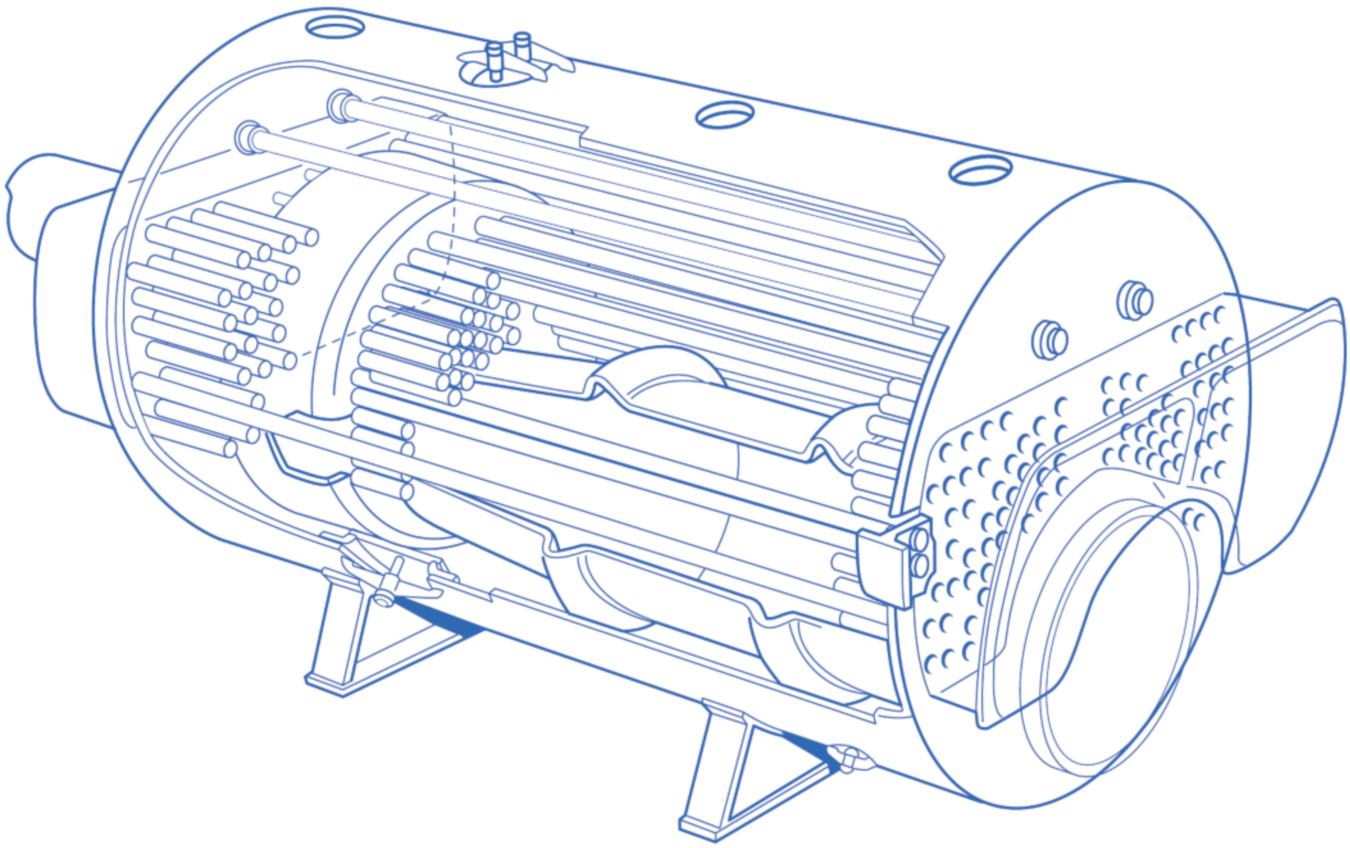
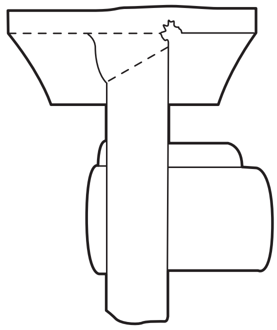
SHELL BOILERS

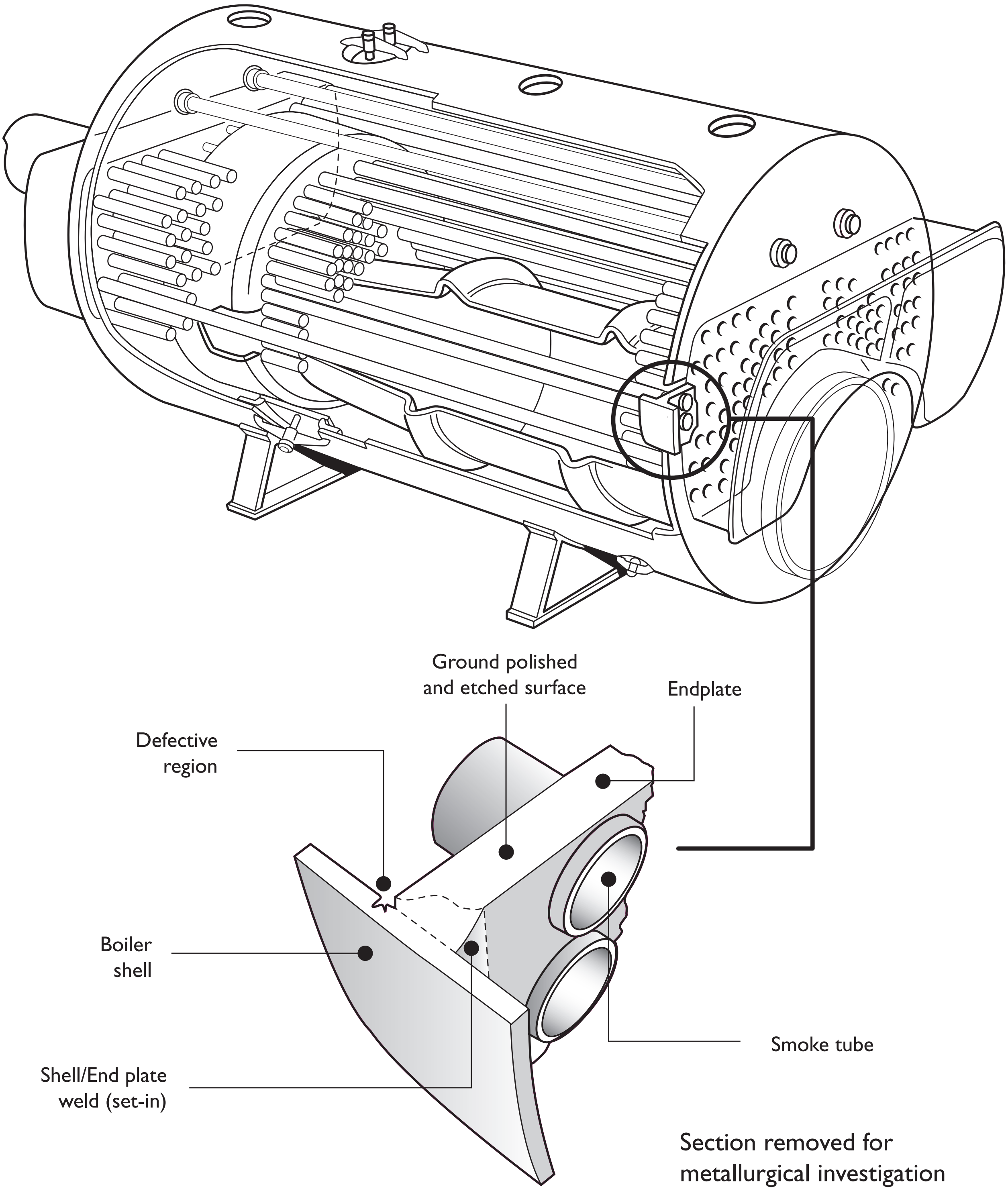
Guidelines for the examination of boiler shell-to-endplate and furnace-to-endplate welded joints (SBG 1)



Cut-away section through a typical shell boiler



Macrograph of Shell/Endplate and tube connection showing defect propagation in susceptible region



Foreword

A revised edition of the Associated offices Technical Committee (AOTC) Guidance Booklet GN4 was prepared by a working group comprising: representatives from the Safety Assessment Federation (SAFed), the Health and Safety Executive (HSE) and other interested parties.

This edition was revised in 2012 by SAFed to update references to standards and regulations where appropriate and to incorporate some changes made by SAFed since its initial publication.

The guidance addresses a particular aspect of boiler examination and is primarily aimed at those with duties under The Pressure Systems Safety Regulations (SI 2000 No. 128) - including owners, users and Competent Persons.

The procedures described in this document represent what is considered to be good practice and incorporate experience gained over many years in assessing defects at shell-to-endplate and furnace-to-endplate welds in shell boilers.

The Safety Assessment Federation - SAFed - represents the interests of companies engaged in independent inspection and safety assessment of engineering and manufacturing plant, systems and machinery.

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1 INTRODUCTION

These guidelines were first published in 1993 under the auspices of the Associated Offices Technical Committee (AOTC).

Since 1993 Inspection Organisations have noted a marked increase in the number of shell boilers exhibiting cracks at shell-to-endplate and furnace-to-endplate welds; records show that over 10% of boilers tested in 1995 exhibited cracks at the furnace and access tube-to-endplate welds* whilst 2.5% of boilers had cracks at the shell-to-endplate welds; these figures represent a threefold increase since 1992/3. While some of the increased incidence of cracking may be attributable to Inspection Organisations taking greater control of the testing of boilers, the overall incidence of cracking appears to be increasing as the general age of boiler plant increases; changes in operational practices and the demand for higher output from smaller boilers are factors which could be contributing to this finding.

The Health and Safety Executive's Guidance Note PM 36[1] provided guidance on weld defect acceptance levels for set-in endplates to furnace and shell connections of shell type boilers; this SAFed document supersedes PM 36 and additionally addresses problems of in-service cracking in the region of such junctions.

The 1982 edition of BS 2790[2] introduced specific requirements for ultrasonic flaw detection testing of flat plates to furnace and shell welds. The probability of unfused lands and other significant defects remaining undetected within these junction welds, in boilers constructed to this Standard, should have been greatly reduced as a result; however for boilers constructed in accordance with other codes, the non-destructive testing (NDT) requirements may not be as stringent.

The Pressure Systems Safety Regulations (SI 2000 No 128)[3] require that a Written Scheme of Examination includes any additional testing considered necessary; these guidelines are designed to assist Competent Persons drawing up or certifying such schemes for shell boilers.

* *For the purposes of this document reference to shell-to-endplate and furnace-to-end plate welds includes access tube attachment welds for which separate acceptance criteria are specified.*

2 BACKGROUND

In the early 1970s Inspection Organisations became aware that an increasing number of shell boilers were suffering cracking from the toe of the internal fillet weld of shell-to-endplate and furnace-to-endplate attachment welds. A programme of ultrasonic examination of these welds was subsequently implemented and, since then, a wealth of information and statistics has been collated.

Experience has shown that the majority of in-service cracks emanate from the toe of the internal fillet weld at the junctions of the endplate to shell and endplate to furnace tube. Such cracks would have developed due to fluctuating stress levels at these junctions and would have been influenced by the internal environment within the boiler. The stresses are due to a combination of pressure loads, differential thermal expansion and local temperature gradients. Oxygen impurities in the boiler water/steam and inadequate pH (water chemistry) control, among other contributing factors, cause a hostile environment within the boiler confines.

The prime purpose of the ultrasonic examinations was to detect cracking from the toe of the internal seal weld of shell and furnace-to-endplate attachment welds; however the NDT procedure was such that other gross defects in the main body of the weld - such as lack of fusion, incomplete penetration and internal cavities - were also discovered.

In 1984 the Health and Safety Executive published Guidance Note PM 36 which addressed the problem of defects within the body of the weld, gave guidance on the assessment of these defects and, based on a fitness for purpose philosophy, on the determination of future ultrasonic examination intervals. By 1990 it was recognised that PM 36 was in need of revision and that a broader approach to the subject would be appropriate; as a consequence these guidelines additionally address such subjects such as the first in-service and subsequent examinations, preparation and repairs.

The information generated by the programme of ultrasonic examination of welds brought other considerations to light; these included the fact that:

- pressurised hot water shell boilers - as well as steam boilers - suffered from cracking
- the requirement for the first in-service ultrasonic examination after ten years operation appeared to be based on a requirement of the Factories Act - for removal of insulation/brickwork - rather than on technical or statistical considerations.

The likelihood of buried defects, such as unfused land in the body of the weld, being propagated under boiler operating conditions and rendering the junctions unsafe has been evaluated; the likely magnitude of stresses in these areas and the capability of the cyclic conditions to initiate significant fatigue crack growth within the specified inspection period have been considered. In particular, stresses induced due to pressure, differential expansion and thermal cycling - especially in the furnace-to-endplate attachments where these stresses can be severe - were the subject of a series of finite element analyses[4] using different models and conditions. The results indicated that, provided defects were within the limits specified in these guidelines, significant crack propagation was unlikely under normal operating conditions. The assessment procedure - Chapter 6 - has been derived from the foregoing and simplified acceptance/rejection criteria for buried defects have been adopted as shown in Graph 1 (page 18).

The guidance on preparation, ultrasonic examination and repair has been based on the collective experience of the Inspecting Organisations participating in the preparation of the document and is not intended to be definitive.

SAFed's Pressure Equipment Committee (PEC) has produced guidance documents on in-service inspection procedures since 1997 and parts of these have been incorporated into this revised edition.

3 SCOPE

This guidance is specifically intended for the following horizontal, multi-tubular, shell-type boilers:

Steam boilers (eg BS 2790)	operating pressure > 2 bar g
Pressurised hot water boilers (eg BS 855[5])	operating pressure > 3 bar g AND boiler diameter > 650 mm AND working temperature > 100°C

Some designs of vertical boilers possess similar features to horizontal, multi-tubular boilers and include furnaces, tube nests and large areas of unsupported tube plates. Under circumstances where all these features are present, this guidance will also be applicable to vertical boilers.

The recommendations - which are applicable to the welded joints at set-in and set-on endplates of furnace and shell connections - are for the detection of:

- in-service cracking emanating from the waterside of the weld and
- buried defects within the weld

and specify the frequency of tests for shell-to-endplate and furnace-to-endplate connections - assuming that the boiler is used at all times within its safe operating limits.

Other conditions - such as overheating or failure under loss of water conditions - are beyond the scope of this document.

4 FREQUENCY AND TESTS

4.1 TIMING OF EXAMINATIONS

4.1.1 First in-service examination

The first, in-service, ultrasonic flaw detection testing of the endplate attachment welds for boilers within the scope of this document should be undertaken no later than FIVE years after the boiler has been taken into use.

Previously, the requirement was for the first in-service ultrasonic flaw detection examination to be undertaken after ten years; however, this appears to have been based on a requirement in the Factories Act for the removal of insulation/brickwork and experience has shown that many failures from cracking have occurred in boilers considerably less than ten years old.

Irrespective of the recommendation that the first in-service ultrasonic flaw detection examination should be undertaken no later than five years after the boiler has been taken into use, if during the course of normal inspections of the boiler there is reason to suspect that one or more of the attachment welds may have suffered cracking or be otherwise defective, the Competent Person may request that the boiler be examined earlier.

Immediate non-destructive testing (NDT) of endplate attachment welds is recommended if any of the following conditions is encountered:

- excessive corrosion
- significant grooving or undercut
- development of cracks
- loss of water - during operation
- overheating

Thermal cycling can have a significant effect on the propagation of cracks especially where the boiler is fitted with an 'on/off' rather than a modulating burner; significant thermal cycling may influence the decision of the Competent Person when setting the ultrasonic inspection frequency.*

4.1.2 Subsequent examination

The periodicity of subsequent NDT should be determined using the assessment procedure given in Chapter 6. However, this periodicity should in no case exceed FIVE years.

4.2 EXTENT OF EXAMINATION (see note to clause 4.3 on page 11)

The endplate attachment welds should be subjected to NDT to detect any cracks propagating from the toe of the waterside fillet weld or from the root of a single-sided weld. In addition, the front and rear furnace to end plate seam (or the front furnace to end plate seam on reversed fired boilers) should be tested to detect cracking from the tubeplate toe of the internal filet weld. At the first in-service ultrasonic examination of these welds, the testing should include scans for buried defects. Where the buried defect sizes are below the threshold given in Graph 1 (page 18) this testing need not be repeated; however, if the buried defect sizes exceed the threshold, the test should be repeated every FIVE years. (See Section 6.2.2.1)

** Reduction of inspection intervals should be considered where boilers operate with excessive thermal cycling - ie burner on/off 50 times per day.*

The extent and nature of NDT, both for the first in-service and for subsequent examinations, should be as shown in 4.2.1 and 4.2.2.

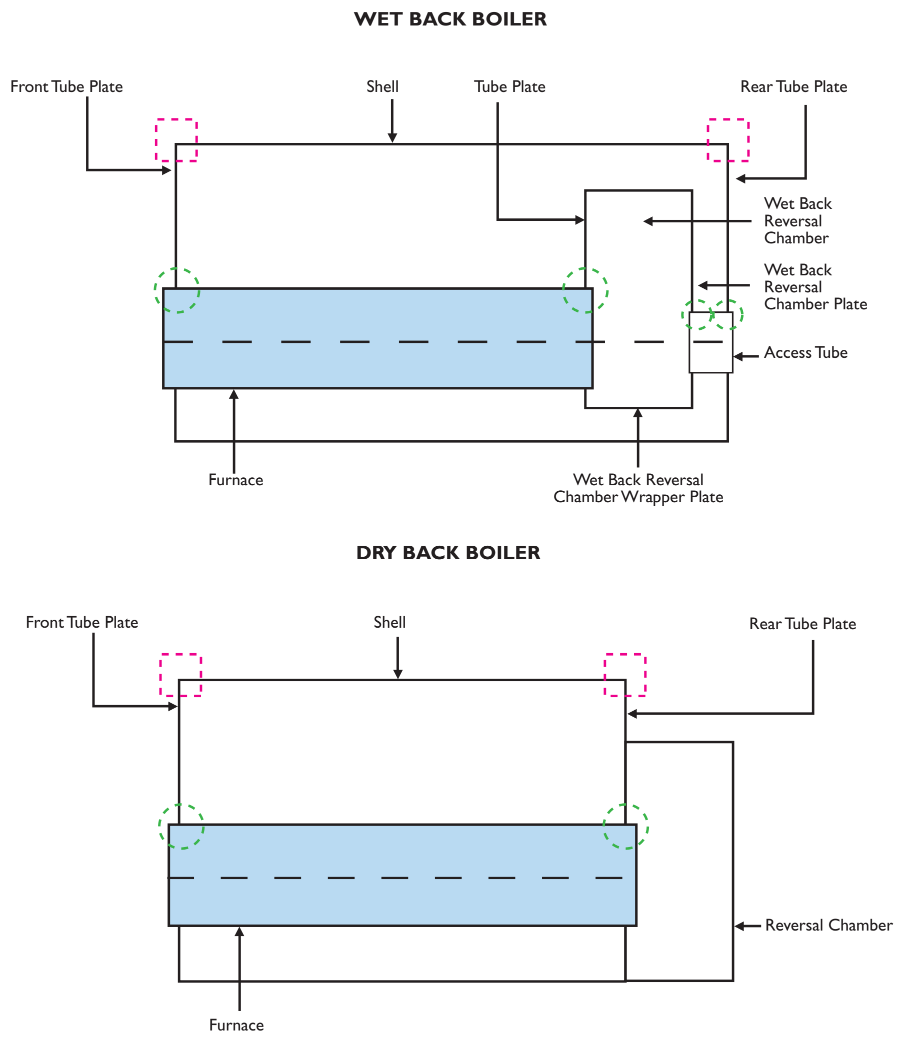
4.2.1 Furnace-to-endplate and access tube attachment welds

Ultrasonic flaw detection over the entire circumference of the welds in the areas indicated by circles in Figure 1 - should be carried out in accordance with Chapter 8.

4.2.2 Shell-to-endplate attachment welds

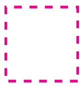
Ultrasonic flaw detection - at selected areas of the welds indicated by squares in Figure 1 - should be carried out in accordance with Chapter 8.

Figure 1: Boiler types



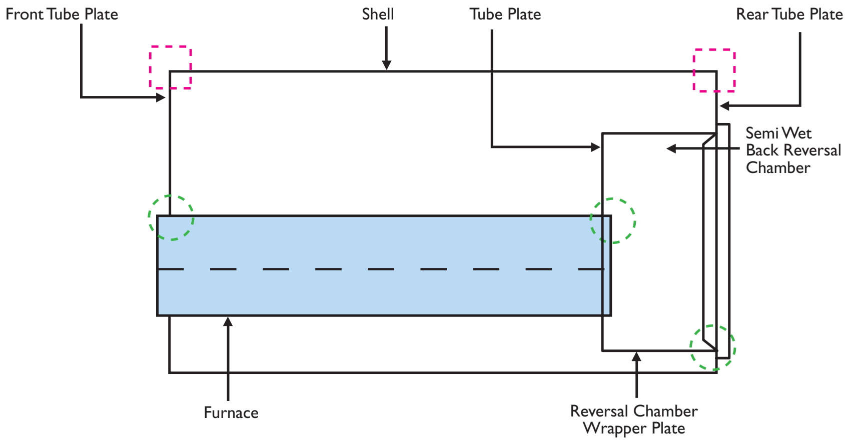
Key to figure 1

Welds to be tested 100% (4.2.1)

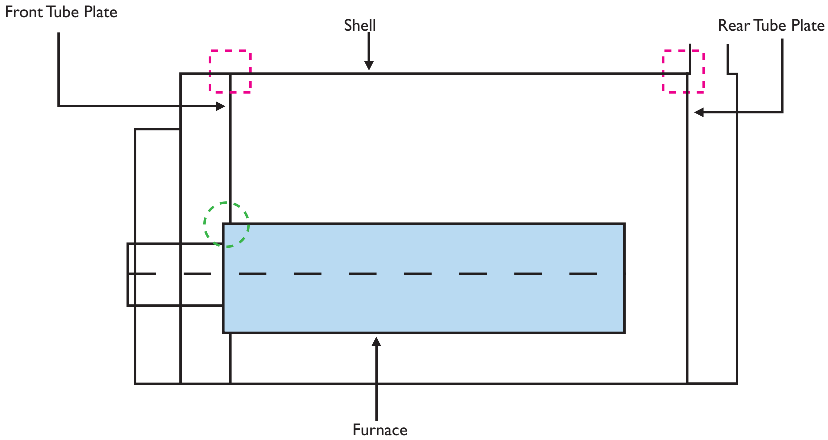


Welds to be tested 20% (4.2.2)

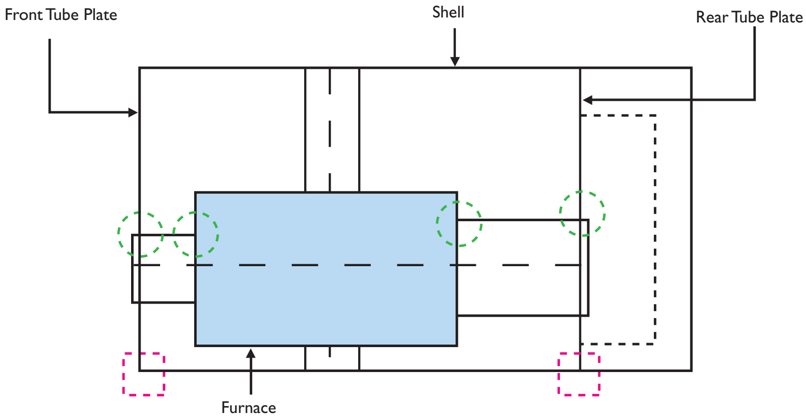
SEMI WET BACK BOILER



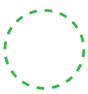
REVERSE FIRED BOILER



COAL FIRED BOILER



Key to figure 1

 Welds to be tested 100% (4.2.1)

 Welds to be tested 20% (4.2.2)

A minimum of four areas should be tested, with the total weld length examined being 20% of the circumferential weld. These should include:

- The 12 o'clock position.

Note
This may require the removal of obstructions. Where this is not reasonably practicable, or could be detrimental to the boiler, the areas to be examined should be agreed with the Competent Person.

- The six o'clock position where the furnace is located centrally near to the bottom of the boiler

- Areas of shell adjacent to the furnace where the furnace is off-set or for twin furnaces

- In some cases - *eg* small diameter boilers - it may be more practical to prepare the entire circumference of the weld for examination.

4.2.3 Set on endplates

The following ultrasonic testing should be carried out, in addition to that already contained within SBG 1, to detect cracking from the toes of the internal fillet weld for **the full circumference** of the shell. The following scans are required:

- A 0° scan from the endplate to test the weld root region

- Angle beam scans from the endplate/shell to test the weld toe regions

See figure 2b (page 12).

Note
Where smokebox, dryback reversal chamber or other attachment welds obstruct access to the endplate, opposite the shell attachment weld, it may not be possible to carry out a 0° scan from the endplate to test the weld root region. In these circumstances it may be necessary to check for root penetration and fusion by alternative methods. An angle scan from the boiler shell and/or dressing off the attachment weld reinforcement for a 0° scan from the shell may offer practical solutions.

4.3 ADDITIONAL TESTING / ASSESSMENT

If any of the areas examined reveal defects which exceed the acceptance criteria of these guidelines, the entire circumference of the weld should be examined.

Note
In some instances the extent of ultrasonic examination recommended by these guidelines may exceed the requirements of the original Code of Construction. It should be borne in mind that the requirements of the code pertain to inspections during construction; the recommendations in these guidelines - for the detection of cracks at the endplate attachment welds - are for boilers in service.

Where NDT reveals defects which are equal to or greater than the acceptance criteria in Chapter 6, **the ultrasonic operator should advise the owner/user immediately** so that repairs or an assessment can be discussed with the Competent Person.

In all cases a report should be submitted to the owner/user as soon as possible.

5 PREPARATION

5.1 RESPONSIBILITY

The owner/user should prepare the boiler for examination in advance of the attendance of the ultrasonic operator/technician.

Cleaning can be achieved by wire brushing or other suitable mechanical means.

Chipping -hammers and needle guns should not be used as they may produce a rough surface which will impede coupling and damage the probe.

5.2 SHELL ATTACHMENT WELDS

Lagging/insulation should be removed to a distance at least 200mm from the position of the weld(s) to be tested (see Section 4.2) as indicated in Figures 2a and 2b.

Since ultrasonic testing of these welds will be carried out from the shell surfaces, the exposed areas should be thoroughly cleaned - of scale, flaking paint etc - to sound metal.

Satisfactory testing cannot be carried out from the tubeplate only.

Figure 2a: NDT preparation areas

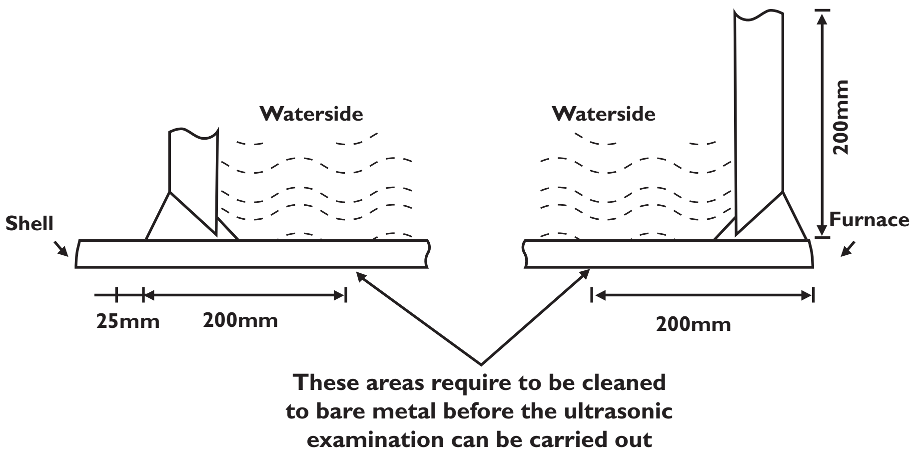
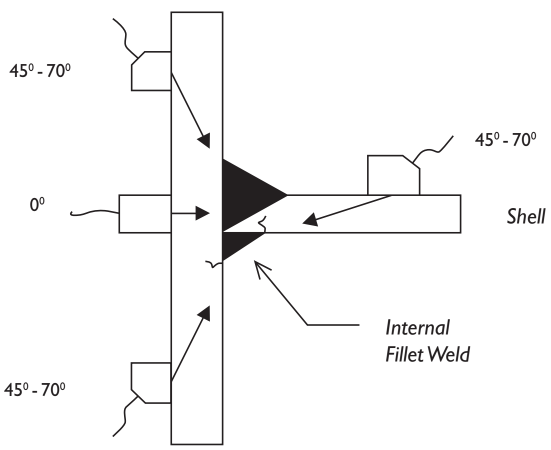


Figure 2b: NDT preparation areas for set-on end plates



Note to Figure 2b: Preparation for Ultrasonic Testing of **set-on** end plates. The endplate and shell surfaces shall be thoroughly cleaned to remove scale for a distance of up to 200 mm back from the toes of the internal fillet weld.

5.3 FURNACE ATTACHMENT WELDS

All brickwork/quarls must be removed from the weld(s) to be tested.

The fireside of the furnace tube adjacent to the weld(s) to be tested should be thoroughly cleaned of scale and combustion products for a width of at least 200mm around the entire circumference as indicated in Figures 2a and 2b.

The tubeplate should be thoroughly cleaned of scale and combustion products for a distance of up to 200mm from the toe of the furnace attachment weld for the full circumference of the furnace as shown in Figures 2a and 2b.

Ultrasonic testing will be carried out from the fireside of the furnace.

5.4 ATTACHMENTS

If, in order to permit examination of a weld, any attachment has to be cut away and subsequently re-welded to the boiler, re-welding should be carried out to an approved weld procedure by an approved welder.

5.5 OTHER CONFIGURATIONS

Some boilers currently in UK have different configurations to the conventional dry back or wet back designs.

5.5.1 Typical European manufactured single furnace wet back

This arrangement incorporates a furnace tube that extends from the front tube plate fully through to the rear tube plate. The rear of the furnace contains a refractory plug which includes a removable section for man access. The furnaces can be either corrugated or completely plain (ie no bowling hoops). The reversal chamber is rectangular in cross section and forms a 'letterbox' opening connection in the furnace tube. The reversal chamber is orientated horizontally and attaches to the side of the furnace tube. The letterbox is anchored at the other end to the boiler shell with the opening in the shell plugged by refractory. The back of the reversal chamber is anchored to the rear tube plate by a series of large diameter stay tubes as opposed to the more conventional stay bar arrangement. These stay tubes are again plugged with refractory. The areas of front and rear tube plates unsupported by the tube nests are supported by gusset stays attaching to the boiler shell as opposed to the more conventional stay bar arrangement.

The areas on the boiler under consideration for NDT are the various attachment welds connecting cylindrical sections to flat plates. These comprise:

Front tube plate and rear tube plate to shell attachment weld	20% UT (except on configurations with flanged ends)
Front tube plate to furnace attachment weld	100% UT
Rear plate to furnace attachment weld	100% UT
Anchor tubes from rear tube plate to reversal chamber	Visual only
Furnace tube to reversal chamber attachment weld	UT to the extent that the geometric configuration allows MPI at the first examination
Reversal chamber to shell attachment weld	Visual only
Gusset stays between front tube plate/rear tube plate and the shell	Visual only

5.5.2 Typical European manufactured twin furnace semi dry back

This arrangement incorporates two furnace tubes that extend from the front tube plate fully through to the rear tube plate. The rear of the furnaces contain refractory plugs which include a removable section for man access. The furnaces can be either corrugated or completely plain (ie no bowling hoops). The reversal chamber is roughly oval in cross section and connects to each furnace tube via a short circular tube. This link tube is approximately 75% of the diameter of the furnace tube. The reversal chamber wrapper connects directly to the rear tube plate, thus forming the dry back. This is insulated with refractory. There is an 'inset' into the front tube plate which forms part of a reversal chamber where the flue gas crosses over from the second to third pass. The areas of front tube plate unsupported by the tube nests are supported by gusset stays attaching to the shell as opposed to the more conventional stay bar arrangement. The lower part of the rear tube plate is supported by gusset stays in an identical manner to the front but on the upper area the gusset stays are attached to the top of the reversal chamber wrapper plate, thus providing support to both flat surfaces.

The areas on the boiler under consideration for NDT are the various attachment welds connecting cylindrical sections to flat plates. These comprise:

Front tube plate and rear tube plate to shell attachment weld	20% UT (except on configurations with flanged ends)
Front tube plate to furnace attachment weld	100% UT
Rear plate to furnace attachment weld	100% UT
Furnace tube to gas pass out tube and gas pass out tube to reversal chamber attachment welds	UT on both ends of tube to the extent that the geometric configuration allows
Reversal chambers (front and rear) attachment welds to tube plates	Visual only
Gusset stays between front tube/rear tube plate and the shell/wrapper plate	Visual only

6 ASSESSMENT OF DEFECTS

The following assessment procedure is recommended; however it does not preclude the Competent Person from making other assessments based on corrosion fatigue and fracture mechanics analyses.

6.1 DEFECT TYPES

These guidelines assess two different categories of defect: surface defects and buried defects.

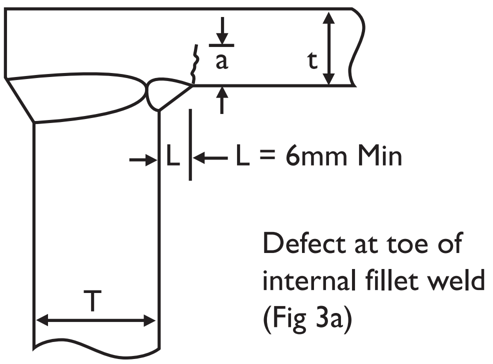
6.1.1 Surface defects

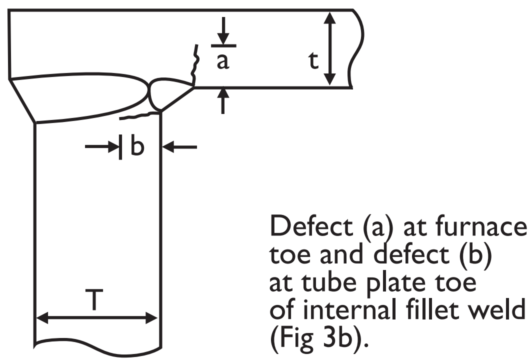
Surface defects can occur at the toe of the internal fillet weld or at the root of single-sided welds as indicated in Figure 3. There are essentially two types of surface defect:

- Original manufacturing imperfections - these may include:
    - undercut
    - root undercut
    - root concavity
    - overlap
    - lack of root fusion
- Fatigue or corrosion-fatigue cracking

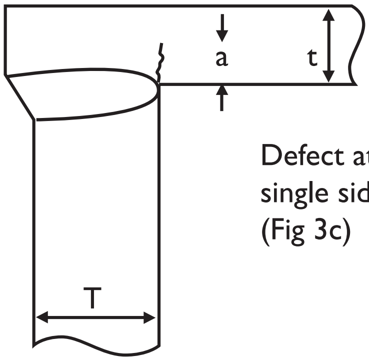
Cracking as a result of fatigue or corrosion-fatigue (the latter is also known as environmentally assisted fatigue) develops during service as a result of fluctuations in pressure, temperature or a combination of both.

Figure 3: Examples of surface defects

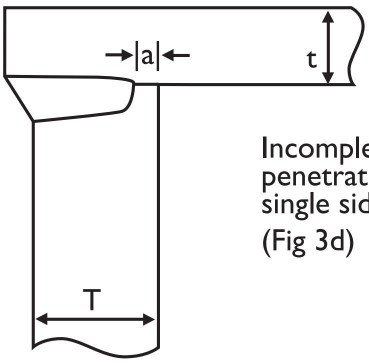




Notation for Figure 3
T = endplate/tubeplate thickness (mm)
t = furnace or shell plate thickness (mm)
a/b = depth of surface defect (mm)
L = fillet weld leg size (mm)



Defect at root of single sided weld (Fig 3c)



Incomplete penetration of single sided weld (Fig 3d)

Notation for Figure 3		
T	=	endplate/tubeplate thickness (mm)
t	=	furnace or shell plate thickness (mm)
a/b	=	depth of surface defect (mm)
L	=	fillet weld leg size (mm)

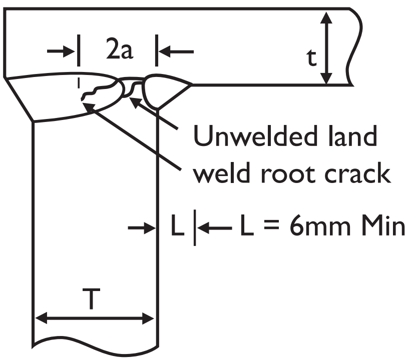
6.1.2 Buried defects

Buried defects occur within the body of the welded area and the heat-affected zone as indicated in Figure 4.

The types of buried defect considered here are common planar defects - such as lack of side wall fusion, and incomplete weld penetration - and are considered to be in the plane of the endplate-to-furnace or endplate-to-shell interface.

Other defects - such as hot and cold weld cracking, weld shrinkage cracks, laminar tearing and volumetric defects (cavities) - may be amenable to similar consideration but in these cases additional consideration should be given to the reasons for these defects and their likely influence on the integrity of the joint

Figure 4: Example of buried defects



Notation for Figure 4		
T	=	endplate/tubeplate thickness (mm)
t	=	furnace or shell plate thickness (mm)
2a	=	depth of buried defect (mm)
L	=	fillet weld leg size (mm)

6.2 ASSESSMENT

6.2.1 Surface defects

Where surface cracks from the toes of the fillet welds or from the root of single-sided-welds are detected, these should be repaired. The high local stress levels in these areas can result in very rapid crack growth when combined with environmental factors.

Shallow grooving or slight undercut at the toe of the fillet weld may increase the risk of crack formation because of the effect of local stress concentration. Such areas should be carefully tested to ensure that there is no cracking associated with the surface defect and they should be rigorously monitored at future inspection intervals.

For single-sided welds on boilers built to BS2790 incomplete penetration or lack of root fusion up to a maximum of 2.5mm is acceptable - see Figure 3d (For access tubes see section 6.2.2.3)

6.2.2 Buried defects

6.2.2.1 Set-in endplates

Buried defects more than 4mm from the surface should be assessed using Graph 1(page 18).

Buried defects need not be measured at future ultrasonic examinations if the owner/user can provide documentary evidence that the defect has been previously tested in accordance with the recommendations in these guidelines and the defect size - 2a - falls below the 'Monitor' line in Graph 1.

If the defect size falls below the appropriate T/t line in Graph 1 but is larger than T/4, the defect size should be monitored at each future test of the weld - ie at 5 yearly intervals. If the defect size falls on or above the appropriate line, further assessment and/or repairs are required. Examples of the use of Graph 1 are given in the Appendix.

If buried defects are closer to the surface than 4mm (fillet weld leg lengths less than 6mm) there is a possibility that the remaining ligament may fail due to shear; in this case the allowable defect size - 2a in Figure 4 - should not exceed 4mm. (For defects greater than 4mm refer to Section 6.2.3)

6.2.2.2 Set-on endplates

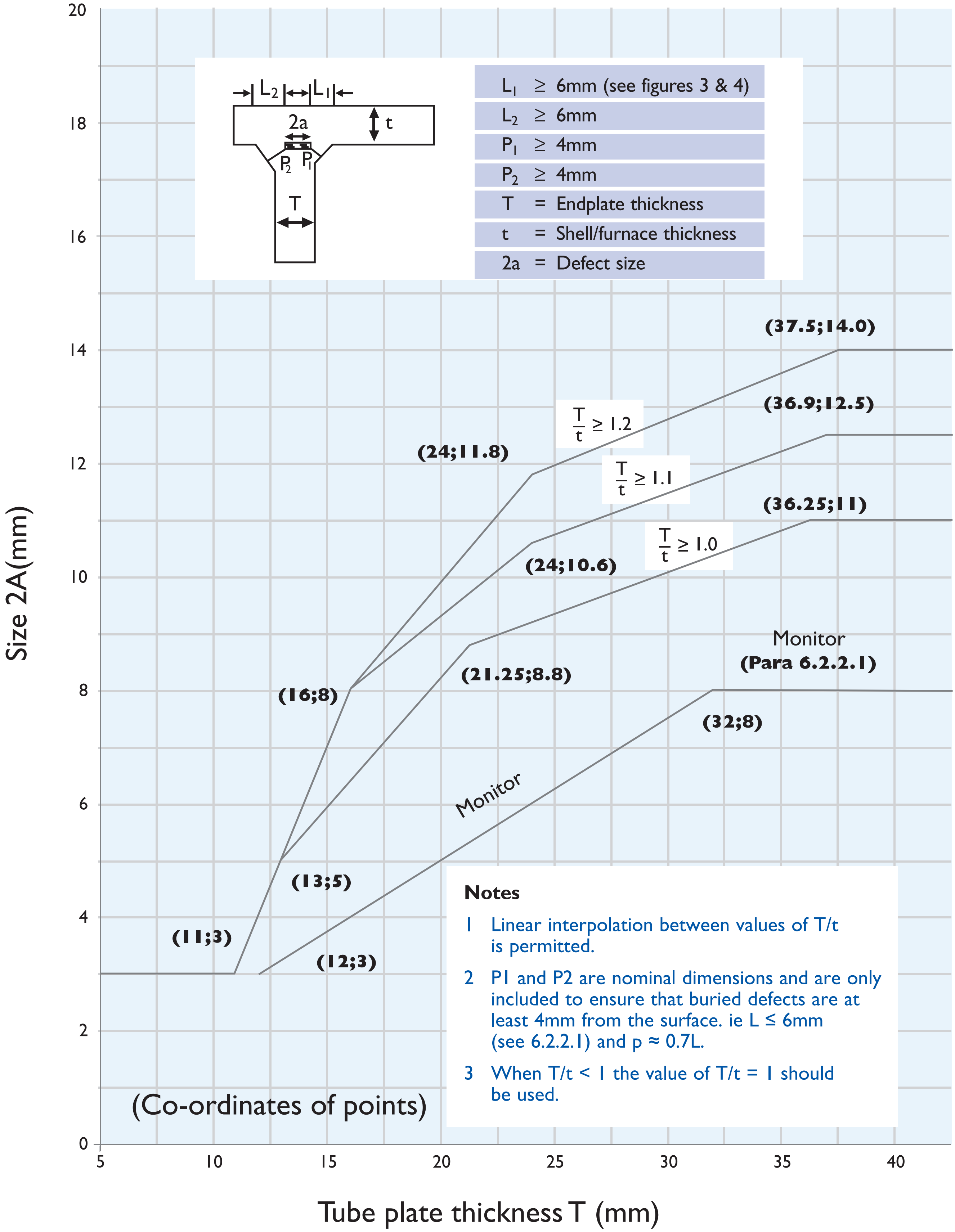
In the case of set-on endplates the acceptance criteria should be subject to special consideration.

Lack of fusion defects can be assessed using Graph 1 taking:

t	=	endplate thickness (mm)
T	=	furnace or shell thickness (mm)
2a	=	buried defect size

Graph 1

Buried defects more than 4mm from the surface



Notes

1. Linear interpolation between values of T/t is permitted.
2. P1 and P2 are nominal dimensions and are only included to ensure that buried defects are at least 4mm from the surface. ie L ≤ 6mm (see 6.2.2.1) and p ≈ 0.7L.
3. When T/t < 1 the value of T/t = 1 should be used.

6.2.2.3 Access tubes

In the particular case of access tubes between the wetback reversal chamber plate and the rear tubeplate, which are fully stayed, different acceptance criteria may be applied. In this case, because of the reduced thermal loading, defect size - a - in a single-sided weld of 0.4T is acceptable - Figure 3d (page 16).

Note
The assessment methods outlined above are designed for application to defects situated in the plane of the shell-to-endplate or furnace-to-endplate interface. For defects inclined to these planes the projected widths - established by ultrasonic techniques - should be used in the assessment.

6.2.3 Refined assessment

A more refined assessment - such as that contained in BS EN 7910[6] - may be carried out where the defect size exceeds the recommended limits in Section 6.2.2 of these guidelines. In such cases:

- stresses due to pressure, thermal expansion and temperature gradients should be taken into account in a detailed engineering critical assessment
- the remaining combined weld throat depth should not be less than the thickness of the furnace or shell plate (t)
- the nominal shear stress on the net weld area should not exceed 100 N/mm^2.

(Stresses due to pressure, thermal expansion and temperature gradients should also be considered if a monitoring exercise is to be carried out).

7 REPAIRS

7.1 GENERAL

All repairs including subsequent NDT should be carried out to the requirements of the Competent Person certifying the boiler. Workmanship and materials should be to a standard equivalent to the original code of construction. For further information on repairs see SAfed Guidance PSG 15, 'Repairs or modifications to pressure systems'.

Departures from design code requirements may be necessary because of:

- the construction of the boiler and/or
- the nature of the repair

eg lack of access for double-sided welds or impracticability of local stress relief.

In such cases deviations should be agreed by the Competent Person and any additional testing to ensure integrity should be specified.

7.2 WELDING

Welder performance and weld procedure qualifications should be certified, to a recognised Standard, as satisfactory for the type of weld concerned; appropriate Standards include:

- BS EN 287 Part 1[7]
- BS EN ISO 15614-1[8]
- ASME IX[9]

Further information on welded repairs is provided in SAFed document PSG 15.

7.3 PREFERRED TYPES OF REPAIR

In most cases the preferred type of repair for a crack at the toe of a fillet weld or root of a single-sided weld (Figures 3a and 3c) is to use a 'D' patch. For cracking into the tube plate (defect (b) in Figure 3b) it will generally be necessary to remove a 'D' patch from the furnace to gain access to the crack for a grind and weld repair.

When the crack is in a small diameter furnace, or extends for a substantial proportion of the circumference of a furnace, it may well be more practical to replace the complete ring.

Shallow cracking or grooving (<t/4 deep) at the toe of the fillet welds may be repaired by grinding and welding.

When deep repairs are required, the metallurgical changes and residual stresses from welding can lead to early recurrence of cracking in these areas.

Gouging out and weld repair of cracks from the outside is not recommended. This is because of the difficulty of:

- ensuring complete removal of the defect
- obtaining an adequate root profile.

Again, the metallurgical and residual stress effects could lead to early recurrence of cracking in these areas.

8 ULTRASONIC EXAMINATIONS

8.1 OVERVIEW

Ultrasonic tests covered in this document will normally be carried out as part of an examination under The Pressure Systems Safety Regulations (SI 2000 No 128). These Regulations place duties on Competent Persons and require them to ensure that proper procedures and precautions are followed - even when some aspects of the work are carried out by other organisations.

In many instances the tests will be undertaken by the Competent Person who has the necessary experience and expertise to perform them; in cases where the ultrasonic testing is carried out by another organisation, the Competent Person will be responsible for determining the acceptability of:

- the NDT organisation and the ultrasonic operator contracted to do the work
- the procedures employed
- the reports produced
- the results.

The recommendations outlined in the following sections are designed to assist the Competent Person in making the above decisions and are regarded as the minimum criteria for such examinations.

8.2 NDT ORGANISATIONS

Suitable organisations would hold a recognised quality accreditation *eg* UKAS accreditation to BS EN ISO 17020 and/or a recognised quality certification *eg* to BS EN ISO 9001.

8.3 ULTRASONIC OPERATORS

Suitability of operators would be indicated by a combination of qualifications, training and experience.

8.3.1 Qualifications

Appropriate level II qualifications *eg* PCN[10] or ASNT[11] with full supporting documentation.

8.3.2 Training

Documented evidence of training in detection of in-service defects in shell boilers (See Chapter 6) and in non-destructive testing.

8.3.3 Experience

Documented evidence of carrying out successful non-destructive testing of shell boilers under the supervision of a fully qualified and experienced level II operator who has previously met these requirements.

8.3.4 Certification

A current SAFed/BINDT qualification for NDT of shell boilers ensures that the above requirements are met and should satisfy the Competent Person's obligations to ensure that proper procedures and precautions are followed.

8.4 PROCEDURE

Testing should be carried out in accordance with formal controlled documentation specific to the boiler(s) to be examined; these documents should be produced by a level III qualified person who meets the training and experience guidelines in Sections 8.3.2, 8.3.3 and 8.3.4 above.

8.5 NDT CARRIED OUT BY ORGANISATIONS OTHER THAN THE COMPETENT PERSON

Where an organisation other than the Competent Person is carrying out the tests, it is the owner/user responsibility to provide to the Competent Person the documentation in support of Sections 8.2, 8.3 and 8.4. This documentation should be supplied at least two weeks prior to the examination and should include:

- The name(s) of the operators who will be performing the tests.
- Copies of the relevant SAFed/BINDT qualifications.

The Competent Person should review the documentation against the recommended guidelines and may also require to witness/audit the tests as they are performed; in such cases, NDT testing should be arranged to coincide with the Competent Person's visit.

8.6 REPORTS

On completion of the ultrasonic tests a full written report should be submitted which should comprise as a minimum:

- Full boiler details including:
  - boiler manufacturer
  - date of manufacture
  - serial number
  - shell diameter
  - furnace diameter
  - access tube diameter
- Areas of boiler tested including:
  - positions and extent of shell-to-endplate attachments tested
- Identification of test procedure
- Identity and certification status of ultrasonic operator
  - date of test
- A sketch of the weld configuration and plate thicknesses for each joint tested
  - single or double-sided welds should be separately identified

- Type and serial number of flaw detector used
- Details of probes used including:
  - make
  - type
  - frequency
  - serial number
- Calibration blocks used
- Test sensitivity
  - this should be related to a common reference *eg* 3mm DAC to BS 3923 Appendix K[12]
- Report of parent metal examination
- Details of any cracks detected (See Figure 3) or a statement that no cracks were detected
- Details of any lack of weld penetration for single-sided welds
- Details of any buried defects (See Figure 4) or a statement that no buried defects were detected.

8.7 NDT METHODS

Ultrasonic testing is considered to be the most effective non-destructive method for locating and sizing the types of defects most likely to be found at the shell-to-endplate and furnace-to-endplate seams of shell boilers.

In consultation with the Competent Person, other methods *eg* magnetic particle inspection to BS EN ISO 9934-1[13] may be applied to supplement ultrasonic testing.

REFERENCES

1 *Weld defect acceptance levels for in-service non destructive examination of set-in endplate to furnace and shell connections of shell boilers*, Health and Safety Executive, Guidance Note PM 36, January 1984.

2 BS 2790, *Specification for design and manufacture of shell boilers of welded construction*, British Standards Institution, London.

3 *Safety of Pressure Systems*, Pressure Systems Safety Regulations (SI 2000 No 128) Health and Safety Commission Approved Code of Practice L122, HSE books

4 *Private correspondence,* HSE Mechanical Engineering Section, 1991/2.

5 BS 855, *Specification for welded boilers for central heating and indirect hot water supply (rated output 44KW to 3MmW)*, British Standards Institution, London.

6 BS EN 7910, *Guide to methods for assessing the acceptability of flaws in metallic structures*, British Standards Institution, London.

7 BS EN 287, *Qualification test of welders-fusion welding*, British Standards Institution, London.

8 BS EN ISO 15614-1, *Specification and qualification of welding procedures for metallic materials*, British Standards Institution, London.

9 *Welding and Brazing Qualifications*, Boiler and Pressure Vessel Code, ASME Section IX, American Society of Mechanical Engineers, New York, USA.

10 PCN/GEN/2011, *General Requirements for Qualification and PCN Certification for NDT Personnel.*

11 *Recommended practice SNT-TC-1A, Personnel Qualification and Certification in NDE*, American Society for Non-Destructive Testing, Columbus, Ohio, USA.

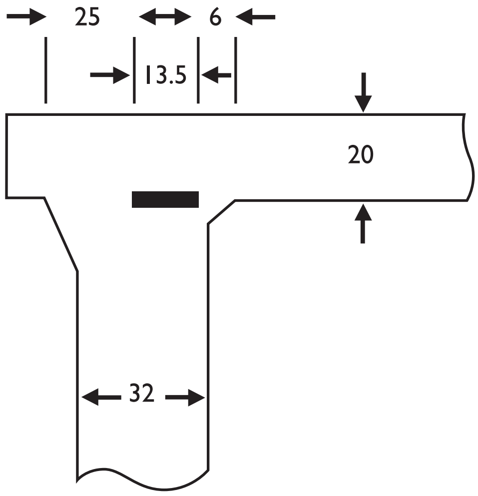
12 BS EN 1714, *Non destructive testing of welded joints. Ultrasonic testing of welded joints.* British Standards Institution, London.

13 BS EN ISO 9934-1, *Non destructive testing. Magnetic particle testing.* General principles, British Standards Institution, London.

APPENDIX

The Case Studies in this Appendix use the assessment procedure outlined in Chapter 6 and Graph 1.

Case study 1

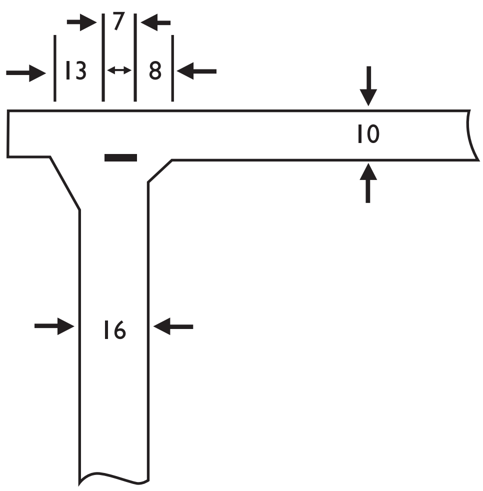


T = 32mm	
t = 20mm	
T/t = 1.6	
2a = 13.5mm	
L1 = 6mm	
L2 = 25mm	

The defect size lies above the T/t >1.2 line in Graph 1 and therefore requires a repair or a more refined assessment as per Section 6.2.3.

Note
A maximum defect of 13mm in this configuration would be acceptable but would be required to be subjected to an ultrasonic examination every 5 years.

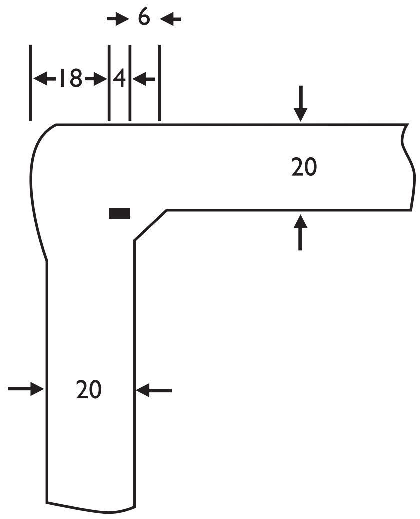
Case study 2



T = 16mm	
t = 10mm	
T/t = 1.6	
2a = 7mm	
L1 = 8mm	
L2 = 13mm	

The defect size falls below the T/t >1.2 line in Graph 1 and is therefore acceptable. It also lies above the 'monitor' line and requires to be subjected to an ultrasonic examination every 5 years.

Case study 3



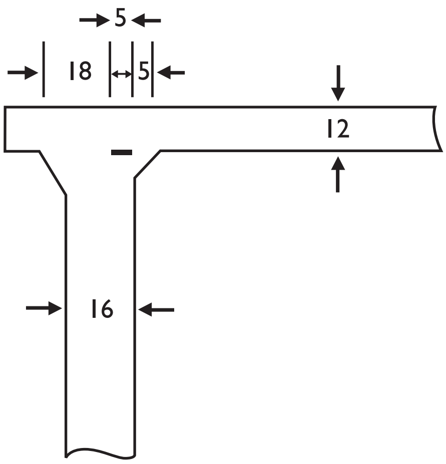
T	= 20mm
t	= 20mm
T/t	= 1.0
2a	= 4mm
L1	= 6mm
L2	= 18mm

The defect size falls below the T/t >1.0 line and also below the 'monitor' line in Graph 1. It is therefore acceptable and the buried defect does not require periodic ultrasonic testing in future.

Note

The joint should be subjected to periodic ultrasonic examination to test for cracks at the toe of the weld.

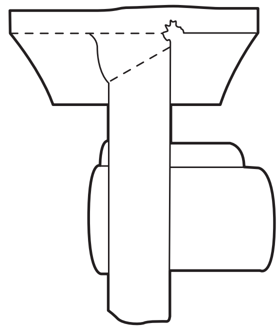
Case study 4



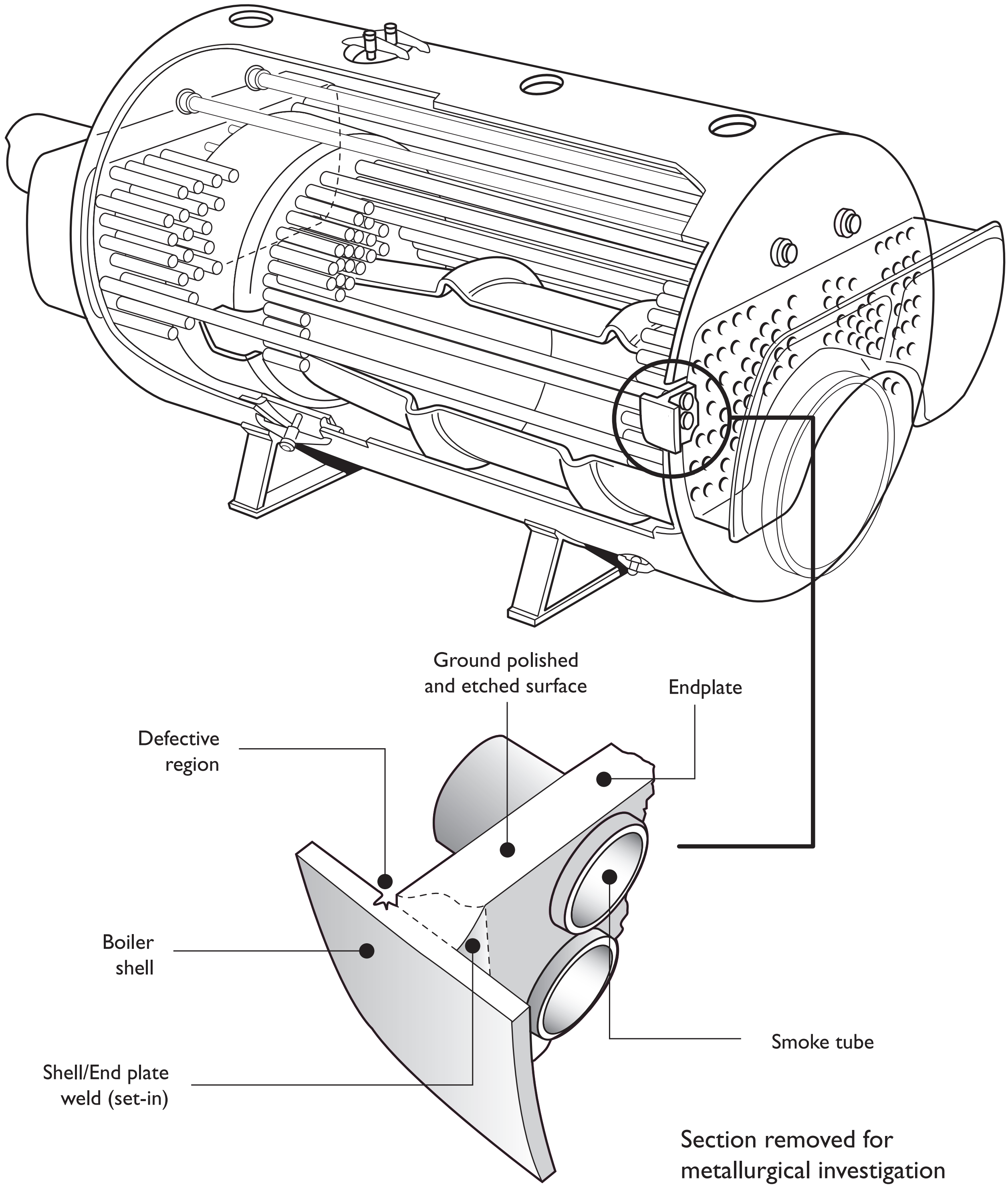
T	= 16mm
t	= 12mm
T/t	= 1.3
2a	= 5mm
L1	= 5mm
L2	= 14mm

The defect is NOT acceptable because L_1 < 6mm (ie P_1 < 4mm) and 2a > 4mm. (See Section 6.2.2.1)

Cut-away section through a typical shell boiler



Macrograph of Shell/Endplate and tube connection showing defect propagation in susceptible region



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