A short Guide to Engineering Changes

Understanding the Risks

&

Controlling the Processes

Altering a machine means making Engineering Changes. You can be held liable if the machine subsequently injures someone. This short publication is designed to help you understand:

- What defines an Engineering Change
- What the risks are
- How the risks can be avoided or minimised
- What part Insurance has to play
- How a formal Engineering Change Process works

This is done by working through the steps involved in designing and building a modified adapter head for a lifting beam.

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Introduction

We all want the same things: to provide the best equipment and service we can for our customers. We all have ideas for how we might do things better. We all need to minimise our costs.

With budgets stretched tighter and tighter there is a huge temptation to carry out modifications in-house rather than involve an expensive and probably much slower professional engineering company, but if you work on, modify or adapt any piece of equipment you may make yourself and your company liable for any failures in the equipment.

In this booklet we hope to explain how an engineering company would carry out a modification using a full Engineering Change process. This is quite involved but we hope to show why it is necessary and what the risks are if a full process if not followed.

What is an Engineering Change?

Technically speaking an Engineering Change is any modification made to a piece of equipment.

For example, if you replace a bolt on a piece of equipment with an identical one of the same size, grade and finish then this is NOT an Engineering Change it is a maintenance operation. In this instance you haven't modified the equipment because you have replaced the part with an identical part. The person who does this needs to be competent to use the tools required and he or she needs to ensure that the bolt is correctly tightened but they do not need any formal Engineering Qualification.

If, on the other hand, you decide to replace that bolt with one of a different length or grade then you have made an Engineering Change. Whoever decides that the different bolt will do the job has made an Engineering Decision and in doing so has now taken responsibility for the fact that the whole piece of equipment is not as originally manufactured.

As a manufacturer we have come across cases of our products being heavily modified by their owners and, regrettably, we have too often become involved because these modifications have failed leading to accidents. We hope that this short guide will help you understand the Engineering Change Process and that this, in turn, will lead to a safer industry.

What are the Risks?

By making an Engineering Change you take full responsibility for the whole piece of equipment.

If you make an Engineering Change to a piece of equipment both you and your company are taking a risk. If that piece of equipment fails and someone gets hurt the original manufacturer can often legitimately claim that the failure had nothing to do with them because the piece of equipment which failed was not in its original form.

The liability for any injury or damage caused by the failure of the equipment will then pass directly back to those responsible for the modification.

Almost all equipment used on the UK rail infrastructure has to be approved by Network Rail and will carry a Network Rail Product Approval certificate, some also have Vehicle Acceptance certificates issued by independent assessment bodies. Engineering changes to approved products invalidate the Product Approval certificate and may also invalidate Vehicle Acceptance. Nnew certificates must be obtained before the device can be used.

This will mean that the modifications will have to be assessed against Rail Industry and Network Rail standards.

How can I offset this risk?

Manufacturers have to carry insurance cover for their design liability (the risk that they might get their sums wrong and design something which fails) and their product liability (the risk that their product might not be made properly). These insurances are expensive because injury claims can be very large.

If you are making Engineering Decisions and Engineering Changes then check that you and your company are covered for the design liability and product liability risks involved.

Design liability insurance is usually called Professional Indemnity Insurance. You do not necessarily have to have a formal Engineering qualification - some insurance companies will, sensibly, accept that years of experience should be recognised but a professional Engineering qualification does make the premiums lower and allows you to get greater cover.

Most commercial insurance brokers can arrange professional indemnity and product liability cover and some workshop insurance policies already include some cover. Premiums are usually based upon the amount of work being undertaken.

All the insurance in the world won't protect you from criminal liability if you are negligent in what you do. Following a clear and thoroughly documented Engineering Change Process helps to demonstrate that you have considered all the risks involved and acted in a diligent manner.

How does an Engineering Change Process Work?

An Engineering Change Process consists of taking and documenting a number of steps to ensure that all the potential risks of failure are formally assessed, considered and eliminated.

A typical Engineering Change Process will work as follows:

- Assess the ways in which the proposed modification affects the product
- Assess how the product might be abused as a result of the Engineering Change
- Create proper documentation for the proposed change - for example: engineering drawings
- Validate the design by performing calculations or computer analyses of the design
- Make the change then check that what has been done exactly follows the documentaion
- Thoroughly test the finished device to ensure that the work has been carried out properly
- Assess and amend any relevant product documentation - for example: operators manual
- Notify Network Rail Acceptance Services of the modification (if product has approval).

Let us now look at a typical Engineering Change and see how an engineering company would tackle it.

A Typical Engineering Change

To properly understand how Engineering Changes should be undertaken let's look at a typical example:

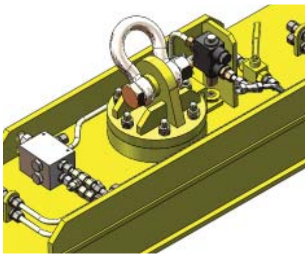
We were approached by a customer who wanted to have the hydraulic rotator on one of his Universal Lifting Beams replaced with a low profile head for attachment to a swivel hook.

There are a number of advantages to this: it lowers the hitch point to give more room under overhead lines and it lowers the weight of the beam.

So there are important advantages for the operator. Let's now go through the Engineering Change Process we adopted to show how we went from the beams pictured (right) with the rotator configuration to the low headroom configuration (below)

Stage 1: Assess the loads

Work out how strong the adapter head has to be.



First of all we have to understand and record what loads the new adapter head has to cope with. The obvious one is that it must withstand the weight of the beam and its load but these beams are often used for tandem lifting in which case the two machines doing the lifting may pull against one another a bit - but how much? What if the operator drags a panel or, if the beam is being used to lift a rail, what happens if he drags the rail or picks it up near the end so the beam doesn't hang straight?

In the Engineering Change Process each of these scenarios is called a 'Load Case' and the Engineer in charge of the Engineering Change has to assess each of these and state what maximum forces will be applied to our adapter head for each and every case. In this particular case our Engineer was able to calculate the forces involved but sometimes we have to set up on-site tests to measure them.

Stage 2: Design the New Adapter Head

Work out the shape and size of all the parts and check that the end result will be strong enough to carry the loads worked out in stage 1.

Now that we know what the adapter head must be able to withstand our Engineer has to design it. This doesn't just mean draw it - that's the very last part - the Engineer must first have an idea of the shape and the size of the parts of his design then calculate the stresses within the adapter head under each load case to assess how the structure of the head will behave under load.

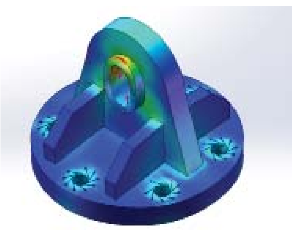
The design process involves calculating the stresses, comparing them with the allowable stress for the material and changing the shape and thickness of the parts until the calculations show that the structure will be safe under every load case.

As well as the main parts the Engineer must also work out the right size for the welds to be sure that they will be strong enough too. Later on we will look at the whole subject of welding.

Finally the Engineer must consider how manufacturing tolerances will affect the strength of the design and how normal wear and tear, corrosion and metal fatigue will affect its long term strength.

Stage 3: Produce a Structural Report

The design is now complete so the next stage is to begin documenting the final calculations to prove that stages 1 and 2 were carried out thoroughly.



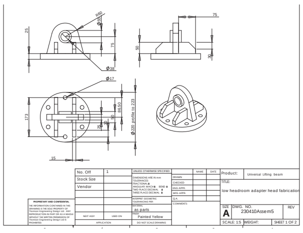
The Engineer now produces a structural report for the design of the adapter head. This will contain the calculations or computer simulations used to show that the design is strong enough.

A lot of British and European standards must be taken into account and it is important that the calculated stresses are recorded as proof that the design was thoroughly checked out.

The Engineer should sign this report as he or she is taking responsibility for the accuracy of the results.

Stage 4: Engineering Drawings

Engineering Drawings tell the workshop precisely how to make the design and what variations are acceptable.



Drawings of the final design must show every detail of the design including details of how the parts are to be joined, cutting tolerances, positioning tolerances and geometric tolerances such as flatness and concentricity where these are important for the fit and function of the final assembly.

In the case of our adapter head, for example, the flatness of the base will be important. If the base plate is dished (which may happen as a result of the welding) then bolting it to the flat plate of the beam will set up stresses in the adapter head and the beam which may not have been taken into account during the design phase.

Copies of the drawings are filed with the structural report so that there is a complete record of what is to be made.

Stage 5: Manufacture the New Design

Finally we get to make the new adapter head.

Once the drawings are complete the workshop can make the adapter head. Staff carrying out the various manufacturing processes must be competent to do so. Welding processes are especially carefully controlled.

Finished adapter heads are checked against the drawings and a record sheet made out which records the names of every person who has worked on the product and what they did. Any materials used may be supplied with certificates and these are kept in the records for the batch of adapter heads made.

Stage 6: Write a Test Procedure

Write a list of tests the adapter head must pass to prove that it is really strong enough.

The finished adapter head will have to be tested to prove that the original calculations were correct. A test procedure is written which takes into account the requirements of any relevant British and European Standards.

In the case of this adapter head the requirements of LOLER must be considered. For most lifting gear LOLER requires every new piece of equipment to be ‘proof tested’. This means loading it to more than the maximum load it will ever encounter, perhaps twice as much.

The Design Engineer will write the test procedure to state how the ‘first of type’ (the initial sample) and all the subsequent production adapter heads must be tested. Usually the ‘first of type testing will include a test to destruction to see what the ultimate failure load is.

Stage 7: Carry out and Record Tests

Every adapter head made now has to be tested according to the written test procedure and a LOLER certificate written out and signed for each one put into service.

Records must be kept of the results of any tests carried out and it is good practise to keep samples if very high proof load tests are carried out on the first ones. Each adapter head will be given its own serial number and this is also be recorded on its test certificate.

For the adapter head, which is to be used for lifting, the guiding rules are contained in the Lifting Operations and Lifting Equipment Regulations (LOLER) and these give guidance as to testing and certification.

Most Engineering Changes will be governed by some regulations or standards and this is the important part: not knowing about these regulations is no excuse for not following them. If you are not sure what the rules are then DON’T DO IT.

All test equipment used must be calibrated.

As a general rule our adapter heads are designed to withstand 3 to 4 times their safe working load before any visible distortion occurs and at least 5 times the safe working load before they break.

Stage 8: Amend all the Relevant Documentation

It is almost inevitable that an Engineering Change to a piece of equipment will affect the manufacturer's documentation.

In the case of the adapter head the tare weight of the beam will be affected, the operator's instructions will have to explain the new way of attaching the beam to its host machine, the beam's LOLER certificate will have to be re-done to show that an Engineering Change has been completed and the serial number of the new adapter head recorded in the build records for that beam.

Maintenance documentation will also have to be amended to remove references to the original rotators and adapter heads and to add maintenance inspection instructions for the new head.

Stage 9: Monitor the Modification in Service

By following a full Engineering Change Procedure we have now completed the modification. Monitoring how that change performs in the field completes the loop.

Whenever the beam is checked over the new adapter head should be carefully inspected to see if it is becoming damaged or distorted. If any damage or distortion occurs this should be reported straight away to the Engineer.

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Report of a Thorough Examination of Lifting Equipment

Report Number	Customer Order Number	Date of Examination	Date of Report
ED011	PDV/60/00020	23/11/2012	26/11/2012

Name and Address of Employer for whom the examination was carried out:	Address of Premises at which the examination was made:
Balfour Beatty Rail Ltd 86 Station Road, Redhill, Surrey, RH11 1PQ	Thomson Engineering Design Ltd Valley Road Cinderford Gloucestershire GL14 2NZ

Qty	Description & Identification of the Equipment	Safe Working Load(s)	Date of Last Thorough Examination
1	Rail Foot Thimble RFT21211001 General Arrangement Drawing: 221012Assem4	2000kg	N/A

Has this Equipment	Yes	No
Supplied New	Yes	
Supplied Reconditioned		No
Examined Only		No
Examined & Tested Only		No
Examined, Repaired & Tested		No

Was the Examination carried	Yes	No
Before being issued for the first time	Yes	
Within an interval of 6 months?		No
Within an interval of 12 months?		No
As part of an examination scheme		No
After Exceptional Circumstances		No

Identification of any part found to have a defect or could become a danger to persons and a description of the defect: (if none state NONE)
NONE

Is the above a defect which is of immediate danger to persons?	NO

If not an immediate danger, when might it become dangerous to persons without recertification?	Date	N/A

Particulars of any repair, renewal or alteration required to remedy the defect identified above:
N/A

Particulars of any tests carried out as part of the examination (if none state NONE)
Tested to twice SWL with calibrated load cell TRLC001

IS THIS EQUIPMENT SAFE TO USE/OPERATE?	**YES**

Equipment Examined By		Latest date by which next through examination must be carried out.	
Name	David Thomson BSc		
Signature	D. Thomson	Date	23/05/2013
Qualifications	Graduate Mechanical Engineer		

Summary

Every Engineering Change that you decide to carry out needs to be carefully thought out and completely documented.

This is because every Engineering Change you carry out brings with it a risk to you personally. If it fails you may be liable. We have taken the example of designing, making and fitting a new adapter head to a lifting beam and shown how a full Engineering Change procedure works but the same philosophy should be adopted for any Engineering Change.

The basic philosophy of an Engineering Change procedure is Assess, Verify, Control and Document:

Assess what the proposed modification must withstand, how it will affect the whole product, how it might fail or create new risks to people working with or near the product.

Verify that the Engineering Change you propose to make will be safe by getting a qualified Engineer with experience of this type of equipment to check your design or proposal.

Control how the Engineering Change is carried out by giving very clear instructions to those actually doing the work either through drawings or written instructions. Control the quality by using competent staff and record who carried out each process. Get your Engineer to check the work done has been carried out in the way he expected.

Document everything from the initial risk assessment to the final test certificates. Create a technical file for future reference. And don't forget to inform any other bodies responsible for the equipment such as the original manufacturer, Network Rail and teh Vehicle Acceptance Body so that they can also assess the modification and ensure that it does not infringe any special regulations.

A few notes on Welding

Welding has been described as the blackest art in Engineering. Many factors affect the strength of a weld most importantly the correct selection of the weld materials and processes and the skill of the welder.

When two pieces of metal are welded together the edges of the parts on both sides of the joint are melted to form a pool of molten metal. More molten metal is poured into this puddle from the welding rod or wire and, as the welder moves along the joint, the pool cools and solidifies.

All metals shrink as they cool and the weld pool is no exception and this means that the parts being welded may warp, move and distort. If the parts cannot move, perhaps because other welds are already holding them firmly, then the shrinking of the weld metal stretches the metal around the weld.

This stretched metal has stresses locked in. Metal can only take so much stress before it fails. The stresses locked in by welding add to the stresses applied to the structure when it is loaded meaning that the weld area, particularly the metal right alongside the weld, acts as if it is weaker than the rest of the metal in the structure.

This problem can be partly overcome by carefully selecting the right welding materials and processes. To do this you need to know precisely what metal is being welded.

High carbon steels and low carbon steels look and feel identical, weld a high carbon steel with a process suitable for a low carbon steel and you can end up with a weld which appears fine but which is as hard, brittle and weak as glass. This is why you should never carry out a weld repair or a modification which includes welding unless you have consulted the original manufacturer to ensure that the welding process you will use is compatible with the materials the original manufacturer used.

In a factory situation every different weld is carried out according to a written weld procedure which records all the welding parameters.

Welders who are going to carry out these procedures do sample welds which are tested for strength, porosity and other mechanical properties to ensure that welds on production work are consistently strong enough to meet the designer's requirements.

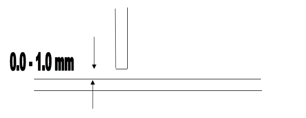
THOMSON ENGINEERING DESIGN LTD

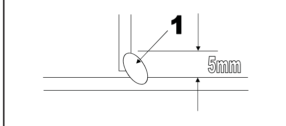
WELDING PROCEDURE SPECIFICATION

Welding Process	TIG	Revision
WPS No	TEWP-T-Al-F-3.2-001	2
WPAR No.		
Date	7th September 2008	

Joint Type	Fillet Weld in 3.2mm 6082-T6		
Welding Specification	BS EN 288		
Material Specification	6082-T6		
Material Thickness (mm)	Part 1	3.2mm	Part 2	3.2mm

Joint Configuration Sketch	Run Sequence Sketch





Run No.	Electrode dia	Filler dia	Current A	Voltage V	Polarity	Position	Gas flow
1	2.4	3.2	185 - 195		AC pulse sq	flat	20 l/min

Filler Specification	4043		
Filler Classification	Al-Si		
Shielding Gas	Ar 100%		
Pre-Heat Temp.	N/A	Interpass Temp.	N/A
Thermometer ID	N/A	NDT Method	*100% Visual Inspection*
Joint Preparation	*Degrease and remove surface oxide*		
Notes			

Document number TED-ECH-11-2012 issue 1