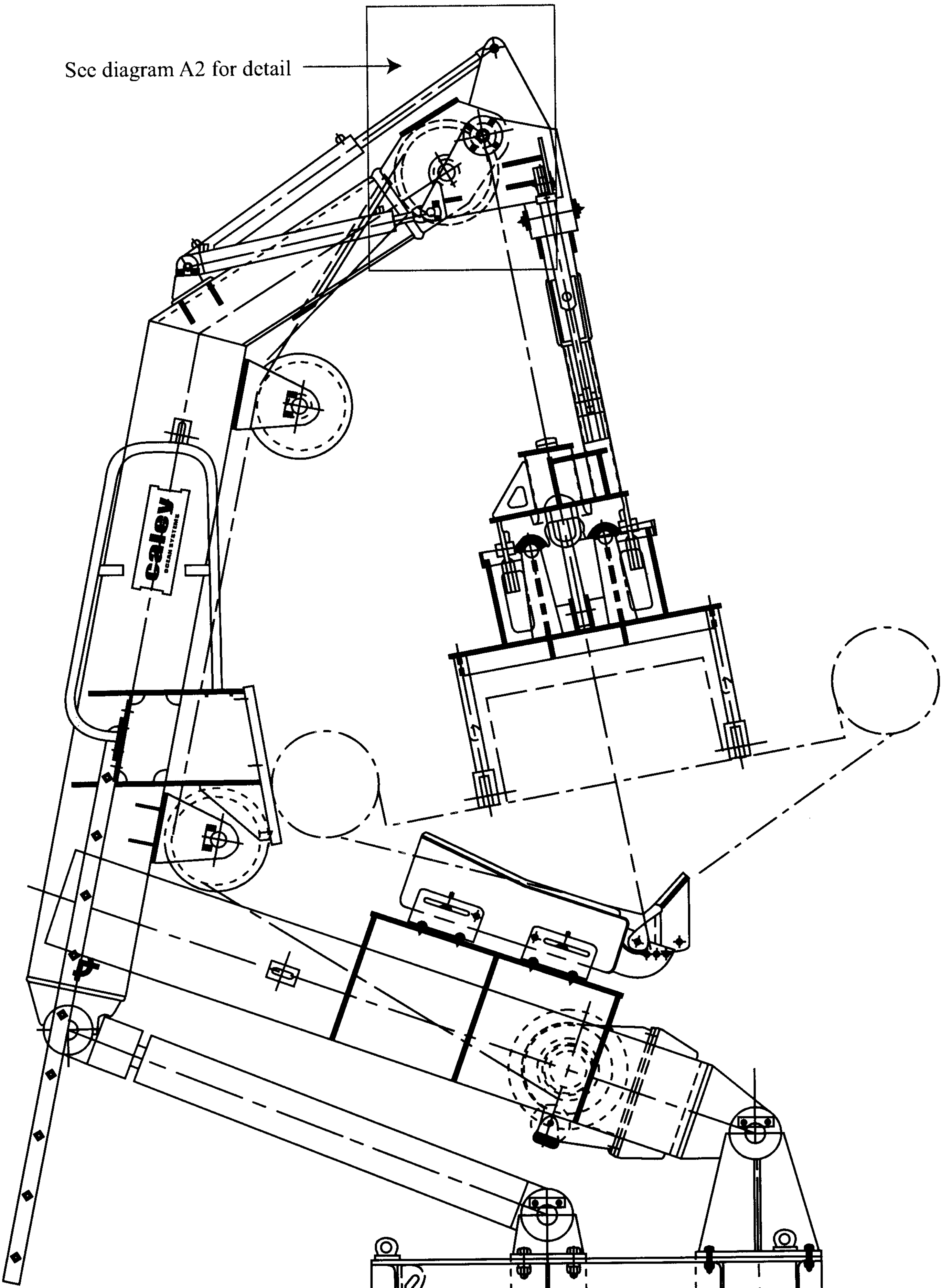
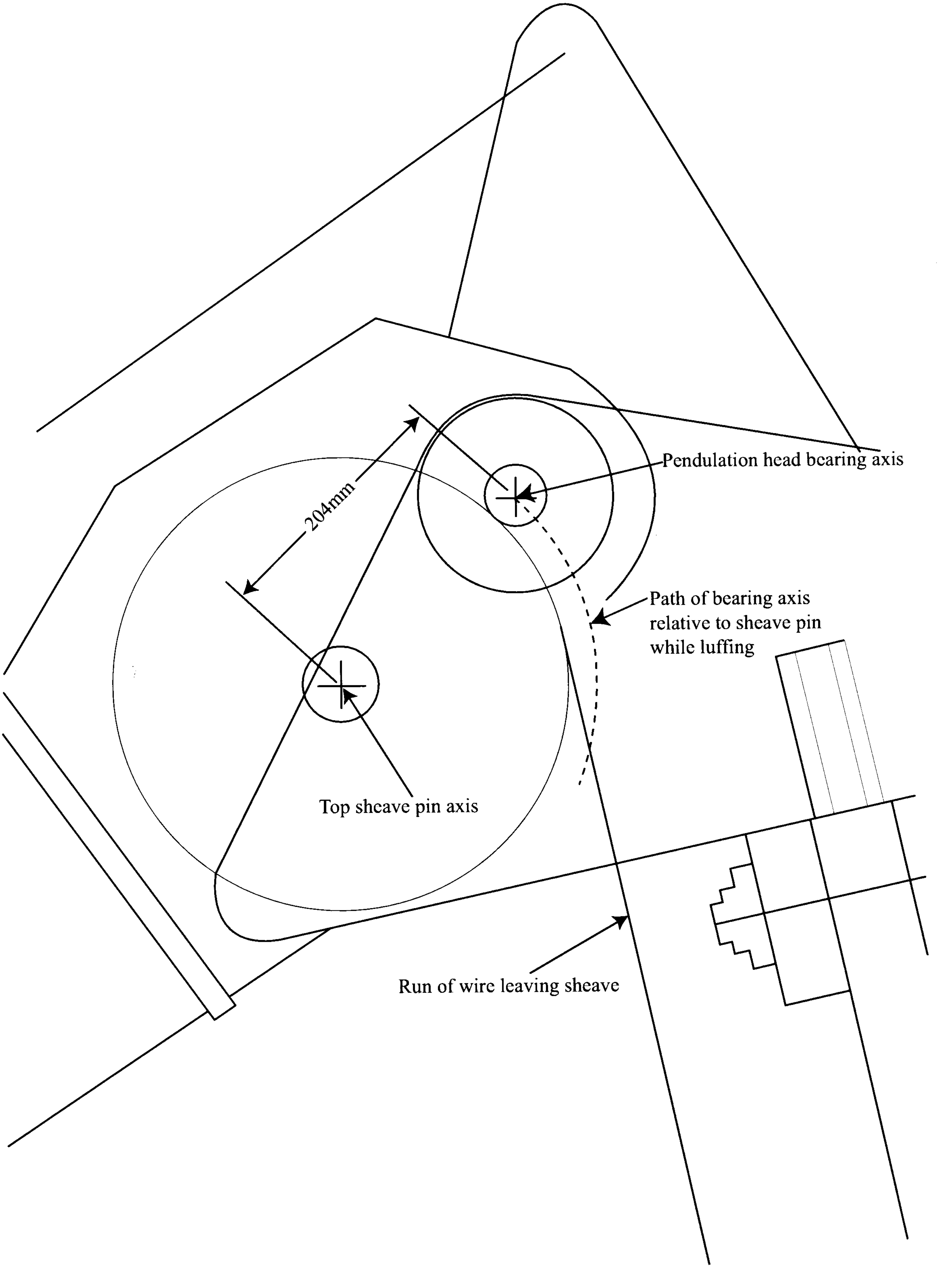


Diagram A1

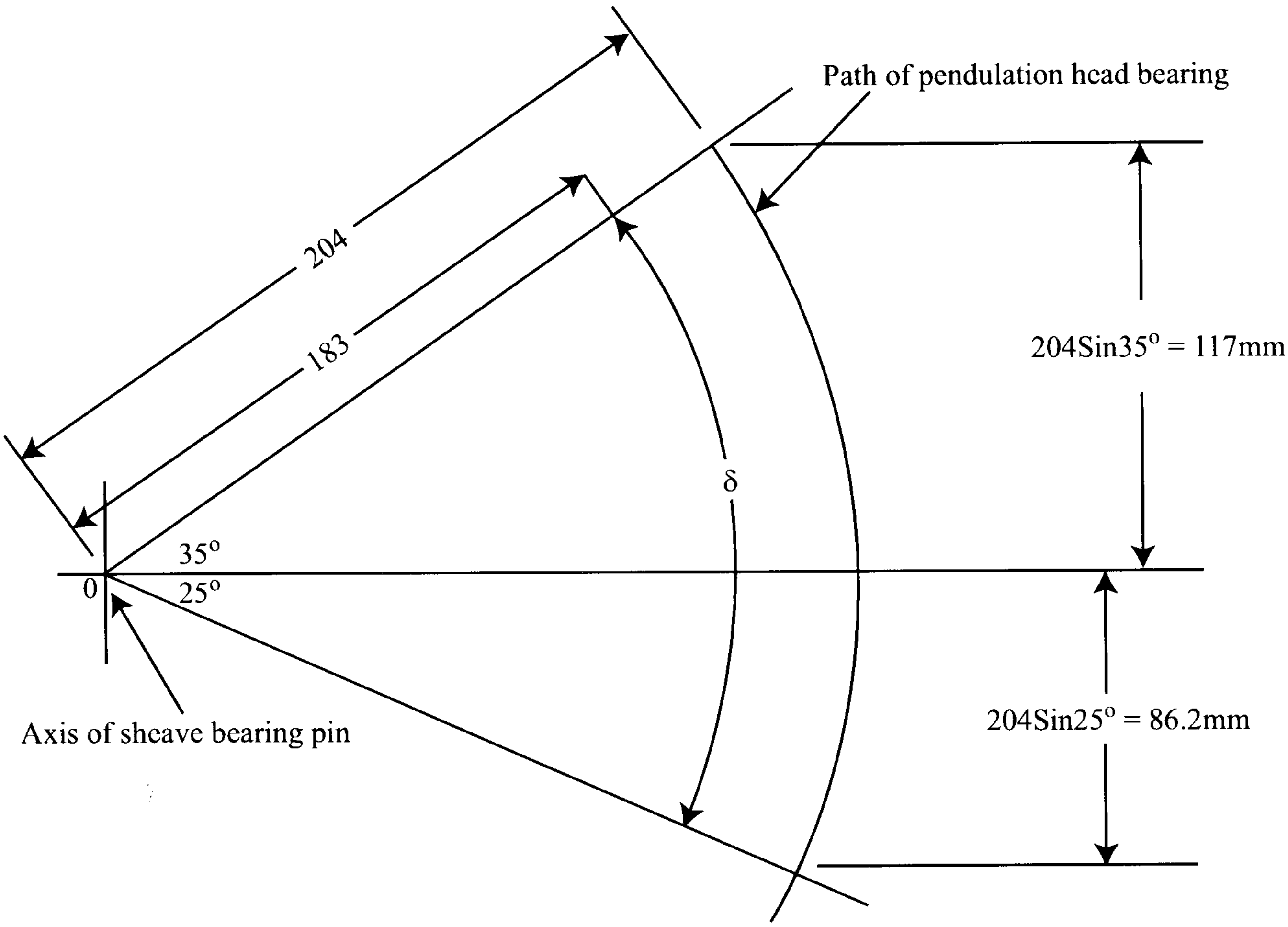


204mm
Pendulation head bearing axis
Path of bearing axis
relative to sheave pin
while luffing
Top sheave pin axis
Run of wire leaving sheave

Diagram A2

ANNEX B

Calculation of relative movement of wire and tele-leg and effect on wire load when swinging out davit. Correct sheave fitted.



Wire run off sheave of 183mm effective radius $\delta = \frac{183(35^\circ + 25^\circ)2\pi}{360^\circ} = 191.6\text{mm}$

Relative to axis of sheave bearing pin;
pendulation head bearing drops 117 + 86.2 = 203.2mm
length of wire run off sheave = 191.6mm
difference = 11.6mm

Annex B - Relative movement of wire and pendulation head (correct sheave diameter)

Assuming strain is uniformly distributed over wire length between lifting eye and winch (6.225m)

$$\text{Strain } e = \frac{11.6 \times 10^{-3}}{6.225}$$

Load P = EeA   Where E = Young's Modulus for wire
A = Area of Cross Section

$$P = \frac{70.632 \times 10^{9} \times 11.6 \times 10^{-3} \times 201 \times 10^{-6}}{6.225}$$

P = 26.255kN = 2.696 tonnes = 2.7 tonnes

If stretch is only 5mm

$$P = \frac{70.632 \times 10^{9} \times 5 \times 10^{-3} \times 201 \times 10^{-6}}{6.225}$$

$P \approx 1.162$ tonnes

If stretch is only 7mm

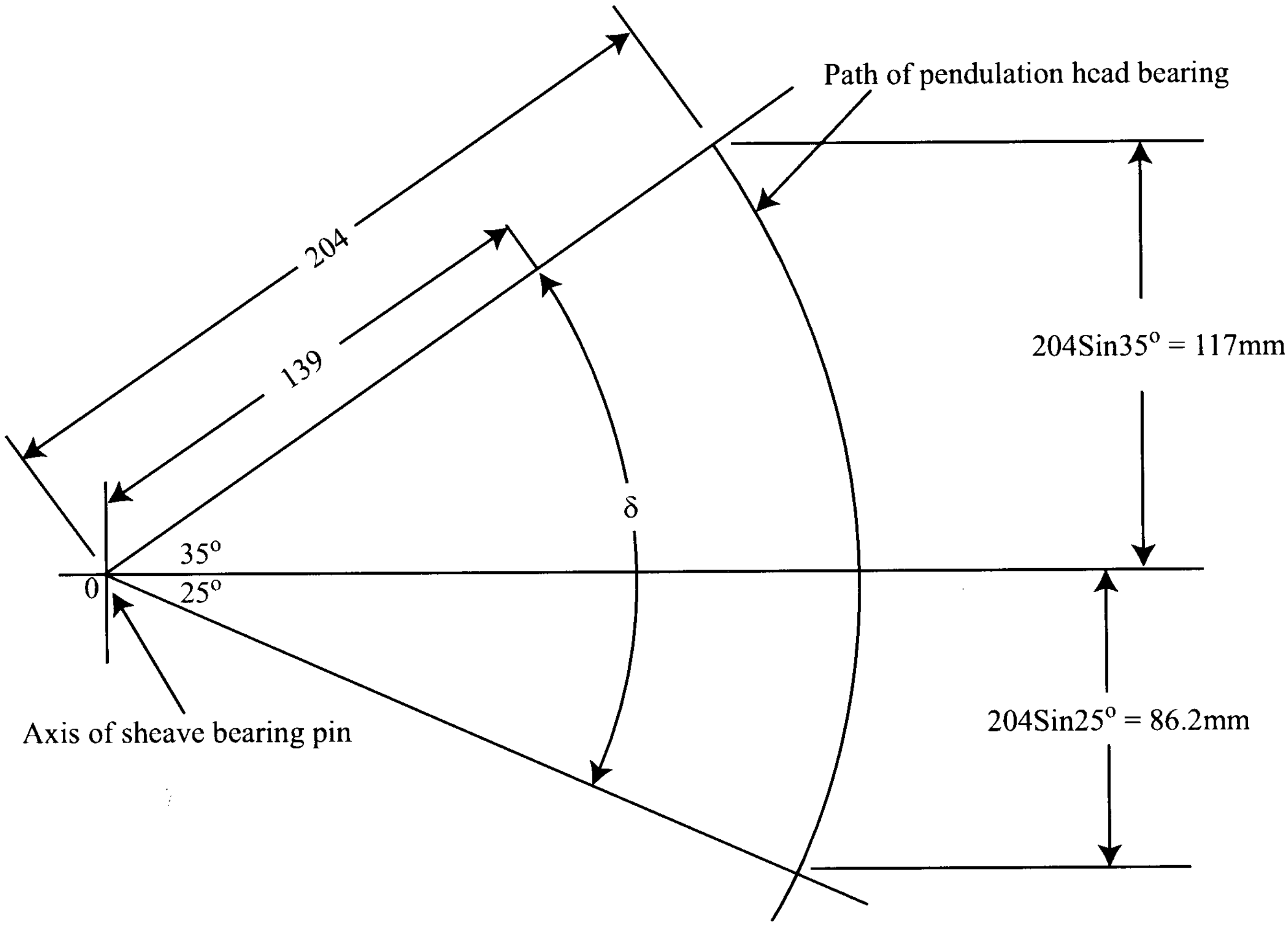
$$P = \frac{70.632 \times 10^{9} \times 7 \times 10^{-3} \times 201 \times 10^{-6}}{6.225}$$

$P \approx 1.627$ tonnes

Calculation of maximum strain-induced wire loading with correct sheave fitted.

ANNEX C

Calculation of relative movement of wire and tele-leg and effect on wire load when swinging out davit. Undersize sheave fitted.



Wire run off sheave of 139mm effective radius $\delta = \frac{139(35^\circ + 25^\circ)2\pi}{360^\circ} = 145.56mm$

Relative to axis of sheave bearing pin;

pendulation head bearing drops 117 + 86.2 = 203.2mm

length of wire run off sheave = 145.56mm

difference = 57.64mm

Annex C - Relative movement of wire and pendulation head (undersized sheave fitted)

Strain $e = \frac{57.64 \times 10^{-3}}{6.225}$

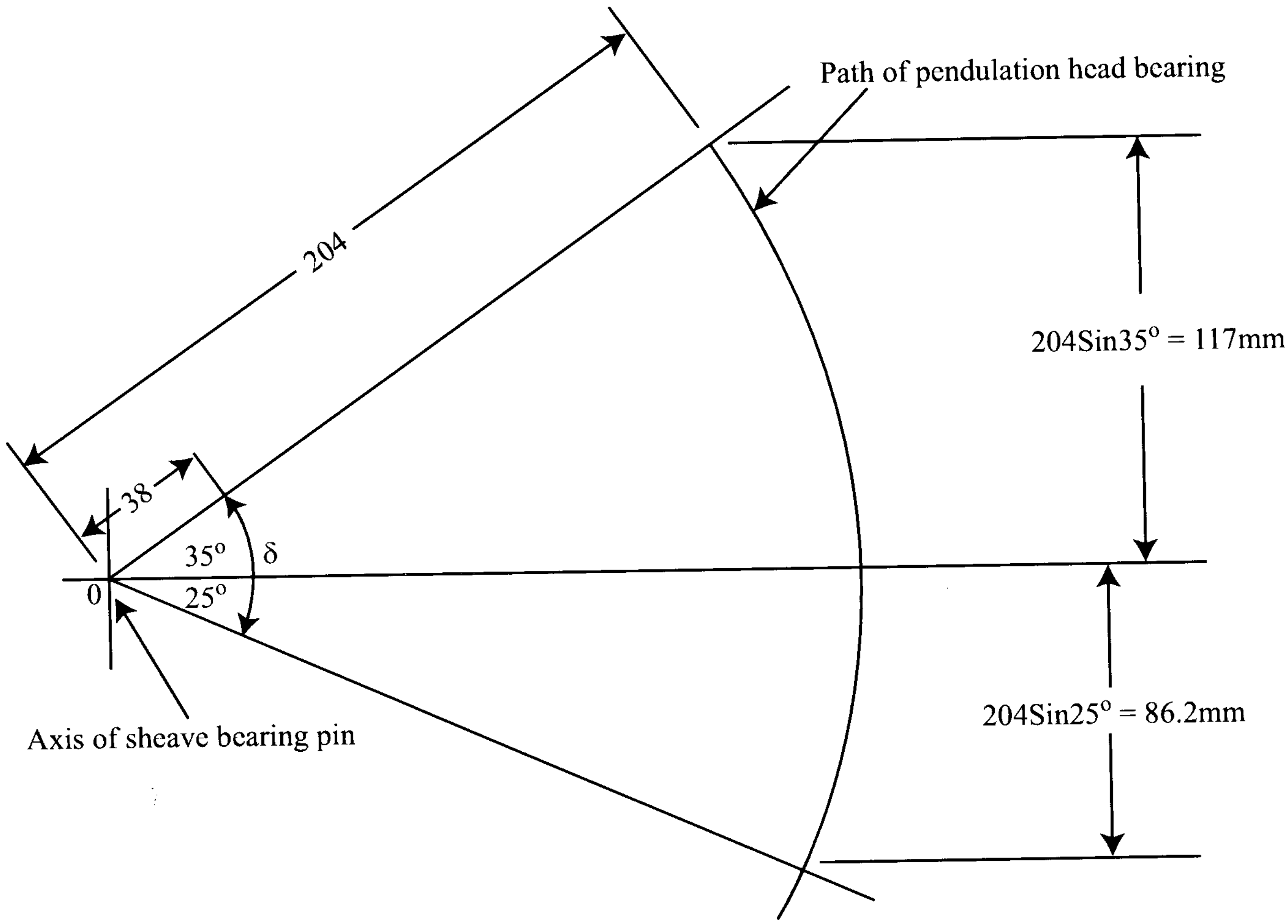
$$P = \frac{70.632 \times 10^{9} \times 57.64 \times 10^{-3} \times 201 \times 10^{-6}}{6.225}$$

$P = 131.45kN \approx 13.4$ tonnes

Calculation of maximum strain-induced wire loading with undersized sheave fitted. (Wire in groove of sheave)

ANNEX D

Calculation of relative movement of wire and tele-leg and theoretical effect on wire load when swinging out davit. Wire slipped and running on sheave pin.



Wire run off sheave pin of 38mm effective radius $\delta = \dfrac{38(35^\circ + 25^\circ)2\pi}{360^\circ} = 39.79\text{mm}$

Relative to axis of sheave bearing pin;
pendulation head bearing drops 117 + 86.2 = 203.2mm
length of wire run off sheave = 39.79mm
difference = 163.41mm

Annex D - Relative movement of wire and pendulation head (wire passing over sheave pin)

$$\text{Strain } e = \frac{163.41 \times 10^{-3}}{6.225}$$

$$P = \frac{70.632 \times 10^{9} \times 163.41 \times 10^{-3} \times 201 \times 10^{-6}}{6.225}$$

$P = 372.7kN \approx 37.9$ tonnes

Calculation of maximum strain-induced wire loading with wire passing over top sheave pin.