11. APPENDIX 4
STRENGTH CALCULATIONS METHODOLOGIES

Strength calculations based on ASME B31G

The Estimated Repair Factor (ERF) is defined with the formula:

$$ERF = \frac{MAOP}{P_{safe}}$$

Unless otherwise specified by the Customer, for the maximum allowable pressure (P) we take the allowable pressure for an anomaly-free pipe defined as:

$$P = \frac{2t}{D} \cdot SMYS \cdot F_d \qquad (1)$$

For a short metal loss feature, i.e. if $\frac{L^2}{D \cdot t} \leq 20$, the maximum safe pressure (P_{safe}) is calculated with the following equations:

$$P_{safe} = 1.1 \cdot P \cdot \left(\frac{1 - Q}{1 - Q/M} \right)$$

where $M = \sqrt{1 + 0.8 \frac{L^2}{D \cdot t}}$

and, at $A = \frac{2}{3} \cdot L \cdot d$ and $A_0 = L \cdot t$, $Q = \frac{A}{A_0} = \frac{2}{3} \cdot \frac{d}{t}$

For a long metal loss feature, i.e. if $\frac{L^2}{D \cdot t} > 20$, the maximum safe pressure (P_{safe}) is calculated with the following equation:

$$P_{safe} = 1.1 \cdot P \cdot \left(1 - \frac{d}{t} \right)$$

P – maximum allowable pressure, which may be defined as:

1) MAOP as stated by the customer, or

2) operating pressure according to the customer's data with or without consideration of the pipeline elevation, or

3) allowable pressure calculated for each pipe using equation (1) above

P_{safe} – maximum safe pressure for a pipe with metal loss

A – area of metal loss

A_0 – area of a through anomaly with length equal to a measured length of metal loss

M – Folias factor

t – nominal wall thickness

d – depth of metal loss

L – measured length of metal loss

D – nominal outer diameter of the pipeline

SMYS – specified minimum yield strength of the pipeline steel

F_d – design factor, $F_d = 0.72$

Strength calculations based on BS 7910 methodology.

Metal loss strength calculations are conducted in compliance with the requirements of BS 7910 standard, section G.

According to BS 7910 it is required to determine whether the defect is a single defect or a part of a cluster, i.e. interacts with adjacent defects

As per the interaction rules set by the Customer two metal loss features shall be considered a single defect if the axial distance between two edges of the two metal loss features is less than the shortest length of these two metal loss features, and if the axial distance between two edges of the two metal loss features is less than the shortest width of these two metal loss features.

Failure pressure of the pipe with a single metal loss is calculated according to the formula:

$$P_f = P_0 \cdot R_s$$

where:

$P_0 = \dfrac{2 \cdot B_0 \cdot \sigma_u}{(D - B_0)}$ - failure pressure for pipes without defects;

$R_S = \dfrac{\left(1 - \dfrac{d_c}{B_0}\right)}{\left(1 - \dfrac{d_c}{B_0 \cdot Q_c}\right)}$ - safety factor

where:

$Q_c = \sqrt{1 + 0.31 \dfrac{l_c^{\,2}}{D \cdot B_0}}$ - length correction factor

where:

σ_u - pipeline material ultimate stress limit;

d_c - metal loss depth (corroded pipe area);

l_c - metal loss length (corroded area) along outer lines of the pipe.

Safe working pressure P_{SW} for the pipe with a defect is calculated according to the formula:

$$P_{SW} = f_c \cdot P_f$$

where f_c - safe factor calculated as:

$$f_c = f_{c1} \cdot f_{c2}$$

where:

f_{c1} - scale factor ($f_{c1} = 0.9$);

f_{c2} - design factor (working safe factor).

Estimated repair factor ERF is calculated according to the formula:

$$ERF = \frac{MAOP}{P_{SW}}$$

Interacting defects are projected onto longitudinal lines drawn with spacing into circumferential direction - ϕ. Minimum safe working pressure is calculated for all possible defect combinations. Detailed calculation algorithm is given in BS 7910 standard.

Pipeline strength calculations are required only for features with a depth to wall thickness ratio (d/t) less than 80%.

Features ≥80% wt in depth should be subject to repair.

Strength calculations (calculations of the maximum safe pressure) for a pipe with an anomaly should not be used as justification to build up the pressure to more than the design or authorized operating pressure.