

Witness Name: James Harrison

Statement No: Third

Exhibits: JH19 – JH21

Dated : 19 March 2021

**THE GRENFELL TOWER INQUIRY**

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**Exhibit JH19**

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**GD/PR/MOB/43**

Issue Date: April 2018

# Work Procedure – Assessment of Corrosion Damage on Steel Pipework Supplying Multi-Occupancy Buildings

**Cadent**

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Prologis Park  
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# Version control

Implementation date: April 2018

Document owner:

John Watkins

Management approval:

Head of Engineering

Disclaimer:

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Mandatory & Non-Mandatory requirements:

In this document:

**Shall:** Indicates a mandatory requirement.

**Should:** Indicates best practice and is the preferred option. If an alternative method is used then a suitable and sufficient risk assessment must be completed to show that the alternative method delivers the same, or better, level of protection.

Purpose:

This work procedure was approved by the Head of Engineering, in **April 2018** for use throughout Cadent.

Users should ensure that they are in possession of the latest edition and related bulletins by referring to the document library of Safety and Engineering documents available on the company Infonet.

Compliance with this safety and engineering document does not confer immunity from prosecution for breach of statutory or other legal obligations.

Background:

To comply with current legislation, Cadent, as a gas transporter, shall satisfy the requirements of Regulation 13 of the Pipeline Safety Regulations 1996, and ensure pipelines are 'maintained in an efficient state, in efficient working order and in good repair'.

The application of this procedure shall satisfy the requirements of the Policy for inspection, maintenance, monitoring and management of supplies to multi-occupancy buildings – GD/PL/MOB/1.

This work procedure should be used alongside GD/PM/MOB/2 Management Procedure for the Asset Management of Gas Supplies to Multi Occupancy Buildings, GD/PR/MOB/40 Work Procedure for the High Rise Building Surveys and Risk Assessment and GD/PR/MOB/41 Work Procedure for Surveys on Medium Rise Multi Occupancy Buildings.

*This document is a reference document within the company Safety Case, all changes to this document shall be notified to the Head of Engineering before any changes are initiated.*

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Name	Position	Date
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## Document history

Brief description	Date approved	New document number
First published as T/PR/LC/33	June 2016	T/PR/LC/33
Full review to reflect changes and introduction of new 'MOB' documents and editorial update for Cadent rebranding	April 2018	GD/PR/MOB/43

## Key Changes

Section	Amendments
All	Re-order, re-format and referencing update
All	Re-branding to reflect Cadent visual identity and nomenclature
All	Editorial update to reflect links to 'MOB' document suite
All	Removed references to T/PR/SL/2 as this has been withdrawn
1. Scope	Reference to laterals removed from scope. This document covers assessment of corrosion damage on vertical steel risers only
8.4.2 Removal of Coating and Hand-Tool Cleaning	Updated text to improve clarity
8.5.2 Determining Minimum Allowable Wall Thickness	Updated text to improve clarity and added NOTE 2
8.5.5 Remaining Wall Thickness Measurements	Updated text to improve clarity and added – "Measuring rods for the micrometer shall be ground to a 1mm diameter tip to permit probing of defects".
8.6 Corrosion Damage Categories	Corrected errors in Table 4



9.4 Records	Added note on use of record sheets
Appendix C	C.3.1. Added "Axial load due to" Table moved from Appendix G to Appendix C, Table C 1. and Appendix G deleted Updated text to improve clarity
Appendix D	Added "Therefore, the plastic metal repair system should only be applied when the ambient air temperature is above 5°C." in section Application of Plastic Metal Repair Systems – Plastic Metal Repair Stick
Appendix G	Deleted as content is now included in Appendix C

## Training needs analysis

Identified users Specifically which roles must have an understanding of this Procedure	Level of understanding Aware Does Controls Manages	Training document / Presentation	Dissemination method A, M email link and brief D, C brief and record
FCO's nominated to undertake this procedure	D	ROSEN training course (1 day)	D, C
Network Supervisors nominated as MOBs leads	A, C	Briefing pack	A, M

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# 1. Scope

This procedure shall be used to determine the integrity and continued fitness for service of vertical steel risers operating at low pressure. It applies to pipework of 100 mm nominal diameter or less and up to and including grade X65 (equivalent to BS EN 10208-2 grade L450MB). It provides guidance for the more detailed assessment of material degradation classed as ‘severe’ - following application of work procedures **GD/PR/MOB/40**, **GD/PR/MOB/41** and the visual inspection requirements contained therein.

The procedure outlines:

- Preparation of the riser surface for detailed inspection.
- Wall thickness determination and categorisation of corrosion damage.
- Remedial action required to ensure the integrity of the riser is satisfactory to allow for a minimum 5 year inspection frequency, as dictated by the expected design life of original or newly applied coating and repair systems.

**NOTE: The implementation of a risk based inspection frequency for high and medium rise multi occupancy buildings assumes that any root cause of corrosion (other than atmospheric corrosion) has been determined and effectively mitigated for continued safe service.**

# 2. Related Documents

This Management Procedure makes references to the documents listed in Appendix A. Unless otherwise specified, the latest editions of the documents apply, including all amendments.

# 3. Definitions

The requirements and definitions applying to this Management Procedure are listed in Appendix B.

# 4. Competence

Operatives shall only undertake the tasks described in this procedure if they have been trained and assessed as competent to do so. There is a specific training course associated with this procedure and all operatives using this document in the field shall have completed this successfully before undertaking this work.

# 5. General Considerations

To facilitate the selection of the most appropriate repair method, consistent with safe operation, different categories of corrosion damage are defined.

Subsequent to a Detailed Inspection (Section 8.4), the damage categories shown in Table 1 are used when assessing corrosion damage to the steel riser pipework:

Damage category	Description
Moderate	Does not significantly affect the integrity of the pipe
Severe	Has the potential to affect the integrity of the pipe
Extreme	Constitutes significant damage and directly affects the integrity of the pipe, requiring additional impact resistance as part of a repair or replacement

Table 1 – Corrosion damage classification

## 6. Safety

It is essential that when removing clips and supports used to hold pipe in place and provide support, due care is taken since the remaining wall thickness may have been overestimated.

The Responsible Engineer shall ensure that the use of materials, solvents and other substances is conducted in accordance with the requirements outlined in Cadent's Hazards and Precautions Manual and/or the manufacturer's instructions/data sheets.

Any impact hand tools used in the Surface Preparation for Detailed Inspection (see Section 8.4) shall not present a sparking hazard.

The normal PPE requirements for the site, access arrangements and fire extinguishing materials shall be available throughout the inspection.

The risk assessment undertaken for the activity shall include any requirement for working at heights and emergency procedures to be followed in the event of pipe wall failure resulting in a gas escape, e.g. location of isolation valve, availability of a **GD/PR/EM/72** competent person, etc.

## 7. Procedural Overview

The procedure for the inspection, assessment and repair of corrosion damaged steel riser pipework is shown in Figure 1.

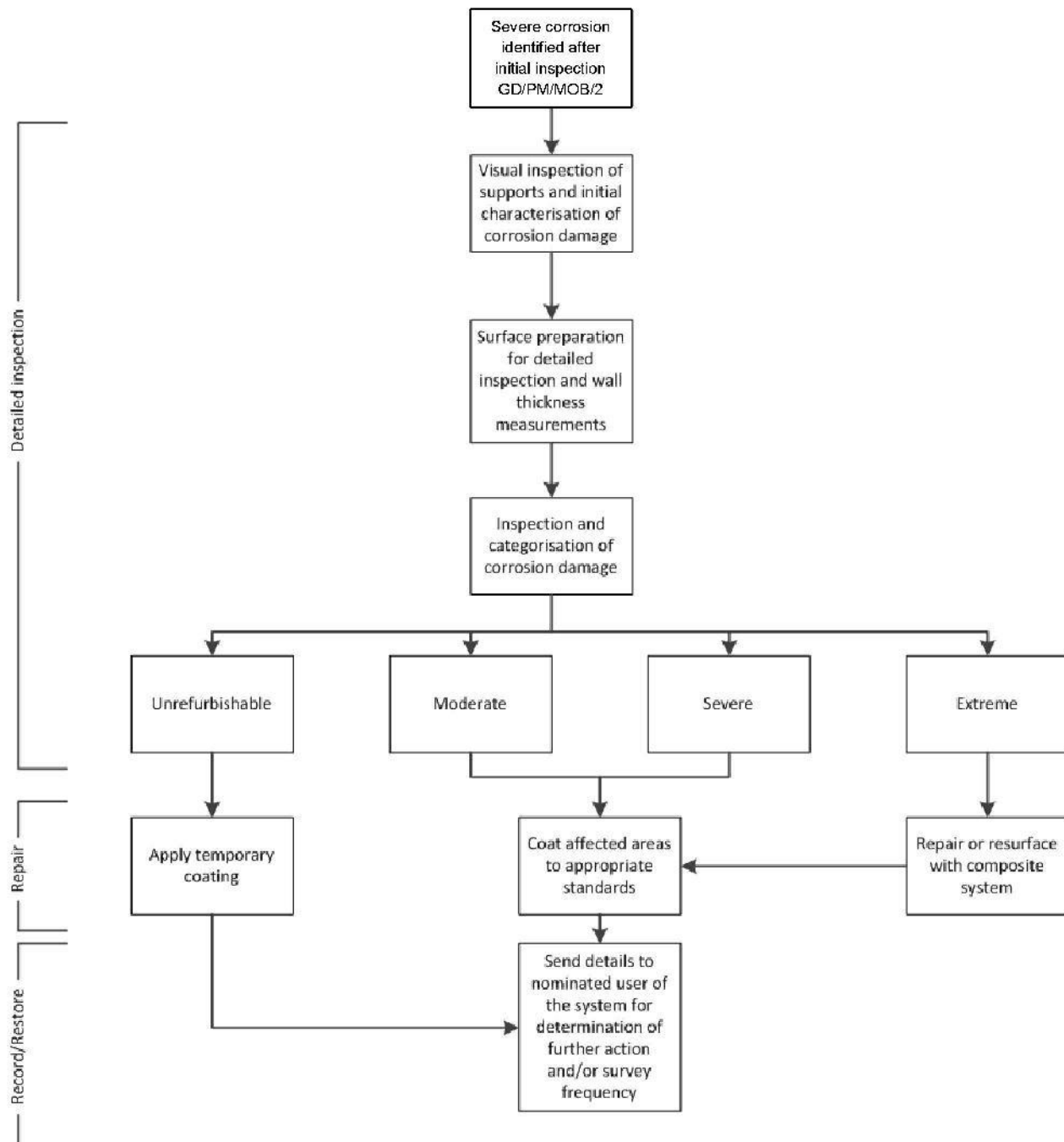


Figure 1 – Algorithm for inspection, assessment and repair of corrosion damaged pipe

## 8. Detailed Inspection

### 8.1. Equipment

In addition to the normal PPE requirements for the site and access arrangements, the following equipment should be available to carry out the examination and be covered by the appropriate work permit:

- Gas detection instrument;
- Digital camera (5MP or above) or iPhone 5 camera minimum;



- c) Torch;
- d) Scale rule and calliper tool;
- e) White chinagraph pencil;
- f) Ultrasonic thickness (UT) gauge and depth micrometer (depth micrometers shall be calibrated, maintained and stored in accordance with the manufacturer's instructions);
- g) Examination mirror on an adjustable / extendable shaft;
- h) Hand-tools suitable for cleaning the pipe which may include the following:
  - i. Knives, scrapers, chisels and chipping hammers for removing slag, laminated rust scale, chipping old paint, loose rust, etc.;
  - ii. Hand wire brushes, abrasive coated paper and plastic fleece with embedded abrasive for final hand preparation including feathering of edges of any firmly adhering coating system;
  - iii. A copy of **BS EN ISO 8501-1:2007**, The Rust Grade book.

## 8.2. Visual Inspection of Supports

A visual assessment of the condition of the riser supports (if applicable) shall be conducted to ensure that they function satisfactorily. The assessment shall be based on a visual estimate of the corrosion damage and the appropriate remedial action taken according to Table 2.

Damage category	% of corrosion damage	Remedial action
Unaffected	0%	No action required
Superficial	<25%	Surface preparation and re-coat
Moderate/Severe	≥25%	Replace*

\*Where necessary, temporary pipe supports should be installed to prevent pipe movement

**Table 2 - Damage categories for visual inspection**

## 8.3. Initial Characterisation of Corrosion Damaged Areas

The following details associated with the corrosion damaged areas shall be recorded and verified with previous **GD/PR/MOB/40 or GD/PR/MOB/41** inspection evaluation:

- Damage location details, i.e. identify whether damage is in a straight section of pipe, bend or associated with a fitting.
- Visual identification of the corrosion damage type (include photographs), i.e. general corrosion, pitting corrosion.
- Axial and circumferential lengths of corrosion damaged areas.

## 8.4. Surface Preparation for Detailed Inspection

### 8.4.1. Isolation Valve

Prior to the removal of any coating, refer to the relevant site risk assessment to confirm the location of the associated isolation valve and ensure it is available for access in the event of an emergency whilst carrying out the detailed inspection. The presence of any associated valve should have been captured in the relevant site risk assessment; if no valve is available do not proceed with works and seek guidance from the Network Lead (MOBs).

With agreement from the Network Lead (MOBs), work may continue when an isolation valve is not present if all of the following conditions are met;



- Corrosion is on an external section of pipe
- Any escape arising from the preparatory work would vent straight to atmosphere
- There is no risk of gas entering the building through ventilation bricks, grilles or other points of entry, etc.
- There is a minimum of 5 metres clearance from flues

## 8.4.2. Removal of Coating and Hand-Tool Cleaning

At the initial inspection stage, a minimal amount of coating shall be removed to facilitate the inspection requirements. The corrosion damaged area and an area adjacent to the corrosion damaged area shall be prepared for pipe wall thickness measurements and re-coating procedures (see Section 8.5). Pipe covered by these procedures tends to have a small wall thickness and it is possible that the build-up of corrosion products could mask that the corrosion is close to being through-wall. Removal of any underlying corrosion product scales should only be attempted if safe and practical to do so; where it is deemed that scale removal is not a safe option, further guidance should be sought. Although caution is required in this process it is important to note that corrosion scale can be up to approximately 7 times the volume of the steel, e.g. for every 1 mm of wall loss the scale could be 7mm thick. As a precautionary approach it is advised to use a 3:1 ratio of corrosion scale thickness to pipe wall thickness. If the scale is in excess of 9 mm thick, the system should be isolated prior to removal of coating and scale.

Surfaces shall be cleaned with a hand-tool, such as a scraper or wire-brush, to ensure that the surface is primarily free from corrosion product to allow for detailed inspection. A leakage survey shall be conducted upon removal of any corrosion products and after each stage of the surface preparation process; any leaks found should be managed in accordance with **GD/PR/EM/72**.

Descriptions of surface preparation methods by hand-tool cleaning - including treatment prior to, and after, the hand-tool cleaning procedure - are detailed below (taken from **BS EN ISO 8504-3:2001**):

1. Initial treatment – remove heavy oil or grease by means of a scraper and then, as far as possible, remove further contamination by one, or a combination of, the following methods:
  - a) Cleaning with appropriate solvents or proprietary solutions (e.g. emulsion or detergent cleaners), provided that this is followed by rinsing with potable (tap) water. The solvents or solutions may be applied with a stiff fibre or wire brush.
  - b) Brushing with stiff fibre or wire brushes.
  - c) Wash with potable (tap) water or proprietary solution to ensure no further contamination (salts) occurs.
2. Hand-tool cleaning – hand-tool cleaning should preferably be carried out in the following sequence of operations:
  - a) Use hand wire brushing, hand abrading, hand scraping or other similar non-impact methods to remove all loose or non-adherent rust and all loose paint. Try to minimise hand abrasion as much as possible as this can lead to further wall thinning of good material.
  - b) Use non-sparking impact hand tools to remove laminated rust and rust scale.
3. Final preparation
  - a) Remove any burrs, sharp ridges or sharp cuts that have been produced during the cleaning operation. The use of emery paper should be limited to ensure that the remaining wall thickness is not unnecessarily compromised.
  - b) Ensure that any remaining intact paint has no residual gloss. Ensure that the edges of any remaining intact paint have been feathered (bevelled) using the hand-tool cleaning methods outlined.
  - c) After hand-tool cleaning, the surface shall be cleared to remove loose dust and debris.

The surface finish achieved by hand-tool cleaning shall conform to the requirements of **BS EN ISO 8501-**

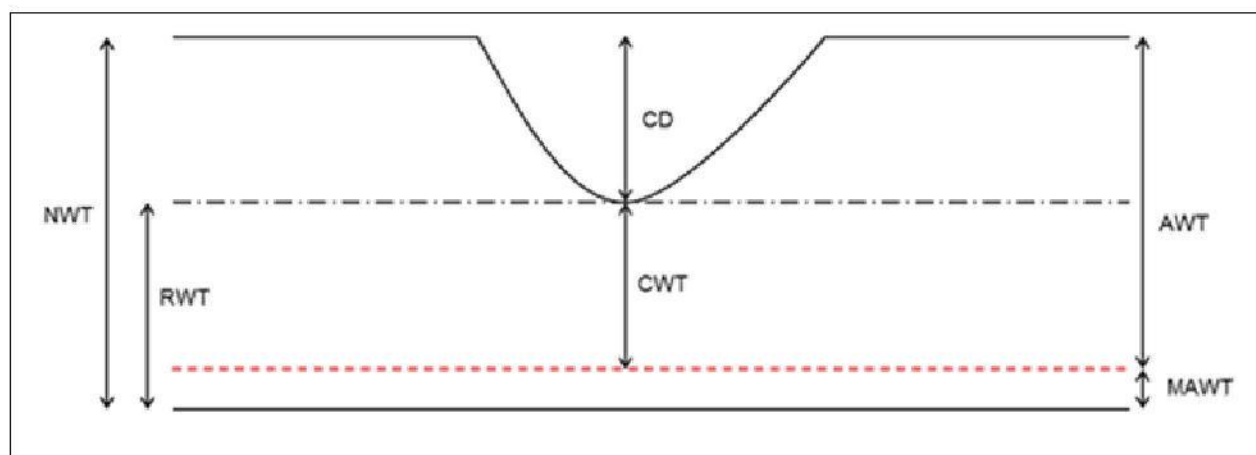
**1:2007**, St 3 grade to allow for detailed inspection, including pipe wall thickness measurements and re-coating procedures.

**NOTE:** The integrity assessment of any fittings associated with the corrosion damaged pipework is not covered under these procedures. However, if the corrosion damaged section of pipework includes a fitting, the surface of the fitting should be prepared for re-coating following the same procedures as for the pipe, to ensure uniform coverage of the coating system across the corroded areas.

## 8.5. Inspection and Categorisation of Corrosion Damaged Areas

### 8.5.1. Wall Thickness Parameters for Determining Damage Category

Figure 2 below illustrates the wall thickness parameters that shall be used in order to determine the corrosion damage category.



**Figure 2- Diagram of wall thickness parameters used in determining corrosion damage category**

Measured wall thickness parameters are:

- Nominal wall thickness (NWT) (UT measurement, 8.5.3)
- Remaining wall thickness (RWT) (UT measurement, 8.5.5)
- Corrosion depth (CD) (depth micrometer measurement, 8.5.5)

The wall thickness parameters determined via calculation are:

- Minimum allowable wall thickness (MAWT) (8.5.2)
- Available wall thickness (AWT) (8.5.4)
- Consumable wall thickness (CWT) (8.5.6)

### 8.5.2. Determining Minimum Allowable Wall Thickness

To establish the category of the corrosion damage it is necessary to determine and record a minimum allowable wall thickness (MAWT). This measure provides the minimum wall thickness that gives sufficient structural integrity when the loading from the weight of the riser is considered at the point of interest.

In order to determine the MAWT, the following parameters shall be identified:

- Nominal pipe size – if the diameter is unknown or cannot be attained from previous inspection records, confirm the nominal pipe size using a calliper tool away from the corrosion damaged area.



- Number of storeys above the point of interest to the nearest load-bearing support accompanied by expansion bellows or to the top of the riser (see Figure C 1, Appendix C).
- Number of laterals per storey.

**NOTE 1: A riser guide restricting lateral movement is not considered as a load-bearing support. If no load-bearing support can be located, the number of storeys above the point of interest shall be assumed to the top of the riser.**

**NOTE 2: If the section of riser used in determining the number of storeys contains any horizontal sections greater than 1m in length, an additional storey shall be added. Horizontal sections are sometimes included in predominantly vertical risers to negotiate building features.**

Table C 1, Appendix C, shall be used to determine the MAWT requirement for the steel riser pipework under inspection using the above information, nominal pipe size, number of storeys and laterals. The assumptions used in the determination of the MAWT are outlined in Appendix C.

### 8.5.3. Nominal Wall Thickness Measurements

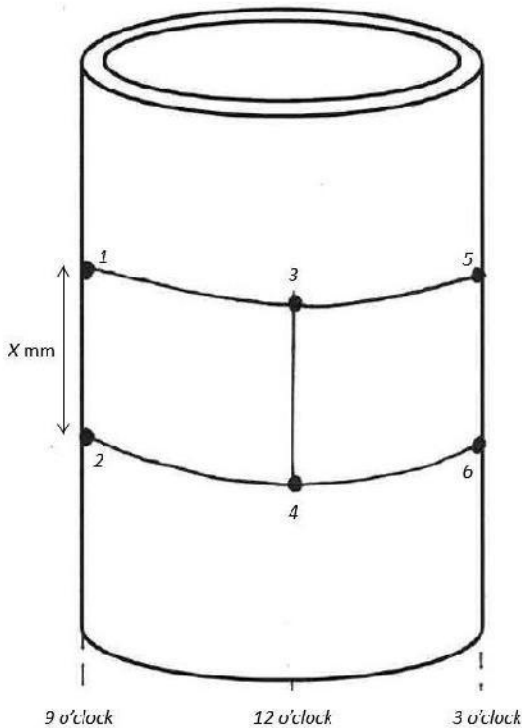
The nominal wall thickness (NWT) of the pipe shall be determined from the average of a minimum of six readings measured using an ultrasonic thickness (UT) gauge.

Measurements using UT gauges shall be made by creating a reference grid (sized according to pipe outside diameter - see Table 3 below) in an area adjacent to the corrosion damaged area. The grid shall be marked using a white chinagraph pencil; once measurements have been recorded the markings should be removed by cleaning the surface with appropriate solvents or proprietary solutions.

Nominal size (outside diameter)	Grid size, X (mm)
≤ 50 mm (60.3 mm)	10
50 < D ≤ 100 mm (60.3 < D ≤ 114.3 mm)	15

**Table 3 - Reference grid size**

An example reference grid diagram for determining NWT is shown in Figure 3; readings should be taken at each corner of the grid at the 12, 3 and 9 o'clock positions as shown.



**Figure 3 - Reference grid example for determining nominal wall thickness**

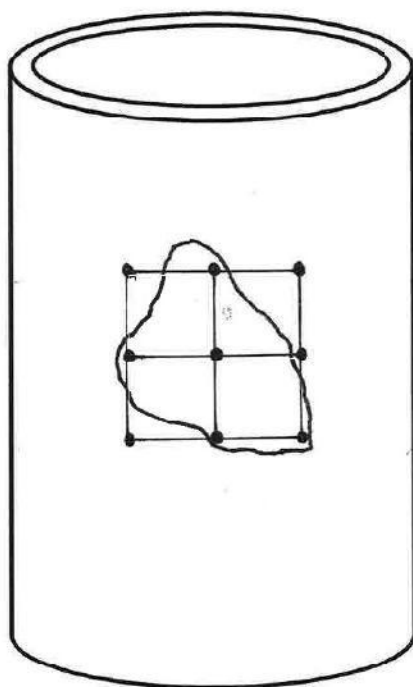
## 8.5.4. Determining Available Wall Thickness

The available wall thickness (AWT) is the nominal wall thickness (NWT) minus the minimum allowable wall thickness (MAWT) (see Figure 2).

$$AWT = NWT - MAWT$$

## 8.5.5. Remaining Wall Thickness Measurements

The remaining wall thickness (RWT) shall be measured using a UT gauge; a minimum of six readings shall be taken using a reference grid surrounding the corrosion damage area. An example reference grid diagram for determining the RWT associated with the corrosion damage is shown in Figure 4; readings should be taken at the corners of each square of the grid. The size of the grid should be determined by the size of the corrosion defect. The lowest reported wall thickness value of all measurements taken shall be used in determining the severity of the corrosion damage.



**Figure 4 - Reference grid example for determining remaining wall thickness**

Due to the variability in corrosion damage location and profile, the use of a reference grid may not be sufficient. RWT measurements should be taken where possible with a UT gauge at the affected area in order to provide confidence that the lowest RWT measurement has been determined.

Alternatively, if RWT measurements cannot accurately be obtained for the corrosion damage using a UT gauge (i.e. pitting corrosion), a depth micrometer shall be used to determine the depth of the corrosion damage. The depth micrometer should ideally have a 100 mm or 50 mm base. Measuring rods for the micrometer shall be ground to a 1mm diameter tip to permit probing of defects.

To accompany the depth micrometer readings, measurements using a UT gauge should be taken around the corrosion affected area in order to yield a minimum RWT (mRWT). The measurements taken using a depth micrometer will give a corrosion depth (CD) and the measurements from the UT gauge will give the mRWT. In this case the RWT is calculated as follows:

$$RWT = mRWT - CD$$

## 8.5.6. Determining Consumable Wall Thickness

The consumable wall thickness (CWT) is the remaining wall thickness (RWT) minus the minimum allowable wall thickness (MAWT), given by the expression:



$$\text{CWT} = \text{RWT} - \text{MAWT}$$

## 8.6. Corrosion Damage Categories

For the purposes of these procedures the corrosion damage shall be assigned to one of the following categories which shall be used to determine the required remedial repair solution:

- a) Moderate Damage.
- b) Severe Damage.
- c) Extreme Damage.

For pipework covered by these procedures, all occurrences of corrosion damage shall be assigned to one of the three damage categories above by applying the corrosion damage criteria given in Table 4. The categorisation of the corrosion damage compares the CWT against the AWT.

Types of damage	Corrosion Damage Categories		
	Moderate	Severe	Extreme
General corrosion	CWT greater than or equal to 60% AWT	CWT less than 60% AWT but greater than 20% AWT	CWT equal to or less than 20% AWT
Pitting corrosion	CWT greater than or equal to 50% AWT	CWT less than 50% AWT but greater than 10% AWT	CWT equal to or less than 10% AWT

CWT = Consumable wall thickness  
AWT = Available wall thickness

**Table 4 - Corrosion damage categories for pipe designed to operate at stress levels not greater than 40% SMYS**

If the CD is determined to be greater than the AWT (i.e.  $\text{CWT} = 0$ ) the corrosion damage shall be referred to as 'unrefurbishable' and alternative repair or replacement of the pipework (whole riser or affected section) progressed. This requirement shall be recorded and escalated on site to the Network Lead (MOBs) for further assessment prior to any further works.

### 8.6.1. Worked Example for Determining Corrosion Damage Category

General corrosion identified following initial characterisation and the measurements are summarised in Table 5.

Parameter	Value
Storeys above point of interest (8.5.2)	8
Number of laterals per storey (8.5.2)	1
Nominal pipe size (8.5.2)	40 mm
Minimum allowable wall thickness (MAWT) (8.5.2)	0.8 mm
Nominal wall thickness (NWT) (8.5.3)	4 mm
Remaining wall thickness (RWT) (8.5.5)	2 mm

**Table 5 - Data for worked example**

The available wall thickness (AWT) is the  $\text{NWT} - \text{MAWT}$  (8.5.4) =  $(4 - 0.8) = 3.2$  mm

The consumable wall thickness (CWT) is the  $\text{RWT} - \text{MAWT}$  (8.5.6) =  $(2 - 0.8) = 1.2$  mm

The corrosion damage category is determined using the following equation, where the consumable wall thickness (CWT) is calculated as a percentage of the available wall thickness (AWT):

$$(\text{CWT} / \text{AWT}) \times 100$$



In this example  $(1.2 / 3.2) \times 100 = 37.5\%$

From Table 4, the corrosion damage is determined to be Severe Damage.

## 9. Repair Procedures

### 9.1. General Requirements

Corrosion damage to pipe shall be repaired using an appropriate procedure as specified in accordance with Figure 1. The corrosion damaged areas shall be repaired by one or more of the following repair procedures, subject to the restrictions on their applications given in Table 6:

- a) Sectional re-coating.
- b) Sectional repair with composite and re-coating.

### 9.2. Coating

The corrosion damaged area shall be protected by a coating selected and applied in accordance with the manufacturer's instructions and guidance given in Appendix D.

**NOTE: Any area where the original coating is removed for inspection shall be re-coated regardless of the corrosion categorisation.**

### 9.3. Repair with Composite

The corrosion damaged area shall be repaired and resurfaced using a composite repair system applied in accordance with the manufacturer's instructions. The selected coating shall subsequently be applied to the repaired and resurfaced areas as per Section 9.2.

### 9.4. Records

Complete details of the investigation, assessment and any repair of corrosion damage shall be recorded and reported to the Responsible Engineer. Suggested formats for recording and assessing damage are given in Appendix E and Appendix F. Records should be retained as per T/PL/RE/1.

**NOTE: Appendix E can be used on site. Appendix F shall be populated after the survey and submitted as the permanent record.**

Full details of the corrosion location, damage category, defect sizes and the type of repair carried out, shall be recorded.

### 9.5. Restoration

Following a permanent repair carried out as required by Table 6, the pipe may be returned to service or its normal operational status should an isolation valve be used.

Repair Method	Moderate Damage	Severe Damage	Extreme Damage
Re-coating	✓	✓	N/A
Composite repair and subsequent re-coating	N/A	N/A	✓

**Table 6 - Appropriate permanent repair methods for corrosion damaged pipe**

### 9.6. Severely Corroded Pipe in Concrete

Occasionally the severely corroded pipe passes through a concrete section, e.g. floor, and it is not possible to remediate the entire section. In these circumstances the remediation process should be applied to the

accessible pipe and the Nominated user (Network Strategy) notified of the situation (with photographs included for information).

# Appendix A – References

## British Standards

BS EN ISO 8501-1	The Rust Grade Book
BS EN ISO 8504-3	Preparation of steel substrates before application of paints and related products: Part 3: Hand- and power-tool cleaning

## Institute of Gas Engineers and Managers publications

IGEM/G/5	Gas in multi-occupancy buildings
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## Cadent specifications and procedures

GD/PM/MOB/2	Management Procedure for the Inspection, Maintenance, Monitoring and Management of Supplies to Multi-Occupancy Buildings
GD/PM/MOB/40	Work Procedure for High Rise Building Survey and Risk Assessment
GD/PM/MOB/41	Work Procedure for surveys on Medium Rise Multi-Occupancy Buildings
T/PR/MAINT/2323	Work procedure for patch repair of coating systems on installations with inlet pressure exceeding 7 barg
T/PL/RE/1	Policy for the capture, update and retention of engineering asset records
GD/PR/EM/72	Cadent Operational Procedures For Dealing With Gas Escapes And Other Emergencies
NGUK/PM/SHE/018	Management Procedure for Confined Spaces
T/PR/SSW8	Work Procedures for Working on Unodorised Gas Installations

## Gas Industry Standards

GIS/L2	Specification for Steel pipe 21.3 mm to 1219 mm outside diameter for operating pressure up to 7 bar (supplementary to BS EN 10208-1)
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## American Petroleum Institute publications

API 5L	Specification for line pipe
API 579-1	Fitness-For-Service

## American Society of Mechanical Engineers publications

ASME B31.8	Gas transmission and distribution piping systems ASME code for pressure piping, B31
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# Appendix B – Definitions

## Wall thickness parameters

NWT	The minimum 'nominal wall thickness' of the pipe measured using ultrasonic equipment over a prepared and undamaged area adjacent to the corrosion damaged area.
MAWT	The 'minimum allowable wall thickness' required to provide sufficient structural integrity under the loading case caused by self-weight (of the riser) at the point of interest.
AWT	'Available wall thickness' is calculated using: The nominal wall thickness (NWT) minus the minimum allowable wall thickness (MAWT).
RWT	The minimum 'remaining wall thickness' associated with the corrosion damaged area, either measured using UT gauge or determined as the nominal wall thickness (NWT) minus the corrosion depth (CD)
mRWT – minimum RWT	When RWT cannot be accurately obtained, e.g. pitting corrosion, then readings taken with a UT gauge and depth micrometer are combined to calculate the RWT. In these situations the UT reading is the mRWT.
Corrosion depth (CD)	The greatest measured depth associated with the corrosion damaged area typically determined using a depth micrometer.
CWT	The consumable wall thickness = remaining wall thickness (RWT) minus the minimum allowable wall thickness (MAWT).
SMYS	Specified minimum yield strength. The strength of steel pipe under specific stresses as required by the relevant standard.
UT Gauge	Ultrasonic thickness gauge.
Point of Interest	The area of the pipe that is affected by corrosion and is being considered for remediation.

## Damage

Corrosion	The result of a reaction of a metallic material with its environment causing a measurable reduction in the thickness of metal including: <b>General corrosion</b> – corrosion resulting in a reduction of metal thickness over a large area of the surface. <b>Pitting corrosion</b> – corrosion which affects small localised areas of surface pipe material, producing pits.
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## Repairs

Corrosion resistant coating	A coating system designed to prevent corrosion.
Composite repair	A multi-component composite system designed to repair and resurface metal components.

## Miscellaneous

Network Lead (MOBs)	The person in the network nominated to implement the Multi Occupancy Building survey process.
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# Appendix C – Assessment of Mechanical Loading

## C.1 Assumptions for determining minimum allowable wall thickness

C.1.1 The guidance from API 579 shall be used to assess the minimum allowable wall thickness (MAWT) requirement and the loading case caused by self-weight at the point of interest. In order to approximate the loading case the following conditions are assumed;

- The weight of the pipework is the same as those given by API 5L for the acceptable pipe sizes outlined in GIS/L2:2006 up to 100 mm nominal size. Where exact wall thicknesses did not correlate, the next largest size was used, therefore a worst-case is always considered for self-weight
- The bending moment acting upon the point of interest is considered to be zero, providing that all riser guides and/or supports are in place around the point of interest and to the distance spacing specified in IGEM/G/5 Edition 2 Section 6.4.1.2 for the pipe size concerned

NOMINAL BORE (mm)	MAXIMUM UNSUPPORTED LENGTH (m)				
	Screwed steel horizontal	Screwed steel vertical	Welded steel horizontal	Welded steel vertical	External PE
15	2.0	2.5	2.5	3.1	See Note
20	2.5	3.1	2.5	3.1	
25	2.5	3.1	3.0	3.7	
32	2.7	3.3	3.0	3.7	
40	3.0	3.7	3.5	4.3	
50	3.0	3.7	4.0	5.0	
65			4.5	5.6	
80			5.5	6.8	
100			6.0	7.5	
150			7.0	8.7	
200			8.5	10.6	
250			9.0	11.2	

- Lateral offtakes are assumed to be 25 mm diameter and fully supported by the riser up to a maximum length of 1.6 m
- Fixtures and fittings are considered to account for 3.2 kg/m (calculated from riser design information supplied by NG)
- The riser is considered to be free to move axially; therefore thermal expansion is not expected to contribute to the riser load. Expansion should have been accounted for at the design stages with the installation of expansion bellows at load bearing supports. This is as per IGEM/G/5 Edition 2
- The axial force at the point of interest will depend on the length and configuration of riser above that point:
  - To the nearest load bearing support (accompanied by expansion bellows), or;
  - To the top of the riser
  - And allowing for any horizontal sections in the riser greater than 1m in length
- In order to allow for an onsite assessment, torsional or bending moments of fixed laterals caused by thermal expansion are not considered and are outside the scope of this assessment. It is assumed that stresses caused by thermal expansion or contraction were considered at the design stage and flexible laterals were installed where necessary as outlined in IGEM/G/5 Edition 2
- The risk of buckling and or bending has been discounted due to the ability of the riser to freely expand and contract with temperature variation. It is assumed that stresses caused by thermal expansion or contraction were considered at the design stage and flexible laterals were installed where necessary as outlined in IGEM/G/5 Edition 2



C.1.2 The riser deadweight is calculated under the assumptions in C.1.1 and using the formula given in API 579, allowing for an over-calculation of 53% of the weight to account for any discrepancies.

$$F_{total} = (1.7(P + P_s + D)RSF_a) \cdot 9.81$$

Where:

P = internal and external maximum allowable working pressure

P<sub>s</sub> = static head from liquid or bulk materials

D = deadweight of the vessel, contents, and appurtenances at the location of interest

RSFa = allowable remaining strength factor based on API 579 – Table 2.3

C.1.3 The minimum thickness requirement for structural stability is then calculated using a manipulation of the formula given in API 579, Paragraph A7.2 (Formula A.324), for thin pressure vessels:

$$T_{sl} = \frac{F_{total}}{2 \cdot S \cdot E \cdot \pi R_m}$$

Where:

T<sub>sl</sub> = the supplementary thickness requirement for self-weight

F<sub>total</sub> = the total force of the sections of the riser above the point of interest

S = the maximum allowable stress (the maximum allowable stress calculated using the guidance of ASME B31.8 for a pipe with a location classification of Class 4 for close proximity to multi-storey buildings. i.e. 40% of SMYS)

E = the weld joint efficiency factor

R<sub>m</sub> = the mean radius of the pipe

C.1.4 The minimum pipe grade used is assumed to be API 5L grade A with an SMYS of 210 MPa in order to account for locations where the grade of pipe is unknown i.e. in older high and medium-rise buildings.

C.1.5 Where the structural requirements of the piping are not critical and the required wall thickness could theoretically be negligible, a maximum loss of wall thickness of 80% of the original wall thickness is applied for good practice.

C.1.6 Given an overloading calculation of 50% and a maximum allowable stress of 40% SMYS, the calculated allowable thickness will also provide a reasonable resistance to impact. However, the requirements will be site specific and at the discretion of the operator.

## C.2 Consideration of buckling effects

C.2.1 Calculations have been performed in order to account for wall loss where the guidance in IGEM/G/5 (see C.1.1, b) may no longer be true.

C.2.2 The buckling critical force has been assessed in line with the Euler Buckling equation in order to identify the required wall thickness to resist buckling. It has been assumed that the end fixing conditions are both fixed:

$$F_{cr} = \frac{n \cdot \pi^2 \cdot E \cdot I}{L^2}$$

Where:

$n$  = the end condition factor

$E$  = Young's modulus

$I$  = second moment of Inertia

$L$  = Effective length of the column

C.2.3 As there are lateral supports in place on the riser, it is assumed that these act as fixed points, making the end condition factor equal to 4. Where the force from the deadweight exceeds that of the critical buckling force, the WT requirement has been calculated so that the critical buckling load is equal to the actual load. This takes into account the 53% over calculation as discussed in the assessment of dead weight.

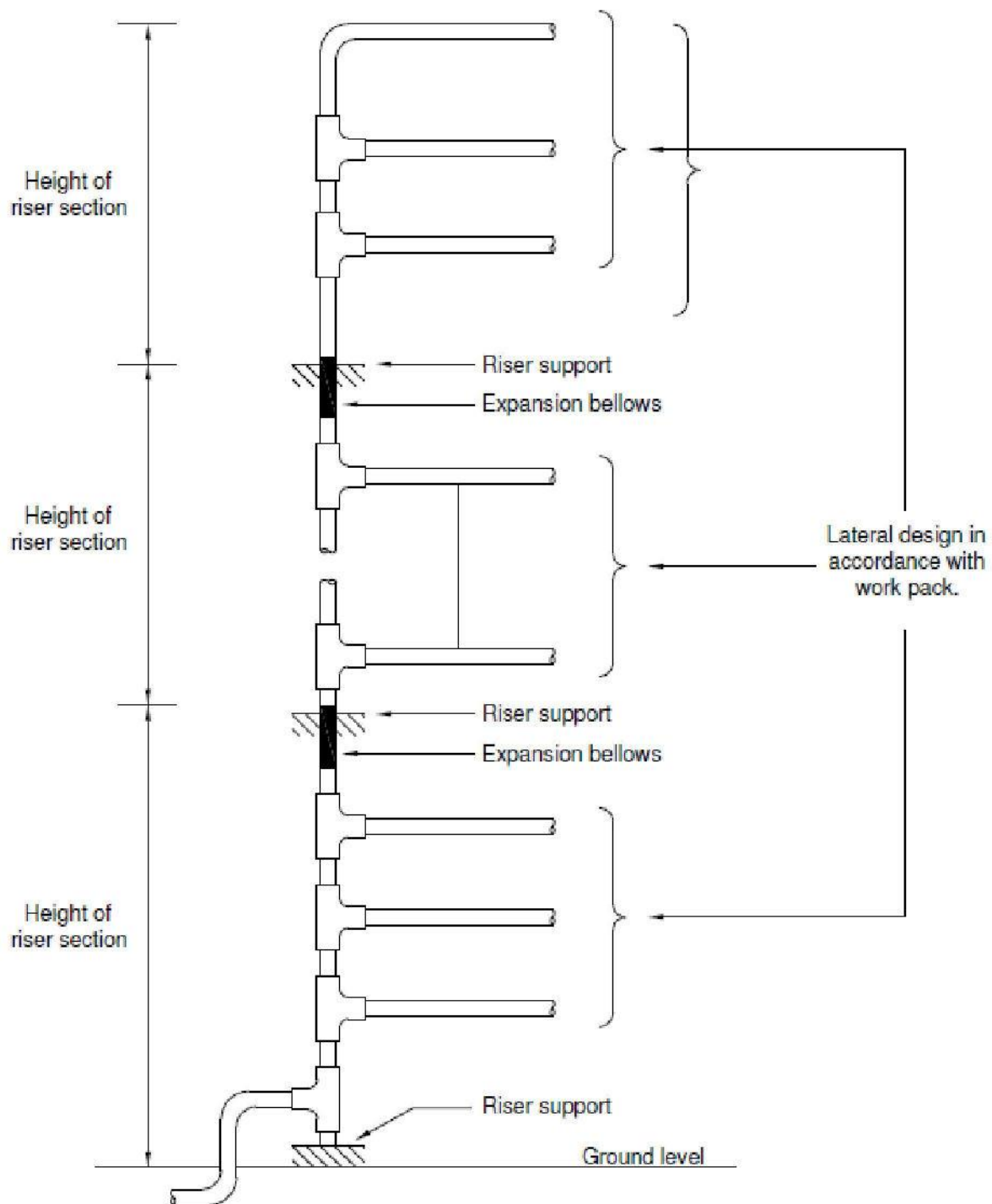
C.2.4 By rearranging the Euler equation to obtain the second moment of inertia, the wall thickness requirement can be obtained. This wall thickness requirement is then used to determine the MAWT to prohibit buckling (Table C 1).

### **C.3 Evidence for the assessment of thermal expansion**

C.3.1 Axial load due to thermal expansion is considered to be zero as per the guidance of IGEN/G/5 Edition 2 which states in Paragraph 6.1.6 Note 2:

"Pipeline supports need to permit pipeline expansion and building movement while limiting lateral movement of the pipeline"

C.3.2 As thermal expansion is considered in the design and slippage between the supports allows for this expansion or contraction the stress is assumed to be zero.



**Figure C 1 – Permissible method of Network Riser and Lateral Design**

MAWT Requirement (mm)		Storeys Above Point of Interest																																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20																				
		Number of Laterals																																							
		1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2												
Nominal Pipe Size (mm)	15	0.6	0.6	0.6	0.6	0.6	0.6	0.6	1.5	1.5	1.8	1.8	2.2	2.1	2.5	2.3	2.7	2.5	3.0	NOT POSSIBLE WITHOUT EXCEEDING CRITICAL BUCKLING LOAD																					
	20	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.6	0.8	0.7	0.8	0.8	0.9	0.9	1.0	0.9	1.1	1.0	1.2	1.1	1.3	1.2	1.4	1.2	1.5	1.3	1.6	1.4	1.7	1.5	1.8	1.5	1.9	
	25	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.9	0.9	1.0	0.9	1.1	1.0	1.2	1.1	1.3	1.1	1.3	1.2	1.4	1.3	1.5	1.3	1.6	1.4	1.7	
	32	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.9	0.8	1.0	0.9	1.1	1.0	1.1	1.0	1.2	1.1	1.3	1.2	1.4	1.2	1.4	1.3	1.5	
	40	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.9	0.8	0.9	0.9	1.0	0.9	1.1	1.0	1.1	1.1	1.2	1.1	1.3	1.2	1.4	1.2	1.4
	50	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	1.0	0.9	1.1	1.0	1.1	1.1	1.2	1.1	1.3	
	80	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.1	1.1	1.2	
	100	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1

Table C 1 – Minimum allowable wall thickness (MAWT) reference table

NOTE: The fields highlighted in red show where buckling has been found to be a potential issue caused by the deadweight of the riser exceeding the critical buckling load. This has been accounted for by increasing the MAWT requirement in these particular cases as given in the table.



# Appendix D – Guidelines for Coating and Resurfacing Repairs

## Before Starting Works

This activity SHALL NOT be carried out by a lone worker unless a lone worker risk assessment has been carried out.

Where applicable, ensure that the necessary arrangements have been made with the customer prior to the work being carried out.

Establish good communications with your manager or supervisor ensuring that your whereabouts are known.

Comply with all applicable safety and environmental codes, rules and regulations including the Control of Substances Hazardous to Health (COSHH) Regulations.

Review site conditions and ensure all hazards have been identified and are controlled. Consider personal safety and the safety of others. If at any time you are unsure of the precautions to be taken, STOP WORK AND CONTACT YOUR MANAGER.

Fire extinguishers shall be deployed as appropriate to the risk but are mandatory when undertaking intrusive maintenance.

Establish a safe working environment to prevent access by passers-by and to eliminate any ignition sources. Erect signs and barriers as appropriate.

Consideration should be given to the presence of confined spaces and these shall be managed with reference to NGUK/PM/SHE/018.

Cadent SCO procedures shall be adhered to at all times.

Equipment that is not certified shall only be used in hazardous areas with the approval of the Authorising Engineer.

For sites within boundaries of unodorised gas sites, checks shall be made for unodorised gas (T/PR/SSW8).

## Preparation of Surfaces

The procedure requirements for surface preparation are detailed in Section 8.4 Surface Preparation for Detailed Inspection.

The area adjacent to the damaged area shall be lightly abraded for at least 5cm onto sound coating.

The coating/resurfacing repair systems shall only be applied to clean, dry and structurally sound surfaces. Surfaces should be free of any loose material and all contaminants such as dirt, oil, grease, salt, loose or flaking paint, etc.

The surface finish achieved by hand-tool cleaning shall conform to the requirements of BS EN ISO 8501-1:2007, St 3 grade to allow for detailed inspection, including pipe wall thickness measurements and re-coating procedures.

## Application of Coating

The coating system should only be applied when the ambient air temperature is above 7°C and when the relative humidity is below 85%. Surfaces being treated should be at least 3°C above the dew-point. The



ambient air temperature, metal surface temperature and relative humidity parameters at time of re-coating shall be recorded.

The coating system should be applied by brush in a single brush-stroke direction. The material should be applied at a wet film thickness of approximately 500 - 600 microns to achieve the desired dry film thickness of 400 microns per coat. Remove excess paint so no runs or sags appear.

All repaired areas should be allowed to cure for the period recommended by the manufacturer of the coating material before any assessment of the patch repair is attempted.

Wipe excess material from tools and equipment immediately. Use soap and water as needed.

#### **Application of Plastic Metal Repair Systems – Plastic Metal Repair Stick**

The surface must be clean and free of grease; roughen up, if necessary. The procedure requirements for surface preparation are detailed in Section 8.4 Surface Preparation for Detailed Inspection.

Prepare at room temperature (approx. 20°C) where possible. At higher temperatures the pot life and curing time are reduced, and at temperatures below 16°C the curing time will be longer. No reaction takes place below approx. 5°C. Therefore, the plastic metal repair system should only be applied when the ambient air temperature is above 5°C.

Cut or break off the required quantity.

Knead the resin and hardener (inner hardener component with outer resin) until the mixture has a uniform colour.

Put the finished mixture within the pot life on the surface to be treated; work in with pressure to achieve a flat surface to minimise further surface preparation prior to re-coating. If further surface preparation is required following curing, lightly abrade surface using emery paper to a re-coatable surface.

#### **Application of Plastic Metal Repair Systems – Plastic Metal for Larger Area Repairs**

Application of the Plastic Metal should be carried out immediately after surface pre-treatment to avoid oxidation and instantaneous rust formation.

Before adding the hardener, it is necessary to stir up the fillers in the resin component thoroughly and bubble-free.

Mix resin and hardener for at least 4 minutes with the processing spatula to get a uniform mass with a uniform colour. Do not mix more material than you are able to use within the pot life of 5 minutes.


Apply to surface using the processing spatula. Apply release agent to flexible plastic mat and smooth applied material to pipe contour and surface finish. Ensure material is worked into surface to fill all corrosion damaged areas.

Allow to cure for a minimum of 3 hours before re-coating surface.

## Appendix E – Record Sheet

<b>1.0 Assessment details</b>							
Site							
Pipe location					Pipe ID		
Technician					NG Engineer		
Date					Time		
Additional information							
<b>2.0 Assessment process</b>				<b>Comments</b>			
Gas detection	Y	N					
Initial photographs	Y	N					
Visual inspection/Nominal diameter	Y	N					
Identification of corroded area	Y	N					
Removal of corrosion product	Y	N					
Gas detection	Y	N					
Preparation of NWT area	Y	N					
Photographs	Y	N					
Cleaning of pipe (potable water)	Y	N					
UT for NWT	Y	N					
UT of corroded area	Y	N					
Pit depth assessments	Y	N					
Calculations	Y	N					
Weather checks	Y	N	See section 5				
Preparation for coating	Y	N					
<b>3.0 Measurements</b>							
<b>MAWT</b> (Refer to table)	Nominal diameter		Storeys above pipework		Number of laterals		MAWT
<b>NWT</b> (Average across 6 readings)	1	2	3	4	5	6	NWT
<b>mRWT</b> (lowest recorded UT measurement (corroded area))	1	2	3	4	5	6	Lowest
<b>CD</b> micrometer measurements (deepest pit depth)	1	2	3	4	5	6	Deepest
<b>RWT = mRWT – CD</b> (lowest recorder UT – deepest pit depth)							RWT
<b>CWT</b>	<b>RWT - MAWT</b>	<b>CWT</b>	<b>AWT</b>		<b>NWT - MAWT</b>	<b>AWT</b>	
<b>4.0 Damage classification - Refer to table</b>							
<b>CWT / AWT x 100</b>	Moderate		Severe		Extreme		Unrepairable
<b>5.0 Weather checks</b>							
Relative humidity	Ambient air Temperature		Surface Temp		Dew point		Delta point
<b>6.0 Coating application</b>		Type		Photographs		Comments	
	Re-coat	2 – part	Y	N			

## Appendix F – Assessment Record Sheet

 Your Gas Network			
<b>GD/PR/MOB/43 PROCEDURE ASSESSMENT REPORT AND RECORD SHEET</b>			
Technician:		Contact details:	
Engineer in charge:		Contact details:	
Scheduled work start date			
<b>SITE DETAILS</b>			
Property Name/Number			
Street/Road			
Town/City			
Postcode			
Building ID			
<b>PREVIOUS ASSESSMENT DETAILS</b>			
Pipe ID			
ID of previous survey			
Year of previous survey			
<b>VISUAL INSPECTION OF SUPPORTS</b>			
<input type="checkbox"/> UNAFFECTED	<input type="checkbox"/> SUPERFICIAL	<input type="checkbox"/> MODERATE/SEVERE	<input type="checkbox"/> N/A
Remedial Action			
<input type="checkbox"/> No action	<input type="checkbox"/> Surface prep. and re-coat	<input type="checkbox"/> Refer for replacement	<input type="checkbox"/> N/A
<b>DAMAGE LOCATION DETAILS (Sketch as appropriate – attach photographs to report)</b>			
<b>Comments:</b>			



# **VISUAL IDENTIFICATION/CHARACTERISATION OF CORROSION DAMAGE**

☐ General corrosion

☐ Localised corrosion (e.g. pitting)

(Sketch as appropriate – attach photographs to report)

**Comments:**

## **CORROSION DEFECT/DAMAGE AREA DIMENSIONS (Excluding depth measurements)**

Axial length

mm

Circumferential length

mm

MINIMUM ALLOWABLE WALL THICKNESS (MAWT) DETERMINATION					
Nominal pipe size			mm		
Storeys above point of interest					
Number of laterals per storey					
MAWT ( <i>determine from table in procedure</i> )			mm		
NON-DESTRUCTIVE TESTING OF DAMAGED AREAS					
Ultrasonic thickness (UT) measurements					
<i>Nominal wall thickness (NWT)</i>					
Sketch of reference grid (Label numbered UT measurements, attach photographs to report)					
UT measurement (mm)					
1	2	3	4	5	6
Average NWT			mm		
<i>Available wall thickness (AWT)</i>					
AWT = NWT – MAWT			mm		

*Remaining wall thickness (RWT)*

Sketch of reference grid (in relation to corrosion damage, label numbered UT measurements, attach photographs to report)

UT measurement (mm)

1	2	3	4	5	6

Minimum RWT measurement

mm

Depth micrometer measurements (if UT measurements cannot be accurately obtained as above)

*Corrosion depth (CD)*

Depth micrometer measurement (mm)

1	2	3	4	5	6

Greatest CD measurement

mm

$RWT = NWT - CD$

mm



Consumable wall thickness (CWT)		
CWT = RWT – MAWT	mm	
DAMAGE CATEGORY CALCULATION		
(CWT / AWT) x 100		
Damage category (from table)		
<input type="checkbox"/> MODERATE	<input type="checkbox"/> SEVERE	<input type="checkbox"/> EXTREME
REPAIR ACTIONS		
<input type="checkbox"/> Re-coating	<input type="checkbox"/> Composite repair and re-coating	
Ambient air temperature:	Relative humidity:	
Metal surface temperature:	Dew-point temperature:	
<b>Comments:</b>          		
Other records sent with this assessment record sheet (labelled photographs, faxed or e-mailed):          		
Technician signature:		Date:
Engineer in charge signature:		Date:

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