

Engineering Procedure

SAEP-306

29 June 2005

Assessment of the Remaining Strength of Corroded Pipes

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Saudi Aramco DeskTop Standards

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1 Scope

- 1.1 This Saudi Aramco Engineering Procedure (SAEP) provides guidelines for assessing carbon steel pipelines containing corrosion metal-loss defects. Application of the guidance will establish the remaining strength of corroded pipelines and provide the technical basis for determining the acceptability of defects.
- 1.2 The assessment methods described in this procedure are intended to be used on corrosion metal-loss defect in pipelines that have been designed to a recognized pipeline design code, including but not limited to ASME B31.4, ASME B31.8.
- 1.3 The procedure can be used for in-plant piping designed and constructed in accordance with ASME B31.8 or ASME B31.4 such as bulk plants and pump stations.
- 1.4 This procedure should be used by experienced engineers or trained inspectors or who have demonstrated capabilities in understanding and applying this procedure. Also, they should be familiar with SAEP-020 [SAEP-310](#) and [SAES-L-410](#).

Commentary:

Attending and successfully completing fitness for service courses is highly recommended.

2 Conflicts and Deviations

- 2.1 Any conflicts between this standard and other applicable Saudi Aramco Engineering Standards (SAESs), Materials System Specifications (SAMSSs), Standard Drawings (SASDs), or industry standards, codes, and forms shall be resolved in writing by the Company or Buyer Representative through the Manager, Consulting Services Department of Saudi Aramco, Dhahran.
- 2.2 Direct all requests to deviate from this standard in writing to the Company or Buyer Representative, who shall follow internal company procedure [SAEP-302](#) and forward such requests to the Manager, Consulting Services Department of Saudi Aramco, Dhahran.

3 Applicable Documents

- 3.1 Saudi Aramco References

Saudi Aramco Engineering Procedures

<u>SAEP-20</u>	<i>Equipment Inspection Schedule</i>
<u>SAEP-302</u>	<i>Instructions for Obtaining a Waiver of a Mandatory Saudi Aramco Engineering Requirement</i>
<u>SAEP-310</u>	<i>Pipeline Repair and Maintenance</i>

Saudi Aramco Engineering Standards

<u>SAES-L-150</u>	<i>Pressure Testing of Plant Piping and Pipelines</i>
<u>SAES-L-310</u>	<i>Design Plant Piping</i>
<u>SAES-L-410</u>	<i>Design of Pipelines</i>

3.2 Industry Codes and Standards

American Society of Mechanical Engineers

<i>ASME B31G</i>	<i>Manual for Determining the Remaining Strength of Corroded Pipelines</i>
<i>ASME B31.4</i>	<i>Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids</i>
<i>ASME B31.8</i>	<i>Gas Transmission and Distribution Piping Systems</i>

American Petroleum Institute

<i>API RP 570</i>	<i>Piping Inspection Code</i>
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3.3 Guidance Document

<i>PRCI-273-9803</i>	<i>Guidance for Assessing the remaining strength of Corroded Pipeline</i>
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4 Definitions

ERF: Estimated Repair Factor can be established by dividing the maximum allowable operation pressure (MAOP) or design pressure by the predicted failure pressure P_f .

ILI: In-Line Inspection of Pipeline

LPC: Line Pipe Corrosion equation

PRCI: Pipeline Research Council International, Inc.

5 General

- 5.1 This procedure mandates the use of two assessment levels which are Level-1 and Level-2 as detailed in paragraph 8. Chart-1 of Appendix-A provides schematic diagram of the two levels.
 - 5.1.1 A level-1 assessment only considers the maximum defect dimensions, i.e., the maximum depth(s), maximum length(s) and separating distance(s) of an isolated defect, and uses one of the simple failure equations. The level-1 assessment method is used for assessing multiple or large number of corrosion metal-loss defect so that severe or critical defects can be identified.
 - 5.1.2 A level-2 assessment considers not only the maximum defect dimensions but also the shape of the metal-loss area(s) of the defect. The level-2 assessment method is more complex and less conservative than a level-1 assessment method, and requires more information about the defect shape, support of computer software and knowledge of specialists. It gives results with higher accuracy when compared with a level-1 assessment.
- 5.2 For defects, which fail to pass the level-1 assessment, a level-2 assessment shall then be considered if the defect shape is considerably variable and detailed measurements are available.
- 5.3 Numerical stress analysis techniques, such as the non-linear finite element (FE) can be used for assessing corrosion defects which fail to pass level-2. The use of such assessment shall be approved by the Chairman of the Piping Standards Committee.
- 5.4 Limitations
 - 5.4.1 This SAEP is applicable for internal corrosion defects or external corrosion defects in the base material of a straight pipe section and pipe bends.
 - 5.4.2 The assessment methods can be empirically applied to corrosion metal-loss defects across or immediately close to pipe welds (longitudinal seam welds, spiral seam welds and girth welds). This is subject to the following conditions:
 - a. There are no significant weld defects present that may interact with the corrosion defects.
 - b. The weld material is not under-matched.
 - c. Fracture is not likely to occur.

6 Data Required

6.1 Data Required

The assessment of the corrosion metal-loss defects in line pipe requires the following information:

- a. The outside diameter of the pipe.
- b. The specified minimum yield strength (SMYS).
- c. The specified minimum tensile strength (SMTS).
- d. The nominal wall thickness of the pipe.
- e. Longitudinal and circumferential spacing between defects.

6.2 Defect shape

6.2.1 For level-1 assessment, the data of corrosion metal-loss defect shall be presented by rectangular boxes that envelop the maximum surface dimensions and maximum through-wall-thickness dimension of the metal-loss area, as shown in Figure-1 and Figure-2 in Appendix-B.

6.2.2 For level-2 assessment, a corrosion metal-loss area shall be presented by a projected profile as shown in Figure-4 in Appendix-B. The profile represents a longitudinal cross section through the corroded area. The profile spacing can be taken as a regular or irregular spacing according to the software used.

6.3 Defect Grouping

6.3.1 A single metal-loss defect is a metal-loss area that is longitudinally or circumferentially separated from other metal-loss areas by at least 3 times the nominal wall thickness.

6.3.2 A number of metal-loss areas, which are longitudinally or circumferentially separated by less than 3 times the nominal wall thickness shall be considered as a single defect as illustrated in Figure-3 in Appendix-B.

6.3.3 A single defect does not interact with any other metal-loss defects.

7 Defect Assessment Levels

7.1 Level-1 Defect Assessment

- 7.1.1 For level-1, the Line Pipe Corrosion failure equation method (LPC) shall be used.
- 7.1.2 ASME B31G failure equation can only be used for level-1 if the corrosion defects data obtained by the instrument scraper.

Commentary:

The B31G method is the most conservative method. Therefore, it is recommended only to be used for IS data to be able to develop the pipeline maintenance repair plan.

- 7.1.3 LPC failure equation is defined by:

$$P_f = P_o R_s \quad (1)$$

$$P_o = \frac{2\bar{\sigma}}{\left(\frac{D}{t} - 1\right)} \quad (2)$$

$$\bar{\sigma} = SMTS \quad (3)$$

$$R_s = \frac{1 - \left(\frac{d}{t}\right)}{1 - \left(\frac{d}{t}\right) \frac{1}{\sqrt{1 + 0.31 \left(\frac{L}{\sqrt{Dt}}\right)^2}}} \quad (4)$$

$$\text{for } \left(\frac{d}{t}\right) \leq 0.85 ; \text{ all lengths}$$

Where:

P_f	Predicted failure pressure for corroded pipe, lb/in ²
$SMTS$	Specified minimum tensile strength, lb/in ²
D	Nominal outside diameter, in
t	Nominal wall thickness, in
d	Maximum depth of a corrosion metal-loss area, in
L	Maximum axial length of corrosion metal-loss area, in

7.2 Level-2 Defect Assessment

- 7.2.1 The RSTRENG effective-area method shall be used for level-2 assessment.
- 7.2.2 The RSTRENG effective-area method is defined by a procedure of progressive failure predictions based on the RSTRENG equation but assuming that the equivalent depths of the incremental "defects" are determined by the areas of the sub-sections.
- 7.2.3 The procedure, as schematically illustrated by Figure-4, can be described by the following steps:
- 1) for a projected defect profile with the area of the profile, A , its axial length, L , and the maximum depth, d , divide the overall defect length, L , by n incremental sub-sections, L_i ($i=1,2,3,\dots,n$ and L_i contains L_{i-1}), then obtain areas of the sub-sections, A_i ($i=1,2,3,\dots,n$ and A_i contains A_{i-1});
 - 2) calculate a predicted failure pressure using the following formulae:

$$P_f = \min\{P_{f1}, P_{f2}, \dots, P_{fi}, \dots, P_{fn}\} \quad (i = 1, 2, 3, \dots, n) \quad (5)$$

$$P_{fi} = \frac{2\bar{\sigma}}{\left(\frac{D}{t}\right)} \left[\frac{1 - \left(\frac{d_i}{t}\right)}{1 - \left(\frac{d_i}{t}\right)\left(\frac{1}{M_i}\right)} \right] \quad \text{for } \left(\frac{d}{t}\right) \leq 0.80 \quad (6)$$

$$\bar{\sigma} = SMYS + 10000 \text{ (lb/in}^2\text{)} \quad (7)$$

$$d_i = \frac{A_i}{L_i} \quad (8)$$

$$M_i = \sqrt{1 + 0.6275\left(\frac{L_i}{\sqrt{Dt}}\right)^2 - 0.003375\left(\frac{L_i}{\sqrt{Dt}}\right)^4} \quad \text{for } \frac{L_i}{\sqrt{Dt}} \leq 7.071 \quad (9)$$

$$M_i = 3.3 + 0.032\left(\frac{L_i}{\sqrt{Dt}}\right)^2 \quad \text{for } \frac{L_i}{\sqrt{Dt}} > 7.071 \quad (10)$$

Where:

P_f Predicted failure pressure for corroded pipe, lb/in²
 $SMYS$ Specified minimum yield strength, lb/in²
 D Nominal outside diameter, in

- t Nominal wall thickness, in
 d Maximum depth of a corrosion metal-loss area, in
 L Maximum axial length of corrosion metal-loss area, in

8 Pipeline Repair Decision

8.1 Estimated Repair Factor (ERF)

The estimated repair factor for a corrosion defect can be established by dividing the maximum allowable operating pressure (MAOP) or design pressure by the predicted failure pressure, P_f , for the corrosion defect, as below:

$$ERF = \frac{MAOP}{P_f} \quad (11)$$

- 8.2 The remedial actions of the assessed pipeline are based on the ERF values for the defects and shall be according to Table-1 below.

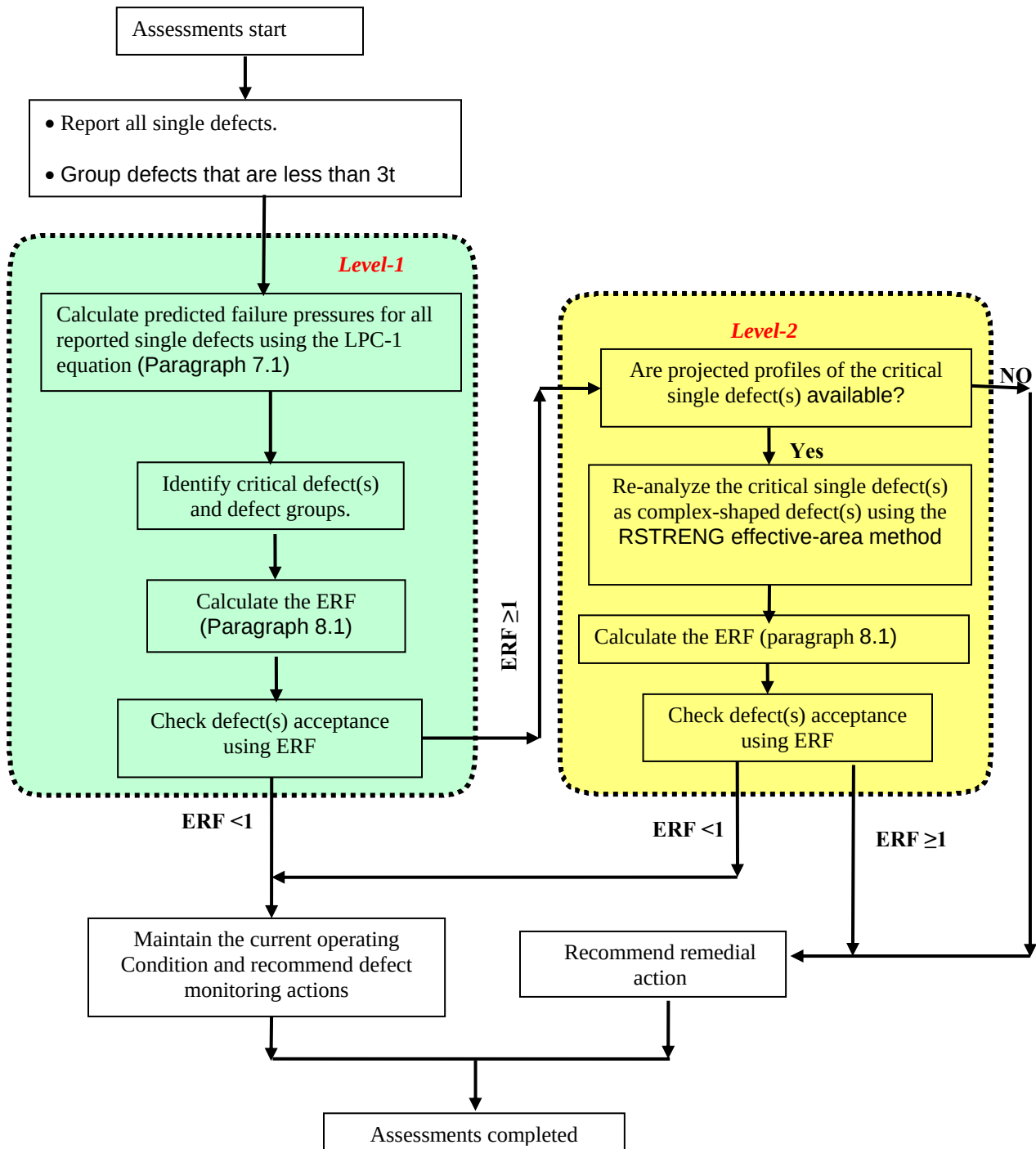
Table-1: Corrosion defects remedial action

Assessment Level	Corrosion Type	ERF Values ≥ 1	ERF Values < 1
Level-1	External	Required repair or consider level-2 assessment	Required coating only to stop corrosion.
Level-2	External	Required immediate repair	Required coating only to stop corrosion.
Level-1	Internal	Required immediate repair	Required periodical corrosion monitoring
Level-2	Internal	Required immediate repair	Required close corrosion monitoring

- 8.3 Internal corrosion defects, which pass the assessment, shall be monitored on a periodical basis. The inspection period shall be determined by the Engineering of the Operating Organization.

29 June 2005	Revision Summary Major revision.
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Appendix-A: Chart-1: Corroded Pipelines Defects Assessment Flowchart



Appendix-B: Schematic Illustrations for Defects Measurements and Grouping

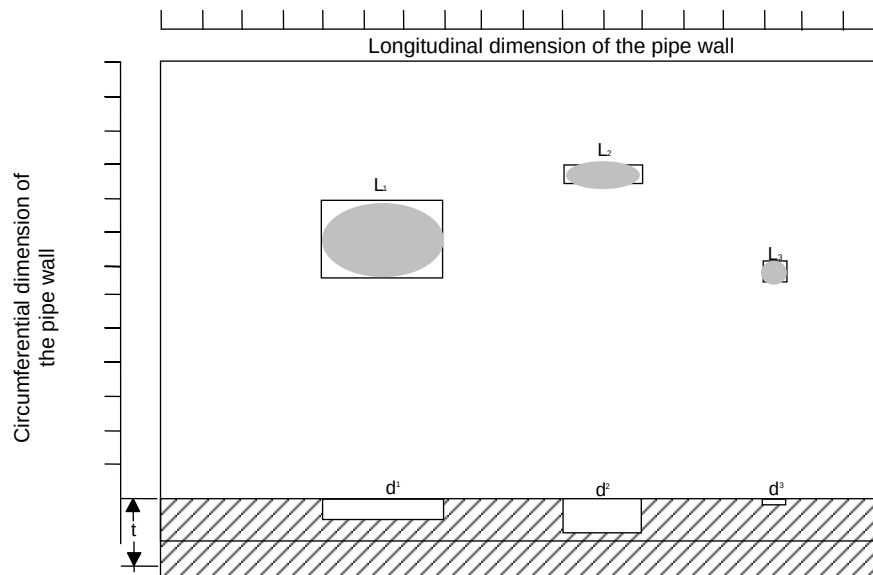
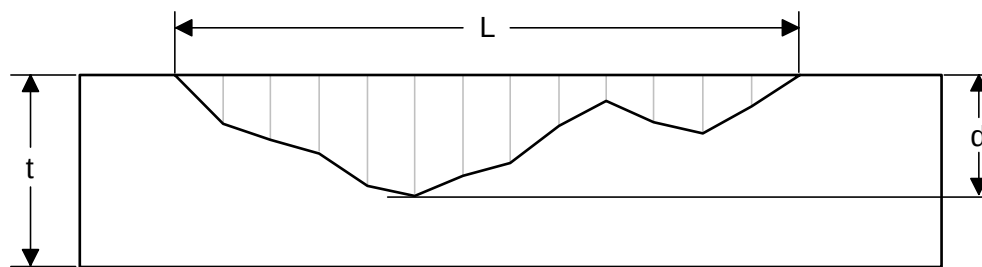


Figure 1. Example of reported corrosion defects



the projected through-wall-thickness profile of a corrosion metal-loss area

Figure 2: Project profile for metal loss

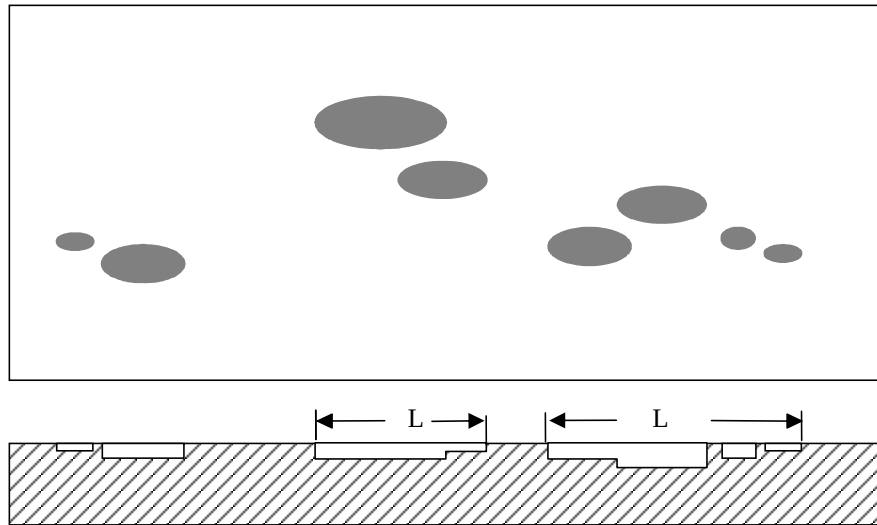
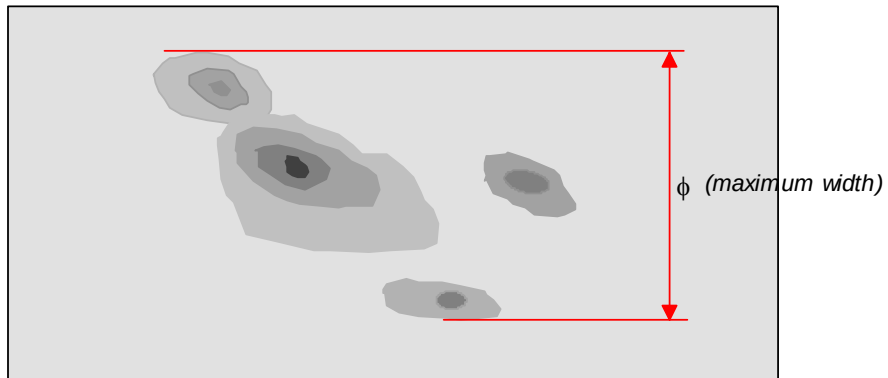


Figure 3: Defect grouping, defects that are less than $3t$ should be considered as a single defect.

a plan view of four corrosion pits



projected defect profile

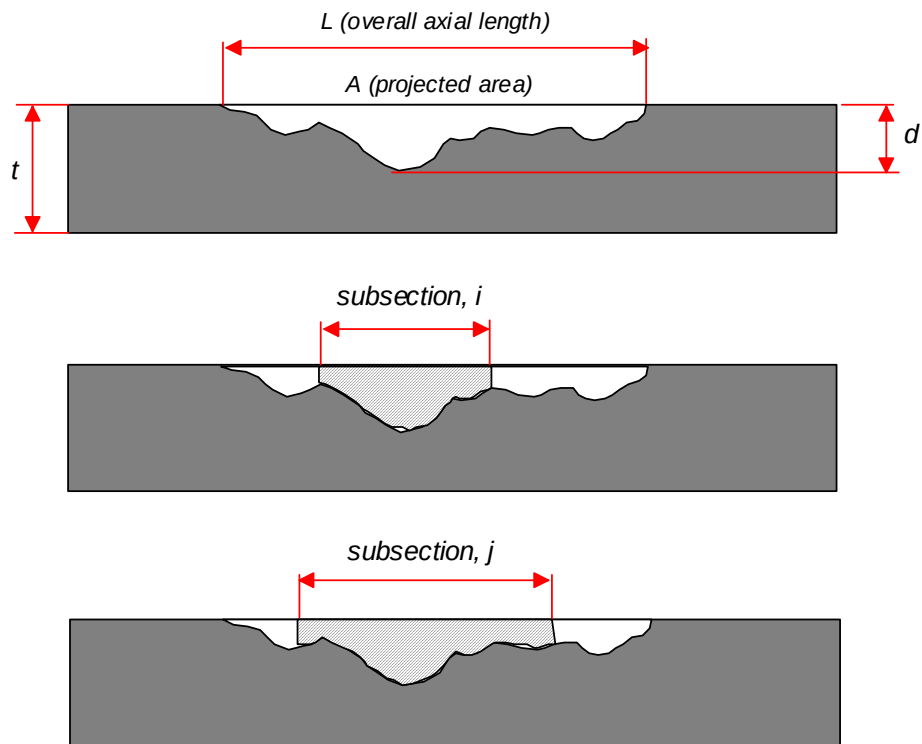


Figure 4: A schematic illustration of level-2 assessment.