Annex A

Laboratory examination and failure analysis of the gantry crane wheel securing bolts

LABORATORY REPORT

LABORATORY EXAMINATION AND FAILURE ANALYSIS OF M16 GANTRY CRANE WHEEL SECURING BOLTS FROM THE VESSEL BLUE NOTE

For: Marine Accident Investigation Branch
Mountbatten House
Grosvenor Square
Southampton
SO15 2JU

This Report Comprises:

Title Page: 1
Text Pages: 1 to 9
Figure Sheets: 1 to 28
Appendices: 1 and 2

UKAS DISCLAIMER

This project includes tests and examinations, some of which were completed against UKAS accredited procedures. The scope of laboratory accreditation does not, however, include the analysis of test data or the offering of professional opinions.

LABORATORY REPORT

LABORATORY EXAMINATION AND FAILURE ANALYSIS OF M16 GANTRY CRANE WHEEL SECURING BOLTS FROM THE VESSEL MV BLUE NOTE

For: Marine Accident Investigation Branch
Mountbatten House
Grosvenor Square
Southampton
SO15 2JU

THE TEST HOUSE (CAMBRIDGE) LTD REFERENCE: T11285
RECEIPT DATE: 3rd and 8th August 2011
INSTRUCTION DATE: 9 August 2010
PURCHASE ORDER NUMBER: 8000093637
REPORT DATE: 8 September 2011

1. INTRODUCTION

The laboratory was initially provided with the cap head end fracture half of two bolts on 3rd August (Figures 1 to 5 inclusive). After discussions with MAIB, during which we identified the possibility that there could be two different failure mechanisms in the samples received, a further sixteen threaded end fracture halves and eight unfractured bolts were provided to the laboratory on 8th August (Figures 6 and 7). The collective bolt sample set was received unidentified in respect of which wheel unit individual bolts or fracture halves had come from. Similarly, the bolts and fracture halves were not identified in respect of their precise location within the mechanically connected joints.

The bolts were reported to be from a ship's gantry crane, which in service was used to lift the vessels hatch covers. The crane had a total of four wheel units, which were located forward and aft of each corner of the crane. The wheels were attached to the crane via a flanged joint which was secured by a total of eight of the subject bolts.

The laboratory was not made aware of the bolts size, specification or strength grade and Test House (TH) had, consequently, provided for verification of the bolts dimensional and strength grade attributes as part of the laboratory work scope.

The samples provided were examined in the TH metallurgical laboratory as follows.

2. SAMPLE MATERIAL AND RECEIPT INSPECTION

2.1 Samples Received 3rd August

This sample set comprised two cap head end fracture halves, both of which had fractured in the threaded section (Figure 1). One exhibited a shear like fracture at 45^{0} to the bolts principal axis (Figure 2) and its fracture surface was seen to be quite rusted (Figure 3). The second bolt exhibited what potentially looked like a fatigue fracture, which was orientated at 90^{0} to the bolts principal axis (Figure 4). The fracture surface of this second bolt also exhibited evidence of moderate rusting (Figure 5).

2.2 Samples Received 8th August

This second sample set comprised eight unfractured bolts and sixteen threaded end fracture halves (Figure 6 and 7), two of which exhibited saw cut end faces (Figure 7).

The unfractured bolts had an overall length of 80.7mm and a combined plain shank and threaded length of 65mm. The thread was confirmed to be standard metric M16 x 2mm pitch. Heads of the bolts exhibited hard stamping marks (Figure 8), which were taken to signify that the bolts were of strength grade 8.8. The plain ends of some bolts exhibited traces of prior zinc or cadmium like plating (Figures 9 and 10). In the main any prior protective plating had long since corroded away and the bolt surfaces exhibited significant general rusting and pitting corrosion (Figures 11 and 12).

Like the two samples received originally, the larger sample set also exhibited fractures that appeared to be of two generally different kinds (Figures 13 to 21 inclusive). Ten fracture halves exhibited what appeared to be fatigue fractures (Figures 13 to 17 inclusive) and four exhibited what appeared to be largely ductile shear type fractures (Figures 18 to 21 inclusive). The fracture surfaces in both classes of fracture exhibited variable degrees of post fracture surface rusting (Figures 13, 14, 15, 18 and 19), which suggested that some of the fractures may have been of some age and could have pre-dated the current casualty.

Two fracture halves exhibited bright freshly sawn ends (Figure 7) and the prevailing fracture type in these two items could obviously not be established.

To facilitate a more detailed fractographic examination, examples of bolts from each of the two visually different fracture types were cleaned in Clarke solution (Figures 16, 17, 20 and 21).

3. DETAILED FRACTOGRAPHIC EXAMINATION

The cleaned fracture surfaces were examined via both an optical stereo microscope and a Scanning Electron Microscope (SEM).

The samples exhibiting fractures that were orientated 90^0 to the bolts principal axis (Figures 16 and 17) exhibited features consistent with fatigue cracking over most of the fracture surface and only very small terminal ductile shear regions were apparent (Figures 22 to 32).

The samples exhibiting fractures at 45^0 to the bolts principal axis (Figures 20 and 21) exhibited features consistent with ductile shear type fracture (Figures 33 to 40). Some fractures in this population also exhibited evidence of some possible prior fatigue cracking.

Some regions of the fracture surfaces exhibited evidence of post fracture general corrosion damage and local pitting corrosion, suggesting again that some of the fractures may have been of some age and possibly pre-dated the current casualty.

4. MAGNETIC PARTICLE INSPECTION OF THE UNFRACTURED BOLTS

The eight unfractured bolts were wire brush cleaned and subjected to Magnetic Particle Inspection (MPI). The testing was completed via a bench unit and water washable fluorescent ink, test conditions and results of which are detailed in Appendix 1.

All eight bolts were found to be free from both surface defects and cracks.

5. METALLOGRAPHIC EXAMINATION

Longitudinal metallographic specimens were removed from the fracture surfaces of bolts exhibiting both fracture types and from the plain shank to threaded region of two unfractured bolts. The specimens were Bakelite mounted and prepared for examination by mechanical polishing to a 1-micron diamond finish. The prepared specimens were first examined in the as polished unetched condition and then again after etching in Nital

The first specimen removed from a bolt that had fracture at 90^0 to the principal axis of the bolt was seen to largely comprise strain free fatigue type cracking (Figures 41, 42 and 43). The fatigue crack had initiated in a thread root that appeared to be free from pre-existing material or manufacturing defects (Figure 41) and no secondary cracking was apparent in adjacent thread roots. The bolt had been manufactured by thread rolling rather than screw cutting and clear evidence of thread rolling intrusions was apparent in the thread tips (Figure 44). The bolts residual microstructure was consistent with it having been subjected to a quench and temper type heat treatment after thread rolling (Figure 45).

The specimen removed from a second bolt that had fractured at 90^0 to the principal axis of the bolt also exhibited features consistent with strain free fatigue cracking over most of the bolts cross section (Figures 46 and 47). In this case, however, there was clear evidence of a small region of ductile shear type fracture in the terminal fracture region (Figures 48 and 49). The fatigue crack had again initiated in a thread root that appeared to be free from pre-existing material or manufacturing defects (Figure 46) and there was no evidence of secondary cracking in the adjacent thread roots. The bolt had again been produced by thread rolling and had entered service in a quench and tempered heat treatment condition.

The specimen removed from a bolt exhibiting fracture at 45^0 to its principal axis was confirmed to exhibit largely ductile shear type fracture (Figures 50 and 51) and the bolt was seen to have expended very significant levels of ductility in the fracture process (Figure 51). The fracture surface exhibited evidence of quite extensive and deep pitting corrosion, which in turn suggested that this could be an old fracture. The bolt had again been produced by thread rolling (Figure

52) and it had entered service in the quench and tempered heat treatment condition (Figure 53).

The specimens removed from two unfractured bolts confirmed both to be totally free from cracking. One of the bolts did, however, exhibit evidence of quite extensive local pitting corrosion (Figures 54, 55 and 56). Like other bolts examined in detail, both had been produced by thread rolling and had received a satisfactory post threading quench and temper type through hardening heat treatment.

6. VICKERS HARDNESS TEST

A Vickers hardness test (HV10) was completed on metallographic specimens exhibiting both fracture types and on a specimen removed from an unfractured bolt, results of which are reported in Appendix 2.

The test results consistently met the specified requirements for strength grade 8.8 bolts. The actual hardness values were consistently towards the upper end of the specified range for strength grade 8.8 and results also met the minimum requirements for the next higher strength grade (Strength Grade 9.8).

7. SUMMARY

7.1 The laboratory was provided with sixteen threaded end fracture halves, two cap head end fracture halves and eight unfractured bolts.

7.2 The fractured bolts exhibited two visually different fracture types, comprising what appeared to be both fatigue fractures and ductile shear fractures.

7.3 The two cap head end fracture halves received on 3rd August included what appeared to be one fatigue fracture and one largely ductile shear fracture.

7.4 The sample set received on 8th August included what visually appeared to be ten fatigue fractures, four largely ductile shear fractures and two with recently sawn ends.

7.5 The bolts were stamped strength grade 8.8, and were of 80.7mm overall length. The bolt shank and threaded end measured 65 mm and the thread was confirmed to be of M16 by standard Metric 2mm pitch.

7.6 The fracture surfaces of both the visually fatigue like fractures and the ductile shear type fractures exhibited varying degrees of post fracture rusting, suggesting that some of the fractures were of some age and one probably pre-dating the current casualty.

7.7 The unfractured bolt set also exhibited evidence of significant general rusting and local pitting corrosion, which had consumed the protective plating in all but limited regions of some threaded ends.

7.8 The eight unfractured bolts were confirmed by MPI to be totally free from evidence of cracking.

7.9 Detailed SEM fractographic examination of the two visually different fracture types confirmed that fractures orientated at 90^0 to the principal axis of the bolts were largely fatigue fractures, in contrast with fractures which were orientated at 45^0 to the bolts principal axis, which were seen to comprise largely ductile shear failures.

7.10 The detailed fractographic examination also identified evidence of post fracture corrosion of the fracture halves, which further suggested that some of the bolt failures pre-dated the current casualty.

7.11 Metallographic examination served further to confirm the presence of two failure mechanisms in the bolt fracture halves, comprising both fatigue and ductile shear.

7.12 The metallographic examination also identified the presence of general and local pitting corrosion.

7.13 The bolts were seen to have been produced by thread rolling, rather than screw cutting and they had been satisfactorily through hardened by a quench and tempering heat treatment after thread rolling.

7.14 Vickers hardness tests on three bolt samples confirmed that they comfortably met the strength grade 8.8 requirements, and that they also met the requirements of the next stronger 9.8 strength grade.

7.15 We saw no evidence of material, microstructural or manufacturing defects that could have pre-disposed the bolts to fatigue cracking in service.

8. CONCLUSIONS, DISCUSSION AND OPINION

We conclude that a large proportion of the fractured bolts had failed by a mechanism of fatigue cracking and based on the presence of variable levels of corrosion at the fracture surfaces some of the fractures most probably pre-dated the current casualty incident.

The bolts were confirmed to be of strength grade 8.8 and based on their Vickers hardness they would have also met the requirements of the next higher strength grade 9.8. The bolts had been thread rolled and quench and temper heat treated after threading; a manufacturing process selection and sequence that would normally provide the best fatigue resistance. Based on the measured hardness falling towards the top end of the range specified for the strength grade and absence of manufacturing defects, the bolts could have been expected to exhibit a fatigue strength towards the top end of the statistical scatter band range expected for the strength grade.

Fatigue cracking results from cyclic loading, over typically thousands or millions of loading reversals, at stress amplitudes above an items fatigue limit. In joints of the type in question failure to suitably tighten the bolts or movement across the bolting faces are usually the most common cause of in-service fatigue cracking. The presence of widespread prior surface pitting corrosion could also have been expected to have locally concentrated resolved cross joint stresses and increased sensitivity to fatigue cracking.

Based on the levels of fracture surface corrosion seen in the sample set, it appears likely that a significant number of the bolts had suffered fractures some time before the current casualty incident.

The high proportion of fatigue fractures in the bolt set provided and the very high fatigue cracking content of individual bolt fractures would also collectively suggest that the overall service loading of the bolted joints is relatively low.

Report prepared and authorised by

[redacted]

Director and Head of Laboratory

UKAS TESTING 1046

The TEST HOUSE

T11285: APPENDIX 1

Certificate of Test

Client:	MAIB, Mountbatten House, Grosvenor Square, Southampton SO15 2JU		
Date of receipt:	3 August 2011	*Date of test:*	30 August 2011
Reference No.:	T11285 Task 1	*MI No.:*	N/A
Order No.:	8000093637	*Specification:*	N/A

Description:	8 off, M16 x 2mm pitch cap head steel bolts.
Identity:	Blue Note, Bolt Nos. 1 to 8
Test methods:	*Procedure:* TP27 Issue 1 Rev 15, BSEN ISO 17638:2009

MAGNETIC PARTICLE INSPECTION REPORT

INSPECTION DETAILS

Description of equipment: J & A Bench unit and 3 turn coil on Emcol MPI Unit Identification number: TTH2 & K146	Viewing equipment: Fixed overhead UVA Lamp Identification number: TTH2 + B438 and hand portable UVA torch
Method of flux generation: Magnetic flow Distance between contact areas (mm): 80	Viewing/lighting conditions: White Light measured at: < 1 Lux UVA Light measured at: 2310µW/cm2
Material surface condition: Corrosion removed with a wire brush Current (Amps): Magnetic flow: N/A Current Flow: N/A	Detection medium and background: Johnson and Allen Neoastra Type F ink, Batch G2113 No background medium required
AC/DC/Half wave/Full wave rectified: AC	Field strength measurement: Berthold Gauge Position 3

RESULTS Acceptance criteria: None specified – identify location of any cracks.

Surface 100% of threads	Accepted/ Rejected	Indications	Comments
Bolt 1	N/A	Nil	No significant indication
Bolt 2	N/A	Nil	No significant indication
Bolt 3	N/A	Nil	No significant indication
Bolt 4	N/A	Nil	No significant indication
Bolt 5	N/A	Nil	No significant indication
Bolt 6	N/A	Nil	No significant indication
Bolt 7	N/A	Nil	No significant indication
Bolt 8	N/A	Nil	No significant indication

- End of Test Results -

Note - The test results detailed above apply only to the sample(s) of material submitted to the laboratory.

Tests Performed by: [redacted]

Certificate Approved by: [redacted] *Managing Director*

Signed ...[redacted]... *Date* ...12.9.11...

Witnessed by:

UKAS TESTING 1046

The TEST HOUSE

T11285: APPENDIX 2

Certificate of Test

Client:	MAIB, Floor 2 Mountbatten House, Grosvenor Square, Southampton, SO15 2JU		
Date of receipt:	3 and 8 August 2011	*Date of test:*	26 August & 6 September 2011
Reference No.:	T11285 Task2	*MI No.:*	N/A
Order No.:	8000093637	*Specification:*	N/A

Description: Mounted and Prepared Sections from Fatigue Fractured, 45° Shear Fractured and Un- fractured Cap Head Bolts

Identity: BLUE NOTE Gantry Crane Bolts
Fatigue Fractured Bolt M1
45° Shear Fractured Bolt M2
Un-fractured Bolt No.4

Test methods: *Procedure:* TP08, BSEN ISO 6507-1:2005
Inspection Authority: N/A

HARDNESS TESTS/SURVEY			
	Method	Indentor	Load (kg)
Section	Vickers Hardness Tester	Diamond Pyramid	10
Fatigue fractured bolt M1	311, 309, 314 Average = 311		
45° shear fractured bolt M2	317, 311, 314 Average = 314		
Un-fractured bolt No.4	309, 306, 311 Average = 309		

- End of Test Results -

Note - The test results detailed above apply only to the sample(s) of material submitted to the laboratory.

Tests Performed by: [redacted]	*Witnessed by:*
Certificate Approved by: [redacted] *Managing Director*	
Signed [redacted] .... *Date* 12.9.11	

Figure 1: Fractured cap head bolt sample halves, received 3rd August 2011.

Figure 2: Detail of figure 1, showing bolt half exhibiting 45° degree shear like fracture.

Figure 3: Detail of figure 1, showing rusted fracture surface of the bolt half exhibiting a shear like fracture.

Figure 4: Detail of figure 1, showing a bolt half exhibiting fatigue like fracture at 90° to the fasteners principal axis.

Figure 5: Detail of figure 1, showing rusted fracture surface of the bolt half exhibiting a fatigue like fracture.

Figure 6: Un-fractured cap head and threaded end bolt fracture halves received 8th August 2011.

Figure 7: Bolt samples received 8th August, showing 8 un-fractured, 4 exhibiting 45° shear like fractures, 10 exhibiting fatigue like fractures and 2 with sawn faces.

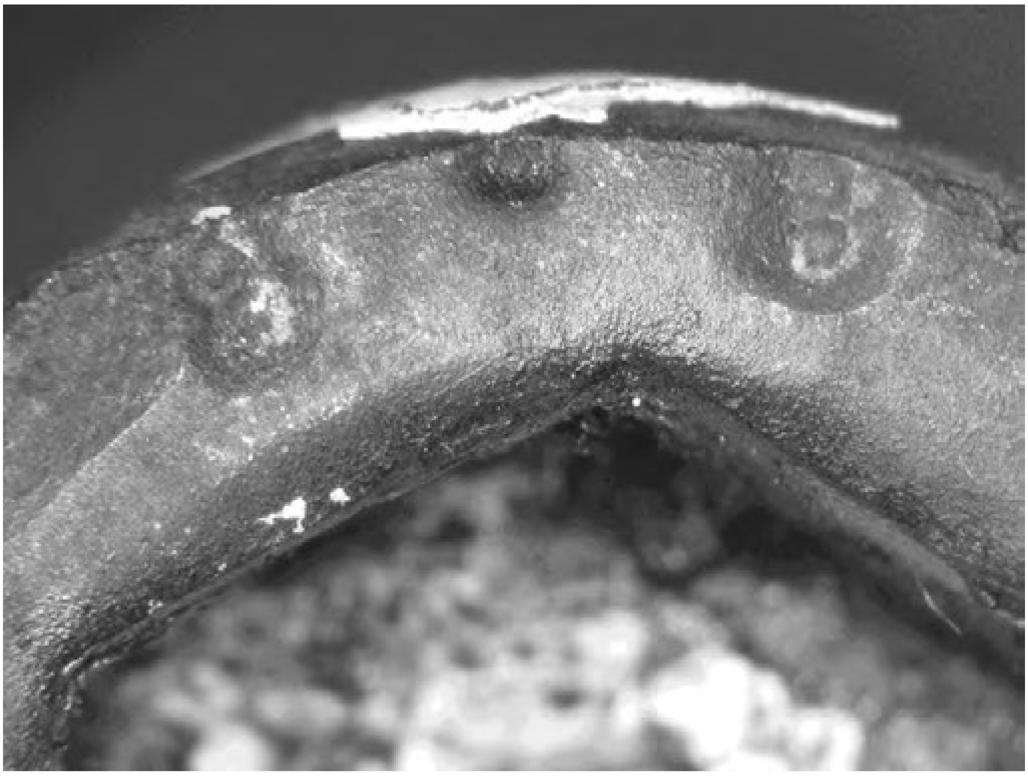


Figure 8: Bolt manufacturers head marking, which were read as 8.8 (strength grade 8.8).

Figure 9: Un-fractured bolt, showing evidence of prior plating at its threaded end.

Figure 10: Second un-fractured bolt, showing evidence of prior plating at its threaded end.

Figure 11: Un-fractured bolt showing external corrosion.

Figure 12: Un-fractured bolt, shown after cleaning and exhibiting evidence of local pitting corrosion.

Figure 13: Threaded bolt half exhibiting fatigue like fracture and showing light rusting of the fracture surface.

Figure 14: Threaded bolt half exhibiting fatigue like fracture and showing moderate rusting of the fracture surface.

Figure 15: Threaded bolt half exhibiting fatigue like fracture and showing heavy rusting of the fracture surface.

Figure 16: Threaded bolt half exhibiting fatigue like fracture, shown after cleaning in Clarke solution.

Figure 17: Second threaded bolt half exhibiting fatigue like fracture, shown after cleaning in Clarke solution.

Figure 18: Threaded bolt half exhibiting 45° shear like fracture and showing moderate rusting.

Figure 19: Second threaded bolt half exhibiting 45° shear like fracture and showing moderate rusting.

Figure 20: Threaded bolt half exhibiting 45° shear like fracture, shown after cleaning in Clarke solution.

Figure 21: Second threaded bolt half exhibiting 45° shear like fracture, shown after cleaning in Clarke solution.

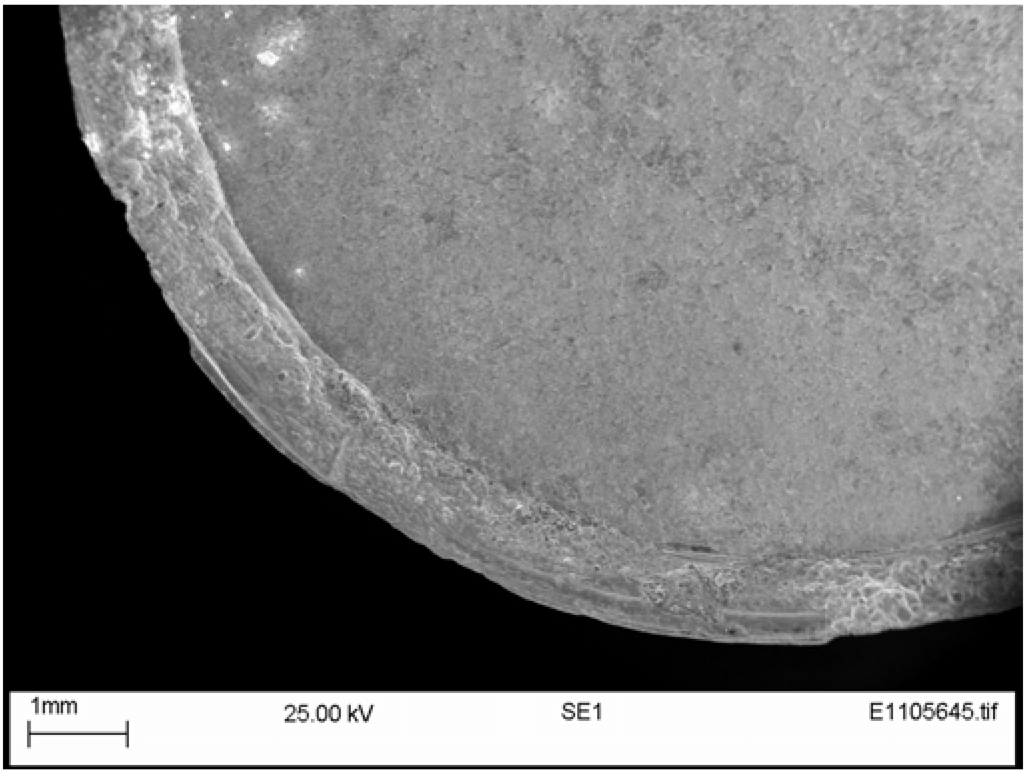


Figure 22: SEM fractograph, showing crack origin region in one of the fracture halves exhibiting fatigue fracture.

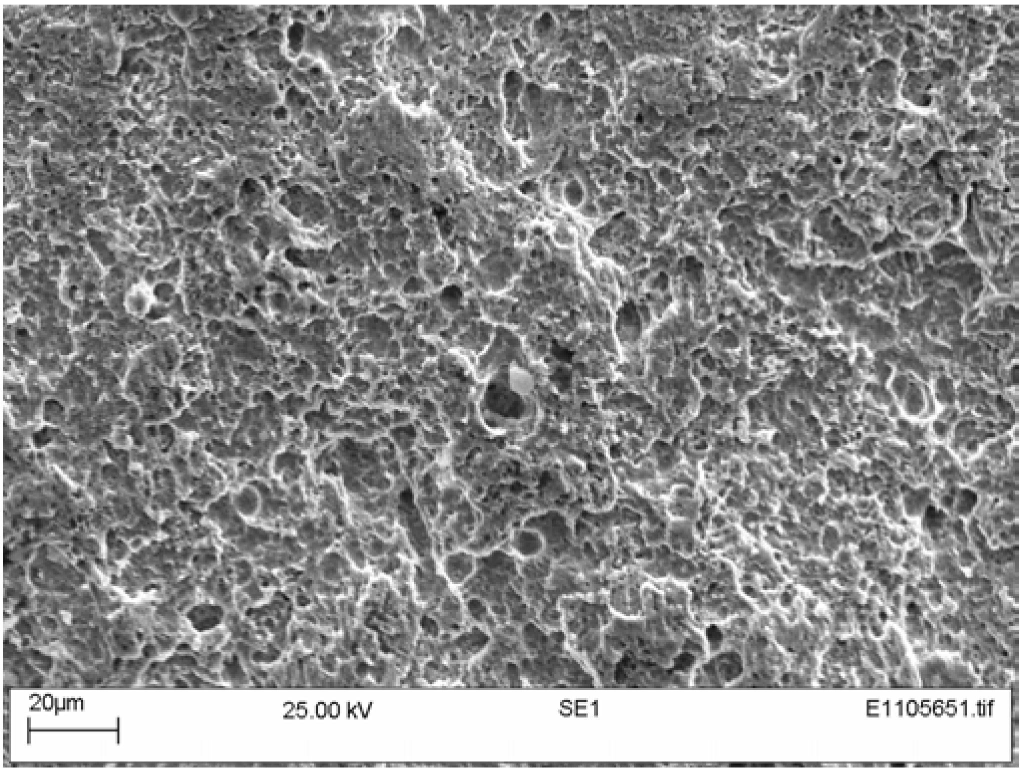


Figure 23: SEM fractograph, showing detail of figure 22 and fractography consistent with fatigue cracking.

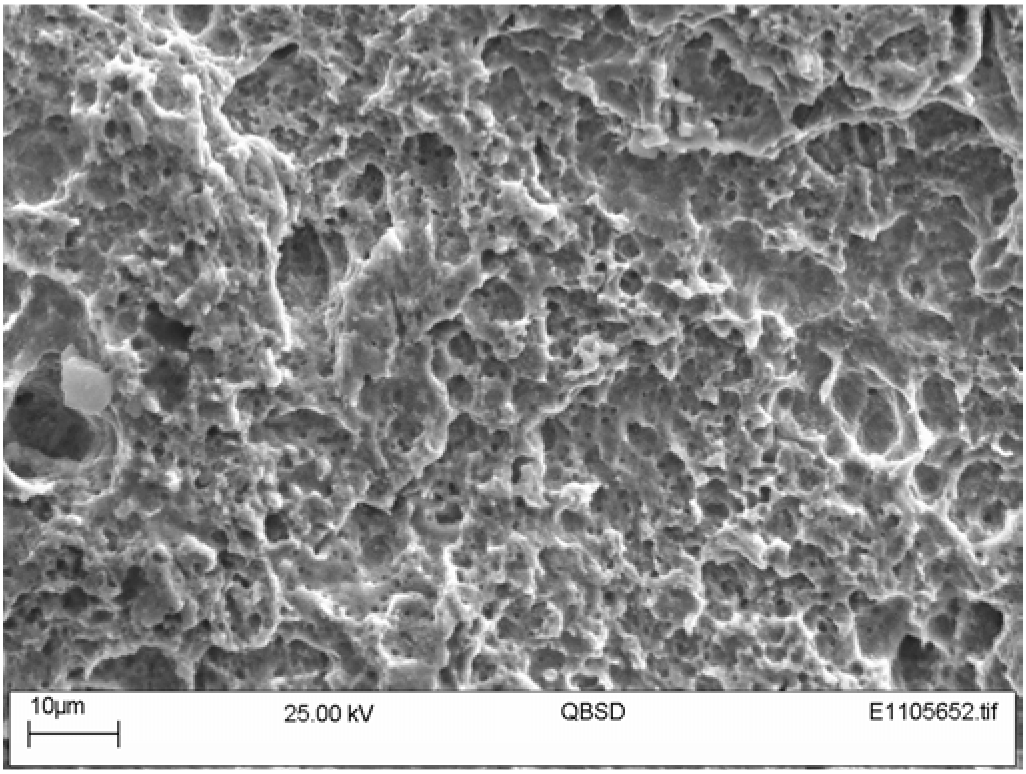


Figure 24: As above.

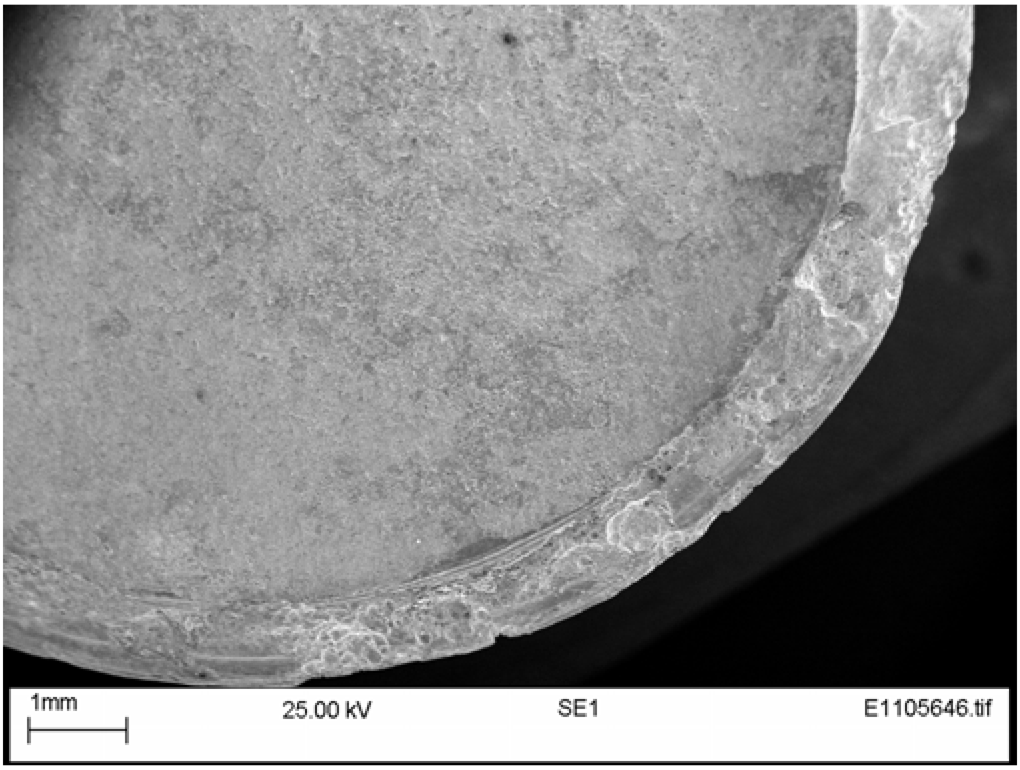


Figure 25: SEM fractograph, showing terminal fracture region of a fatigue cracked bolt.

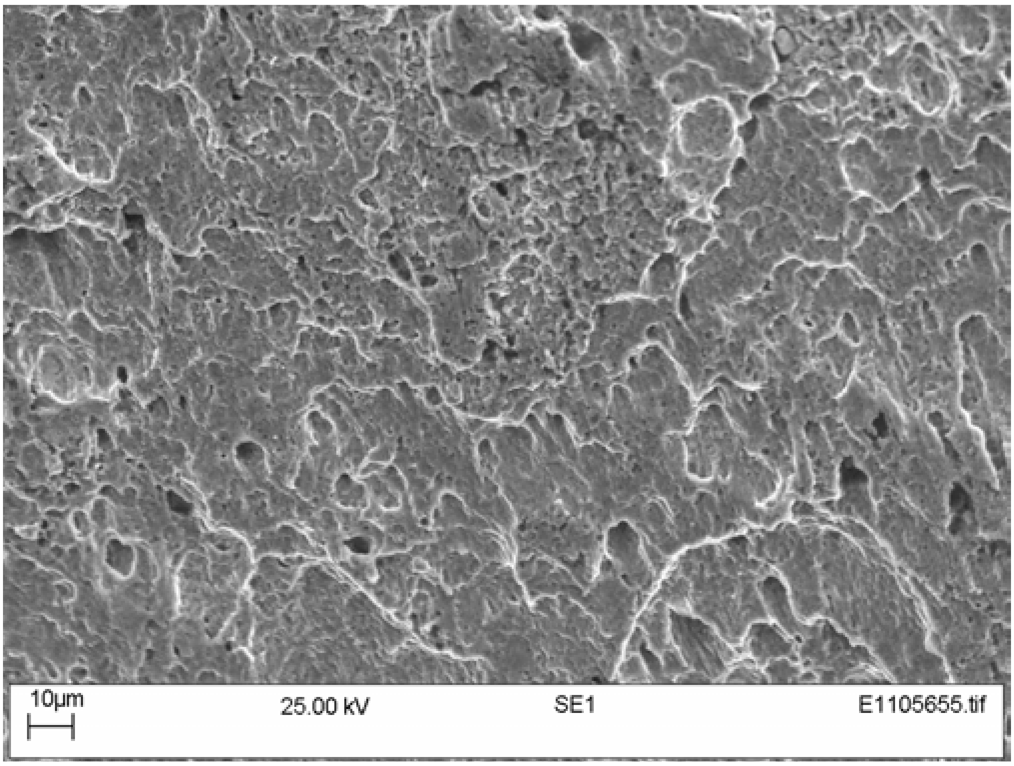


Figure 26: SEM fractograph, showing detail of figure 25 and fractography consistent with high ductility shear fracture.

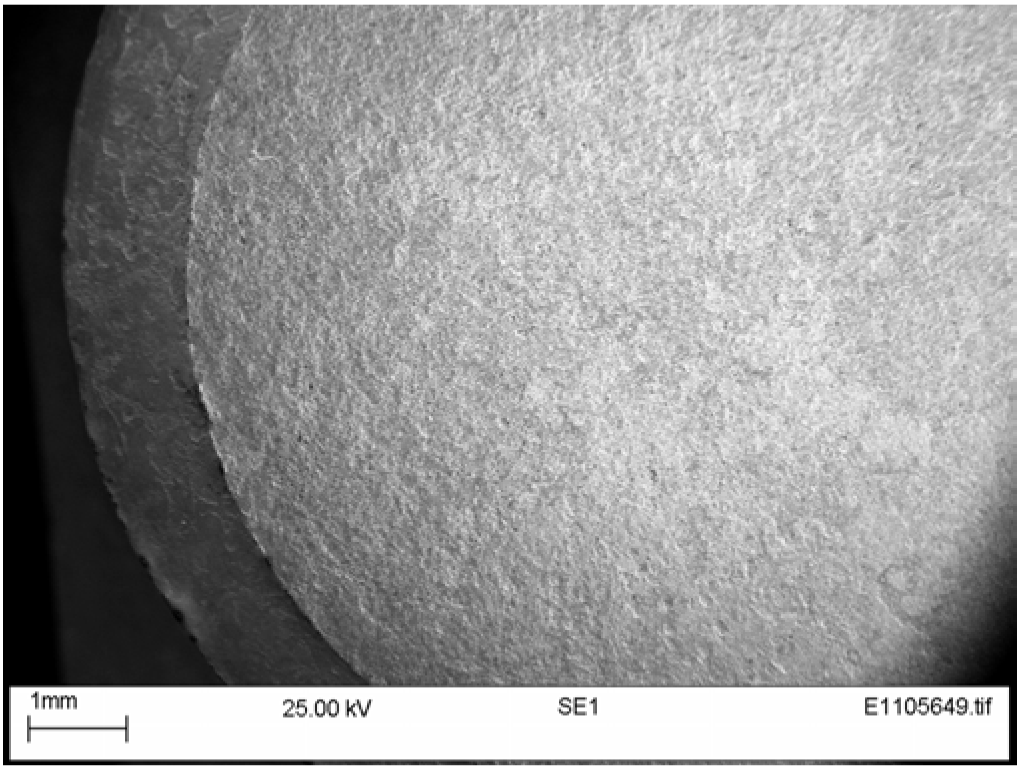


Figure 27: SEM fractograph, showing crack origin region of a second fracture half exhibiting fatigue fracture.

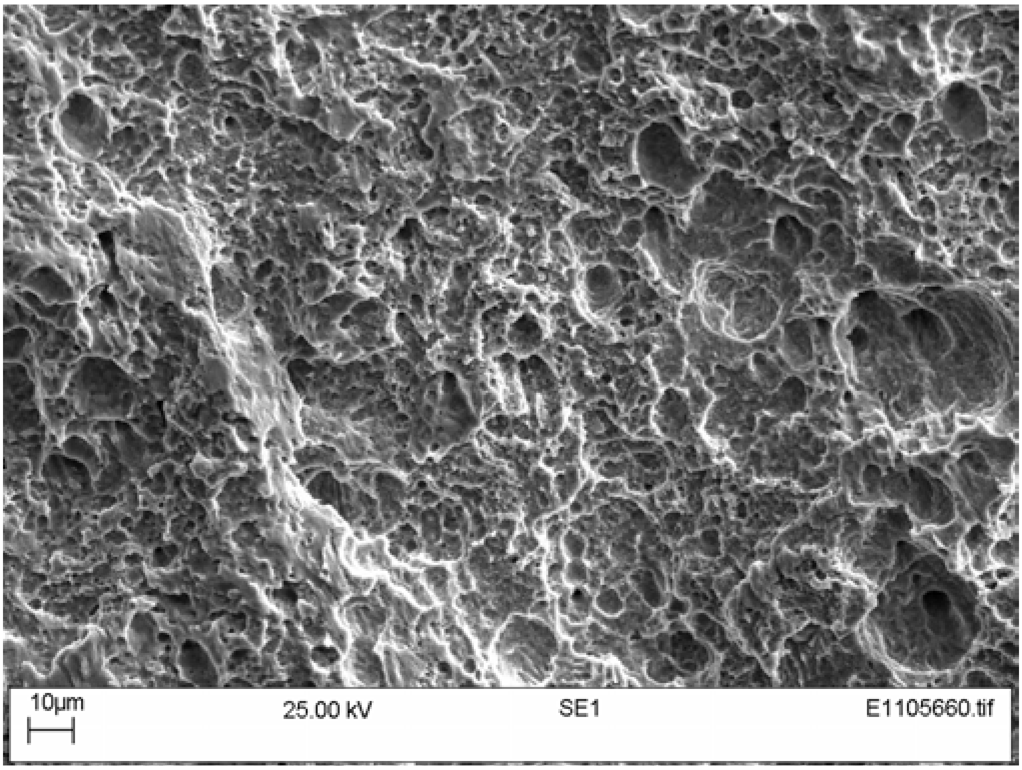


Figure 28: SEM fractograph, showing detail of figure 27 and fractography consistent with fatigue cracking.

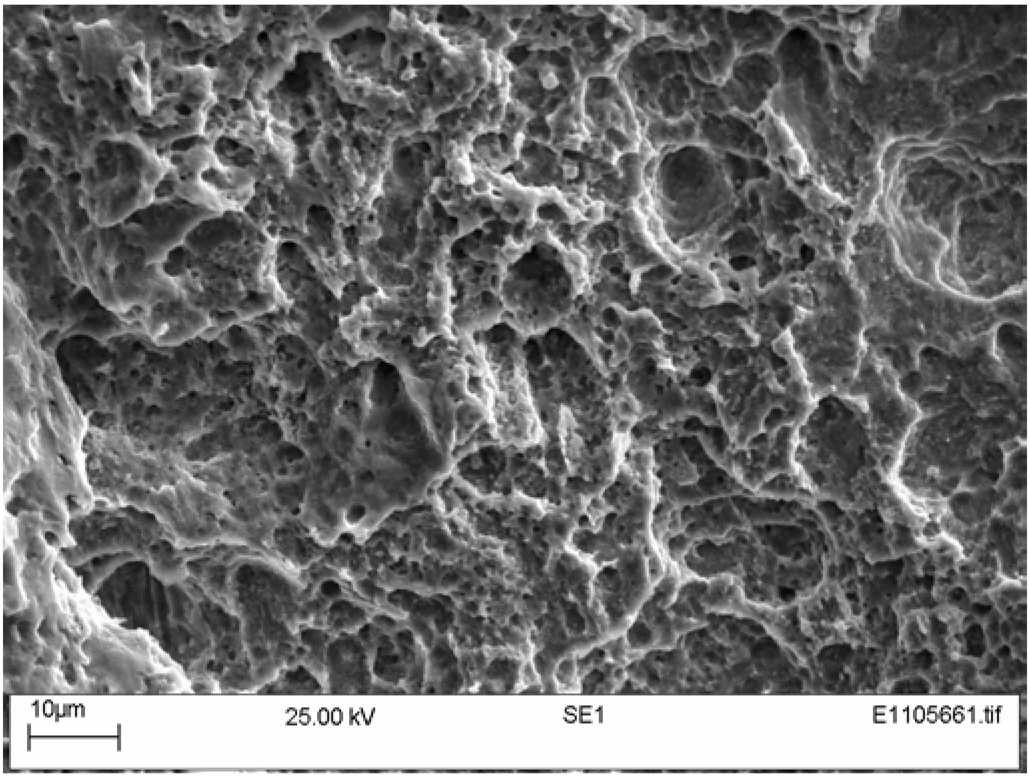


Figure 29: As figure 28.

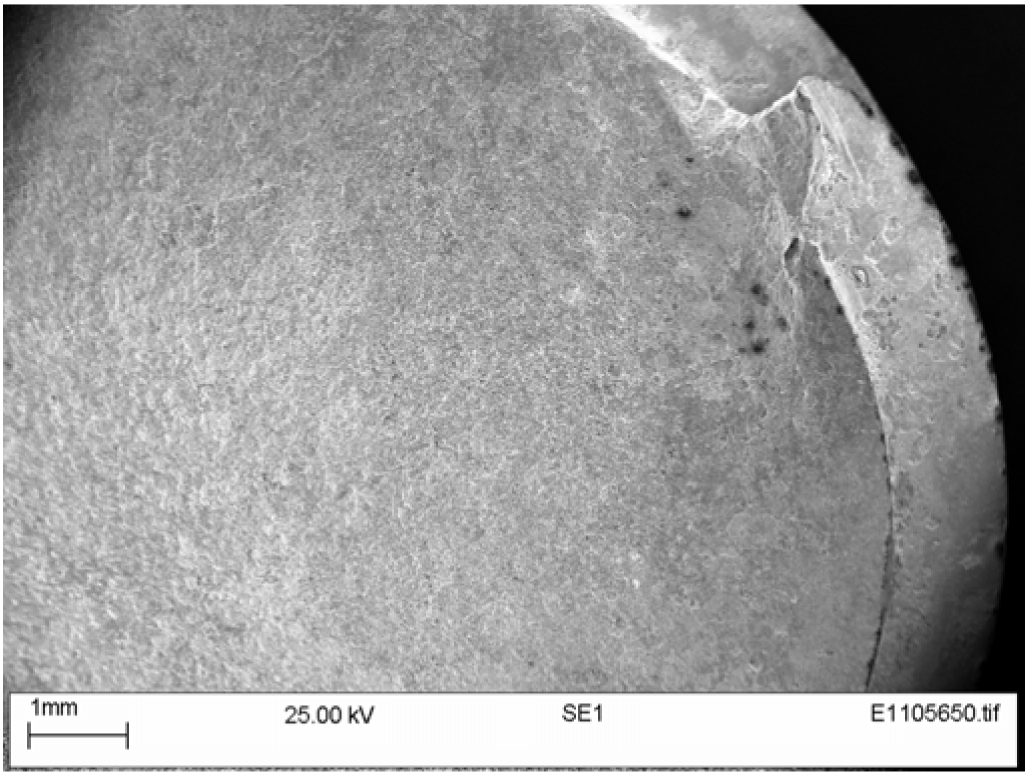


Figure 30: SEM fractograph, showing terminal fracture region of a fatigue cracked bolt.

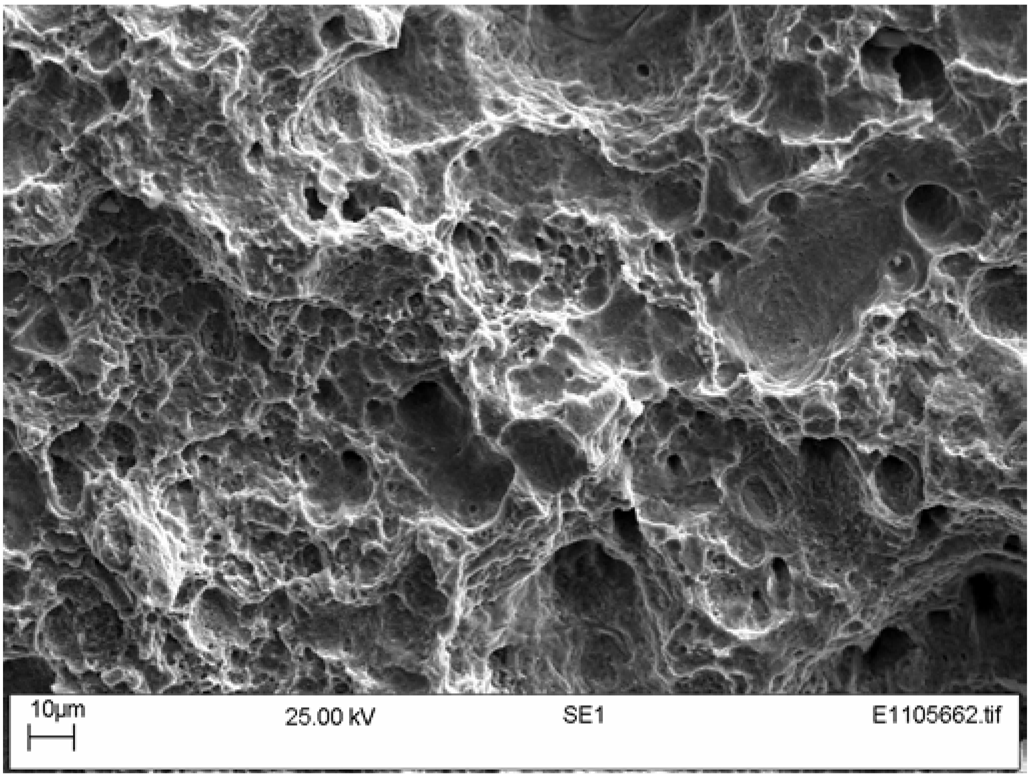


Figure 31: SEM fractograph, showing detail of figure 30 and fractography consistent with ductile microvoid coalescence type terminal fracture.

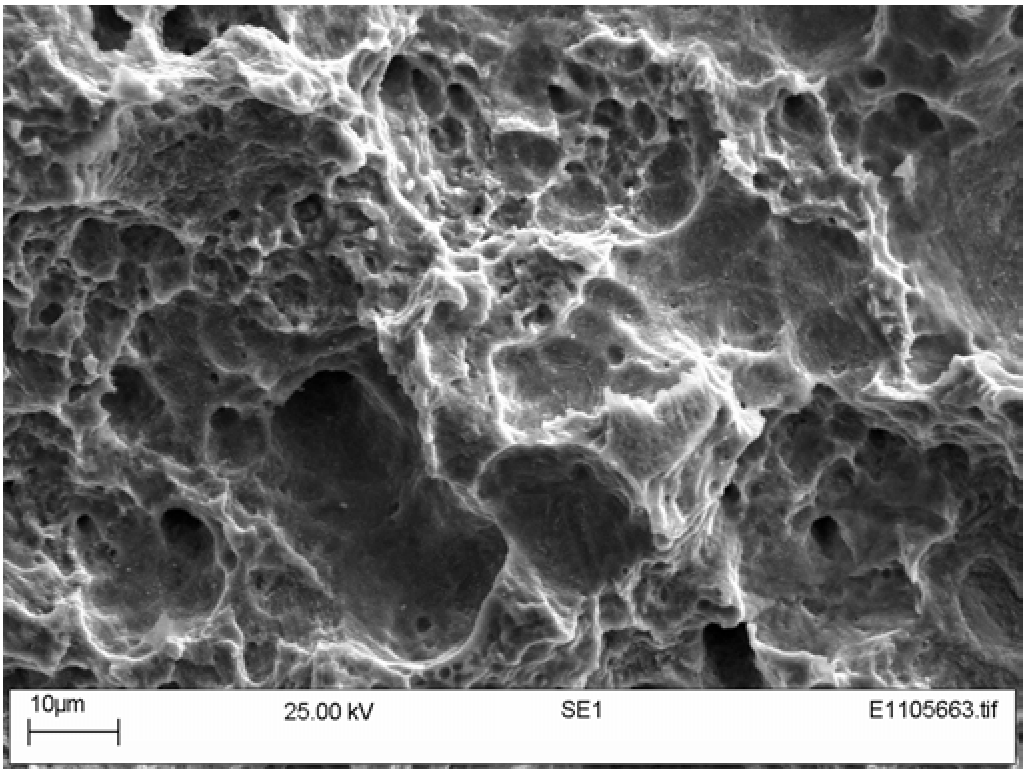


Figure 32: As above.

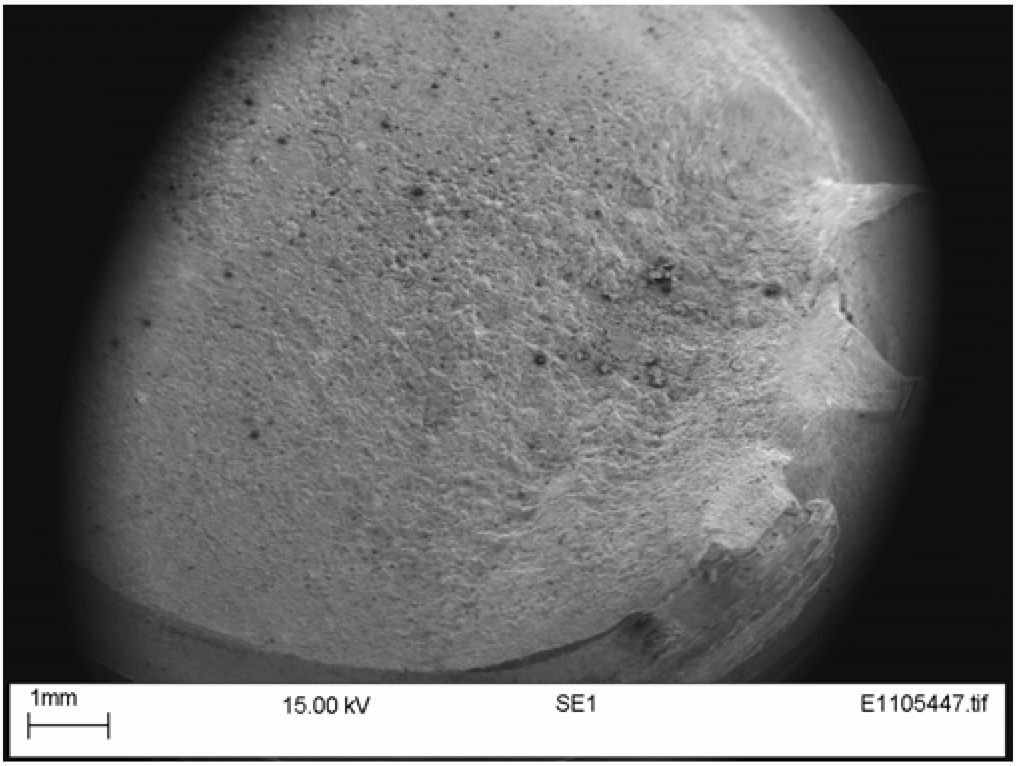


Figure 33: SEM fractograph, showing fracture origin region of a sample from the 45° shear like fracture.

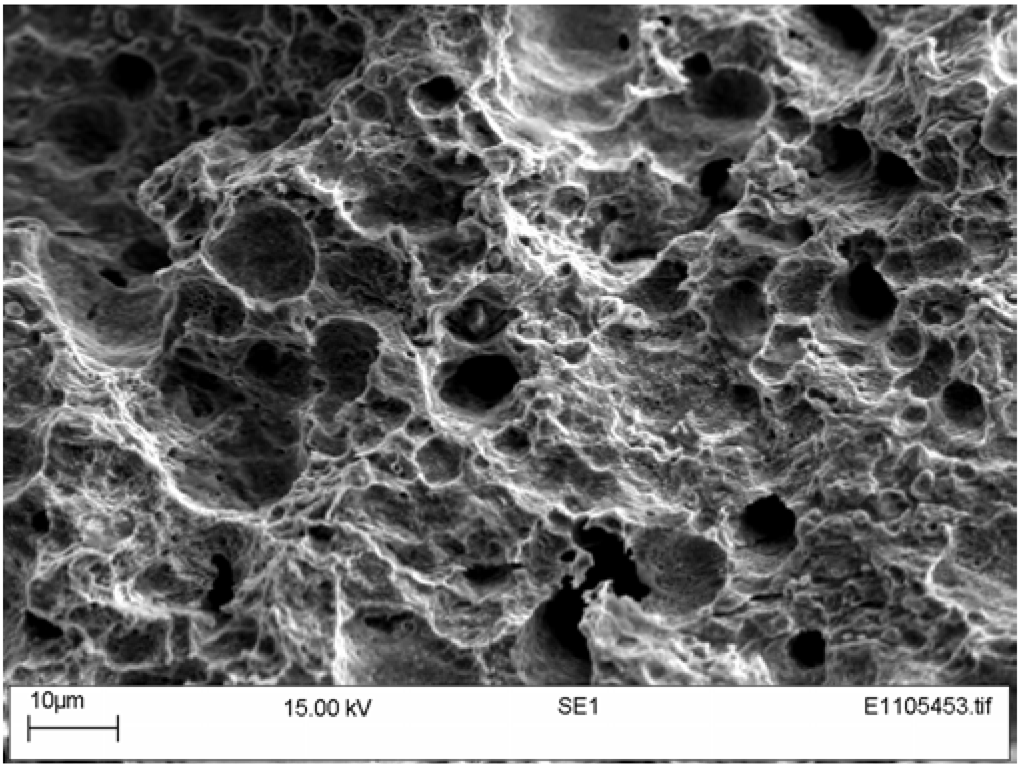


Figure 34: SEM fractograph, showing detail of figure 33 and fractography consistent with ductile microvoid coalescence type fracture.

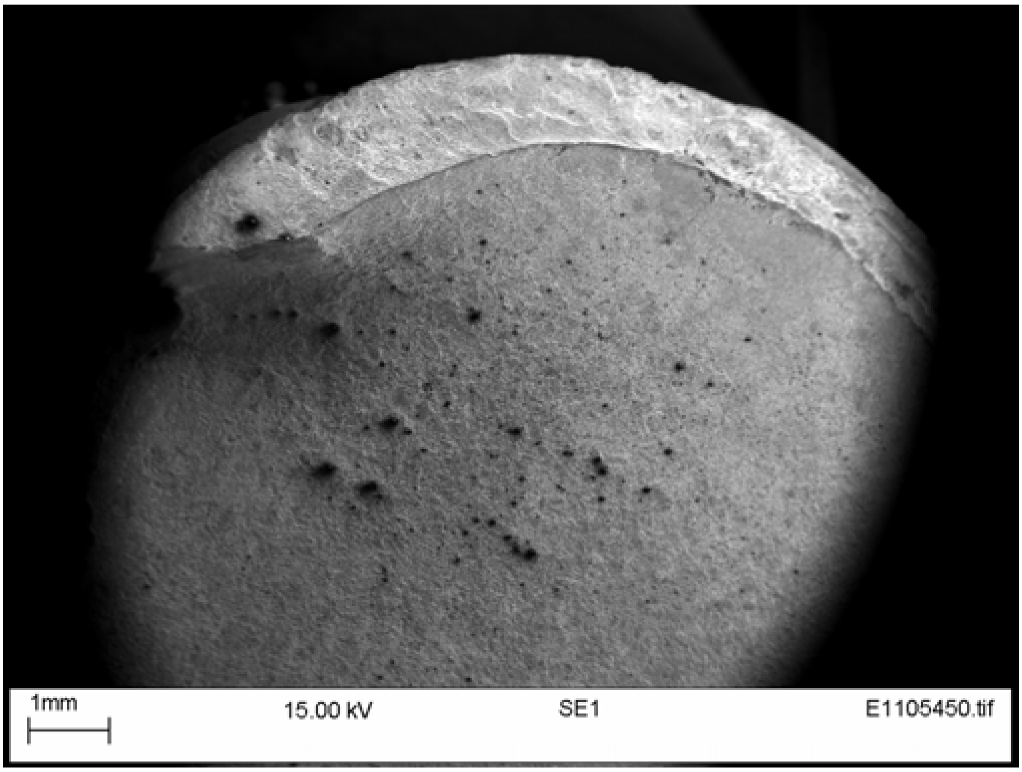


Figure 35: SEM fractograph, showing terminal fracture region of a 45° shear like fracture.

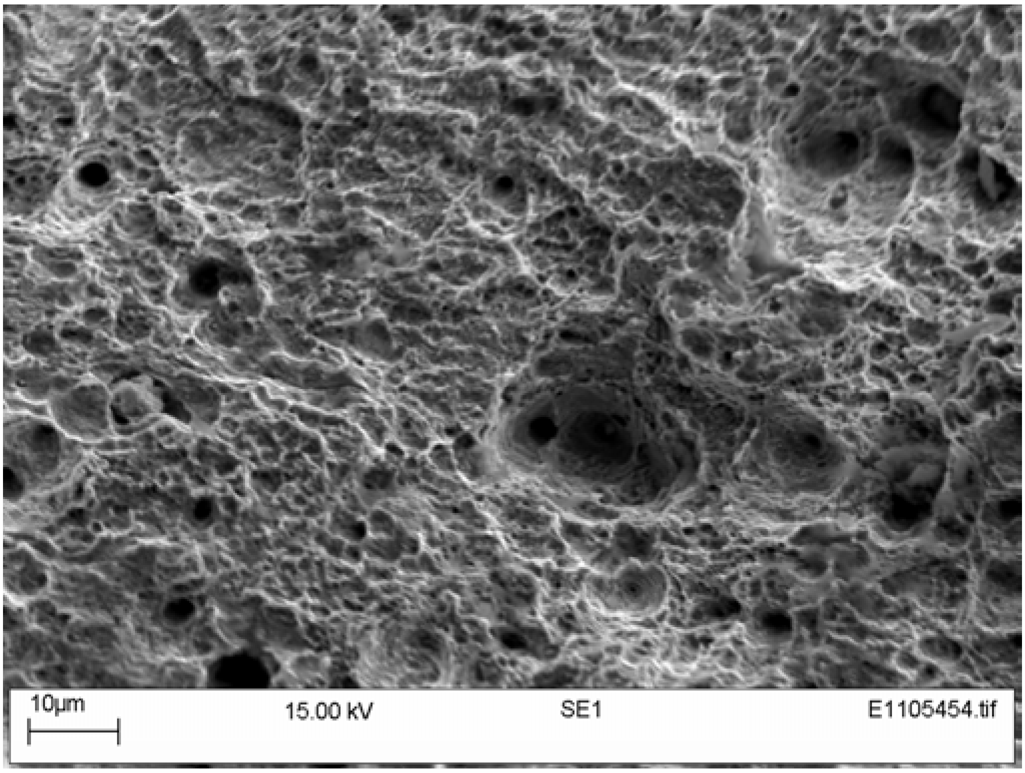


Figure 36: SEM fractograph, showing detail of figure 35 and fractography consistent with ductile microvoid coalescence type fracture.

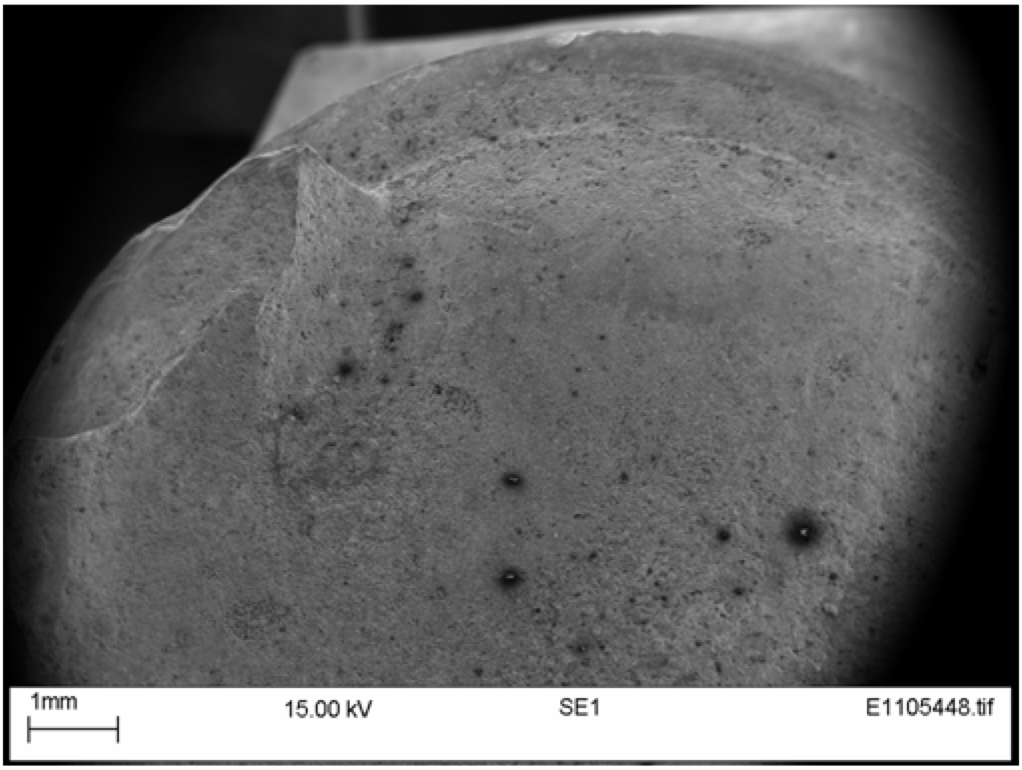


Figure 37: SEM fractograph, showing fracture origin region of a second 45° shear like fracture.

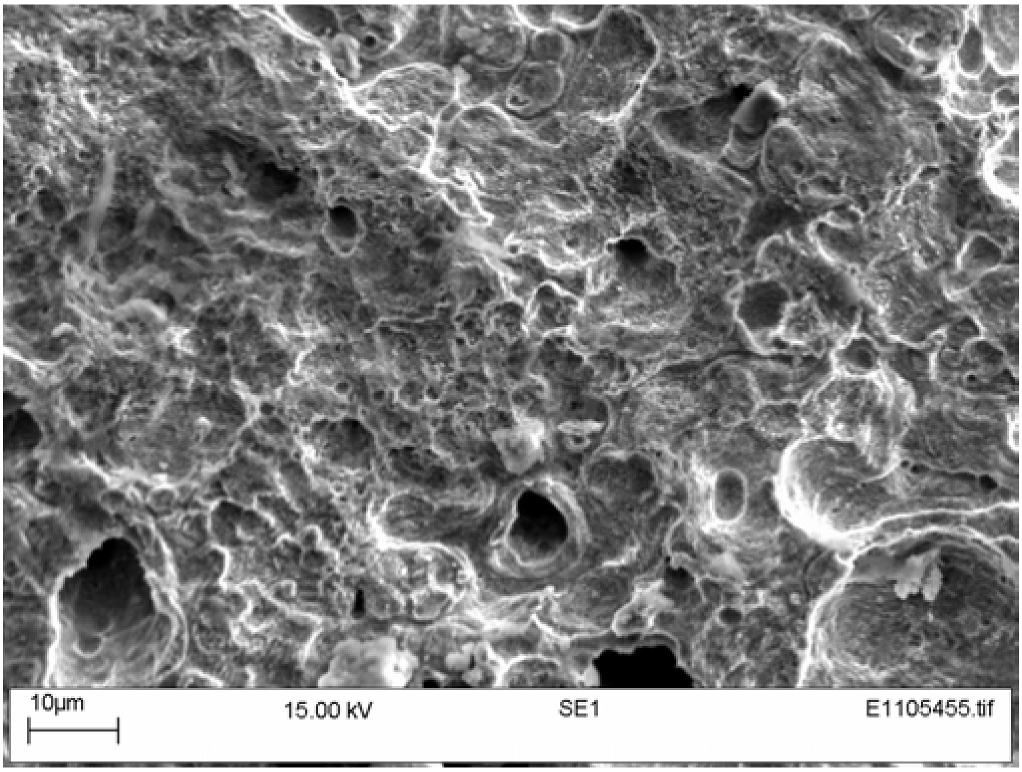


Figure 38: SEM fractograph, showing detail of figure 37 and fractography consistent with corrosion damaged ductile microvoid coalescence type fracture.

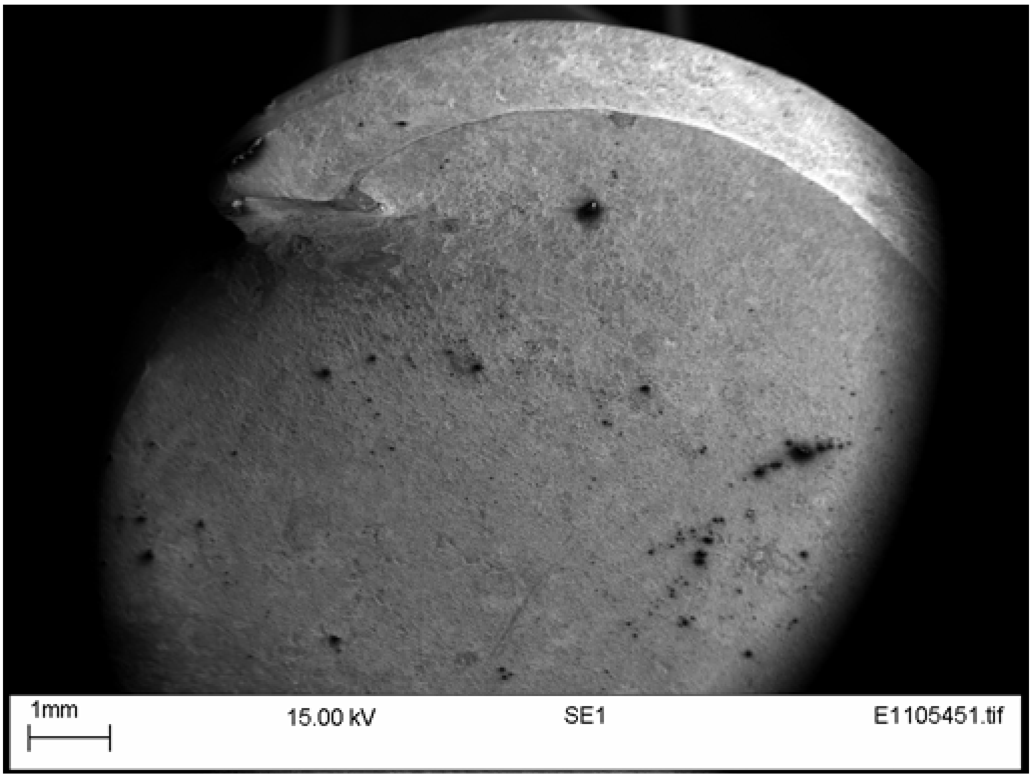


Figure 39: SEM fractograph, showing terminal fracture region of a 45° shear like fracture.

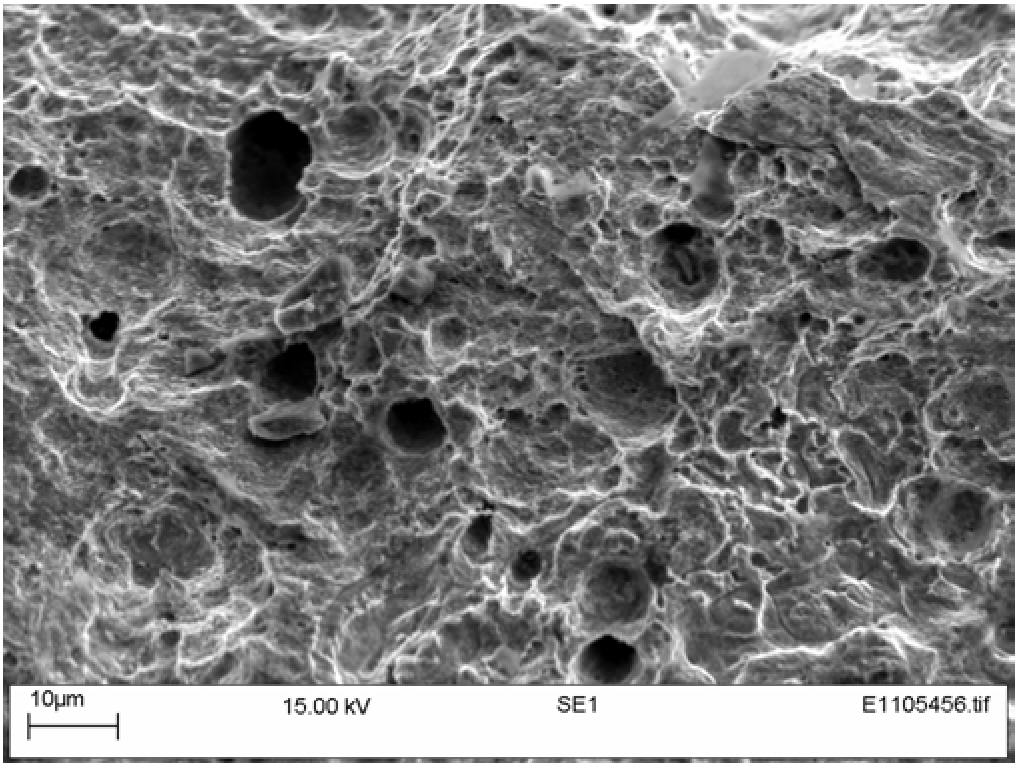


Figure 40: SEM fractograph, showing detail of figure 39 and fractography consistent with ductile microvoid coalescence type fracture.

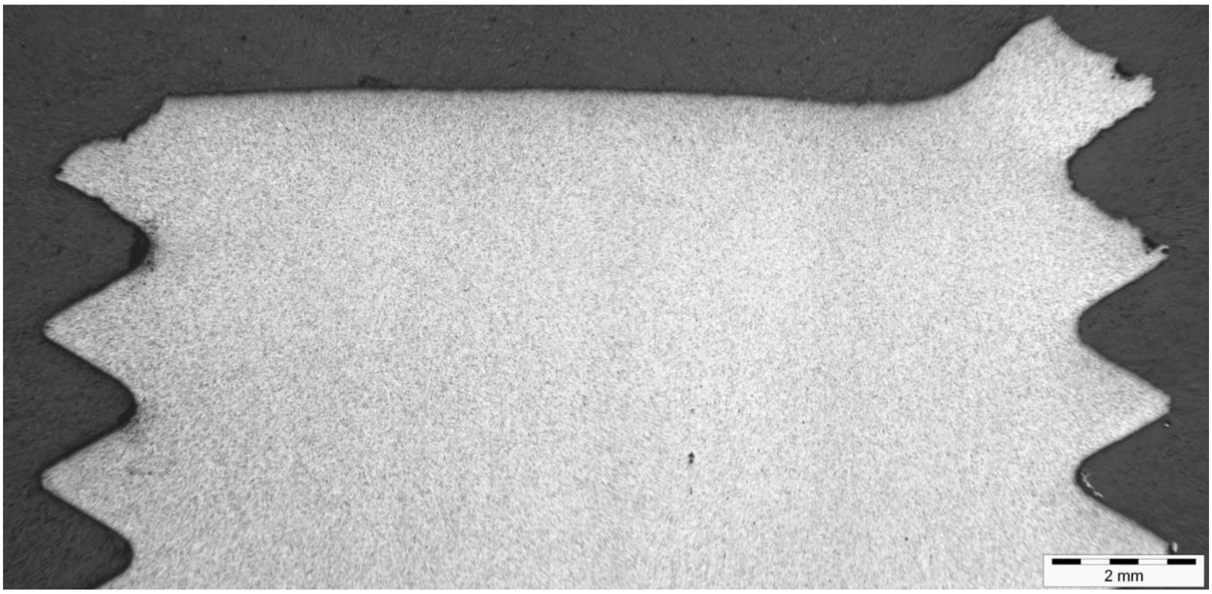


Figure 41: Micrograph (original image captured at X12.5), specimen etched in Nital. Longitudinal section through fatigue fractured bolt, showing crack origin (top left of field) and terminal fracture region (top right of field).

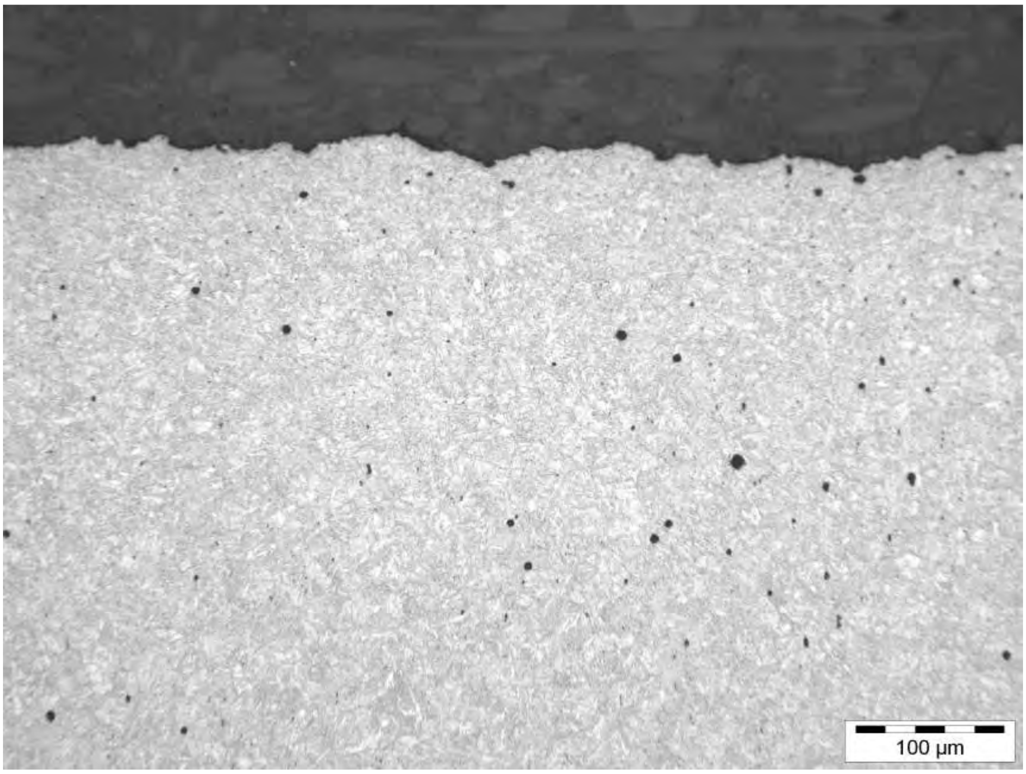


Figure 42: Micrograph (original image captured at X200), specimen etched in Nital. Detail of the crack origin region of figure 41, showing strain free fracture edge consistent with fatigue cracking.

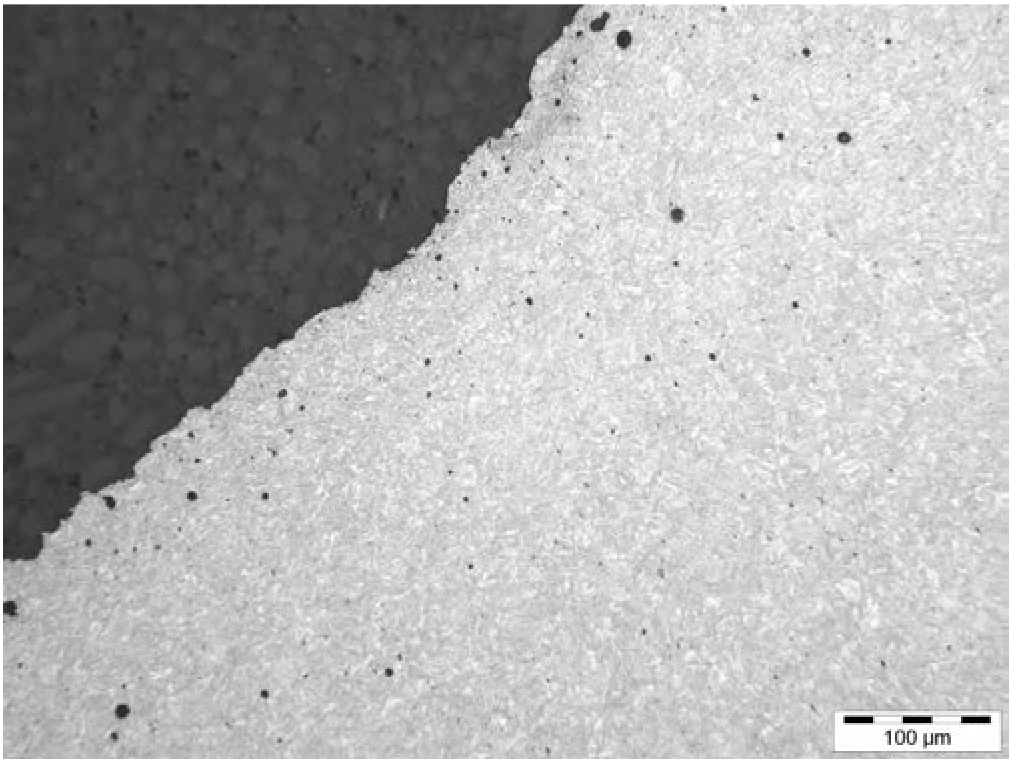


Figure 43: Micrograph (original image captured at X200), specimen etched in Nital. Detail of the terminal fracture region of figure 41which again appeared consistent with fatigue cracking.

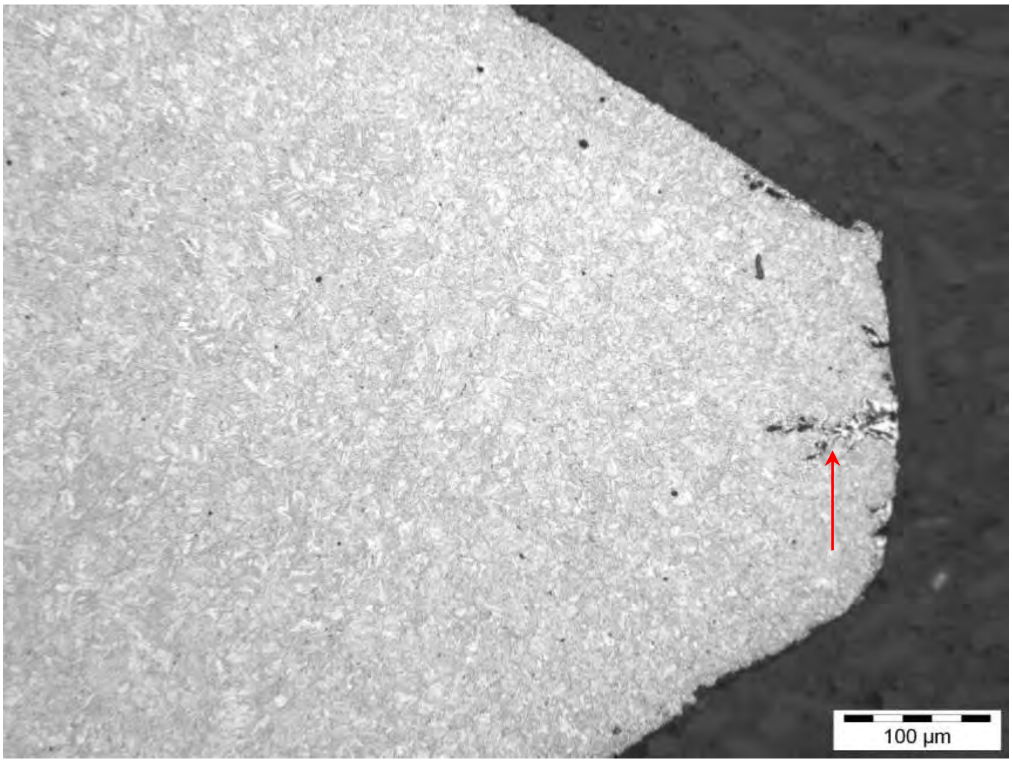


Figure 44: Micrograph (original image captured at X200), specimen etched in Nital. Detail of thread rolling intrusion (arrowed) in fatigue fractured bolt, which confirmed that the bolt had been thread rolled rather than screw cut and heat treated after threading.

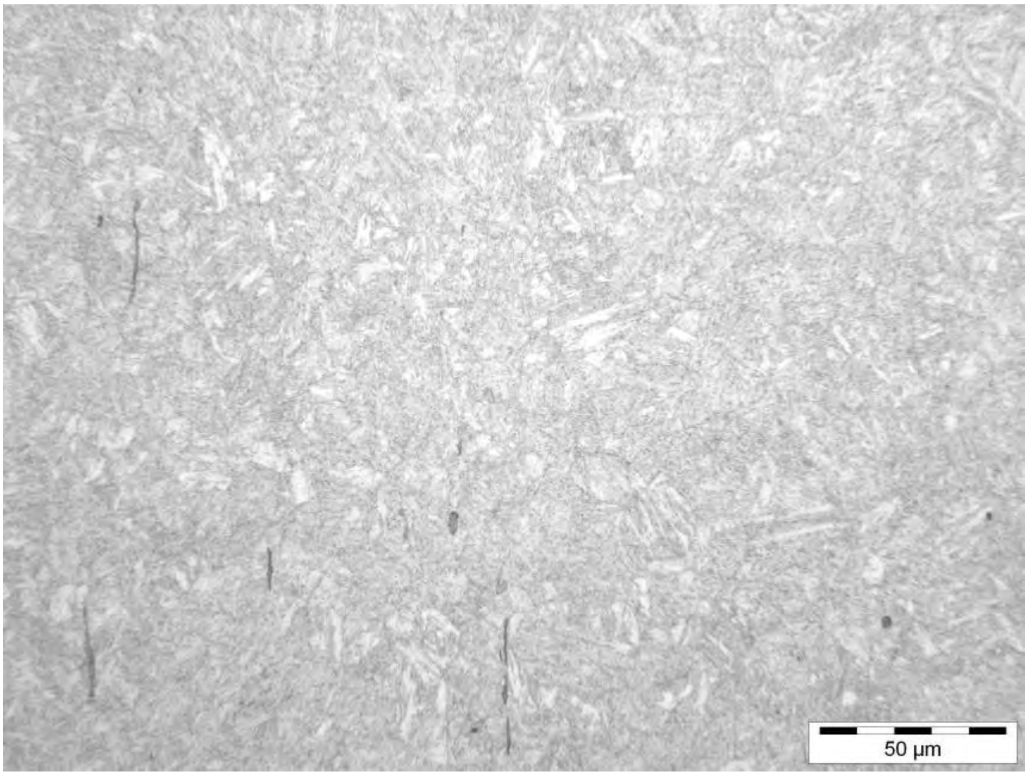


Figure 45: Micrograph (original image captured at X500), specimen etched in Nital. Longitudinal section through fatigue cracked bolt, showing a microstructure consistent with the bolt having received a quench and temper type through hardening heat treatment.

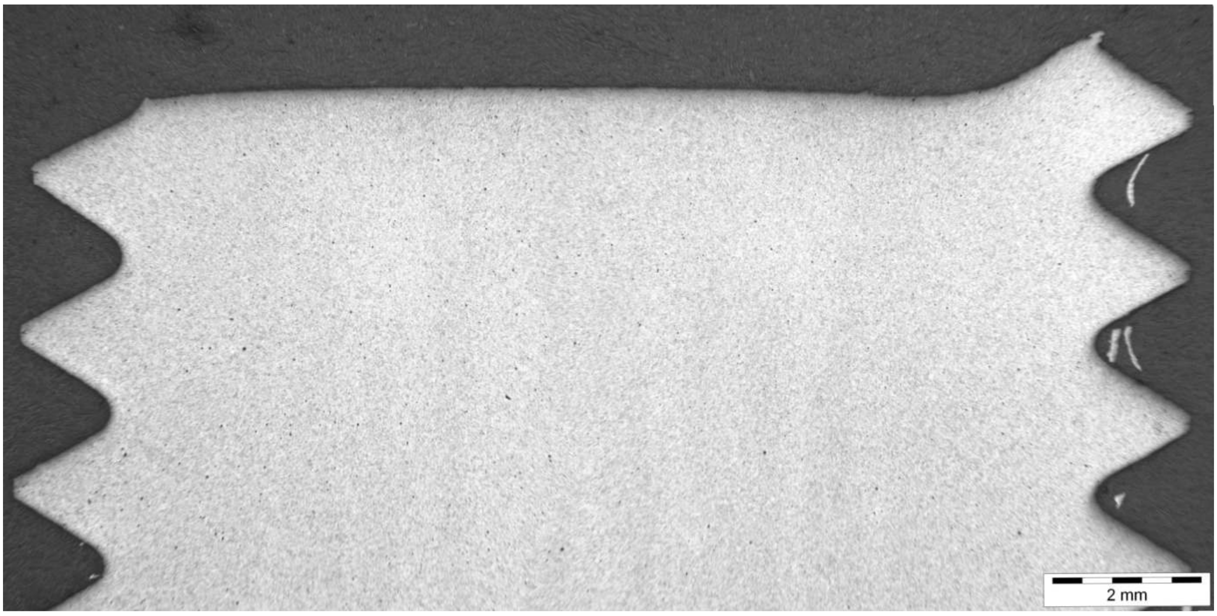


Figure 46: Micrograph (original image captured at X12.5), specimen etched in Nital. Longitudinal section through a second fatigue fractured bolt, showing crack origin (top left of field) and terminal fracture region (top right of field).

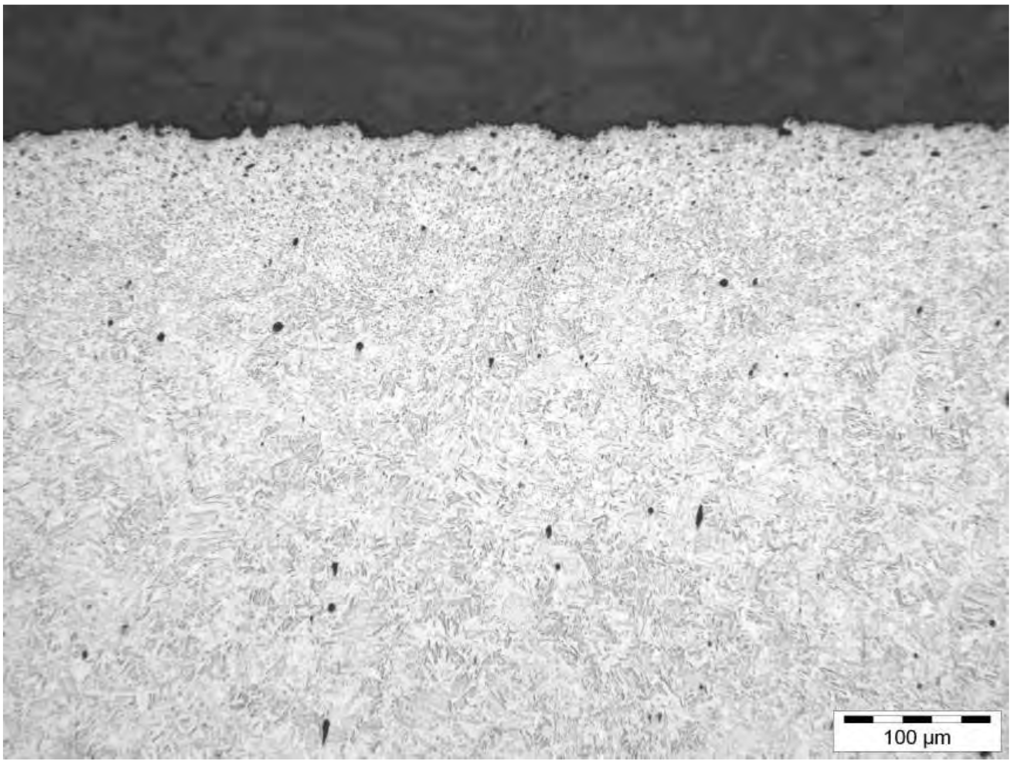


Figure 47: Micrograph (original image captured at X200), specimen etched in Nital. Detail of the crack origin region of figure 46, showing strain free fracture edge consistent with fatigue cracking.

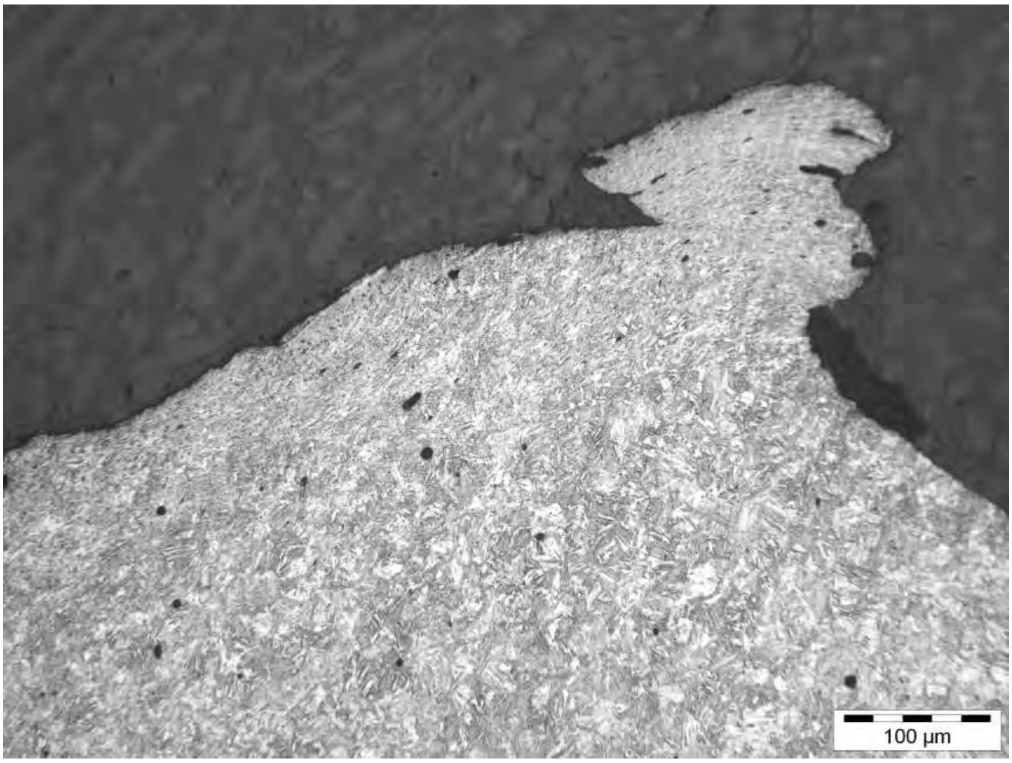


Figure 48: Micrograph (original image captured at X200), specimen etched in Nital. Detail of the terminal fracture region of figure 46 and showing evidence of ductile terminal overload type fracture.

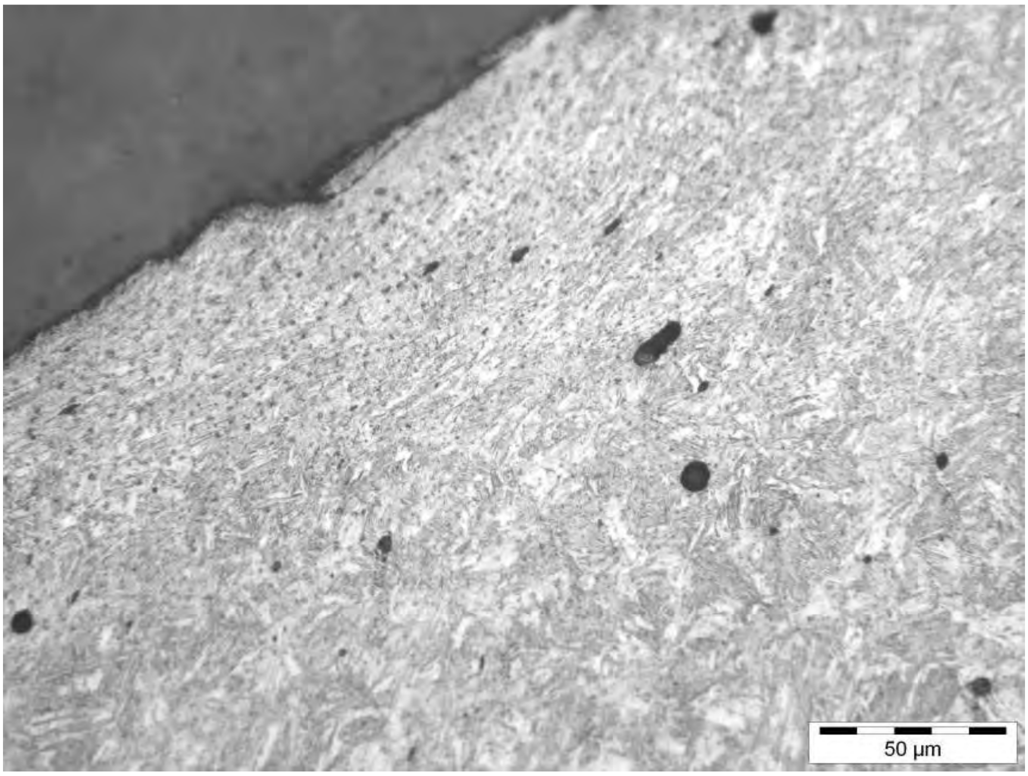


Figure 49: Micrograph (original image captured at X500), specimen etched in Nital. Detail of figure 48.

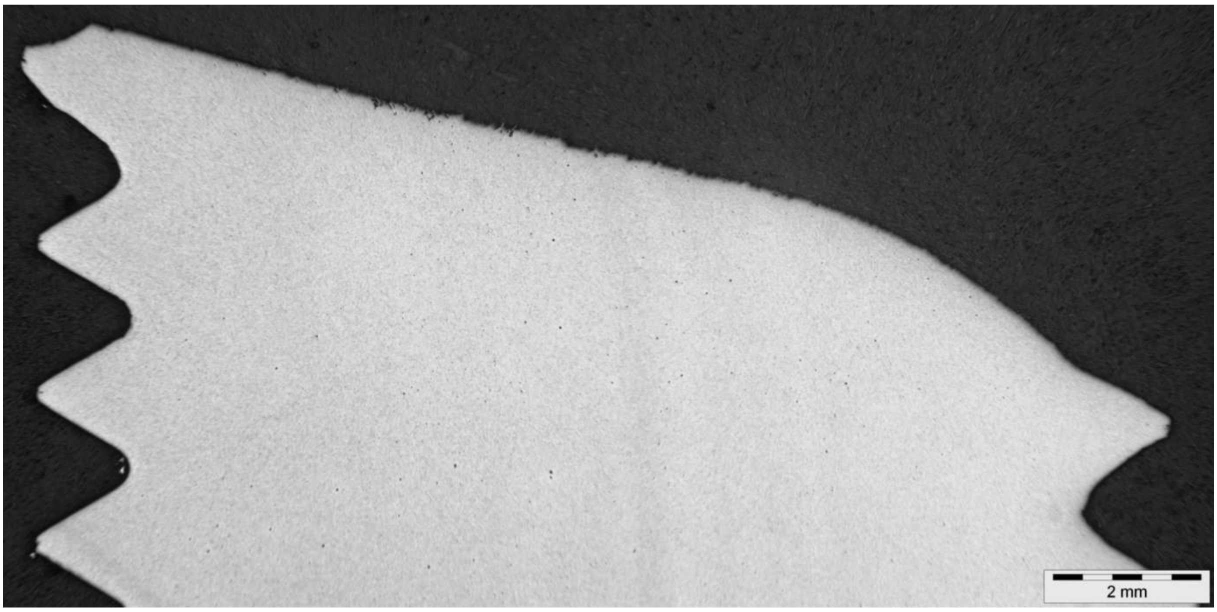


Figure 50: Micrograph (original image captured at X12.5), specimen etched in Nital. Longitudinal section through a 45° shear type fracture.

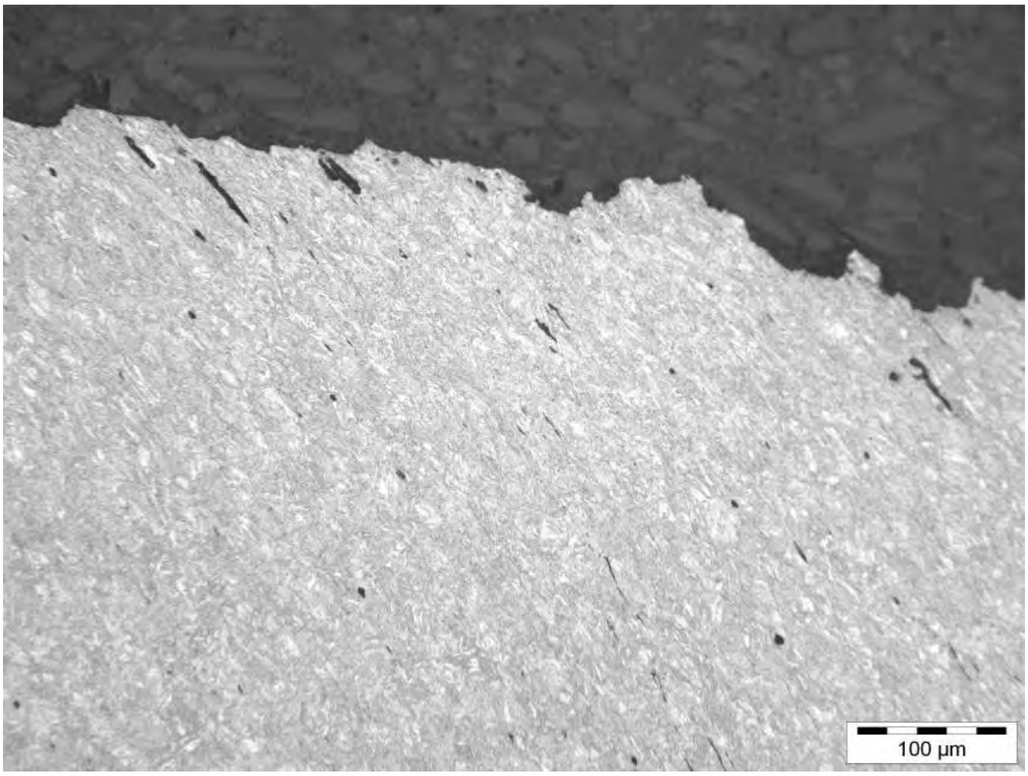


Figure 51: Micrograph (original image captured at X200), specimen etched in Nital. Detail of figure 50, showing features consistent with ductile shear type fracture.

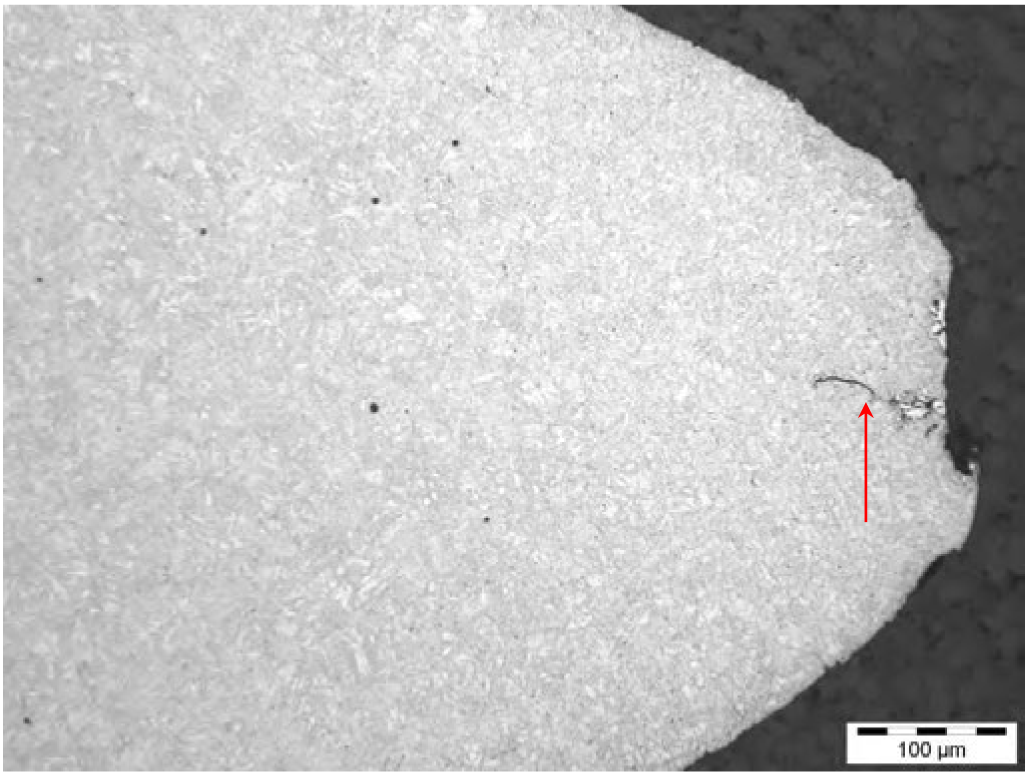


Figure 52: Micrograph (original image captured at X200), specimen etched in Nital. Detail of thread rolling intrusion (arrowed) in shear fractured bolt, which confirmed that the bolt had been thread rolled rather than screw cut and heat treated after threading.

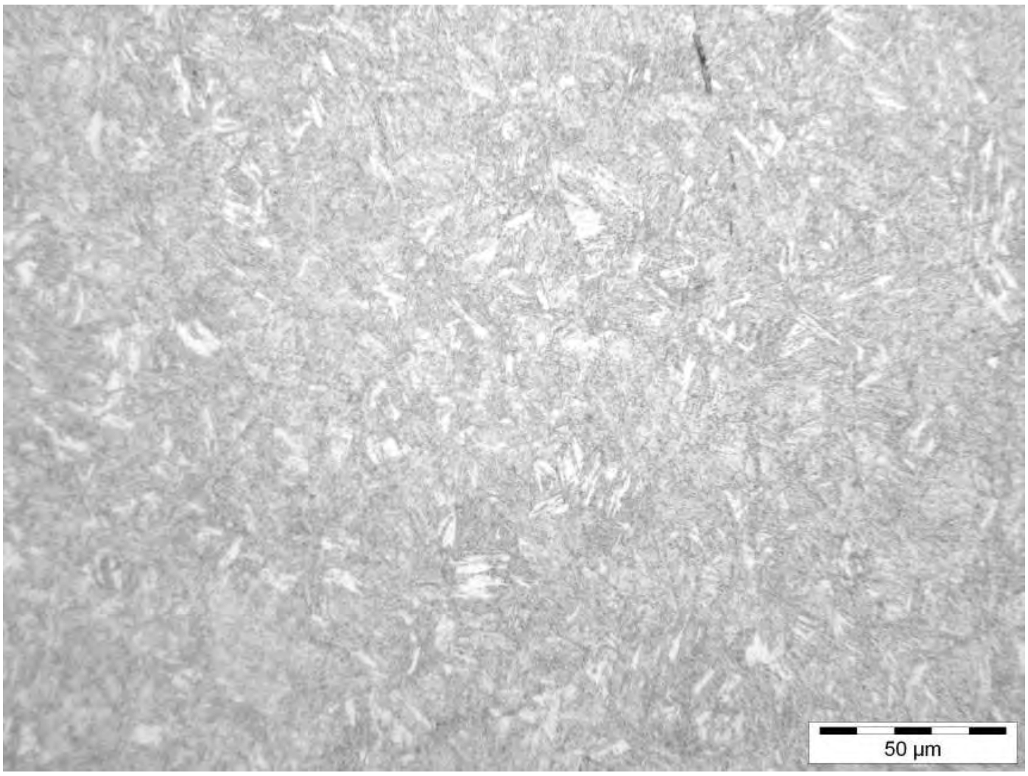


Figure 53: Micrograph (original image captured at X500), specimen etched in Nital. Longitudinal section through 45° shear type fracture, showing a microstructure consistent with the bolt having received a quench and temper type through hardening heat treatment.

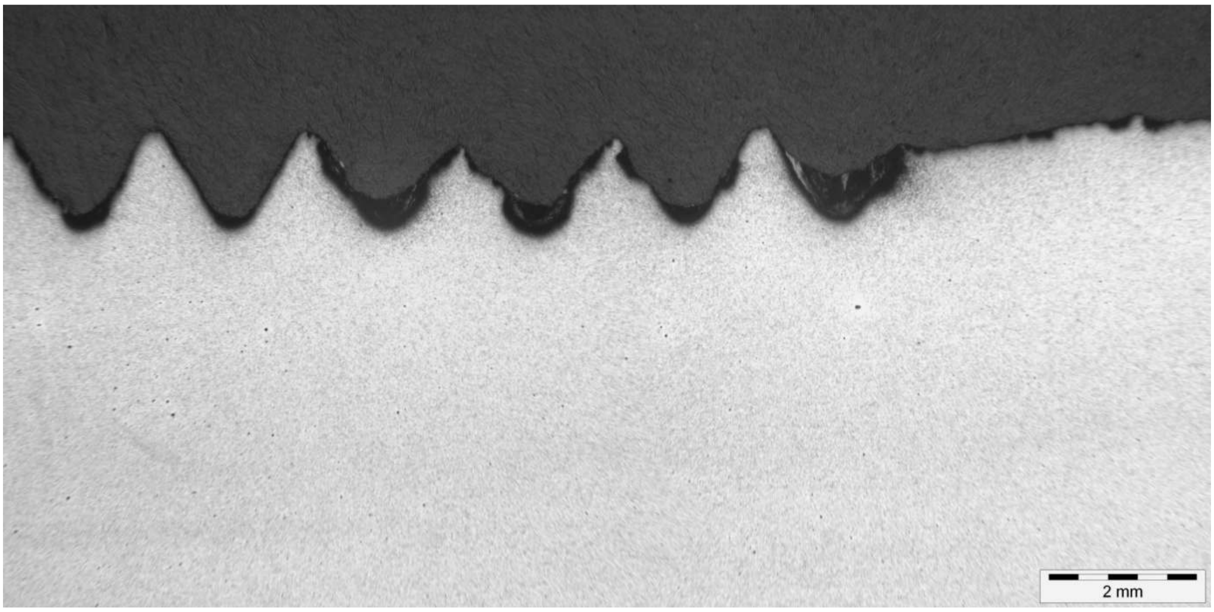


Figure 54: Micrograph (original image captured at X12.5), specimen etched in Nital. Longitudinal section from an un-fractured bolt, showing corrosion of the plain shank and threads.

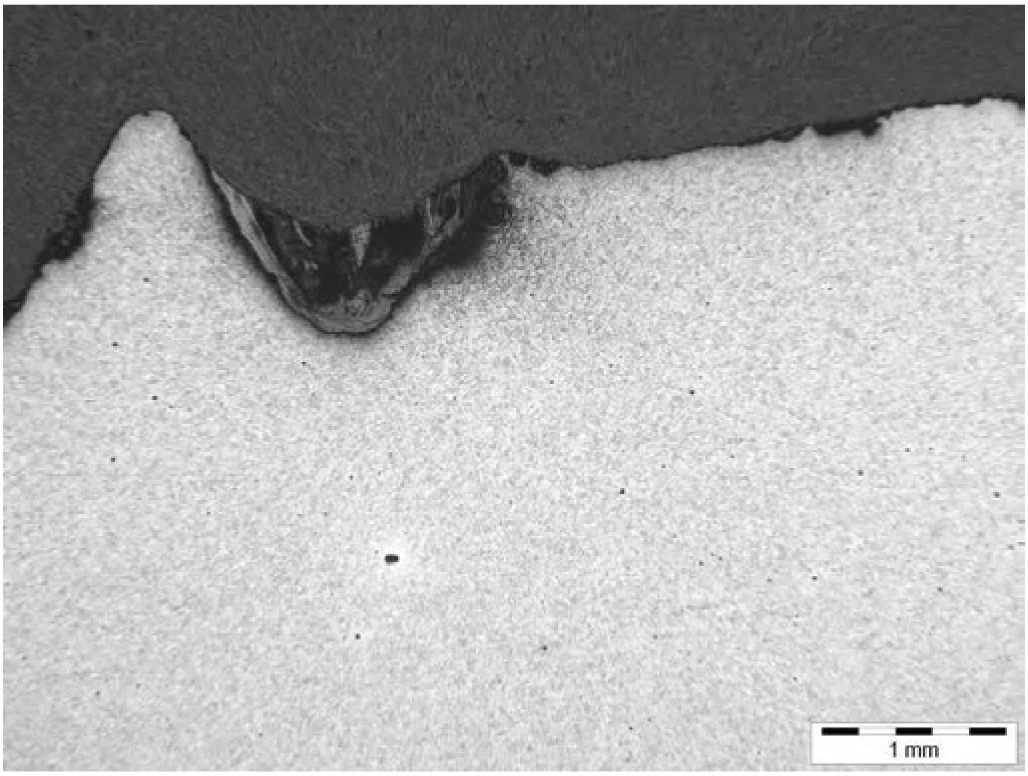


Figure 55: Micrograph (original image captured at X25), specimen etched in Nital. Detail of the corrosion damage shown in figure 54.

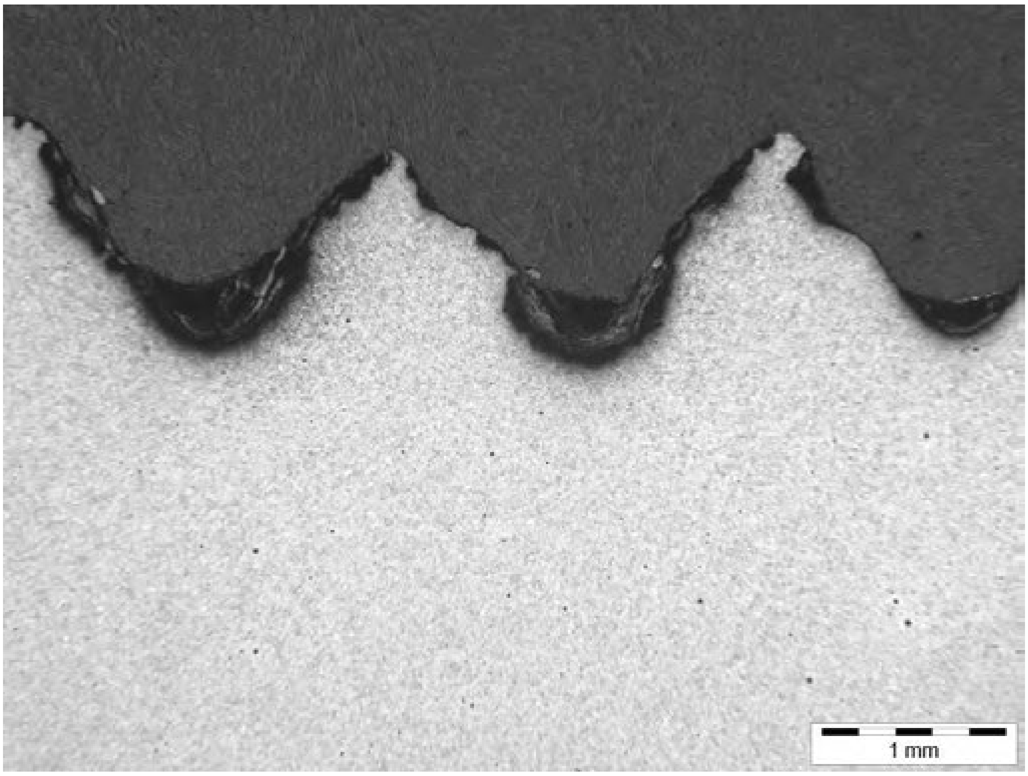


Figure 56: Micrograph (original image captured at X25), specimen etched in Nital. Further detail of the corrosion damage shown in figure 54.

Guideline internal ISM inspection report

:guideLINE
QUALITY SAFETY ENVIRONMENT

Ship's VISIT

No.: 2

MV BLUE NOTE

Date: 17./18.02.2011

Place: MONTOIR

Berth: – " –

Agent/ Tel.: 02 40907083

Name of Master: [redacted]

Reason for the visit:
- [x] Training
- [x] Internal Audit
- [ ] External Audit
- [ ] ....

Non-Conformities: **Total no. of NC's:**

ISM – 1–7 AS AUDIT REPORT

Notes:

[redacted]

Ship-type:
t dwat:
No. of crew:
Nationalities:
No. of watches:

Travel costs

Kilometer: 28 x 0,45 = 12,60
Hotel: x
Flight: x
Parking:
Others: ESSEN 28,30
TAXI REINTDIEK HH. = 38,–

79.40

Revision: 4
page 1/1

:guideLINE (QUALITY SAFETY ENVIRONMENT)	INTERNAL AUDIT REPORT	Revision: 0 Page 1 of 1

Name of vessel:	BLUE NOTE
Place of audit:	MONTOIR
Date of audit:	17./18.02.2011
Name of internal auditor:	[redacted]

Standard internal audit conducted against:	
X	ISM-Code
X	ISPS-Code
	ISO 9001
	ISO 14001
	OHSAS 18001

AUDIT SUMMARY	
Audit atmosphere:	GOOD
Audit conduct:	GOOD
Overall condition of the vessel:	GOOD
Condition of the safety equipment:	GOOD
Condition of the engine-room:	GOOD
Masters attitude/ -cooperation:	GOOD
Training standard of crew:	GOOD
Status of implementation:	GOOD
General remarks:	NONE [redacted]

QUALITY SAFETY ENVIRONMENT **:guideLINE**	**INTERNAL AUDIT REPORT** (Appendix ISM)	Revision: 0 Page 1 of 2

"BLUE NOTE"

		DEPARTMENTS								
			A	B	C	D	E	F	G	
		Master	Deck Department/ Cargo	Safety Department	Bridge	Engine Department	Cook	Ratings		
2	**Safety- and Environmental Protection Policy** known	✓								
3	**Responsibility and auhtority** known									
4	**Designated Person(s)** known	✓	✓				✓	✓		
5	**Master responsibility and (overriding) authority**	✓								
6	**Resources and personnel**	✓				✓	✓	✓		
	Valid licenses, certificates and medical fitness	✓								
	Ability to understand and speak English	✓	✓			✓	✓	✓		
	Resttimes documented correctly	✓	✓			✓				
7	**Shipboard operations**	✓	✓			✓				
	Risk Assessments	✓	✓		✓					
8	**Emergency preparedness**	✓	✓		✓	✓				
9	**Reports and analyses of system improvements, accidents + hazardous occurrences**	✓	✓							
10	**Maintenance of the ship and equipment**	✓	✓			✓				
	Critical Equipment maintained		✓			✓				
	Inspections performed	✓								
11	**Documentation**	✓								
	Valid and complete ships certificates	✓								
	ISM-Manual and forms in latest edition	✓								
	Seacharts/ lists of lights corrected properly	✓	✓							
12	**Internal Audits** (performed in the required intervals)									
13	**Certification, verification and control**									
	Document of compliance available/ valid/ endorsed	✓								
	Date of last Masters Review	✓								
	Non-conformities from internal/ external audits cleared	NOT ALL								
	ISM 3.1 – Flagstate Letter available on board	YES								
	Lifeboats/ Rescueboats/ Liferafts launched	12/2010								
	Lookouts documented properly	YES								
	Follow-up on PSC-control inspections	YES								

QUALITY SAFETY ENVIRONMENT :guideLINE	INTERNAL AUDIT REPORT (Appendix ISM)	Revision: 0 Page 2 of 2

BLUE NOTE

NON-CONFORMITIES/ OBSERVATIONS
1) SAFETY MEETING REPORT IN THE LOG BOOK 2) HOT WORK PERMIT # FILL IN NO SUITABLE TESTING EQUIPMENT FOR SAFE ENTRY AVAILABLE MISSING. 3) NO BUNKERING PROCEDURE ON BOARD 4) MENTENANCE LIST CH. ENG./DECK "REGULAR FORM" 5) VOYAGE PLAN DATE AND SIGNATURE MISSING 6) NO DATE AND SIGNATURE IN THE SEAFARER BOOK (CH. MATE) 7) DRILL'S AND MEETING ARE MISSING IN THE LOG-BOOK/DETAILLIERT/DETAILED, PERSON AND NATURE

CORRECTIVE-/ PREVENTIVE ACTIONS	Cleared date/ signature
1) SAFETY MEETING REPORT IN THE LOG BOOK 2) HOT WORK PERMIT MISSING 3) BUNKERING PROCEDURE ON BOARD 4) MENTENANCE LIST DECK/ENG REGULAR FORM 5) VOYAGE PLAN DATE AND SIGNATURE MISSING 6). DATE AND SIGNATURE IN THE SEAFARER BOOK (CH. MATE) 7) RECORD ALL DRILL'S/MEETINGS IN THE LOG BOOK/PERSON AND NATURE	

Is a follow-up audit required?	

Signature Internal Auditor	[redacted]	Signature Master	[redacted]

18.02.2011

Familiarisation with duty and emergency preparedness form

FAMILIARISATION with Duty and Emergency Preparedness

Responsibility: Master
To be completed: right after joining, before sailing

Name of trainer: .... Position of trainer: ....
Master and Mate have to ensure that the new employee is familiarised and briefed about the following:

No.		√
1	crew-members cabin, assigned life-boat, location of life-jacket and immersion suits, nearest fire extinguisher and other fire fighting equipment, escape routes, safety plan and any other vessel specific personal life saving appliances	
2	all on board safety information symbols, signs, alarms, signals	
3	procedures for „Man over board"	
4	Immediate actions when detecting fire or smoke, raising of alarms	
5	actions after hearing „abandon ship" or „general alarm"	
6	all locations of Muster Stations, station bills and their content	
7	special duties assigned in case of life boat launching	
8	demonstration of vessel's internal communication system	
9	assignment of station during mooring and unmooring	
10	familiarisation tour through vessel	
11	introduction of new employee to all crew-members	
12	location of company's safety manuals	
13	cabin control - all cabin items in good order	
14	Familiarisation with duty	

Declarations:

I, ..., trainer assigned by Master of .... hereby confirm that

.... has been fully briefed and familiarised in all above issues and I will ensure that he will be further trained in accordance with company's safety- and environmental protection system.

....
Date Signature Trainer

I, ..., ... hereby confirm that I have been
(name) (rank)
familiarised with the above and that I have read the company's quality, safety, environmental protection, anti-drug and alcohol policy.

I herewith undertake to work according to this policy.

....
Date Signature Crew-member

Manufacturer’s maintenance schedule

MAINTENANCE SCHEDULE FOR GANTRY CRANE

SUBJECT	PERIOD	APPLICATION
Steel Construction	Every 2 months	Major steel parts of the crane structure to be inspected regularly at every 2 months for rust, damages and cracks visually. If rust found at welded areas, grind the surface to check crack, if necessary liquid spray penetrant can be applied. Before making any repair contact to MARINER first. As may cause damages to the bearings direct welding on the crane parts in general not allowed.
Bolted connections	Routine	After the first 50 hours operation and at every 200 operation hours or every 2 months whichever comes first,all bolted joints to be visually inspected and any bolt tendency to slacken, to be overhauled and tightened up.
Wire Ropes and Rope Clamps	Routine	Every 6 months or every 500 working hours the rope must be examined for tear and wear. Please see instruction for wire ropes.
Machinery	Every 2 months	The machinery must be checked for loose bolts and cracks with the same interval as the steel construction. Also rope sheaves, slide ways and rope fixing must be checked, just like gear and hydraulic system must be examined for cleanness and oil spillage. System valves already adjusted and need not any future adjusting.
Hydraulic System	Every 2 months	Hydraulic system should be inspected for leaks, loose bolts, and cracks with the same intervals as the other machinery. If a single jointing proves to be leaky several times in spite of tightening up, the tube should be renewed.
Hydraulic System	Routine	Hydraulic oil sample analysis to be done at every 6 months. If no analysis is done oil to be changed at every two years or maximum 1500 hours of operation. Oil filter cartridge to be changed at every 1000 hours. Air breather on the tank to be checked for free air flow.
Rope Sheave and other Bearing Axles	Routine	Apply grease to the grease nipples every 100 hours or at every 2 months to axles and drive chain gears and chain.
Rope	Routine	The rope is delivered grease lubricated, but before the crane is put to service and then at least every 2 months the rope must be lubricated with a suitable sea water resistant grease.
Lifting cylinder	Every month	The cylinder is suspended in hinged bearing with grease nipple. Re-lubrication necessary at every month.

MAINTENANCE SCHEDULE FOR GANTRY CRANE

SUBJECT	PERIOD	APPLICATION
General	Every week	Check insulation resistance of following: motor motor heater
Electric motor and coupling	Every 6 months	Electric motor and coupling to be checked visually for wears or damages. When gantry crane is not under use, the hydraulic power pack and electric motor together with associated pump to covered with canvas or similar for protection of shaft line of e-motor from external effects.
Control box	Routine	Before starting crane or every week whichever comes first; check lamps functioning, handle condition, cover condition. Blow out lamps to be replaced. Rusted or malfunctioning handle, hinge to be cleaned and painted if necessary.

Annex E

Three monthly deck maintenance list

MAINTENANCE LIST DECK

every three month!

Name of vessel : BLUE NOTE
Name of Master : [redacted]
Name of C/Off. : [redacted]
Date/Month/Year: 01.07.2011 - 30.09.2011

Following to be checked respectively carried out regularly:

1) Daily at Sea
- check of bilge wells bow thruster room / cargo holds

2) Daily in Port
- check of gangway, ropes, hatches, winches, lamps a.s.o.
- stores a.s.o. have to be locked properly! Pay attention to thieves + stowaways!
- loading and discharging operations always under supervision of captain or officers
- opening and closing of hatchcovers under supervision of captain or officers only

3) Weekly (if necessary and possible)
a) Greasing of winches, hatches, hydraulic wheelhouse, davits, flaps, hinges, a.s.o.

	Date of performance:	Performed by:	Remarks:
1.st week	04.07.2011	DECK STAFF	OK
2.	11.07.2011	DECK STAFF	OK
3.	18.07.2011	DECK STAFF	OK
4.			
5.			
6.			

7.th week
8.
9.
10.
11.
12.

b) Check of all rubber seals and gaskets of hatches and ramps:
(all rubber seals from hatchcovers and flaps to be greased with soft soap)

Date of performance:	Performed by:	Remarks:
1.st week 04.07.2011	CH.OFF. / DECK STAFF	OK
2. 11.07.2011	CH.OFF. / DECK STAFF	OK
3. 18.07.2011	CH.OFF / DECK STAFF	OK
4.		
5.		
6.		
7.		
8.		
9.		
10.		
11.		
12.		

c) Check of lighting and ventilation installations:

Date of performance:	Performed by:	Remarks:
1st week 04.07.2011	CH.OFF.	OK
2. 11.07.2011	CH. OFF.	OK
3. 18.07.2011	CH. OFF.	OK
4.		
5.		
6.		
7.		
8.		
9.		
10.		
11.		
12.		

3) Monthly:

3.1.Check of Safety Equipment acc. to SOLAS (See BG report 'F', or German Lloyd record of approved Safety Equipment for ship and life boat(s) respectively acc. vsls. Safety Plan

Date of Performance:	Performed by:	Remarks:
1st month 11.07.2011	CH. OFF.	OK
2.		
3.		

3.2.Check of watertightness of all hatches, portholes, doors and flaps by hose tests

Date of Performance:	Performed by:	Remarks:
1st month 05.07.2011	CH. OFF / SHORE SERVICE	ULTRA-SONIC TEST in Turkey - OK
2.		
3.		

3.3.Check of draining system hatches

Date of Performance:	Performed by:	Remarks:
1st month 06.07.2011	CH. OFF / DECK STAFF	OK
2.		
3.		

3.4. Check of seacharts, navigation publications a.s.o.

Date of Performance:	Performed by:	Remarks:
1st month 11.07.2011	CH. OFF / 3RD OFF.	OK
2.		
3.		

3.5. Check of all cabins, sanitary rooms, galley and provision stores

Date of Performance:	Performed by:	Remarks:

1st month 11.07.2011 CH.OFF OK
2.
3.

We herewith confirm that above checks have been carried out by vsls. crew in accordance with masters and officers instructions.

Signature of Master

Signature of Chief Officer

Name in block letters

Name in block letters

Annex F

Risk assessment procedure

7.4 *Risk Assessment*

The core to assess all risks to ship, personnel and the environment is the investigation and evaluation of hazards, the determination of adequate measures and the verification of the effectiveness of measures. It is Masters obligation to conduct and to document risk assessment. Risk assessment has to be repeated periodically in order to ensure the effectiveness of measures. Risk assessment should be conducted in exceptional circumstances, e.g. new equipment, changes in workflow, change of personnel, etc.

Following items have to be considered:

- Design and condition of the working stations
- Design, choice, operating condition of equipment and technical systems on board
- Process and organisation of work (workflow, working hours, rest hours, responsibilities)
- Working conditions (climate, lighting, exposition to noise, vibration)
- Person protective equipment
- Group of persons concerned, qualifications, abilities, familiarisation

Following basic principles should be considered:

- The work process has to be organised in such a way that hazards for life and safety are avoided as far as possible and the remaining hazards are reduced to a minimum
- Hazards have to fought at their roots
- In all measures the technical, medical and sanitary standards and other work scientific knowledge have to be considered
- Measures have to be planned with the objective to connect technology, organisation of work, other work conditions, social relations and environmental influences on work stations in an appropriate way
- Individual safety measures are subsequent to other measures
- Special hazards for employees with a special need for protection are to be taken into account
- Appropriate instructions to employees

Risk Assessment Procedure

Please use Form "Risk Assessment" when performing risk assessments.

Responsibilities: The Master onboard is responsible for performing Risk Assessments.

0.) Definition of work process / investigation unit

Master	defines the work process/ investigation unit to be analysed and documents the results on form "Risk Assessment"

1.) Determination of hazards

Master	determines hazards by analysing harms, accidents and occupational diseases to get information about their causes
	considers all factors of hazards (e.g. mechanical, electrical, chemical, psychological factors, noise, vibration)

2.) Determination of possible consequences

Master	determines the possible consequences of the identified hazards

3.) Risk Assessment (evaluation of health and safety)

Master	takes into account the consequences and likelihood of the hazard with the matrix on form "Risk Assessment"
	compares with relevant rules and regulations, scientific knowledge, limits and safety distance, existing safeguards, company objectives and targets and professional judgement
	evaluates if the risk is acceptable (if green or yellow in the risk assessment matrix) (then no measure have to be initiated)

4.) Deduction and implementation of additional safety measures

Master	implements additional safety measures if existing safety measures are not sufficient (if orange or red on the risk assessment matrix) to avoid hazards according to following hierarchy: 1.) Elimination , avoidance, reduction of sources of hazard 2.) Technical measures 3.) Organisational measures 4.) Personal protection equipment 5.) Behaviour-oriented measures 6.) Date of implementation, definition of responsible persons

5.) Monitoring of effectiveness

Master	monitors the effectiveness of additional safety measures, assesses the new risk assessment factor (if this is at least green or yellow), otherwise additional measure have to be implemented

6.) Documentation

Master	documents the above on form "Risk Assessment"

Annex G

Sand Falcon safety flyer

MARINE ACCIDENT INVESTIGATION BRANCH

SAFETY FLYER TO THE SHIPPING INDUSTRY

Failure of non-cargo handling lifting appliances

The dredger *Sand Falcon* was alongside at a jetty when the trolley from its gantry-type stores crane came off and fell 7.5m landing on the deck guardrails. The trolley weighed over 400kg and narrowly missed the 7 people who were working nearby on the main deck and ashore on the jetty. The crane was being prepared to load ship's stores at the time and was not carrying any load.

The failure was due to a combination of design flaws, lack of maintenance and weaknesses in the inspection and testing methods used to assess the safety of the crane.

The floating sheerleg *Cormorant* was raising her 85t 'A' frame when two pad eye fittings holding wire supports detached from the deck causing the sheerleg to fall back onto the wheelhouse. Considerable damage resulted but there were no injuries.

The failure was due to the rigging being overloaded by the uncoordinated use of the hoisting and luffing winches. The raising of the sheerleg had not been identified as a key shipboard activity. There had been no risk assessment and no written operational procedures were provided. No alarms or interlocks were fitted to the hoisting system.

The pad eyes had not been identified as lifting equipment and had not been inspected or tested for 37 years. Although their condition was not considered to have contributed to the failure, weld fatigue was identified by non-destructive testing to corresponding pad eyes on board a similar vessel

The 77m general cargo vessel, *Velox,* was loading grain and the crew was tasked with painting the hull using the ship's workboat. Instead of using the workboat's hand-operated davit, a larger electrically-driven stores crane was used. An AB and cadet boarded the workboat and it was hoisted off the cradle. After some problems slewing the workboat outboard, the workboat was then lowered. When it had descended approximately 2m, the lifting wire parted and the boat, with its occupants, fell 8m into the water. Both the AB and the cadet suffered serious injuries.

The lifting wire was in an extremely poor condition and it was later found that the stores crane had not been maintained for some time. The stores crane was meant to have been decommissioned, but not everyone knew this and it had not been put out of use.

Overseas Camar was alongside loading a cargo of gas oil and a stores barge was secured on the outboard side. The stores crane had lifted the first load of hydraulic oil drums safely and a second load was being hoisted, when suddenly the load began to fall back onto the deck of the stores barge. The crewmen on the stores barge looked up and saw both the crane and its operator, who was in the control platform attached to the crane, falling. The crane struck the side of the ship, crushed a skip on the stores barge and fell into the sea. It was first thought that the operator had fallen into the sea too, but he landed on a lifeboat deck, some 5m below the crane pedestal. Although his injuries were severe, he was extremely fortunate not to have fallen further and been killed. Both crewmen on the stores barge were able to run clear.

The nuts and bolts used to hold the crane pedestal to the mounting ring were badly corroded, allowing the bolts to pull straight through the nuts. Neither the ship's planned maintenance nor inspections by the classification society had detected how bad the corrosion had become.

These accidents are examples of the 29 similar cases that have been reported to MAIB since 2001 involving the failure of non-cargo handling cranes. The majority of these cases had the potential to cause fatal injuries and although there were no fatalities, a total of 11 people were injured.

Safety Lessons

- Check that planned maintenance and inspections cover all parts of the equipment and arrange proper access to reach components in awkward positions.
- If the manufacturer's maintenance instructions are poor, or there are none, get expert assistance to make sure that the right maintenance is being done.
- Check that all non-cargo lifting appliances have been identified and recorded in accordance with national regulations. Some, like the rigging used to raise a sheerleg, might not be obvious.
- Make sure that those carrying out statutory inspections, load tests and thorough examinations are competent to do so. Employing contractors who meet a recognised industry standard should provide greater quality assurance.
- Follow the guidance on lifting equipment published by the Maritime and Coastguard Agency in Marine Guidance Notes 331 and 332, and in the Code of Safe Working Practices.
- Ensure that all key shipboard activities are identified, risk assessed and that the control measures identified, such as procedures, alarms and interlocks, are provided.

This flyer and relevant MAIB's investigation reports are posted on our website: www.maib.gov.uk

For all other enquiries:

Marine Accident Investigation Branch
Mountbatten House
Grosvenor Square
Southampton
SO15 2JU

Tel: 023 8039 5500
Fax: 023 8023 2459
Email: maib@dft.gsi.gov.uk

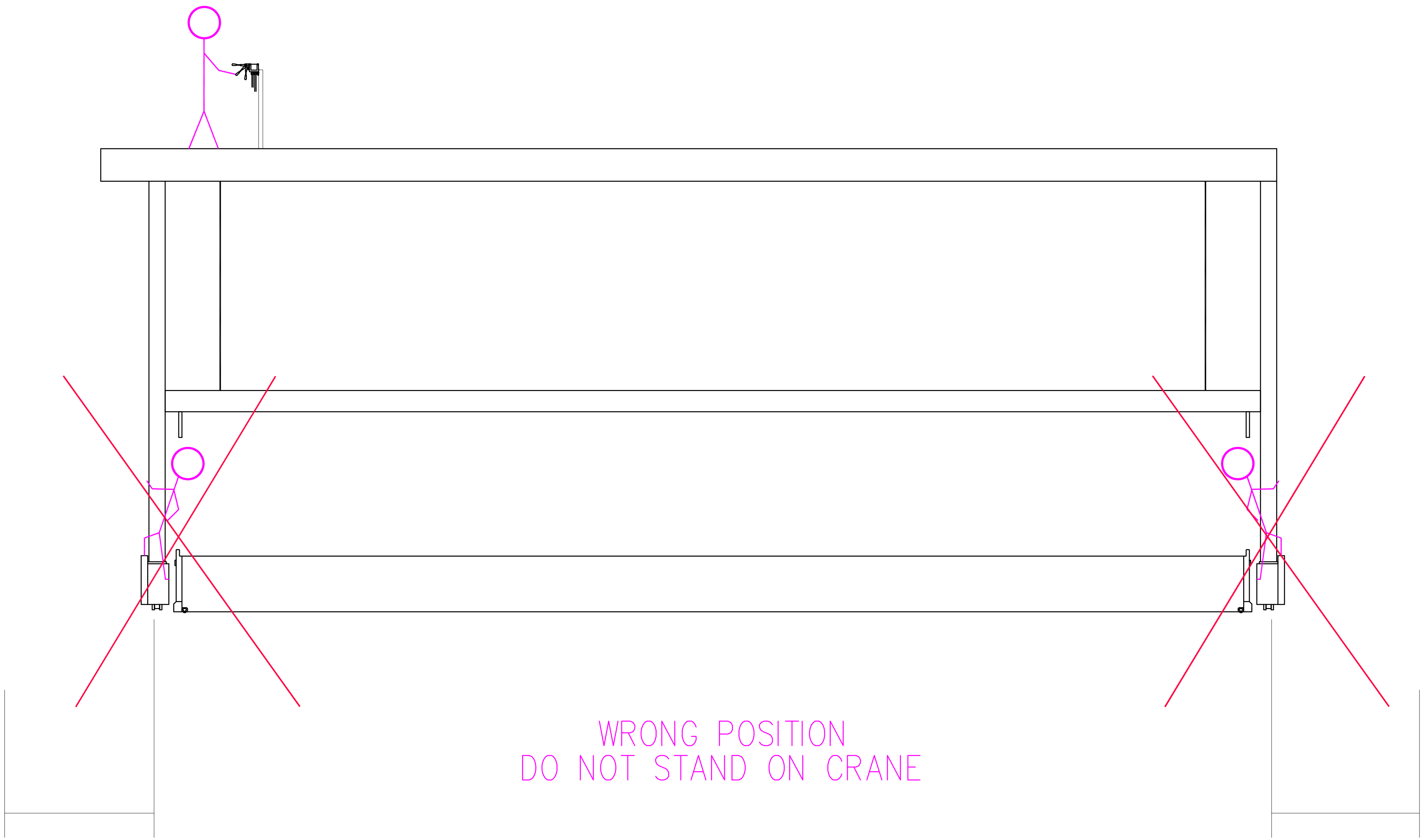
November 2010

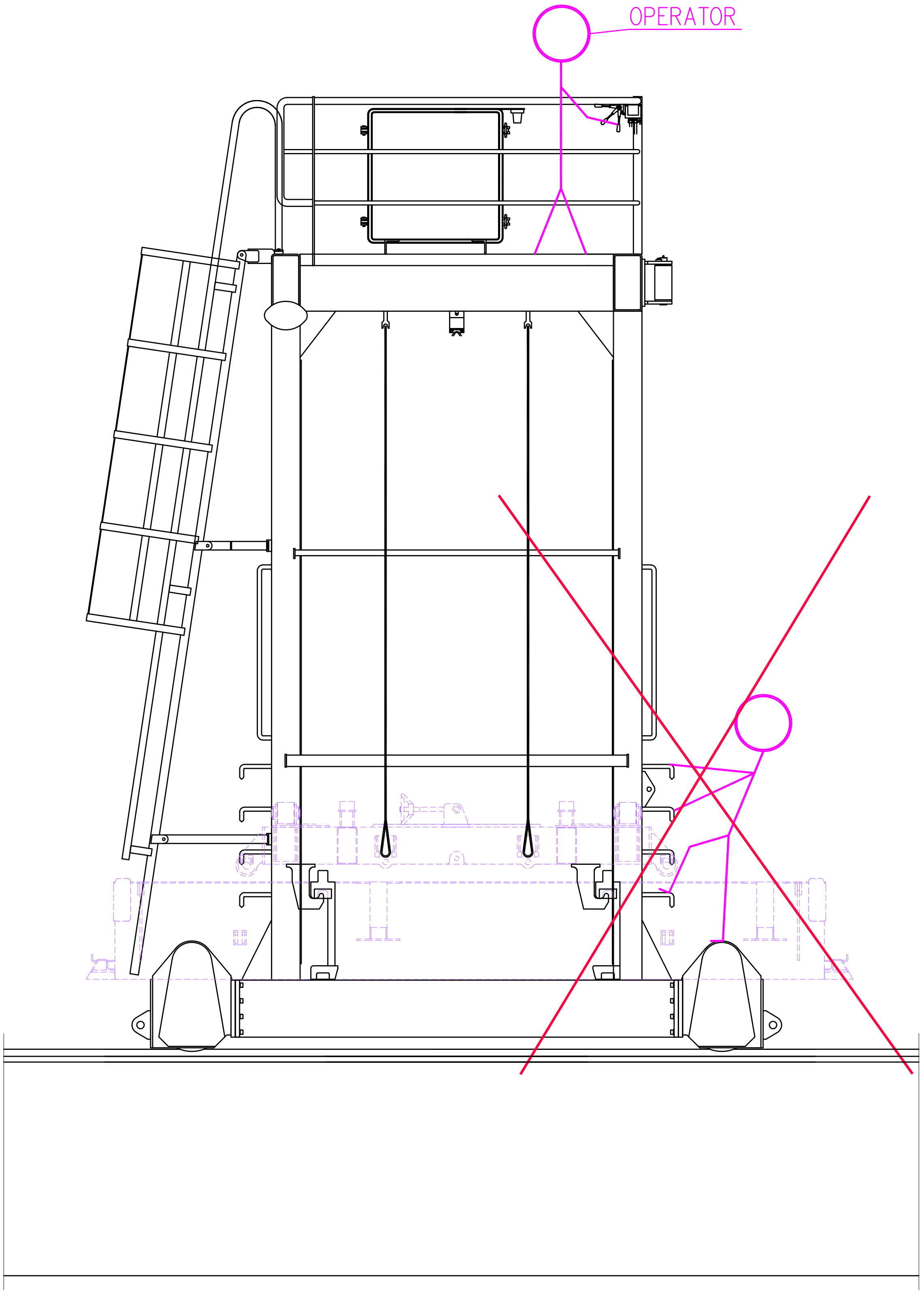
Summary of cases involving the failure of non-cargo handling cranes reported to MAIB from 2001 to November 2011

Year	Summary	Injuries
2001	Hydraulic lifting ram failed in way of a weld repair	None
2002	Fitter struck by a manual winding handle causing broken ribs during maintenance procedure	1
2003	Lifting wire parted after becoming trapped in a sheave	None
2003	Motor failed, allowing crane boom to fall. Two stevedores injured by falling wire	2
2003	Crewman riding on a gantry crane was crushed between the crane and ship's structure	1
2003	Gangway davit came away from mountings when a securing pin worked loose	None
2003	Lifting wire parted due to chafing damage	None
2004	Electrical fault caused loss of luffing control, leading to structural damage	None
2004	Crane operator injured his arm when it became trapped between the crane and ship's structure while slewing	1
2005	Lifting wire parted – found to be corroded and crushed in way of a bulldog clip	None
2005	Crane luffed uncontrollably due to mechanical control defect	None
2005	Lifting wire parted - overloaded	None
2006	Unexpected release of a 'riding turn' in the luffing wire caused the jib to lower rapidly, injuring a crewman on the head	1
2006	Lifting wire parted due to corrosion. Corroded area hidden by ball weight.	None
2007	Lifting wire parted on a 1 tonne swl stores crane while it was lifting 350kg. Wire found to be in poor condition due to lack of maintenance	None
2007	Crewman crushed by hydraulic crane when the controls were activated inadvertently. Crewman's leg subsequently amputated.	1
2007	Crane lowered uncontrollably due to leak on hydraulic system	None
2007	Lifting wire parted – found to be in poor condition	1
2007	Crane jib collapsed - overloaded	None
2008	Bosun seriously injured when the provisions crane he was operating detached from its mountings and fell onto a stores barge secured alongside the vessel	1
2008	Hydraulic hose burst while the crane was in use	None
2008	Hydraulic hose burst while the crane was in use	None
2008	Hydraulic cylinder failed while in use, causing crane jib to fall	None
2008	Lifting wire parted - overloaded	None
2009	Error while using crane controls led to wrong function to be used, causing crane to be driven into ship's structure.	None
2009	Structure deformed due to misuse	None
2009	Lifting wire parted – found to be in poor condition	None
2009	Lifting hook detached from wire – not fitted correctly	None
2009	Lifting wire parted while lowering a workboat with two crew on board. Both crew injured. Wire found to be in poor condition and not maintained	2
2010	Stern crane failure	None
2010	A frame collapsed	None
2010	Crewman fell while acting as banksman	1
2010	Entrapment in lifting wire/block	1
2010	Crane failed during load test due to structural wastage	None
2010	Crewman crushed due to poor lifting technique	1
2010	Jib cylinder mounting lug failed while lifting gangway causing jib to collapse	None
2010	Micro switch failed causing loss of control & damage to crane head	None
2011	Hatch lid gantry crane, poor procedures	1
2011	Poor operations	1
2011	Poor procedures. Banksman crushed by load	1
2011	Failure of lifting sling	1
	Total injured	**18**

Annex I

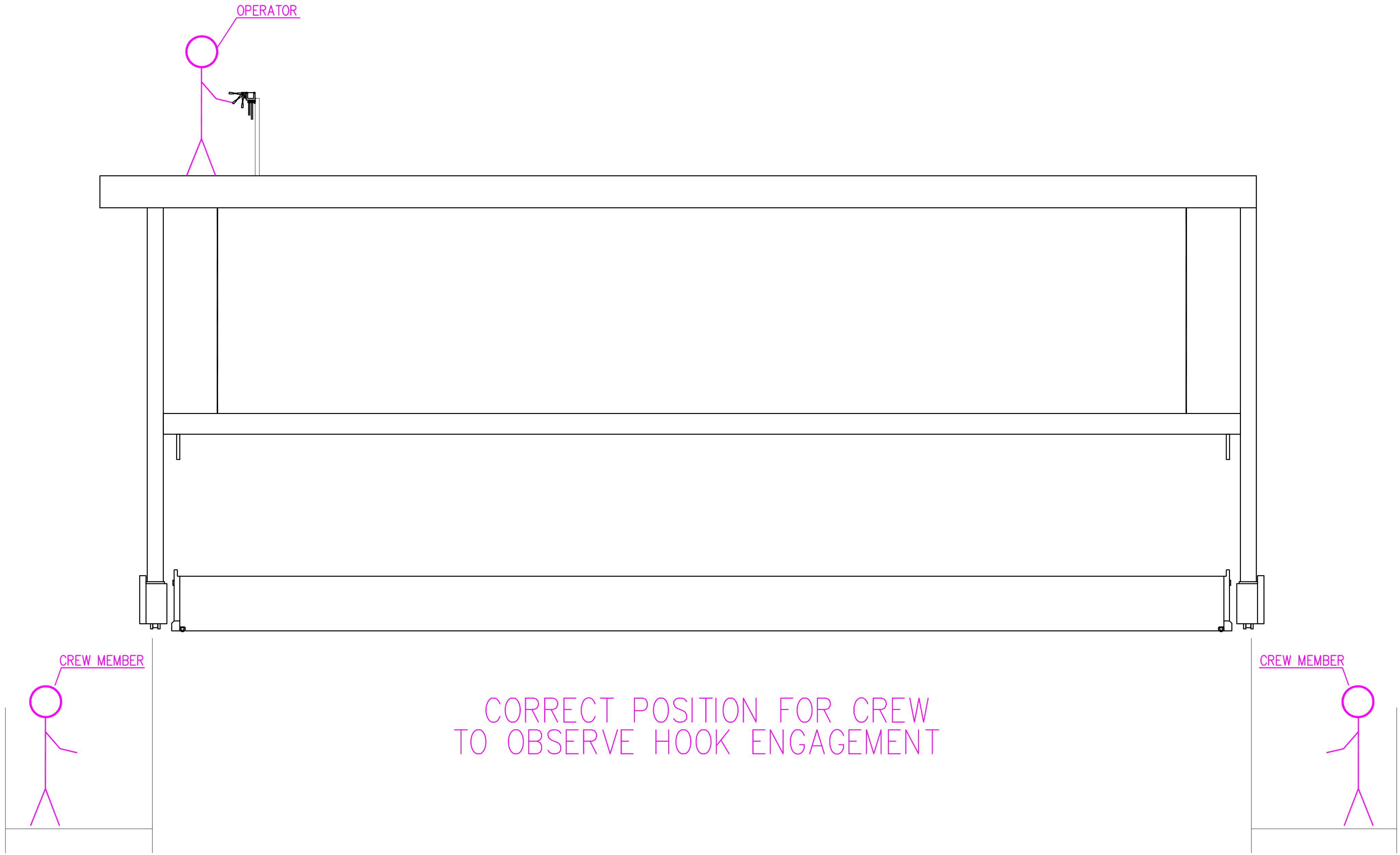
Manufacturer’s additional instructions and design modifications following the accident

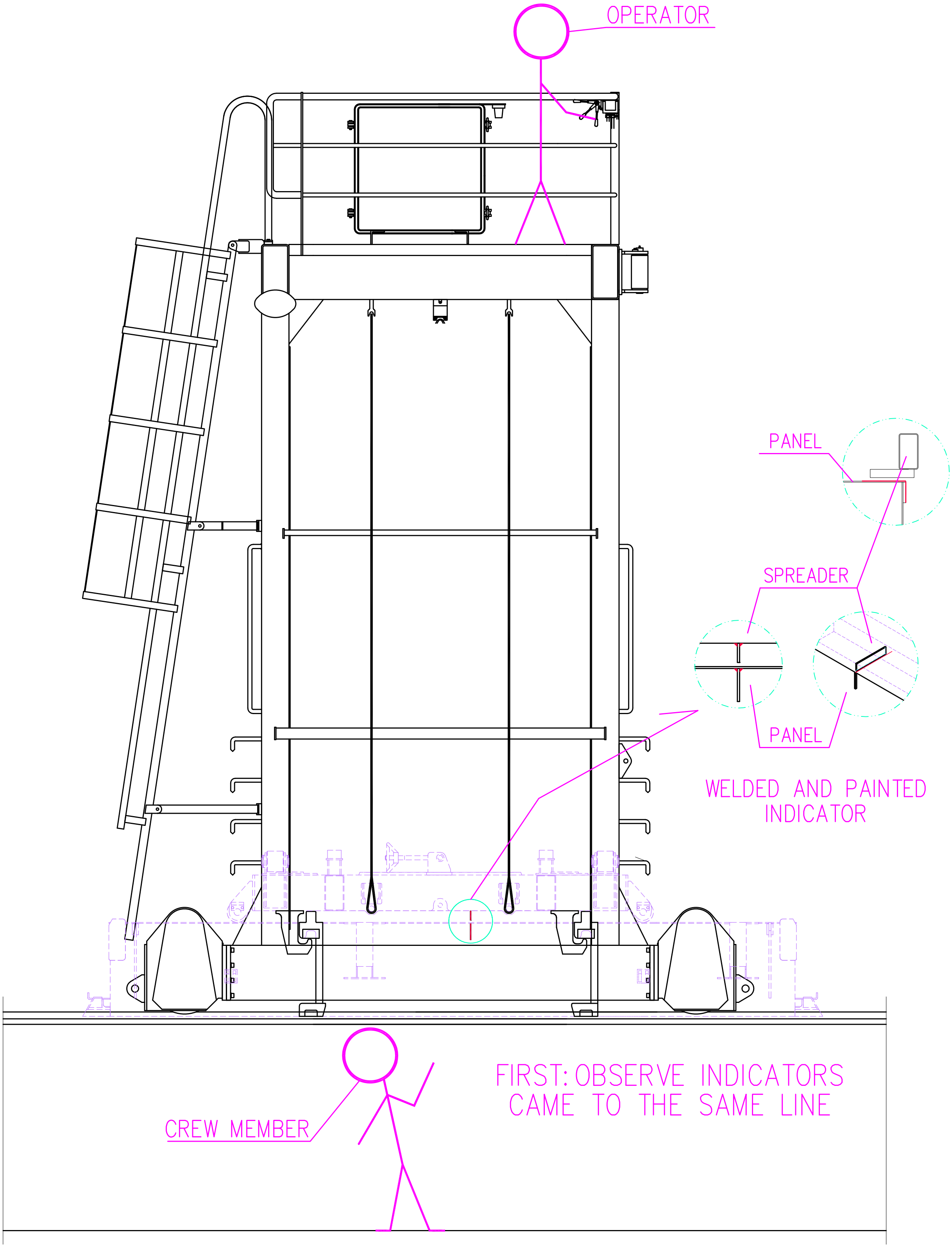

WRONG POSITION
DO NOT STAND ON CRANE



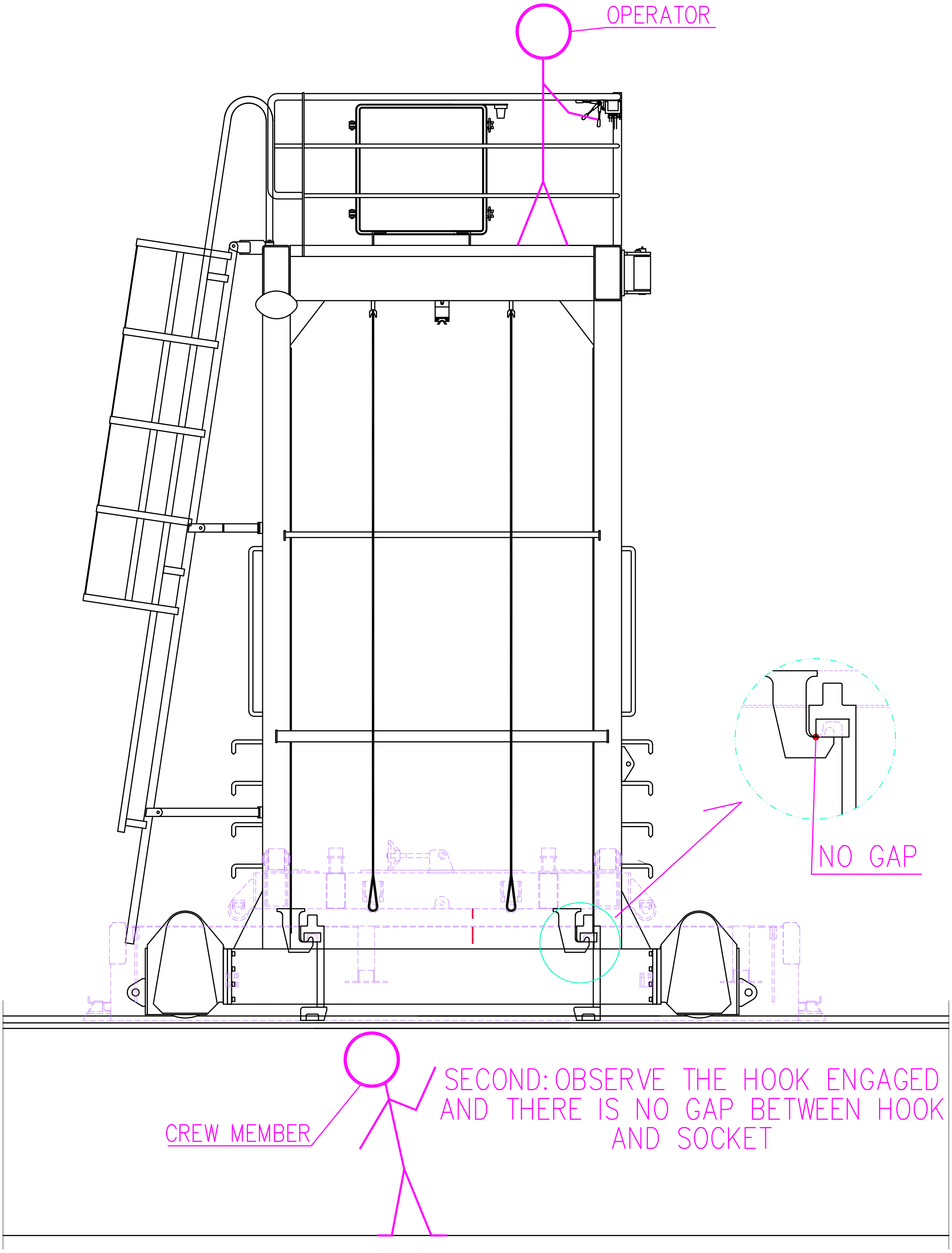
WRONG POSITION
DO NOT STAND ON CRANE

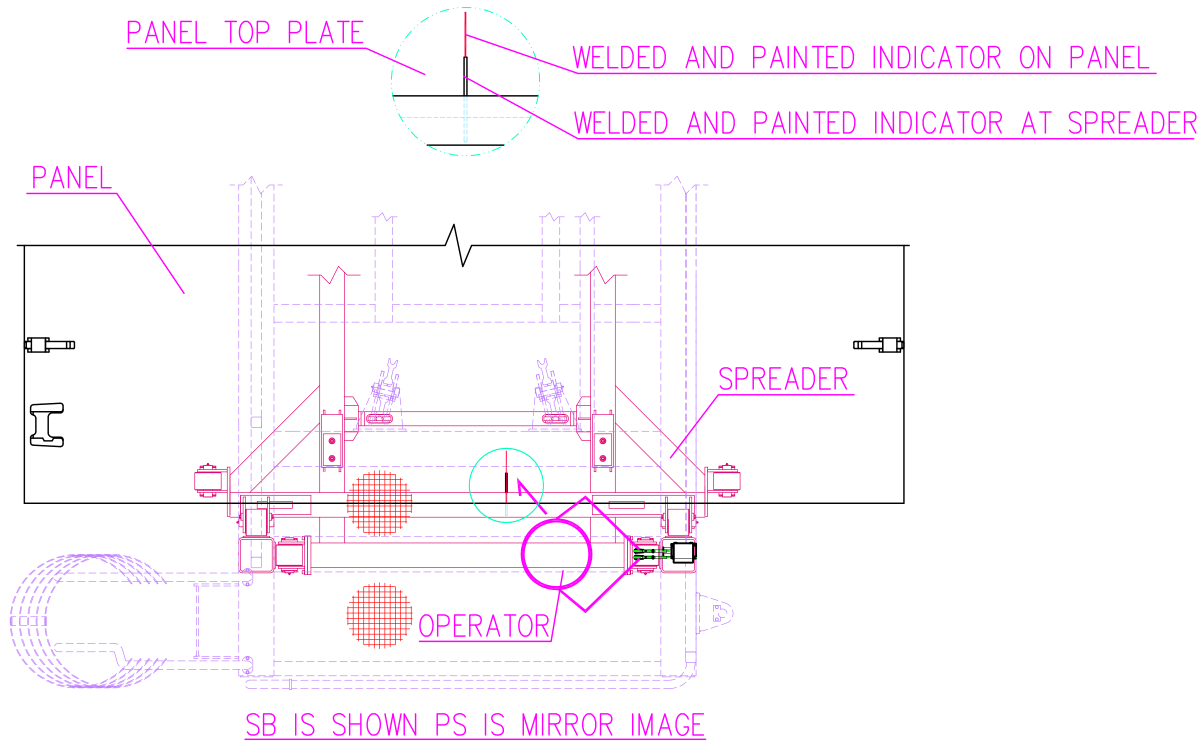
MARINER SHIP'S EQUIPMENT



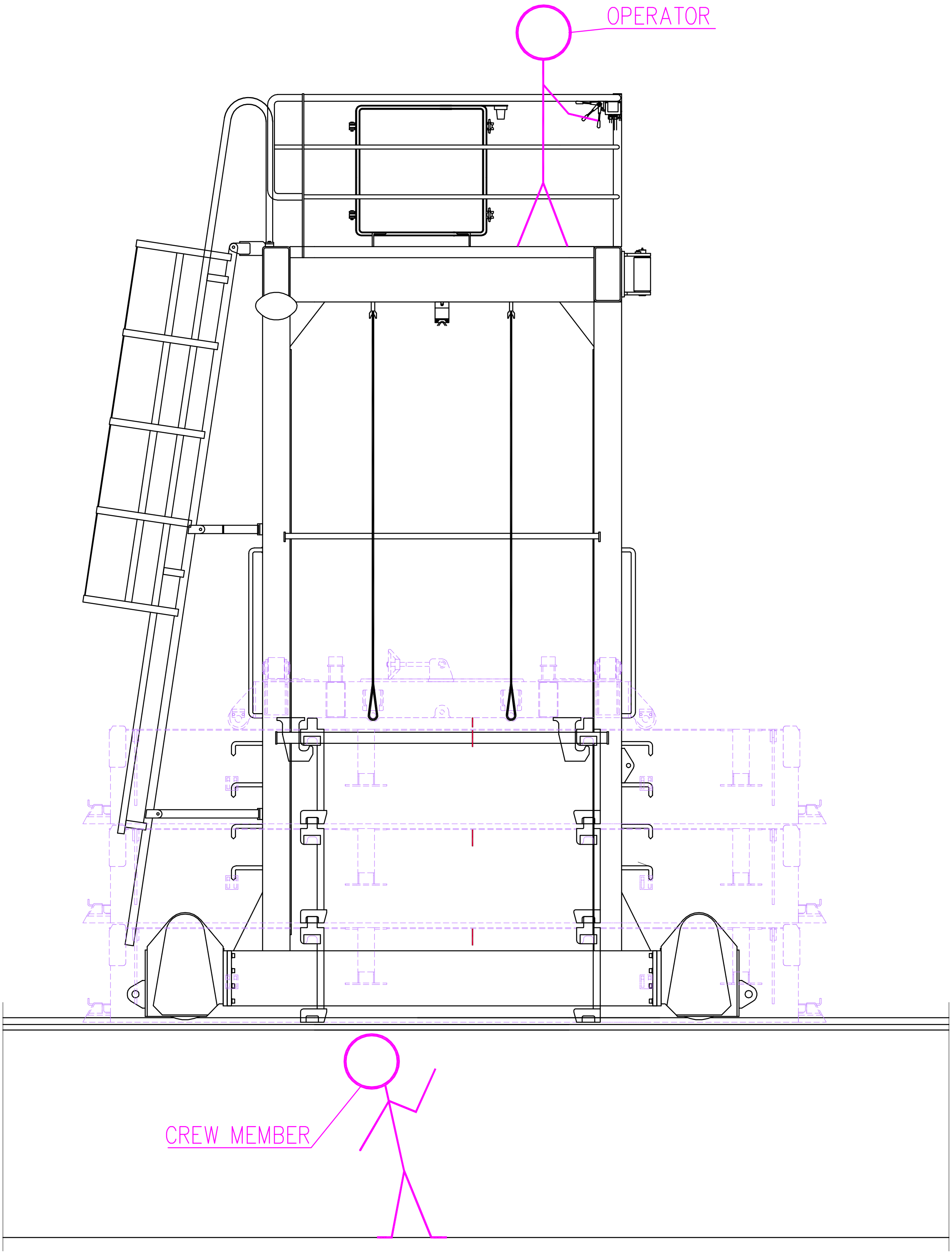


CORRECT POSITION FOR CREW
TO OBSERVE HOOK ENGAGEMENT

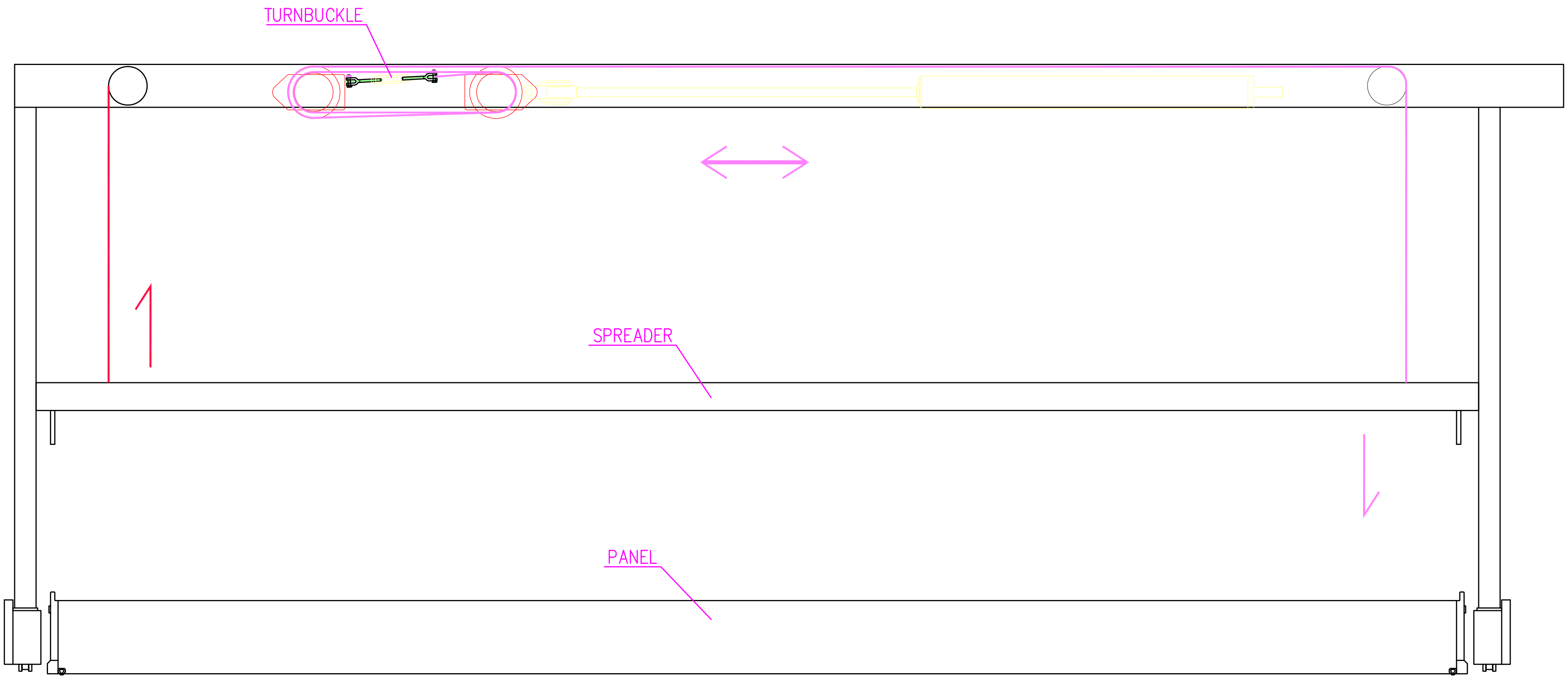

OPERATOR
NO GAP
CREW MEMBER
SECOND: OBSERVE THE HOOK ENGAGED AND THERE IS NO GAP BETWEEN HOOK AND SOCKET



BEFORE LIFFTING UP OPERATOR CAN ALSO
OBSERVE THAT INDICATORS ARE IN LINE

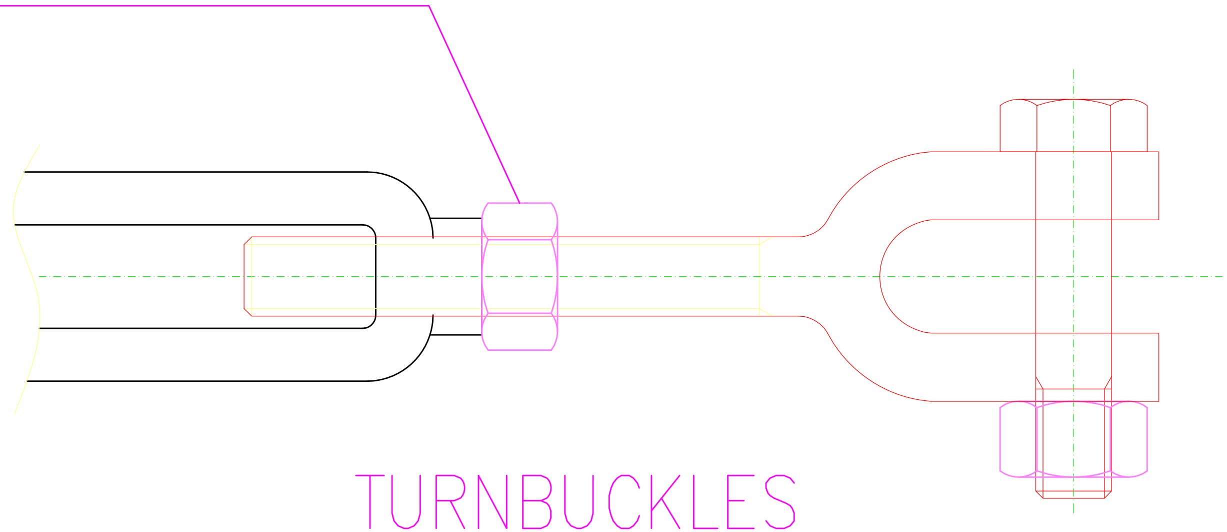


APPLY THE SAME PROCEDURE FOR STOWAGE OF PANELS ON TOP OF EACH OTHER



ADJUST LEVEL OF SPREADER BY TURNBUCKLES

DO NOT FORGET TO TIGHTEN NUT
TO BODY AFTER ADJUSTMENT



TURNBUCKLES