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KAPA™

Kiefner and Associates, Inc. Pipe Assessment

Spreadsheet Documentation

Introduction

The attached spreadsheet provides two methods for calculating the failure pressure levels of longitudinally oriented part-through flaws of varying depths in pressurized pipe. One method applies to blunt defects, such as corrosion-caused metal loss. It provides failure pressure levels based on user-supplied data, including pipe diameter, wall thickness, pipe grade or actual measured yield strength, and the appropriate axial length and through-thickness depth dimensions of the defect. The other method applies to crack-like defects. To use the latter, the user must supply an appropriate level of Charpy V-notch energy to account for the material's toughness. The equations are semi-empirical fracture mechanics expressions. They were developed and validated thanks to various research efforts sponsored by individual pipeline operators and industry consortia. It is important to note that the equations are relatively straightforward. Anyone with reasonable algebra knowledge and access to a pocket calculator can solve them in closed form. The equations have been in the public domain for over 35 years. They originated in concepts advanced by early fracture mechanics experts prior to any involvement in the pipeline industry. Kiefner and Associates, Inc. (Kiefner) offer these equations for your use free of charge out of gratitude for the pipeline industry's generous support for pipeline integrity research over the years. We also believe the industry needs unrestricted access to reliable, consistent methods for assessing pipeline anomalies to protect public safety and the environment.

For information on the background of these equations, please consult the references list at the end of this document.

Opening the Spreadsheet

The spreadsheet is designed to work with the 32-bit version of Microsoft Excel but will not work properly with the 64-bit version due to macro coding differences in VBA. The program uses these macros to perform the pipeline integrity assessment calculations. Because of this, the macro functionality must be enabled for the program to function properly.

A Disclaimer page, shown in Figure 1, will open every time KAPA™ is launched to ensure the user is able to review the use information contained within the spreadsheet. Clicking on the radio button "Agree" opens KAPA™ user functionality completely.

Figure 1. KAPA™ Disclaimer Agreement Page

Spreadsheet Organization

The Microsoft Excel spreadsheet is organized into three tabs to facilitate the data entry of the defect(s) to be analyzed. These tabs are "Main," "Grid," and "Chart."

Main. This sheet contains the pipe's physical properties to be evaluated, the options for data entry units, the options for the assessment approach, and the assessment results. Portions of this spreadsheet are protected to prevent potential corruption of assessment algorithms.

Grid. This sheet contains a place for the user to enter a description of the analysis or defect, the defect profile information, and an option for data entry as remaining thickness or pit depth. The program is set up by default to allow for 10 individual grid profiles with 1000 individual depths per profile. Portions of this spreadsheet are protected to prevent accidental corruption of the assessment algorithms.

Chart. This sheet contains a graphic representation of the defect profile information entered. The chart is part of any assessment algorithms and, consequently, is not

protected. Excel allows the graph to be changed to suit the needs of the individual user.

Several comments to aid the user are embedded in the spreadsheet at various cells, giving further details or suggestions about the input required. To access the comments, the mouse pointer should be placed over the cell containing a red triangle in the upper right-hand portion of the cell.

Pipe Parameters

Before entry of data, the user should select the unit system (US Customary or Metric) to be used. This is accomplished by selecting the appropriate option box. It is suggested that if one unit system is preferred, that system should be selected, and the spreadsheet be resaved for future analysis.

The physical pipe properties required are as follows:

Diameter. This is the nominal outside diameter of the pipe to be used. This should not be confused with the Nominal Pipe Size or the actual measured pipe diameter. Examples for entry include: 12-inch NPS should be entered as 12.750 inches, and 20-inch NPS should be entered as 20.0 inches.

WT. This parameter is the pipe wall thickness. It should be entered in as the nominal thickness or if known, the actual measured thickness of the pipe.

SMYS. The specified minimum yield strength of the pipe or the actual yield strength if known.

MAOP/MOP. The maximum operating pressure of the line at the point where the evaluation is to occur.

CVN. This is the full-size specimen (10 mm x 10 mm) Charpy V-notch upper shelf energy of the pipe material. This is only used in the crack-like assessment algorithm and is not used for the corrosion assessment.

Design Factor. This is the net operating design factor accounting for transported commodity, pipeline location, pipe seam type, and temperature. Typical values are shown in Table 1.

Table 1. Examples of Design Factors to Apply

Description	Design Factor
Liquid Hazardous Pipeline	0.72
Gas Pipeline Operating in Class 1	0.72
Gas Pipeline Operating in Class 2	0.60
Gas Pipeline Operating in Class 3	0.50
Gas Pipeline Operating in Class 4	0.40

The spreadsheet displays the maximum allowable pressure for the pipe segment based on Barlow's equation,

$$P = \frac{DF * SMYS * 2t}{D}$$

If the MAOP/MOP entered exceeds the calculated maximum allowable pressure, the value entered for MAOP/MOP changes color to red to warn the user that the pipe is overstressed. After the pipe properties are entered, the defect profile should be entered in the Grid spreadsheet as described below.

Grid Entry

KAPA[TM] allows for the entry of up to 10 individual defect profiles. Each profile represents a longitudinal cross-section through the corroded area and is listed vertically in the Grid spreadsheet. The profile information is used to develop a maximum depth profile envelope, or "river bottom." This "river bottom" typically results in the lowest predicted failure pressure and, consequently, the most conservative approach for evaluating a pipeline segment.

Before entering defect profiles begins, the user should select the method for entering the data, either pit depth or remaining wall thickness. This is accomplished by clicking the appropriate option box.

The profile spacing, located in the leftmost column, can be entered as regular, irregular, or any combination of spacing. Standard spreadsheet-type equations can be used to help the user enter data or spacing more efficiently. The units are either inches or millimeters, depending on the unit selection from the Main Sheet. If using inches, mils (thousandths of an inch) may also be used by checking the "MILS" box.

The defect profile data should be entered starting in the column to the right of "Max. Envelope Defect Profile," and each progressing profile should be entered in the next adjacent column without skipping any columns. If a column is left blank, the analysis will terminate at the blank column, and any data entered beyond that point will not be analyzed. Standard Excel commands can be used to help simplify data entry. However, it is recommended that when cutting and pasting, the "Paste Special" function with "Values Only" be used instead of the standard paste function to avoid changing the formats of the cells.

Profile data entries that exceed the pipe wall thickness will be automatically highlighted for easy identification by the user.

Above each column of grid profiles is a space for a label to identify the profile. This label is also printed on the results section.

In cases where the user prefers to enter only the "river bottom" profile, this profile should be entered as described above for a single profile. If the user wishes to evaluate other scenarios by varying the profile and observing the change in predicted failure pressure, these can be entered as additional columns. If multiple scenarios are entered, the results from the defect envelope profile should be disregarded in the results section.

Analyzing the Data

The final step is selecting the evaluation method, "Corrosion Defects" or "Crack-like Defects". At this time, the program macro will begin execution. When completed, the results will be displayed on the sheet labeled "Main."

For corrosion or other blunt defects, the results will show the predicted failure pressure and the factor of safety for the Effective Area Method, Modified B31G, and ASME B31G methodologies. The factor of safety is the ratio of the predicted failure pressure and the MAOP/MOP user entry. The program does not compute a safe operating pressure. An engineer familiar with pipeline integrity issues should determine the safe operating pressure. Additional calculated parameters are also displayed to aid the Engineer's evaluation process.

For crack-like defects, the results will indicate the failure pressure and the factor of safety for the Effective Area Method using the actual crack profile. The other calculated parameters are displayed to aid the Engineer in evaluating a safe operating pressure for the pipeline segment.

An error message is displayed during the analysis if the defect depth exceeds 80 percent of the pipe wall thickness. The maximum depth and maximum depth/thickness will be changed to red to indicate which grids had defect depths exceeding 80 percent of the wall thickness.

The results and data can be printed using the standard Excel Spreadsheet functions. It is advised that the page setup be reviewed prior to printing to ensure that the desired print ranges are set up.

Additional Help

Additional help or program customization can be obtained by contacting Kiefner and Associates, Inc. at:

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References

1. Kiefner, J. F., & Duffy, A. R. (1971, July 20). *Summary of research to determine the strength of corroded areas in line pipe*. Presented at a public hearing of the U.S. Department of Transportation.

2. Kiefner, J. F., Maxey, W. A., Eiber, R. J., & Duffy, A. R. (1973). Failure stress levels of flaws in pressurized cylinders. *Progress in Flaw Growth and Toughness Testing, ASTM STP 536*, 461–481. American Society for Testing and Materials.

3. Kiefner, J. F., & Vieth, P. H. (1990, August 6). Evaluating pipe: New method corrects criterion for evaluating corroded pipe. *Oil and Gas Journal*.

4. Kiefner, J. F., & Vieth, P. H. (1990, August 20). Evaluating pipe: PC program speeds new criterion for evaluating corroded pipe. *Oil and Gas Journal*.

Equations

Effective Area Calculation
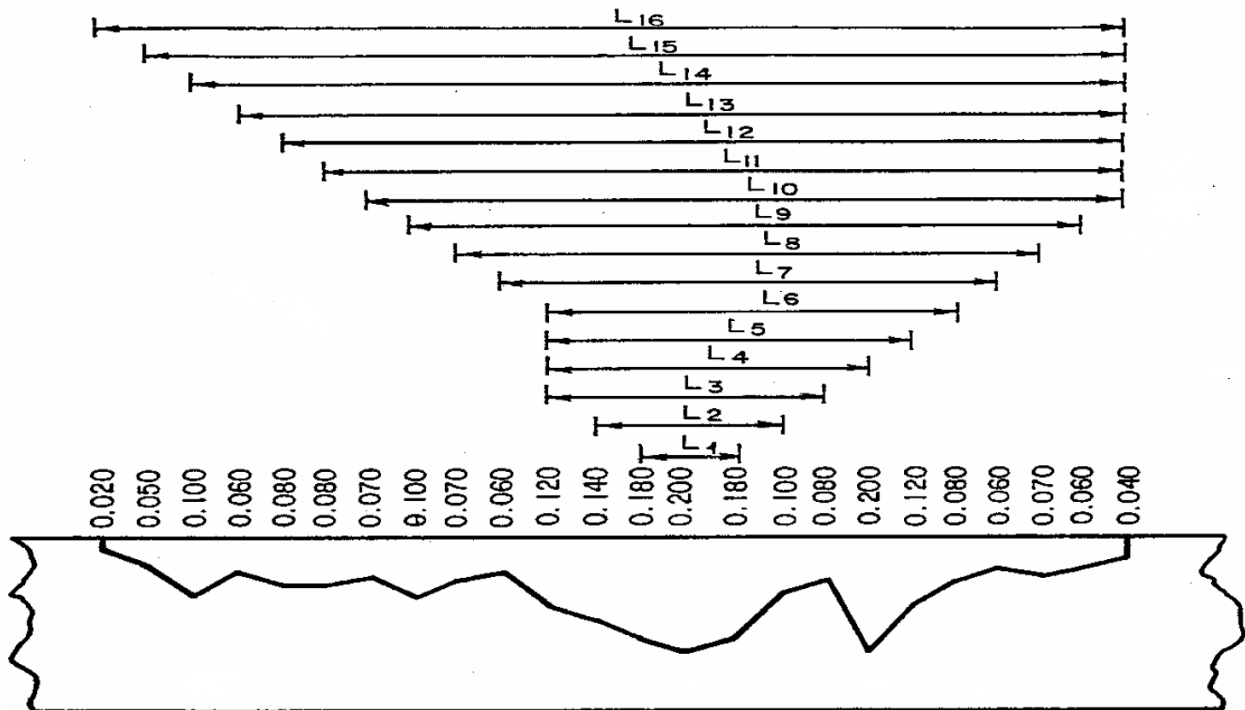
Corroded Pipe Assessment

Failure Criterion

$$\sigma_{Failure} = \bar{\sigma}\left[\frac{1 - \dfrac{A}{A_O}}{1 - \dfrac{A}{A_O}M^{-1}}\right]$$

Where:

$\sigma_{Failure}$	Predicted Failure Stress
$\bar{\sigma}$	Flow Stress, f{SMYS}
A	Effective Area of Missing Metal
A_O	Original Area, {L x t}
M	Folias Factor, f{L, D, t}
L	Effective Length

Folias Factor

$$For\ L \leq \sqrt{50Dt}, \quad M = \sqrt{1 + 0.6275\frac{L^2}{Dt} - 0.003375\left(\frac{L^2}{Dt}\right)^2}$$

$$For\ L > \sqrt{50Dt}, \quad M = 0.032\frac{L^2}{Dt} + 3.3$$

Crack-Like Defects

$$\frac{12\left(\frac{C_V}{A_V}\right)E\pi}{4L\overline{\sigma}^2} = LN\left(SEC\left(\frac{\pi}{2}\left[\frac{M_P\sigma_P}{\overline{\sigma}}\right]\right)\right)$$

$$M_P^{-1} = \left[\frac{1 - \frac{A}{A_O}}{1 - \frac{A}{A_O}M_T^{-1}}\right]$$

$$For\ L \leq \sqrt{50Dt}, \quad M_T = \sqrt{1 + 0.6275\frac{L^2}{Dt} - 0.003375\left(\frac{L^2}{Dt}\right)^2}$$

$$For\ L > \sqrt{50Dt}, \quad M_T = 0.032\frac{L^2}{Dt} + 3.3$$

Where:

C_V	Upper shelf Charpy V-notch impact energy, ft-lb
A_V	Area of Charpy V-notch specimen, inch^2
E	Elastic Modulus, psi
L	Axial length of area affected by corrosion and/or SCC, inch (L can also be an "effective length" defined by an iterative process such as that embodied in KAPA)
$\overline{\sigma}$	Flow Stress, psi (SMYS + 10,000 psi)
σ_P	Failure Stress, psi
$SMYS$	Specified minimum yield strength, psi
D	Nominal outside diameter of the pipe, inch
T	Nominal wall thickness of the pipe, inch
A	The area of metal missing due to either corrosion-caused metal loss or SCC or both.
A_O	Area of metal, L x t, which would be present if there are no flaws