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A REVIEW OF METHODS FOR ASSESSING THE REMAINING STRENGTH OF CORRODED PIPELINES

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EXECUTIVE SUMMARY

Introduction

When corrosion damage in pipelines is detected by in-line inspection (ILI), a replace, repair or ignore decision must be made. This decision is based on the prediction of the failure pressure of the corroded pipe. This prediction must be accurate without being over conservative. The general view is that existing assessment methods used by the pipeline industry, such as ASME B31G, satisfy this requirement. However, because the methods are empirically based, there may be cases when the assessment methods are used outside their range of validity. Because it has been recognized that in some cases, existing assessment methods may not give conservative failure predictions, additional margins or safety factors are used. For example in ASME B31.8S, following a successful ILI, the operator must address promptly defects (or anomalies or features) that pose an imminent threat to the integrity of the pipeline. An immediate response is required for pipelines with corrosion defects when the predicted failure pressure is less than 1.1 times the maximum allowable operating pressure (MAOP). The factor of 1.1 is consistent with the hydrotest test level above the MAOP for pipelines designed to ASME B31.8 [34], Location Class 1, Division 2 (i.e. for pipelines operating at 72% SMYS or less).

US Federal Regulations 49 CFR Part 192 and 195 stipulate that ASME B31G or RSTRENG is used to assess the remaining strength of corroded pipe. Concerns have been raised that use of these methods may give non-conservative failure predictions when assessing relatively deep corrosion defects in higher strength line pipe.

Advantica has been active in developing methods for assessing corrosion damage in pipelines for Pipeline Research Council International (PRCI) and more recently for the Pipelines and Hazardous Materials Safety Administration (PHMSA). Advantica also led a Group Sponsored Project (GSP) in the late 1990's funded by 8 operators and 2 regulators which ultimately resulted in the development of assessment methods that are now embodied into internationally recognized fitness for service standards. PHMSA has now requested guidance from Advantica to determine under what conditions use of ASME B31G and RSTRENG may give rise to non-conservative failure predictions.

To investigate the performance of these methods, an integrated database of burst test results has been collated, similar to that described in [6] and [7]. Since the publication of these documents, burst tests undertaken by Advantica on higher strength material (grade X80 and X100), together with test results available in the public domain, have also been reviewed and included in the database.

The intent of this report is to collate a comprehensive burst test database that includes the results from tests conducted on grade X80 and X100 line pipe material previously not published by Advantica. Using this database, sensitivity studies have been undertaken to investigate failure pressure predictions using common assessment methods such as ASME B31G, Modified ASME B31G and RSTRENG against the recorded test burst pressures. These methods have been successfully used to and in the vast majority of cases give conservative predictions of the failure pressure of corroded pipelines. However, these methods were validated using a database of vintage, predominately lower strength pipe. One of the aims of this project was to investigate the performance of these methods to predict the failure pressure of higher strength, modern pipelines.

It is to be noted that reports previously published by PRCI have on occasion made reference to the Modified ASME B31G method as the RSTRENG 0.85*dL* method. In some instances this has led to confusion. In this report a clear distinction is made between the ASME B31G, Modified ASME B31G and the RSTRENG Effective Area (for brevity, hereafter referred to as RSTRENG) methods.

In addition to the ASME B31G, Modified ASME B31G and RSTRENG methods, the performance of other corrosion assessment methods developed by the pipeline industry, such as LPC-1, PCORRC and SHELL92, has also been undertaken. These methods have evolved over

Conclusions

1. For the majority of the tests investigated in this report, standard assessment methods used by the pipeline industry give conservative failure predictions. In a number of cases predictions of the remaining strength are very conservative. Failure predictions on pipe with real corrosion defects were shown to be conservative using the ASME B31G, Modified ASME B31G and RSTRENG methods.

2. For a very small number of test points reviewed in this report, use of the ASME B31G and Modified ASME B31G methods resulted in non-conservative failure predictions. These were for test points with defects greater than 40% of the pipe wall and in line pipe of grade X52 and above. Where non-conservative failure predictions are predicted, they were on tests with artificially introduced (machined) defects, rather than pipe with real corrosion defects. Typically machined defects consist of a rectangular, flat bottomed patch and use of, for example ASME B31G or Modified ASME B31G, may be inappropriate in these cases because the area of metal loss can be underestimated, particularly if the defect is long.

3. RSTRENG is the most accurate method for predicting the failure pressure in pipelines. RSTRENG predicts conservative failure pressures for defect depths up to 80% of the pipe wall in line pipe of strength grades up to X100.

4. The SHELL92 method, which is a modified version of the ASME B31G method, conservatively predicts failure pressures for defect depths up to 80% of the pipe wall in line pipe of strength grades up to X100.

Recommendations

1. The ASME B31G or the Modified ASME B31G methods can continue to be used to rank/screen defects following ILI. This is because both methods predict conservative failure pressures for tests conducted on pipe with real corrosion defects. However, the test database for pipe with real corrosion defects given in this report is limited to pipe generally below grade X65. Failure predictions for burst tests conducted on pipe of higher grades have resulted in some non-conservative failure predictions when the ASME B31G and Modified ASME B31G methods have been used. These tests were

conducted on pipe with machined defects. It is recommended that a focused program of full-scale tests is conducted on higher strength pipe with simulated defects that represent real corrosion damage in the field. Failure pressure predictions using ASME B31G, Modified ASME B31G and RSTRENG should then be compared to the recorded burst test pressures.

2. The RSTRENG method has been shown to be the most accurate in predicting the failure pressure of pipe up to grade X100. In the absence of burst test data on higher strength pipe (above Grade X65) with real corrosion defects, remaining strength assessments can be conducted using either RSTRENG or SHELL92 as both methods are shown to predict conservative failure pressures in pipe up to Grade X100. Specified minimum material properties should be used as required by the assessment methods.

3. Work described in this report and the output from PRCI Project EC4-1 (Project to determine the true performance in 'real' field conditions of in-line inspection tools utilizing Magnetic Flux Leakage (MFL) technology) is critically reviewed to determine how the algorithms used by inspection vendors to screen defects are implemented.

CONTENTS

1 INTRODUCTION

When corrosion damage in pipelines is detected by in-line inspection (ILI), a replace, repair, or ignore decision must be made. This decision is based on the prediction of the failure pressure of the corroded pipe. This prediction must be accurate without being over conservative. The general view is that existing assessment methods used by the pipeline industry, such as ASME B31G [3], satisfy this requirement. However, because the methods are empirically based, there may be cases when the assessment methods are used outside their range of validity. Because it has been recognized that in some cases, existing assessment methods may not give conservative failure predictions, additional margins or safety factors are used. For example in ASME B31.8S [31], following a successful ILI, the operator must address promptly defects (or anomalies or features) that pose an imminent threat to the integrity of the pipeline. An immediate response is required for pipelines with corrosion defects when the predicted failure pressure is less than 1.1 times the maximum allowable operating pressure (MAOP). The factor of 1.1 is consistent with the hydrotest test level above the MAOP for pipelines designed to ASME B31.8 [34], Location Class 1, Division 2 (i.e. for pipelines operating at 72% SMYS or less).

US Federal Regulations 49 CFR Part 192 [1] and 195 [2] stipulate that ASME B31G [3] or RSTRENG [4], [5] is used to assess the remaining strength of corroded pipe. Concerns have been raised that use of these methods may give non-conservative failure predictions when assessing relatively deep corrosion defects in higher strength line pipe [6], [7].

Advantica has been active in developing methods for assessing corrosion damage in pipelines for Pipeline Research Council International (PRCI) and more recently for the Pipelines and Hazardous Materials Safety Administration (PHMSA). Advantica also led a Group Sponsored Project (GSP) in the late 1990's funded by 8 operators and 2 regulators which ultimately resulted in the development of assessment methods that are now embodied into internationally recognized fitness for service standards. PHMSA has now requested guidance from Advantica to determine under what conditions use of ASME B31G and RSTRENG may give rise to non-conservative failure predictions.

To investigate the performance of these methods, an integrated database of burst test results has been collated, similar to that described in [6] and [7]. Since the publication of these documents, burst tests undertaken by Advantica on higher strength material (grade X80 and X100), together with test results available in the public domain, have also been reviewed and included in the database.

The intent of this report is to collate a comprehensive burst test database that includes the results from tests conducted on grade X80 and X100 line pipe material previously not published by Advantica. Using this database, sensitivity studies have been undertaken to investigate failure pressure predictions using common assessment methods such as ASME B31G, Modified ASME B31G and RSTRENG against the recorded test burst pressures. These methods have been successfully used to and in the vast majority of cases give conservative predictions of the failure pressure of corroded pipelines. However, these methods were validated using a database of vintage, predominately lower strength pipe. One of the aims of this project was to investigate the performance of these methods to predict the failure pressure of higher strength, modern pipelines.

It is to be noted that reports previously published by PRCI have on occasion made reference to the Modified ASME B31G method as the RSTRENG 0.85*dL* method. In some instances this has led to confusion. In this report a clear distinction is made between the ASME B31G, Modified ASME B31G and the RSTRENG Effective Area (for brevity, hereafter referred to as RSTRENG) methods.

In addition to the ASME B31G, Modified ASME B31G and RSTRENG methods, the performance of other corrosion assessment methods developed by the pipeline industry, such as LPC-1 [8], PCORRC [9] and SHELL92 [10], has also been undertaken.

2 BURST TEST DATABASE

Full scale vessel and ring expansion tests of real and machined defects in line pipe have been carried out by a number of different organizations over the last forty years. The primary focus of the research has been to investigate the significance of longitudinally orientated corrosion defects in line pipe subject to internal pressure loading. A database, comprising the results of tests on line pipe with both real and single machined (pit, groove and patch) defects, has been generated, see Appendix A.

Because the data has been obtained from a number of different sources, care has been taken during the execution of this study to ensure that it is accurate. For example, some of the test results are deemed to be unreliable because some defects were subject to a number of pressure reversals, when a vessel containing multiple defects was tested repeatedly. Some tests involved the study of closely spaced defects in line pipe subjected to axial and/or bending loads combined with internal pressure. Other tests have involved the study of interaction of closely spaced defects. For some tests, the defect depths exceeded the limits of validity of the assessment methods[1]. These tests have been included into the integrated database but were not used for comparison with the assessment methods described in this report. For some tests, key information required to compare burst pressure with failure predictions is not available; these test results were not included in the integrated database. To summarize, test results were selected for inclusion into the integrated test database using the following criteria:

- Tests on line pipe with isolated areas of corrosion
- Tests on line pipe subjected only to internal pressure loading

[1] The ASME B31G, Modified ASME B31G, RSTRENG, SHELL92 and PCORRC methods are applicable for assessing defect depths up to 80% of the wall thickness. The LPC-1 method is applicable for assessing defect depths up to 85% of the wall thickness.

- Tests where the pipe geometry, defect geometry, materials data and test pressure have been documented

The sources used to compile the database are described below.

2.1 AGA/PRCI Database of Corroded Pipe Tests

The AGA/PRCI database [11] comprising 124 full scale tests was compiled in 1993. The first 47 tests were used to develop and validate the ASME B31G method. The results of an additional 39 burst test results were included into a database that was subsequently used to develop and validate the Modified ASME B31G and the RSTRENG methods. All the tests were conducted on pipes containing real corrosion damage removed from service. Discussions with the principal investigator responsible for generating the PRCI database [12] have indicated that the results of early tests undertaken on grade B pipe by Battelle (INDEX 6 to 25)[2] should be treated with caution because the defect dimensions were not recorded accurately and in some cases the test vessels had been subject to pressure reversals. Also, these early tests are likely to have been carried out on line pipe of relatively low toughness material. For completeness these tests (INDEX 6 to 25) have been included in the database, but are not included in the main sensitivity studies described in this report.

2.2 PRCI Database for Further Validation of RSTRENG

Since the issue of [11], several researchers have published the results of additional test results on the behavior of corroded pipe. The main issues addressed included the behavior of very long defects; interaction of closely spaced defects; effects of corrosion defects having both longitudinal (axial) and transverse (circumferential) extent; and the effects of large axial stresses on the behavior of corroded pipe. This larger database, reported in [13], included the results of 168 tests and was used to provide additional validation of the RSTRENG method.

Using the criteria described in section 2, test results from [13] were collated for incorporation into the integrated test database.

2.3 Advantica Corrosion Group Sponsored Project Test Database

In the late 1990's, Advantica (then BG Technology) led a group sponsored project (GSP) aimed at developing advanced guidance for assessing the integrity of corroded pipelines. The GSP was funded by 8 operators and 2 regulators. The motivation behind the project was to critically review the use of existing assessment

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[2] For ease of reference, each test has been given a unique index number and key data regarding the pipe geometry, defect geometry (in normalized format) and material grade has been recorded, see section 2.9.

methods such as ASME B31G and RSTRENG in the light of operating experience. It was also recognized that the validation database used to develop ASME B31G and RSTRENG contained vintage pipe, and in some cases likely to be of low toughness. To investigate this concern, Advantica undertook a series of full scale burst tests on higher strength (up to grade X65) and relatively thick walled pipes. The test program consisted of 79 full scale pipe burst tests and 52 ring expansion tests. The vast majority of these tests were performed on modern line pipe with defects machined on the external or internal surface of the pipe. The results of the test program are described in [14]. In addition to the test program, a large number of non-linear finite element (FE) analyses were undertaken to simulate the tests. The output from the GSP led to the development of the method now referred to as the Line Pipe Corrosion (LPC) method which is embodied into a British Standard, BS 7910 [15] and DNV-RP-F101 [16]. The LPC method has been developed for assessing corrosion damage in pipe when failure is controlled by plastic collapse. A screening level assessment is undertaken using the LPC-1 method which allows single defects, with the knowledge of the maximum defect depth and length, to be assessed. Complex defect shapes and interaction can be assessed using the LPC-2 method. Only the LPC-1 method has been considered in this report.

2.4 Petrobras Tests

Petrobras conducted a series of 14 full scale vessels tests on pipes to investigate the behavior of long corrosion defects in pipelines. The tests were undertaken using 12¾ inch grade X60 and 18 inch grade X46 pipe. The results of the former tests are described in [17] and were undertaken using pipe with defects machined onto the external surface of the pipe. The later results are described in [18] and were undertaken on pipe with real corrosion defects.

2.5 Korean Gas Corporation Tests

The Korean Gas Corporation conducted a series of 7 full scale burst tests on 30 inch grade X65 pipe in order to develop a limit load solution for assessing corrosion defects in gas transmission pipelines. All the defects were machined onto the external surface of the pipe; the results are described in [19].

2.6 Advantica Tests

Advantica has undertaken a large number of vessel and ring expansion tests for a number of clients since completion of the corrosion GSP described in section 2.3. 51 tests have been undertaken to assess interaction between closely spaced defects [20] and to assess corrosion in higher strength (grade X80 and X100) steels [21], [22]. INDEX 299 is a relatively deep defect (77% of the pipe wall) in grade X100 line pipe. A review of the source reference [22] for the test shows that the defect is a machined slit and it is arguable whether existing assessment methods are suitable for this type of defect. For completeness INDEX 299 has been included in the database but excluded from the sensitivity studies. For the study described in this report only the test results satisfying the criteria described in section 2 were used.

2.7 University of Waterloo Tests

A series of 40 burst tests on pipe with real defects was conducted by the University of Waterloo and reported in [23]. All of the burst tests were on pipes removed from service due to the presence of natural corrosion defects. The material properties of the pipes were measured, the defects mapped and the pipe sections were subsequently burst to determine the remaining strength of the corroded pipe sections. Pipe materials tested ranged from grade X46 to grade X56. Only the maximum defect depths and lengths are reported. The maximum depth of corrosion was in the range 20% to 50% of the pipe wall. The deepest defect was 72% of the pipe wall. A comparison of actual failure pressures and those predicted using ASME B31G and the RSTRENG methods was made and documented in [23]. It was concluded that both ASME B31G and RSTRENG were conservative. It was also concluded that RSTRENG predictions were less conservative and more consistent than ASME B31G predictions.

2.8 Other Published Tests

A small number of test results undertaken on vessels with both real and machined defects in grade X46 and X60 pipe were obtained from published sources [24], [25]. The tests meeting the criteria described in section 2 have been included in the integrated database.

2.9 Overview of Test Database

The integrated test database is given in Appendix A and includes the results from 313 tests. For ease of reference, each test has been given a unique index number and key data regarding the pipe geometry, defect geometry (in normalized format) and material grade has been recorded. The failure mode, either a leak (L) or rupture (R), has also been recorded. Where this information was not been available from the source reference then 'N/A' has been recorded in the integrated test database.

Figures 1 and 2 show pie charts of the material grades and pipe (*D/t*) ratios covered in the database. There is a fairly even split (between 13% to 18%) in material grades ranging from grade B to X100. There are 8 vessel tests on grade X80 pipe, representing 3% of the database. Pipe (*D/t*) ratios are predominantly in the range 40 to 80, representing 77% of the database. There are 59 ring expansion tests, representing just less than 19% of the database (INDEX 135 to 149, INDEX 248 to 254 and INDEX 263 to 299). These tests are color coded blue in Appendix A.

Out of the 313 test results the following is concluded from the integrated test database;

1. 79 are recorded as leaks and 161 as ruptures. The mode of failure for the other 73 remaining tests has not been recorded.

2. 133 tests were undertaken on line pipe with real corrosion defects and 180 tests were undertaken on line pipe with machined defects.

3 DEVELOPMENT OF EQUATION BASED ASSESSMENT METHODS

The assessment methods reviewed against the test database described in this report are the ASME B31G, the Modified ASME B31G, RSTRENG, LPC-1, SHELL92 and the PCORRC methods.

The ASME B31G assessment method was developed using a modified version of a toughness independent ductile failure criterion developed for pressurized pipes containing axially orientated surface breaking defects. The criterion was developed by Battelle Columbus Laboratories under sponsorship of the Pipeline Research Committee of the American Gas Association Project NG-18 [26]. The basic form of the equation can be expressed as follows:

$$\sigma = \bar{\sigma}\left[\frac{1-\left(\frac{d}{t}\right)}{1-\frac{1}{M}\left(\frac{d}{t}\right)}\right] \qquad (1)$$

The flow stress, $\bar{\sigma}$, is a concept suggested by Hahn et al [27] to account for work hardening of a material in a single parameter. Line pipe steels exhibit work hardening and Project NG-18 used the concept of the flow stress in both the toughness dependent and toughness independent forms of the failure criterion that was developed. The flow stress is not a precisely defined parameter; its magnitude lies somewhere between the yield strength and the ultimate tensile strength. Various magnitudes of the flow stress have been proposed and embodied into the assessment methods described in this report; these are summarized in Table 1.

The Folias factor, M, also referred to as a bulging correction factor, is a means for accounting the stress amplification or concentration at an axially orientated defect due to outward radial deflection in a pressurized pipe. It is a function of the defect length, *L*, the pipe diameter, *D* and wall thickness, t. After a number of iterations, Folias proposed Equation 2 for M, [29], [30].

$$M = \sqrt{1+0.52\left(\frac{L}{\sqrt{Dt}}\right)^2} \qquad (2)$$

This version of the factor was used to develop the Shannon Battelle equation [28] for assessing the failure behavior of defects in line pipe. Various forms of the Folias factor have been proposed for the assessment methods described in this report; these are summarized in Table 1. Figure 3 shows the variation of the Folias factor against the normalized defect length (L/√Dt) for the different assessment methods considered in this report.

As ASME B31G began to be used by the pipeline industry, it became apparent that it could be over conservative. Work was undertaken to reduce the perceived conservatisms that were inherent in the ASME B31G method. The main modifications were a change to the Folias factor and flow stress. Along with the change in flow stress, a modified parameter to model the shape of the defect was proposed. This led to the development of the Modified ASME B31G method and the RSTRENG method, where account could be taken of complex corrosion shapes. The main modifications to the original ASME B31G method were to change the definition of the flow stress.

In the 1990's the motivation began to develop alternative assessment methods such as LPC, PCORRC and SHELL92. A comparison of the assessment methods is discussed briefly below.

4 COMPARISON OF METHODS

The failure equations developed for each assessment method are given in Appendix B and the main differences are summarized in Table 1.

The ASME B31G method idealizes the corrosion defect with a parabolic profile and the area of metal loss assumed to be (2/3)*dL*. The assumption of a parabolic shape is intended to be a reasonable representation of the fact that a contiguous area of corrosion has an irregular profile, but it is entirely empirical. For long defects, the assumption of a parabolic shape is inappropriate. In the case of ASME B31G, a cut-off is introduced when the normalized length, $L/\sqrt{Dt}$ is greater than 4.479, when the defect shape is assumed to have a rectangular profile, see Appendix B.

The Modified ASME B31G method uses revised definitions of the flow stress and the Folias factor. The parabolic area assumption for the defect is replaced by an arbitrary shape correction factor, taken to equal 0.85, i.e. the method assumes that the area of metal loss is equal to 0.85*dL*. Changing the shape factor from 0.67 to 0.85 has been taken to mean that the arbitrary shape is applicable to longer (although not infinitely long) areas of corrosion; hence the limit on defect length given in the ASME B31G method has been removed from the Modified ASME B31G method. Ring expansion testing provides a good way of investigating the failure behavior of infinitely long axial corrosion defects. However, it is to be noted that the 0.85 shape factor used in the Modified ASME B31G method is considered inappropriate for assessing very long areas of corrosion.

For comparison purposes, however, the test results using ring expansion specimens with machined defects (see section 2.9) have been assessed strictly according to each method described in this report. It is reiterated that the comparison is to be treated with caution for the reason given above. In some cases non conservative failure predictions can be obtained, particularly for tests with machined defects which are flat bottomed. A distinction between test results on machined and real corrosion defects is discussed in section 5 below.

Operators have tended to use the Modified ASME B31G method as a means to rank anomalies detected by in-line inspection where only an overall length and maximum depth are given.

The RSTRENG method was developed to allow an iterative assessment to be undertaken based on a river bottom profile of the corroded area. RSTRENG provides a more accurate prediction of the failure pressure in comparison to screening level assessment methods such as ASME B31G and Modified ASME B31G. It should be noted that in developing the RSTRENG method, the researchers concluded that the method was not good in predicting leaks as it was for predicting ruptures [4]. This was attributed to the fact that Equation (1) did not work well for deep defects and this is why the assessment methods were limited to assessing defects up to 80% of the pipe wall.

The Line Pipe Corrosion (LPC) method was developed for assessing single and interacting defects in pipelines subjected to internal pressure loading. The method was developed using tests on modern, relatively high toughness line pipe steels. This is a notable difference to ASME B31G, Modified ASME B31G and RSTRENG methods which were validated using a test database that was dominated by vintage steels of relatively lower strength grades and toughness. The LPC method assumes a rectangular defect profile and uses a Folias factor that was calibrated from test results and non-linear finite element analyses. For the LPC method, the flow stress is defined to equal the ultimate tensile strength of the material. The LPC method also allows higher level assessments to be undertaken for assessing complex shaped defects. This method is described in [6], [15], [16].

PCORRC uses a failure criterion that is different in form to the NG-18 Equation. The method was developed using the results of a finite element study and subsequently validated using burst test results. The defect profile is again assumed to be rectangular and as with the LPC method, the flow stress is defined to equal the ultimate tensile strength of the material. The failure locus described by PCORRC is very similar to that of LPC and hence failure predictions are very similar.

The SHELL92 method uses the same Folias factor as that for the ASME B31G but assumes a rectangular defect profile, thus removing the step jump in predictions between short and long defects. The flow stress is also modified to equal $0.9\sigma_{SMTS}$. This method has been used by Shell for a number of years and has been reported to have provided an improvement over the ASME B31G method [10].

5 SENSITIVITY STUDIES

The results of the burst tests given in Appendix A were compared with each of the assessment methods considered in this report. Strictly according to these methods, the **nominal** pipe diameter and wall thickness and **specified minimum material properties** should be used to determine failure pressures. However, in order to make a comparison with burst test results, **actual** diameter, wall thickness and material properties were used; this is consistent with the approach taken by the developers of RSTRENG [11][3]. The results of these assessments are given in Appendix C. The predicted failure pressure, P_f[4], is compared to the recorded burst failure pressure, P_A, and the results are presented in a non-dimensional form. Values of the ratio (P_A/P_f) less than unity indicate that the failure prediction is non-conservative.

[3] In practice, knowledge of actual material properties is not generally known. Remaining strength assessments of corroded pipelines are conducted using nominal pipe dimensions and specified minimum material properties.

[4] It is important to note that the objective of the study conducted in this report is to compare predicted failure pressures using the different assessment methods considered against the reported burst test pressure. Additional safety factors have NOT been included in the calculated failure predictions.

A number of studies were undertaken by modifying the definition of the flow stress, $\bar{\sigma}$, to investigate the sensitivity to the ratio (P_A/P_f). The sensitivity studies are labeled as Cases 1 to 6, as described below.

Case 1	Flow stress based on the recommendation given by each assessment method, but using actual material properties.
Case 2	Flow stress based on the recommendation given by each assessment method, using specified minimum material properties.
Case 3	Flow stress modified to equal the actual tensile strength of the pipe.
Case 4	Flow stress modified to equal the specified minimum tensile strength of the pipe.
Case 5	Flow stress modified to equal the mean of the actual yield strength and ultimate tensile strength.
Case 6	Flow stress modified to equal the mean of the specified minimum yield strength and ultimate tensile strength.

The studies concentrated on investigating the sensitivity of the ratio (P_A/P_f) to defect depth. It is to be noted that the profiles for the real corrosion defects were not available for all the test results collated in the integrated test database. Only maximum defect depths and lengths were recorded in some cases. Consequently RSTRENG calculations could not be performed. Some authors did, however, present RSTRENG calculations in the source documents and where appropriate these were used as the basis of the sensitivity studies presented in this report.

5.1 Case 1 Assessments

Figures 4 to 9 show plots of the ratio (P_A/P_f) versus normalized defect depth (*d/t*) for each valid test point using the ASME B31G, Modified ASME B31G, RSTRENG, LPC-1, SHELL92 and PCORRC assessment methods.

Tabulated values of the assessment points are given in Appendix C and Table 2 summarizes the statistical analysis of the burst tests. The statistical analysis was performed with and without the suspect grade B test results conducted by Battelle (INDEX 6 to 25), see section 2.1. Figures 10 to 15 show the comparison of actual and predicted failure pressures split between tests on machined and real defects and between leaks and ruptures. These latter comparisons have been limited to the ASME B31G, Modified ASME B31G and RSTRENG assessment methods.

Briefly the assessments show the following:

1. The ASME B31G method is non-conservative for 25 test points. 5 points are for tests undertaken on vintage grade B pipe with real corrosion defects by Battelle (INDEX 6, 9, 11, 12 and 20). These are relatively deep defects ranging from 60% to 72% of the pipe wall. However, as discussed in section

2.1, these early tests need to be treated with caution and were discounted from the sensitivity studies. ASME B31G is non-conservative for another 12 test points (INDEX 101, 113, 117, 152, 153, 154, 156, 158, 177, 178, 185 and 186). These are all tests with machined defects of depths ranging from 40% to over 78% of the pipe wall in grades X46 to X65. The remaining 8 test points, where ASME B31G in non-conservative, are for grades X80 and X100 material. These are tests with machined defects (INDEX 255, 300, 302, 275, 276, 277, 292, and 299) from which the last 5 points are confirmed to be ring expansion tests on grade X100 material. For the test on grade X80 line pipe the defect is over 77% of the wall deep. For the tests on grade X100 line pipe, the defect depth ranges from 10% to nearly 78% of the wall. INDEX 299 is a relatively deep defect (77% of the pipe wall) with a machined slit is discounted (see section 2.1).

2. The Modified ASME B31G method is non-conservative for 73 test points; these points are highlighted in Appendix C. 6 of these points are for tests undertaken on vintage grade B pipe with real corrosion defects by Battelle (INDEX 6, 9, 11, 12, 16 and 20). As discussed in section 2.1 these test points are suspect and discounted. A further 1 test point is on vintage grade B pipe with a real corrosion defect (INDEX 48). 4 points are for grades X52 and X65 line pipes with real corrosion defects (INDEX 1, 2, 84, and 90). 38 points are for machined defects on grade X46 to X65 material with the majority of defect depths ranging from 50% to over 77% of the pipe wall. Of these points, 6 are confirmed to be rings expansion tests (INDEX 137, 139 to 142, and 144). Failure pressures are predicted to be non-conservative for two X80 test points (INDEX 255 and 259) with defect depths of 77% and 78% of the pipe wall when the Modified ASME B31G method is used. Similarly 22 test points are non-conservative for machined defects in grade X100 line pipe (INDEX 266 to 271, 275 to 277, 281, 282, 285, 286, 292, 293, and 297 to 303) from which INDEX 299 is discounted (see section 2.1). Defect depths range from 10% to 77% of the wall. Some of these non-conservative test points (17) are obtained from ring expansion tests. As discussed in section 4, these non-conservative predictions need to be treated with caution when the Modified ASME B31G method is used.

3. Figure 6 shows that there is a marked reduction in the scatter in the predicted failure pressures when the RSTRENG method is used. RSTRENG is non-conservative for 37 test points. A large proportion of these tests (15 tests) are on vintage grade B material pipe with real corrosion defects conducted by Battelle. As discussed in section 2.1, the results of these tests should be treated with caution and were discounted from the sensitivity study. There are also 10 tests on grade A25 to X65 line pipe with real corrosion defects where non-conservative predictions are obtained using RSTRENG (INDEX 1, 2, 32, 34, 48, 75, 86, 90, 228, and 234). The defect depths in these cases range from 34% to nearly 80% of the pipe wall. There are another 3 tests on grade X46 line pipe with machined defects (INDEX 101, 104, and 105). 1 further point is for a machined defect on grade X65 line pipe with depth .48% of the pipe wall (INDEX 162). The other non-conservative predictions are for 8 tests on grade X100 pipe (INDEX 275 to 277, 292, 299, and 301 to 303), from which the first 5 points are confirmed to be ring expansion tests. INDEX 299 is

shown to be consistently non-conservative. This test is discounted (see section 2.1). It is noted that in most cases the ratio of actual failure pressure to predicted failure pressure is just less than unity and therefore the failure predictions are only marginally non-conservative. Depths for these defects range from 10% to 77% of the pipe wall. Also to note is that RSTRENG is conservative for all the tests on grade X80 pipe.

4. The LPC-1 method is non-conservative for the vast majority of the early tests on vintage grade B and X52 line pipe (INDEX 6 to 24). A similar trend is also observed for PCORRC. These early tests recorded in the PRCI database were undertaken on pipe with relatively lower toughness than that used to calibrate the LPC-1 and PCORRC assessment methods and consequently this result is to be expected. A small number of tests (16) with real corrosion defects (INDEX 1 to 3, 5, 32, 42, 60, 90, 91, 218, 219, 228, 230, 245, 304, and 306) are predicted to be non- conservative using LPC-1 with depths ranging from 26% to just above 80% of the pipe wall. There are also 35 tests with machined defects that are predicted to be marginally non-conservative using LPC-1. From these points, 7 points are confirmed to be ring expansion tests. 12 tests on grade X80 and X100 line pipe are also predicted to be non-conservative using LPC-1 from which 1 point on grade X100 material is confirmed to be ring expansion test (INDEX 299) and is discounted (see section 2.1). However, for the majority of these results the ratio of actual to predicted failure pressure is just below unity.

5. The SHELL92 method is non-conservative for 16 test points. 9 of these points are for the early grade B tests which are known to be suspect and were discounted (see section 2.1). The remaining test points that give non-conservative predictions are INDEX numbers 2, 105, 162, 253, 254, 299 and 304 from which INDEX 299 is discounted (see section 2.1). For all these tests the ratio of actual to predicted failure pressures is just below unity and hence only marginally non-conservative.

6. A statistical analysis of the integrated test database (Table 2) shows that the mean of the ratio of actual to predicted failure pressure (P_A/P_f) is greater than unity for all the assessment methods described in this report. As expected the least scatter is obtained using the RSTRENG method. The most scatter is obtained using the SHELL92 method, although it is noted that the scatter is only marginally greater than the ASME B31G method. However, the main conclusion is that the SHELL92 method predicts conservative failure pressures for line pipe with relatively deep defects when compared to the ASME B31G and Modified ASME B31G methods. This conclusion is valid for strength grades up to X100. It is also concluded that removing the suspect grade B tests conducted by Battelle does not significantly alter the results of the statistical analyses.

7. Figures 50 to 55 show a breakdown of test points split according to material grade for which non-conservative failure pressures are predicted using the assessment methods described in this report. The Case 1 assessments show that from the 313 tests, excluding 20 tests conducted on grade B pipe, and the test on a machined slit (INDEX 299), the number of non-conservative predictions obtained using each assessment method are as follows:

- ASME B31G – 19 tests (7% of test database)
- Modified ASME B31G – 66 tests (21% of test database)[5]
- RSTRENG – 21 tests (7% of test database)
- LPC-1 – 62 tests (20% of test database)
- SHELL92 – 6 tests (2% of test database)
- PCORRC – 44 tests (15% of test database)

8. Figures 10 to 12 show the comparison of actual and predicted failure pressures split between tests on machined and real defects. The general conclusion is that failure predictions tend to be non-conservative for tests on pipe with machined defects, rather than pipe with real corrosion defects. For machined defects, particularly those that are rectangular flat bottomed patches and use of ASME B31G and Modified ASME B31G to predict failure pressures may be inappropriate because the area of metal loss can be underestimated.

5.2 Case 2 Assessments

Figures 16 to 21 show plots of the ratio (P_A/P_f) versus normalized defect depth (*d/t*) for each valid test point for Case 2 using the ASME B31G, Modified ASME B31G, RSTRENG, LPC-1, SHELL92 and PCORRC assessment methods. Tabulated values of the assessment points are given in Appendix D. Table 3 summarizes the statistical analysis of the burst tests. The statistical analysis was performed with and without the suspect grade B test results conducted by Battelle (INDEX 6 to 25), see section 2.1. Figures 22 to 27 shows the comparison of actual and predicted failure pressures split between tests on machined and real defects and between leaks and ruptures. These latter comparisons have been limited to the ASME B31G, Modified ASME B31G and RSTRENG methods.

Briefly, the assessments show the following:

1. The trend in the results is similar to Case 1 but use of specified minimum properties introduces added conservatism to the assessments. Thus only 15 test points are now predicted to be non-conservative using the ASME B31G method. 2 of these points are early tests on grade B material with real corrosion defects of depths above 70% of the pipe wall (INDEX 9 and 11); these tests should be treated with caution and are discounted from the sensitivity study (see section 2.1). The remaining tests where the ASME B31G method is non-conservative are for machined defects in line pipe of grades X65 to X100 (INDEX 152, 153, 156, 158, 164, 165, 166, 177, 190, 255, 299,

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[5] As discussed in Section 4 the Modified ASME B31G method has been used to predict failure pressure from ring expansion tests. If the ring expansion tests are discounted then the number of non-conservative failure predictions reduces to 39 tests (12% of the test database)

300 and 302) from which the last 3 points are confirmed to be ring expansion tests. The defect depths for these tests are above 63% of the pipe wall for grades X65 to X80. For the tests on X100 pipe, non-conservative failure predictions using the ASME B31G method are obtained for defect depths above 50% of the pipe wall. As discussed in section 2.1, INDEX 299 is a machined slit in grade X100 line pipe with a relatively deep defect (77% of the pipe wall) and is discounted.

2. The Modified ASME B31G method is now non-conservative for 26 test points, highlighted in Appendix D. Of these points, 2 are early tests on grade B material with real corrosion defects of depths above 70% of the pipe wall (INDEX 9 and 11). As discussed in section 2.1, the results of these tests should be treated with caution and are discounted. For grades up to X80, non-conservative failure predictions are obtained for: (a) 14 machined defects on vessels with depths above 70% of the wall, (b) 4 ring expansion tests with depths range from 50% to 69% of the pipe wall. For tests on grade X100 material, non-conservative predictions are obtained for 6 defects on ring expansion tests (INDEX 277, 92, 299, and 301 to 303) with depths above 50% of the wall from which INDEX 299 is discounted (see section 2.1). The level of non- conservatism increases as the defect depth increases. As discussed in section 4, these non-conservative predictions from ring expansion tests (INDEX 251 to 254, 277, 292, and 301 to 303) need to be treated with caution when the Modified ASME B31G method is used.

3. The reduction in the scatter in failure predictions using the RSTRENG method is again clear from Figure 18. In this case only 9 test points are predicted to be non-conservative. 5 of these points (INDEX 6, 9, 11, 12 and 20) are on vintage grade B pipe and are discounted (see section 2.1). The remaining 4 tests are INDEX 32, 75, 104 and 299. INDEX 32 is a test on a real defect in grade B pipe. INDEX 75 and 104 are on X52 and X46 pipe. The former is a test with a real corrosion defect and the latter a test with a machined defect. Both tests were in line pipe with defects of depths of approximately 79% of the wall. In both cases the failure was as a leak. As discussed in section 4, the RSTRENG developers had already noted that the assessment method did not work very well for deep defects that failed as a leak. The other test, INDEX 299, is a relatively deep defect (77% of the pipe wall) in grade X100 line pipe and is discounted (see section 2.1).

4. Regarding the LPC-1 and PCORRC methods, the same trends are noted as for the Case 1 assessments described above. It is also noted that both these methods are good at predicting the failure pressure of higher toughness pipe. However, both LPC-1 and PCORRC are non-conservative when assessing relatively deep machined defects in strength grades of X80 and X100.

5. The SHELL92 method is non-conservative for only 5 test points (INDEX 9, 11, 13, 16 and 20). These are again on vintage grade B pipe and are discounted (see section 2.1).

6. A statistical analysis of the integrated test database (Table 3) shows that the mean of the ratio of actual to predicted failure pressure (P_A/P_f) is greater than unity for all the assessment methods described in this report. As expected the

mean of the ratio (P_A/P_f) is greater than that for the Case 1 assessments because of the added conservatism of using specified minimum material properties in the assessments. As with the Case 1 assessments, the least scatter is obtained using the RSTRENG method and the most scatter is obtained using the SHELL92 method. The Case 2 assessments conclude again that the SHELL92 method predicts conservative failure pressures for line pipe with relatively deep defects when compared to the ASME B31G and Modified ASME B31G methods. This conclusion is valid for strength grades up to X100. It is also concluded that removing the suspect grade B tests conducted by Battelle does not significantly alter the results of the statistical analyses.

7. Figures 50 to 55 show a breakdown of test points split according to material grade for which non-conservative failure pressures are predicted using the assessment methods described in this report. The Case 2 assessments show that from 313 tests, excluding 20 tests conducted on grade B pipe, and the test on a machined slit (INDEX 299), the number of non-conservative predictions obtained using each assessment method are as follows:

    - ASME B31G – 12 tests (4% of test database)
    - Modified ASME B31G – 23 tests (7% of test database)[6]
    - RSTRENG – 3 tests (1% of test database)
    - LPC-1 – 18 tests (6% of test database)
    - SHELL92 – 0 tests (0% of test database)
    - PCORRC – 10 tests (3% of test database)

8. Figures 22 to 24 show the comparison of actual and predicted failure pressures split between tests on machined and real defects. The same conclusion is drawn as that obtained for the Case 1 assessments, i.e. failure predictions tend to be non-conservative for tests on pipe with machined defects, rather than pipe with real corrosion defects. As already noted above, for machined defects, particularly those that are rectangular flat bottomed patches and use of ASME B31G to predict failure pressures may be inappropriate because the area of metal loss can be underestimated.

[6] As discussed in Section 4 the Modified ASME B31G method has been used to predict failure pressure from ring expansion tests. If the ring expansion tests are discounted then the number of non-conservative failure predictions reduces to 14 tests (5% of the test database)

5.3 Case 3 Assessments

Figures 28 to 30 show plots of the ratio (P_A/P_f) versus normalized defect depth (*d/t*) for each valid test point for Case 3 using the ASME B31G, Modified ASME B31G and RSTRENG methods. These results shows that there is no merit in modifying the flow stress, $\bar{\sigma}$, to equal the actual tensile strength of the pipe.

5.4 Case 4 Assessments

Figures 31 to 33 show plots of the ratio (P_A/P_f) versus normalized defect depth (*d/t*) for each valid test point for Case 3 using the ASME B31G, Modified ASME B31G and RSTRENG methods. As with the Case 3 assessments, the same conclusion is drawn that there is no merit in modifying the flow stress, $\bar{\sigma}$, to equal the specified minimum tensile strength of the pipe.

5.5 Case 5 Assessments

Figures 34 to 39 show plots of the ratio (P_A/P_f) versus normalized defect depth (*d/t*) for each valid test point for Case 5 using the ASME B31G, Modified ASME B31G, RSTRENG, LPC-1, SHELL92 and PCORRC assessment methods. These results show that failure predictions using ASME B31G, Modified ASME B31G and RSTRENG are not particularly sensitive to the modifying the flow stress, $\bar{\sigma}$, to equal the mean of the actual yield strength and ultimate tensile strength. For higher strength grades (X80 and to a lesser extent X100), use of the LPC-1 and PCORRC assessment methods shows that there is a trend for the predictions to be more accurate. A similar trend is also observed for the SHELL92 method.

5.6 Case 6 Assessments

Figures 40 to 45 show plots of the ratio (P_A/P_f) versus normalized defect depth (*d/t*) for each valid test point for Case 6 using the ASME B31G, Modified ASME B31G, RSTRENG, LPC-1, SHELL92 and PCORRC assessment methods. Tabulated values of the assessment points are given in Appendix E. Table 3 summarizes the statistical analysis of the burst tests. The statistical analysis was performed with and without the suspect grade B test results conducted by Battelle (INDEX 6 to 25), see section 2.1.

Briefly, the results show the following;

1. For the ASME B31G method, there is a small improvement in predictions, but the overall trends are similar to Case 2. Non-conservative predictions are obtained for 21 test points, as highlighted in Appendix E. 6 of these points (INDEX 6, 9, 11, 12, 16 and 20) are on vintage grade B pipe and are discounted (see section 2.1). The points to note are a cluster of tests (8) on; grade X65 pipe, with machined defect depths of approximately 70% of the pipe wall (INDEX 152, 153, 156, 158, 164 to 166 and 190). 3 points on grade X60 pipe for machined defects with depths over 50% of the pipe wall are marginally non-conservative (INDEX 113, 117, and 185). There is another 1 test on grade X80 pipe with a machined defect of 77% of the pipe wall (INDEX 255). The remaining 3 non-conservative points are on grade X100 pipe with

machined defects of over 50% of the pipe wall (INDEX 299, 300 and 302) from which the first point is known to be ring expansion test with an approximate depth of 77% of the pipe wall and is discounted (see section 2.1).

2. For the Modified ASME B31G Method, apart from the tests on vintage grade B pipe, non-conservative predictions are obtained for 13 tests on pipes of grade X52, to X100 pipe with defect depths above 50% of the wall from which INDEX 299 in grade X100 line pipe is discounted (see section 2.1). Apart from INDEX 299, 3 of the non-conservative test points are obtained from ring expansion tests. As discussed in section 4, these non-conservative predictions (INDEX 252 to 254) need to be treated with caution when the Modified ASME B31G method is used.

3. For the RSTRENG Method, there is again a small improvement in predictions compared to Case 2. Apart from the tests on grade B pipe, 3 non-conservative predictions are obtained (INDEX 32, 104 and 299). INDEX 32 is a test on a real defect in grade B pipe with 64% depth of the pipe wall. INDEX 104 is a test on grade X46 pipe with a 79% deep machined defect. It is however, noted that the failure prediction is only marginally non-conservative. The other test, INDEX 299 is a relatively deep defect (77% of the pipe wall). As discussed above the assessments for INDEX 299 are consistently shown to be non-conservative irrespective of the method used. As discussed in section 2.1, this test is discounted.

4. The LPC-1 and PCORRC methods again provide similar results. A point of note is that apart from the vintage tests on grade B pipe, the LPC-1 method is non-conservative for 3 tests (INDEX 164, 168, and 299). INDEX 164 and 168 are tests on grade X65 pipe with a low pipe *D/t* ratio (8.6). The majority of the test database used to validate assessment methods are undertaken on line pipe with *D/t* ratios in the range 40 to 80 (see Figure 2). Apart from the vintage tests on grade B pipes, PCORRC is non-conservative for only one test (INDEX 299). Both LPC-1 and PCORRC are non-conservative for INDEX 299; the reason for this is explained in section 2.1.

5. The SHELL92 method is non-conservative for only 3 test points. Two of these points are on vintage grade B line pipe, which were discounted, and the remaining test (INDEX 299) is on a grade X100 pipe with a deep machined slit. As explained in section 2.1, this test is discounted.

6. A statistical analysis of the integrated test database (Table 4) shows that the mean of the ratio of actual to predicted failure pressure (P_A/P_f) is greater than unity for all the assessment methods described in this report. The mean value of the ratio (P_A/P_f) is greater than that obtained for Case 1 and 2 indicating that the Case 6 assessments are more conservative. As has already been concluded for Case 1 and 2, the least scatter is obtained using the RSTRENG method and the most scatter is obtained using the SHELL92 and ASME B31G methods. The Case 6 assessments conclude again that the SHELL92, LPC-1 and PCORRC methods predict conservative failure pressures for line pipe with relatively deep defects when compared to the ASME B31G and Modified ASME B31G methods. This conclusion is valid for strength grades up to X100.

7. Figures 50 to 55 show a breakdown of test points split according to material grade for which non-conservative failure pressures are predicted using the assessment methods described in this report. The Case 2 assessments show that from 313 tests, excluding 20 tests conducted on grade B pipe, and the test on a machined slit (INDEX 299), the number of non-conservative predictions obtained using each assessment method are as follows:

    - ASME B31G – 14 tests (4% of test database)
    - Modified ASME B31G – 12 tests (4% of test database)[7]
    - RSTRENG – 2 tests (<1% of test database)
    - LPC-1 – 2 tests (<1% of test database)
    - SHELL92 – 0 tests (0% of test database)
    - PCORRC – 0 tests (0% of test database)

8. Figures 46 to 48 show the comparison of actual and predicted failure pressures split between tests on machined defects on vessels, machined defects on ring expansion specimens, and real defects. For ASME B31G and the Modified ASME B31G, the same conclusion is drawn as that obtained for the Case 1 assessments, i.e. failure predictions tend to be non-conservative for tests on pipe with machined defects, rather than pipe with real corrosion defects. However, it is noted that a marked improvement in conservatism is obtained when the RSTRENG, LPC-1, SHELL 92, PCORRC assessment methods are used.

6 RESPONSE TO PIPELINE IN-LINE INSPECTIONS

Metal loss defects can generally be detected with magnetic flux leakage (MFL) tools. Assessment methods described in Appendix B require knowledge of the defect to determine the failure pressure of the pipeline. Characterization of the defect in terms of its depth, length and shape is therefore a critical input to the integrity management of pipelines.

The characterization accuracy of MFL tools is generally quite variable. Most vendors report sufficiently high accuracy on depth and length predictions of individual defects to make accurate serviceability calculations. However the confidence level of the measurement can mean a significant number of defects will not be properly characterized. The technical specifications, including location, orientation and sizing capabilities of inspection tools are generally given by ILI vendors in their literature.

[7] As discussed in Section 4 the Modified ASME B31G method has been used to predict failure pressure from ring expansion tests. If the ring expansion tests are discounted then the number of non-conservative failure predictions reduces to 9 tests (3% of the test database)

Tables 5 and 6 give the stated sizing capabilities from two tool vendors. This sizing capability has been developed using a combination of analytical and experimental validation using real and machined defects. Typically for metal loss defects, the size of defects is usually quoted at a confidence interval of 80%. However, some vendors now offer advanced or ultra high resolution tools where sizing errors are lower and quoted to a higher confidence interval of 90%. Clearly use of higher resolution tools to conduct ILI will increase the ability to more accurately size defects. With the high resolution MFL tools, it is possible to determine the profile of a clustered defect, and thereby determine a 'river bottom profile'. It would then be possible to use a method such as RSTRENG to calculate the failure pressure of the corroded pipeline.

When deterministic assessments are undertaken using ASME B31G, RSTRENG or similar, inspection or sizing errors are normally added to the reported defect dimensions in order to determine a conservative failure pressure of the damaged pipeline. For the assessments described in this report, the dimensions of the defects were not obtained from ILI. The defects were well characterized and hence sizing errors were not included.

Following an ILI, a prioritized schedule is established by the operator depending on the severity of the defects that are detected. For example, where metal loss defects are detected, ASME B31.8S [31] requires an immediate response for those defects that might be expected to cause immediate or near-term leaks or ruptures. ASME B31.8S specifically states that this includes corroded areas that have a predicted failure pressure (P_f) less than 1.1 times the maximum allowable operating pressure (MAOP) as determined by ASME B31G or equivalent. Defects that give a predicted failure pressure greater than 1.1 times the MAOP have to be examined and evaluated according to a schedule identified in Figure 4 of ASME B31.8S; for convenience this is reproduced in Figure 49 of this report.

7 CONFIDENCE LEVELS OF PREDICTED FAILURE PRESSURES

7.1 Introduction

PHMSA requested a study be undertaken to investigate the confidence level of the predicted failure pressure (P_f), using the ASME B31G, Modified ASME B31G, RSTRENG and SHELL92 methods, to the actual failure pressure (P_A). Specifically the question asked was *'what is the likelihood of predicting a non-conservative failure pressure by more than say 5%, 10%, 15% and 20% of the actual failure pressure?*[8]

[8] It is reiterated here again that the objective of the study conducted in this report is to compare predicted failure pressures using the different assessment methods considered against the reported burst test pressure. Additional safety factors have NOT been included in the calculated failure predictions.

The approach taken to address this question was to examine the relationship of the ratio (P_A/P_f), obtained using each of the respective assessment methods above, for a range of different datasets. As already discussed, when the ratio (P_A/P_f) was calculated to be less than unity then the prediction was non-conservative. Conversely when the ratio was calculated to be greater than unity then the prediction was conservative. PHMSA were interested in determining the confidence levels of failure pressures that were predicted to be non-conservative.

Where there is sufficient test data available, the relationship between P_A and P_f for a selected group of results, for example based on material grade, defect depth, etc. can be described by a probability density function (PDF). This in turn allows a confidence level to be determined of a non-conservative failure prediction when compared to the actual burst failure pressure by a given amount. Consider, for example Figure 56 which shows a typical graph of the ratio (P_A/P_f) versus the PDF. The actual data was fitted with a normal and log-normal distribution. Examination of the PDF confirmed that in general a lognormal distribution provided the best fit to the data. The area under the distribution between two points on the x-axis describes the probability of the ratio (P_A/P_f) lying between two selected values. Thus, for the question, 'what is the likelihood of predicting a non-conservative failure pressure by more than 5%', the area under the PDF between (P_A/P_f) = -∞ and (P_A/P_f) = 0.95 is calculated. This area provides a measure of the likelihood of a non-conservative failure prediction being made for any given dataset that is chosen.

PHMSA requested that the approach described above be used to determine confidence levels with test results split by material grade and defect depth. The main focus of this work was to use the Case 1 results, i.e. using actual material properties. However, as previously discussed, the Case 2 assessments, using specified minimum material properties, give more conservative failure predictions than Case 1. Therefore, some of the analyses were repeated to investigate the sensitivity to material properties.

A variety of different subsets of the burst test data split according to material grade, defect depth, real defects and machined defects, were used to determine confidence levels in the manner described above.

The correlation (R^2 value) between P_A and P_f was used to show the degree of accuracy of the predictions of the different methods. The correlation has a value ranging from plus or minus unity. Where the value is close to zero, there is no relationship between P_A and P_f. When the value is close unity there is a strong relationship between P_A and P_f.

The sections below describe the outcome of the assessments for each dataset investigated. In each case results are presented which show the likelihood of **non-conservative** failure pressures being predicted by greater than 5%, 10%, 15%, and 20% using the ASME B31G, Modified ASME B31G, SHELL92 and RSTRENG methods. Additional assessments were also undertaken to determine the likelihood of the failure prediction being the same as the actual burst pressure or that the prediction is conservative; this is labeled as 'none' in the results tables that follow.

7.2 Real versus Machined Defects

For this study, datasets were created to investigate the sensitivity of the assessment methods to real versus machined defects. The results of the assessment are summarized in Table 7. The following was concluded from this analysis:

- The correlations show that failure predictions for pipe with machined defects are more accurate than for pipe with real defects. The most marked differences are noted when predictions are made using the ASME B31G method. The most accurate method is RSTRENG.
- There is a greater likelihood of predicting a conservative failure pressure in a pipe with a real corrosion defect rather than a machined defect.
- RSTRENG is the most accurate method when specified minimum material properties are used. For example the likelihood of predicting a conservative failure pressure using RSTRENG is 99% for real defects and 98.1% for machined defects. Using RSTRENG, the likelihood of predicting a non-conservative failure pressure by 5% or more is less than 0.3%; this value increases marginally to 0.7% when assessing machined defects.
- The Modified ASME B31G is marginally better at predicting failure pressures than the ASME B31G method for real defects. The converse is true for assessing machined defects.

7.3 Material Grade

For this study, datasets were created to investigate the sensitivity of the assessment methods to the material grade. The results of the assessment are summarized in Table 8. The following is concluded from this analysis:

- The likelihood of ASME B31G and Modified ASME B31G being non-conservative by greater than 10% ranges from 4.5% to 14.1% for material strength grades up to X65. For grades X80 and X100, the likelihood of ASME B31G and Modified ASME B31G being non-conservative by greater than 10% rises to a range from 14.3% to 33.4%.
- The SHELL92 and RSTRENG methods are the most conservative. For example using the SHELL92 method, the likelihood of a non-conservative prediction by 5% or greater is less than 4%. Using RSTRENG with specified minimum material properties, the likelihood of a non-conservative prediction by 5% or greater is less than 1%.

7.4 Defect Depth to Pipe Wall Thickness (d/t) ratio

For this study, datasets were created to investigate the sensitivity of the assessment methods to the defect depth (d/t ratio). Datasets were constructed for (d/t) ratios; less than 0.4; between 0.4 and 0.6; greater than 0.6 up to 0.8; and less than 0.6. The results of the assessment are summarized in Table 9. The following was concluded from this analysis:

- As defect depth increases there is an increasing likelihood that non-conservative failure pressures are predicted using ASME B31G and Modified

ASME B31G. For example using the Modified ASME B31G methods, the likelihood of a non-conservative prediction greater than 10% rises from 3.1% for a (d/t) ratio less than 0.4 to 16.2% for a (d/t) ratio greater than 0.6.

- This trend is also observed when the SHELL92 and RSTRENG methods are used. However, the likelihood of non-conservative predictions is much lower, for example RSTRENG using specified minimum material properties is predicted to be non-conservative by less than 1% for a (d/t) ratio greater than 5%.

7.5 Defect Depth to Pipe Wall Thickness (d/t) ratio and Material Grade

For this study, datasets were created to investigate the sensitivity of the assessment methods to both the defect depth to pipe wall thickness (d/t) ratio and the pipe material grade. Datasets were constructed for (d/t) ratios; less than and greater than 0.6 for each material grades grouped as A25/B; X42/X46; X52/55/56; X60; X65; and X80/X100. It is to be noted that for some of these datasets, the number of test results is very limited. For example there are only three test points with a (d/t) ratio greater than 0.6 for grade X80/X100 material. Therefore, until more data is available, the results of the assessments have to be treated with caution. For this study, the sensitivity of the results using both the Case 1 and Case 2 assessments was investigated. The results for the Case 1 and Case 2 assessments are summarized in Tables 10 and 11 respectively. The following is concluded from this analysis:

- For (d/t) ratios less than 0.6 the likelihood of both ASME B31G and Modified ASME B31G predicting non-conservative failure pressures increases as the material grade increases. For example the likelihood of ASME B31G predicting a non-conservative failure pressure by 10% or more for a (d/t) ratio of 0.6 or more increases from just over 4% for Grade A25/B material to just less than 14% for grade X65 material using Case 1 results. The same trend is observed when Case 2 results are used, but the likelihood of non-conservative failure pressures being predicted is reduced. A similar trend is observed with the Modified ASME B31G method. For grade X80/X100 material, the likelihood of predicting non-conservative failure pressures is much higher. However, as already discussed there are only a limited number of test results and hence the assessment needs to be treated with caution.

- There is no clearly identified trend that the SHELL92 method is sensitive to the (d/t) ratio up to grade X65. The likelihood of the SHELL92 method predicting non-conservative failure pressures by more than 10% is less than 1%.

- The RSTRENG method, using specified minimum material properties, is the most accurate for predicting failure pressures. In general using RSTRENG, with specified minimum material properties, the likelihood of predicting non-conservative failure pressure by more than 5% is just less than 1% for material strength grades up to X65 and for (d/t) ratios greater than 0.6. For grade X80/X100 material the likelihood of predicting non-conservative failure pressures by more than 5% rises to just over than 18% for (d/t) ratios greater than 0.6. However, as previously discussed, this result is based on only three test points and hence the assessment needs to be treated with caution.

8 SUMMARY AND DISCUSSION

This report has collated a comprehensive database of tests undertaken by researchers over the last forty years. Using valid test results from this database, studies have been undertaken to assess the sensitivity of material properties for a number of different assessment methods used by the pipeline industry.

The results show that for the majority of the test results, conservative failure predictions are obtained using the assessment methods described in this report. However, for a small number of the test results, non-conservative failure predictions were predicted. Where non-conservative failure predictions were obtained, they tended to be for tests conducted on pipe with machined defects rather than on pipe with real corrosion defects. To recognize that in some cases marginally non-conservative failure predictions can be obtained from remaining strength assessments, an appropriate safety factor is used.

Sensitivity studies were conducted using both actual and specified minimum material properties. The number of non-conservative predictions was reduced when specified minimum material properties were used in the assessments. In general actual pipe material properties are not known and hence all of the methods described in this report require use of specified minimum material properties. The following summarizes the trends observed when assessments were undertaken using specified minimum material properties:

ASME B31G

The ASME B31G method predicts non-conservative failure pressures for 12 tests, representing 4% of the database. The majority of these tests were undertaken on vessels constructed from grade X65 pipe. In all these cases, the (d/t) ratio of the defects was in excess of 0.67. It is noted that the non-conservative failure predictions are obtained from tests with machined defects rather than those on tests with real corrosion defects. Typically machined defects consist of a rectangular, flat bottomed patch and use of ASME B31G may be inappropriate because the area of metal loss can be underestimated.

Modified ASME B31G

The Modified ASME B31G method predicts non-conservative failure pressures for 23 tests, representing approximately 7% of the database. These tests were on grade X52, X60, X65, X80 and X100 material. However, 9 of these tests were undertaken using ring expansion specimens. The 0.85 shape correction factor is inappropriate for these cases and it can be argued that these results should be discounted from the tests that are deemed to be non-conservative. For the cases where non-conservative failure pressures were predicted the (d/t) ratio of the defect was greater than 0.72 for grades up to X80. For grade X100 the (d/t) ratio was approximately 0.5.

As described above, non-conservative failure predictions are obtained from tests with machined defects rather than those on tests with real corrosion defects. Once again, machined defects consist of a rectangular, flat bottomed patch and use of Modified ASME B31G may be inappropriate because the area of metal loss can be underestimated.

RSTRENG

The RSTRENG method predicts non-conservative failure pressures for 3 tests, representing approximately 1% of the database. These tests were on grade B, X46 and X52 material. The (d/t) ratio for these tests was greater than 0.64 and in two of the cases it was 0.79. As discussed in section 4, the RSTRENG developers had already noted that the toughness independent criterion, the NG-18 equation (1), did not work very well for deep defects in pipelines that failed as a leak.

SHELL92

The SHELL92 method predicts conservative failure pressures for the complete test database.

LPC-1 and PCORRC

The LPC-1 and PCORRC methods predict 18 and 10 non-conservative failure pressures respectively; the majority of these results are for tests with relatively deep defects.

8.1 Confidence Levels

Studies to investigate confidence levels of the predicted failure pressure, using ASME B31G, Modified ASME B31G, RSTRENG and SHELL92 methods, to the actual failure pressure concluded the following:

- Failure predictions are conservative for pipe with real defects in comparison to pipe with machined defects. The most accurate method is RSTRENG using specified minimum material properties.
- When the sensitivity to material grades is investigated, the RSTRENG and SHELL92 methods are the most accurate. The results show that the likelihood of the ASME B31G and Modified ASME B31G methods being non-conservative tends to increase as the material grade increases.
- There is an increasing likelihood of non-conservative failure pressures being predicted as the defect depth (d/t) ratio increases. This is true of all the assessment methods, however it is more pronounced for the ASME B31G and Modified ASME B31G methods.
- The RSTRENG method using specified minimum material properties is the most accurate, irrespective of the defect depth. The likelihood of the ASME B31G and Modified ASME B31G methods to predict non-conservative failure pressures increases with increasing defect depth and material grade. However, there is only limited test data available for deeper defects in higher strength steels, i.e. grade X65 to X100. Additional test work to increase the database would be beneficial to the studies described in this report.

8.2 Material Properties and Flow Stress Definition

The above findings conclude that when an accurate defect profile is available and an RSTRENG assessment can be undertaken, then the failure predictions are the most accurate. The RSTRENG method predicts conservative failure pressures when the specified minimum material properties (i.e. using σ_{SMYS}) are used in the assessment for defect depths up to 80% of the wall and in pipe grades up to X100.

It is acknowledged that the yield strength to tensile strength ratio ($\sigma_{SMYS}/\sigma_{SMTS}$) is limited to 0.93 for pipe material grades given in API 5L [32]. As the material strength increases, the ratio ($\sigma_{SMYS}/\sigma_{SMTS}$) increases; for grade X80 and X100 material, this ratio is equal to 0.89 and 0.91 respectively. However, **actual** as opposed to **specified minimum** material properties may result in the ratio exceeding 0.93. As discussed in [33], this may result in the flow stress, $\bar{\sigma}$, exceeding the tensile strength of the material. To ensure work hardening of the material is included in the assessment, an alternative definition of flow stress based on the average of the yield and ultimate tensile strength has been proposed when assessing corrosion damage in grade X80 and X100 material [33]. This definition of flow stress is consistent with that recommended in BS 7910 [15]. However, the assessments described in this report show that the RSTRENG method, without modification of the flow stress, gives conservative failure predictions when assessing defects in pipelines of grade up to X100.

The SHELL92 method uses the maximum defect depth and length dimensions. The method uses the same Folias factor as that for the ASME B31G method. The only difference is that the defect shape is modified to be rectangular and the flow stress is modified to equal $0.9\sigma_{SMTS}$. For higher strength line pipe, the SHELL92 effectively reduces the flow stress compared to the ASME B31G and Modified ASME B31G methods. The modification in the flow stress and the defect shape is sufficient to allow the prediction of conservative failure pressures for the integrated test database described in this report.

8.3 Defect Assessment Following In Line Inspection

Section 6 describes the approach taken to manage the integrity of a pipeline following ILI. Note should be made of the capability of ILI tools in characterizing defects in the context of the assessments described in this report. In practice, following an ILI, the operator will receive a list of metal loss defects identifying their location, depth, length and width. All these measurements will have a tolerance, with a confidence level depending on many factors including the resolution of the tool used. A typical accuracy for sizing defect depth is ±10% of the pipe wall thickness (t) with an 80% confidence level for a high resolution inspection tool. Care is therefore required to determine in what form the inspection data provided by the tool vendor is used in conjunction assessment methods described in this report.

Where defects are being screened or ranked following an ILI then the assessments described in this report show that in for tests conducted on pipe with real corrosion defects, the ASME B31G or the Modified ASME B31G methods give conservative failure predictions. However, for a very small percentage of tests reviewed in this report, non-conservative failure predictions were obtained; these were on tests conducted on pipe with machined defects. This is when relatively deep defects (greater than 40%, but increasingly above 60% of the pipe wall) are assessed in line pipe of strength grade X52 and above.

As already discussed, machined patches are rectangular and flat. Depending of the shape of the machined defect, use of ASME B31G and Modified ASME B31G may be inappropriate, particularly if the defects are very long, because the area of metal loss may be underestimated. However, it is should be noted that some of the burst tests used to validate the Modified ASME B31G (given in the AGA/PRCI Database) method were conducted on vessels with machined defects.

To investigate the behavior of real or machined defects, it is recommended that a focused program of full-scale burst tests is conducted using high strength pipe with simulated defects that represent real corrosion damage in the field. More realistic corrosion defects could be produced by a number of methods. Starting with a flat bottomed machined defect, corrosion features could be produced by either treating an area of the pipe with a mineral acid such as hydrochloric acid (HCl) or by accelerating corrosion by simulated ground water (e.g. NS4 solution) using electrochemical methods. In either case a realistic corroded surface would be produced which would better simulate an actual service defect compared to a machined defect. Failure pressure predictions using ASME B31G, Modified ASME B31G and RSTRENG should then be compared to the recorded burst test pressures.

There is no evidence to suggest that the ranking/screening of defects using the ASME B31G or Modified ASME B31G in pipelines of strength grade up to X65 has led to premature failures of corroded pipelines. However, if the ILI detects defects in this regime, based on the findings described in this report, it is recommended that the screening/ranking of defects undertaken using ASME B31G or Modified ASME B31G is supplemented by an RSTRENG assessment. The SHELL92 method has been shown to predict conservative failure pressures, even for relatively deep defects in higher strength steels. An alternative approach that can also be considered is to screen/rank defects using the SHELL92 method. It is reiterated that specified minimum material properties must be used, as recommended by the assessment methods.

The first phase of a Joint Industry Project has recently been completed to determine the true performance in 'real' field conditions of ILI tools utilizing Magnetic Flux Leakage (MFL) technology. The second phase of this project is now being sponsored by PRCI (Project EC4-1). This project should help operators to incorporate appropriate tolerances according to the tool being used. It is recommended that the work described in this report and the output from PRCI Project EC4-1, is critically reviewed to determine whether the algorithms and methodologies used by tool vendors to screen defects, are being implemented appropriately.

9 CONCLUSIONS

1. For the majority of the tests investigated in this report, standard assessment methods used by the pipeline industry give conservative failure predictions. In a number of cases predictions of the remaining strength are very conservative. Failure predictions on pipe with real corrosion defects were shown to be conservative using the ASME B31G, Modified ASME B31G and RSTRENG methods.

2. For a very small number of test points reviewed in this report, use of the ASME B31G and Modified ASME B31G methods resulted in non-conservative failure predictions. These were for test points with defects greater than 40% of the pipe wall and in line pipe of grade X52 and above. Where non-

conservative failure predictions are predicted, they were on tests with artificially introduced (machined) defects, rather than pipe with real corrosion defects. Typically machined defects consist of a rectangular, flat bottomed patch and use of, for example ASME B31G or Modified ASME B31G, may be inappropriate in these cases because the area of metal loss can be underestimated, particularly if the defect is long.

3. RSTRENG is the most accurate method for predicting the failure pressure in pipelines. RSTRENG predicts conservative failure pressures for defect depths up to 80% of the pipe wall in line pipe of strength grades up to X100.

4. The SHELL92 method, which is a modified version of the ASME B31G method, conservatively predicts failure pressures for defect depths up to 80% of the pipe wall in line pipe of strength grades up to X100.

10 RECOMMENDATIONS

1. The ASME B31G or the Modified ASME B31G methods can continue to be used to rank/screen defects following ILI. This is because both methods predict conservative failure pressures for tests conducted on pipe with real corrosion defects. However, the test database for pipe with real corrosion defects given in this report is limited to pipe generally below grade X65. Failure predictions for burst tests conducted on pipe of higher grades have resulted in some non-conservative failure predictions when the ASME B31G and Modified ASME B31G methods have been used. These tests were conducted on pipe with machined defects. It is recommended that a focused program of full-scale tests is conducted on higher strength pipe with simulated defects that represent real corrosion damage in the field. Failure pressure predictions using ASME B31G, Modified ASME B31G and RSTRENG should then be compared to the recorded burst test pressures.

2. The RSTRENG method has been shown to be the most accurate in predicting the failure pressure of pipe up to grade X100. In the absence of burst test data on higher strength pipe (above Grade X65) with real corrosion defects, remaining strength assessments can be conducted using either RSTRENG or SHELL92 as both methods are shown to predict conservative failure pressures in pipe up to Grade X100. Specified minimum material properties should be used as required by the assessment methods.

3. Work described in this report and the output from PRCI Project EC4-1 (Project to determine the true performance in 'real' field conditions of in-line inspection tools utilizing Magnetic Flux Leakage (MFL) technology) is critically reviewed to determine how the algorithms used by inspection vendors to screen defects are implemented.

11 NOMENCLATURE

σ	Hoop stress at failure (units: psi)
$\bar{\sigma}$	Flow stress for the line pipe material (units: psi)
d	Depth of the defect (units: Mil)
t	Uncorroded pipe wall thickness (units: inch)
M	Folias (bulging) correction factor
L	Axial length of the defect (units: inch)
D	Outside Diameter of Pipe (units: inch)
R_s	Remaining Strength Factor
σ_{SMYS}	Specified Minimum Yield Strength (units: psi)
σ_{SMTS}	Specified Minimum Tensile Strength (units: psi)
A	Area of a Part Wall Defect = Ld (units: inch^2)
A_o	Reference Area = Lt (units: inch^2)
$MAOP$	Maximum Allowable Operating Pressure (units: psi)
P_o	Failure Pressure of Plain, Undamaged Pipe (units: psi)
P_f	Predicted Failure Pressure of the Corroded Pipe (units: psi)
P_A	l Failure Pressure of the Corroded Pipe (units: psi)

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TABLES

Method	**Origin of Basic Equation**	**Flow Stress, $\bar{\sigma}$, Definition**	**Defect Shape**	**Folias Factor (*M*)**
NG-18	AGA NG-18 Toughness Independent Equation	σ_{SMYS}+10,000 psi	Rectangular	$\sqrt{1+0.6275\left(\frac{L}{\sqrt{Dt}}\right)^2-0.003375\left(\frac{L}{\sqrt{Dt}}\right)^4}$
ASME B31G	AGA NG-18 Toughness Independent Equation	$1.1\sigma_{SMYS}$	Parabolic (shape factor 0.67)	$\sqrt{1+0.8\left(\frac{L}{\sqrt{Dt}}\right)^2}$ for $\frac{L}{\sqrt{Dt}} \le 4.479$
Modified ASME B31G	AGA NG-18 Toughness Independent Equation	σ_{SMYS}+10,000 psi	Arbitrary (shape factor 0.85)	$\sqrt{1+0.6275\left(\frac{L}{\sqrt{Dt}}\right)^2-0.003375\left(\frac{L}{\sqrt{Dt}}\right)^4}$ for $\frac{L}{\sqrt{Dt}} \le 7.071$ $3.3+0.032\left(\frac{L}{\sqrt{Dt}}\right)^2$ for $\frac{L}{\sqrt{Dt}} > 7.071$
RSTRENG	AGA NG-18 Toughness Independent Equation	σ_{SMYS}+10,000 psi	Effective area and length (river bottom)	Consistent with Modified ASME B31G
LPC-1	AGA NG-18 Toughness Independent Equation	σ_{SMTS}	Rectangular	$\sqrt{1+0.31\left(\frac{L}{\sqrt{Dt}}\right)^2}$ for all defect lengths
SHELL92	AGA NG-18 Toughness Independent Equation	$0.9\sigma_{SMTS}$	Rectangular	$\sqrt{1+0.8\left(\frac{L}{\sqrt{Dt}}\right)^2}$ for all defect lengths
PCORRC	Battelle New Approach	σ_{SMTS}	Rectangular	Incorporated into PCORRC failure equation

Table 1 - Summary of Defect Assessment Methods

Assessment Method	P_A/P_f All Test Data		P_A/P_f All Test Data Minus Early Grade B Results	
	Mean	Standard Deviation	Mean	Standard Deviation
ASME B31G	1.330	0.468	1.347	0.479
Modified ASME B31G	1.184	0.285	1.194	0.289
RSTRENG	1.170	0.177	1.188	0.168
LPC-1	1.178	0.318	1.205	0.309
PCORRC	1.191	0.310	1.220	0.301
SHELL92	1.436	0.407	1.465	0.403

Table 2 - Case 1 Statistical Assessment Summary

Assessment Method	P_A/P_f All Test Data		P_A/P_f All Test Data Minus Early Grade B Results	
	Mean	Standard Deviation	Mean	Standard Deviation
ASME B31G	1.534	0.624	1.550	0.642
Modified ASME B31G	1.330	0.348	1.340	0.356
RSTRENG	1.305	0.178	1.322	0.168
LPC-1	1.277	0.335	1.306	0.326
PCORRC	1.295	0.342	1.325	0.334
SHELL92	1.562	0.436	1.592	0.432

Table 3 Case 2 Statistical Assessment Summary

Assessment Method	P_A/P_f All Test Data		P_A/P_f All Test Data Minus Early Grade B Results	
	Mean	Standard Deviation	Mean	Standard Deviation
ASME B31G	1.443	0.505	1.471	0.511
Modified ASME B31G	1.363	0.328	1.380	0.330
RSTRENG	1.343	0.188	1.368	0.168
LPC-1	1.450	0.424	1.474	0.425
PCORRC	1.471	0.427	1.496	0.429
SHELL92	1.601	0.505	1.622	0.512

Table 4 Case 6 Statistical Assessment Summary

	General Corrosion	Pitting corrosion	Axial Groove	Circum Groove
Depth Sizing Accuracy at 80% Confidence	0.1t	0.12t	0.2t	0.12t
Length Sizing Accuracy at 80% Confidence	±0.59"	±0.47"	±0.59"	±0.47"
Width Sizing Accuracy at 80% Confidence	±0.79"	±0.47"	±0.47"	±0.79"

Table 5 Typical Sizing Capabilities of a High Resolution Magnetic Flux Leakage Tool – Vendor 1[9]

[9] Taken from Rosen Group website, http://www.roseninspection.net/NR/rdonlyres/312699E9-7BBE-47BF-B72C-AB900B45DD8B/1956/ROSEN_CDP_TF_200709.pdf

	Standard Magnetic Flux Tool	Advanced Magnetic Flux Tool
Depth Sizing Accuracy	±0.1t	±0.1t
Length Sizing Accuracy	±0.787"	±0.394"
Width Sizing Accuracy	±0.787"	±0.59"
Confidence	80%	90%

Table 6 Typical Sizing Capabilities of a High Resolution Magnetic Flux Leakage Tool – Vendor 2[10]

		ASME B31G (Case 1)	Modified ASME B31G (Case 1)	SHELL92 (Case 1)	RSTRENG (Case 1)	RSTRENG (Case 2)
Real Defects	Correlation	0.7032	0.7924	0.7615	0.8808	0.8955
P(non-conservative)	>20%	2.2%	0.7%	0.6%	0.2%	0.0%
	>15%	3.4%	1.5%	1.1%	0.9%	0.0%
	>10%	5.0%	2.8%	1.8%	2.7%	0.1%
	>5%	7.0%	4.8%	2.8%	6.8%	0.3%
	>0%	90.6%	92.4%	95.8%	86.0%	99.0%
Machined Defects	Correlation	0.9426	0.9701	0.9771	0.9531	0.9759
P(non-conservative)	>20%	1.6%	3.4%	0.0%	0.2%	0.0%
	>15%	3.5%	7.7%	0.1%	0.8%	0.0%
	>10%	6.9%	14.6%	0.3%	2.2%	0.2%
	>5%	12.0%	24.1%	0.8%	5.2%	0.7%
	None	81.2%	64.4%	97.7%	89.7%	98.1%

Table 7 Likelihood of Non Conservative Failure Predictions with Data Split According to Real and Machined Defects

Note:

The row labeled None gives the likelihood of the failure prediction being the same as the actual burst pressure or that the prediction the prediction is conservative.

[10] Taken from GE-PII website http://www.geoilandgas.com/businesses/ge_oilandgas/en/prod_serv/serv/pipeline/en/downloads/mfl_3.0_fs_us.pdf

		ASME B31G (Case 1)	Modified ASME B31G (Case 1)	SHELL92 (Case 1)	RSTRENG (Case 1)	RSTRENG (Case 2)
Grade A25/B	Correlation	0.0659	0.0930	0.1366	0.4912	0.5012
	>20%	2.4%	0.5%	0.4%	0.3%	0.0%
	>15%	3.3%	1.0%	0.6%	1.0%	0.0%
	>10%	4.5%	1.6%	0.9%	2.8%	0.0%
	>5%	5.9%	2.7%	1.4%	6.4%	0.1%
	None	92.5%	95.9%	97.9%	87.5%	99.6%
Grade X42, X46	Correlation	0.7276	0.8188	0.7585	0.8352	0.8817
	>20%	2.1%	0.4%	0.2%	0.5%	0.0%
	>15%	3.7%	1.1%	0.6%	1.8%	0.0%
	>10%	6.1%	2.6%	1.3%	4.9%	0.0%
	>5%	9.3%	5.4%	2.5%	10.6%	0.2%
	None	86.7%	90.2%	95.5%	80.4%	99.3%
Grade X52/55/56	Correlation	0.8404	0.8727	0.8360	0.8571	0.8817
	>20%	0.5%	0.2%	0.0%	0.0%	0.0%
	>15%	1.1%	0.8%	0.1%	0.3%	0.0%
	>10%	2.2%	2.1%	0.2%	1.0%	0.0%
	>5%	3.9%	4.7%	0.4%	3.2%	0.1%
	None	93.5%	90.8%	99.1%	92.1%	99.7%
Grade X60	Correlation	0.9223	0.9253	0.9217	0.9531	0.9143
	>20%	0.8%	3.6%	0.0%	0.0%	0.0%
	>15%	2.0%	7.7%	0.1%	0.0%	0.0%
	>10%	4.1%	14.1%	0.4%	0.1%	0.1%
	>5%	7.6%	22.7%	1.0%	0.5%	0.2%
	None	87.5%	66.8%	97.5%	98.4%	99.3%
Grade X65	Correlation	0.9800	0.9952	0.9877	0.9876	0.9924
	>20%	1.8%	3.1%	0.0%	0.1%	0.0%
	>15%	3.7%	6.7%	0.0%	0.3%	0.0%
	>10%	6.9%	12.5%	0.1%	1.0%	0.0%
	>5%	11.6%	20.6%	0.4%	2.6%	0.1%
	None	82.3%	69.5%	98.8%	94.3%	99.5%
Grade X80/X100	Correlation	0.9268	0.9464	0.9787	0.9737	0.9814
	>20%	2.2%	9.0%	0.0%	0.0%	0.0%
	>15%	6.3%	19.2%	0.0%	0.1%	0.0%
	>10%	14.3%	33.4%	0.0%	1.0%	0.0%
	>5%	26.4%	49.6%	0.0%	6.7%	0.0%
	None	58.6%	34.9%	99.7%	76.4%	99.5%

Table 8 Likelihood of Non Conservative Failure Predictions with Data Split According to Pipe Material Grade

Note:

The row labeled None gives the likelihood of the failure prediction being the same as the actual burst pressure or that the prediction the prediction is conservative.

		ASME B31G (Case 1)	Modified ASME B31G (Case 1)	SHELL92 (Case 1)	RSTRENG (Case 1)	RSTRENG (Case 2)
d/t less than 0.4	Correlation	0.9236	0.9502	0.9803	0.9612	0.9926
P(non-conservative)	>20%	0.5%	0.2%	0.1%	0.0%	0.0%
	>15%	1.4%	1.0%	0.3%	0.2%	0.0%
	>10%	3.2%	3.1%	0.8%	1.1%	0.0%
	>5%	6.6%	7.8%	2.1%	4.0%	0.1%
	None	88.0%	84.0%	95.3%	89.4%	99.3%
d/t greater than 0.4 and less than 0.6	Correlation	0.9039	0.9200	0.9729	0.9498	0.9652
P(non-conservative)	>20%	2.7%	2.5%	0.0%	0.2%	0.0%
	>15%	4.6%	5.0%	0.1%	0.7%	0.0%
	>10%	7.3%	8.9%	0.3%	2.0%	0.0%
	>5%	10.8%	14.4%	0.8%	5.0%	0.2%
	None	84.9%	78.7%	98.2%	89.8%	99.2%
d/t greater than 0.6	Correlation	0.9308	0.9519	0.9699	0.9742	0.9763
P(non-conservative)	>20%	6.0%	8.0%	1.0%	0.5%	0.0%
	>15%	8.5%	11.7%	1.7%	1.4%	0.1%
	>10%	11.5%	16.2%	2.8%	3.3%	0.3%
	>5%	14.9%	21.4%	4.2%	6.9%	0.8%
	None	81.2%	72.9%	93.9%	87.5%	97.9%
d/t less than 0.6	Correlation	0.9121	0.9361	0.9760	0.9533	0.9796
P(non-conservative)	>20%	1.9%	1.4%	0.0%	0.1%	0.0%
	>15%	3.6%	3.4%	0.2%	0.5%	0.0%
	>10%	6.3%	7.0%	0.5%	1.8%	0.0%
	>5%	10.0%	12.5%	1.4%	4.9%	0.2%
	None	85.2%	79.9%	96.9%	89.1%	99.1%

Table 9 Likelihood of Non Conservative Failure Predictions with Data Split According to Defect Depth, (d/t) ratio

Note:

The row labeled None gives the likelihood of the failure prediction being the same as the actual burst pressure or that the prediction the prediction is conservative.

		ASME B31G (Case 1)		Modified ASME B31G (Case 1)		SHELL92 (Case 1)		RSTRENG (Case 1)	
		d/t<60	d/t>60	d/t<60	d/t>60	d/t<60	d/t>60	d/t<60	d/t>60
A25/B	No.Tests	6	22	6	22	5	21	6	22
	>20%	3.8%	2.1%	0.5%	0.5%	1.3%	0.0%	0.3%	0.2%
	>15%	4.8%	3.0%	1.0%	0.9%	2.2%	0.0%	0.9%	0.9%
	>10%	6.0%	4.2%	1.9%	1.6%	3.5%	0.1%	2.1%	2.8%
	>5%	7.3%	5.6%	3.2%	2.6%	5.4%	0.1%	4.4%	6.8%
	None	91.2%	92.7%	94.9%	96.1%	92.2%	99.8%	91.9%	86.3%
X42/X46	No.Tests	27	20	27	20	27	20	26	17
	>20%	2.0%	2.1%	0.9%	0.1%	0.4%	0.0%	0.6%	0.3%
	>15%	3.5%	3.9%	2.1%	0.2%	1.0%	0.1%	1.9%	1.3%
	>10%	5.6%	6.7%	4.3%	0.8%	2.1%	0.2%	4.7%	4.4%
	>5%	8.4%	10.5%	7.7%	2.4%	4.1%	0.5%	9.8%	11.3%
	None	88.1%	84.7%	87.4%	94.4%	92.8%	98.9%	82.5%	77.1%
X52/55/56	No.Tests	49	16	49	16	49	16	48	16
	>20%	0.3%	1.1%	0.0%	2.9%	0.0%	0.2%	0.0%	0.5%
	>15%	0.8%	2.0%	0.1%	5.2%	0.0%	0.4%	0.1%	1.6%
	>10%	1.7%	3.3%	0.5%	8.6%	0.0%	0.7%	0.5%	3.8%
	>5%	3.3%	5.2%	1.6%	13.1%	0.1%	1.3%	1.9%	7.8%
	None	94.2%	92.3%	95.6%	81.3%	99.7%	97.9%	94.4%	86.0%
X60	No.Tests	24	21	24	21	24	21	23	21
	>20%	0.1%	2.7%	0.0%	11.0%	0.0%	0.1%	0.0%	0.0%
	>15%	0.3%	4.9%	0.3%	19.7%	0.0%	0.3%	0.0%	0.1%
	>10%	1.1%	8.1%	1.1%	30.9%	0.1%	0.9%	0.0%	0.4%
	>5%	2.9%	12.5%	3.4%	43.5%	0.4%	2.0%	0.1%	1.3%
	None	93.6%	82.2%	91.4%	43.9%	98.6%	95.9%	99.4%	96.8%
X65	No.Tests	16	25	16	25	16	25	16	25
	>20%	0.0%	5.4%	1.3%	4.8%	0.0%	0.0%	0.0%	0.2%
	>15%	0.0%	8.9%	3.4%	9.4%	0.0%	0.0%	0.0%	0.7%
	>10%	0.0%	13.7%	7.6%	16.0%	0.1%	0.2%	0.2%	1.7%
	>5%	0.1%	19.5%	14.3%	24.6%	0.3%	0.5%	0.9%	3.6%
	None	99.4%	73.8%	76.4%	65.4%	99.0%	98.5%	97.1%	93.1%
X80/X100	No.Tests	37	3	37	3	37	3	37	3
	>20%	0.0%	38.7%	0.7%	78.0%	0.0%	0.4%	0.0%	9.3%
	>15%	0.5%	44.5%	4.2%	86.0%	0.0%	1.8%	0.0%	16.2%
	>10%	3.1%	50.1%	15.5%	91.5%	0.0%	5.5%	0.2%	25.3%
	>5%	12.4%	55.4%	36.6%	95.1%	0.0%	12.9%	2.8%	36.0%
	None	68.8%	39.7%	38.4%	2.8%	100.0%	75.3%	82.8%	52.9%

Table 10 Likelihood of Non Conservative Failure Predictions With Data Split According to Pipe Material Grade and Defect Depth (d/t) Ratio – Based on Case 1 Assessments

Notes:

1. *The results marked in red are for indicative purposes only because of the limited number of test points*
2. *The row labeled 'None' gives the likelihood of the failure prediction being the same as the actual burst pressure or that the prediction is conservative*

		ASME B31G (Case 2)		Modified ASME B31G (Case 2)		Shell 92 (Case 2)		RSTRENG (Case 2)	
		d/t<60	d/t>60	d/t<60	d/t>60	d/t<60	d/t>60	d/t<60	d/t>60
A25/B	No.Tests	6	22	6	22	5	23	6	22
	>20%	1.0%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	>15%	1.4%	0.7%	0.0%	0.0%	0.1%	0.1%	0.0%	0.0%
	>10%	1.9%	1.0%	0.0%	0.1%	0.3%	0.1%	0.0%	0.1%
	>5%	2.4%	1.4%	0.0%	0.2%	0.6%	0.2%	0.0%	0.3%
	None	96.9%	98.0%	100.0%	99.7%	98.9%	99.6%	100.0%	99.2%
X42/X46	No.Tests	27	20	27	20	27	20	26	17
	>20%	0.1%	0.2%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%
	>15%	0.2%	0.5%	0.0%	0.0%	0.3%	0.0%	0.0%	0.0%
	>10%	0.4%	1.1%	0.2%	0.0%	0.7%	0.0%	0.0%	0.1%
	>5%	0.8%	2.0%	0.5%	0.1%	1.5%	0.1%	0.1%	0.5%
	None	98.5%	96.6%	98.8%	99.7%	97.2%	99.8%	99.6%	98.3%
X52/55/56	No.Tests	49	16	49	16	49	16	48	16
	>20%	0.0%	0.5%	0.0%	0.8%	0.0%	0.0%	0.0%	0.0%
	>15%	0.0%	0.9%	0.0%	1.7%	0.0%	0.0%	0.0%	0.1%
	>10%	0.1%	1.6%	0.0%	3.1%	0.0%	0.1%	0.0%	0.3%
	>5%	0.2%	2.5%	0.0%	5.2%	0.0%	0.2%	0.0%	0.8%
	None	99.5%	96.2%	99.9%	91.9%	99.9%	99.6%	99.9%	97.8%
X60	No.Tests	24	21	24	21	24	21	23	21
	>20%	0.0%	0.2%	0.0%	5.9%	0.0%	0.1%	0.0%	0.0%
	>15%	0.0%	0.5%	0.0%	10.5%	0.0%	0.2%	0.0%	0.1%
	>10%	0.0%	1.1%	0.2%	16.9%	0.0%	0.4%	0.0%	0.2%
	>5%	0.1%	2.3%	0.9%	24.8%	0.0%	1.0%	0.0%	0.6%
	None	99.4%	95.8%	97.2%	66.2%	99.9%	98.0%	99.8%	98.6%
X65	No.Tests	16	24	16	24	16	24	16	25
	>20%	0.0%	4.7%	0.0%	0.7%	0.0%	0.0%	0.0%	0.0%
	>15%	0.0%	7.7%	0.2%	2.4%	0.0%	0.0%	0.0%	0.0%
	>10%	0.1%	11.7%	1.1%	6.2%	0.0%	0.0%	0.0%	0.0%
	>5%	0.3%	16.6%	4.1%	13.1%	0.1%	0.1%	0.1%	0.1%
	None	98.9%	77.6%	89.1%	76.7%	99.6%	99.8%	99.4%	99.6%
X80/X100	No.Tests	37	3	37	3	37	3	37	3
	>20%	0.0%	31.3%	0.0%	70.7%	0.0%	0.6%	0.0%	1.6%
	>15%	0.0%	37.0%	0.0%	82.3%	0.0%	1.6%	0.0%	4.4%
	>10%	0.0%	42.8%	0.4%	90.1%	0.0%	3.6%	0.0%	9.7%
	>5%	0.2%	48.3%	2.9%	94.8%	0.0%	7.0%	0.0%	18.1%
	None	98.6%	46.4%	87.8%	2.6%	100.0%	87.8%	100.0%	70.8%

Table 11 Likelihood of Non Conservative Failure Predictions With Data Split According to Pipe Material Grade and Defect Depth (d/t) Ratio – Based on Case 2 Assessments

Notes:

1. *The results marked in red are for indicative purposes only because of the limited number of test points*
2. *The row labeled 'None' gives the likelihood of the failure prediction being the same as the actual burst pressure or that the prediction is conservative*

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FIGURES

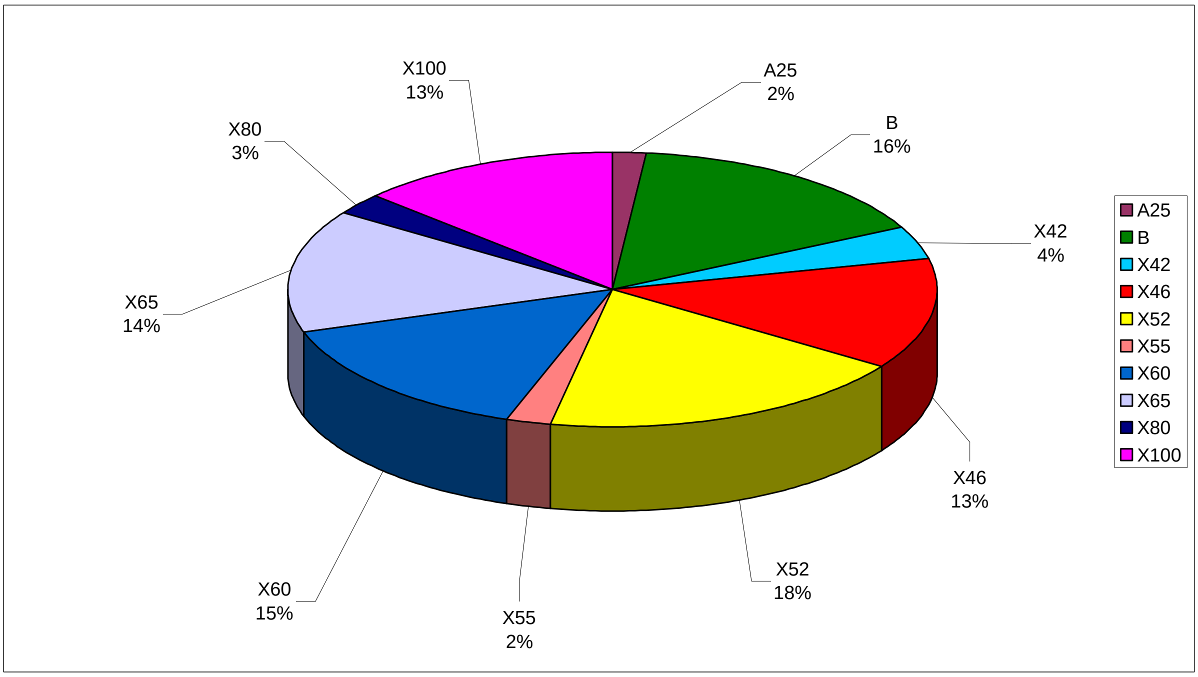

Figure 1 Material Grades Covered in the Integrated Burst Test Database

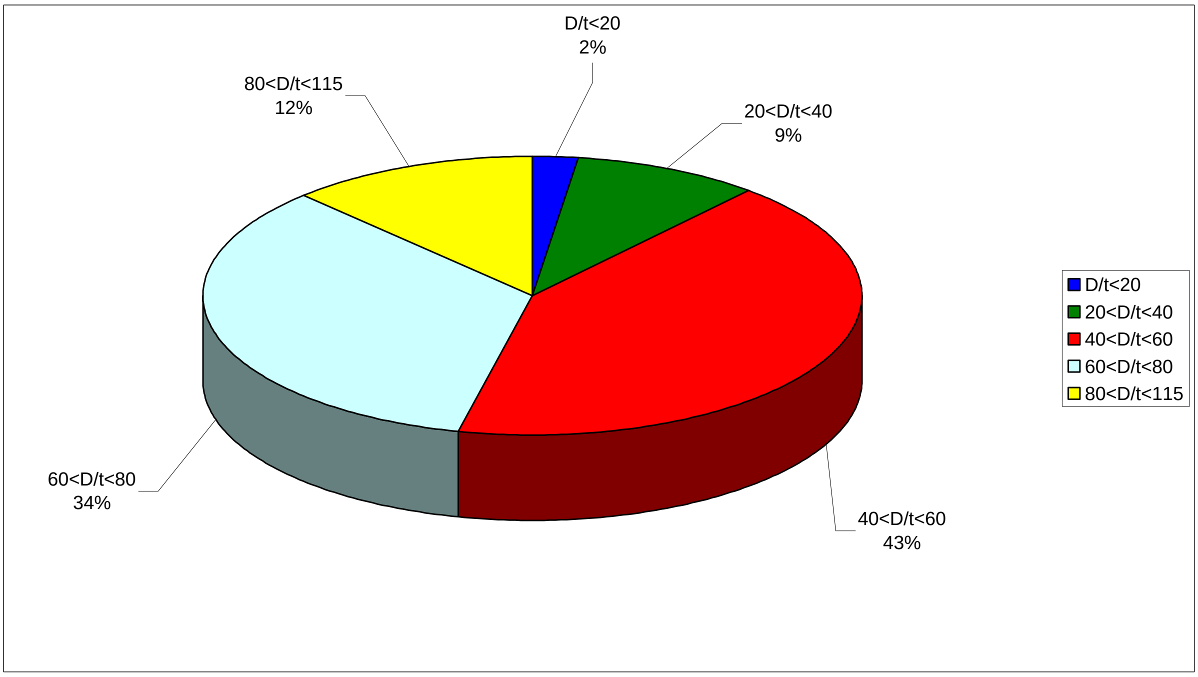

Figure 2 Pipe Diameter to Thickness (D/t) Ratios Covered in the Integrated Test Database

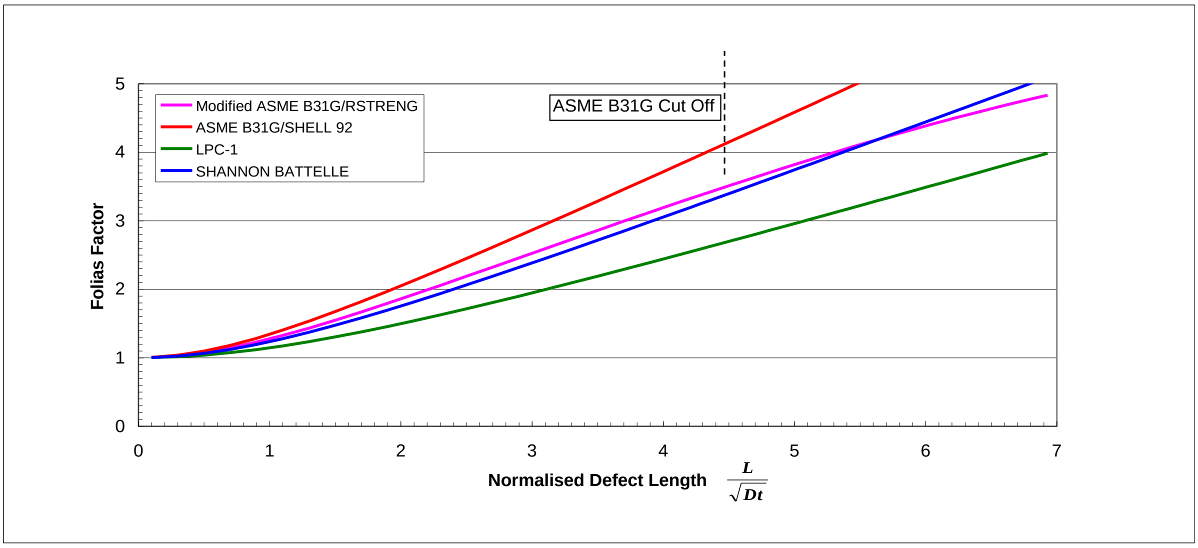

Figure 3 Comparison of Folias Factors

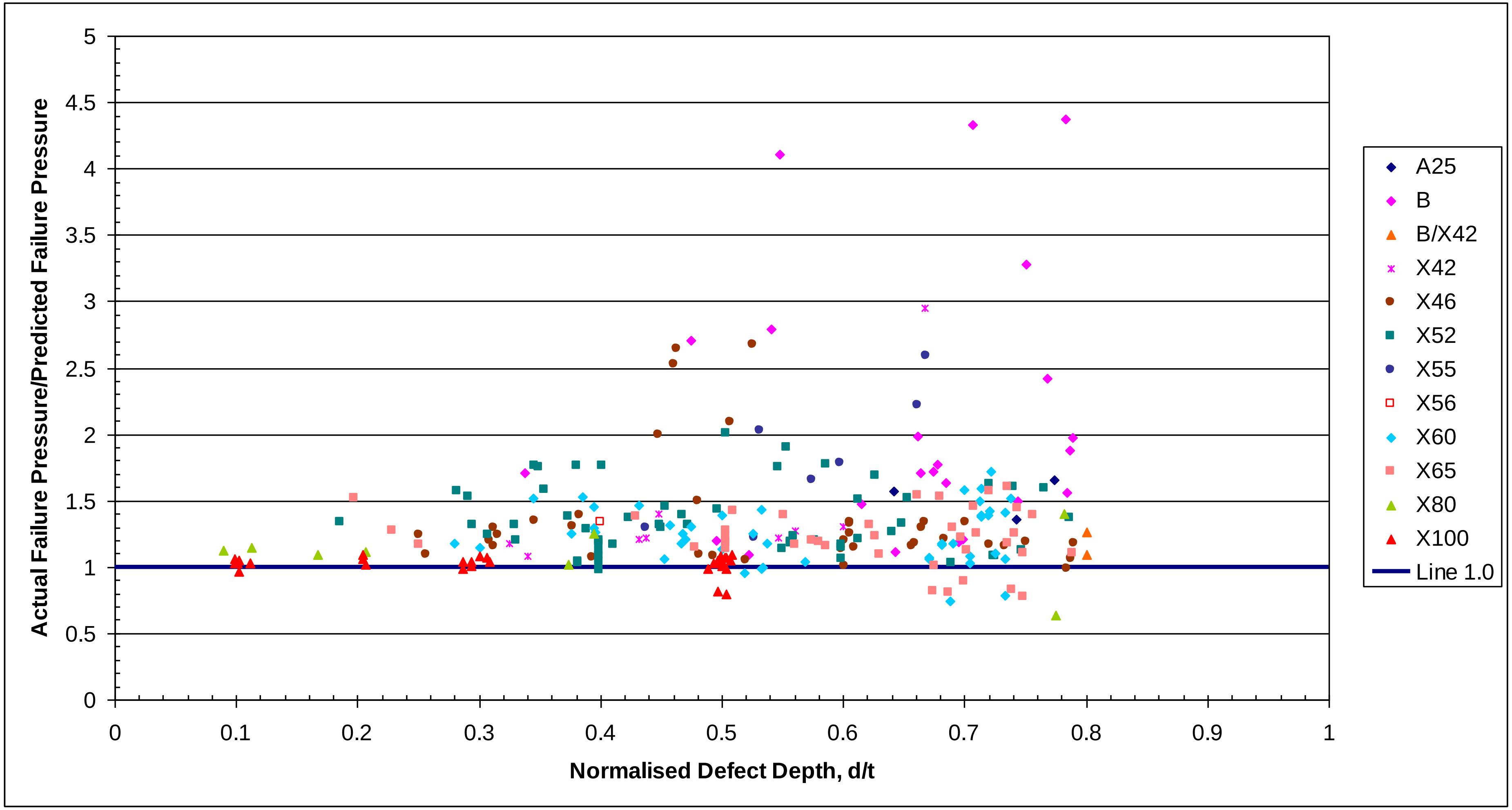

Figure 4 Comparison of Actual and Predicted Failure Pressures for the Integrated Database Using the ASME B31G Method (Case 1 Actual Material Properties)

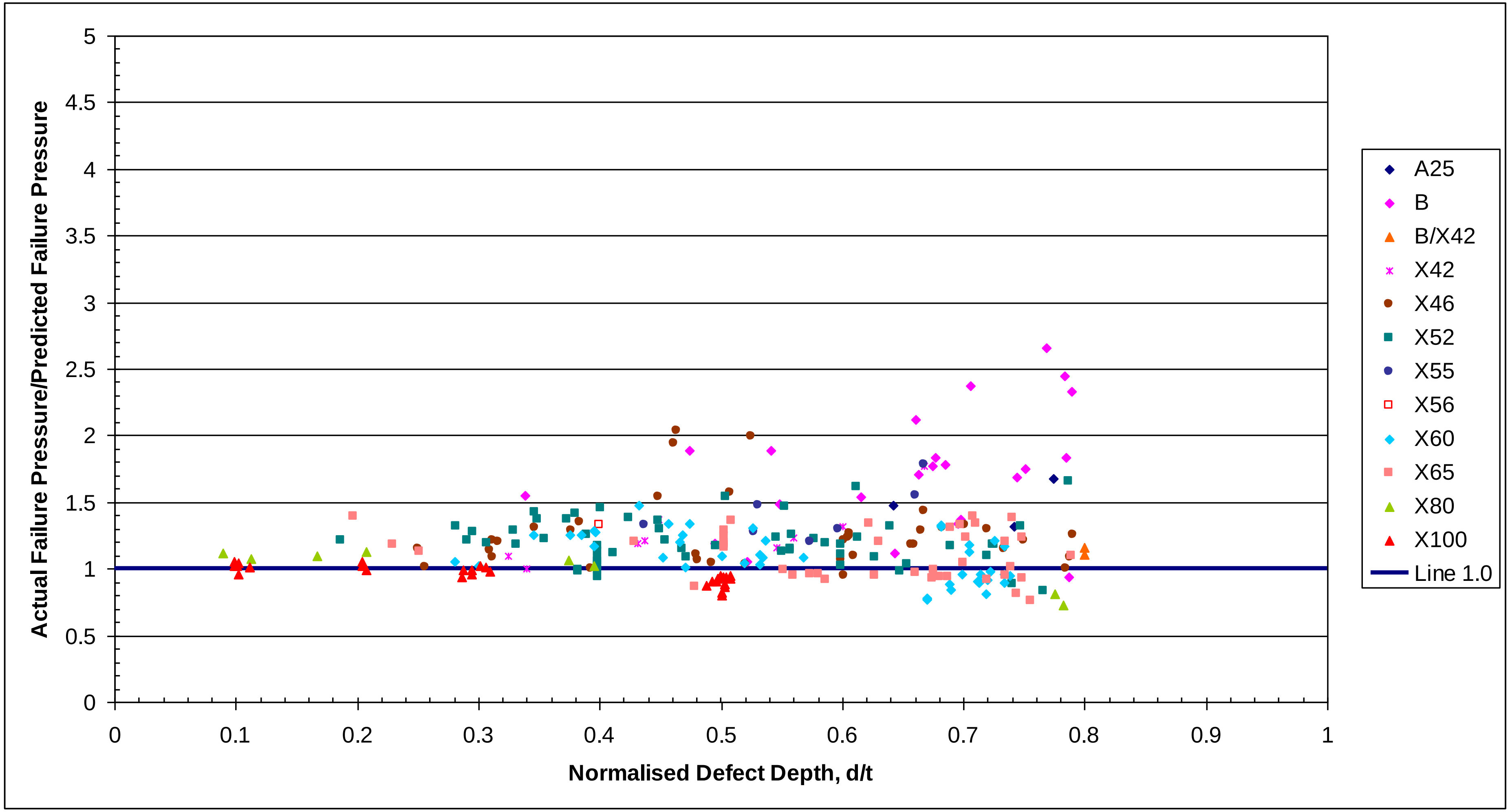

Figure 5 Comparison of Actual and Predicted Failure Pressure for the Integrated Test Database Using the Modified ASME B31G Method (Case 1 Actual Material Properties, including Ring Expansion Tests)

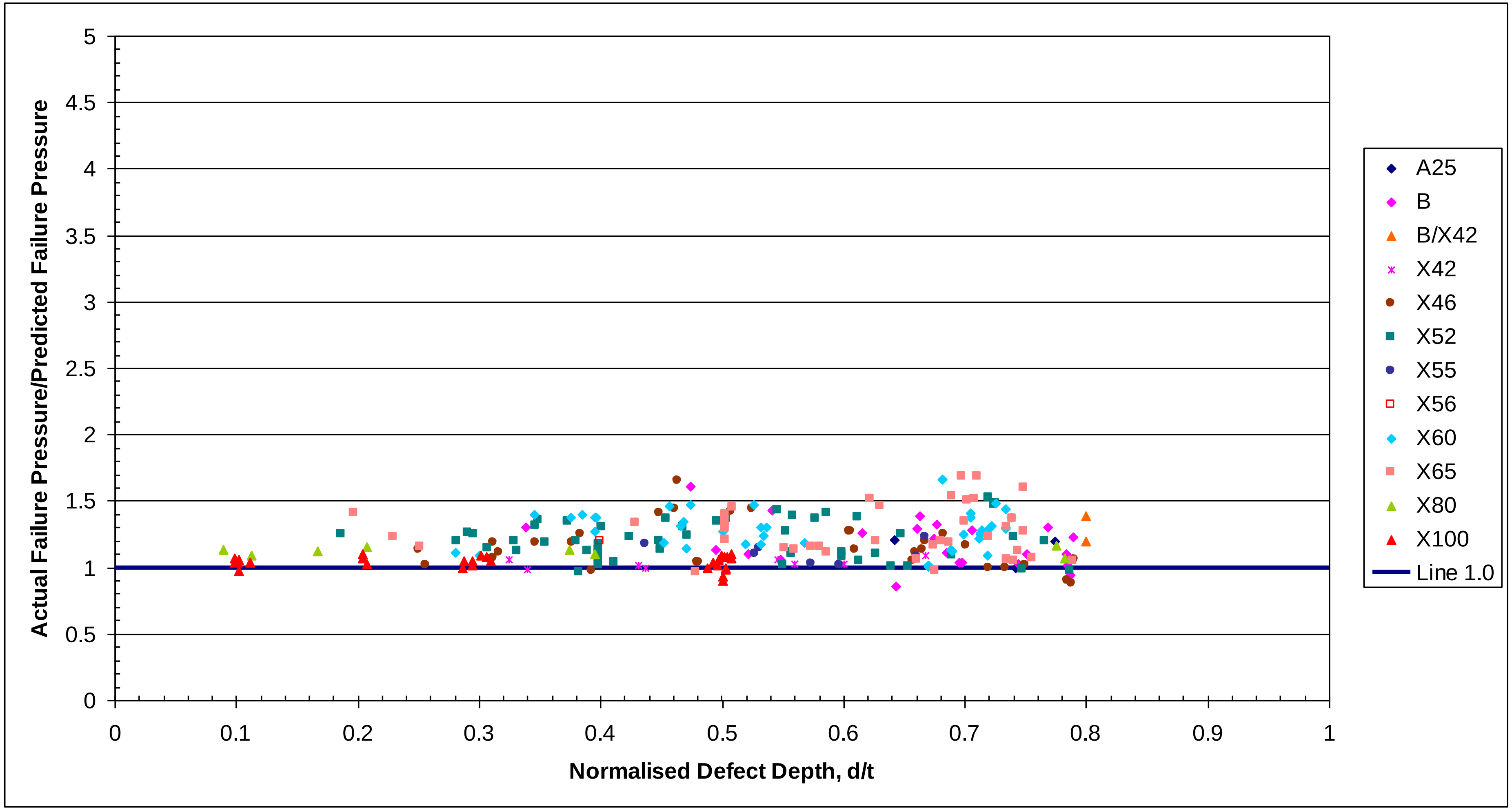

Figure 6 Comparison of Actual and Predicted Failure Pressure for the Integrated Test Database Using the RSTRENG Method (Case 1 Actual Material Properties)

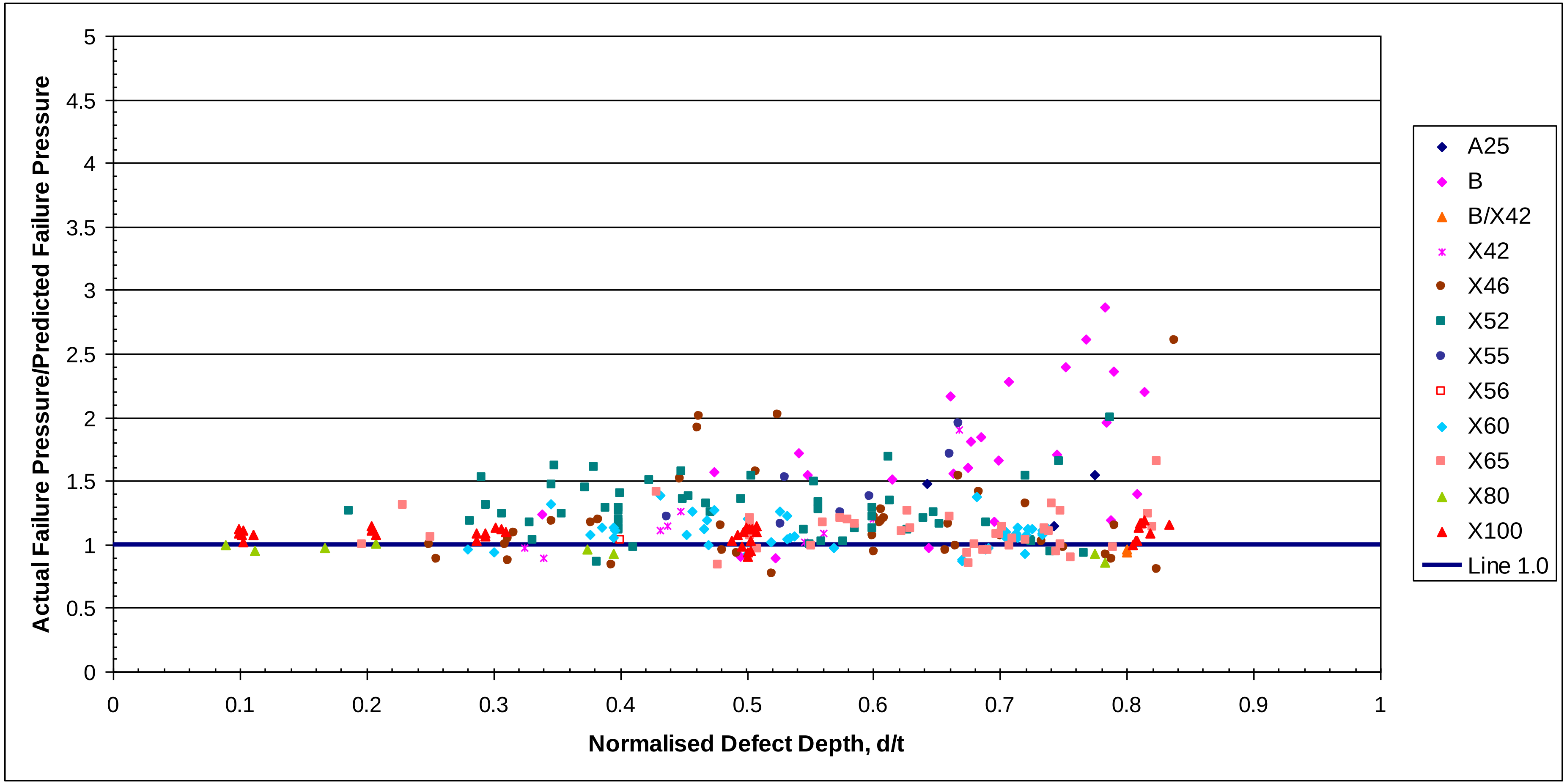

Figure 7 Comparison of Actual and Predicted Failure Pressure for the Integrated Test Database Using the LPC-1 Method (Case 1 Actual Material Properties)

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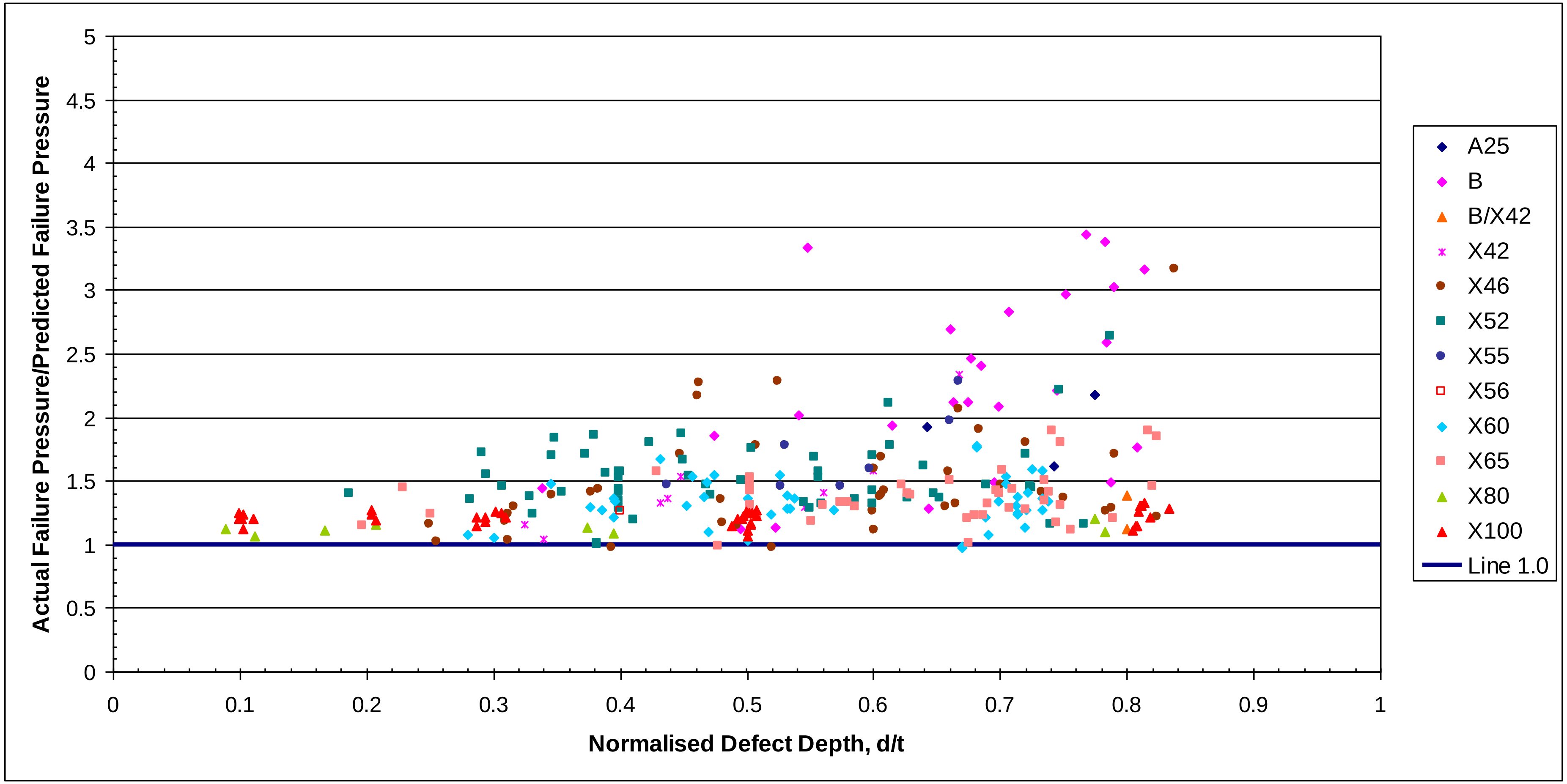

Figure 8 Comparison of Actual and Predicted Failure Pressure for the Integrated Test Database Using the SHELL92 Method (Case 1 Actual Material Properties)

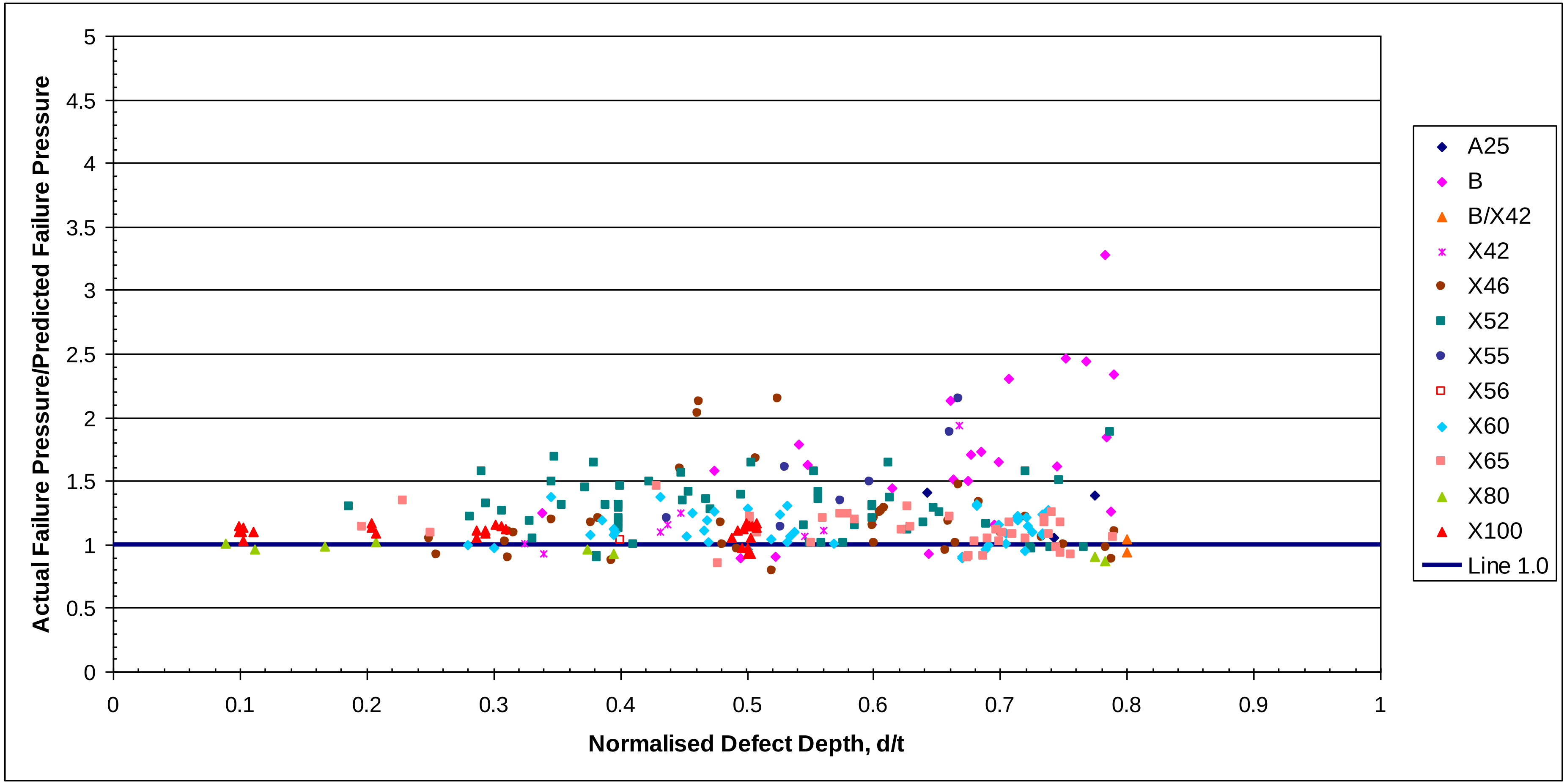

Figure 9 Comparison of Actual and Predicted Failure Pressure for the Integrated Test Database Using the PCORRC Method (Case 1 Actual Material Properties)

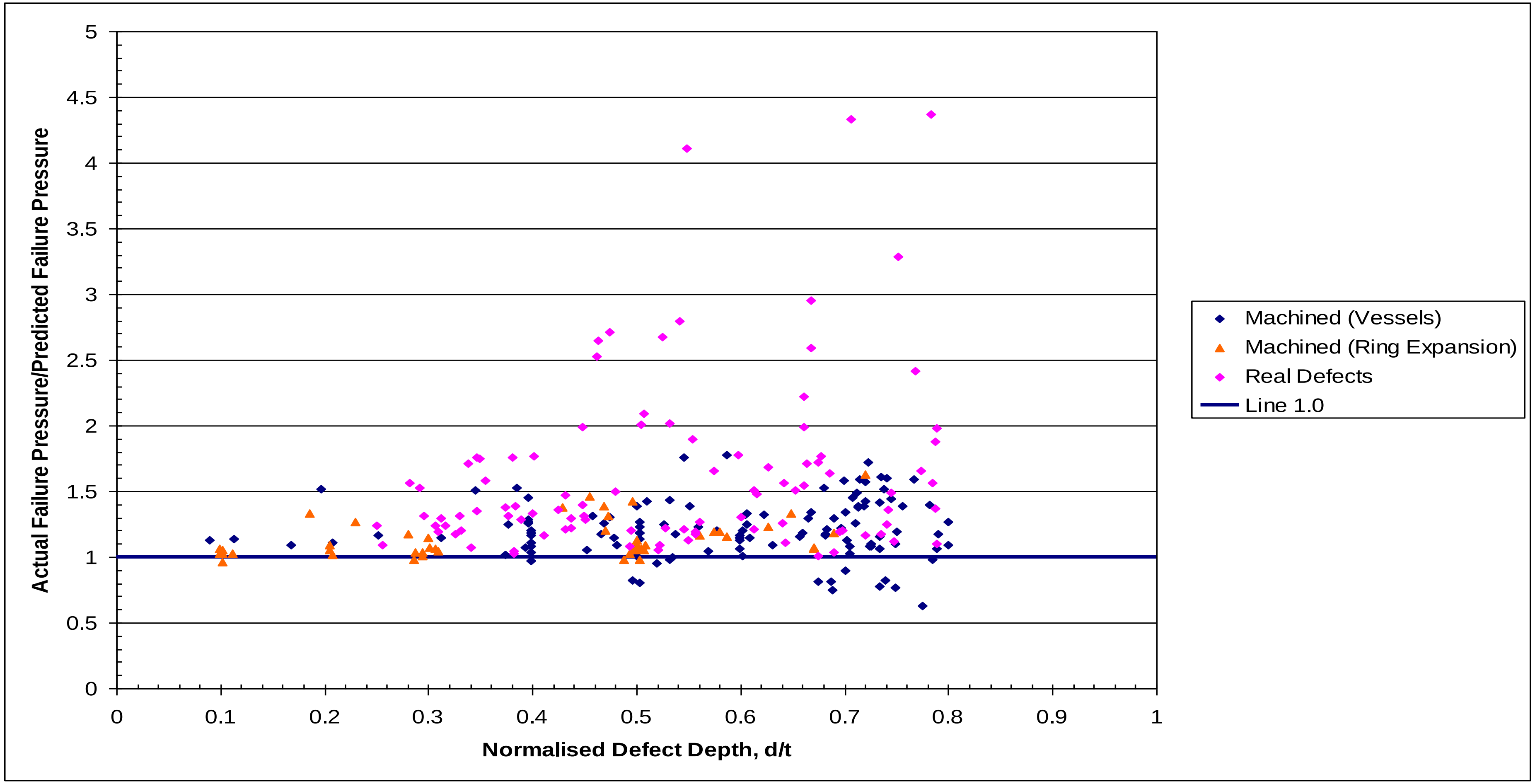

Figure 10 Comparison of Actual and Predicted Failure Pressures for the Integrated Database Using the ASME B31G Method (Case 1 Actual Material Properties) – Split Between Machined and Real Corrosion Defects

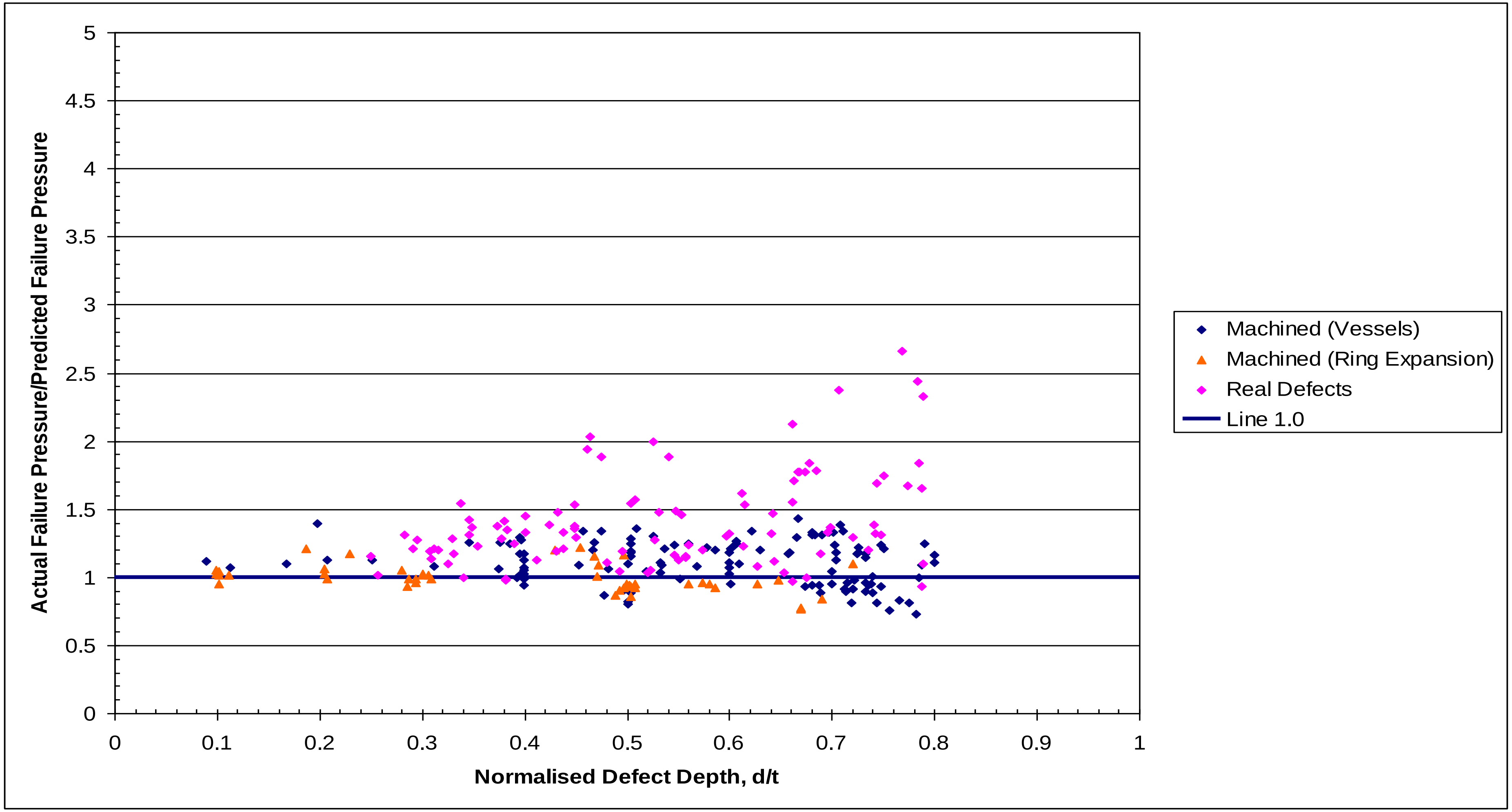

Figure 11 Comparison of Actual and Predicted Failure Pressure for the Integrated Test Database Using the Modified ASME B31G Method (Case 1 Actual Material Properties, including Ring Expansion Tests) – Split Between Machined and Real Corrosion Defects

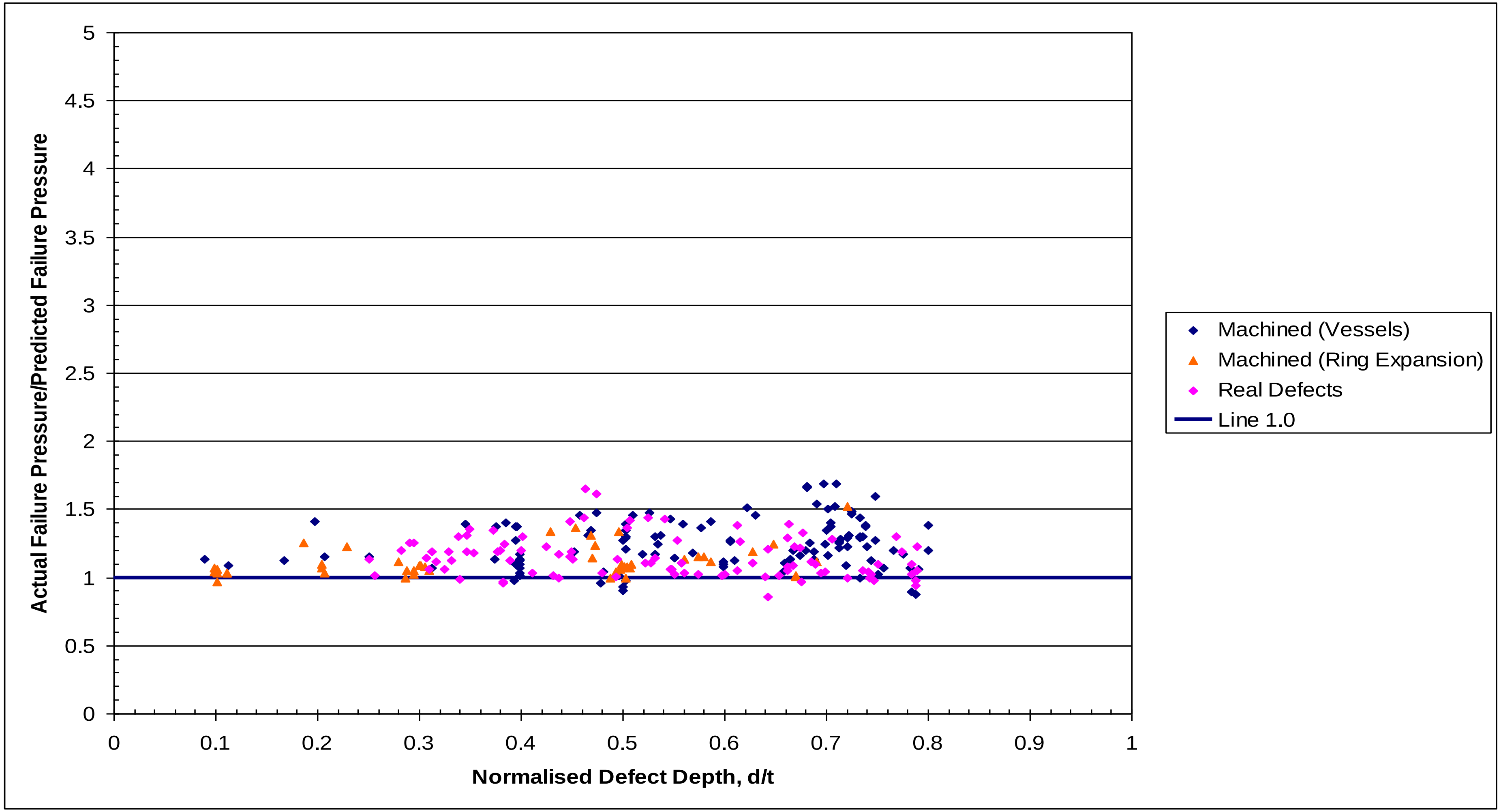

Figure 12 Comparison of Actual and Predicted Failure Pressure for the Integrated Test Database Using the RSTRENG Method (Case 1 Actual Material Properties) – Split Between Machined and Real Corrosion Defects

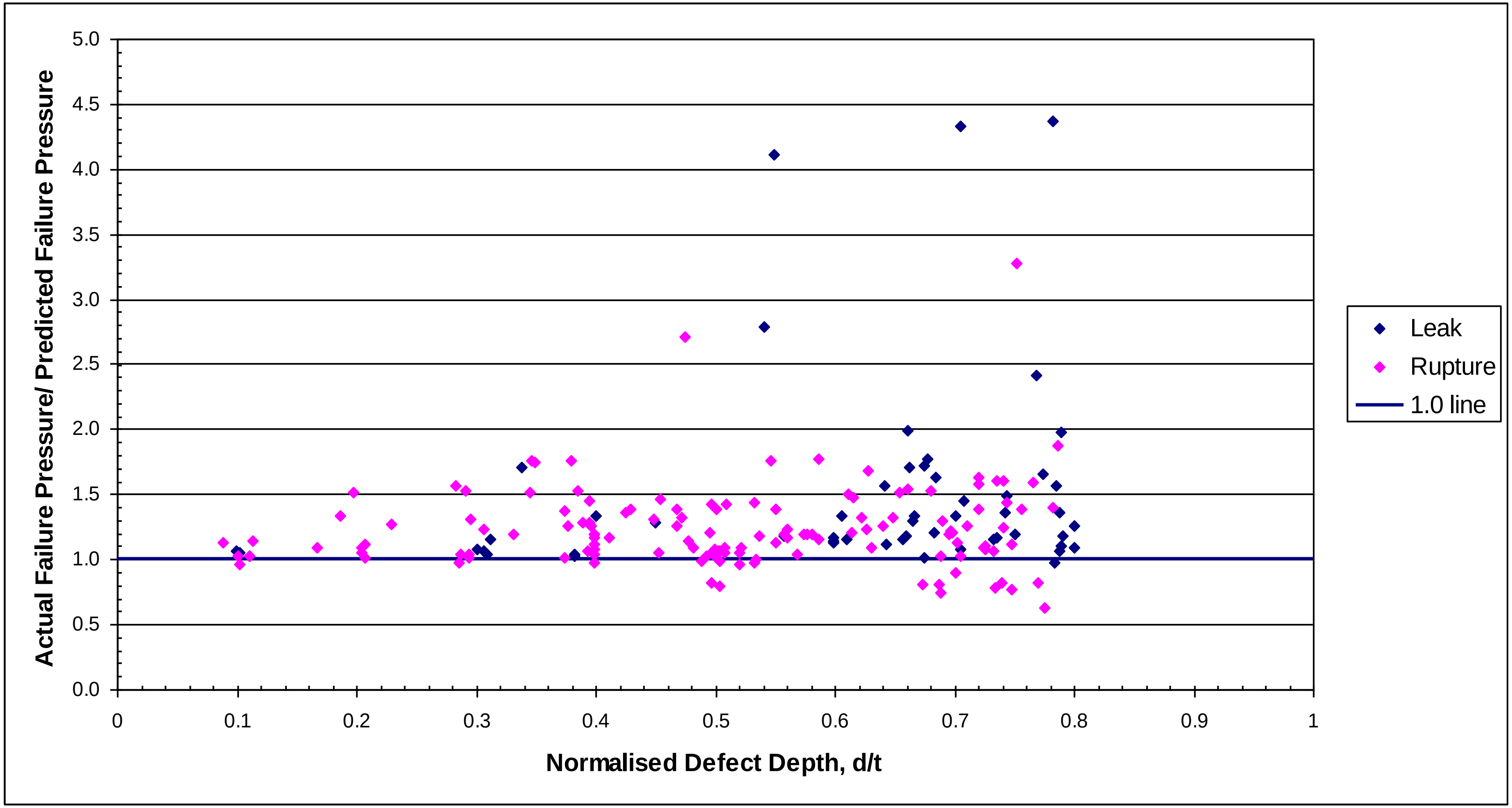

Figure 13 Comparison of Actual and Predicted Failure Pressures for the Integrated Database Using the ASME B31G Method (Case 1 Actual Material Properties) – Split Between Leaks and Ruptures

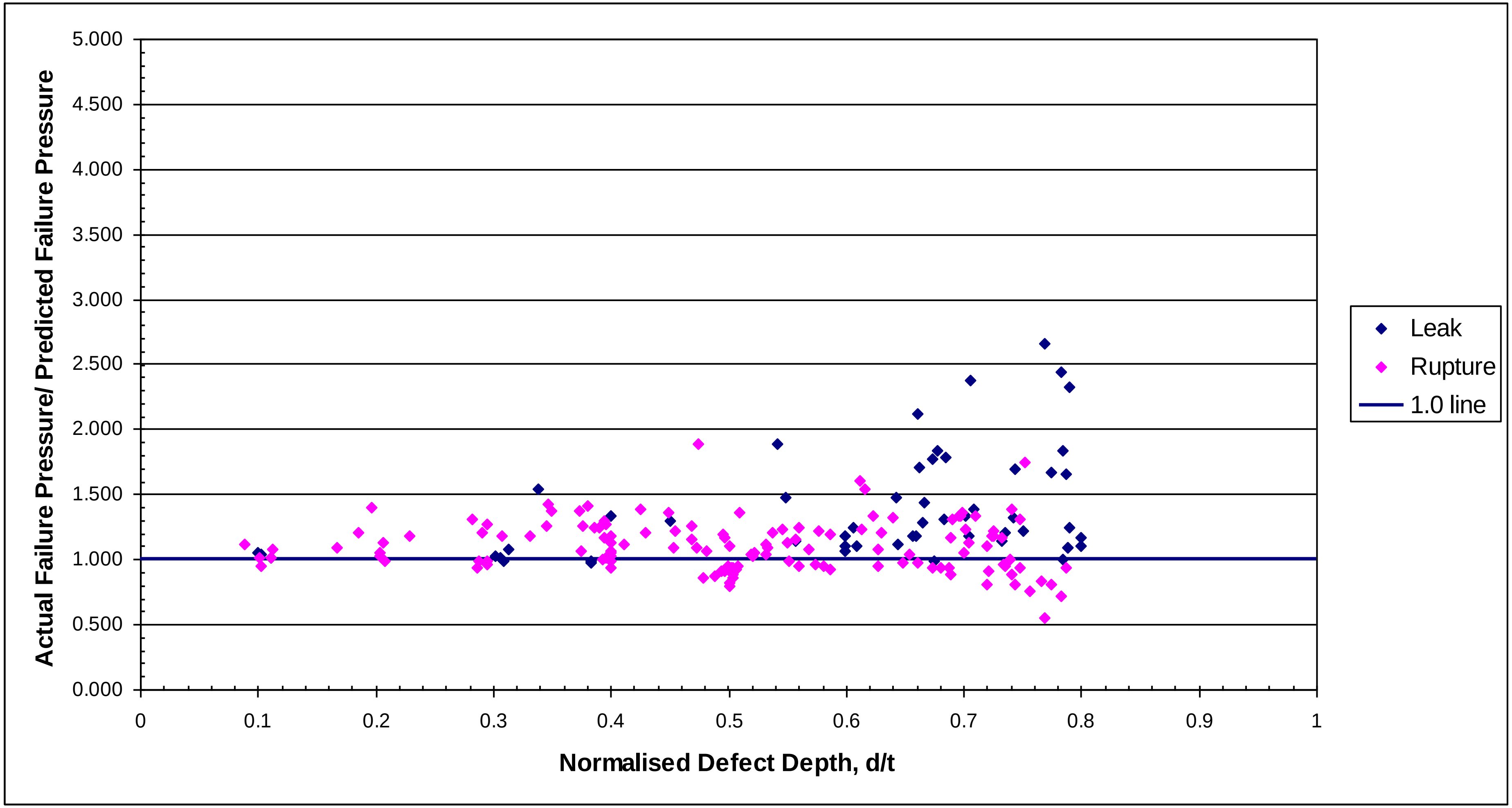

Figure 14 Comparison of Actual and Predicted Failure Pressures for the Integrated Database Using the Modified ASME B31G Method (Case 1 Actual Material Properties, including Ring Expansion Tests) – Split Between Leaks and Ruptures

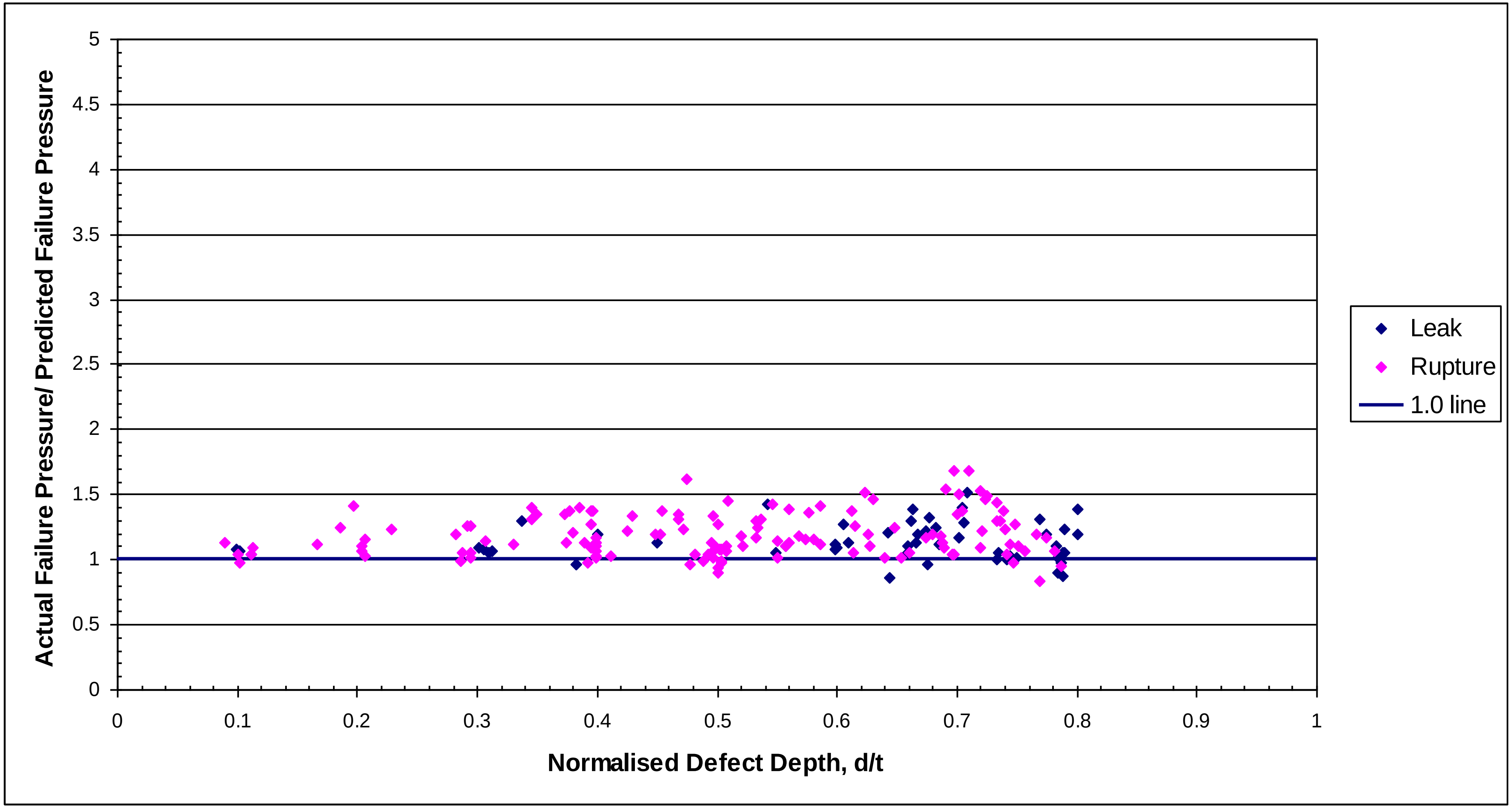

Figure 15 Comparison of Actual and Predicted Failure Pressures for the Integrated Database Using the RSTRENG Method (Case 1 Actual Material Properties)

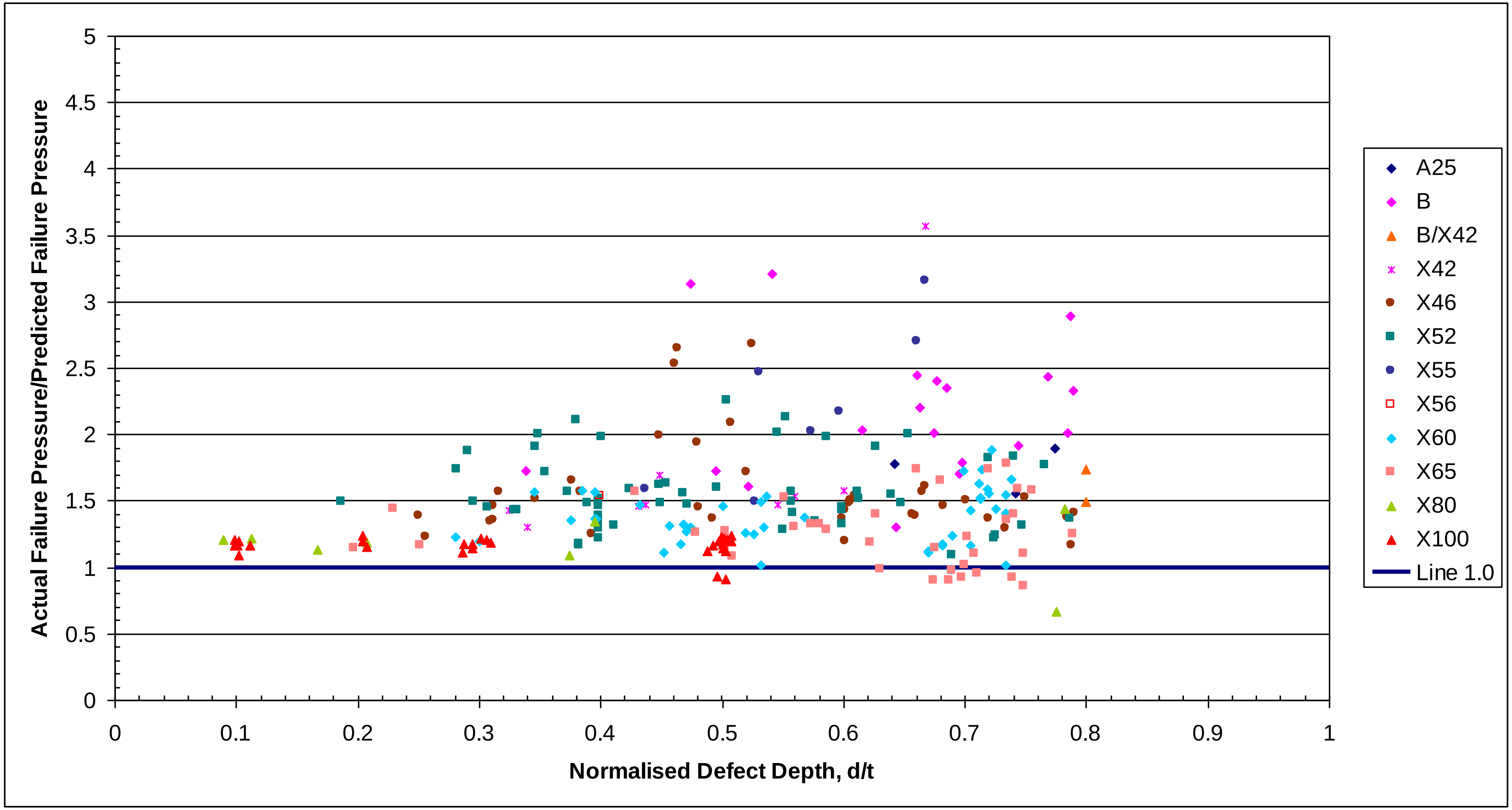

Figure 16 Comparison of Actual and Predicted Failure Pressures Using the ASME B31G Method (Case 2 Specified Minimum Material Properties)

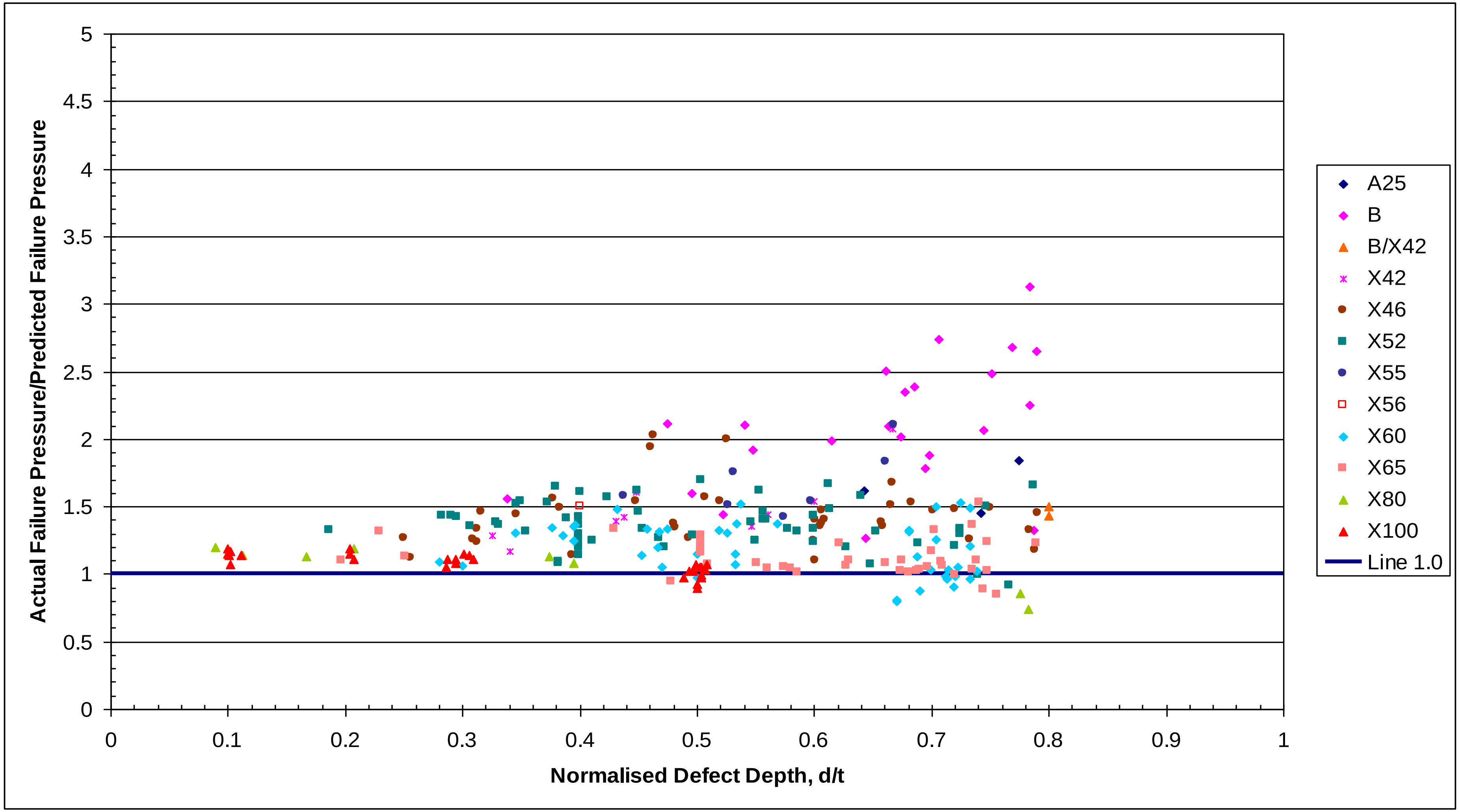

Figure 17 Comparison of Actual and Predicted Failure Pressures Using the Modified ASME B31G Method (Case 2 Specified Minimum Material Properties, including Ring Expansion Tests)

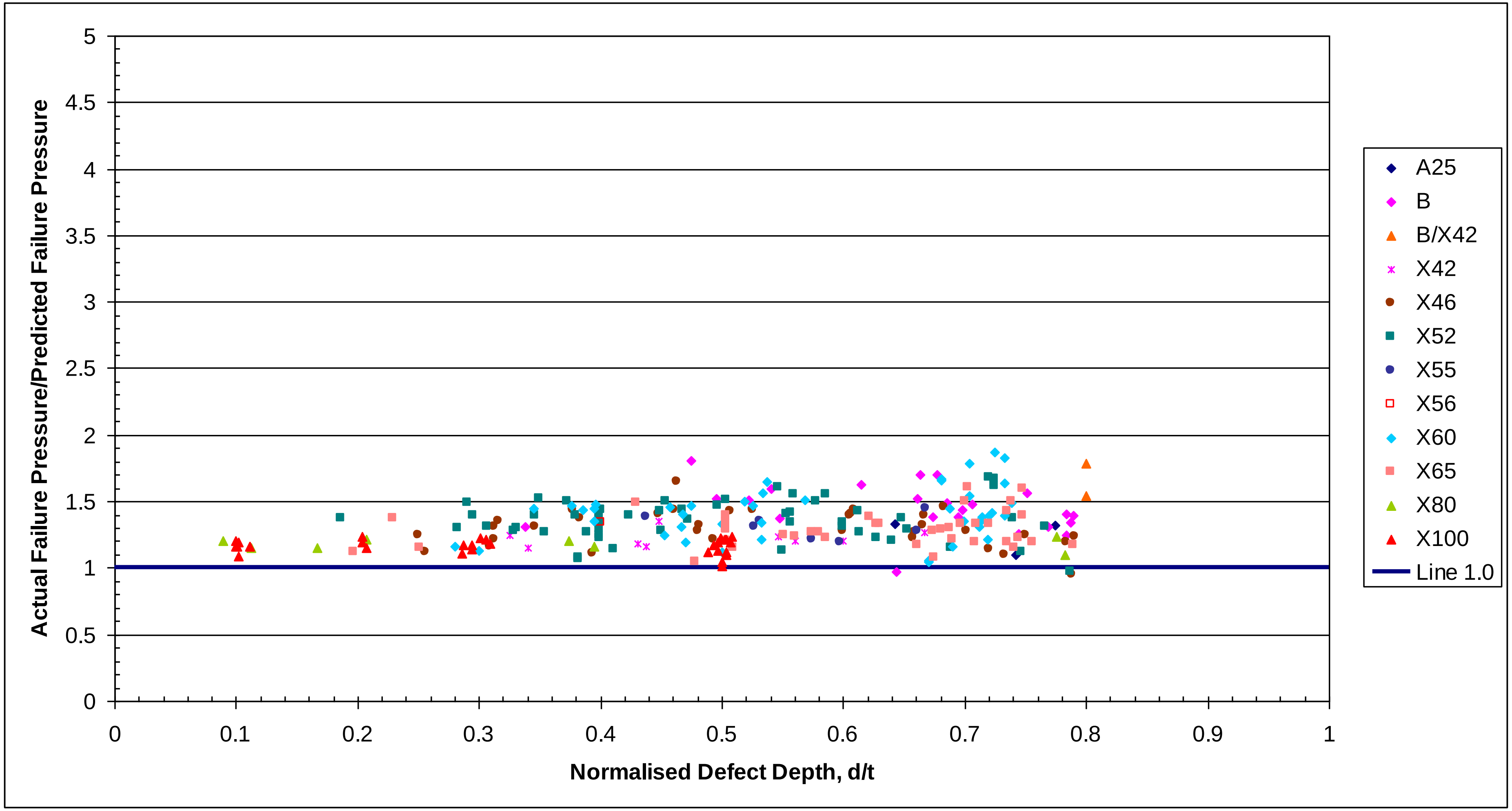

Figure 18 Comparison of Actual and Predicted Failure Pressures Using the RSTRENG Method (Case 2 Specified Minimum Material Properties)

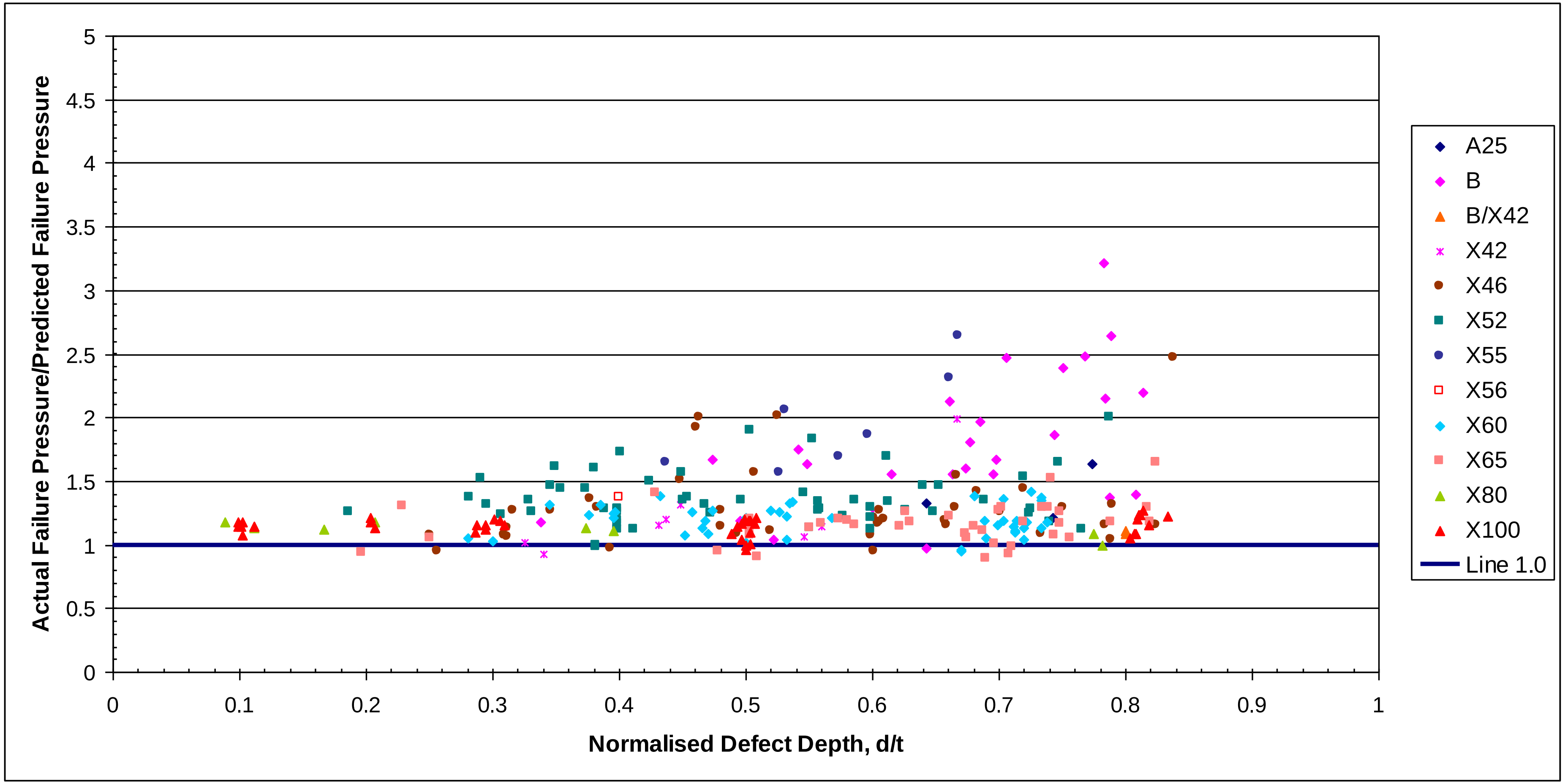

Figure 19 Comparison of Actual and Predicted Failure Pressures Using the LPC-1 Method (Case 2 Specified Minimum Material Properties)

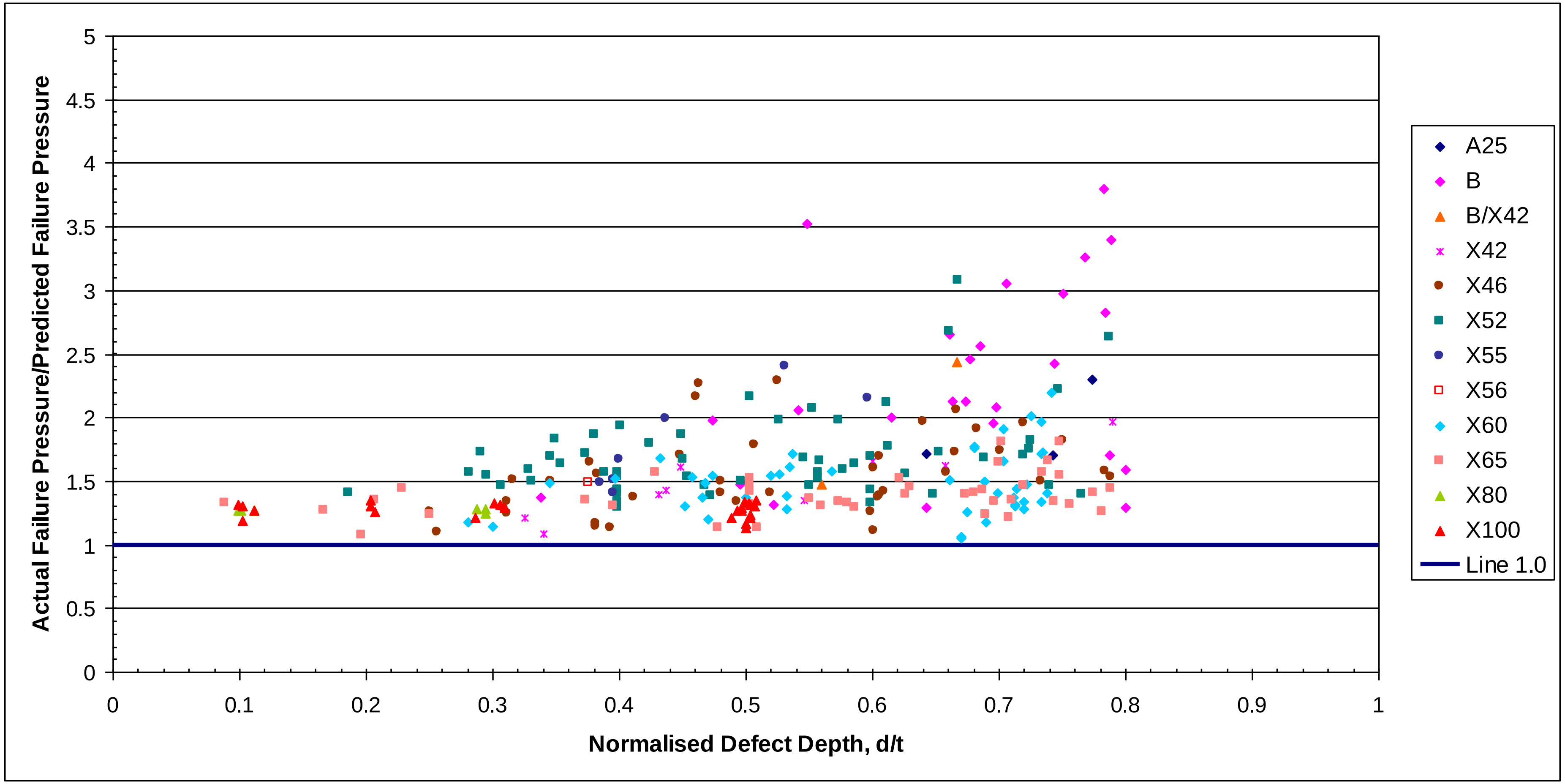

Figure 20 Comparison of Actual and Predicted Failure Pressures Using the SHELL92 Method (Case 2 Specified Minimum Material Properties)

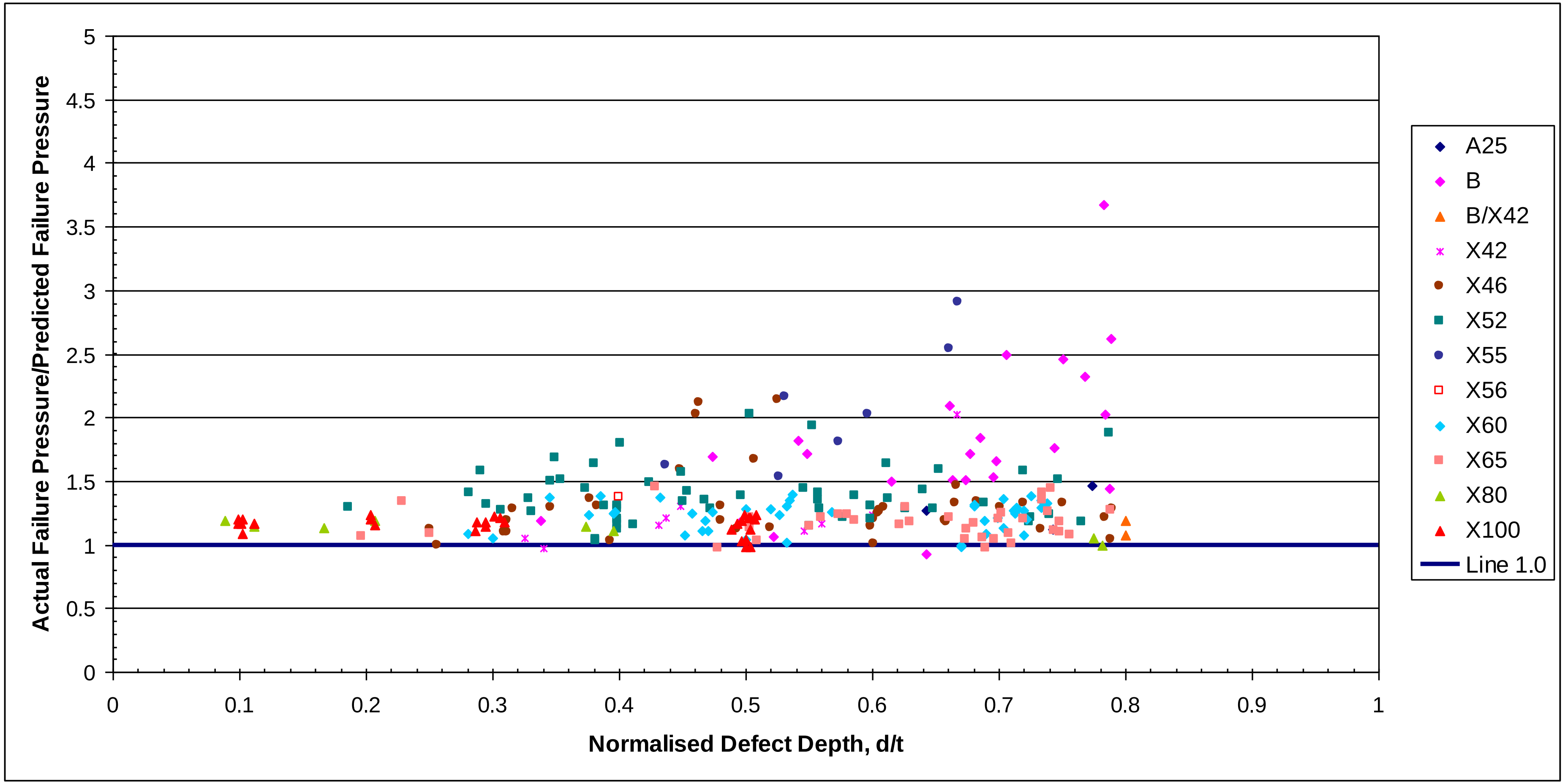

Figure 21 Comparison of Actual and Predicted Failure Pressures Using the PCORRC Method (Case 2 Specified Minimum Material Properties)

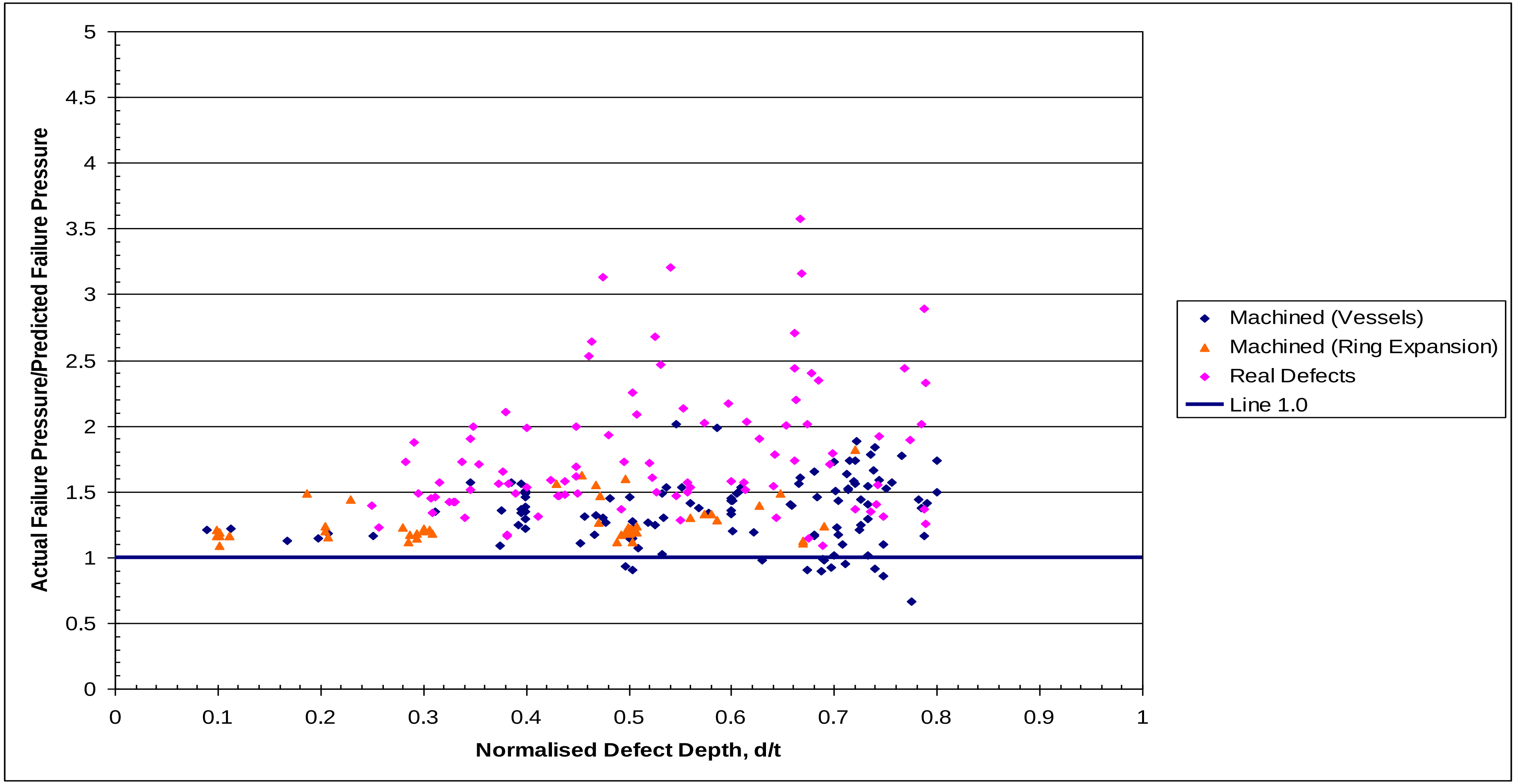

Figure 22 Comparison of Actual and Predicted Failure Pressures Using the ASME B31G Method (Case 2 Specified Minimum Material Properties) – Split Between Machined and Real Corrosion Defects

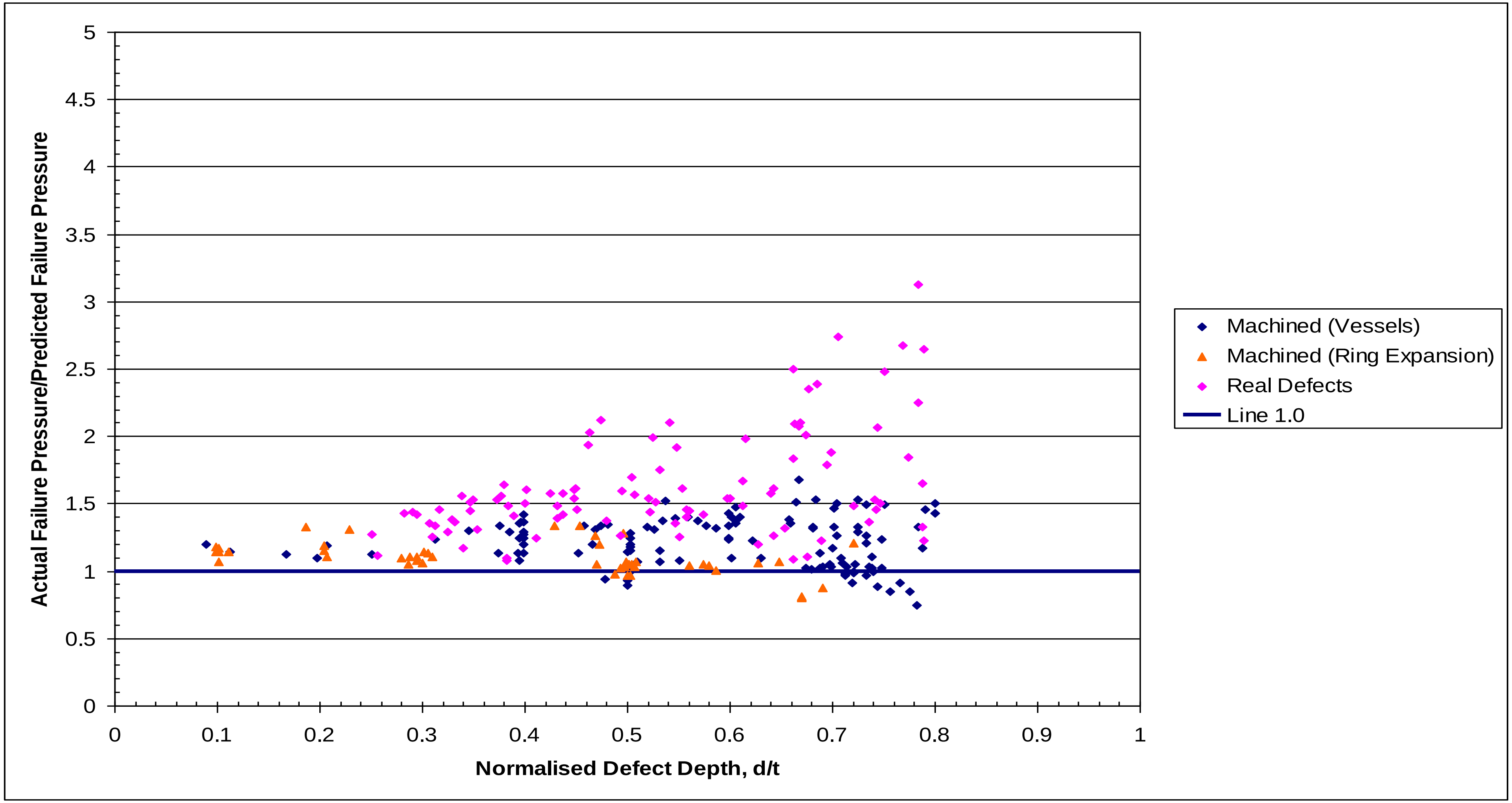

Figure 23 Comparison of Actual and Predicted Failure Pressures Using the Modified ASME B31G Method (Case 2 Specified Minimum Material Properties, including Ring Expansion Tests) – Split Between Machined and Real Corrosion Defects

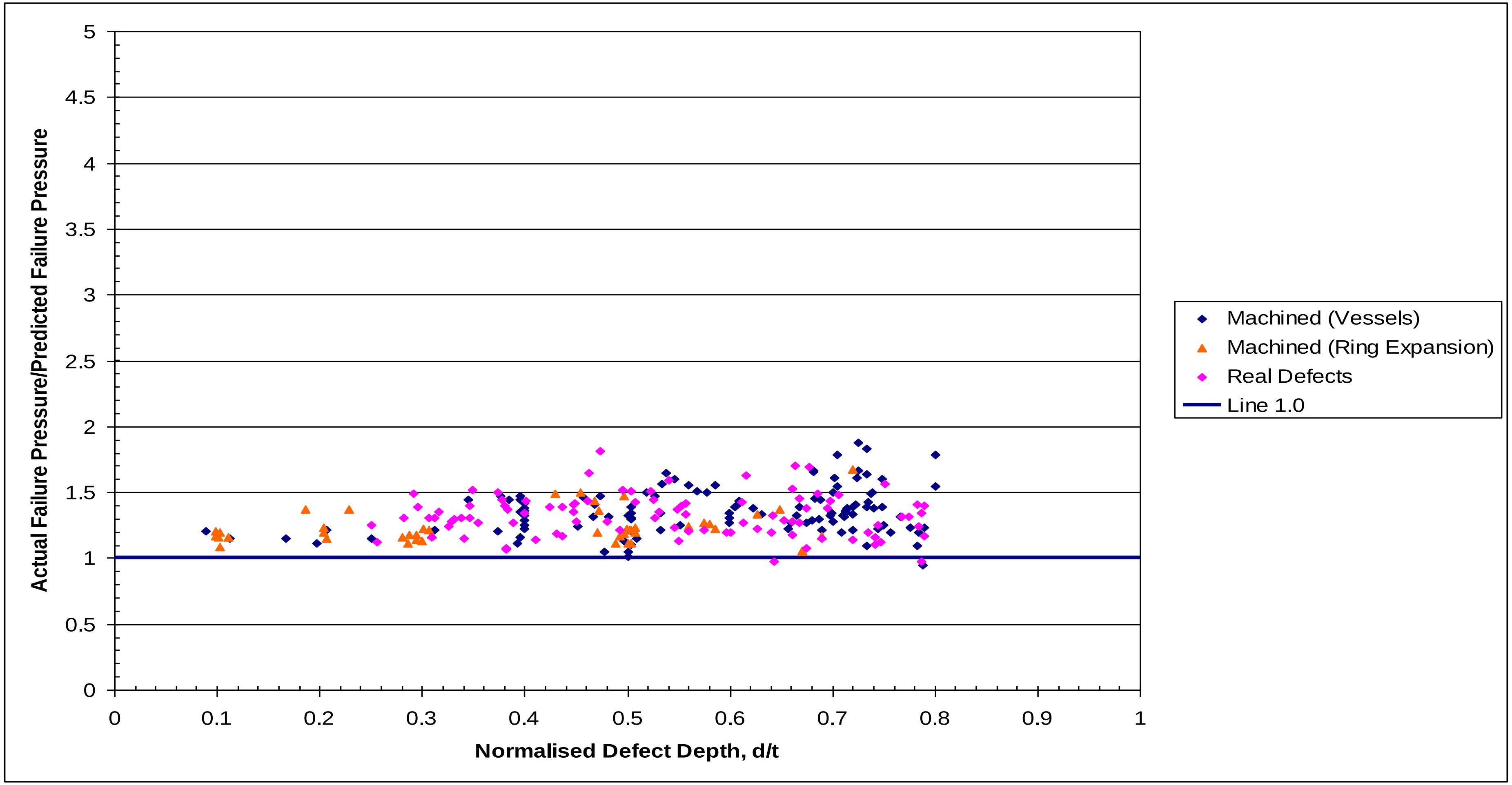

Figure 24 Comparison of Actual and Predicted Failure Pressure Using the RSTRENG Method (Case 2 Specified Minimum Material Properties) – Split Between Machined and Real Corrosion Defects

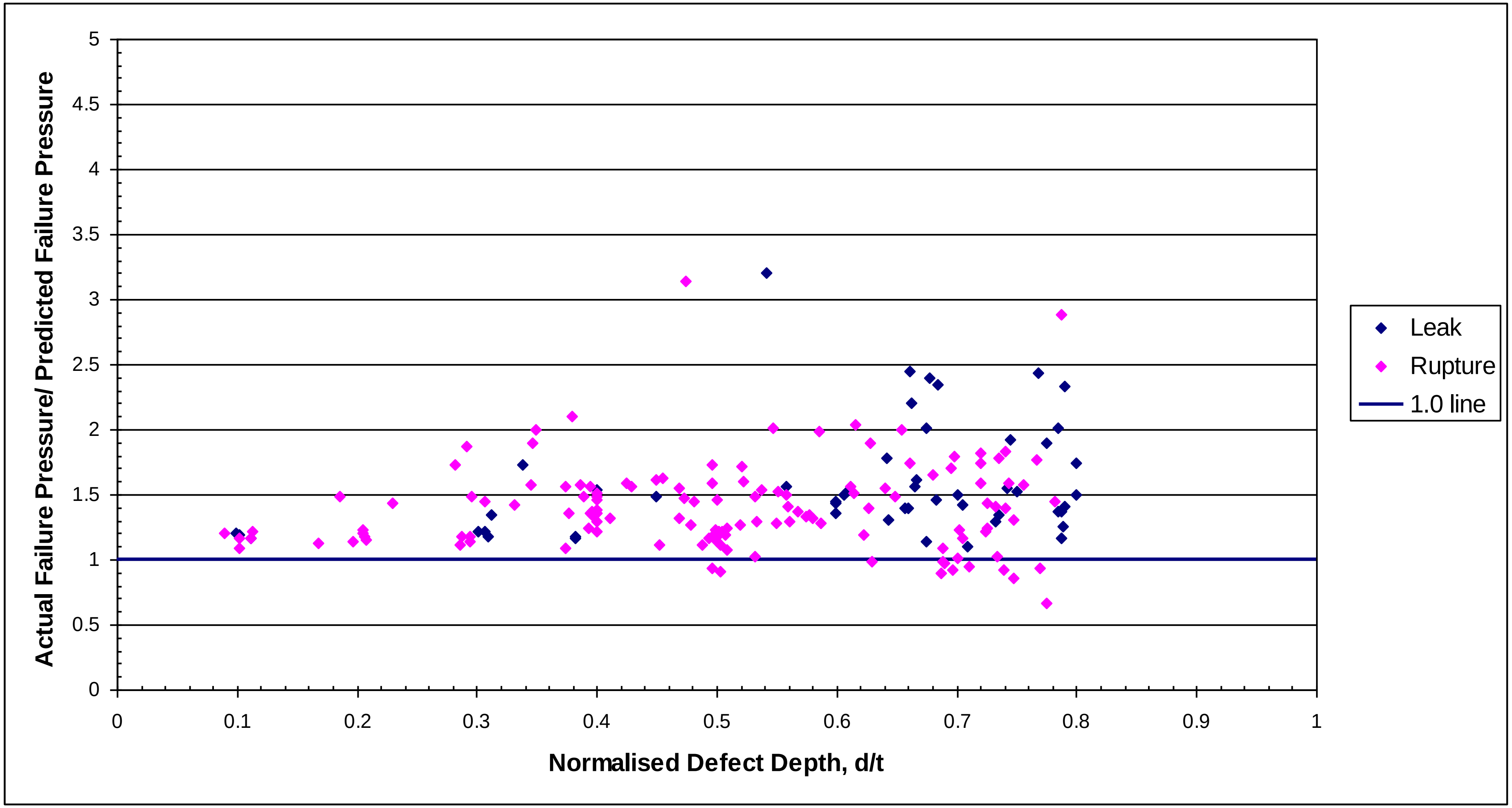

Figure 25 Comparison of Actual and Predicted Failure Pressures Using the ASME B31G Method (Case 2 Specified Minimum Material Properties) – Split Between Leaks and Ruptures

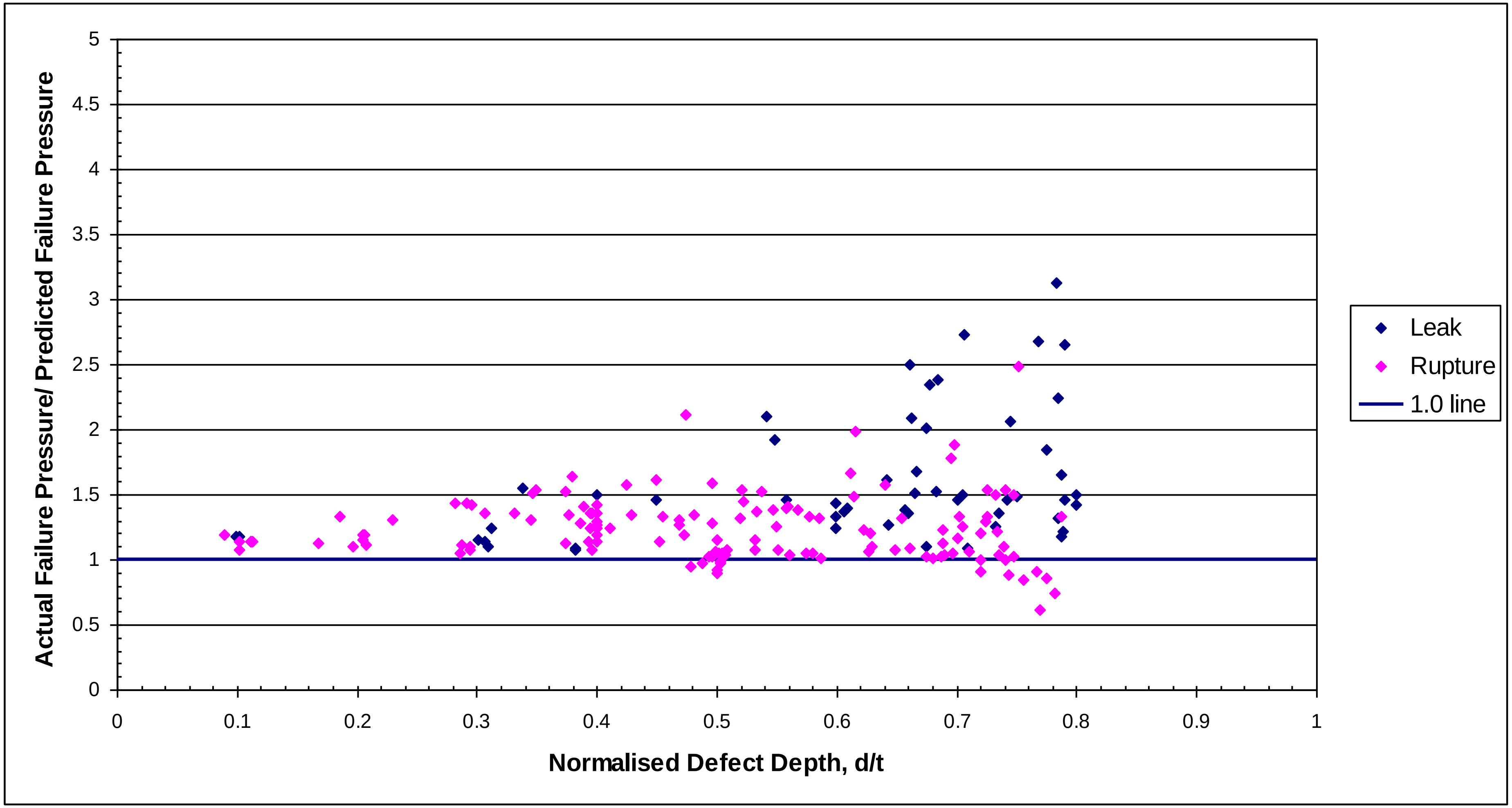

Figure 26 Comparison of Actual and Predicted Failure Pressures Using the Modified ASME B31G Method (Case 2 Specified Minimum Material Properties, including Ring Expansion Tests) – Split Between Leaks and Ruptures

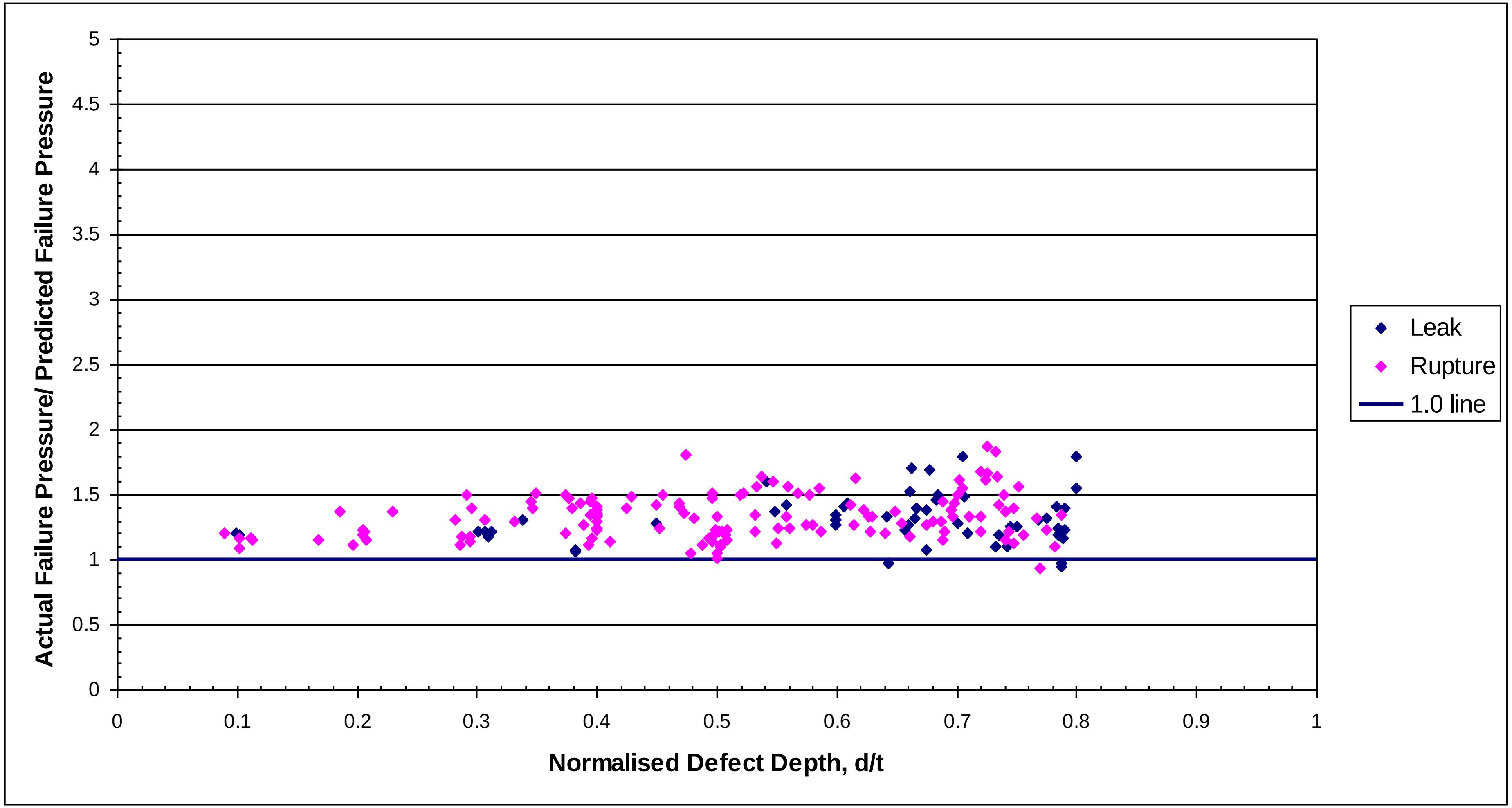

Figure 27 Comparison of Actual and Predicted Failure Pressures Using the RSTRENG Method (Case 2 Specified Minimum Material Properties) – Split Between Leaks and Ruptures Leak v Rupture

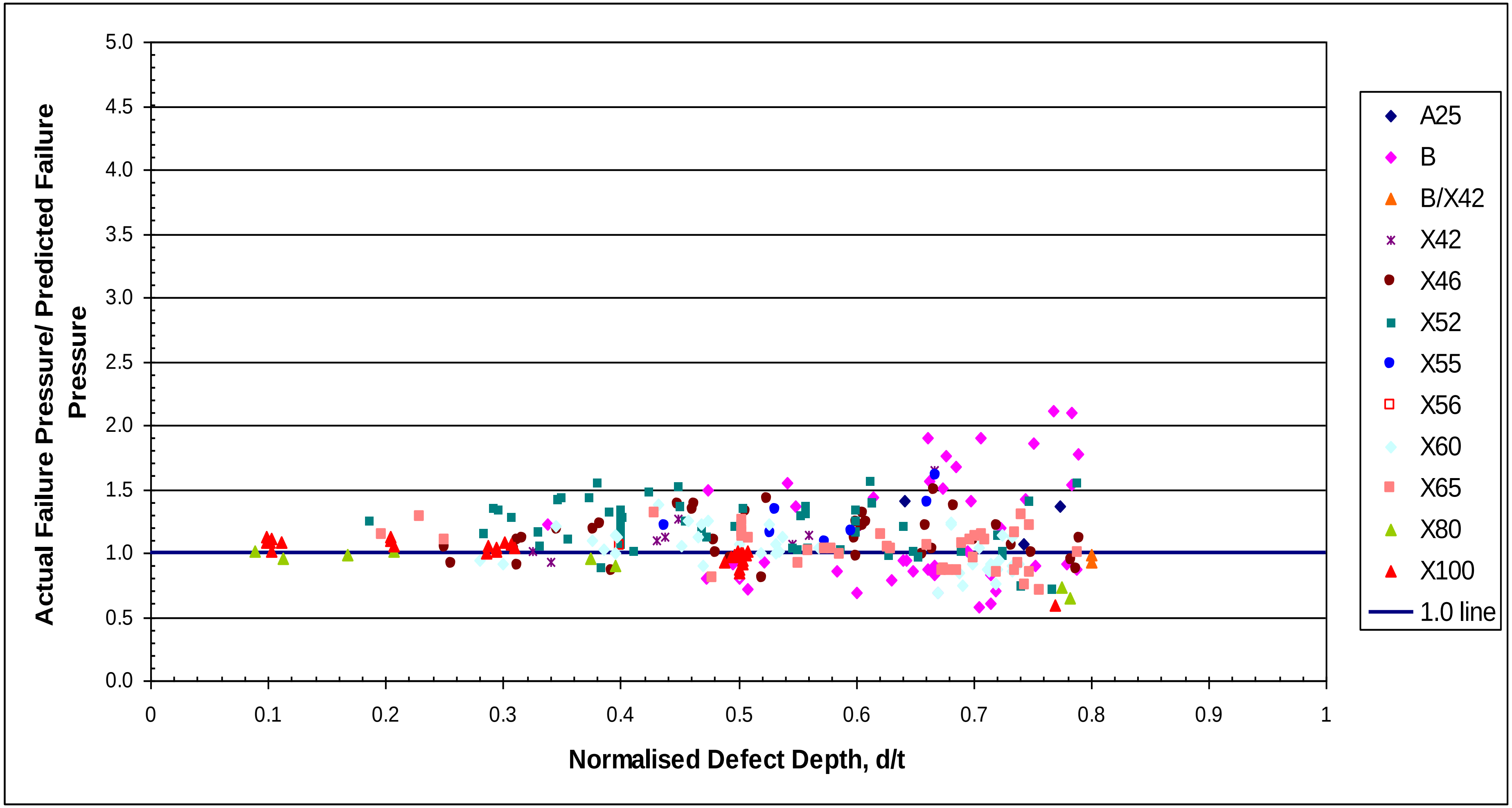

Figure 28 Comparison of Actual and Predicted Failure Pressures for the Integrated Test Database Using the ASME B31G Method (Case 3 Flow Stress Modified to Equal the Actual Tensile Strength)

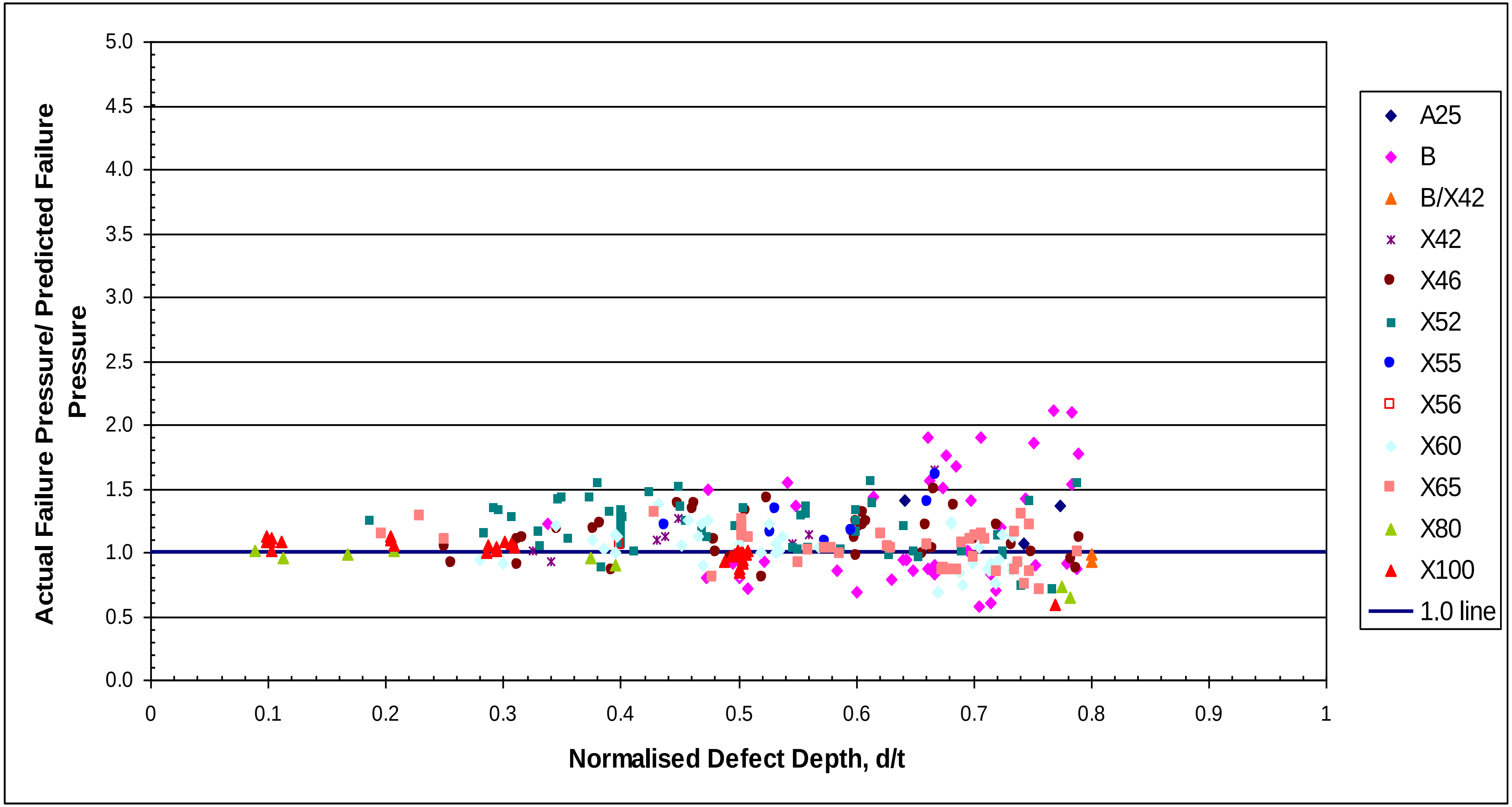

Figure 29 Comparison of Actual and Predicted Failure Pressures for the Integrated Test Database Using the Modified ASME B31G Method (Case 3 Flow Stress Modified to Equal the Actual Tensile Strength, including Ring Expansion Tests)

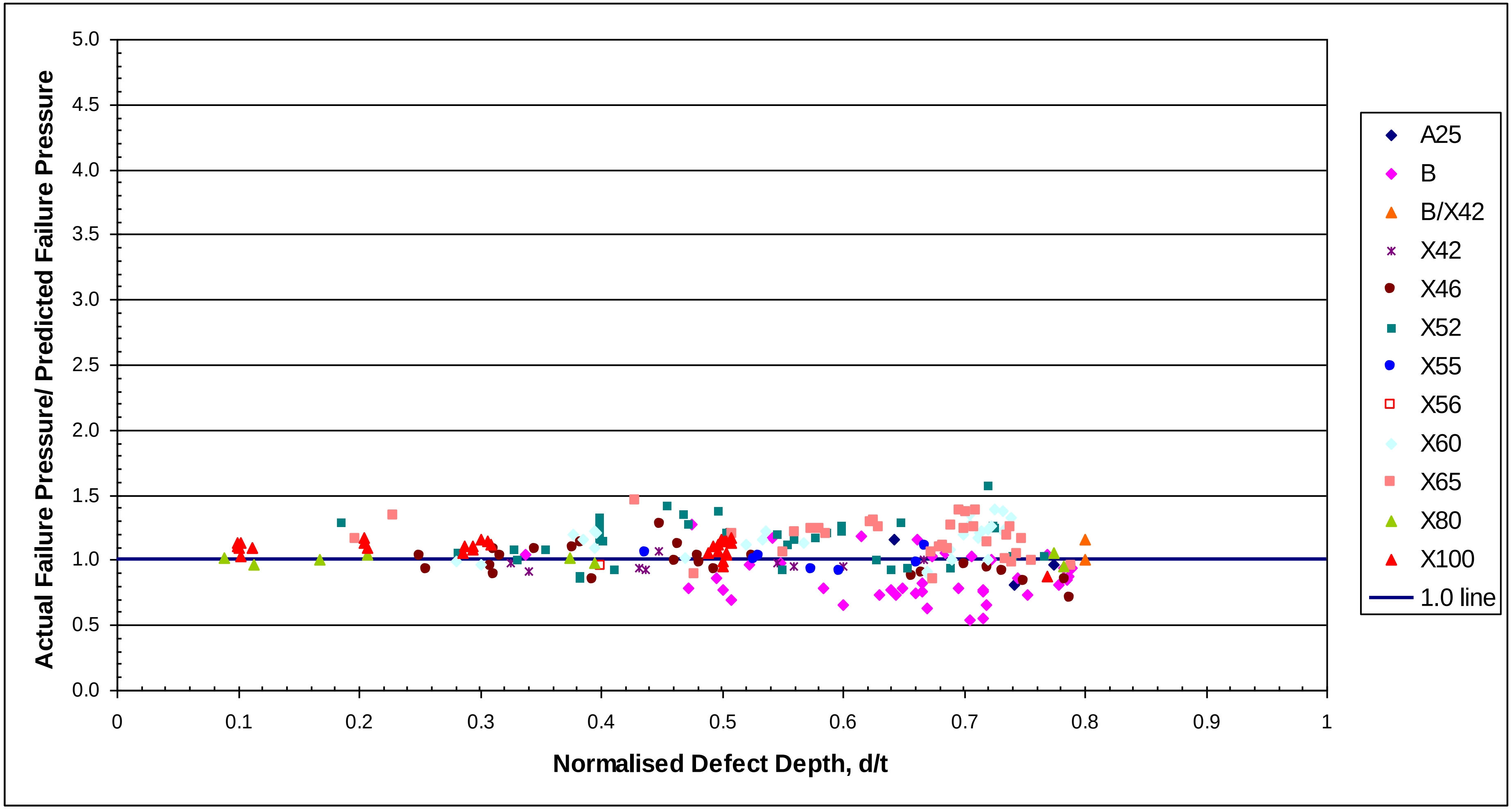

Figure 30 Comparison of Actual and Predicted Failure Pressures for the Integrated Test Database Using the RSTRENG Method (Case 3 Flow Stress Modified to Equal the Actual Tensile Strength)

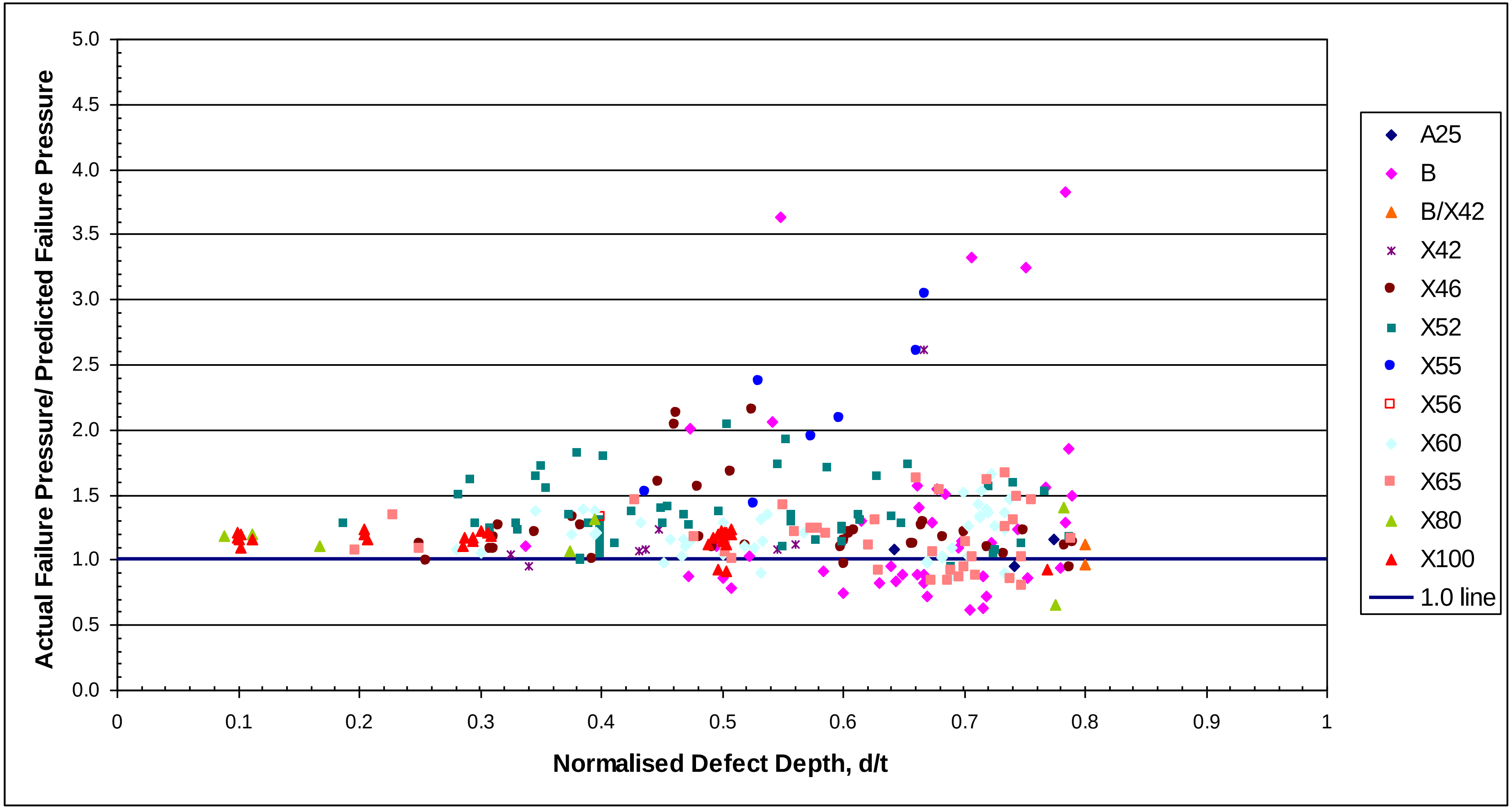

Figure 31 Comparison of Actual and Predicted Failure Pressures for the Integrated Test Database Using the ASME B31G Method (Case 4 Flow Stress Modified to Equal the Specified Minimum Tensile Strength)

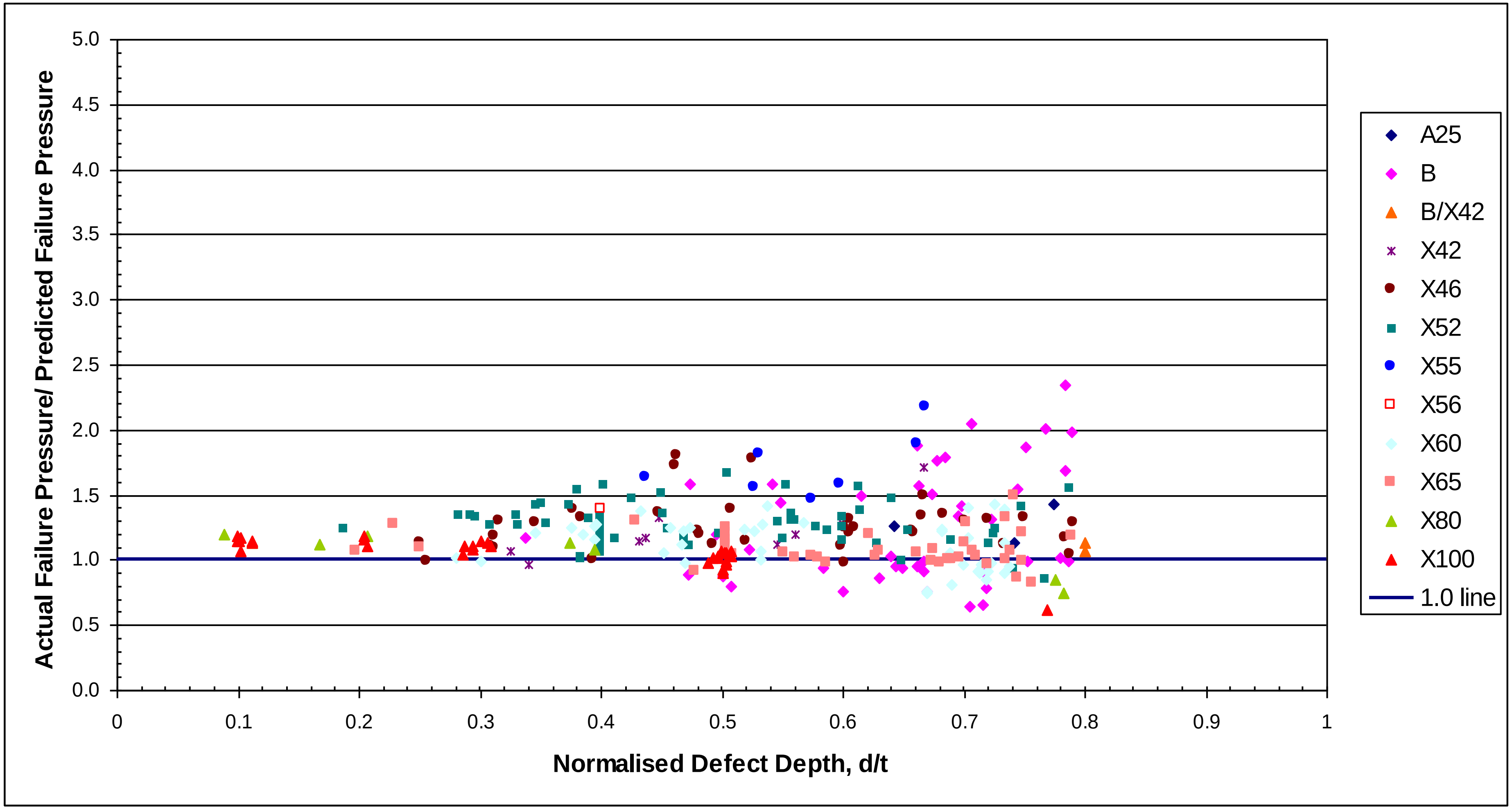

Figure 32 Comparison of Actual and Predicted Failure Pressures for the Integrated Test Database Using the Modified ASME B31G Method (Case 4 Flow Stress Modified to Equal the Specified Minimum Tensile Strength, including Ring Expansion Tests)

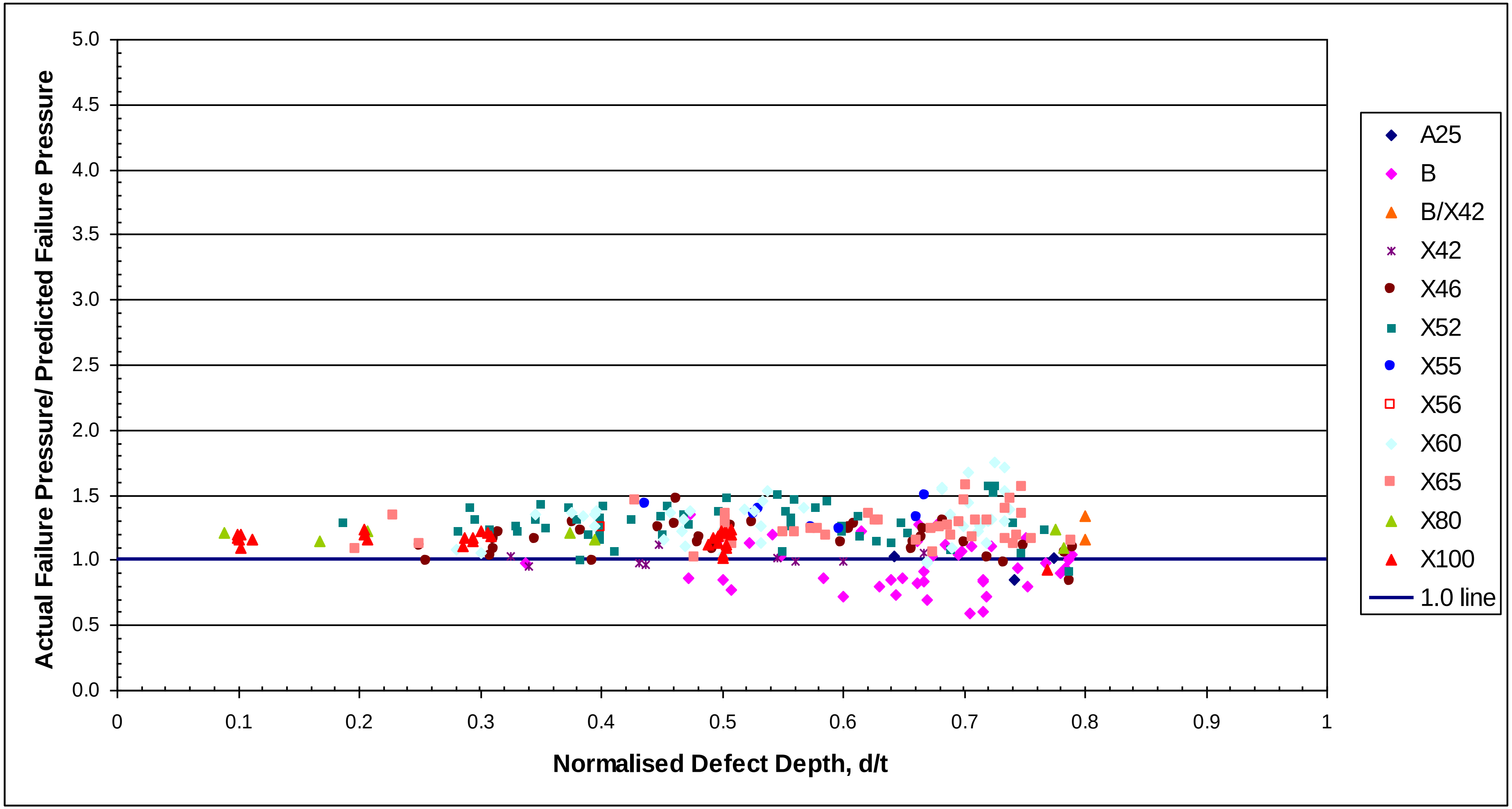

Figure 33 Comparison of Actual and Predicted Failure Pressures for the Integrated Test Database Using the RSTRENG Method (Case 4 Flow Stress Modified to Equal the Specified Minimum Tensile Strength)

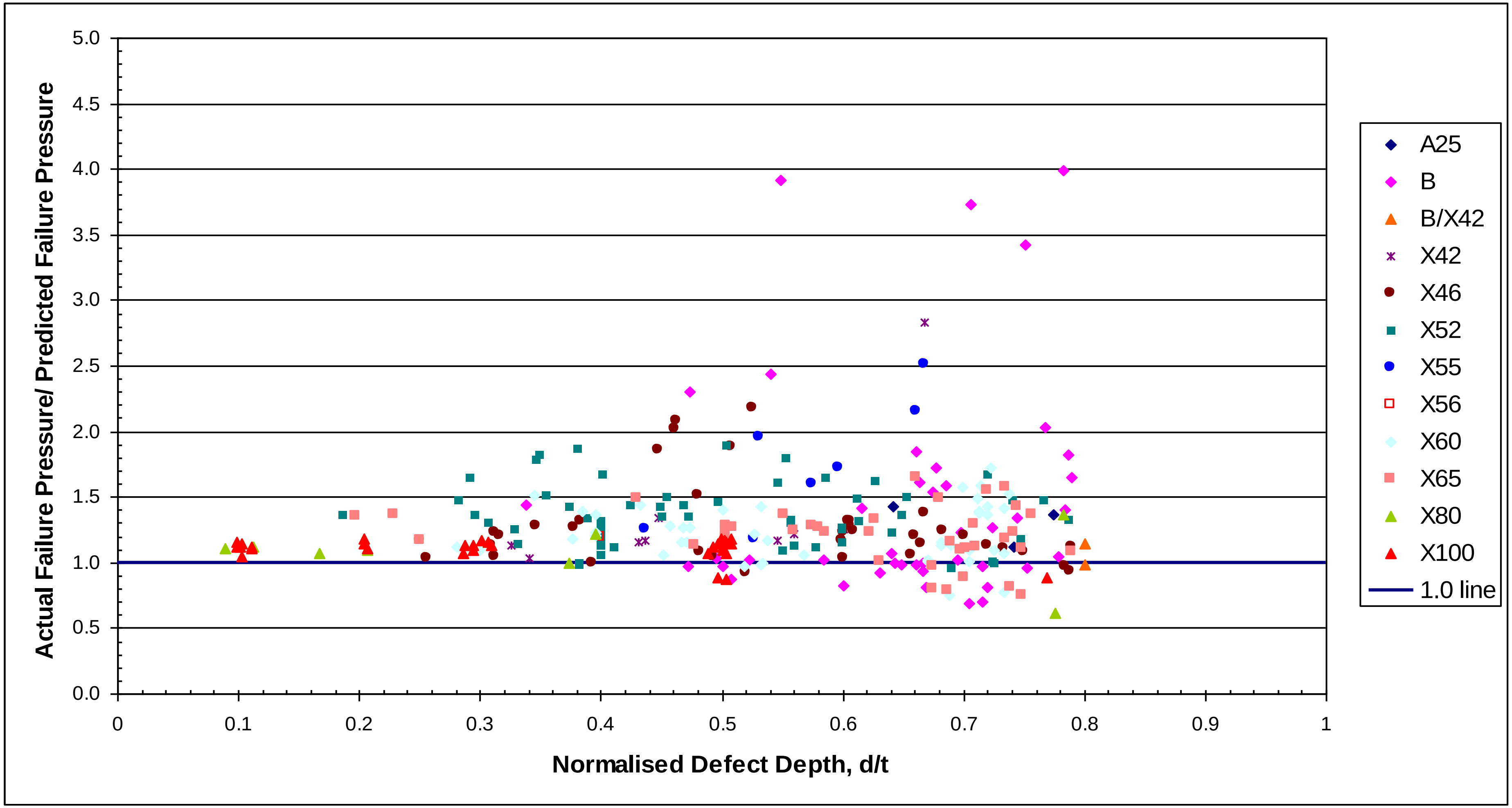

Figure 34 Comparison of Actual and Predicted Failure Pressures for the Integrated Test Database Using the ASME B31G Method (Case 5 Flow Stress Modified to Equal the Mean of the Actual Tensile and Ultimate Tensile Strength)

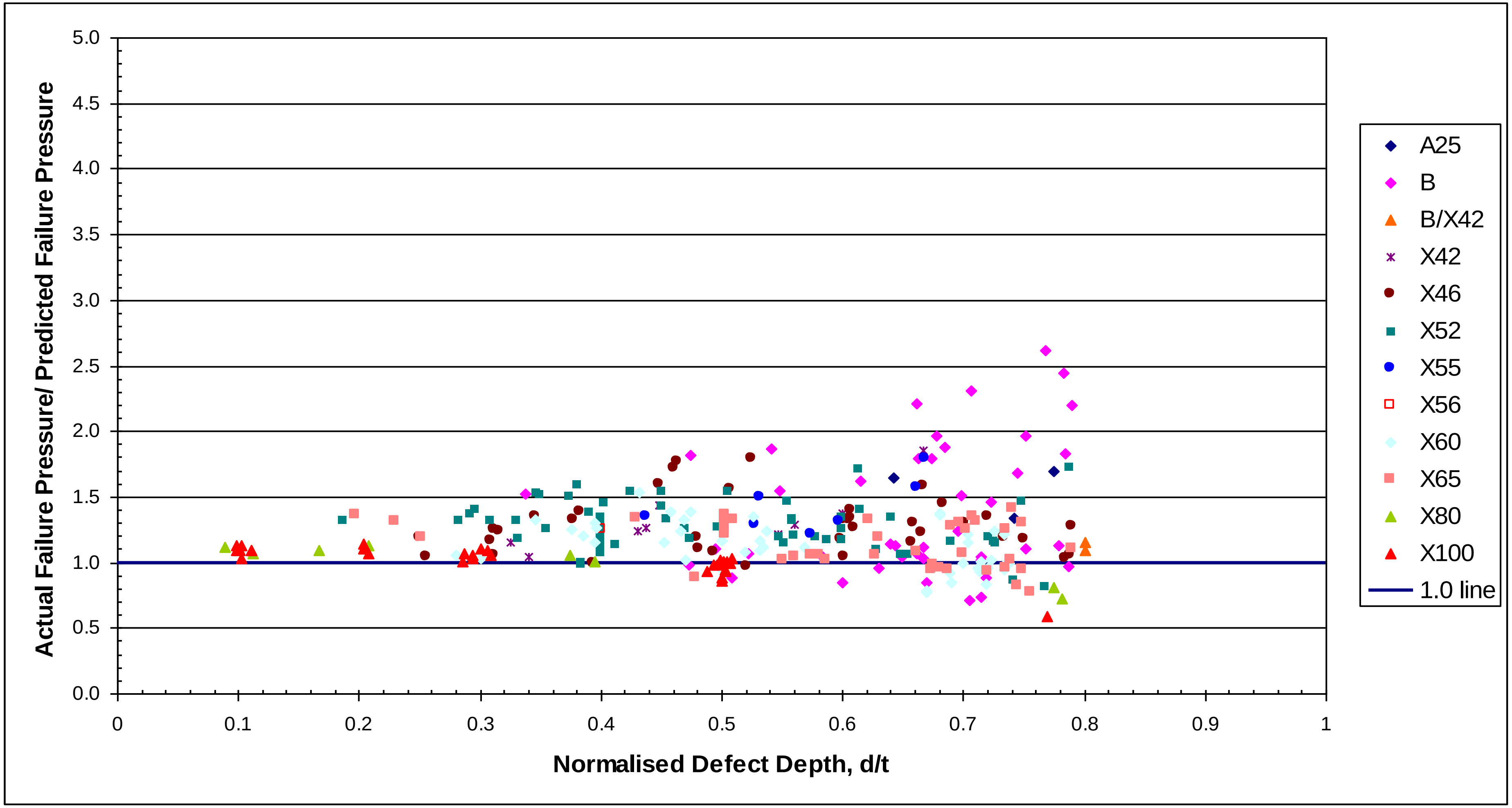

Figure 35 Comparison of Actual and Predicted Failure Pressures for the Integrated Test Database Using the Modified ASME B31G Method (Case 5 Flow Stress Modified to Equal the Mean of the Actual Tensile and Ultimate Tensile Strength, including Ring Expansion Tests)

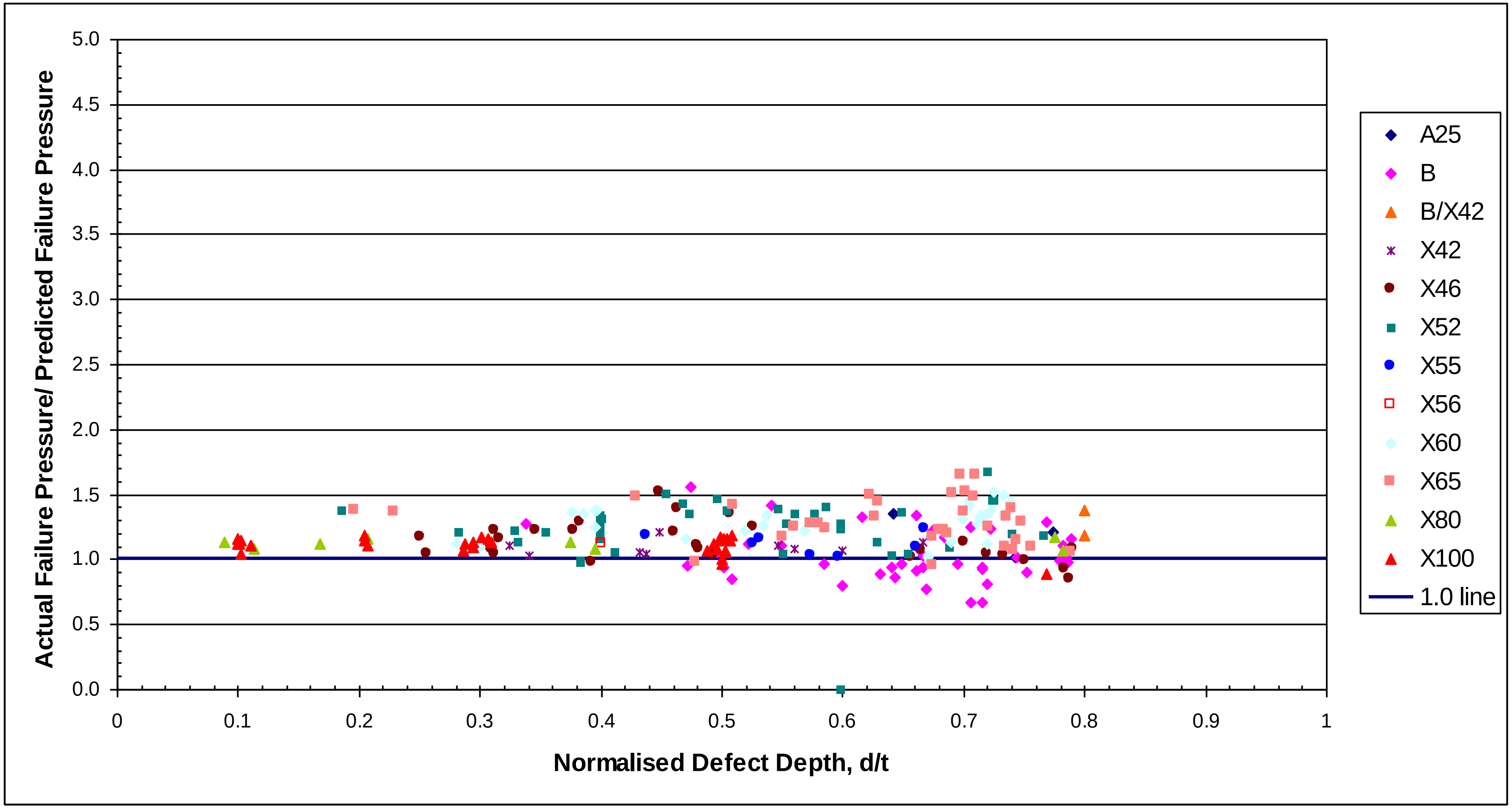

Figure 36 Comparison of Actual and Predicted Failure Pressures Using the RSTRENG Method (Case 5 Flow Stress Modified to Equal the Mean of the Actual Tensile and Ultimate Tensile Strength)

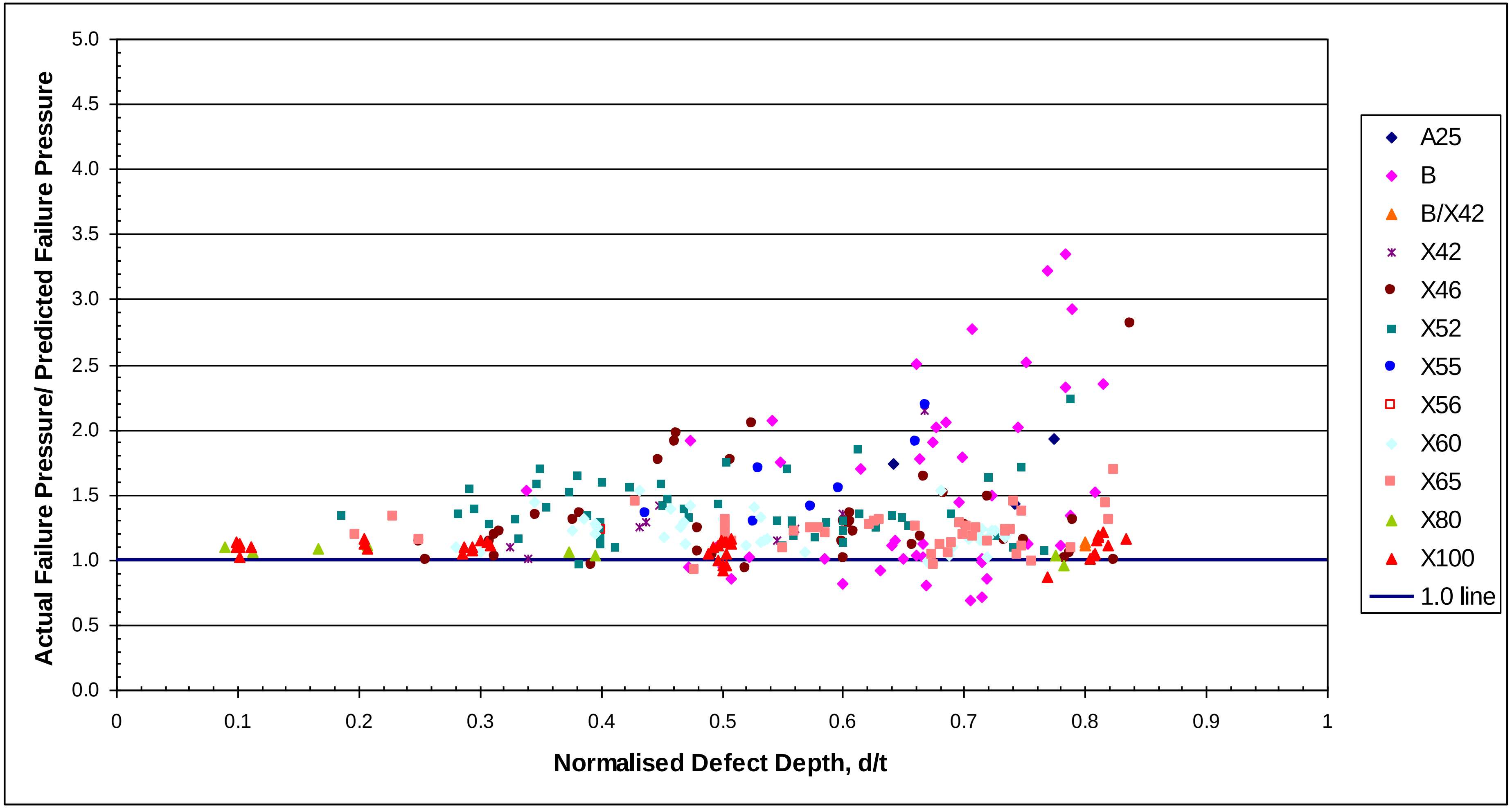

Figure 37 Comparison of Actual and Predicted Failure Pressures Using the LPC-1 Method (Case 5 Flow Stress Modified to Equal the Mean of the Actual Tensile and Ultimate Tensile Strength)

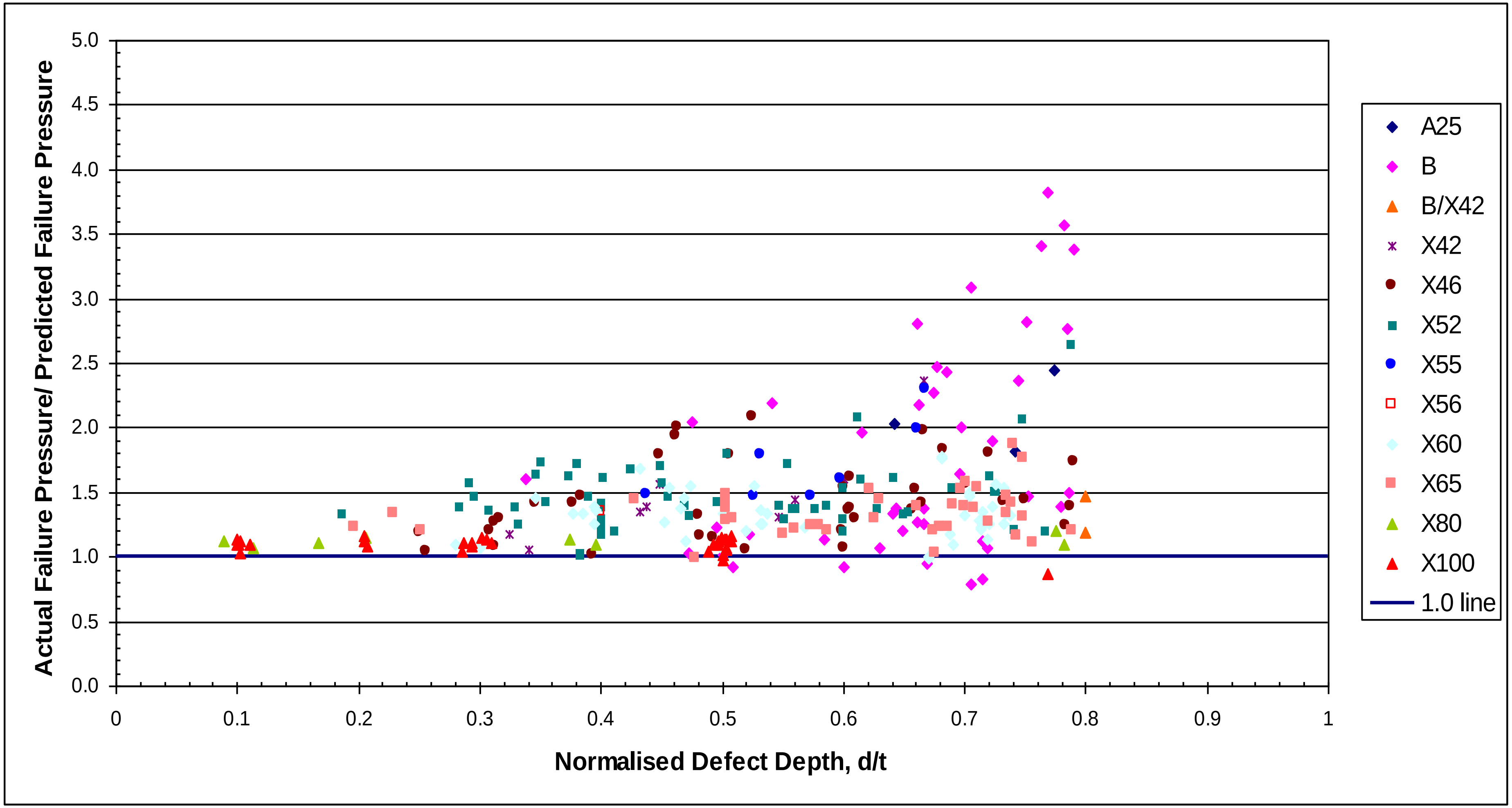

Figure 38 Comparison of Actual and Predicted Failure Pressure Using the SHELL92 Method (Case 5 Flow Stress Modified to Equal the Mean of the Actual Tensile and Ultimate Tensile Strength)

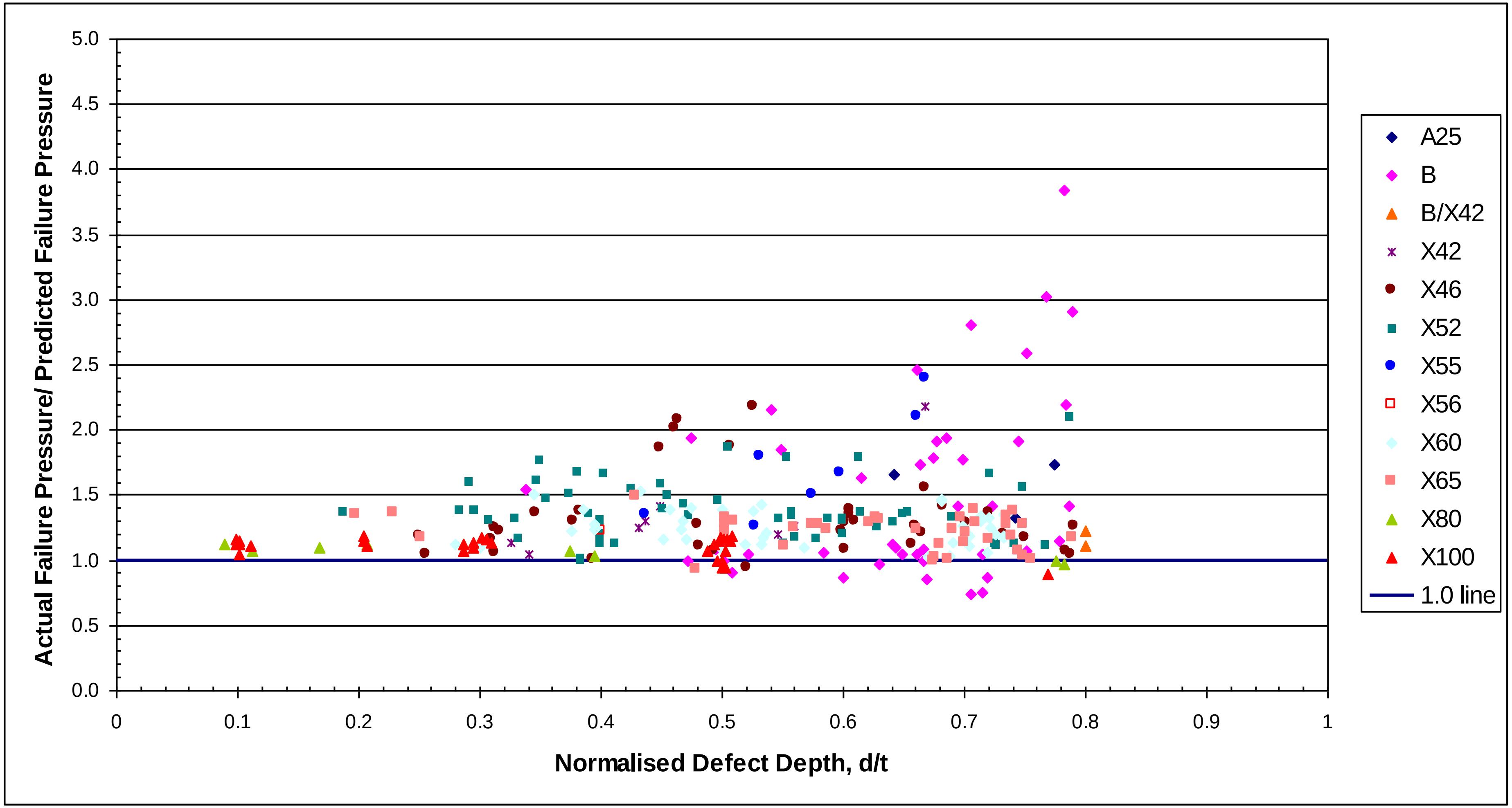

Figure 39 Comparison of Actual and Predicted Failure Pressures Using the PCORRC Method (Case 5 Flow Stress Modified to Equal the Mean of the Actual Tensile and Ultimate Tensile Strength)

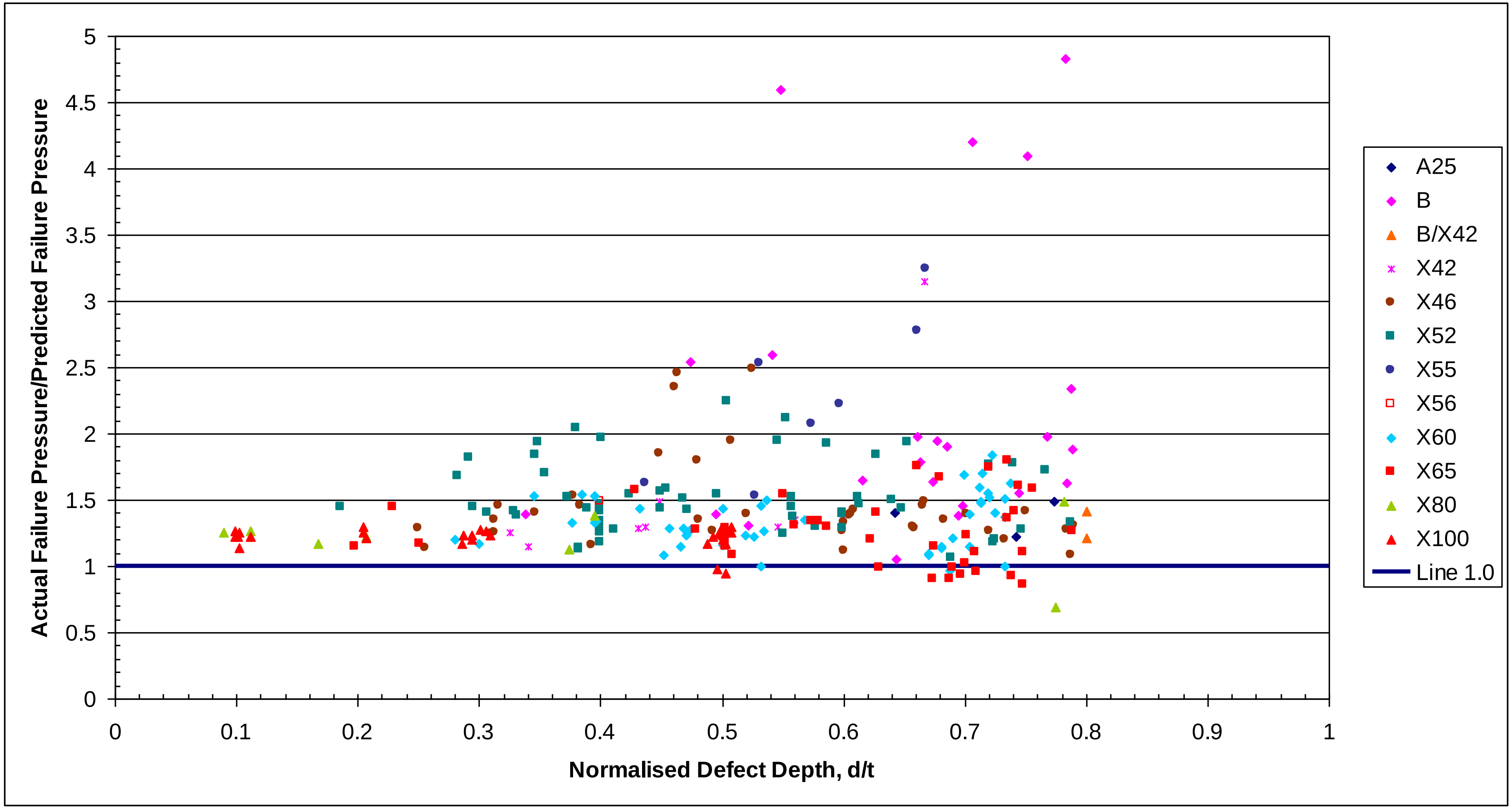

Figure 40 Comparison of Actual and Predicted Failure Pressures Using the ASME B31G Method (Case 6 Flow Stress Modified to Equal the Mean of the Specified Minimum Tensile and Ultimate Tensile Strength)

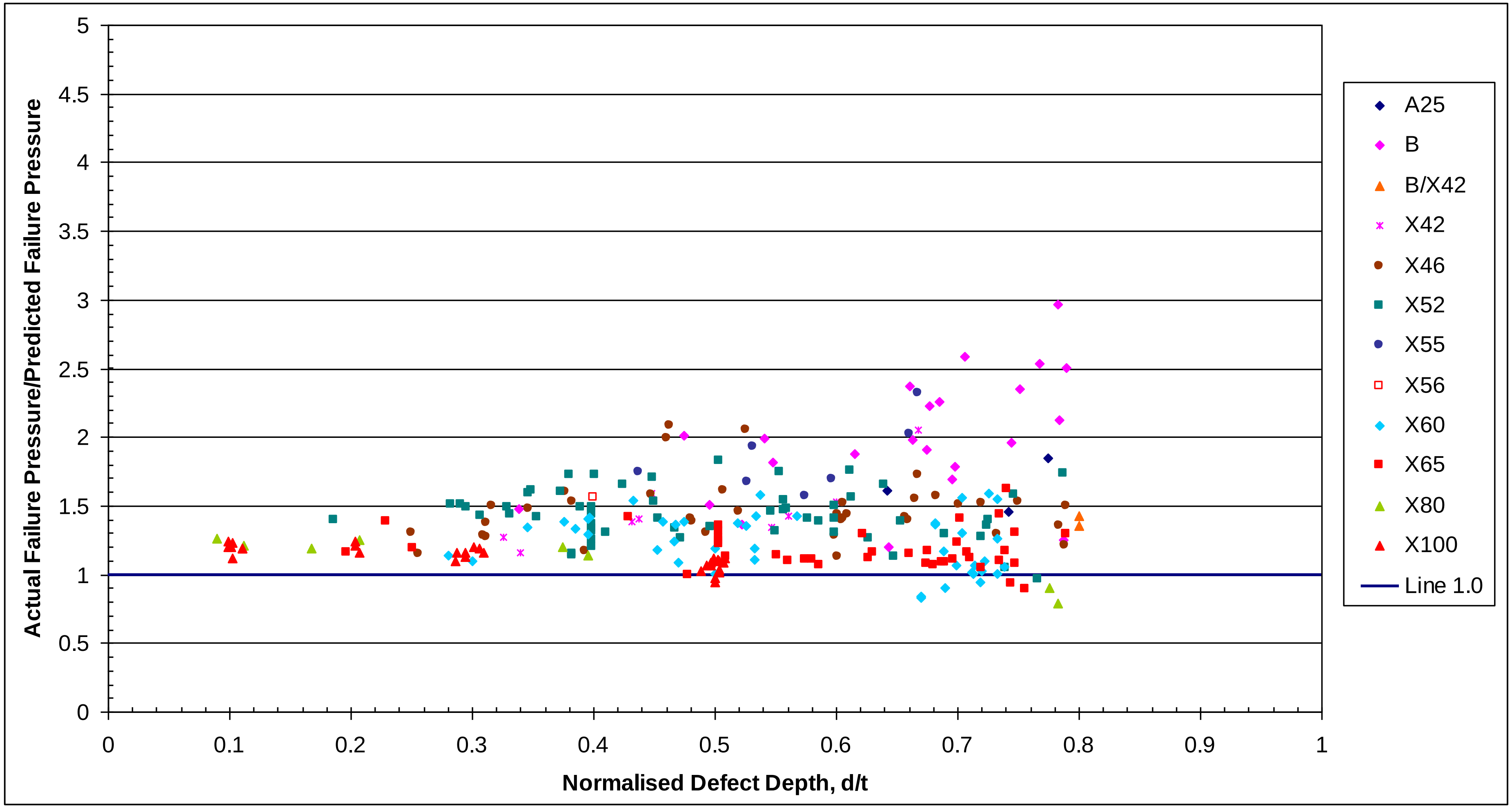

Figure 41 Comparison of Actual and Predicted Failure Pressures Using the Modified ASME B31G Method (Case 6 Flow Stress Modified to Equal the Mean of the Specified Minimum Tensile and Ultimate Tensile Strength, including Ring Expansion Tests)

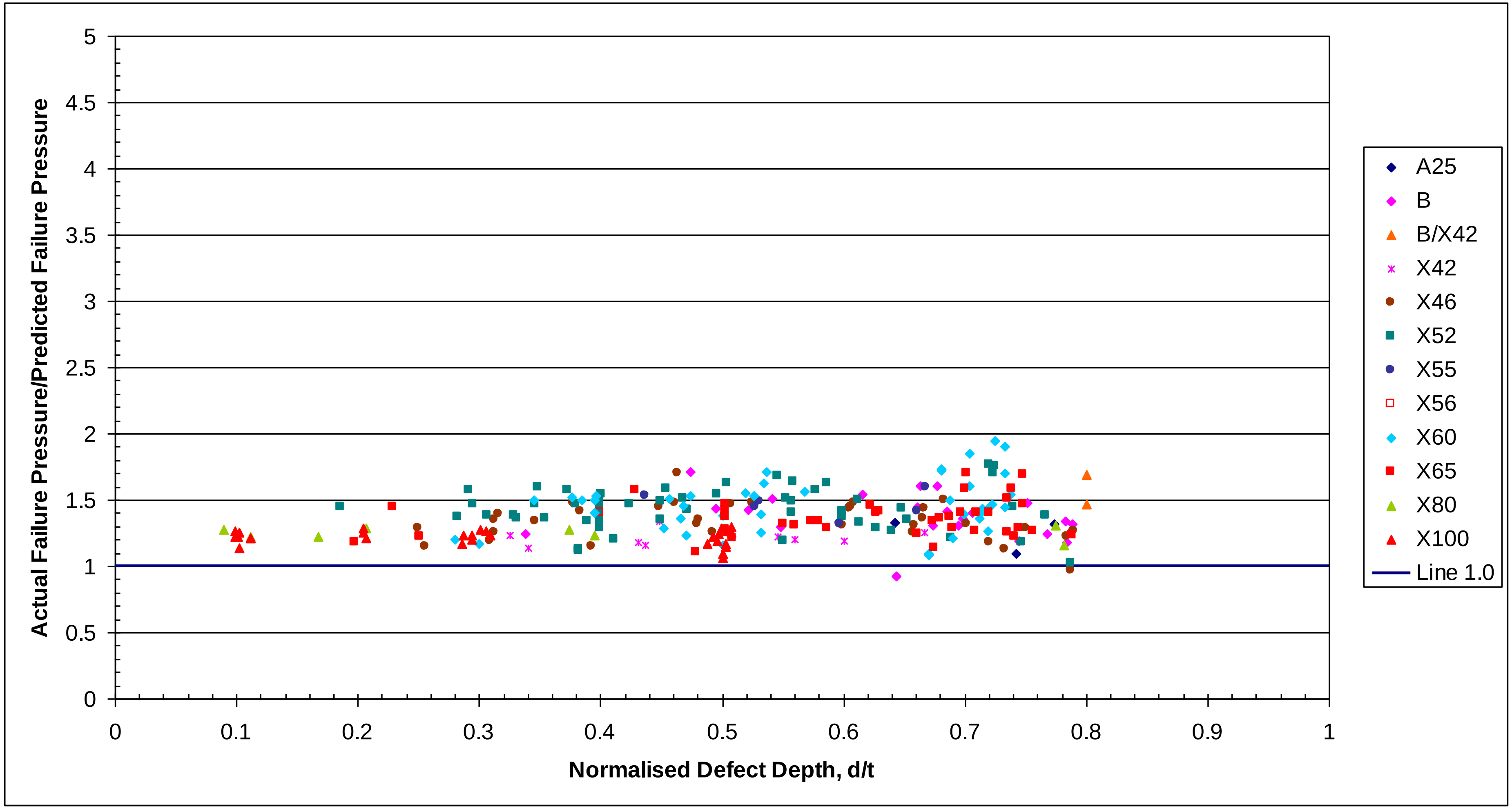

Figure 42 Comparison of Actual and Predicted Failure Pressures Using the RSTRENG Method (Case 6 Flow Stress Modified to Equal the Mean of the Specified Minimum Tensile and Ultimate Tensile Strength)

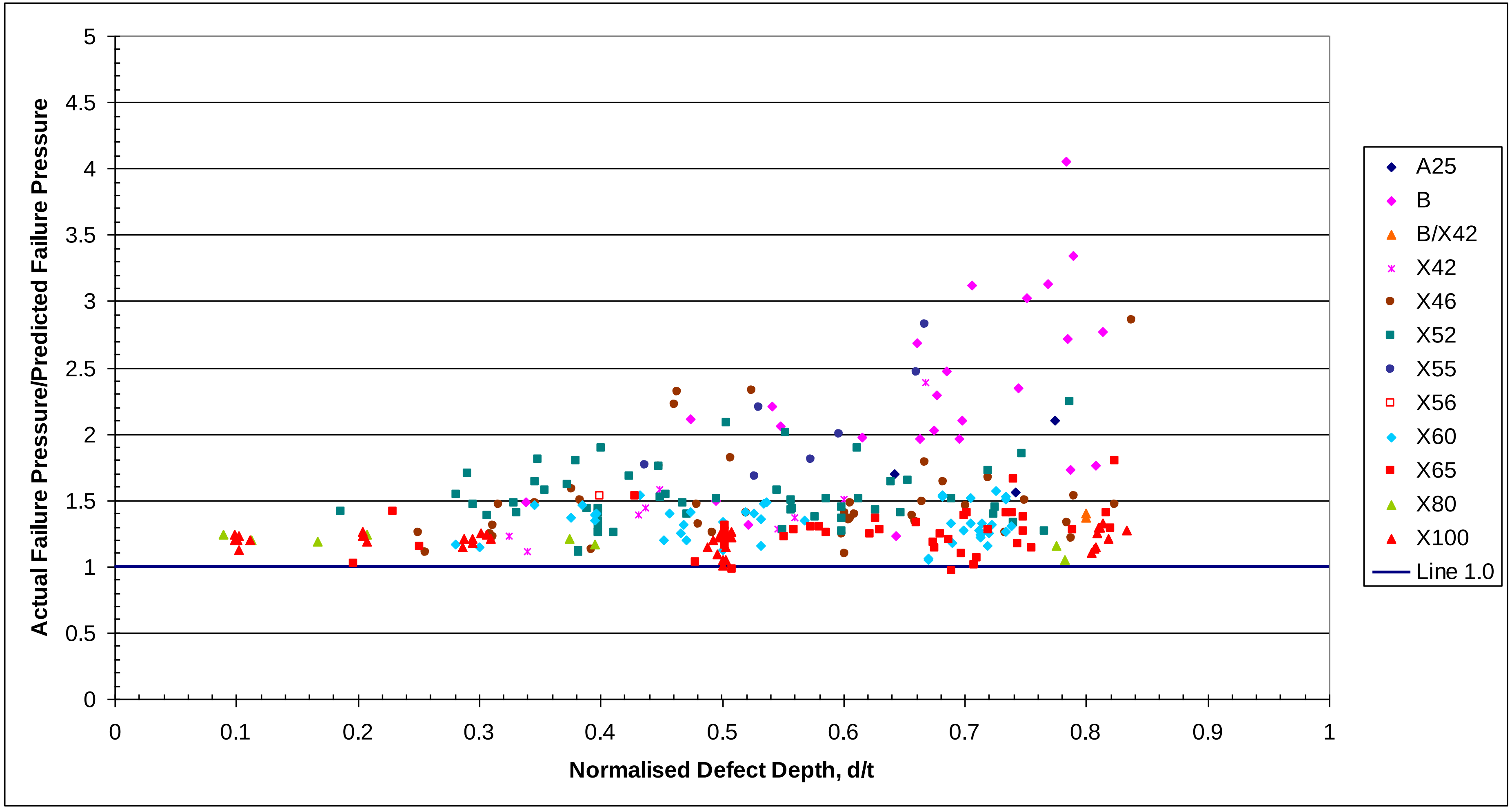

Figure 43 Comparison of Actual and Predicted Failure Pressures Using the LPC-1 Method (Case 6 Flow Stress Modified to Equal the Mean of the Specified Minimum Tensile and Ultimate Tensile Strength)

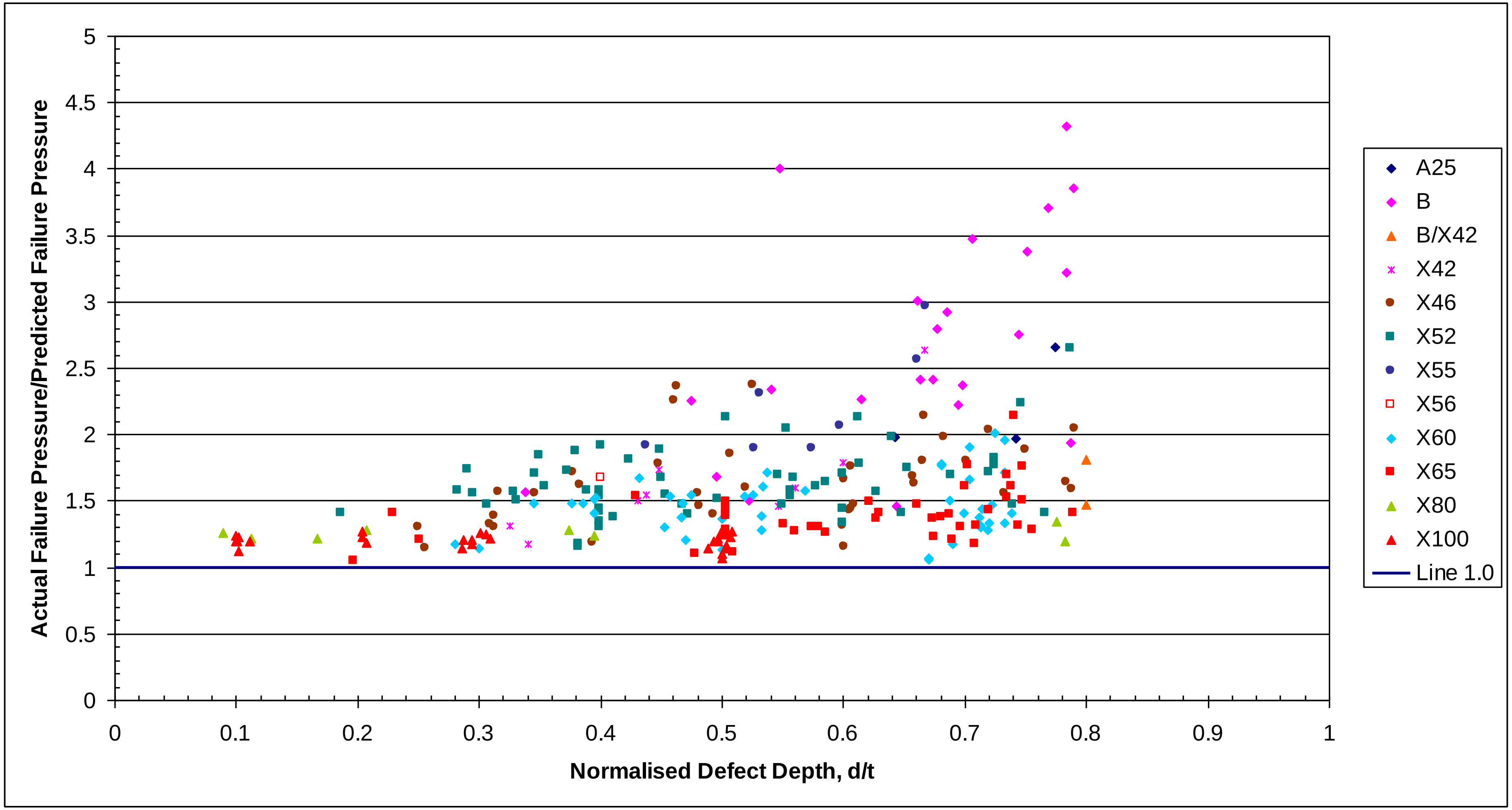

Figure 44 Comparison of Actual and Predicted Failure Pressures Using the SHELL92 Method (Case 6 Flow Stress Modified to Equal the Mean of the Specified Minimum Tensile and Ultimate Tensile Strength)

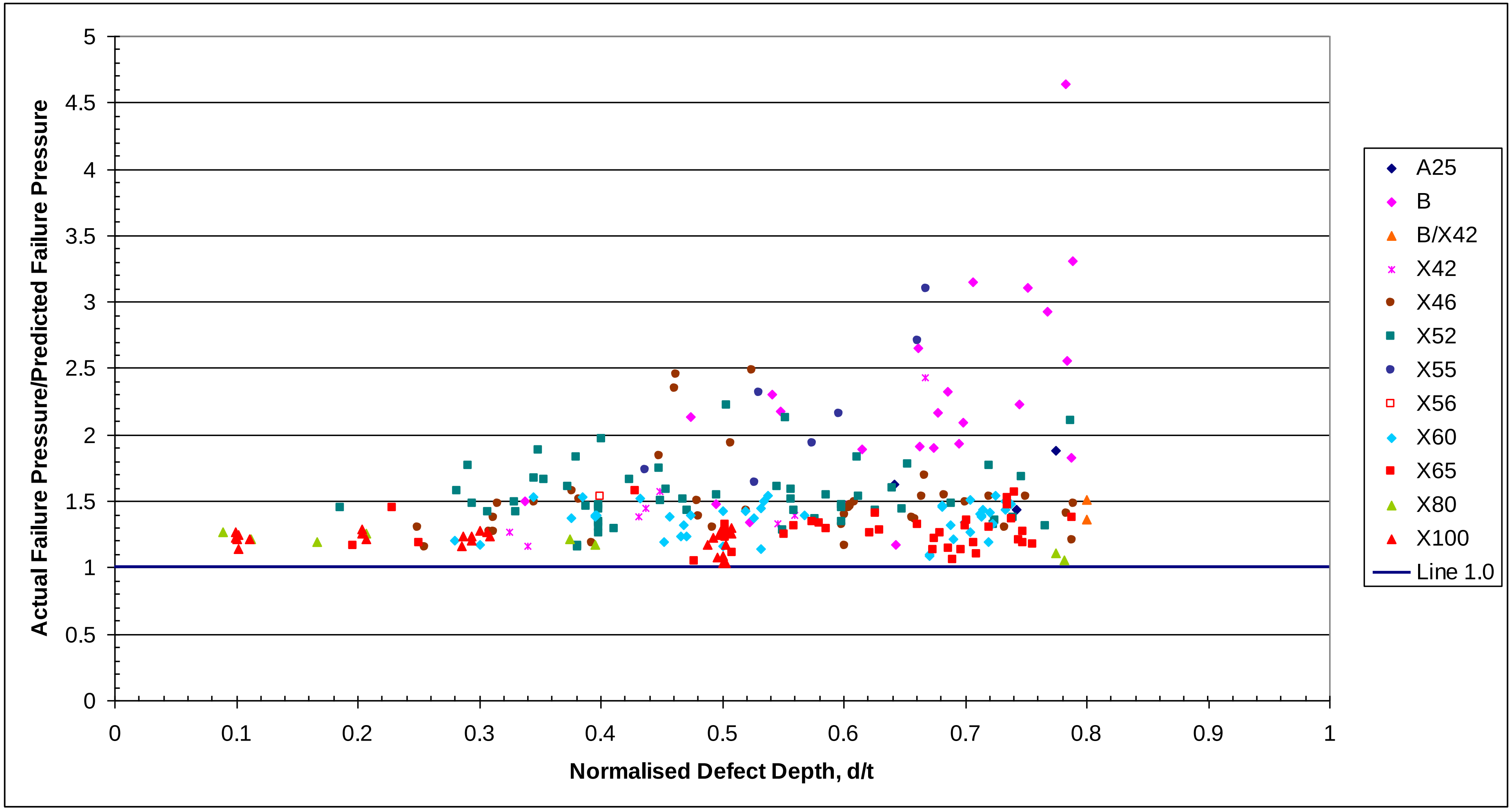

Figure 45 Comparison of Actual and Predicted Failure Pressures Using the PCORRC Method (Case 6 Flow Stress Modified to Equal the Mean of the Specified Minimum Tensile and Ultimate Tensile Strength)

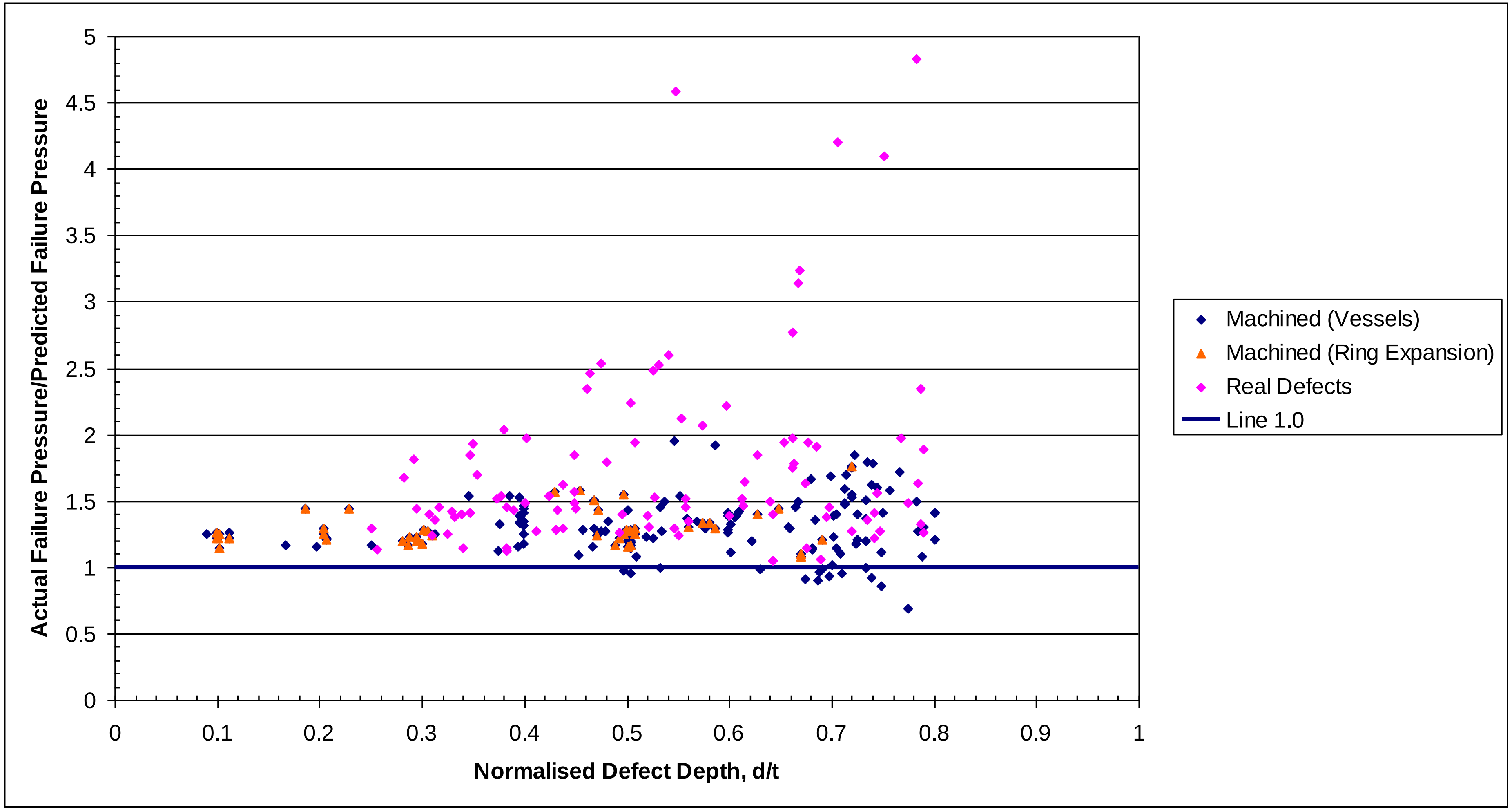

Figure 46 Comparison of Actual and Predicted Failure Pressure Using the ASME B31G Method (Case 6 Flow Stress Modified to Equal the Mean of the Specified Minimum Tensile and Ultimate Tensile Strength) – Split Between Machined and Real Corrosion Defects

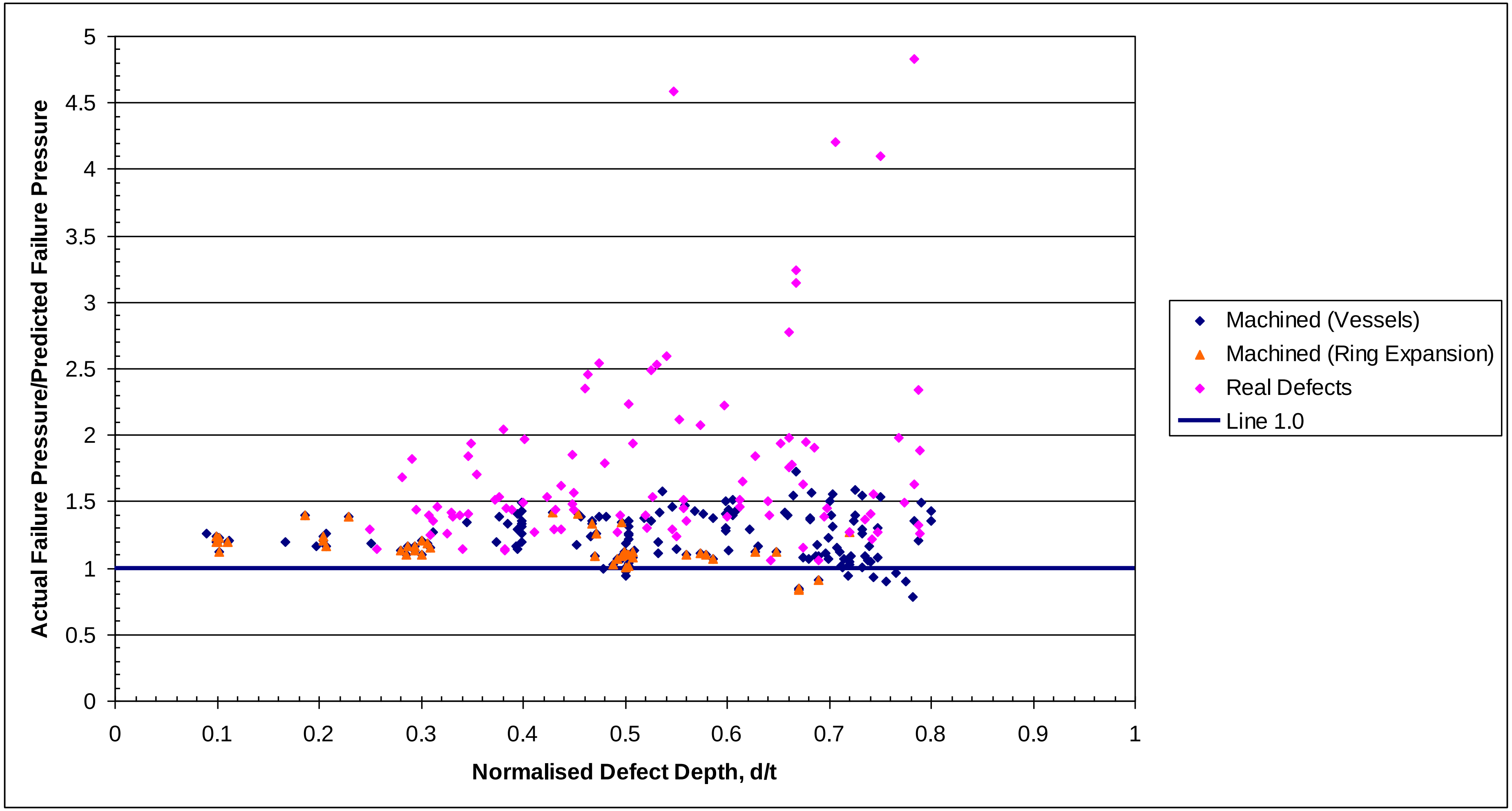

Figure 47 Comparison of Actual and Predicted Failure Pressure Using the Modified ASME B31G Method (Case 6 Flow Stress Modified to Equal the Mean of the Specified Minimum Tensile and Ultimate Tensile Strength) – Split Between Machined and Real Corrosion Defects

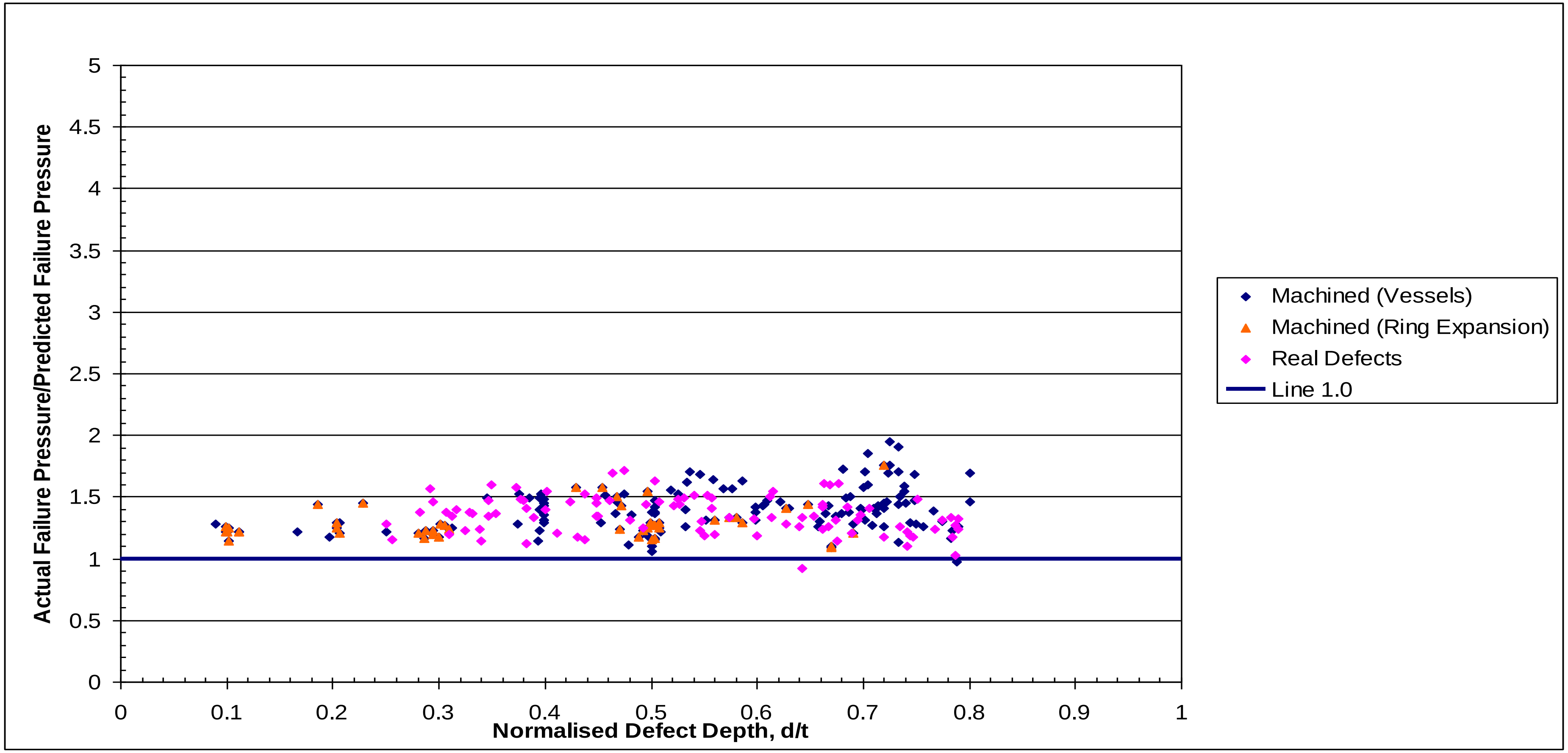

Figure 48 Comparison of Actual and Predicted Failure Pressure Using the RSTRENG Method (Case 6 Flow Stress Modified to Equal the Mean of the Specified Minimum Tensile and Ultimate Tensile Strength) – Split Between Machined and Real Corrosion Defects

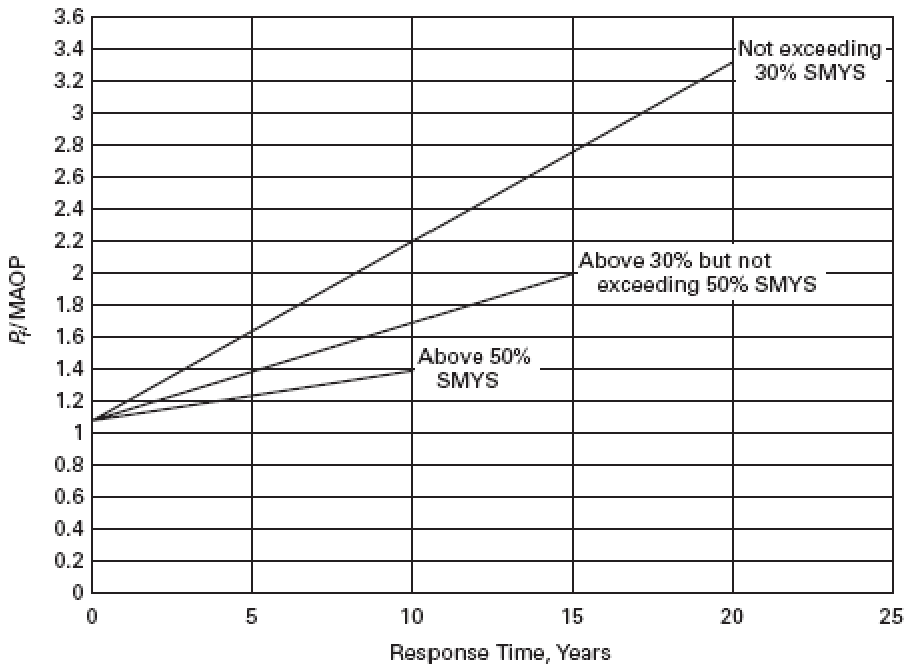

Fig. 4 Timing for Scheduled Responses: Time-Dependent Threats, Prescriptive Integrity Management Plan

Figure 49 Timing of Scheduled Responses for Internal and External Corrosion Defects[11]

[11] Figure extracted from ASME B31.8S [31]

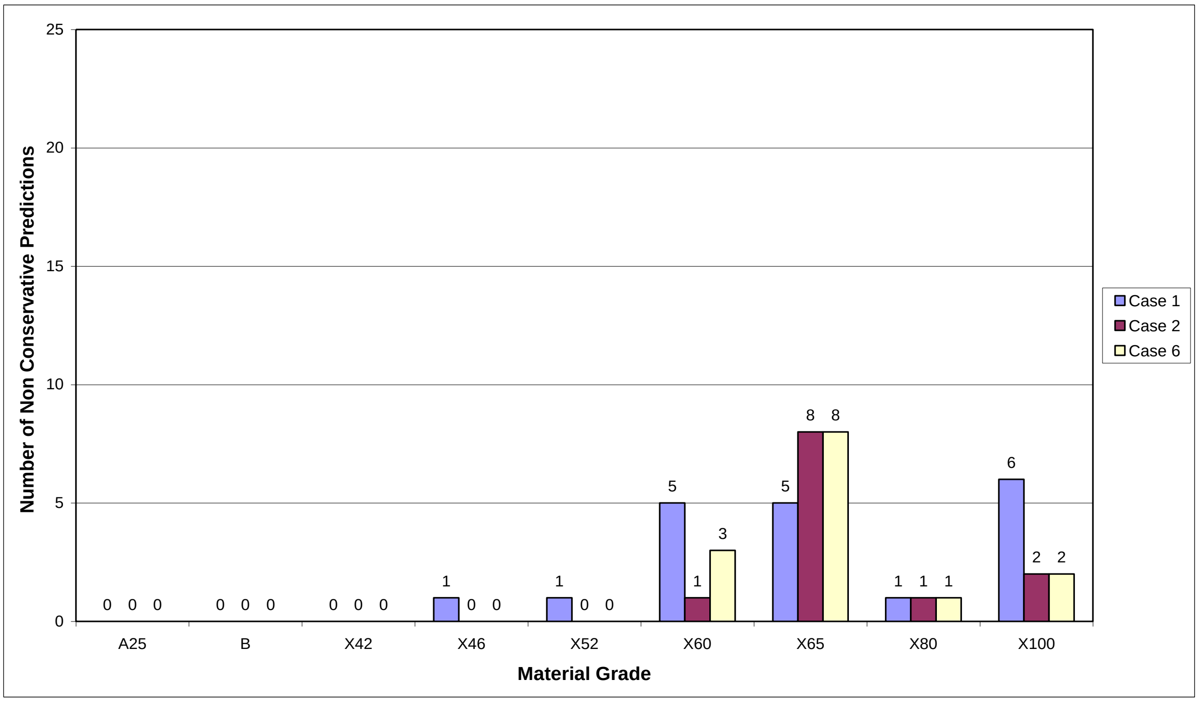

Figure 50 Number of Non-Conservative Failure Predictions Using the ASME B31G Method

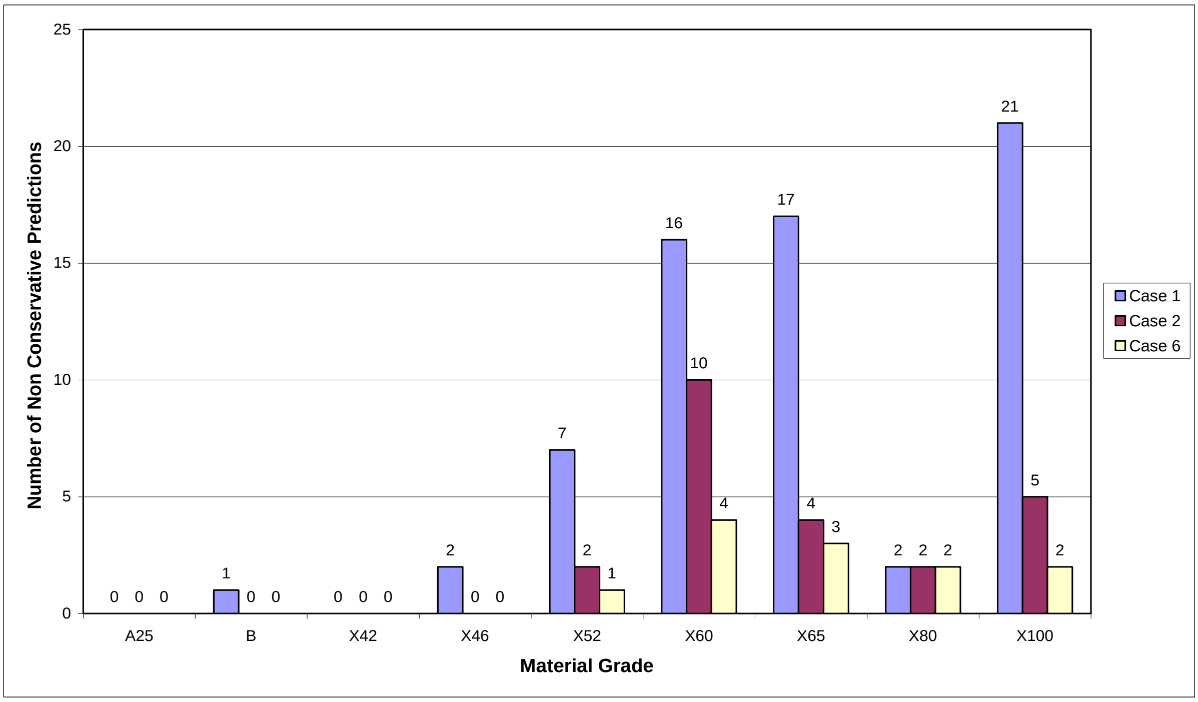

Figure 51 Number of Non-Conservative Failure Predictions Using the Modified ASME B31G Method (including ring expansion tests)

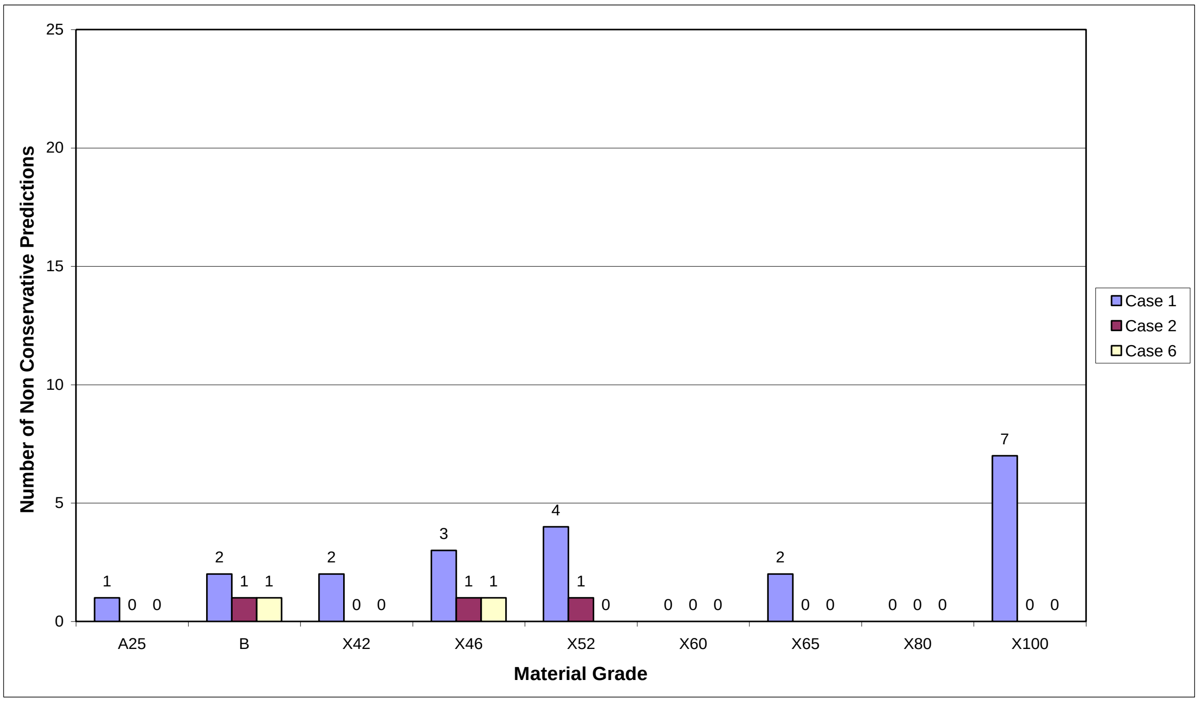

Figure 52 Number of Non-Conservative Failure Predictions Using the RSTRENG Method

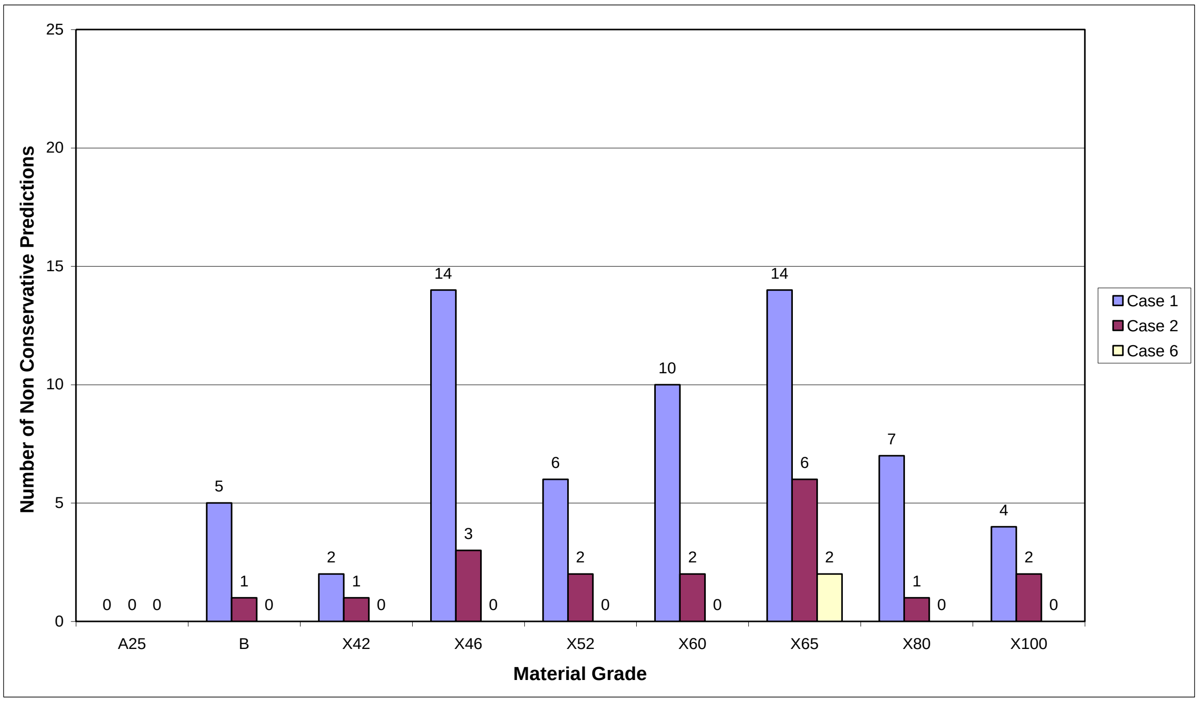

Figure 53 Number of Non-Conservative Failure Predictions Using the LPC-1Method

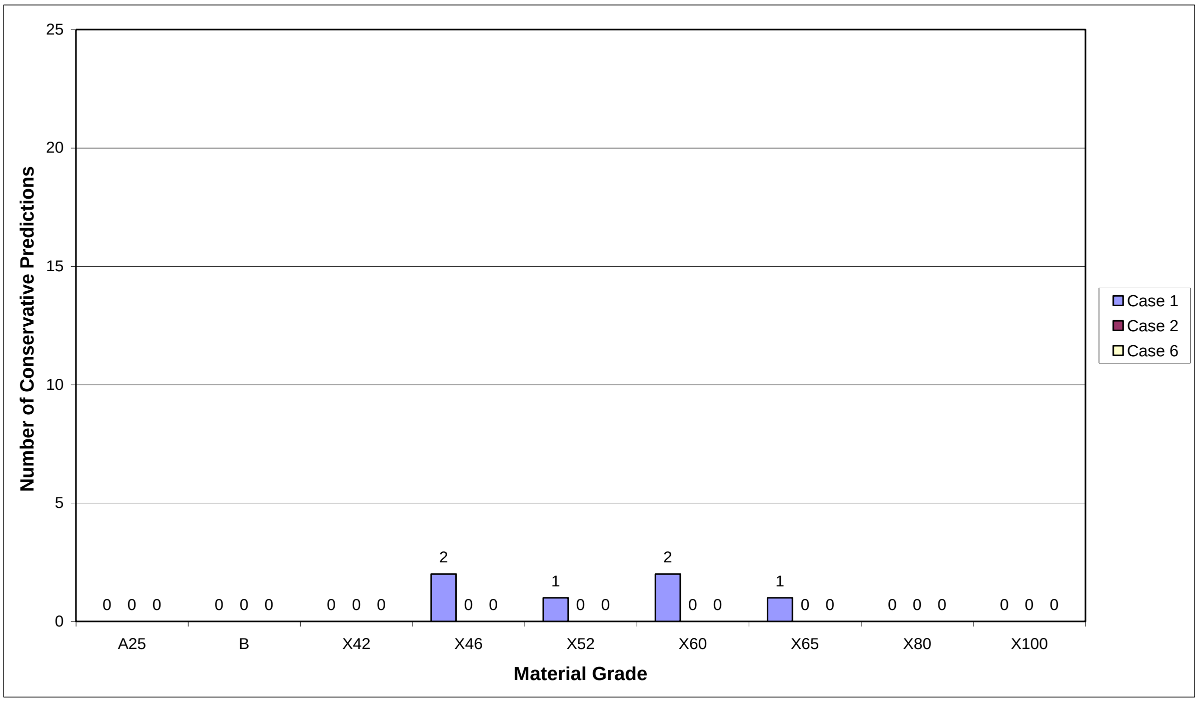

Figure 54 Number of Non-Conservative Failure Predictions Using the SHELL92 Method

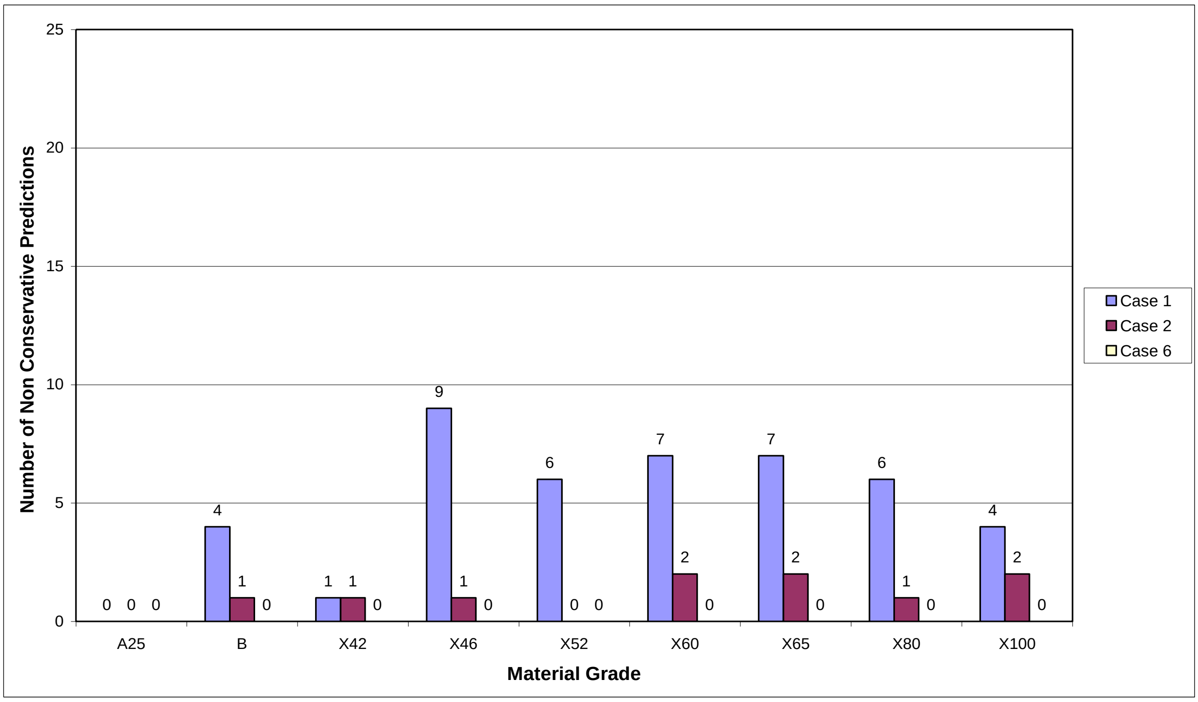

Figure 55 Number of Non-Conservative Failure Predictions Using the PCORRC Method

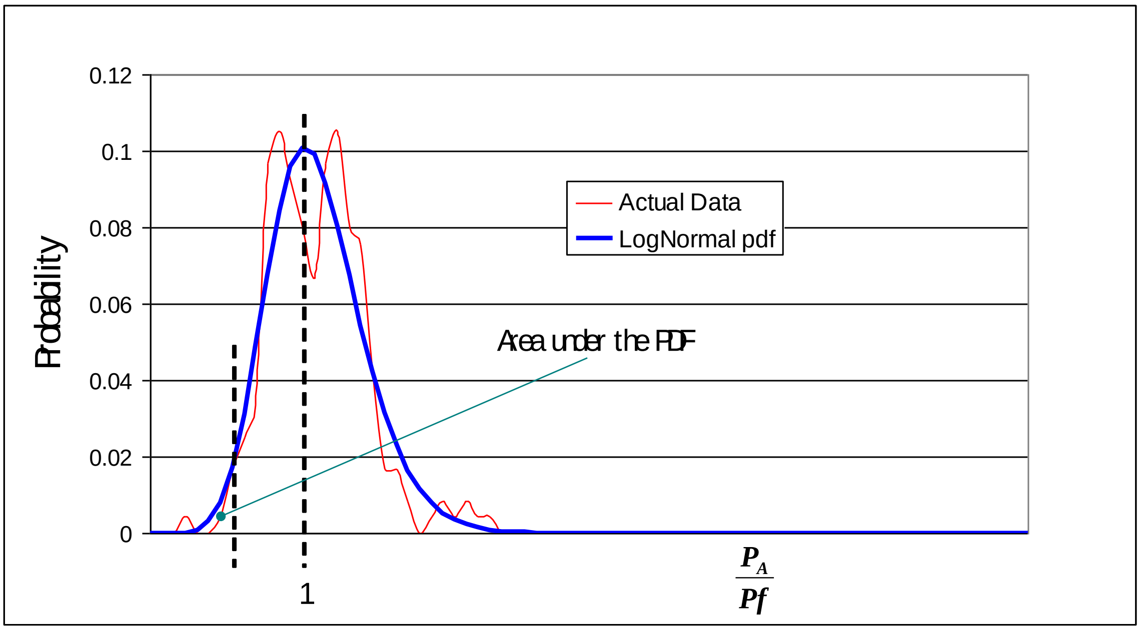

Figure 56 Probability Density Function of (P_A/P_f)

APPENDIX A DATABASE OF PIPE TESTS

A.1 Database of Pipe Tests

A.1.1 Background

This database is a collection of valid test results collated from a number of sources. The results of full scale burst tests on both actual corroded pipe taken out of service and pipes containing machined metal loss defects are included in the database. This integrated database compiles the results of 313 burst tests. The test results are presented in a normalized format.

Failure modes are marked as L (leak) or R (rupture). Ring expansion tests are color coded blue; vessel tests are color coded black. For modeling the ring expansion tests, the length of the defect was assumed to be very long (1000 inch).

INDEX	Source Reference	Grade	D/t	Defect Type	$\frac{L}{\sqrt{Dt}}$	$\frac{d}{t}$	$\frac{YS}{SMYS}$	$\frac{UTS}{SMTS}$	$\frac{YS}{UTS}$	Failure Mode	Failure Pressure (psi)
INDEX 1	PRCI-001	X52	78.5	Real	0.738	0.382	1.129	1.153	0.771	L	1623
INDEX 2	PRCI-002	X52	78.5	Real	0.665	0.382	1.129	1.153	0.771	L	1620
INDEX 3	PRCI-003	X52	78.5	Real	1.255	0.411	1.129	1.153	0.771	R	1700
INDEX 4	PRCI-004	X52	80.0	Real	1.640	0.640	1.227	1.221	0.792	R	1670
INDEX 5	PRCI-005	X52	78.9	Real	1.407	0.550	1.131	1.141	0.781	R	1525
INDEX 6	PRCI-006	B	63.7	Real	0.997	0.719	1.157	1.100	0.614	L	1100
INDEX 7	PRCI-007	B	63.7	Real	1.579	0.666	1.157	1.100	0.614	L	1165
INDEX 8	PRCI-008	B	63.7	Real	1.745	0.666	1.157	1.100	0.614	R	1220
INDEX 9	PRCI-009	B	64.9	Real	0.587	0.705	1.194	1.098	0.634	L	1040
INDEX 10	PRCI-010	B	64.0	Real	1.417	0.752	1.194	1.098	0.634	L	1165
INDEX 11	PRCI-011	B	65.8	Real	0.676	0.715	1.194	1.098	0.634	L	1020
INDEX 12	PRCI-012	B	65.8	Real	0.760	0.600	1.194	1.098	0.634	L	1215
INDEX 13	PRCI-013	B	65.8	Real	0.845	0.630	1.194	1.098	0.634	L	1320
INDEX 14	PRCI-014	B	65.8	Real	0.929	0.715	1.194	1.098	0.634	L	1320
INDEX 15	PRCI-015	B	63.2	Real	1.242	0.661	1.194	1.098	0.634	L	1335
INDEX 16	PRCI-016	B	64.9	Real	0.671	0.508	1.194	1.098	0.634	L	1350
INDEX 17	PRCI-017	B	64.9	Real	1.007	0.649	1.194	1.098	0.634	L	1375
INDEX 18	PRCI-018	B	64.0	Real	1.250	0.640	1.194	1.098	0.634	L	1438
INDEX 19	PRCI-019	B	65.8	Real	0.591	0.715	1.194	1.098	0.634	L	1450
INDEX 20	PRCI-020	B	64.0	Real	0.750	0.669	1.194	1.098	0.634	L	1200
INDEX 21	PRCI-021	B	64.0	Real	0.750	0.779	1.194	1.098	0.634	L	1490
INDEX 22	PRCI-022	B	64.0	Real	0.833	0.584	1.194	1.098	0.634	L	1520
INDEX 23	PRCI-023	B	64.0	Real	0.667	0.501	1.194	1.098	0.634	L	1520
INDEX 24	PRCI-024	B	64.0	Real	0.750	0.472	1.194	1.098	0.634	L	1520
INDEX 25	PRCI-025	B	64.0	Real	1.667	0.723	1.194	1.098	0.634	R	1510

INDEX	Source Reference	Grade	D/t	Defect Type	$\frac{L}{\sqrt{Dt}}$	$\frac{d}{t}$	$\frac{YS}{SMYS}$	$\frac{UTS}{SMTS}$	$\frac{YS}{UTS}$	Failure Mode	Failure Pressure (psi)
INDEX 26	PRCI-026	X52	80.0	Real	0.820	1.000	1.169	N/A	N/A	R	1745
INDEX 27	PRCI-027	X52	80.0	Real	1.640	0.389	1.156	N/A	N/A	R	1840
INDEX 28	PRCI-028	X52	80.0	Real	1.342	0.307	1.169	N/A	N/A	R	1895
INDEX 29	PRCI-029	X52	80.0	Real	1.193	0.613	1.246	N/A	N/A	R	1775
INDEX 30	PRCI-030	X52	80.0	Real	0.477	0.557	1.331	N/A	N/A	L	2140
INDEX 31	PRCI-031	X52	80.0	Real	0.596	0.557	1.254	N/A	N/A	R	2000
INDEX 32	PRCI-032	B	61.5	Real	2.255	0.643	1.171	1.002	0.682	L	1150
INDEX 33	PRCI-033	B	61.5	Real	2.550	0.674	1.171	1.002	0.682	L	1695
INDEX 34	PRCI-034	A25	51.6	Real	2.021	0.742	1.144	1.056	0.602	L	1100
INDEX 35	PRCI-035	A25	51.6	Real	2.245	0.774	1.144	1.056	0.602	L	1270
INDEX 36	PRCI-036	A25	51.6	Real	2.694	0.910	1.144	1.056	0.602	R	820
INDEX 37	PRCI-037	A25	51.6	Real	1.235	0.877	1.144	1.056	0.602	L	890
INDEX 38	PRCI-038	A25	51.6	Real	2.806	0.642	1.136	0.893	0.706	L	1290
INDEX 39	PRCI-039	B	57.6	Real	4.109	0.695	1.434	1.317	0.635	R	1395
INDEX 40	PRCI-040	B	58.5	Real	2.550	0.927	1.337	1.355	0.576	R	1660
INDEX 41	PRCI-041	B	60.6	Real	1.865	0.909	1.434	1.317	0.635	L	930
INDEX 42	PRCI-042	B	54.1	Real	2.527	0.495	1.434	1.317	0.635	R	1900
INDEX 43	PRCI-043	B	65.6	Real	5.061	0.751	1.540	N/A	N/A	R	1476
INDEX 44	PRCI-044	B	65.9	Real	4.398	0.698	1.486	N/A	N/A	R	1265
INDEX 45	PRCI-045	B	67.6	Real	2.227	0.814	1.486	N/A	N/A	L	1505
INDEX 46	PRCI-046	B	75.2	Real	1.988	0.677	1.357	N/A	N/A	L	1732
INDEX 47	PRCI-047	B	72.3	Real	1.594	0.663	1.286	N/A	N/A	L	1752
INDEX 48	PRCI-048	B	64.0	Real	5.333	0.787	1.537	1.145	0.783	R	742
INDEX 49	PRCI-049	B	64.0	Real	3.000	0.853	1.319	N/A	N/A	R	788
INDEX 50	PRCI-050	B	64.1	Real	4.804	0.808	1.429	N/A	N/A	R	713
INDEX 51	PRCI-051	X52	65.6	Real	4.251	0.689	1.060	1.145	0.729	R	1170

INDEX	Source Reference	Grade	D/t	Defect Type	$\frac{L}{\sqrt{Dt}}$	$\frac{d}{t}$	$\frac{YS}{SMYS}$	$\frac{UTS}{SMTS}$	$\frac{YS}{UTS}$	Failure Mode	Failure Pressure (psi)
INDEX 52	PRCI-052	B	66.5	Real	3.567	0.884	1.354	1.068	0.739	L	1290
INDEX 53	PRCI-053	B	66.5	Real	4.247	0.789	1.177	1.120	0.613	L	1475
INDEX 54	PRCI-054	B	67.6	Real	2.912	0.685	1.437	1.065	0.787	L	1741
INDEX 55	PRCI-055	B	64.7	Real	3.519	0.744	1.286	1.093	0.686	L	1357
INDEX 56	PRCI-056	B	64.7	Real	3.519	0.784	1.286	1.093	0.686	L	1357
INDEX 57	PRCI-057	B	64.5	Real	7.363	0.548	1.377	1.055	0.761	L	1599
INDEX 58	PRCI-058	B	65.9	Real	2.876	0.615	1.374	1.033	0.776	R	1645
INDEX 59	PRCI-059	B	65.6	Real	4.218	0.661	1.229	0.983	0.729	L	1808
INDEX 60	PRCI-060	B	65.6	Real	1.350	0.522	1.471	1.167	0.736	R	1583
INDEX 61	PRCI-061	B	65.2	Real	9.422	0.783	1.363	1.122	0.709	L	1530
INDEX 62	PRCI-062	B	70.7	Real	12.610	0.968	1.083	1.013	0.623	R	1090
INDEX 63	PRCI-063	B	73.0	Real	5.126	0.474	1.157	1.068	0.632	R	1739
INDEX 64	PRCI-064	B	64.3	Real	3.408	0.768	1.009	0.948	0.620	L	1694
INDEX 65	PRCI-065	B	64.3	Real	4.411	0.338	1.009	0.948	0.620	L	1694
INDEX 66	PRCI-066	B	75.2	Real	6.720	0.541	1.149	1.017	0.659	L	1507
INDEX 67	PRCI-067	B	64.7	Real	4.827	0.706	1.197	1.082	0.646	L	1816
INDEX 68	PRCI-068	X52	80.6	Real	10.776	0.349	1.142	N/A	N/A	R	1844
INDEX 69	PRCI-069	X52	79.8	Real	3.573	0.612	1.040	N/A	N/A	R	1515
INDEX 70	PRCI-070	X52	80.0	Real	3.578	0.373	1.135	N/A	N/A	R	1815
INDEX 71	PRCI-071	X52	78.5	Real	5.908	0.380	1.196	N/A	N/A	R	1902
INDEX 72	PRCI-072	X52	79.8	Real	5.955	0.346	1.081	N/A	N/A	R	1785
INDEX 73	PRCI-073	X52	79.4	Real	9.800	0.291	1.225	N/A	N/A	R	1916
INDEX 74	PRCI-074	X52	79.2	Real	4.152	0.449	1.229	N/A	N/A	R	1775
INDEX 75	PRCI-075	X52	78.7	Real	3.549	0.787	1.000	N/A	N/A	L	1120
INDEX 76	PRCI-076	X52	79.4	Real	2.376	0.450	1.152	N/A	N/A	L	1720
INDEX 77	PRCI-077	X52	79.6	Real	3.568	0.424	1.163	N/A	N/A	R	1789

INDEX	Source Reference	Grade	D/t	Defect Type	$\frac{L}{\sqrt{Dt}}$	$\frac{d}{t}$	$\frac{YS}{SMYS}$	$\frac{UTS}{SMTS}$	$\frac{YS}{UTS}$	Failure Mode	Failure Pressure (psi)
INDEX 78	PRCI-078	X52	80.4	Real	2.690	0.295	1.133	N/A	N/A	R	1840
INDEX 79	PRCI-079	X42	64.0	Real	5.583	0.859	1.135	1.000	0.671	R	804
INDEX 80	PRCI-080	X52	82.2	Real	4.835	0.627	1.127	1.144	0.776	R	987
INDEX 81	PRCI-081	X52	80.0	Real	8.050	0.653	1.323	1.274	0.818	R	992
INDEX 82	PRCI-082	X56	80.0	Real	2.236	0.400	1.150	1.320	0.687	L	1970
INDEX 83	PRCI-083	X46	76.9	Real	7.016	0.838	1.102	0.949	0.848	R	835
INDEX 84	PRCI-084	X65	109.1	Real	4.642	0.661	1.129	N/A	N/A	R	775
INDEX 85	PRCI-085	X60	100.7	Real	21.070	0.903	1.183	N/A	N/A	R	815
INDEX 86	PRCI-086	X52	111.1	Real	2.875	0.747	1.172	N/A	N/A	R	828
INDEX 87	PRCI-087	X65	94.5	Real	0.729	0.735	1.150	1.152	0.843	L	1770
INDEX 88	PRCI-088	X52	82.6	Real	2.364	0.331	1.189	1.212	0.773	R	1700
INDEX 89	PRCI-089	X65	88.9	Real	1.453	0.741	1.124	1.158	0.819	R	1635
INDEX 90	PRCI-090	X65	90.0	Real	0.422	0.675	1.130	1.240	0.769	L	1724
INDEX 91	PRCI-091	X65	91.6	Real	0.372	0.789	1.135	1.197	0.800	L	1850
INDEX 92	PRCI-092	X52	75.2	Real	6.867	0.282	1.106	1.161	0.751	R	1891
INDEX 93	PRCI-097	X60	76.6	Machined	6.565	0.395	1.073	1.157	0.741	R	1631
INDEX 94	PRCI-098	X60	76.3	Machined	17.474	0.385	1.033	1.161	0.712	R	1674
INDEX 95	PRCI-099	X60	78.1	Machined	2.652	0.395	1.057	1.104	0.766	R	1892
INDEX 96	PRCI-100	X60	78.4	Machined	2.657	0.376	1.080	1.143	0.756	R	1892
INDEX 97	PRCI-101	X60	78.4	Machined	2.657	0.396	1.084	1.136	0.763	R	1892
INDEX 98	PRCI-106	X46	54.7	Machined	1.137	0.790	1.198	1.156	0.757	L	1957
INDEX 99	PRCI-108	X46	53.3	Machined	1.352	0.657	1.211	1.248	0.708	L	2072
INDEX 100	PRCI-109	X46	55.4	Machined	1.028	0.665	1.208	1.310	0.673	L	2363
INDEX 101	PRCI-110	X46	54.0	Machined	0.669	0.784	1.400	1.250	0.818	L	2228
INDEX 102	PRCI-111	X46	54.0	Machined	0.899	0.750	1.277	1.324	0.704	L	2333
INDEX 103	PRCI-112	X46	53.3	Machined	1.008	0.481	1.324	1.197	0.808	R	2458

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INDEX 104	PRCI-113	X46	49.2	Machined	0.969	0.788	1.094	1.188	0.672	L	1886
INDEX 105	PRCI-114	X46	52.7	Machined	0.660	0.393	1.167	1.172	0.727	R	2288
INDEX 106	PRCI-115	X46	52.5	Machined	0.886	0.733	1.119	1.066	0.767	L	2072
INDEX 107	PRCI-116	X46	54.5	Machined	1.042	0.701	1.122	1.183	0.693	L	2258
INDEX 108	PRCI-117	X46	53.8	Machined	1.243	0.312	1.173	1.218	0.703	L	2338
INDEX 109	PRCI-119	X60	79.4	Machined	17.372	0.532	1.039	N/A	N/A	R	1160
INDEX 110	PRCI-120	X60	79.4	Machined	17.817	0.345	1.039	N/A	N/A	R	1712
INDEX 111	PRCI-121	X60	79.4	Machined	1.782	0.468	1.051	N/A	N/A	R	1813
INDEX 112	PRCI-122	X60	79.4	Machined	3.563	0.452	1.051	N/A	N/A	R	1422
INDEX 113	PRCI-123	X60	79.4	Machined	3.595	0.532	1.039	N/A	N/A	R	1226
INDEX 114	PRCI-124	X60	79.4	Machined	17.537	0.500	1.052	N/A	N/A	R	1218
INDEX 115	PRCI-125	X52	49.4	Machined	35.136	0.399	1.258	1.000	0.991	R	2103
INDEX 116	PRCI-126	X52	49.4	Machined	7.027	0.399	1.248	1.000	0.983	R	2030
INDEX 117	PRCI-127	X52	49.4	Machined	3.514	0.399	1.248	1.000	0.983	R	2248
INDEX 118	PRCI-128	X52	49.4	Machined	3.514	0.399	1.248	1.000	0.983	R	2393
INDEX 119	PRCI-129	X52	49.4	Machined	1.757	0.399	1.248	1.000	0.983	R	2683
INDEX 120	PRCI-136	X52	49.4	Machined	0.439	0.599	1.248	1.000	0.983	L	3176
INDEX 121	PRCI-137	X52	49.4	Machined	0.439	0.599	1.248	1.000	0.983	N/A	2944
INDEX 122	PRCI-142	X52	49.4	Machined	1.318	0.599	1.248	1.000	0.983	L	2726
INDEX 123	PRCI-144	X52	49.4	Machined	3.514	0.399	1.248	1.000	0.983	R	2567
INDEX 124	PRCI-147	X52	49.4	Machined	1.757	0.399	1.248	1.000	0.983	R	2944
INDEX 125	PRCI-163	X46	52.5	Machined	0.449	0.605	1.122	N/A	N/A	N/A	2734
INDEX 126	PRCI-165	X46	51.8	Machined	0.440	0.606	1.122	N/A	N/A	L	2795
INDEX 127	PRCI-166	X46	52.5	Machined	0.443	0.609	1.330	N/A	N/A	L	2819
INDEX 128	PRCI-171	X46	51.6	Machined	0.440	0.599	1.202	N/A	N/A	L	2554
INDEX 129	PRCI-173	X46	51.4	Machined	1.597	0.601	1.191	N/A	N/A	N/A	2191

INDEX	Source Reference	Grade	D/t	Defect Type	$\frac{L}{\sqrt{Dt}}$	$\frac{d}{t}$	$\frac{YS}{SMYS}$	$\frac{UTS}{SMTS}$	$\frac{YS}{UTS}$	Failure Mode	Failure Pressure (psi)
INDEX 130	PRCI-174	X46	51.8	Machined	1.604	0.606	1.202	N/A	N/A	N/A	2273
INDEX 131	PRCI-176	X46	52.5	Machined	0.449	0.601	1.191	N/A	N/A	N/A	2212
INDEX 132	PRCI-182	X46	47.2	Machined	1.186	0.659	1.176	N/A	N/A	L	2393
INDEX 133	PRCI-183	X46	48.9	Machined	2.286	0.667	1.202	N/A	N/A	L	2302
INDEX 134	PRCI-184	X46	47.6	Machined	2.223	0.683	1.202	N/A	N/A	L	2126
INDEX 135	ADVANTICA-TR020	X65	41.3	Machined	200.935	0.229	1.132	0.998	0.957	R	3838
INDEX 136	ADVANTICA-TR021	X65	42.2	Machined	203.044	0.429	1.132	0.998	0.957	R	3028
INDEX 137	ADVANTICA-TR022	X65	40.9	Machined	199.776	0.627	1.132	0.998	0.957	R	1825
INDEX 138	ADVANTICA-TR023	X65	41.1	Machined	200.417	0.824	1.132	0.998	0.957	R	1123
INDEX 139	ADVANTICA-TR024	X65	40.8	Machined	199.649	0.574	1.111	0.998	0.939	R	1984
INDEX 140	ADVANTICA-TR025	X65	40.7	Machined	199.268	0.580	1.111	0.998	0.939	R	1958
INDEX 141	ADVANTICA-TR026	X65	41.1	Machined	200.289	0.560	1.111	0.998	0.939	R	1991
INDEX 142	ADVANTICA-TR027	X65	43.7	Machined	206.619	0.586	1.111	0.998	0.939	R	1738
INDEX 143	ADVANTICA-TR029	X52	46.0	Machined	282.526	0.186	1.117	1.000	0.880	R	3019
INDEX 144	ADVANTICA-TR030	X52	45.6	Machined	281.450	0.648	1.117	1.000	0.880	R	1310
INDEX 145	ADVANTICA-TR031	X52	46.2	Machined	283.069	0.454	1.117	1.000	0.880	R	2206
INDEX 146	ADVANTICA-TR032	X52	46.2	Machined	283.069	0.720	1.117	1.000	0.880	R	1261
INDEX 147	ADVANTICA-TR033	X52	45.7	Machined	281.718	0.468	1.117	1.000	0.880	R	2073
INDEX 148	ADVANTICA-TR034	X52	46.0	Machined	282.526	0.472	1.117	1.000	0.880	R	1935
INDEX 149	ADVANTICA-TR035	X52	46.5	Machined	284.164	0.496	1.117	1.000	0.880	R	1979
INDEX 150	ADVANTICA-TV006	X65	42.6	Machined	1.629	0.702	1.085	1.146	0.799	R	2983
INDEX 151	ADVANTICA-TV008	X65	41.2	Machined	4.811	0.680	1.085	1.146	0.799	R	1839
INDEX 152	ADVANTICA-TV010	X65	41.7	Machined	3.227	0.687	1.110	1.168	0.802	R	1970
INDEX 153	ADVANTICA-TV011	X65	40.9	Machined	3.196	0.674	1.110	1.168	0.802	R	2044
INDEX 154	ADVANTICA-TV016	X65	40.7	Machined	3.188	0.700	1.132	1.181	0.809	R	2248

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INDEX 155	ADVANTICA-TV017	X65	41.2	Machined	4.816	0.756	1.132	1.181	0.809	R	1333
INDEX 156	ADVANTICA-TV018	X65	40.9	Machined	3.836	0.739	1.110	1.168	0.802	R	1891
INDEX 157	ADVANTICA-TV019	X65	40.7	Machined	6.377	0.735	1.110	1.168	0.802	R	1661
INDEX 158	ADVANTICA-TV022	X65	40.3	Machined	3.172	0.748	1.109	1.176	0.797	R	1827
INDEX 159	ADVANTICA-TV027	X65	40.7	Machined	4.782	0.720	1.103	1.145	0.813	R	1709
INDEX 160	ADVANTICA-TV028	X65	44.0	Machined	4.972	0.744	1.103	1.145	0.813	R	1329
INDEX 161	ADVANTICA-TV031	X65	44.0	Machined	4.972	0.551	1.103	1.145	0.813	R	2238
INDEX 162	ADVANTICA-TV032	X65	40.5	Machined	4.770	0.478	1.103	1.145	0.813	R	2334
INDEX 163	ADVANTICA-TV033	X65	8.8	Machined	0.688	0.708	0.757	0.937	0.681	L	15774
INDEX 164	ADVANTICA-TV034	X65	8.6	Machined	1.357	0.690	0.757	0.937	0.681	R	12488
INDEX 165	ADVANTICA-TV035	X65	8.8	Machined	2.064	0.710	0.757	0.937	0.681	R	10486
INDEX 166	ADVANTICA-TV036	X65	8.7	Machined	2.729	0.697	0.757	0.937	0.681	R	9935
INDEX 167	ADVANTICA-TV037	X65	8.6	Machined	1.362	0.197	0.757	0.937	0.681	R	17999
INDEX 168	ADVANTICA-TV038	X65	8.6	Machined	1.357	0.509	0.757	0.937	0.681	R	15156
INDEX 169	ADVANTICA-TV039	X65	8.7	Machined	1.367	0.941	0.757	0.937	0.681	L	10283
INDEX 170	ADVANTICA-TV045	X52	48.1	Machined	1.737	0.725	1.146	1.260	0.717	R	2068
INDEX 171	ADVANTICA-TV046	X52	49.2	Machined	1.756	0.559	1.146	1.260	0.717	R	2577
INDEX 172	ADVANTICA-TV047	X52	48.1	Machined	5.212	0.740	1.146	1.260	0.717	R	1136
INDEX 173	ADVANTICA-TV048	X52	49.5	Machined	5.283	0.546	1.146	1.260	0.717	R	2112
INDEX 174	ADVANTICA-TV049	X60	29.5	Machined	1.360	0.704	1.319	1.240	0.851	L	4833
INDEX 175	ADVANTICA-TV050	X60	29.1	Machined	1.352	0.733	1.319	1.240	0.851	R	4727
INDEX 176	ADVANTICA-TV051	X60	29.5	Machined	1.360	0.568	1.319	1.240	0.851	R	5043
INDEX 177	ADVANTICA-TV052	X60	28.8	Machined	4.029	0.688	1.319	1.240	0.851	R	2795
INDEX 178	ADVANTICA-TV053	X60	29.3	Machined	4.068	0.519	1.319	1.240	0.851	R	4094
INDEX 179	ADVANTICA-TV056	X52	45.2	Machined	1.687	0.724	1.117	1.205	0.731	R	2170
INDEX 180	ADVANTICA-TV057	X52	46.9	Machined	1.730	0.577	1.117	1.205	0.731	R	2547

INDEX	Source Reference	Grade	D/t	Defect Type	$\frac{L}{\sqrt{Dt}}$	$\frac{d}{t}$	$\frac{YS}{SMYS}$	$\frac{UTS}{SMTS}$	$\frac{YS}{UTS}$	Failure Mode	Failure Pressure (psi)
INDEX 181	ADVANTICA-TV058	X52	46.5	Machined	5.147	0.766	1.117	1.205	0.731	R	1021
INDEX 182	ADVANTICA-TV059	X52	45.2	Machined	5.073	0.586	1.117	1.205	0.731	R	2080
INDEX 183	ADVANTICA-TV060	X60	31.6	Machined	1.411	0.725	1.305	1.261	0.828	R	4437
INDEX 184	ADVANTICA-TV061	X60	29.7	Machined	1.369	0.537	1.305	1.261	0.828	R	5658
INDEX 185	ADVANTICA-TV062	X60	30.8	Machined	4.186	0.733	1.305	1.261	0.828	R	2561
INDEX 186	ADVANTICA-TV063	X60	31.6	Machined	4.241	0.534	1.305	1.261	0.828	R	3851
INDEX 187	ADVANTICA-TV064	X65	32.3	Machined	1.435	0.817	0.901	1.041	0.730	R	3217
INDEX 188	ADVANTICA-TV065	X65	32.4	Machined	1.429	0.622	0.901	1.041	0.730	R	4121
INDEX 189	ADVANTICA-TV066	X65	32.3	Machined	4.286	0.820	0.901	1.041	0.730	R	1534
INDEX 190	ADVANTICA-TV067	X65	32.3	Machined	4.286	0.630	0.901	1.041	0.730	R	2828
INDEX 191	ADVANTICA-TV072	X60	46.9	Machined	1.715	0.704	1.141	1.127	0.810	R	2351
INDEX 192	ADVANTICA-TV073	X60	47.1	Machined	5.165	0.719	1.141	1.127	0.810	R	1246
INDEX 193	PETROBRAS TS02	X46	76.0	Real	18.860	0.463	N/A	N/A	N/A	N/A	1891
INDEX 194	PETROBRAS TS04	X46	73.6	Real	18.550	0.525	N/A	N/A	N/A	N/A	1749
INDEX 195	PETROBRAS TS05	X46	75.7	Real	18.821	0.448	N/A	N/A	N/A	N/A	1469
INDEX 196	PETROBRAS TS06	X46	69.7	Real	18.101	0.507	N/A	N/A	N/A	N/A	1500
INDEX 197	PETROBRAS TS10	X46	75.3	Real	18.792	0.461	N/A	N/A	N/A	N/A	1832
INDEX 198	PETROBRAS TS 5.1	X60	33.0	Machined	4.537	0.722	1.092	1.048	0.834	N/A	2090
INDEX 199	PETROBRAS TS 1.2	X60	33.5	Machined	5.464	0.699	1.092	1.048	0.834	N/A	2041
INDEX 200	PETROBRAS TS 2.2	X60	33.4	Machined	6.241	0.714	1.092	1.048	0.834	N/A	1970
INDEX 201	PETROBRAS TS 2.1	X60	33.4	Machined	7.035	0.712	1.092	1.048	0.834	N/A	1863
INDEX 202	PETROBRAS TS 3.1	X60	32.7	Machined	7.650	0.738	1.092	1.048	0.834	N/A	1759
INDEX 203	PETROBRAS TS 1.1	X60	33.2	Machined	8.310	0.720	1.092	1.048	0.834	N/A	1734
INDEX 204	PETROBRAS TS 3.2	X60	33.1	Machined	8.679	0.713	1.092	1.048	0.834	N/A	1728
INDEX 205	PETROBRAS TS 4.1	X60	33.1	Machined	8.880	0.713	1.092	1.048	0.834	N/A	1739
INDEX 206	PETROBRAS TS 4.2	X60	33.2	Machined	9.398	0.733	1.092	1.048	0.834	N/A	1640

INDEX	Source Reference	Grade	D/t	Defect Type	$\frac{L}{\sqrt{Dt}}$	$\frac{d}{t}$	$\frac{YS}{SMYS}$	$\frac{UTS}{SMTS}$	$\frac{YS}{UTS}$	Failure Mode	Failure Pressure (psi)
INDEX 207	KOREAN GAS CO DA	X65	43.5	Machined	1.732	0.251	N/A	N/A	N/A	N/A	3498
INDEX 208	KOREAN GAS CO DB	X65	43.5	Machined	1.732	0.503	N/A	N/A	N/A	N/A	3157
INDEX 209	KOREAN GAS CO DC	X65	43.5	Machined	1.732	0.748	N/A	N/A	N/A	N/A	2488
INDEX 210	KOREAN GAS CO LA	X65	43.5	Machined	0.866	0.503	N/A	N/A	N/A	N/A	3526
INDEX 211	KOREAN GAS CO LC	X65	43.5	Machined	2.598	0.503	N/A	N/A	N/A	N/A	2873
INDEX 212	KOREAN GAS CO CB	X65	43.5	Machined	1.732	0.503	N/A	N/A	N/A	N/A	3398
INDEX 213	KOREAN GAS CO CC	X65	43.5	Machined	1.732	0.503	N/A	N/A	N/A	N/A	3285
INDEX 214	WATERLOO SOL-2	X46	37.4	Real	1.202	0.250	1.124	1.080	0.759	N/A	3535
INDEX 215	WATERLOO SOL-4	X46	37.6	Real	3.858	0.346	1.124	1.080	0.759	N/A	3351
INDEX 216	WATERLOO SOL-6	X46	37.4	Real	1.154	0.312	1.124	1.080	0.759	N/A	3659
INDEX 217	WATERLOO SOL-10	X46	37.6	Real	2.743	0.383	1.124	1.080	0.759	N/A	3471
INDEX 218	WATERLOO SOL-11	X46	37.5	Real	2.402	0.309	1.124	1.080	0.759	N/A	3154
INDEX 219	WATERLOO SOL-12	X46	37.9	Real	0.967	0.256	1.124	1.080	0.759	N/A	3127
INDEX 220	WATERLOO NOR-1	X52	52.2	Real	10.819	0.354	1.084	1.156	0.774	N/A	2423
INDEX 221	WATERLOO NOR-2	X52	51.9	Real	3.687	0.329	1.084	1.156	0.774	N/A	2619
INDEX 222	WATERLOO TNG-01	X46	33.1	Real	5.083	0.480	1.291	1.108	0.851	N/A	3076
INDEX 223	WATERLOO RLK-1	X52	93.3	Real	14.246	0.504	1.123	1.231	0.753	N/A	1370
INDEX 224	WATERLOO RLK-2	X52	95.3	Real	22.833	0.553	1.123	1.231	0.753	N/A	1143
INDEX 225	WATERLOO RLK-3	X52	95.5	Real	21.924	0.401	1.123	1.231	0.753	N/A	1423
INDEX 226	WATERLOO BCG-1	X42	55.2	Real	4.971	0.667	1.211	1.045	0.773	N/A	1994
INDEX 227	WATERLOO BCG-2	X42	58.4	Real	1.351	0.560	1.211	1.045	0.773	N/A	2000
INDEX 228	WATERLOO BCG-3	X42	57.3	Real	0.843	0.340	1.211	1.045	0.773	N/A	1988
INDEX 229	WATERLOO BCG-4	X42	56.0	Real	2.784	0.448	1.211	1.045	0.773	N/A	2201
INDEX 230	WATERLOO BCG-5	X42	55.6	Real	1.245	0.325	1.211	1.045	0.773	N/A	2174
INDEX 231	WATERLOO BCG-6	X42	54.8	Real	3.360	0.431	1.211	1.045	0.773	N/A	1936
INDEX 232	WATERLOO BCG-7	X42	60.0	Real	1.864	0.600	1.211	1.045	0.773	N/A	1838

INDEX	Source Reference	Grade	D/t	Defect Type	$\frac{L}{\sqrt{Dt}}$	$\frac{d}{t}$	$\frac{YS}{SMYS}$	$\frac{UTS}{SMTS}$	$\frac{YS}{UTS}$	Failure Mode	Failure Pressure (psi)
INDEX 233	WATERLOO BCG-8	X42	55.1	Real	1.031	0.546	1.211	1.045	0.773	N/A	2147
INDEX 234	WATERLOO BCG-9	X42	56.9	Real	4.327	0.437	1.211	1.045	0.773	N/A	1831
INDEX 235	WATERLOO ESS-01	X46	63.8	Real	2.442	0.720	1.175	1.087	0.789	N/A	1412
INDEX 236	WATERLOO NOV01	X55	88.3	Real	2.449	0.527	1.219	1.352	0.787	N/A	1556
INDEX 237	WATERLOO NOV02-2	X55	89.1	Real	8.644	0.574	1.219	1.352	0.787	N/A	1168
INDEX 238	WATERLOO NOV03-2	X55	89.3	Real	11.528	0.661	1.219	1.352	0.787	N/A	1244
INDEX 239	WATERLOO NOV04	X55	88.5	Real	9.878	0.668	1.219	1.352	0.787	N/A	1434
INDEX 240	WATERLOO NOV04-2	X55	88.5	Real	7.714	0.531	1.219	1.352	0.787	N/A	1582
INDEX 241	WATERLOO NOV05	X55	90.5	Real	11.175	0.597	1.219	1.352	0.787	N/A	1167
INDEX 242	WATERLOO NOV06	X55	90.1	Real	3.180	0.437	1.219	1.352	0.787	N/A	1669
INDEX 243	WATERLOO TCP01	X46	89.7	Real	2.340	0.377	1.262	1.170	0.788	N/A	1567
INDEX 244	WATERLOO TCP02	X46	91.2	Real	2.050	0.316	1.262	1.170	0.788	N/A	1531
INDEX 245	WATERLOO TCP03	X46	92.1	Real	1.016	0.493	1.262	1.170	0.788	N/A	1330
INDEX 246	ADVANTICA V1	B/X42	77.2	Machined	0.228	0.800	1.376	1.151	0.697	L	1698
INDEX 247	ADVANTICA V2	B/X42	77.2	Machined	0.911	0.800	1.376	1.151	0.697	L	1190
INDEX 248	BRITISH GAS RING1	X60	40.9	Machined	177.799	0.300	1.049	1.089	0.771	N/A	2712
INDEX 249	BRITISH GAS RING2	X60	41.4	Machined	178.784	0.280	1.049	1.089	0.771	N/A	2828
INDEX 250	BRITISH GAS RING3	X60	41.5	Machined	179.122	0.470	1.049	1.089	0.771	N/A	2132
INDEX 251	BRITISH GAS RING4	X60	41.5	Machined	179.122	0.500	1.049	1.089	0.771	N/A	1885
INDEX 252	BRITISH GAS RING5	X60	40.7	Machined	177.184	0.690	1.049	1.089	0.771	N/A	1247
INDEX 253	BRITISH GAS RING6	X60	41.3	Machined	178.508	0.670	1.049	1.089	0.771	N/A	1175
INDEX 254	BRITISH GAS RING7	X60	41.2	Machined	178.387	0.670	1.049	1.089	0.771	N/A	1189
INDEX 255	ADVANTICA P1V1A	X80	60.1	Machined	3.890	0.775	1.060	1.166	0.808	R	1106
INDEX 256	ADVANTICA P1V1B	X80	60.1	Machined	3.877	0.207	1.060	1.166	0.808	R	3106
INDEX 257	ADVANTICA P1V2A	X80	60.1	Machined	3.890	0.374	1.073	1.179	0.809	R	2574
INDEX 258	ADVANTICA P1V2B	X80	60.1	Machined	3.903	0.089	1.073	1.179	0.809	R	3392

INDEX	Source Reference	Grade	D/t	Defect Type	$\frac{L}{\sqrt{Dt}}$	$\frac{d}{t}$	$\frac{YS}{SMYS}$	$\frac{UTS}{SMTS}$	$\frac{YS}{UTS}$	Failure Mode	Failure Pressure (psi)
INDEX 259	ADVANTICA P2V1A	X80	81.8	Machined	4.538	0.782	1.030	1.149	0.797	R	677
INDEX 260	ADVANTICA P2V1B	X80	81.8	Machined	4.450	0.167	1.030	1.149	0.797	R	2219
INDEX 261	ADVANTICA P2V2A	X80	81.8	Machined	4.546	0.395	1.068	1.191	0.797	R	1744
INDEX 262	ADVANTICA P2V2B	X80	81.8	Machined	4.523	0.112	1.068	1.191	0.797	R	2332
INDEX 263	ADVANTICA HKL-R03	X100	57.7	Machined	146.332	0.111	1.134	1.057	0.976	R	3947
INDEX 264	ADVANTICA HKL-R04	X100	57.7	Machined	146.332	0.099	1.134	1.057	0.976	N/A	4015
INDEX 265	ADVANTICA HKL-R05	X100	57.7	Machined	146.396	0.101	1.134	1.057	0.976	R	3993
INDEX 266	ADVANTICA HKL-R06	X100	57.6	Machined	146.300	0.294	1.134	1.057	0.976	R	3089
INDEX 267	ADVANTICA HKL-R07	X100	57.9	Machined	146.588	0.294	1.134	1.057	0.976	R	3164
INDEX 268	ADVANTICA HKL-R08	X100	57.9	Machined	146.588	0.287	1.134	1.057	0.976	R	3193
INDEX 269	ADVANTICA HKL-R09	X100	57.8	Machined	146.372	0.502	1.134	1.057	0.976	R	2307
INDEX 270	ADVANTICA HKL-R10	X100	57.8	Machined	146.404	0.497	1.134	1.057	0.976	R	2282
INDEX 271	ADVANTICA HKL-R11	X100	57.8	Machined	146.460	0.502	1.134	1.057	0.976	R	2306
INDEX 272	ADVANTICA HKL-R12	X100	57.7	Machined	146.308	0.809	1.134	1.057	0.976	R	895
INDEX 273	ADVANTICA HKL-R13	X100	57.8	Machined	146.492	0.833	1.134	1.057	0.976	R	798
INDEX 274	ADVANTICA HKL-R14	X100	57.8	Machined	146.372	0.814	1.134	1.057	0.976	R	921
INDEX 275	ADVANTICA HKB-R01	X100	63.9	Machined	154.075	0.102	1.134	1.057	0.976	R	3371
INDEX 276	ADVANTICA HKB-R02	X100	63.9	Machined	154.171	0.286	1.134	1.057	0.976	R	2739
INDEX 277	ADVANTICA HKB-R03	X100	63.9	Machined	154.075	0.503	1.134	1.057	0.976	R	1913
INDEX 278	ADVANTICA HKB-R04	X100	63.9	Machined	154.075	0.807	1.134	1.057	0.976	R	740
INDEX 279	ADVANTICA HKL-R15	X100	57.9	Machined	146.620	0.204	1.134	1.057	0.976	R	3628
INDEX 280	ADVANTICA HKL-R16	X100	58.0	Machined	146.597	0.204	1.134	1.057	0.976	R	3732
INDEX 281	ADVANTICA HKL-R17	X100	57.8	Machined	146.492	0.508	1.134	1.057	0.976	R	2319
INDEX 282	ADVANTICA HKL-R18	X100	57.9	Machined	146.588	0.499	1.134	1.057	0.976	R	2343
INDEX 283	ADVANTICA HKL-R19	X100	57.8	Machined	146.524	0.810	1.134	1.057	0.976	R	918
INDEX 284	ADVANTICA HKL-R20	X100	57.9	Machined	146.468	0.811	1.134	1.057	0.976	R	912

INDEX	Source Reference	Grade	D/t	Defect Type	$\frac{L}{\sqrt{Dt}}$	$\frac{d}{t}$	$\frac{YS}{SMYS}$	$\frac{UTS}{SMTS}$	$\frac{YS}{UTS}$	Failure Mode	Failure Pressure (psi)
INDEX 285	ADVANTICA HKB-R05	X100	63.8	Machined	154.096	0.207	1.134	1.057	0.976	R	3158
INDEX 286	ADVANTICA HKB-R06	X100	63.8	Machined	153.888	0.504	1.134	1.057	0.976	R	2075
INDEX 287	ADVANTICA HKB-R07	X100	63.9	Machined	154.075	0.818	1.134	1.057	0.976	R	742
INDEX 288	ADVANTICA HKL-R21	X100	57.7	Machined	146.276	0.099	1.134	1.057	0.976	L	4144
INDEX 289	ADVANTICA HKL-R22	X100	57.7	Machined	146.340	0.102	1.134	1.057	0.976	L	4090
INDEX 290	ADVANTICA HKL-R23	X100	57.7	Machined	146.332	0.301	1.134	1.057	0.976	L	3263
INDEX 291	ADVANTICA HKL-R24	X100	57.7	Machined	146.396	0.306	1.134	1.057	0.976	L	3209
INDEX 292	ADVANTICA HKL-R25	X100	57.7	Machined	146.332	0.488	1.134	1.057	0.976	R	2185
INDEX 293	ADVANTICA HKL-R26	X100	57.8	Machined	146.492	0.507	1.134	1.057	0.976	R	2246
INDEX 294	ADVANTICA HKL-R27	X100	57.7	Machined	146.308	0.804	1.134	1.057	0.976	R	812
INDEX 295	ADVANTICA HKL-R28	X100	57.7	Machined	146.244	0.808	1.134	1.057	0.976	R	821
INDEX 296	ADVANTICA HKB-R08	X100	63.7	Machined	153.851	0.111	1.134	1.057	0.976	L	3568
INDEX 297	ADVANTICA HKB-R09	X100	63.8	Machined	154.059	0.309	1.134	1.057	0.976	L	2816
INDEX 298	ADVANTICA HKB-R10	X100	63.4	Machined	153.444	0.493	1.134	1.057	0.976	R	2058
INDEX 299	ADVANTICA HKB-R11	X100	63.8	Machined	153.888	0.769	1.134	1.057	0.976	R	742
INDEX 300	ADVANTICA HKL V01	X100	57.9	Machined	3.503	0.496	1.134	1.057	0.976	R	2630
INDEX 301	ADVANTICA HKK V01	X100	57.9	Machined	6.384	0.500	1.134	1.057	0.976	R	2232
INDEX 302	ADVANTICA HKL V02	X100	57.9	Machined	2.962	0.503	1.134	1.057	0.976	R	2601
INDEX 303	ADVANTICA HKK V02	X100	57.8	Machined	5.825	0.500	1.134	1.057	0.976	R	2179
INDEX 304	NAT GAS PCA V1	X46	76.8	Real	1.278	0.520	1.631	1.435	0.663	R	1460
INDEX 305	NAT GAS PCA V2	X46	76.8	Real	2.191	0.862	1.491	1.440	0.604	L	1075
INDEX 306	NAT GAS PCA V3	X46	76.8	Real	0.913	0.824	1.491	1.440	0.604	L	1215
INDEX 307	TRANSGAST1	X60	70.7	Machined	3.281	0.681	N/A	N/A	N/A	N/A	1407
INDEX 308	TRANSGAST2	X60	70.7	Machined	3.486	0.474	N/A	N/A	N/A	N/A	1842
INDEX 309	TRANSGAST3	X60	70.7	Machined	3.486	0.681	N/A	N/A	N/A	N/A	1378
INDEX 310	TRANSGAST4	X60	70.7	Machined	3.486	0.526	N/A	N/A	N/A	N/A	1697

INDEX	Source Reference	Grade	D/t	Defect Type	$\frac{L}{\sqrt{Dt}}$	$\frac{d}{t}$	$\frac{\text{YS}}{\text{SMYS}}$	$\frac{\text{UTS}}{\text{SMTS}}$	$\frac{\text{YS}}{\text{UTS}}$	Failure Mode	Failure Pressure (psi)
INDEX 311	TRANSGAST5	X60	70.7	Machined	3.076	0.466	N/A	N/A	N/A	N/A	1697
INDEX 312	TRANSGAST6	X60	70.7	Machined	3.179	0.457	N/A	N/A	N/A	N/A	1900
INDEX 313	TRANSGAST7	X60	73.9	Real	3.040	0.432	N/A	N/A	N/A	N/A	2074

APPENDIX B FAILURE EQUATIONS

B.1 The ASME B31G Method

ASME B31G is the best known method for assessing the remaining strength of corroded pipelines. It is a supplement to the B31 pipeline code and was developed over 25 years ago. ASME B31G is based on an empirical fit to 47 full scale burst tests on pipes containing real corrosion defects. The burst test results used to develop ASME B31G are incorporated into the integrated database described in this report, see Appendix A. The burst tests are labeled as PRCI-01 to PRCI-048 in the integrated database.

The ASME B31G method idealizes the irregular shape of the corrosion with a parabolic profile and the area of the metal loss is assumed to equal (2/3)dL. As the length of the defect increases, the parabolic representation of the metal loss area becomes less and less accurate. For long defects, ASME B31G approximates the area of metal loss to be rectangular. Briefly the assessment is undertaken using the equations below.

$$P_f = P_o R_s \tag{B.2}$$

$$P_o = \frac{2\bar{\sigma}}{\left(\frac{D}{t}\right)} \tag{B.3}$$

$$\bar{\sigma} = 1.1\sigma_{SMYS} \tag{B.4}$$

$$R_S = \frac{1-\frac{2}{3}\left(\frac{d}{t}\right)}{1-\frac{2}{3}\left(\frac{d}{t}\right)\frac{1}{\sqrt{1+0.8\left(\frac{L}{\sqrt{Dt}}\right)^2}}} \quad \text{for} \quad \left(\frac{d}{t}\right) \le 0.8\,;\ \frac{L}{\sqrt{Dt}} \le 4.479 \tag{B.5}$$

$$R_s = 1-\left(\frac{d}{t}\right) \quad \text{for} \quad \left(\frac{d}{t}\right) \le 0.8\,;\ \frac{L}{\sqrt{Dt}} > 4.479 \tag{B.6}$$

The flow stress, $\bar{\sigma}$, is taken to be equal to 1.1 times the specified minimum yield strength, σ_{SMYS}, and the Folias factor, *M*, is represented by Equation (7)

$$M = \sqrt{1+0.8\left(\frac{L}{\sqrt{Dt}}\right)^2} \tag{B.7}$$

B.2 The Modified ASME B31G Method

The rationale for developing the RSTRENG method was that there was excessive conservatism embodied in the ASME B31G method. The sources of conservatism in ASME B31G were identified to be;

- The expression for the flow stress
- The Folias (bulging) correction factor
- The parabolic representation of the metal loss defect
- The inability to consider the strengthening effect of islands of full thickness or near full thickness pipe at the ends of or in-between corroded sections of the pipe

Battelle were contracted by the American Gas Association to modify the ASME B31G method in order to reduce the conservatisms and inherent limitations of the method. The method was initially validated using a more extensive database of 86 tests. The first 47 test results were the same as those used to develop ASME B31G. A more extensive validation of the RSTRENG method was undertaken using the results of 168 test results. These test results are all incorporated into the database developed by PRCI/AGA. The results from the tests on isolated defects are included into the integrated database described in this report.

Briefly, the RSTRENG method can be used in one of two ways. The first approach is often referred to as the Modified ASME B31G Method. The main changes introduced are a modified flow stress and Folias factor. The assessment is undertaken using the equations below:

$$P_f = P_o R_s \qquad \text{(B.8)}$$

$$P_o = \frac{2\bar{\sigma}}{\left(\frac{D}{t}\right)} \qquad \text{(B.9)}$$

$$\bar{\sigma} = \sigma_{SMYS} + 10{,}000 \text{ (psi)} \qquad \text{(B.10)}$$

$$R_s = \frac{1 - 0.85\left(\frac{d}{t}\right)}{1 - 0.85\left(\frac{d}{t}\right)\frac{1}{\sqrt{1 + 0.6275\left(\frac{L}{\sqrt{Dt}}\right)^2 - 0.003375\left(\frac{L}{\sqrt{Dt}}\right)^4}}}$$

for $\left(\frac{d}{t}\right) \le 0.8$; $\frac{L}{\sqrt{Dt}} \le 7.071$ (B.11)

$$R_s = \frac{1 - 0.85\left(\frac{d}{t}\right)}{1 - 0.85\left(\frac{d}{t}\right)\frac{1}{\left[3.3 + 0.032\left(\frac{L}{\sqrt{Dt}}\right)^2\right]}}$$

for $\left(\frac{d}{t}\right) \le 0.8\,;\frac{L}{\sqrt{Dt}} > 7.071$ (B.12)

The second method is described below.

B.3 The RSTRENG Effective Area Method

A method for assessing the actual shape of the corroded area was developed as part of the RSTRENG approach. The method is based on determining an effective area and effective length of the corroded area. Briefly, the method requires a 'river bed' profile of the corroded area. This is obtained by obtaining a number of profiles of the corroded area parallel to the axis of the pipe and then combined to give the most onerous profile for assessment. Calculations of the predicted failure pressure of various subsections of the total defect profile are undertaken. The length of a subsection is taken as L and the area of metal loss, A, is calculated. This process is repeated for all possible combinations of the various subsections and the minimum failure pressure predicted according to equations (B.13) to (B.17) below.

$$P_f = P_o \min \{R_{s,i}\} \qquad i = 1,2,3,\ldots n \tag{B.13}$$

$$P_o = \frac{2\bar{\sigma}}{\left(\frac{D}{t}\right)} \tag{B.14}$$

$$\bar{\sigma} = \sigma_{SMYS} + 10{,}000 \text{ (psi)} \tag{B.15}$$

$$\boldsymbol{R_s} = \frac{1-\left(\frac{\boldsymbol{A_i}}{\boldsymbol{A_{o,i}}}\right)}{1-\left(\frac{\boldsymbol{A_i}}{\boldsymbol{A_{o,i}}}\right)\frac{1}{\sqrt{1+0.6275\left(\frac{\boldsymbol{L_i}}{\sqrt{\boldsymbol{Dt}}}\right)^2 - 0.003375\left(\frac{\boldsymbol{L_i}}{\sqrt{\boldsymbol{Dt}}}\right)^4}}}$$

for $\left(\frac{\boldsymbol{d}}{\boldsymbol{t}}\right) \le 0.8\,;\ \frac{L_i}{\sqrt{Dt}} \le 7.071$ (B.16)

$$\boldsymbol{R_s} = \frac{1-\left(\frac{\boldsymbol{A_i}}{\boldsymbol{A_{o,i}}}\right)}{1-\left(\frac{\boldsymbol{A_i}}{\boldsymbol{A_{o,i}}}\right)\frac{1}{\left[3.3+0.032\left(\frac{\boldsymbol{L_i}}{\sqrt{\boldsymbol{Dt}}}\right)^2\right]}}$$

for $\left(\frac{\boldsymbol{d}}{\boldsymbol{t}}\right) \le 0.8\,;\ \frac{L_i}{\sqrt{Dt}} > 7.071$ (B.17)

The effective area method is based on an iterative method. This iterative method has been incorporated into a software program, RSTRENG for Windows. In most cases, although not all, the RSTRENG effective area method will predict a failure pressure that is higher than the value predicted using the Modified ASME B31G method.

B.4 The LPC-1 Method

Section 2.3 describes the background to the Linepipe Corrosion (LPC) Group Sponsored Project which was led by Advantica. The project was resulted in the development of new guidance, commonly referred to as the LPC method, for assessing part-wall, smooth, metal loss defects in pipelines subject to internal pressure loading.

The level 1 assessment method (referred to as LPC-1) is similar in form to the ASME B31G and the Modified ASME B31G methods, as given in equation (B.18) to (B.21) below.

$$P_f = P_o R_s \qquad \text{(B.18)}$$

$$P_o = \frac{2\bar{\sigma}}{\left(\frac{D}{t} - 1\right)} \qquad \text{(B.19)}$$

$$\bar{\sigma} = \sigma_{SMTS} \qquad \text{(B.20)}$$

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

for $\left(\frac{d}{t}\right) \le 0.85$; all lengths (B.21)

When actual material properties are used in the assessment, a factor of 0.9 is used to calculate the safe working pressure of the corroded pipe.

The main differences are in the definition of the flow stress, which is taken to equal the specified minimum tensile strength (SMTS) of the pipe; and the definition of the Folias factor, M. The Folias factor was derived by calibrating the results of burst tests and an extensive series of non-linear finite element analyses.

B.5 The SHELL92 Method

The SHELL92 method uses the same bulging factor as that for the ASME B31G method but extends its application to all defect lengths. The defect shape is modified to rectangular and the flow stress is modified to equal $0.9\sigma_{SMTS}$.

$$P_f = P_o R_s \tag{B.22}$$

$$P_o = \frac{2\overline{\sigma}}{\left(\frac{D}{t} - 1\right)} \tag{B.23}$$

$$\overline{\boldsymbol{\sigma}} = 0.9\boldsymbol{\sigma}_{SMTS} \tag{B.24}$$

$$R_s = \frac{1 - \left(\frac{d}{t}\right)}{1 - \left(\frac{d}{t}\right)\frac{1}{\sqrt{1 + 0.8\left(\frac{L}{\sqrt{Dt}}\right)^2}}}$$

for $\left(\frac{d}{t}\right) \leq 0.8$; all lengths (B.25)

The Shell-92 equation uses the same bulging factor as that in the ASME B31G equation but extends its application to all defect lengths.

B.6 The PCORRC Method

$$P_f = P_o R_s \tag{B.26}$$

$$P_o = \frac{2\overline{\sigma}}{\left(\frac{D}{t}\right)} \tag{B.27}$$

$$\overline{\boldsymbol{\sigma}} = \boldsymbol{\sigma}_{SMTS} \tag{B.28}$$

$$R_s = 1 - \left(\frac{d}{t}\right)\left\{1 - \exp\left[-0.222\left(\frac{L}{\sqrt{Dt}}\right)\frac{1}{\sqrt{1 - \left(\frac{d}{t}\right)}}\right]\right\}$$

for all lengths (B.29)

The PCORRC method does not specifically define the limit of maximum applicable defect depth. Reference [7] has recommended that PCORRC is limited to the assessment of defect depths up to 80% of the nominal wall thickness of corroded pipe.

APPENDIX C LIST OF FAILURE PREDICTIONS FOR THE INTEGRATED DATABASE – CASE 1 (FLOW STRESS BASED ON THE ACTUAL MATERIAL PROPERTIES)

Notes

1. For clarity non-conservative failure predictions are marked in red.
2. INDEX 6 to 25 are Battelle tests on Grade B pipe. These results have been discounted from the sensitivity studies described in this report.

INDEX	Source Reference	Grade	D/t	Defect Type	$\frac{L}{\sqrt{Dt}}$	d/t	ASME B31G P_A/P_f	Mod ASME B31G P_A/P_f	RSTRENG P_A/P_f	LPC-1 P_A/P_f	SHELL 92 P_A/P_f	PCORRC P_A/P_f
INDEX 1	PRCI-001	X52	78.5	Real	0.738	0.382	1.043	0.989	0.968	0.865	1.013	0.902
INDEX 2	PRCI-002	X52	78.5	Real	0.665	0.382	1.032	0.977	0.963	0.857	0.997	0.894
INDEX 3	PRCI-003	X52	78.5	Real	1.255	0.411	1.165	1.123	1.033	0.975	1.187	1.003
INDEX 4	PRCI-004	X52	80.0	Real	1.640	0.640	1.261	1.323	1.009	1.199	1.615	1.169
INDEX 5	PRCI-005	X52	78.9	Real	1.407	0.550	1.134	1.129	1.021	0.995	1.282	1.005
INDEX 6	PRCI-006	B	63.7	Real	0.997	0.719	0.969	0.927	0.861	0.690	0.957	0.703
INDEX 7	PRCI-007	B	63.7	Real	1.579	0.666	1.113	1.091	0.996	0.827	1.131	0.806
INDEX 8	PRCI-008	B	63.7	Real	1.745	0.666	1.192	1.181	1.085	0.905	1.234	0.872
INDEX 9	PRCI-009	B	64.9	Real	0.587	0.705	0.808	0.742	0.691	0.564	0.714	0.603
INDEX 10	PRCI-010	B	64.0	Real	1.417	0.752	1.121	1.144	0.931	0.920	1.333	0.873
INDEX 11	PRCI-011	B	65.8	Real	0.676	0.715	0.825	0.766	0.701	0.582	0.758	0.617
INDEX 12	PRCI-012	B	65.8	Real	0.760	0.600	0.969	0.886	0.830	0.668	0.835	0.705
INDEX 13	PRCI-013	B	65.8	Real	0.845	0.630	1.082	1.001	0.929	0.754	0.969	0.791
INDEX 14	PRCI-014	B	65.8	Real	0.929	0.715	1.142	1.090	0.970	0.830	1.138	0.854
INDEX 15	PRCI-015	B	63.2	Real	1.242	0.661	1.156	1.111	0.957	0.847	1.150	0.852
INDEX 16	PRCI-016	B	64.9	Real	0.671	0.508	1.022	0.920	0.891	0.697	0.834	0.736
INDEX 17	PRCI-017	B	64.9	Real	1.007	0.649	1.160	1.091	1.005	0.823	1.091	0.850
INDEX 18	PRCI-018	B	64.0	Real	1.250	0.640	1.249	1.193	0.980	0.906	1.216	0.915
INDEX 19	PRCI-019	B	65.8	Real	0.591	0.715	1.146	1.055	0.984	0.802	1.022	0.857
INDEX 20	PRCI-020	B	64.0	Real	0.750	0.669	0.949	0.878	0.803	0.663	0.856	0.701
INDEX 21	PRCI-021	B	64.0	Real	0.750	0.779	1.227	1.173	1.038	0.906	1.263	0.942
INDEX 22	PRCI-022	B	64.0	Real	0.833	0.584	1.192	1.092	1.002	0.821	1.032	0.864
INDEX 23	PRCI-023	B	64.0	Real	0.667	0.501	1.133	1.020	0.979	0.772	0.922	0.815
INDEX 24	PRCI-024	B	64.0	Real	0.750	0.472	1.140	1.027	0.995	0.777	0.930	0.817
INDEX 25	PRCI-025	B	64.0	Real	1.667	0.723	1.484	1.517	1.281	1.224	1.728	1.154

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INDEX 26	PRCI-026	X52	80.0	Real	0.820	1.000	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid
INDEX 27	PRCI-027	X52	80.0	Real	1.640	0.389	1.284	1.251	1.126	1.285	1.564	1.304
INDEX 28	PRCI-028	X52	80.0	Real	1.342	0.307	1.238	1.189	1.148	1.234	1.461	1.265
INDEX 29	PRCI-029	X52	80.0	Real	1.193	0.613	1.214	1.230	1.050	1.344	1.772	1.366
INDEX 30	PRCI-030	X52	80.0	Real	0.477	0.557	1.178	1.144	1.111	1.335	1.567	1.413
INDEX 31	PRCI-031	X52	80.0	Real	0.596	0.557	1.193	1.155	1.103	1.274	1.527	1.348
INDEX 32	PRCI-032	B	61.5	Real	2.255	0.643	1.112	1.117	0.861	0.973	1.288	0.927
INDEX 33	PRCI-033	B	61.5	Real	2.550	0.674	1.721	1.777	1.219	1.602	2.121	1.506
INDEX 34	PRCI-034	A25	51.6	Real	2.021	0.742	1.358	1.320	0.998	1.152	1.617	1.058
INDEX 35	PRCI-035	A25	51.6	Real	2.245	0.774	1.658	1.674	1.194	1.547	2.180	1.388
INDEX 36	PRCI-036	A25	51.6	Real	2.694	0.910	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid
INDEX 37	PRCI-037	A25	51.6	Real	1.235	0.877	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid
INDEX 38	PRCI-038	A25	51.6	Real	2.806	0.642	1.568	1.473	1.212	1.483	1.921	1.416
INDEX 39	PRCI-039	B	57.6	Real	4.109	0.695	1.190	1.335	1.035	1.183	1.489	1.161
INDEX 40	PRCI-040	B	58.5	Real	2.550	0.927	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid
INDEX 41	PRCI-041	B	60.6	Real	1.865	0.909	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid
INDEX 42	PRCI-042	B	54.1	Real	2.527	0.495	1.203	1.192	1.134	0.902	1.123	0.891
INDEX 43	PRCI-043	B	65.6	Real	5.061	0.751	3.283	1.749	1.101	2.392	2.974	2.462
INDEX 44	PRCI-044	B	65.9	Real	4.398	0.698	1.207	1.369	1.040	1.668	2.084	1.654
INDEX 45	PRCI-045	B	67.6	Real	2.227	0.814	Invalid	Invalid	Invalid	2.197	Invalid	Invalid
INDEX 46	PRCI-046	B	75.2	Real	1.988	0.677	1.770	1.840	1.328	1.812	2.463	1.712
INDEX 47	PRCI-047	B	72.3	Real	1.594	0.663	1.710	1.711	1.392	1.556	2.124	1.513
INDEX 48	PRCI-048	B	64.0	Real	5.333	0.787	1.881	0.936	0.945	1.194	1.486	1.262
INDEX 49	PRCI-049	B	64.0	Real	3.000	0.853	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid
INDEX 50	PRCI-050	B	64.1	Real	4.804	0.808	Invalid	Invalid	Invalid	1.398	Invalid	Invalid
INDEX 51	PRCI-051	X52	65.6	Real	4.251	0.689	1.033	1.173	1.096	1.174	1.470	1.157

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INDEX 52	PRCI-052	B	66.5	Real	3.567	0.884	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid
INDEX 53	PRCI-053	B	66.5	Real	4.247	0.789	1.978	2.328	1.228	2.364	3.030	2.341
INDEX 54	PRCI-054	B	67.6	Real	2.912	0.685	1.636	1.783	1.116	1.843	2.412	1.731
INDEX 55	PRCI-055	B	64.7	Real	3.519	0.744	1.495	1.693	1.027	1.703	2.214	1.612
INDEX 56	PRCI-056	B	64.7	Real	3.519	0.784	1.564	1.839	1.020	1.966	2.588	1.851
INDEX 57	PRCI-057	B	64.5	Real	7.363	0.548	4.113	1.484	1.060	1.546	3.336	1.630
INDEX 58	PRCI-058	B	65.9	Real	2.876	0.615	1.480	1.538	1.262	1.510	1.934	1.447
INDEX 59	PRCI-059	B	65.6	Real	4.218	0.661	1.988	2.123	1.295	2.164	2.695	2.132
INDEX 60	PRCI-060	B	65.6	Real	1.350	0.522	1.093	1.056	1.105	0.890	1.132	0.908
INDEX 61	PRCI-061	B	65.2	Real	9.422	0.783	4.374	2.442	1.100	2.866	3.387	3.277
INDEX 62	PRCI-062	B	70.7	Real	12.610	0.968	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid
INDEX 63	PRCI-063	B	73.0	Real	5.126	0.474	2.711	1.888	1.613	1.567	1.856	1.586
INDEX 64	PRCI-064	B	64.3	Real	3.408	0.768	2.417	2.658	1.305	2.612	3.440	2.448
INDEX 65	PRCI-065	B	64.3	Real	4.411	0.338	1.710	1.546	1.303	1.242	1.450	1.253
INDEX 66	PRCI-066	B	75.2	Real	6.720	0.541	2.793	1.888	1.431	1.719	2.023	1.791
INDEX 67	PRCI-067	B	64.7	Real	4.827	0.706	4.330	2.372	1.286	2.283	2.828	2.308
INDEX 68	PRCI-068	X52	80.6	Real	10.776	0.349	1.749	1.371	1.356	1.612	1.832	1.685
INDEX 69	PRCI-069	X52	79.8	Real	3.573	0.612	1.506	1.613	1.380	1.689	2.115	1.636
INDEX 70	PRCI-070	X52	80.0	Real	3.578	0.373	1.379	1.373	1.349	1.443	1.712	1.441
INDEX 71	PRCI-071	X52	78.5	Real	5.908	0.380	1.759	1.413	1.202	1.602	1.860	1.635
INDEX 72	PRCI-072	X52	79.8	Real	5.955	0.346	1.761	1.421	1.309	1.466	1.694	1.495
INDEX 73	PRCI-073	X52	79.4	Real	9.800	0.291	1.530	1.209	1.258	1.520	1.724	1.576
INDEX 74	PRCI-074	X52	79.2	Real	4.152	0.449	1.315	1.358	1.193	1.566	1.871	1.563
INDEX 75	PRCI-075	X52	78.7	Real	3.549	0.787	1.367	1.653	0.976	2.000	2.632	1.881
INDEX 76	PRCI-076	X52	79.4	Real	2.376	0.450	1.291	1.294	1.137	1.352	1.667	1.341
INDEX 77	PRCI-077	X52	79.6	Real	3.568	0.424	1.365	1.383	1.225	1.497	1.795	1.488

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INDEX 78	PRCI-078	X52	80.4	Real	2.690	0.295	1.314	1.278	1.255	1.313	1.547	1.319
INDEX 79	PRCI-079	X42	64.0	Real	5.583	0.859	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid
INDEX 80	PRCI-080	X52	82.2	Real	4.835	0.627	1.689	1.085	1.104	1.113	1.359	1.118
INDEX 81	PRCI-081	X52	80.0	Real	8.050	0.653	1.513	1.039	1.011	1.153	1.359	1.248
INDEX 82	PRCI-082	X56	80.0	Real	2.236	0.400	1.336	1.334	1.195	1.037	1.263	1.037
INDEX 83	PRCI-083	X46	76.9	Real	7.016	0.838	Invalid	Invalid	Invalid	2.599	Invalid	Invalid
INDEX 84	PRCI-084	X65	109.1	Real	4.642	0.661	1.542	0.975	1.056	1.221	1.505	1.214
INDEX 85	PRCI-085	X60	100.7	Real	21.070	0.903	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid
INDEX 86	PRCI-086	X52	111.1	Real	2.875	0.747	1.120	1.315	0.981	1.652	2.216	1.507
INDEX 87	PRCI-087	X65	94.5	Real	0.729	0.735	1.175	1.206	1.055	1.122	1.502	1.175
INDEX 88	PRCI-088	X52	82.6	Real	2.364	0.331	1.200	1.178	1.123	1.037	1.236	1.041
INDEX 89	PRCI-089	X65	88.9	Real	1.453	0.741	1.249	1.384	1.045	1.319	1.894	1.250
INDEX 90	PRCI-090	X65	90.0	Real	0.422	0.675	1.011	0.994	0.970	0.847	1.012	0.905
INDEX 91	PRCI-091	X65	91.6	Real	0.372	0.789	1.104	1.096	1.049	0.980	1.203	1.056
INDEX 92	PRCI-092	X52	75.2	Real	6.867	0.282	1.567	1.317	1.199	1.185	1.354	1.215
INDEX 93	PRCI-097	X60	76.6	Machined	6.565	0.395	1.458	1.174	1.271	1.052	1.218	1.081
INDEX 94	PRCI-098	X60	76.3	Machined	17.474	0.385	1.525	1.252	1.402	1.132	1.277	1.188
INDEX 95	PRCI-099	X60	78.1	Machined	2.652	0.395	1.290	1.292	1.376	1.133	1.369	1.129
INDEX 96	PRCI-100	X60	78.4	Machined	2.657	0.376	1.254	1.255	1.376	1.082	1.301	1.080
INDEX 97	PRCI-101	X60	78.4	Machined	2.657	0.396	1.265	1.272	1.376	1.108	1.339	1.103
INDEX 98	PRCI-106	X46	54.7	Machined	1.137	0.790	1.177	1.252	1.060	1.143	1.703	1.105
INDEX 99	PRCI-108	X46	53.3	Machined	1.352	0.657	1.157	1.177	1.044	0.955	1.299	0.954
INDEX 100	PRCI-109	X46	55.4	Machined	1.028	0.665	1.297	1.290	1.132	0.984	1.320	1.013
INDEX 101	PRCI-110	X46	54.0	Machined	0.669	0.784	0.982	0.997	0.899	0.921	1.262	0.973
INDEX 102	PRCI-111	X46	54.0	Machined	0.899	0.750	1.191	1.215	1.020	0.977	1.370	1.003
INDEX 103	PRCI-112	X46	53.3	Machined	1.008	0.481	1.097	1.064	1.042	0.954	1.174	0.998

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INDEX 104	PRCI-113	X46	49.2	Machined	0.969	0.788	1.065	1.090	0.878	0.878	1.287	0.878
INDEX 105	PRCI-114	X46	52.7	Machined	0.660	0.393	1.071	1.001	0.979	0.833	0.970	0.875
INDEX 106	PRCI-115	X46	52.5	Machined	0.886	0.733	1.158	1.148	1.000	1.019	1.405	1.054
INDEX 107	PRCI-116	X46	54.5	Machined	1.042	0.701	1.338	1.333	1.166	1.066	1.466	1.088
INDEX 108	PRCI-117	X46	53.8	Machined	1.243	0.312	1.152	1.085	1.066	0.869	1.028	0.899
INDEX 109	PRCI-119	X60	79.4	Machined	17.372	0.532	1.433	1.112	1.303	1.223	1.389	1.305
INDEX 110	PRCI-120	X60	79.4	Machined	17.817	0.345	1.513	1.259	1.398	1.319	1.485	1.378
INDEX 111	PRCI-121	X60	79.4	Machined	1.782	0.468	1.257	1.257	1.347	1.189	1.487	1.193
INDEX 112	PRCI-122	X60	79.4	Machined	3.563	0.452	1.059	1.088	1.190	1.080	1.303	1.070
INDEX 113	PRCI-123	X60	79.4	Machined	3.595	0.532	0.983	1.037	1.175	1.043	1.280	1.023
INDEX 114	PRCI-124	X60	79.4	Machined	17.537	0.500	1.393	1.100	1.273	1.208	1.369	1.284
INDEX 115	PRCI-125	X52	49.4	Machined	35.136	0.399	1.201	1.026	1.135	1.257	1.407	1.309
INDEX 116	PRCI-126	X52	49.4	Machined	7.027	0.399	1.169	0.942	1.018	1.116	1.290	1.161
INDEX 117	PRCI-127	X52	49.4	Machined	3.514	0.399	0.974	0.989	1.035	1.122	1.339	1.126
INDEX 118	PRCI-128	X52	49.4	Machined	3.514	0.399	1.037	1.053	1.101	1.195	1.426	1.199
INDEX 119	PRCI-129	X52	49.4	Machined	1.757	0.399	1.084	1.072	1.067	1.170	1.429	1.192
INDEX 120	PRCI-136	X52	49.4	Machined	0.439	0.599	1.149	1.107	1.115	1.214	1.427	1.299
INDEX 121	PRCI-137	X52	49.4	Machined	0.439	0.599	1.065	1.026	N/A	1.125	1.323	1.204
INDEX 122	PRCI-142	X52	49.4	Machined	1.318	0.599	1.164	1.184	1.082	1.288	1.695	1.310
INDEX 123	PRCI-144	X52	49.4	Machined	3.514	0.399	1.112	1.129	1.129	1.281	1.529	1.286
INDEX 124	PRCI-147	X52	49.4	Machined	1.757	0.399	1.189	1.176	1.171	1.283	1.568	1.308
INDEX 125	PRCI-163	X46	52.5	Machined	0.449	0.605	1.325	1.236	1.268	1.168	1.378	1.249
INDEX 126	PRCI-165	X46	51.8	Machined	0.440	0.606	1.336	1.245	1.276	1.177	1.387	1.260
INDEX 127	PRCI-166	X46	52.5	Machined	0.443	0.609	1.151	1.102	1.130	1.204	1.420	1.288
INDEX 128	PRCI-171	X46	51.6	Machined	0.440	0.599	1.134	1.068	1.093	1.070	1.258	1.144
INDEX 129	PRCI-173	X46	51.4	Machined	1.597	0.601	1.201	1.211	N/A	1.210	1.599	1.205

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INDEX 130	PRCI-174	X46	51.8	Machined	1.604	0.606	1.249	1.265	N/A	1.275	1.689	1.267
INDEX 131	PRCI-176	X46	52.5	Machined	0.449	0.601	1.009	0.949	N/A	0.944	1.113	1.010
INDEX 132	PRCI-182	X46	47.2	Machined	1.186	0.659	1.183	1.185	1.111	1.159	1.568	1.179
INDEX 133	PRCI-183	X46	48.9	Machined	2.286	0.667	1.339	1.437	1.196	1.542	2.061	1.463
INDEX 134	PRCI-184	X46	47.6	Machined	2.223	0.683	1.214	1.311	1.251	1.415	1.909	1.335
INDEX 135	ADVANTICA-TR020	X65	41.3	Machined	200.935	0.229	1.272	1.178	1.231	1.303	1.449	1.338
INDEX 136	ADVANTICA-TR021	X65	42.2	Machined	203.044	0.429	1.383	1.203	1.338	1.415	1.575	1.455
INDEX 137	ADVANTICA-TR022	X65	40.9	Machined	199.776	0.627	1.234	0.954	1.194	1.260	1.403	1.299
INDEX 138	ADVANTICA-TR023	X65	41.1	Machined	200.417	0.824	Invalid	Invalid	Invalid	1.656	Invalid	Invalid
INDEX 139	ADVANTICA-TR024	X65	40.8	Machined	199.649	0.574	1.197	0.961	1.156	1.200	1.336	1.236
INDEX 140	ADVANTICA-TR025	X65	40.7	Machined	199.268	0.580	1.194	0.955	1.153	1.197	1.333	1.234
INDEX 141	ADVANTICA-TR026	X65	41.1	Machined	200.289	0.560	1.170	0.949	1.130	1.174	1.307	1.209
INDEX 142	ADVANTICA-TR027	X65	43.7	Machined	206.619	0.586	1.156	0.920	1.116	1.161	1.292	1.194
INDEX 143	ADVANTICA-TR029	X52	46.0	Machined	282.526	0.186	1.333	1.209	1.251	1.261	1.402	1.291
INDEX 144	ADVANTICA-TR030	X52	45.6	Machined	281.450	0.648	1.329	0.977	1.247	1.254	1.395	1.287
INDEX 145	ADVANTICA-TR031	X52	46.2	Machined	283.069	0.454	1.459	1.217	1.369	1.379	1.534	1.413
INDEX 146	ADVANTICA-TR032	X52	46.2	Machined	283.069	0.720	1.626	1.101	1.526	1.534	1.707	1.575
INDEX 147	ADVANTICA-TR033	X52	45.7	Machined	281.718	0.468	1.393	1.155	1.307	1.316	1.464	1.349
INDEX 148	ADVANTICA-TR034	X52	46.0	Machined	282.526	0.472	1.318	1.091	1.237	1.245	1.385	1.277
INDEX 149	ADVANTICA-TR035	X52	46.5	Machined	284.164	0.496	1.428	1.168	1.340	1.349	1.501	1.383
INDEX 150	ADVANTICA-TV006	X65	42.6	Machined	1.629	0.702	1.130	1.236	1.501	1.130	1.577	1.089
INDEX 151	ADVANTICA-TV008	X65	41.2	Machined	4.811	0.680	1.526	0.941	1.201	0.998	1.231	1.016
INDEX 152	ADVANTICA-TV010	X65	41.7	Machined	3.227	0.687	0.811	0.939	1.187	0.947	1.225	0.905
INDEX 153	ADVANTICA-TV011	X65	40.9	Machined	3.196	0.674	0.814	0.933	1.163	0.930	1.200	0.892
INDEX 154	ADVANTICA-TV016	X65	40.7	Machined	3.188	0.700	0.896	1.048	1.343	1.074	1.397	1.022

INDEX	Source Reference	Grade	D/t	Defect Type	$\frac{L}{\sqrt{Dt}}$	d/t	ASME B31G P_A/P_f	Mod ASME B31G P_A/P_f	RSTRENG P_A/P_f	LPC-1 P_A/P_f	SHELL 92 P_A/P_f	PCORRC P_A/P_f
INDEX 155	ADVANTICA-TV017	X65	41.2	Machined	4.816	0.756	1.392	0.761	1.073	0.889	1.113	0.914
INDEX 156	ADVANTICA-TV018	X65	40.9	Machined	3.836	0.739	0.828	1.008	1.371	1.103	1.416	1.073
INDEX 157	ADVANTICA-TV019	X65	40.7	Machined	6.377	0.735	1.608	0.947	1.304	1.108	1.342	1.205
INDEX 158	ADVANTICA-TV022	X65	40.3	Machined	3.172	0.748	0.771	0.933	1.273	0.992	1.311	0.931
INDEX 159	ADVANTICA-TV027	X65	40.7	Machined	4.782	0.720	1.576	0.915	1.224	1.027	1.277	1.047
INDEX 160	ADVANTICA-TV028	X65	44.0	Machined	4.972	0.744	1.445	0.810	1.122	0.944	1.174	0.973
INDEX 161	ADVANTICA-TV031	X65	44.0	Machined	4.972	0.551	1.388	0.993	1.146	0.986	1.185	1.004
INDEX 162	ADVANTICA-TV032	X65	40.5	Machined	4.770	0.478	1.147	0.866	0.963	0.832	0.990	0.847
INDEX 163	ADVANTICA-TV033	X65	8.8	Machined	0.688	0.708	1.453	1.389	1.519	0.990	1.288	1.165
INDEX 164	ADVANTICA-TV034	X65	8.6	Machined	1.357	0.690	1.294	1.309	1.540	0.948	1.315	1.040
INDEX 165	ADVANTICA-TV035	X65	8.8	Machined	2.064	0.710	1.255	1.343	1.685	1.044	1.438	1.078
INDEX 166	ADVANTICA-TV036	X65	8.7	Machined	2.729	0.697	1.224	1.332	1.685	1.073	1.422	1.114
INDEX 167	ADVANTICA-TV037	X65	8.6	Machined	1.362	0.197	1.514	1.396	1.414	0.998	1.151	1.140
INDEX 168	ADVANTICA-TV038	X65	8.6	Machined	1.357	0.509	1.423	1.361	1.456	0.960	1.214	1.093
INDEX 169	ADVANTICA-TV039	X65	8.7	Machined	1.367	0.941	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid
INDEX 170	ADVANTICA-TV045	X52	48.1	Machined	1.737	0.725	1.086	1.186	1.488	1.022	1.440	0.962
INDEX 171	ADVANTICA-TV046	X52	49.2	Machined	1.756	0.559	1.234	1.252	1.389	1.017	1.318	1.014
INDEX 172	ADVANTICA-TV047	X52	48.1	Machined	5.212	0.740	1.604	0.890	1.228	0.940	1.162	0.977
INDEX 173	ADVANTICA-TV048	X52	49.5	Machined	5.283	0.546	1.756	1.238	1.427	1.118	1.336	1.143
INDEX 174	ADVANTICA-TV049	X60	29.5	Machined	1.360	0.704	1.084	1.179	1.406	1.098	1.538	1.095
INDEX 175	ADVANTICA-TV050	X60	29.1	Machined	1.352	0.733	1.065	1.175	1.440	1.108	1.583	1.093
INDEX 176	ADVANTICA-TV051	X60	29.5	Machined	1.360	0.568	1.045	1.083	1.184	0.979	1.271	1.012
INDEX 177	ADVANTICA-TV052	X60	28.8	Machined	4.029	0.688	0.748	0.888	1.135	0.962	1.212	0.959
INDEX 178	ADVANTICA-TV053	X60	29.3	Machined	4.068	0.519	0.958	1.041	1.176	1.025	1.243	1.038
INDEX 179	ADVANTICA-TV056	X52	45.2	Machined	1.687	0.724	1.087	1.178	1.470	1.031	1.455	0.977
INDEX 180	ADVANTICA-TV057	X52	46.9	Machined	1.730	0.577	1.200	1.220	1.363	1.015	1.325	1.010

INDEX	Source Reference	Grade	D/t	Defect Type	$\frac{L}{\sqrt{Dt}}$	d/t	ASME B31G P_A/P_f	Mod ASME B31G P_A/P_f	RSTRENG P_A/P_f	LPC-1 P_A/P_f	SHELL 92 P_A/P_f	PCORRC P_A/P_f
INDEX 181	ADVANTICA-TV058	X52	46.5	Machined	5.147	0.766	1.588	0.833	1.198	0.934	1.162	0.975
INDEX 182	ADVANTICA-TV059	X52	45.2	Machined	5.073	0.586	1.775	1.197	1.413	1.122	1.355	1.145
INDEX 183	ADVANTICA-TV060	X60	31.6	Machined	1.411	0.725	1.102	1.216	1.487	1.122	1.594	1.099
INDEX 184	ADVANTICA-TV061	X60	29.7	Machined	1.369	0.537	1.177	1.209	1.306	1.064	1.362	1.103
INDEX 185	ADVANTICA-TV062	X60	30.8	Machined	4.186	0.733	0.782	0.962	1.303	1.075	1.362	1.074
INDEX 186	ADVANTICA-TV063	X60	31.6	Machined	4.241	0.534	0.996	1.089	1.241	1.057	1.281	1.070
INDEX 187	ADVANTICA-TV064	X65	32.3	Machined	1.435	0.817	Invalid	Invalid	Invalid	1.237	Invalid	Invalid
INDEX 188	ADVANTICA-TV065	X65	32.4	Machined	1.429	0.622	1.320	1.343	1.515	1.097	1.465	1.112
INDEX 189	ADVANTICA-TV066	X65	32.3	Machined	4.286	0.820	Invalid	Invalid	Invalid	1.133	Invalid	Invalid
INDEX 190	ADVANTICA-TV067	X65	32.3	Machined	4.286	0.630	1.091	1.205	1.462	1.126	1.391	1.133
INDEX 191	ADVANTICA-TV072	X60	46.9	Machined	1.715	0.704	1.026	1.126	1.378	1.058	1.475	1.010
INDEX 192	ADVANTICA-TV073	X60	47.1	Machined	5.165	0.719	1.389	0.813	1.088	0.925	1.141	0.956
INDEX 193	PETROBRAS TS02	X46	76.0	Real	18.860	0.463	2.431	1.892	1.653	1.534	1.734	1.621
INDEX 194	PETROBRAS TS04	X46	73.6	Real	18.550	0.525	2.388	1.814	1.443	1.623	1.839	1.728
INDEX 195	PETROBRAS TS05	X46	75.7	Real	18.821	0.448	2.217	1.676	1.409	1.533	1.731	1.617
INDEX 196	PETROBRAS TS06	X46	69.7	Real	18.101	0.507	1.854	1.420	1.424	1.491	1.690	1.587
INDEX 197	PETROBRAS TS10	X46	75.3	Real	18.792	0.461	2.214	1.738	1.437	1.494	1.689	1.579
INDEX 198	PETROBRAS TS 5.1	X60	33.0	Machined	4.537	0.722	1.725	0.978	1.310	1.126	1.410	1.143
INDEX 199	PETROBRAS TS 1.2	X60	33.5	Machined	5.464	0.699	1.579	0.955	1.249	1.098	1.342	1.154
INDEX 200	PETROBRAS TS 2.2	X60	33.4	Machined	6.241	0.714	1.594	0.958	1.280	1.138	1.378	1.232
INDEX 201	PETROBRAS TS 2.1	X60	33.4	Machined	7.035	0.712	1.494	0.912	1.218	1.095	1.312	1.208
INDEX 202	PETROBRAS TS 3.1	X60	32.7	Machined	7.650	0.738	1.523	0.948	1.380	1.126	1.344	1.268
INDEX 203	PETROBRAS TS 1.1	X60	33.2	Machined	8.310	0.720	1.427	0.914	1.292	1.076	1.275	1.213
INDEX 204	PETROBRAS TS 3.2	X60	33.1	Machined	8.679	0.713	1.384	0.895	1.254	1.053	1.243	1.188
INDEX 205	PETROBRAS TS 4.1	X60	33.1	Machined	8.880	0.713	1.393	0.902	1.264	1.064	1.254	1.202
INDEX 206	PETROBRAS TS 4.2	X60	33.2	Machined	9.398	0.733	1.415	0.898	1.292	1.086	1.278	1.238

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INDEX 207	KOREAN GAS CO DA	X65	43.5	Machined	1.732	0.251	1.163	1.128	1.155	1.057	1.239	1.087
INDEX 208	KOREAN GAS CO DB	X65	43.5	Machined	1.732	0.503	1.183	1.195	1.294	1.119	1.418	1.132
INDEX 209	KOREAN GAS CO DC	X65	43.5	Machined	1.732	0.748	1.103	1.238	1.599	1.261	1.804	1.174
INDEX 210	KOREAN GAS CO LA	X65	43.5	Machined	0.866	0.503	1.187	1.157	1.204	1.072	1.311	1.133
INDEX 211	KOREAN GAS CO LC	X65	43.5	Machined	2.598	0.503	1.141	1.180	1.303	1.140	1.421	1.130
INDEX 212	KOREAN GAS CO CB	X65	43.5	Machined	1.732	0.503	1.273	1.287	1.393	1.205	1.526	1.218
INDEX 213	KOREAN GAS CO CC	X65	43.5	Machined	1.732	0.503	1.231	1.244	1.347	1.165	1.475	1.178
INDEX 214	WATERLOO SOL-2	X46	37.4	Real	1.202	0.250	1.238	1.152	1.134	1.000	1.163	1.041
INDEX 215	WATERLOO SOL-4	X46	37.6	Real	3.858	0.346	1.349	1.311	1.187	1.178	1.385	1.197
INDEX 216	WATERLOO SOL-6	X46	37.4	Real	1.154	0.312	1.300	1.214	1.189	1.049	1.237	1.096
INDEX 217	WATERLOO SOL-10	X46	37.6	Real	2.743	0.383	1.392	1.351	1.246	1.195	1.438	1.208
INDEX 218	WATERLOO SOL-11	X46	37.5	Real	2.402	0.309	1.195	1.138	1.057	0.997	1.181	1.017
INDEX 219	WATERLOO SOL-12	X46	37.9	Real	0.967	0.256	1.093	1.014	1.018	0.882	1.020	0.922
INDEX 220	WATERLOO NOR-1	X52	52.2	Real	10.819	0.354	1.579	1.228	1.184	1.242	1.412	1.308
INDEX 221	WATERLOO NOR-2	X52	51.9	Real	3.687	0.329	1.315	1.288	1.195	1.167	1.371	1.178
INDEX 222	WATERLOO TNG-01	X46	33.1	Real	5.083	0.480	1.498	1.108	1.035	1.142	1.355	1.175
INDEX 223	WATERLOO RLK-1	X52	93.3	Real	14.246	0.504	2.006	1.539	1.368	1.540	1.754	1.643
INDEX 224	WATERLOO RLK-2	X52	95.3	Real	22.833	0.553	1.899	1.464	1.273	1.489	1.683	1.572
INDEX 225	WATERLOO RLK-3	X52	95.5	Real	21.924	0.401	1.766	1.454	1.301	1.401	1.576	1.461
INDEX 226	WATERLOO BCG-1	X42	55.2	Real	4.971	0.667	2.950	1.775	1.087	1.904	2.335	1.935
INDEX 227	WATERLOO BCG-2	X42	58.4	Real	1.351	0.560	1.270	1.235	1.033	1.095	1.416	1.114
INDEX 228	WATERLOO BCG-3	X42	57.3	Real	0.843	0.340	1.078	1.000	0.984	0.891	1.043	0.930
INDEX 229	WATERLOO BCG-4	X42	56.0	Real	2.784	0.448	1.396	1.374	1.157	1.261	1.542	1.253
INDEX 230	WATERLOO BCG-5	X42	55.6	Real	1.245	0.325	1.179	1.101	1.062	0.979	1.161	1.012
INDEX 231	WATERLOO BCG-6	X42	54.8	Real	3.360	0.431	1.210	1.194	1.015	1.108	1.335	1.105
INDEX 232	WATERLOO BCG-7	X42	60.0	Real	1.864	0.600	1.306	1.318	1.026	1.203	1.583	1.177

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INDEX 233	WATERLOO BCG-8	X42	55.1	Real	1.031	0.546	1.217	1.160	1.058	1.022	1.292	1.066
INDEX 234	WATERLOO BCG-9	X42	56.9	Real	4.327	0.437	1.218	1.213	0.997	1.149	1.366	1.156
INDEX 235	WATERLOO ESS-01	X46	63.8	Real	2.442	0.720	1.165	1.295	1.000	1.324	1.797	1.220
INDEX 236	WATERLOO NOV01	X55	88.3	Real	2.449	0.527	1.226	1.278	1.106	1.159	1.462	1.132
INDEX 237	WATERLOO NOV02-2	X55	89.1	Real	8.644	0.574	1.657	1.201	1.023	1.253	1.460	1.339
INDEX 238	WATERLOO NOV03-2	X55	89.3	Real	11.528	0.661	2.219	1.549	1.083	1.707	1.976	1.876
INDEX 239	WATERLOO NOV04	X55	88.5	Real	9.878	0.668	2.592	1.778	1.224	1.954	2.280	2.148
INDEX 240	WATERLOO NOV04-2	X55	88.5	Real	7.714	0.531	2.023	1.481	1.142	1.524	1.778	1.603
INDEX 241	WATERLOO NOV05	X55	90.5	Real	11.175	0.597	1.779	1.299	1.012	1.379	1.592	1.496
INDEX 242	WATERLOO NOV06	X55	90.1	Real	3.180	0.437	1.299	1.334	1.171	1.217	1.473	1.203
INDEX 243	WATERLOO TCP01	X46	89.7	Real	2.340	0.377	1.311	1.286	1.187	1.167	1.409	1.166
INDEX 244	WATERLOO TCP02	X46	91.2	Real	2.050	0.316	1.245	1.203	1.117	1.084	1.292	1.093
INDEX 245	WATERLOO TCP03	X46	92.1	Real	1.016	0.493	1.082	1.044	1.003	0.926	1.145	0.960
INDEX 246	ADVANTICA V1	B/X42	77.2	Machined	0.228	0.800	1.265	1.164	1.198	0.966	1.124	1.038
INDEX 247	ADVANTICA V2	B/X42	77.2	Machined	0.911	0.800	1.089	1.105	1.384	0.940	1.385	0.938
INDEX 248	BRITISH GAS RING1	X60	40.9	Machined	177.799	0.300	1.145	1.021	1.086	0.945	1.051	0.971
INDEX 249	BRITISH GAS RING2	X60	41.4	Machined	178.784	0.280	1.174	1.052	1.114	0.969	1.078	0.996
INDEX 250	BRITISH GAS RING3	X60	41.5	Machined	179.122	0.470	1.207	1.010	1.145	0.994	1.106	1.023
INDEX 251	BRITISH GAS RING4	X60	41.5	Machined	179.122	0.500	1.131	0.933	1.073	0.932	1.037	0.959
INDEX 252	BRITISH GAS RING5	X60	40.7	Machined	177.184	0.690	1.181	0.840	1.121	0.970	1.081	1.002
INDEX 253	BRITISH GAS RING6	X60	41.3	Machined	178.508	0.670	1.061	0.771	1.007	0.872	0.971	0.899
INDEX 254	BRITISH GAS RING7	X60	41.2	Machined	178.387	0.670	1.072	0.780	1.018	0.881	0.982	0.909
INDEX 255	ADVANTICA P1V1A	X80	60.1	Machined	3.890	0.775	0.632	0.810	1.169	0.933	1.207	0.902
INDEX 256	ADVANTICA P1V1B	X80	60.1	Machined	3.877	0.207	1.115	1.126	1.158	1.006	1.154	1.019
INDEX 257	ADVANTICA P1V2A	X80	60.1	Machined	3.890	0.374	1.016	1.062	1.134	0.965	1.140	0.969
INDEX 258	ADVANTICA P1V2B	X80	60.1	Machined	3.903	0.089	1.128	1.122	1.133	0.997	1.123	1.014

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INDEX 259	ADVANTICA P2V1A	X80	81.8	Machined	4.538	0.782	1.402	0.726	1.071	0.864	1.096	0.868
INDEX 260	ADVANTICA P2V1B	X80	81.8	Machined	4.450	0.167	1.096	1.098	1.122	0.975	1.109	0.986
INDEX 261	ADVANTICA P2V2A	X80	81.8	Machined	4.546	0.395	1.255	1.019	1.098	0.929	1.094	0.934
INDEX 262	ADVANTICA P2V2B	X80	81.8	Machined	4.523	0.112	1.143	1.075	1.090	0.949	1.070	0.960
INDEX 263	ADVANTICA HKL-R03	X100	57.7	Machined	146.332	0.111	1.026	1.017	1.036	1.081	1.201	1.101
INDEX 264	ADVANTICA HKL-R04	X100	57.7	Machined	146.332	0.099	1.030	1.023	1.040	1.085	1.206	1.105
INDEX 265	ADVANTICA HKL-R05	X100	57.7	Machined	146.396	0.101	1.027	1.020	1.037	1.082	1.203	1.103
INDEX 266	ADVANTICA HKL-R06	X100	57.6	Machined	146.300	0.294	1.010	0.960	1.020	1.062	1.182	1.085
INDEX 267	ADVANTICA HKL-R07	X100	57.9	Machined	146.588	0.294	1.039	0.988	1.049	1.092	1.215	1.116
INDEX 268	ADVANTICA HKL-R08	X100	57.9	Machined	146.588	0.287	1.038	0.989	1.049	1.092	1.214	1.115
INDEX 269	ADVANTICA HKL-R09	X100	57.8	Machined	146.372	0.502	1.073	0.941	1.083	1.125	1.252	1.151
INDEX 270	ADVANTICA HKL-R10	X100	57.8	Machined	146.404	0.497	1.051	0.925	1.062	1.102	1.227	1.128
INDEX 271	ADVANTICA HKL-R11	X100	57.8	Machined	146.460	0.502	1.072	0.940	1.082	1.123	1.251	1.150
INDEX 272	ADVANTICA HKL-R12	X100	57.7	Machined	146.308	0.809	Invalid	Invalid	Invalid	1.132	Invalid	Invalid
INDEX 273	ADVANTICA HKL-R13	X100	57.8	Machined	146.492	0.833	Invalid	Invalid	Invalid	1.155	Invalid	Invalid
INDEX 274	ADVANTICA HKL-R14	X100	57.8	Machined	146.372	0.814	Invalid	Invalid	Invalid	1.197	Invalid	Invalid
INDEX 275	ADVANTICA HKB-R01	X100	63.9	Machined	154.075	0.102	0.962	0.955	0.971	1.015	1.128	1.032
INDEX 276	ADVANTICA HKB-R02	X100	63.9	Machined	154.171	0.286	0.982	0.936	0.992	1.035	1.151	1.055
INDEX 277	ADVANTICA HKB-R03	X100	63.9	Machined	154.075	0.503	0.986	0.864	0.996	1.036	1.153	1.058
INDEX 278	ADVANTICA HKB-R04	X100	63.9	Machined	154.075	0.807	Invalid	Invalid	Invalid	1.027	Invalid	Invalid
INDEX 279	ADVANTICA HKL-R15	X100	57.9	Machined	146.620	0.204	1.057	1.028	1.068	1.113	1.237	1.135
INDEX 280	ADVANTICA HKL-R16	X100	58.0	Machined	146.597	0.204	1.089	1.059	1.100	1.146	1.275	1.169
INDEX 281	ADVANTICA HKL-R17	X100	57.8	Machined	146.492	0.508	1.091	0.954	1.102	1.144	1.274	1.171
INDEX 282	ADVANTICA HKL-R18	X100	57.9	Machined	146.588	0.499	1.084	0.953	1.095	1.137	1.266	1.164
INDEX 283	ADVANTICA HKL-R19	X100	57.8	Machined	146.524	0.810	Invalid	Invalid	Invalid	1.169	Invalid	Invalid
INDEX 284	ADVANTICA HKL-R20	X100	57.9	Machined	146.468	0.811	Invalid	Invalid	Invalid	1.169	Invalid	Invalid

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INDEX	Source Reference	Grade	D/t	Defect Type	$\frac{L}{\sqrt{Dt}}$	d/t	ASME B31G P_A/P_f	Mod ASME B31G P_A/P_f	RSTRENG P_A/P_f	LPC-1 P_A/P_f	SHELL 92 P_A/P_f	PCORRC P_A/P_f
INDEX 285	ADVANTICA HKB-R05	X100	63.8	Machined	154.096	0.207	1.019	0.990	1.029	1.074	1.194	1.094
INDEX 286	ADVANTICA HKB-R06	X100	63.8	Machined	153.888	0.504	1.069	0.937	1.080	1.123	1.251	1.148
INDEX 287	ADVANTICA HKB-R07	X100	63.9	Machined	154.075	0.818	Invalid	Invalid	Invalid	1.094	Invalid	Invalid
INDEX 288	ADVANTICA HKL-R21	X100	57.7	Machined	146.276	0.099	1.064	1.056	1.074	1.121	1.246	1.142
INDEX 289	ADVANTICA HKL-R22	X100	57.7	Machined	146.340	0.102	1.054	1.046	1.064	1.111	1.235	1.132
INDEX 290	ADVANTICA HKL-R23	X100	57.7	Machined	146.332	0.301	1.078	1.023	1.089	1.133	1.261	1.158
INDEX 291	ADVANTICA HKL-R24	X100	57.7	Machined	146.396	0.306	1.069	1.013	1.080	1.124	1.250	1.148
INDEX 292	ADVANTICA HKL-R25	X100	57.7	Machined	146.332	0.488	0.986	0.871	0.996	1.034	1.152	1.059
INDEX 293	ADVANTICA HKL-R26	X100	57.8	Machined	146.492	0.507	1.055	0.923	1.066	1.106	1.232	1.133
INDEX 294	ADVANTICA HKL-R27	X100	57.7	Machined	146.308	0.804	Invalid	Invalid	Invalid	1.001	Invalid	Invalid
INDEX 295	ADVANTICA HKL-R28	X100	57.7	Machined	146.244	0.808	Invalid	Invalid	Invalid	1.032	Invalid	Invalid
INDEX 296	ADVANTICA HKB-R08	X100	63.7	Machined	153.851	0.111	1.025	1.016	1.035	1.082	1.203	1.101
INDEX 297	ADVANTICA HKB-R09	X100	63.8	Machined	154.059	0.309	1.042	0.986	1.052	1.097	1.221	1.119
INDEX 298	ADVANTICA HKB-R10	X100	63.4	Machined	153.444	0.493	1.031	0.909	1.042	1.083	1.206	1.107
INDEX 299	ADVANTICA HKB-R11	X100	63.8	Machined	153.888	0.769	0.821	0.553	0.830	0.860	0.959	0.882
INDEX 300	ADVANTICA HKL V01	X100	57.9	Machined	3.503	0.496	0.821	0.910	1.013	0.989	1.206	0.979
INDEX 301	ADVANTICA HKK V01	X100	57.9	Machined	6.384	0.500	1.036	0.826	0.933	0.945	1.110	0.980
INDEX 302	ADVANTICA HKL V02	X100	57.9	Machined	2.962	0.503	0.801	0.884	0.981	0.948	1.172	0.933
INDEX 303	ADVANTICA HKK V02	X100	57.8	Machined	5.825	0.500	1.010	0.800	0.902	0.908	1.072	0.934
INDEX 304	NAT GAS PCA V1	X46	76.8	Real	1.278	0.520	1.054	1.031	N/A	0.772	0.978	0.789
INDEX 305	NAT GAS PCA V2	X46	76.8	Real	2.191	0.862	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid
INDEX 306	NAT GAS PCA V3	X46	76.8	Real	0.913	0.824	Invalid	Invalid	Invalid	0.804	Invalid	Invalid
INDEX 307	TRANSGAST1	X60	70.7	Machined	3.281	0.681	1.178	1.327	1.668	1.379	1.777	1.309
INDEX 308	TRANSGAST2	X60	70.7	Machined	3.486	0.474	1.303	1.338	1.474	1.274	1.546	1.260
INDEX 309	TRANSGAST3	X60	70.7	Machined	3.486	0.681	1.164	1.317	1.660	1.381	1.766	1.320
INDEX 310	TRANSGAST4	X60	70.7	Machined	3.486	0.526	1.250	1.306	1.474	1.262	1.551	1.240

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INDEX 311	TRANSGAST5	X60	70.7	Machined	3.076	0.466	1.178	1.200	1.313	1.129	1.378	1.115
INDEX 312	TRANSGAST6	X60	70.7	Machined	3.179	0.457	1.315	1.338	1.461	1.260	1.532	1.246
INDEX 313	TRANSGAST7	X60	73.9	Real	3.040	0.432	1.469	1.481	N/A	1.385	1.678	1.373

APPENDIX D LIST OF FAILURE PREDICTIONS FOR THE INTEGRATED DATABASE – CASE 2 (FLOW STRESS BASED ON THE SPECIFIED MINIMUM MATERIAL PROPERTIES)

Notes

1. For clarity non-conservative failure predictions are marked in red.
2. INDEX 6 to 25 are Battelle tests on Grade B pipe. These results have been discounted from the sensitivity studies described in this report.

INDEX	Source Reference	Grade	D/t	Defect Type	$\frac{L}{\sqrt{Dt}}$	d/t	ASME B31G P_A/P_f	Mod ASME B31G P_A/P_f	RSTRENG P_A/P_f	LPC-1 P_A/P_f	SHELL 92 P_A/P_f	PCORRC P_A/P_f
INDEX 1	PRCI-001	X52	78.5	Real	0.738	0.382	1.177	1.095	1.073	0.998	1.168	1.040
INDEX 2	PRCI-002	X52	78.5	Real	0.665	0.382	1.166	1.083	1.067	0.988	1.149	1.031
INDEX 3	PRCI-003	X52	78.5	Real	1.255	0.411	1.315	1.244	1.145	1.124	1.369	1.156
INDEX 4	PRCI-004	X52	80.0	Real	1.640	0.640	1.547	1.575	1.201	1.464	1.973	1.428
INDEX 5	PRCI-005	X52	78.9	Real	1.407	0.550	1.283	1.252	1.133	1.135	1.463	1.147
INDEX 6	PRCI-006	B	63.7	Real	0.997	0.719	1.122	1.040	0.967	0.759	1.052	0.773
INDEX 7	PRCI-007	B	63.7	Real	1.579	0.666	1.288	1.225	1.117	0.910	1.244	0.886
INDEX 8	PRCI-008	B	63.7	Real	1.745	0.666	1.379	1.325	1.218	0.996	1.357	0.959
INDEX 9	PRCI-009	B	64.9	Real	0.587	0.705	0.965	0.854	0.795	0.619	0.784	0.662
INDEX 10	PRCI-010	B	64.0	Real	1.417	0.752	1.339	1.317	1.072	1.010	1.464	0.959
INDEX 11	PRCI-011	B	65.8	Real	0.676	0.715	0.985	0.882	0.807	0.639	0.833	0.678
INDEX 12	PRCI-012	B	65.8	Real	0.760	0.600	1.157	1.020	0.956	0.733	0.918	0.775
INDEX 13	PRCI-013	B	65.8	Real	0.845	0.630	1.292	1.152	1.069	0.828	1.064	0.868
INDEX 14	PRCI-014	B	65.8	Real	0.929	0.715	1.364	1.254	1.116	0.912	1.250	0.938
INDEX 15	PRCI-015	B	63.2	Real	1.242	0.661	1.380	1.279	1.102	0.930	1.263	0.936
INDEX 16	PRCI-016	B	64.9	Real	0.671	0.508	1.220	1.059	1.025	0.765	0.916	0.808
INDEX 17	PRCI-017	B	64.9	Real	1.007	0.649	1.385	1.256	1.157	0.904	1.199	0.933
INDEX 18	PRCI-018	B	64.0	Real	1.250	0.640	1.492	1.374	1.128	0.995	1.336	1.005
INDEX 19	PRCI-019	B	65.8	Real	0.591	0.715	1.369	1.214	1.133	0.881	1.122	0.941
INDEX 20	PRCI-020	B	64.0	Real	0.750	0.669	1.134	1.011	0.925	0.728	0.940	0.769
INDEX 21	PRCI-021	B	64.0	Real	0.750	0.779	1.465	1.350	1.194	0.995	1.388	1.035
INDEX 22	PRCI-022	B	64.0	Real	0.833	0.584	1.423	1.257	1.153	0.902	1.133	0.949
INDEX 23	PRCI-023	B	64.0	Real	0.667	0.501	1.353	1.174	1.127	0.848	1.012	0.896
INDEX 24	PRCI-024	B	64.0	Real	0.750	0.472	1.362	1.182	1.146	0.853	1.021	0.897
INDEX 25	PRCI-025	B	64.0	Real	1.667	0.723	1.772	1.746	1.474	1.344	1.897	1.268

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INDEX 26	PRCI-026	X52	80.0	Real	0.820	1.000	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid
INDEX 27	PRCI-027	X52	80.0	Real	1.640	0.389	1.484	1.414	1.273	1.285	1.564	1.304
INDEX 28	PRCI-028	X52	80.0	Real	1.342	0.307	1.448	1.357	1.311	1.234	1.461	1.265
INDEX 29	PRCI-029	X52	80.0	Real	1.193	0.613	1.513	1.484	1.266	1.344	1.772	1.366
INDEX 30	PRCI-030	X52	80.0	Real	0.477	0.557	1.567	1.461	1.419	1.335	1.567	1.413
INDEX 31	PRCI-031	X52	80.0	Real	0.596	0.557	1.496	1.401	1.338	1.274	1.527	1.348
INDEX 32	PRCI-032	B	61.5	Real	2.255	0.643	1.302	1.266	0.976	0.974	1.290	0.929
INDEX 33	PRCI-033	B	61.5	Real	2.550	0.674	2.016	2.013	1.381	1.604	2.125	1.508
INDEX 34	PRCI-034	A25	51.6	Real	2.021	0.742	1.553	1.456	1.101	1.216	1.707	1.117
INDEX 35	PRCI-035	A25	51.6	Real	2.245	0.774	1.896	1.846	1.316	1.633	2.301	1.465
INDEX 36	PRCI-036	A25	51.6	Real	2.694	0.910	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid
INDEX 37	PRCI-037	A25	51.6	Real	1.235	0.877	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid
INDEX 38	PRCI-038	A25	51.6	Real	2.806	0.642	1.781	1.616	1.330	1.325	1.716	1.265
INDEX 39	PRCI-039	B	57.6	Real	4.109	0.695	1.707	1.786	1.384	1.557	1.961	1.529
INDEX 40	PRCI-040	B	58.5	Real	2.550	0.927	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid
INDEX 41	PRCI-041	B	60.6	Real	1.865	0.909	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid
INDEX 42	PRCI-042	B	54.1	Real	2.527	0.495	1.726	1.595	1.517	1.187	1.479	1.173
INDEX 43	PRCI-043	B	65.6	Real	5.061	0.751	5.056	2.483	1.564	2.392	2.974	2.462
INDEX 44	PRCI-044	B	65.9	Real	4.398	0.698	1.793	1.886	1.433	1.668	2.084	1.654
INDEX 45	PRCI-045	B	67.6	Real	2.227	0.814	Invalid	Invalid	Invalid	2.197	Invalid	Invalid
INDEX 46	PRCI-046	B	75.2	Real	1.988	0.677	2.402	2.351	1.697	1.812	2.463	1.712
INDEX 47	PRCI-047	B	72.3	Real	1.594	0.663	2.199	2.091	1.701	1.556	2.124	1.513
INDEX 48	PRCI-048	B	64.0	Real	5.333	0.787	2.891	1.327	1.340	1.368	1.701	1.445
INDEX 49	PRCI-049	B	64.0	Real	3.000	0.853	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid
INDEX 50	PRCI-050	B	64.1	Real	4.804	0.808	Invalid	Invalid	Invalid	1.398	Invalid	Invalid
INDEX 51	PRCI-051	X52	65.6	Real	4.251	0.689	1.095	1.231	1.150	1.345	1.684	1.326

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INDEX 52	PRCI-052	B	66.5	Real	3.567	0.884	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid
INDEX 53	PRCI-053	B	66.5	Real	4.247	0.789	2.328	2.649	1.397	2.647	3.394	2.622
INDEX 54	PRCI-054	B	67.6	Real	2.912	0.685	2.352	2.389	1.495	1.962	2.568	1.844
INDEX 55	PRCI-055	B	64.7	Real	3.519	0.744	1.922	2.069	1.256	1.861	2.421	1.763
INDEX 56	PRCI-056	B	64.7	Real	3.519	0.784	2.011	2.247	1.246	2.149	2.830	2.024
INDEX 57	PRCI-057	B	64.5	Real	7.363	0.548	5.664	1.919	1.371	1.631	3.520	1.720
INDEX 58	PRCI-058	B	65.9	Real	2.876	0.615	2.033	1.985	1.629	1.560	1.998	1.495
INDEX 59	PRCI-059	B	65.6	Real	4.218	0.661	2.442	2.500	1.525	2.128	2.650	2.097
INDEX 60	PRCI-060	B	65.6	Real	1.350	0.522	1.609	1.443	1.510	1.038	1.320	1.059
INDEX 61	PRCI-061	B	65.2	Real	9.422	0.783	5.961	3.131	1.410	3.214	3.799	3.676
INDEX 62	PRCI-062	B	70.7	Real	12.610	0.968	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid
INDEX 63	PRCI-063	B	73.0	Real	5.126	0.474	3.137	2.119	1.810	1.674	1.983	1.694
INDEX 64	PRCI-064	B	64.3	Real	3.408	0.768	2.438	2.676	1.314	2.477	3.262	2.322
INDEX 65	PRCI-065	B	64.3	Real	4.411	0.338	1.725	1.557	1.312	1.177	1.375	1.189
INDEX 66	PRCI-066	B	75.2	Real	6.720	0.541	3.208	2.106	1.597	1.747	2.057	1.821
INDEX 67	PRCI-067	B	64.7	Real	4.827	0.706	5.183	2.736	1.483	2.469	3.059	2.496
INDEX 68	PRCI-068	X52	80.6	Real	10.776	0.349	1.998	1.535	1.518	1.612	1.832	1.685
INDEX 69	PRCI-069	X52	79.8	Real	3.573	0.612	1.567	1.668	1.427	1.689	2.115	1.636
INDEX 70	PRCI-070	X52	80.0	Real	3.578	0.373	1.564	1.528	1.502	1.443	1.712	1.441
INDEX 71	PRCI-071	X52	78.5	Real	5.908	0.380	2.105	1.646	1.400	1.602	1.860	1.635
INDEX 72	PRCI-072	X52	79.8	Real	5.955	0.346	1.903	1.517	1.397	1.466	1.694	1.495
INDEX 73	PRCI-073	X52	79.4	Real	9.800	0.291	1.875	1.437	1.495	1.520	1.724	1.576
INDEX 74	PRCI-074	X52	79.2	Real	4.152	0.449	1.616	1.619	1.422	1.566	1.871	1.563
INDEX 75	PRCI-075	X52	78.7	Real	3.549	0.787	1.367	1.653	0.976	2.000	2.632	1.881
INDEX 76	PRCI-076	X52	79.4	Real	2.376	0.450	1.487	1.459	1.282	1.352	1.667	1.341
INDEX 77	PRCI-077	X52	79.6	Real	3.568	0.424	1.589	1.573	1.393	1.497	1.795	1.488

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INDEX 78	PRCI-078	X52	80.4	Real	2.690	0.295	1.489	1.420	1.395	1.313	1.547	1.319
INDEX 79	PRCI-079	X42	64.0	Real	5.583	0.859	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid
INDEX 80	PRCI-080	X52	82.2	Real	4.835	0.627	1.903	1.201	1.222	1.273	1.554	1.278
INDEX 81	PRCI-081	X52	80.0	Real	8.050	0.653	2.001	1.320	1.285	1.469	1.732	1.590
INDEX 82	PRCI-082	X56	80.0	Real	2.236	0.400	1.536	1.503	1.348	1.369	1.667	1.369
INDEX 83	PRCI-083	X46	76.9	Real	7.016	0.838	Invalid	Invalid	Invalid	2.467	Invalid	Invalid
INDEX 84	PRCI-084	X65	109.1	Real	4.642	0.661	1.742	1.085	1.174	1.221	1.505	1.214
INDEX 85	PRCI-085	X60	100.7	Real	21.070	0.903	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid
INDEX 86	PRCI-086	X52	111.1	Real	2.875	0.747	1.313	1.505	1.123	1.652	2.216	1.507
INDEX 87	PRCI-087	X65	94.5	Real	0.729	0.735	1.352	1.363	1.193	1.293	1.731	1.355
INDEX 88	PRCI-088	X52	82.6	Real	2.364	0.331	1.427	1.365	1.301	1.257	1.499	1.262
INDEX 89	PRCI-089	X65	88.9	Real	1.453	0.741	1.403	1.532	1.157	1.527	2.193	1.447
INDEX 90	PRCI-090	X65	90.0	Real	0.422	0.675	1.142	1.106	1.079	1.051	1.255	1.122
INDEX 91	PRCI-091	X65	91.6	Real	0.372	0.789	1.252	1.224	1.171	1.173	1.441	1.265
INDEX 92	PRCI-092	X52	75.2	Real	6.867	0.282	1.732	1.434	1.305	1.376	1.571	1.410
INDEX 93	PRCI-097	X60	76.6	Machined	6.565	0.395	1.564	1.247	1.350	1.217	1.409	1.251
INDEX 94	PRCI-098	X60	76.3	Machined	17.474	0.385	1.575	1.288	1.442	1.314	1.483	1.380
INDEX 95	PRCI-099	X60	78.1	Machined	2.652	0.395	1.364	1.356	1.444	1.251	1.512	1.246
INDEX 96	PRCI-100	X60	78.4	Machined	2.657	0.376	1.355	1.341	1.470	1.236	1.486	1.234
INDEX 97	PRCI-101	X60	78.4	Machined	2.657	0.396	1.371	1.363	1.475	1.258	1.521	1.253
INDEX 98	PRCI-106	X46	54.7	Machined	1.137	0.790	1.410	1.456	1.232	1.320	1.968	1.277
INDEX 99	PRCI-108	X46	53.3	Machined	1.352	0.657	1.401	1.381	1.225	1.192	1.621	1.191
INDEX 100	PRCI-109	X46	55.4	Machined	1.028	0.665	1.566	1.510	1.325	1.289	1.729	1.327
INDEX 101	PRCI-110	X46	54.0	Machined	0.669	0.784	1.374	1.324	1.194	1.151	1.578	1.216
INDEX 102	PRCI-111	X46	54.0	Machined	0.899	0.750	1.520	1.491	1.252	1.294	1.814	1.328
INDEX 103	PRCI-112	X46	53.3	Machined	1.008	0.481	1.453	1.347	1.319	1.142	1.405	1.194

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INDEX 104	PRCI-113	X46	49.2	Machined	0.969	0.788	1.165	1.175	0.946	1.043	1.528	1.043
INDEX 105	PRCI-114	X46	52.7	Machined	0.660	0.393	1.250	1.138	1.113	0.976	1.136	1.026
INDEX 106	PRCI-115	X46	52.5	Machined	0.886	0.733	1.296	1.261	1.098	1.086	1.498	1.123
INDEX 107	PRCI-116	X46	54.5	Machined	1.042	0.701	1.502	1.467	1.283	1.262	1.735	1.288
INDEX 108	PRCI-117	X46	53.8	Machined	1.243	0.312	1.351	1.239	1.217	1.059	1.252	1.095
INDEX 109	PRCI-119	X60	79.4	Machined	17.372	0.532	1.489	1.149	1.347	1.223	1.389	1.305
INDEX 110	PRCI-120	X60	79.4	Machined	17.817	0.345	1.572	1.302	1.444	1.319	1.485	1.378
INDEX 111	PRCI-121	X60	79.4	Machined	1.782	0.468	1.322	1.312	1.406	1.189	1.487	1.193
INDEX 112	PRCI-122	X60	79.4	Machined	3.563	0.452	1.114	1.136	1.242	1.080	1.303	1.070
INDEX 113	PRCI-123	X60	79.4	Machined	3.595	0.532	1.022	1.072	1.215	1.043	1.280	1.023
INDEX 114	PRCI-124	X60	79.4	Machined	17.537	0.500	1.465	1.148	1.329	1.208	1.369	1.284
INDEX 115	PRCI-125	X52	49.4	Machined	35.136	0.399	1.511	1.248	1.380	1.257	1.407	1.309
INDEX 116	PRCI-126	X52	49.4	Machined	7.027	0.399	1.458	1.138	1.229	1.116	1.290	1.161
INDEX 117	PRCI-127	X52	49.4	Machined	3.514	0.399	1.216	1.195	1.250	1.122	1.339	1.126
INDEX 118	PRCI-128	X52	49.4	Machined	3.514	0.399	1.294	1.272	1.330	1.195	1.426	1.199
INDEX 119	PRCI-129	X52	49.4	Machined	1.757	0.399	1.353	1.295	1.289	1.170	1.429	1.192
INDEX 120	PRCI-136	X52	49.4	Machined	0.439	0.599	1.434	1.338	1.347	1.214	1.427	1.299
INDEX 121	PRCI-137	X52	49.4	Machined	0.439	0.599	1.329	1.240	N/A	1.125	1.323	1.204
INDEX 122	PRCI-142	X52	49.4	Machined	1.318	0.599	1.453	1.430	1.307	1.288	1.695	1.310
INDEX 123	PRCI-144	X52	49.4	Machined	3.514	0.399	1.388	1.364	1.364	1.281	1.529	1.286
INDEX 124	PRCI-147	X52	49.4	Machined	1.757	0.399	1.484	1.421	1.414	1.283	1.568	1.308
INDEX 125	PRCI-163	X46	52.5	Machined	0.449	0.605	1.486	1.359	1.394	1.168	1.378	1.249
INDEX 126	PRCI-165	X46	51.8	Machined	0.440	0.606	1.499	1.370	1.404	1.177	1.387	1.260
INDEX 127	PRCI-166	X46	52.5	Machined	0.443	0.609	1.532	1.401	1.437	1.204	1.420	1.288
INDEX 128	PRCI-171	X46	51.6	Machined	0.440	0.599	1.363	1.245	1.275	1.070	1.258	1.144
INDEX 129	PRCI-173	X46	51.4	Machined	1.597	0.601	1.430	1.402	N/A	1.210	1.599	1.205

INDEX	Source Reference	Grade	D/t	Defect Type	$\frac{L}{\sqrt{Dt}}$	d/t	ASME B31G P_A/P_f	Mod ASME B31G P_A/P_f	RSTRENG P_A/P_f	LPC-1 P_A/P_f	SHELL 92 P_A/P_f	PCORRC P_A/P_f
INDEX 130	PRCI-174	X46	51.8	Machined	1.604	0.606	1.502	1.475	N/A	1.275	1.689	1.267
INDEX 131	PRCI-176	X46	52.5	Machined	0.449	0.601	1.202	1.099	N/A	0.944	1.113	1.010
INDEX 132	PRCI-182	X46	47.2	Machined	1.186	0.659	1.392	1.356	1.272	1.159	1.568	1.179
INDEX 133	PRCI-183	X46	48.9	Machined	2.286	0.667	1.610	1.675	1.394	1.542	2.061	1.463
INDEX 134	PRCI-184	X46	47.6	Machined	2.223	0.683	1.459	1.529	1.458	1.415	1.909	1.335
INDEX 135	ADVANTICA-TR020	X65	41.3	Machined	200.935	0.229	1.439	1.312	1.371	1.301	1.447	1.336
INDEX 136	ADVANTICA-TR021	X65	42.2	Machined	203.044	0.429	1.564	1.340	1.491	1.413	1.572	1.453
INDEX 137	ADVANTICA-TR022	X65	40.9	Machined	199.776	0.627	1.396	1.063	1.331	1.258	1.400	1.296
INDEX 138	ADVANTICA-TR023	X65	41.1	Machined	200.417	0.824	Invalid	Invalid	Invalid	1.653	Invalid	Invalid
INDEX 139	ADVANTICA-TR024	X65	40.8	Machined	199.649	0.574	1.329	1.054	1.267	1.198	1.334	1.234
INDEX 140	ADVANTICA-TR025	X65	40.7	Machined	199.268	0.580	1.327	1.047	1.264	1.195	1.331	1.232
INDEX 141	ADVANTICA-TR026	X65	41.1	Machined	200.289	0.560	1.300	1.040	1.239	1.172	1.305	1.207
INDEX 142	ADVANTICA-TR027	X65	43.7	Machined	206.619	0.586	1.284	1.009	1.224	1.159	1.290	1.192
INDEX 143	ADVANTICA-TR029	X52	46.0	Machined	282.526	0.186	1.489	1.328	1.374	1.261	1.402	1.291
INDEX 144	ADVANTICA-TR030	X52	45.6	Machined	281.450	0.648	1.485	1.073	1.370	1.253	1.395	1.287
INDEX 145	ADVANTICA-TR031	X52	46.2	Machined	283.069	0.454	1.631	1.337	1.504	1.379	1.533	1.413
INDEX 146	ADVANTICA-TR032	X52	46.2	Machined	283.069	0.720	1.817	1.209	1.676	1.533	1.707	1.575
INDEX 147	ADVANTICA-TR033	X52	45.7	Machined	281.718	0.468	1.557	1.268	1.436	1.316	1.463	1.349
INDEX 148	ADVANTICA-TR034	X52	46.0	Machined	282.526	0.472	1.473	1.198	1.359	1.245	1.385	1.277
INDEX 149	ADVANTICA-TR035	X52	46.5	Machined	284.164	0.496	1.596	1.283	1.472	1.349	1.501	1.383
INDEX 150	ADVANTICA-TV006	X65	42.6	Machined	1.629	0.702	1.226	1.327	1.612	1.296	1.807	1.248
INDEX 151	ADVANTICA-TV008	X65	41.2	Machined	4.811	0.680	1.656	1.011	1.289	1.144	1.411	1.164
INDEX 152	ADVANTICA-TV010	X65	41.7	Machined	3.227	0.687	0.900	1.028	1.299	1.106	1.431	1.057
INDEX 153	ADVANTICA-TV011	X65	40.9	Machined	3.196	0.674	0.903	1.022	1.274	1.086	1.401	1.041
INDEX 154	ADVANTICA-TV016	X65	40.7	Machined	3.188	0.700	1.014	1.168	1.497	1.268	1.649	1.207

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INDEX 155	ADVANTICA-TV017	X65	41.2	Machined	4.816	0.756	1.575	0.847	1.195	1.050	1.314	1.079
INDEX 156	ADVANTICA-TV018	X65	40.9	Machined	3.836	0.739	0.919	1.104	1.502	1.289	1.654	1.254
INDEX 157	ADVANTICA-TV019	X65	40.7	Machined	6.377	0.735	1.784	1.037	1.428	1.294	1.568	1.407
INDEX 158	ADVANTICA-TV022	X65	40.3	Machined	3.172	0.748	0.856	1.022	1.394	1.166	1.542	1.095
INDEX 159	ADVANTICA-TV027	X65	40.7	Machined	4.782	0.720	1.737	0.996	1.333	1.175	1.462	1.199
INDEX 160	ADVANTICA-TV028	X65	44.0	Machined	4.972	0.744	1.593	0.882	1.221	1.080	1.344	1.114
INDEX 161	ADVANTICA-TV031	X65	44.0	Machined	4.972	0.551	1.530	1.081	1.248	1.129	1.357	1.150
INDEX 162	ADVANTICA-TV032	X65	40.5	Machined	4.770	0.478	1.264	0.943	1.049	0.952	1.133	0.969
INDEX 163	ADVANTICA-TV033	X65	8.8	Machined	0.688	0.708	1.100	1.096	1.199	0.928	1.208	1.092
INDEX 164	ADVANTICA-TV034	X65	8.6	Machined	1.357	0.690	0.979	1.033	1.215	0.889	1.233	0.975
INDEX 165	ADVANTICA-TV035	X65	8.8	Machined	2.064	0.710	0.949	1.059	1.330	0.979	1.348	1.011
INDEX 166	ADVANTICA-TV036	X65	8.7	Machined	2.729	0.697	0.926	1.051	1.329	1.006	1.333	1.044
INDEX 167	ADVANTICA-TV037	X65	8.6	Machined	1.362	0.197	1.146	1.101	1.116	0.936	1.079	1.068
INDEX 168	ADVANTICA-TV038	X65	8.6	Machined	1.357	0.509	1.077	1.074	1.149	0.900	1.138	1.024
INDEX 169	ADVANTICA-TV039	X65	8.7	Machined	1.367	0.941	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid
INDEX 170	ADVANTICA-TV045	X52	48.1	Machined	1.737	0.725	1.244	1.331	1.670	1.287	1.814	1.212
INDEX 171	ADVANTICA-TV046	X52	49.2	Machined	1.756	0.559	1.413	1.405	1.558	1.281	1.660	1.278
INDEX 172	ADVANTICA-TV047	X52	48.1	Machined	5.212	0.740	1.838	0.999	1.377	1.184	1.464	1.231
INDEX 173	ADVANTICA-TV048	X52	49.5	Machined	5.283	0.546	2.012	1.389	1.601	1.408	1.683	1.440
INDEX 174	ADVANTICA-TV049	X60	29.5	Machined	1.360	0.704	1.429	1.501	1.789	1.362	1.907	1.358
INDEX 175	ADVANTICA-TV050	X60	29.1	Machined	1.352	0.733	1.404	1.496	1.834	1.374	1.963	1.355
INDEX 176	ADVANTICA-TV051	X60	29.5	Machined	1.360	0.568	1.378	1.378	1.507	1.214	1.576	1.255
INDEX 177	ADVANTICA-TV052	X60	28.8	Machined	4.029	0.688	0.987	1.131	1.445	1.193	1.503	1.189
INDEX 178	ADVANTICA-TV053	X60	29.3	Machined	4.068	0.519	1.263	1.326	1.497	1.271	1.541	1.287
INDEX 179	ADVANTICA-TV056	X52	45.2	Machined	1.687	0.724	1.215	1.294	1.615	1.242	1.753	1.177
INDEX 180	ADVANTICA-TV057	X52	46.9	Machined	1.730	0.577	1.341	1.340	1.497	1.222	1.596	1.217

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INDEX 181	ADVANTICA-TV058	X52	46.5	Machined	5.147	0.766	1.774	0.915	1.316	1.125	1.400	1.175
INDEX 182	ADVANTICA-TV059	X52	45.2	Machined	5.073	0.586	1.983	1.315	1.552	1.352	1.632	1.380
INDEX 183	ADVANTICA-TV060	X60	31.6	Machined	1.411	0.725	1.438	1.533	1.875	1.414	2.010	1.386
INDEX 184	ADVANTICA-TV061	X60	29.7	Machined	1.369	0.537	1.535	1.524	1.647	1.341	1.717	1.390
INDEX 185	ADVANTICA-TV062	X60	30.8	Machined	4.186	0.733	1.021	1.213	1.643	1.355	1.717	1.354
INDEX 186	ADVANTICA-TV063	X60	31.6	Machined	4.241	0.534	1.300	1.374	1.565	1.333	1.615	1.349
INDEX 187	ADVANTICA-TV064	X65	32.3	Machined	1.435	0.817	Invalid	Invalid	Invalid	1.288	Invalid	Invalid
INDEX 188	ADVANTICA-TV065	X65	32.4	Machined	1.429	0.622	1.189	1.227	1.384	1.143	1.526	1.159
INDEX 189	ADVANTICA-TV066	X65	32.3	Machined	4.286	0.820	Invalid	Invalid	Invalid	1.180	Invalid	Invalid
INDEX 190	ADVANTICA-TV067	X65	32.3	Machined	4.286	0.630	0.983	1.101	1.336	1.173	1.449	1.180
INDEX 191	ADVANTICA-TV072	X60	46.9	Machined	1.715	0.704	1.170	1.262	1.545	1.193	1.663	1.138
INDEX 192	ADVANTICA-TV073	X60	47.1	Machined	5.165	0.719	1.585	0.911	1.220	1.043	1.286	1.078
INDEX 193	PETROBRAS TS02	X46	76.0	Real	18.860	0.463	2.648	2.031	1.653	2.006	2.268	2.120
INDEX 194	PETROBRAS TS04	X46	73.6	Real	18.550	0.525	2.678	1.995	1.443	2.014	2.283	2.145
INDEX 195	PETROBRAS TS05	X46	75.7	Real	18.821	0.448	1.992	1.537	1.409	1.512	1.708	1.596
INDEX 196	PETROBRAS TS06	X46	69.7	Real	18.101	0.507	2.092	1.570	1.424	1.573	1.783	1.675
INDEX 197	PETROBRAS TS10	X46	75.3	Real	18.792	0.461	2.530	1.941	1.437	1.917	2.166	2.026
INDEX 198	PETROBRAS TS 5.1	X60	33.0	Machined	4.537	0.722	1.884	1.056	1.413	1.180	1.478	1.197
INDEX 199	PETROBRAS TS 1.2	X60	33.5	Machined	5.464	0.699	1.725	1.030	1.348	1.151	1.407	1.210
INDEX 200	PETROBRAS TS 2.2	X60	33.4	Machined	6.241	0.714	1.741	1.033	1.382	1.193	1.444	1.291
INDEX 201	PETROBRAS TS 2.1	X60	33.4	Machined	7.035	0.712	1.632	0.984	1.314	1.148	1.375	1.266
INDEX 202	PETROBRAS TS 3.1	X60	32.7	Machined	7.650	0.738	1.663	1.023	1.489	1.180	1.408	1.328
INDEX 203	PETROBRAS TS 1.1	X60	33.2	Machined	8.310	0.720	1.558	0.986	1.395	1.128	1.336	1.271
INDEX 204	PETROBRAS TS 3.2	X60	33.1	Machined	8.679	0.713	1.511	0.966	1.354	1.103	1.303	1.245
INDEX 205	PETROBRAS TS 4.1	X60	33.1	Machined	8.880	0.713	1.521	0.974	1.364	1.115	1.314	1.260
INDEX 206	PETROBRAS TS 4.2	X60	33.2	Machined	9.398	0.733	1.546	0.969	1.394	1.138	1.339	1.297

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INDEX 207	KOREAN GAS CO DA	X65	43.5	Machined	1.732	0.251	1.163	1.128	1.155	1.057	1.239	1.087
INDEX 208	KOREAN GAS CO DB	X65	43.5	Machined	1.732	0.503	1.183	1.195	1.294	1.119	1.418	1.132
INDEX 209	KOREAN GAS CO DC	X65	43.5	Machined	1.732	0.748	1.103	1.238	1.599	1.261	1.804	1.174
INDEX 210	KOREAN GAS CO LA	X65	43.5	Machined	0.866	0.503	1.187	1.157	1.204	1.072	1.311	1.133
INDEX 211	KOREAN GAS CO LC	X65	43.5	Machined	2.598	0.503	1.141	1.180	1.303	1.140	1.421	1.130
INDEX 212	KOREAN GAS CO CB	X65	43.5	Machined	1.732	0.503	1.273	1.287	1.393	1.205	1.526	1.218
INDEX 213	KOREAN GAS CO CC	X65	43.5	Machined	1.732	0.503	1.231	1.244	1.347	1.165	1.475	1.178
INDEX 214	WATERLOO SOL-2	X46	37.4	Real	1.202	0.250	1.391	1.269	1.249	1.080	1.257	1.125
INDEX 215	WATERLOO SOL-4	X46	37.6	Real	3.858	0.346	1.516	1.444	1.308	1.272	1.496	1.293
INDEX 216	WATERLOO SOL-6	X46	37.4	Real	1.154	0.312	1.461	1.337	1.310	1.133	1.337	1.185
INDEX 217	WATERLOO SOL-10	X46	37.6	Real	2.743	0.383	1.565	1.488	1.372	1.291	1.553	1.305
INDEX 218	WATERLOO SOL-11	X46	37.5	Real	2.402	0.309	1.343	1.254	1.164	1.077	1.276	1.099
INDEX 219	WATERLOO SOL-12	X46	37.9	Real	0.967	0.256	1.228	1.117	1.122	0.952	1.102	0.996
INDEX 220	WATERLOO NOR-1	X52	52.2	Real	10.819	0.354	1.712	1.315	1.267	1.436	1.632	1.513
INDEX 221	WATERLOO NOR-2	X52	51.9	Real	3.687	0.329	1.426	1.379	1.279	1.350	1.585	1.362
INDEX 222	WATERLOO TNG-01	X46	33.1	Real	5.083	0.480	1.933	1.373	1.282	1.265	1.501	1.302
INDEX 223	WATERLOO RLK-1	X52	93.3	Real	14.246	0.504	2.252	1.698	1.509	1.895	2.159	2.022
INDEX 224	WATERLOO RLK-2	X52	95.3	Real	22.833	0.553	2.132	1.615	1.404	1.833	2.071	1.935
INDEX 225	WATERLOO RLK-3	X52	95.5	Real	21.924	0.401	1.983	1.604	1.434	1.723	1.939	1.798
INDEX 226	WATERLOO BCG-1	X42	55.2	Real	4.971	0.667	3.572	2.077	1.272	1.989	2.440	2.022
INDEX 227	WATERLOO BCG-2	X42	58.4	Real	1.351	0.560	1.537	1.445	1.208	1.144	1.479	1.164
INDEX 228	WATERLOO BCG-3	X42	57.3	Real	0.843	0.340	1.305	1.170	1.151	0.931	1.089	0.972
INDEX 229	WATERLOO BCG-4	X42	56.0	Real	2.784	0.448	1.690	1.608	1.354	1.318	1.611	1.309
INDEX 230	WATERLOO BCG-5	X42	55.6	Real	1.245	0.325	1.428	1.289	1.242	1.022	1.213	1.057
INDEX 231	WATERLOO BCG-6	X42	54.8	Real	3.360	0.431	1.465	1.397	1.188	1.158	1.395	1.155
INDEX 232	WATERLOO BCG-7	X42	60.0	Real	1.864	0.600	1.581	1.542	1.201	1.257	1.654	1.230

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INDEX 233	WATERLOO BCG-8	X42	55.1	Real	1.031	0.546	1.473	1.358	1.238	1.068	1.350	1.113
INDEX 234	WATERLOO BCG-9	X42	56.9	Real	4.327	0.437	1.475	1.419	1.167	1.201	1.427	1.207
INDEX 235	WATERLOO ESS-01	X46	63.8	Real	2.442	0.720	1.369	1.482	1.144	1.440	1.954	1.327
INDEX 236	WATERLOO NOV01	X55	88.3	Real	2.449	0.527	1.494	1.515	1.311	1.568	1.976	1.530
INDEX 237	WATERLOO NOV02-2	X55	89.1	Real	8.644	0.574	2.020	1.423	1.213	1.694	1.974	1.811
INDEX 238	WATERLOO NOV03-2	X55	89.3	Real	11.528	0.661	2.706	1.836	1.284	2.308	2.672	2.537
INDEX 239	WATERLOO NOV04	X55	88.5	Real	9.878	0.668	3.160	2.107	1.451	2.642	3.083	2.905
INDEX 240	WATERLOO NOV04-2	X55	88.5	Real	7.714	0.531	2.467	1.756	1.353	2.060	2.404	2.168
INDEX 241	WATERLOO NOV05	X55	90.5	Real	11.175	0.597	2.168	1.540	1.199	1.864	2.152	2.022
INDEX 242	WATERLOO NOV06	X55	90.1	Real	3.180	0.437	1.584	1.582	1.389	1.645	1.991	1.627
INDEX 243	WATERLOO TCP01	X46	89.7	Real	2.340	0.377	1.655	1.563	1.443	1.365	1.648	1.364
INDEX 244	WATERLOO TCP02	X46	91.2	Real	2.050	0.316	1.571	1.462	1.357	1.268	1.511	1.279
INDEX 245	WATERLOO TCP03	X46	92.1	Real	1.016	0.493	1.365	1.268	1.219	1.083	1.339	1.123
INDEX 246	ADVANTICA V1	B/X42	77.2	Machined	0.228	0.800	1.741	1.505	1.548	1.112	1.294	1.194
INDEX 247	ADVANTICA V2	B/X42	77.2	Machined	0.911	0.800	1.499	1.429	1.789	1.082	1.593	1.079
INDEX 248	BRITISH GAS RING1	X60	40.9	Machined	177.799	0.300	1.202	1.064	1.132	1.028	1.144	1.057
INDEX 249	BRITISH GAS RING2	X60	41.4	Machined	178.784	0.280	1.232	1.096	1.160	1.055	1.173	1.084
INDEX 250	BRITISH GAS RING3	X60	41.5	Machined	179.122	0.470	1.266	1.053	1.193	1.082	1.205	1.114
INDEX 251	BRITISH GAS RING4	X60	41.5	Machined	179.122	0.500	1.187	0.973	1.119	1.014	1.129	1.044
INDEX 252	BRITISH GAS RING5	X60	40.7	Machined	177.184	0.690	1.239	0.876	1.168	1.056	1.177	1.090
INDEX 253	BRITISH GAS RING6	X60	41.3	Machined	178.508	0.670	1.113	0.804	1.049	0.949	1.057	0.979
INDEX 254	BRITISH GAS RING7	X60	41.2	Machined	178.387	0.670	1.125	0.813	1.060	0.959	1.069	0.990
INDEX 255	ADVANTICA P1V1A	X80	60.1	Machined	3.890	0.775	0.670	0.853	1.232	1.088	1.408	1.052
INDEX 256	ADVANTICA P1V1B	X80	60.1	Machined	3.877	0.207	1.183	1.186	1.220	1.173	1.346	1.189
INDEX 257	ADVANTICA P1V2A	X80	60.1	Machined	3.890	0.374	1.090	1.131	1.208	1.138	1.345	1.143
INDEX 258	ADVANTICA P1V2B	X80	60.1	Machined	3.903	0.089	1.210	1.195	1.207	1.176	1.324	1.195

INDEX	Source Reference	Grade	D/t	Defect Type	$\frac{L}{\sqrt{Dt}}$	d/t	ASME B31G P_A/P_f	Mod ASME B31G P_A/P_f	RSTRENG P_A/P_f	LPC-1 P_A/P_f	SHELL 92 P_A/P_f	PCORRC P_A/P_f
INDEX 259	ADVANTICA P2V1A	X80	81.8	Machined	4.538	0.782	1.443	0.745	1.099	0.993	1.259	0.997
INDEX 260	ADVANTICA P2V1B	X80	81.8	Machined	4.450	0.167	1.128	1.127	1.152	1.120	1.274	1.133
INDEX 261	ADVANTICA P2V2A	X80	81.8	Machined	4.546	0.395	1.340	1.080	1.164	1.106	1.302	1.112
INDEX 262	ADVANTICA P2V2B	X80	81.8	Machined	4.523	0.112	1.221	1.139	1.155	1.130	1.274	1.144
INDEX 263	ADVANTICA HKL-R03	X100	57.7	Machined	146.332	0.111	1.164	1.141	1.162	1.142	1.269	1.164
INDEX 264	ADVANTICA HKL-R04	X100	57.7	Machined	146.332	0.099	1.168	1.147	1.166	1.146	1.274	1.168
INDEX 265	ADVANTICA HKL-R05	X100	57.7	Machined	146.396	0.101	1.165	1.144	1.164	1.144	1.271	1.165
INDEX 266	ADVANTICA HKL-R06	X100	57.6	Machined	146.300	0.294	1.146	1.077	1.145	1.122	1.248	1.146
INDEX 267	ADVANTICA HKL-R07	X100	57.9	Machined	146.588	0.294	1.179	1.108	1.177	1.154	1.284	1.179
INDEX 268	ADVANTICA HKL-R08	X100	57.9	Machined	146.588	0.287	1.178	1.109	1.176	1.153	1.283	1.178
INDEX 269	ADVANTICA HKL-R09	X100	57.8	Machined	146.372	0.502	1.217	1.056	1.216	1.188	1.323	1.217
INDEX 270	ADVANTICA HKL-R10	X100	57.8	Machined	146.404	0.497	1.192	1.037	1.191	1.164	1.297	1.192
INDEX 271	ADVANTICA HKL-R11	X100	57.8	Machined	146.460	0.502	1.215	1.055	1.215	1.187	1.322	1.215
INDEX 272	ADVANTICA HKL-R12	X100	57.7	Machined	146.308	0.809	Invalid	Invalid	Invalid	1.196	Invalid	Invalid
INDEX 273	ADVANTICA HKL-R13	X100	57.8	Machined	146.492	0.833	Invalid	Invalid	Invalid	1.220	Invalid	Invalid
INDEX 274	ADVANTICA HKL-R14	X100	57.8	Machined	146.372	0.814	Invalid	Invalid	Invalid	1.265	Invalid	Invalid
INDEX 275	ADVANTICA HKB-R01	X100	63.9	Machined	154.075	0.102	1.091	1.071	1.089	1.072	1.192	1.091
INDEX 276	ADVANTICA HKB-R02	X100	63.9	Machined	154.171	0.286	1.114	1.050	1.113	1.093	1.216	1.114
INDEX 277	ADVANTICA HKB-R03	X100	63.9	Machined	154.075	0.503	1.118	0.970	1.117	1.094	1.218	1.118
INDEX 278	ADVANTICA HKB-R04	X100	63.9	Machined	154.075	0.807	Invalid	Invalid	Invalid	1.086	Invalid	Invalid
INDEX 279	ADVANTICA HKL-R15	X100	57.9	Machined	146.620	0.204	1.199	1.153	1.198	1.175	1.307	1.199
INDEX 280	ADVANTICA HKL-R16	X100	58.0	Machined	146.597	0.204	1.235	1.188	1.234	1.211	1.347	1.235
INDEX 281	ADVANTICA HKL-R17	X100	57.8	Machined	146.492	0.508	1.238	1.071	1.237	1.209	1.346	1.238
INDEX 282	ADVANTICA HKL-R18	X100	57.9	Machined	146.588	0.499	1.230	1.069	1.229	1.201	1.338	1.230
INDEX 283	ADVANTICA HKL-R19	X100	57.8	Machined	146.524	0.810	Invalid	Invalid	Invalid	1.235	Invalid	Invalid
INDEX 284	ADVANTICA HKL-R20	X100	57.9	Machined	146.468	0.811	Invalid	Invalid	Invalid	1.235	Invalid	Invalid

INDEX	Source Reference	Grade	D/t	Defect Type	$\frac{L}{\sqrt{Dt}}$	d/t	ASME B31G P_A/P_f	Mod ASME B31G P_A/P_f	RSTRENG P_A/P_f	LPC-1 P_A/P_f	SHELL 92 P_A/P_f	PCORRC P_A/P_f
INDEX 285	ADVANTICA HKB-R05	X100	63.8	Machined	154.096	0.207	1.156	1.111	1.154	1.135	1.262	1.156
INDEX 286	ADVANTICA HKB-R06	X100	63.8	Machined	153.888	0.504	1.212	1.051	1.212	1.186	1.321	1.212
INDEX 287	ADVANTICA HKB-R07	X100	63.9	Machined	154.075	0.818	Invalid	Invalid	Invalid	1.155	Invalid	Invalid
INDEX 288	ADVANTICA HKL-R21	X100	57.7	Machined	146.276	0.099	1.206	1.185	1.205	1.184	1.316	1.206
INDEX 289	ADVANTICA HKL-R22	X100	57.7	Machined	146.340	0.102	1.196	1.174	1.194	1.174	1.305	1.196
INDEX 290	ADVANTICA HKL-R23	X100	57.7	Machined	146.332	0.301	1.223	1.148	1.222	1.198	1.332	1.223
INDEX 291	ADVANTICA HKL-R24	X100	57.7	Machined	146.396	0.306	1.213	1.136	1.212	1.187	1.321	1.213
INDEX 292	ADVANTICA HKL-R25	X100	57.7	Machined	146.332	0.488	1.118	0.978	1.118	1.092	1.217	1.118
INDEX 293	ADVANTICA HKL-R26	X100	57.8	Machined	146.492	0.507	1.197	1.036	1.196	1.169	1.301	1.197
INDEX 294	ADVANTICA HKL-R27	X100	57.7	Machined	146.308	0.804	Invalid	Invalid	Invalid	1.058	Invalid	Invalid
INDEX 295	ADVANTICA HKL-R28	X100	57.7	Machined	146.244	0.808	Invalid	Invalid	Invalid	1.090	Invalid	Invalid
INDEX 296	ADVANTICA HKB-R08	X100	63.7	Machined	153.851	0.111	1.163	1.140	1.161	1.143	1.271	1.163
INDEX 297	ADVANTICA HKB-R09	X100	63.8	Machined	154.059	0.309	1.182	1.107	1.181	1.159	1.290	1.182
INDEX 298	ADVANTICA HKB-R10	X100	63.4	Machined	153.444	0.493	1.169	1.020	1.169	1.144	1.274	1.169
INDEX 299	ADVANTICA HKB-R11	X100	63.8	Machined	153.888	0.769	0.931	0.621	0.931	0.909	1.013	0.931
INDEX 300	ADVANTICA HKL V01	X100	57.9	Machined	3.503	0.496	0.931	1.021	1.136	1.045	1.274	1.034
INDEX 301	ADVANTICA HKK V01	X100	57.9	Machined	6.384	0.500	1.175	0.927	1.047	0.999	1.173	1.036
INDEX 302	ADVANTICA HKL V02	X100	57.9	Machined	2.962	0.503	0.909	0.992	1.101	1.001	1.238	0.986
INDEX 303	ADVANTICA HKK V02	X100	57.8	Machined	5.825	0.500	1.145	0.897	1.012	0.960	1.133	0.987
INDEX 304	NAT GAS PCA V1	X46	76.8	Real	1.278	0.520	1.720	1.538	N/A	1.107	1.404	1.132
INDEX 305	NAT GAS PCA V2	X46	76.8	Real	2.191	0.862	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid
INDEX 306	NAT GAS PCA V3	X46	76.8	Real	0.913	0.824	Invalid	Invalid	Invalid	1.157	Invalid	Invalid
INDEX 307	TRANSGAST1	X60	70.7	Machined	3.281	0.681	1.178	1.327	1.668	1.379	1.777	1.309
INDEX 308	TRANSGAST2	X60	70.7	Machined	3.486	0.474	1.303	1.338	1.474	1.274	1.546	1.260
INDEX 309	TRANSGAST3	X60	70.7	Machined	3.486	0.681	1.164	1.317	1.660	1.381	1.766	1.320
INDEX 310	TRANSGAST4	X60	70.7	Machined	3.486	0.526	1.250	1.306	1.474	1.262	1.551	1.240

INDEX	Source Reference	Grade	D/t	Defect Type	$\frac{L}{\sqrt{Dt}}$	d/t	ASME B31G P_A/P_f	Mod ASME B31G P_A/P_f	RSTRENG P_A/P_f	LPC-1 P_A/P_f	SHELL 92 P_A/P_f	PCORRC P_A/P_f
INDEX 311	TRANSGAST5	X60	70.7	Machined	3.076	0.466	1.178	1.200	1.313	1.129	1.378	1.115
INDEX 312	TRANSGAST6	X60	70.7	Machined	3.179	0.457	1.315	1.338	1.461	1.260	1.532	1.246
INDEX 313	TRANSGAST7	X60	73.9	Real	3.040	0.432	1.469	1.481	N/A	1.385	1.678	1.373

APPENDIX E LIST OF FAILURE PREDICTIONS FOR THE INTEGRATED DATABASE – CASE 6 (FLOW STRESS BASED ON THE MEAN OF THE SPECIFIED MINIMUM TENSILE AND ULTIMATE TENSILE STRENGTHS)

Notes

1. For clarity non-conservative failure predictions are marked in red.
2. INDEX 6 to 25 are Battelle tests on Grade B pipe. These results have been discounted from the sensitivity studies described in this report.

INDEX	Source Reference	Grade	D/t	Defect Type	$\frac{L}{\sqrt{Dt}}$	d/t	ASME B31G P_A/P_f	Mod ASME B31G P_A/P_f	RSTRENG P_A/P_f	LPC-1 P_A/P_f	SHELL 92 P_A/P_f	PCORRC P_A/P_f
INDEX 1	PRCI-001	X52	78.5	Real	0.738	0.382	1.141	1.151	1.128	1.116	1.176	1.164
INDEX 2	PRCI-002	X52	78.5	Real	0.665	0.382	1.130	1.138	1.121	1.105	1.157	1.154
INDEX 3	PRCI-003	X52	78.5	Real	1.255	0.411	1.274	1.307	1.203	1.258	1.378	1.293
INDEX 4	PRCI-004	X52	80.0	Real	1.640	0.640	1.500	1.655	1.262	1.638	1.986	1.597
INDEX 5	PRCI-005	X52	78.9	Real	1.407	0.550	1.243	1.316	1.190	1.269	1.473	1.283
INDEX 6	PRCI-006	B	63.7	Real	0.997	0.719	0.909	0.986	0.916	0.959	1.196	0.977
INDEX 7	PRCI-007	B	63.7	Real	1.579	0.666	1.044	1.160	1.059	1.150	1.415	1.120
INDEX 8	PRCI-008	B	63.7	Real	1.745	0.666	1.118	1.255	1.154	1.258	1.543	1.211
INDEX 9	PRCI-009	B	64.9	Real	0.587	0.705	0.782	0.809	0.753	0.782	0.891	0.836
INDEX 10	PRCI-010	B	64.0	Real	1.417	0.752	1.085	1.247	1.016	1.276	1.664	1.211
INDEX 11	PRCI-011	B	65.8	Real	0.676	0.715	0.799	0.835	0.764	0.807	0.947	0.856
INDEX 12	PRCI-012	B	65.8	Real	0.760	0.600	0.938	0.966	0.906	0.926	1.043	0.978
INDEX 13	PRCI-013	B	65.8	Real	0.845	0.630	1.047	1.091	1.013	1.045	1.210	1.097
INDEX 14	PRCI-014	B	65.8	Real	0.929	0.715	1.106	1.188	1.058	1.152	1.421	1.185
INDEX 15	PRCI-015	B	63.2	Real	1.242	0.661	1.119	1.212	1.044	1.175	1.436	1.182
INDEX 16	PRCI-016	B	64.9	Real	0.671	0.508	0.989	1.004	0.971	0.967	1.041	1.021
INDEX 17	PRCI-017	B	64.9	Real	1.007	0.649	1.123	1.190	1.096	1.142	1.363	1.179
INDEX 18	PRCI-018	B	64.0	Real	1.250	0.640	1.209	1.302	1.068	1.257	1.519	1.270
INDEX 19	PRCI-019	B	65.8	Real	0.591	0.715	1.110	1.150	1.073	1.113	1.276	1.189
INDEX 20	PRCI-020	B	64.0	Real	0.750	0.669	0.919	0.958	0.876	0.920	1.069	0.972
INDEX 21	PRCI-021	B	64.0	Real	0.750	0.779	1.188	1.279	1.132	1.257	1.577	1.307
INDEX 22	PRCI-022	B	64.0	Real	0.833	0.584	1.153	1.191	1.093	1.139	1.288	1.199
INDEX 23	PRCI-023	B	64.0	Real	0.667	0.501	1.097	1.112	1.068	1.071	1.151	1.131
INDEX 24	PRCI-024	B	64.0	Real	0.750	0.472	1.104	1.120	1.086	1.078	1.161	1.134
INDEX 25	PRCI-025	B	64.0	Real	1.667	0.723	1.436	1.654	1.397	1.698	2.157	1.601

INDEX	Source Reference	Grade	D/t	Defect Type	$\frac{L}{\sqrt{Dt}}$	d/t	ASME B31G P_A/P_f	Mod ASME B31G P_A/P_f	RSTRENG P_A/P_f	LPC-1 P_A/P_f	SHELL 92 P_A/P_f	PCORRC P_A/P_f
INDEX 26	PRCI-026	X52	80.0	Real	0.820	1.000	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid
INDEX 27	PRCI-027	X52	80.0	Real	1.640	0.389	1.438	1.486	1.338	1.437	1.575	1.459
INDEX 28	PRCI-028	X52	80.0	Real	1.342	0.307	1.404	1.427	1.378	1.380	1.471	1.415
INDEX 29	PRCI-029	X52	80.0	Real	1.193	0.613	1.466	1.560	1.331	1.503	1.784	1.528
INDEX 30	PRCI-030	X52	80.0	Real	0.477	0.557	1.520	1.535	1.492	1.493	1.577	1.580
INDEX 31	PRCI-031	X52	80.0	Real	0.596	0.557	1.450	1.473	1.406	1.425	1.537	1.508
INDEX 32	PRCI-032	B	61.5	Real	2.255	0.643	1.056	1.200	0.924	1.231	1.467	1.173
INDEX 33	PRCI-033	B	61.5	Real	2.550	0.674	1.634	1.907	1.308	2.027	2.415	1.905
INDEX 34	PRCI-034	A25	51.6	Real	2.021	0.742	1.221	1.456	1.101	1.563	1.975	1.436
INDEX 35	PRCI-035	A25	51.6	Real	2.245	0.774	1.490	1.846	1.316	2.100	2.663	1.884
INDEX 36	PRCI-036	A25	51.6	Real	2.694	0.910	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid
INDEX 37	PRCI-037	A25	51.6	Real	1.235	0.877	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid
INDEX 38	PRCI-038	A25	51.6	Real	2.806	0.642	1.399	1.616	1.330	1.704	1.986	1.627
INDEX 39	PRCI-039	B	57.6	Real	4.109	0.695	1.384	1.692	1.312	1.967	2.229	1.931
INDEX 40	PRCI-040	B	58.5	Real	2.550	0.927	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid
INDEX 41	PRCI-041	B	60.6	Real	1.865	0.909	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid
INDEX 42	PRCI-042	B	54.1	Real	2.527	0.495	1.399	1.511	1.438	1.500	1.682	1.482
INDEX 43	PRCI-043	B	65.6	Real	5.061	0.751	4.098	2.352	1.482	3.021	3.381	3.110
INDEX 44	PRCI-044	B	65.9	Real	4.398	0.698	1.454	1.786	1.358	2.106	2.369	2.089
INDEX 45	PRCI-045	B	67.6	Real	2.227	0.814	Invalid	Invalid	Invalid	2.775	Invalid	Invalid
INDEX 46	PRCI-046	B	75.2	Real	1.988	0.677	1.947	2.227	1.608	2.289	2.800	2.162
INDEX 47	PRCI-047	B	72.3	Real	1.594	0.663	1.782	1.981	1.611	1.966	2.414	1.911
INDEX 48	PRCI-048	B	64.0	Real	5.333	0.787	2.343	1.257	1.270	1.727	1.934	1.825
INDEX 49	PRCI-049	B	64.0	Real	3.000	0.853	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid
INDEX 50	PRCI-050	B	64.1	Real	4.804	0.808	Invalid	Invalid	Invalid	1.766	Invalid	Invalid
INDEX 51	PRCI-051	X52	65.6	Real	4.251	0.689	1.062	1.294	1.209	1.505	1.696	1.483

INDEX	Source Reference	Grade	D/t	Defect Type	$\frac{L}{\sqrt{Dt}}$	d/t	ASME B31G P_A/P_f	Mod ASME B31G P_A/P_f	RSTRENG P_A/P_f	LPC-1 P_A/P_f	SHELL 92 P_A/P_f	PCORRC P_A/P_f
INDEX 52	PRCI-052	B	66.5	Real	3.567	0.884	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid
INDEX 53	PRCI-053	B	66.5	Real	4.247	0.789	1.887	2.509	1.324	3.344	3.859	3.312
INDEX 54	PRCI-054	B	67.6	Real	2.912	0.685	1.906	2.264	1.417	2.479	2.920	2.329
INDEX 55	PRCI-055	B	64.7	Real	3.519	0.744	1.558	1.960	1.189	2.351	2.752	2.227
INDEX 56	PRCI-056	B	64.7	Real	3.519	0.784	1.630	2.129	1.181	2.715	3.217	2.556
INDEX 57	PRCI-057	B	64.5	Real	7.363	0.548	4.590	1.818	1.299	2.060	4.001	2.173
INDEX 58	PRCI-058	B	65.9	Real	2.876	0.615	1.648	1.881	1.543	1.970	2.272	1.889
INDEX 59	PRCI-059	B	65.6	Real	4.218	0.661	1.980	2.369	1.445	2.688	3.013	2.649
INDEX 60	PRCI-060	B	65.6	Real	1.350	0.522	1.304	1.367	1.430	1.312	1.501	1.338
INDEX 61	PRCI-061	B	65.2	Real	9.422	0.783	4.832	2.966	1.336	4.060	4.319	4.643
INDEX 62	PRCI-062	B	70.7	Real	12.610	0.968	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid
INDEX 63	PRCI-063	B	73.0	Real	5.126	0.474	2.542	2.007	1.715	2.114	2.254	2.140
INDEX 64	PRCI-064	B	64.3	Real	3.408	0.768	1.976	2.535	1.245	3.129	3.708	2.933
INDEX 65	PRCI-065	B	64.3	Real	4.411	0.338	1.398	1.475	1.243	1.487	1.563	1.501
INDEX 66	PRCI-066	B	75.2	Real	6.720	0.541	2.601	1.995	1.512	2.207	2.338	2.301
INDEX 67	PRCI-067	B	64.7	Real	4.827	0.706	4.201	2.592	1.405	3.119	3.478	3.153
INDEX 68	PRCI-068	X52	80.6	Real	10.776	0.349	1.937	1.613	1.595	1.803	1.844	1.885
INDEX 69	PRCI-069	X52	79.8	Real	3.573	0.612	1.519	1.752	1.499	1.889	2.129	1.831
INDEX 70	PRCI-070	X52	80.0	Real	3.578	0.373	1.517	1.606	1.578	1.614	1.723	1.612
INDEX 71	PRCI-071	X52	78.5	Real	5.908	0.380	2.040	1.730	1.471	1.792	1.872	1.829
INDEX 72	PRCI-072	X52	79.8	Real	5.955	0.346	1.845	1.594	1.468	1.640	1.705	1.672
INDEX 73	PRCI-073	X52	79.4	Real	9.800	0.291	1.818	1.510	1.571	1.701	1.736	1.763
INDEX 74	PRCI-074	X52	79.2	Real	4.152	0.449	1.567	1.701	1.494	1.752	1.883	1.748
INDEX 75	PRCI-075	X52	78.7	Real	3.549	0.787	1.325	1.737	1.025	2.237	2.650	2.104
INDEX 76	PRCI-076	X52	79.4	Real	2.376	0.450	1.441	1.533	1.347	1.513	1.678	1.500
INDEX 77	PRCI-077	X52	79.6	Real	3.568	0.424	1.540	1.653	1.464	1.675	1.807	1.664

INDEX	Source Reference	Grade	D/t	Defect Type	$\frac{L}{\sqrt{Dt}}$	d/t	ASME B31G P_A/P_f	Mod ASME B31G P_A/P_f	RSTRENG P_A/P_f	LPC-1 P_A/P_f	SHELL 92 P_A/P_f	PCORRC P_A/P_f
INDEX 78	PRCI-078	X52	80.4	Real	2.690	0.295	1.443	1.493	1.466	1.469	1.558	1.476
INDEX 79	PRCI-079	X42	64.0	Real	5.583	0.859	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid
INDEX 80	PRCI-080	X52	82.2	Real	4.835	0.627	1.845	1.262	1.284	1.424	1.565	1.430
INDEX 81	PRCI-081	X52	80.0	Real	8.050	0.653	1.940	1.387	1.350	1.643	1.744	1.779
INDEX 82	PRCI-082	X56	80.0	Real	2.236	0.400	1.490	1.563	1.401	1.531	1.677	1.531
INDEX 83	PRCI-083	X46	76.9	Real	7.016	0.838	Invalid	Invalid	Invalid	2.852	Invalid	Invalid
INDEX 84	PRCI-084	X65	109.1	Real	4.642	0.661	1.754	1.146	1.241	1.324	1.469	1.317
INDEX 85	PRCI-085	X60	100.7	Real	21.070	0.903	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid
INDEX 86	PRCI-086	X52	111.1	Real	2.875	0.747	1.273	1.581	1.180	1.848	2.231	1.686
INDEX 87	PRCI-087	X65	94.5	Real	0.729	0.735	1.361	1.440	1.260	1.403	1.690	1.469
INDEX 88	PRCI-088	X52	82.6	Real	2.364	0.331	1.383	1.434	1.367	1.406	1.509	1.412
INDEX 89	PRCI-089	X65	88.9	Real	1.453	0.741	1.413	1.619	1.223	1.656	2.140	1.569
INDEX 90	PRCI-090	X65	90.0	Real	0.422	0.675	1.150	1.168	1.140	1.140	1.225	1.217
INDEX 91	PRCI-091	X65	91.6	Real	0.372	0.789	1.261	1.292	1.237	1.272	1.406	1.371
INDEX 92	PRCI-092	X52	75.2	Real	6.867	0.282	1.680	1.507	1.372	1.539	1.582	1.577
INDEX 93	PRCI-097	X60	76.6	Machined	6.565	0.395	1.529	1.293	1.400	1.352	1.409	1.390
INDEX 94	PRCI-098	X60	76.3	Machined	17.474	0.385	1.540	1.335	1.495	1.460	1.483	1.534
INDEX 95	PRCI-099	X60	78.1	Machined	2.652	0.395	1.334	1.406	1.497	1.390	1.512	1.385
INDEX 96	PRCI-100	X60	78.4	Machined	2.657	0.376	1.325	1.391	1.525	1.373	1.486	1.371
INDEX 97	PRCI-101	X60	78.4	Machined	2.657	0.396	1.341	1.414	1.530	1.398	1.521	1.393
INDEX 98	PRCI-106	X46	54.7	Machined	1.137	0.790	1.309	1.496	1.266	1.526	2.047	1.476
INDEX 99	PRCI-108	X46	53.3	Machined	1.352	0.657	1.301	1.419	1.258	1.378	1.686	1.377
INDEX 100	PRCI-109	X46	55.4	Machined	1.028	0.665	1.454	1.551	1.362	1.490	1.799	1.534
INDEX 101	PRCI-110	X46	54.0	Machined	0.669	0.784	1.276	1.360	1.227	1.331	1.641	1.406
INDEX 102	PRCI-111	X46	54.0	Machined	0.899	0.750	1.412	1.532	1.287	1.495	1.887	1.535
INDEX 103	PRCI-112	X46	53.3	Machined	1.008	0.481	1.349	1.384	1.355	1.321	1.462	1.380

INDEX	Source Reference	Grade	D/t	Defect Type	$\frac{L}{\sqrt{Dt}}$	d/t	ASME B31G P_A/P_f	Mod ASME B31G P_A/P_f	RSTRENG P_A/P_f	LPC-1 P_A/P_f	SHELL 92 P_A/P_f	PCORRC P_A/P_f
INDEX 104	PRCI-113	X46	49.2	Machined	0.969	0.788	1.082	1.207	0.972	1.205	1.590	1.206
INDEX 105	PRCI-114	X46	52.7	Machined	0.660	0.393	1.160	1.169	1.144	1.128	1.182	1.186
INDEX 106	PRCI-115	X46	52.5	Machined	0.886	0.733	1.203	1.295	1.128	1.255	1.558	1.298
INDEX 107	PRCI-116	X46	54.5	Machined	1.042	0.701	1.395	1.508	1.318	1.459	1.805	1.489
INDEX 108	PRCI-117	X46	53.8	Machined	1.243	0.312	1.254	1.273	1.250	1.224	1.303	1.266
INDEX 109	PRCI-119	X60	79.4	Machined	17.372	0.532	1.456	1.192	1.397	1.359	1.389	1.450
INDEX 110	PRCI-120	X60	79.4	Machined	17.817	0.345	1.537	1.350	1.498	1.465	1.485	1.531
INDEX 111	PRCI-121	X60	79.4	Machined	1.782	0.468	1.292	1.361	1.458	1.321	1.487	1.326
INDEX 112	PRCI-122	X60	79.4	Machined	3.563	0.452	1.089	1.178	1.288	1.200	1.303	1.189
INDEX 113	PRCI-123	X60	79.4	Machined	3.595	0.532	0.999	1.112	1.260	1.159	1.280	1.137
INDEX 114	PRCI-124	X60	79.4	Machined	17.537	0.500	1.432	1.191	1.378	1.342	1.369	1.426
INDEX 115	PRCI-125	X52	49.4	Machined	35.136	0.399	1.465	1.312	1.450	1.406	1.417	1.465
INDEX 116	PRCI-126	X52	49.4	Machined	7.027	0.399	1.414	1.196	1.292	1.248	1.298	1.299
INDEX 117	PRCI-127	X52	49.4	Machined	3.514	0.399	1.178	1.256	1.313	1.255	1.348	1.260
INDEX 118	PRCI-128	X52	49.4	Machined	3.514	0.399	1.254	1.337	1.398	1.336	1.435	1.341
INDEX 119	PRCI-129	X52	49.4	Machined	1.757	0.399	1.311	1.361	1.354	1.308	1.439	1.333
INDEX 120	PRCI-136	X52	49.4	Machined	0.439	0.599	1.390	1.406	1.415	1.358	1.437	1.453
INDEX 121	PRCI-137	X52	49.4	Machined	0.439	0.599	1.289	1.303	N/A	1.259	1.332	1.347
INDEX 122	PRCI-142	X52	49.4	Machined	1.318	0.599	1.408	1.503	1.373	1.441	1.707	1.465
INDEX 123	PRCI-144	X52	49.4	Machined	3.514	0.399	1.346	1.434	1.433	1.434	1.540	1.439
INDEX 124	PRCI-147	X52	49.4	Machined	1.757	0.399	1.439	1.494	1.486	1.436	1.579	1.463
INDEX 125	PRCI-163	X46	52.5	Machined	0.449	0.605	1.380	1.396	1.433	1.350	1.433	1.444
INDEX 126	PRCI-165	X46	51.8	Machined	0.440	0.606	1.392	1.408	1.443	1.361	1.443	1.456
INDEX 127	PRCI-166	X46	52.5	Machined	0.443	0.609	1.422	1.439	1.476	1.391	1.477	1.489
INDEX 128	PRCI-171	X46	51.6	Machined	0.440	0.599	1.265	1.279	1.310	1.237	1.309	1.323
INDEX 129	PRCI-173	X46	51.4	Machined	1.597	0.601	1.328	1.440	N/A	1.399	1.664	1.393

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INDEX 130	PRCI-174	X46	51.8	Machined	1.604	0.606	1.394	1.515	N/A	1.474	1.757	1.465
INDEX 131	PRCI-176	X46	52.5	Machined	0.449	0.601	1.116	1.129	N/A	1.091	1.158	1.167
INDEX 132	PRCI-182	X46	47.2	Machined	1.186	0.659	1.292	1.393	1.307	1.340	1.631	1.363
INDEX 133	PRCI-183	X46	48.9	Machined	2.286	0.667	1.494	1.721	1.433	1.783	2.144	1.691
INDEX 134	PRCI-184	X46	47.6	Machined	2.223	0.683	1.355	1.571	1.498	1.635	1.986	1.543
INDEX 135	ADVANTICA-TR020	X65	41.3	Machined	200.935	0.229	1.449	1.386	1.448	1.411	1.412	1.449
INDEX 136	ADVANTICA-TR021	X65	42.2	Machined	203.044	0.429	1.575	1.415	1.575	1.532	1.534	1.575
INDEX 137	ADVANTICA-TR022	X65	40.9	Machined	199.776	0.627	1.406	1.123	1.406	1.364	1.367	1.406
INDEX 138	ADVANTICA-TR023	X65	41.1	Machined	200.417	0.824	Invalid	Invalid	Invalid	1.793	Invalid	Invalid
INDEX 139	ADVANTICA-TR024	X65	40.8	Machined	199.649	0.574	1.339	1.113	1.338	1.299	1.302	1.339
INDEX 140	ADVANTICA-TR025	X65	40.7	Machined	199.268	0.580	1.336	1.106	1.335	1.296	1.299	1.336
INDEX 141	ADVANTICA-TR026	X65	41.1	Machined	200.289	0.560	1.309	1.099	1.309	1.271	1.273	1.309
INDEX 142	ADVANTICA-TR027	X65	43.7	Machined	206.619	0.586	1.293	1.066	1.292	1.257	1.259	1.293
INDEX 143	ADVANTICA-TR029	X52	46.0	Machined	282.526	0.186	1.444	1.396	1.444	1.411	1.412	1.444
INDEX 144	ADVANTICA-TR030	X52	45.6	Machined	281.450	0.648	1.439	1.128	1.439	1.402	1.404	1.439
INDEX 145	ADVANTICA-TR031	X52	46.2	Machined	283.069	0.454	1.581	1.405	1.580	1.542	1.544	1.581
INDEX 146	ADVANTICA-TR032	X52	46.2	Machined	283.069	0.720	1.761	1.271	1.761	1.715	1.718	1.761
INDEX 147	ADVANTICA-TR033	X52	45.7	Machined	281.718	0.468	1.509	1.333	1.509	1.472	1.473	1.509
INDEX 148	ADVANTICA-TR034	X52	46.0	Machined	282.526	0.472	1.428	1.259	1.428	1.393	1.394	1.428
INDEX 149	ADVANTICA-TR035	X52	46.5	Machined	284.164	0.496	1.547	1.348	1.547	1.509	1.511	1.547
INDEX 150	ADVANTICA-TV006	X65	42.6	Machined	1.629	0.702	1.235	1.402	1.703	1.405	1.764	1.354
INDEX 151	ADVANTICA-TV008	X65	41.2	Machined	4.811	0.680	1.668	1.068	1.362	1.241	1.377	1.262
INDEX 152	ADVANTICA-TV010	X65	41.7	Machined	3.227	0.687	0.906	1.086	1.372	1.200	1.397	1.147
INDEX 153	ADVANTICA-TV011	X65	40.9	Machined	3.196	0.674	0.909	1.080	1.346	1.178	1.368	1.129
INDEX 154	ADVANTICA-TV016	X65	40.7	Machined	3.188	0.700	1.021	1.233	1.581	1.375	1.426	1.309

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INDEX 155	ADVANTICA-TV017	X65	41.2	Machined	4.816	0.756	1.586	0.895	1.263	1.139	1.283	1.170
INDEX 156	ADVANTICA-TV018	X65	40.9	Machined	3.836	0.739	0.925	1.166	1.586	1.398	1.615	1.359
INDEX 157	ADVANTICA-TV019	X65	40.7	Machined	6.377	0.735	1.797	1.095	1.508	1.403	1.530	1.526
INDEX 158	ADVANTICA-TV022	X65	40.3	Machined	3.172	0.748	0.862	1.079	1.472	1.265	1.505	1.188
INDEX 159	ADVANTICA-TV027	X65	40.7	Machined	4.782	0.720	1.750	1.052	1.408	1.274	1.427	1.300
INDEX 160	ADVANTICA-TV028	X65	44.0	Machined	4.972	0.744	1.604	0.932	1.290	1.171	1.312	1.208
INDEX 161	ADVANTICA-TV031	X65	44.0	Machined	4.972	0.551	1.541	1.142	1.318	1.225	1.324	1.247
INDEX 162	ADVANTICA-TV032	X65	40.5	Machined	4.770	0.478	1.273	0.996	1.108	1.033	1.106	1.051
INDEX 163	ADVANTICA-TV033	X65	8.8	Machined	0.688	0.708	1.107	1.158	1.267	1.006	1.179	1.184
INDEX 164	ADVANTICA-TV034	X65	8.6	Machined	1.357	0.690	0.986	1.091	1.284	0.964	1.203	1.058
INDEX 165	ADVANTICA-TV035	X65	8.8	Machined	2.064	0.710	0.956	1.119	1.405	1.061	1.316	1.096
INDEX 166	ADVANTICA-TV036	X65	8.7	Machined	2.729	0.697	0.932	1.111	1.404	1.091	1.301	1.133
INDEX 167	ADVANTICA-TV037	X65	8.6	Machined	1.362	0.197	1.154	1.163	1.179	1.015	1.053	1.159
INDEX 168	ADVANTICA-TV038	X65	8.6	Machined	1.357	0.509	1.084	1.134	1.213	0.976	1.111	1.111
INDEX 169	ADVANTICA-TV039	X65	8.7	Machined	1.367	0.941	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid
INDEX 170	ADVANTICA-TV045	X52	48.1	Machined	1.737	0.725	1.206	1.398	1.755	1.439	1.827	1.356
INDEX 171	ADVANTICA-TV046	X52	49.2	Machined	1.756	0.559	1.370	1.476	1.638	1.433	1.671	1.429
INDEX 172	ADVANTICA-TV047	X52	48.1	Machined	5.212	0.740	1.782	1.049	1.447	1.324	1.474	1.377
INDEX 173	ADVANTICA-TV048	X52	49.5	Machined	5.283	0.546	1.950	1.459	1.683	1.575	1.695	1.610
INDEX 174	ADVANTICA-TV049	X60	29.5	Machined	1.360	0.704	1.398	1.557	1.856	1.513	1.907	1.509
INDEX 175	ADVANTICA-TV050	X60	29.1	Machined	1.352	0.733	1.373	1.551	1.902	1.527	1.963	1.505
INDEX 176	ADVANTICA-TV051	X60	29.5	Machined	1.360	0.568	1.348	1.429	1.563	1.349	1.576	1.394
INDEX 177	ADVANTICA-TV052	X60	28.8	Machined	4.029	0.688	0.965	1.172	1.499	1.326	1.503	1.321
INDEX 178	ADVANTICA-TV053	X60	29.3	Machined	4.068	0.519	1.235	1.375	1.553	1.412	1.541	1.430
INDEX 179	ADVANTICA-TV056	X52	45.2	Machined	1.687	0.724	1.178	1.359	1.697	1.390	1.765	1.316
INDEX 180	ADVANTICA-TV057	X52	46.9	Machined	1.730	0.577	1.300	1.408	1.573	1.367	1.607	1.362

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INDEX 181	ADVANTICA-TV058	X52	46.5	Machined	5.147	0.766	1.720	0.961	1.383	1.258	1.409	1.314
INDEX 182	ADVANTICA-TV059	X52	45.2	Machined	5.073	0.586	1.923	1.382	1.631	1.513	1.643	1.543
INDEX 183	ADVANTICA-TV060	X60	31.6	Machined	1.411	0.725	1.406	1.590	1.945	1.571	2.010	1.540
INDEX 184	ADVANTICA-TV061	X60	29.7	Machined	1.369	0.537	1.501	1.581	1.708	1.490	1.717	1.545
INDEX 185	ADVANTICA-TV062	X60	30.8	Machined	4.186	0.733	0.998	1.258	1.704	1.506	1.717	1.505
INDEX 186	ADVANTICA-TV063	X60	31.6	Machined	4.241	0.534	1.271	1.425	1.623	1.481	1.615	1.499
INDEX 187	ADVANTICA-TV064	X65	32.3	Machined	1.435	0.817	Invalid	Invalid	Invalid	1.397	Invalid	Invalid
INDEX 188	ADVANTICA-TV065	X65	32.4	Machined	1.429	0.622	1.197	1.296	1.462	1.239	1.489	1.256
INDEX 189	ADVANTICA-TV066	X65	32.3	Machined	4.286	0.820	Invalid	Invalid	Invalid	1.280	Invalid	Invalid
INDEX 190	ADVANTICA-TV067	X65	32.3	Machined	4.286	0.630	0.990	1.163	1.411	1.272	1.414	1.279
INDEX 191	ADVANTICA-TV072	X60	46.9	Machined	1.715	0.704	1.144	1.308	1.602	1.326	1.663	1.265
INDEX 192	ADVANTICA-TV073	X60	47.1	Machined	5.165	0.719	1.550	0.944	1.265	1.158	1.286	1.197
INDEX 193	PETROBRAS TS02	X46	76.0	Real	18.860	0.463	2.458	2.086	1.698	2.319	2.359	2.451
INDEX 194	PETROBRAS TS04	X46	73.6	Real	18.550	0.525	2.486	2.050	1.482	2.328	2.375	2.479
INDEX 195	PETROBRAS TS05	X46	75.7	Real	18.821	0.448	1.850	1.579	1.448	1.748	1.777	1.844
INDEX 196	PETROBRAS TS06	X46	69.7	Real	18.101	0.507	1.942	1.614	1.463	1.819	1.855	1.936
INDEX 197	PETROBRAS TS10	X46	75.3	Real	18.792	0.461	2.349	1.995	1.476	2.216	2.254	2.342
INDEX 198	PETROBRAS TS 5.1	X60	33.0	Machined	4.537	0.722	1.842	1.095	1.466	1.311	1.478	1.330
INDEX 199	PETROBRAS TS 1.2	X60	33.5	Machined	5.464	0.699	1.686	1.068	1.398	1.279	1.407	1.344
INDEX 200	PETROBRAS TS 2.2	X60	33.4	Machined	6.241	0.714	1.703	1.072	1.433	1.325	1.444	1.434
INDEX 201	PETROBRAS TS 2.1	X60	33.4	Machined	7.035	0.712	1.596	1.020	1.363	1.275	1.375	1.406
INDEX 202	PETROBRAS TS 3.1	X60	32.7	Machined	7.650	0.738	1.627	1.061	1.544	1.311	1.408	1.476
INDEX 203	PETROBRAS TS 1.1	X60	33.2	Machined	8.310	0.720	1.524	1.022	1.446	1.253	1.336	1.413
INDEX 204	PETROBRAS TS 3.2	X60	33.1	Machined	8.679	0.713	1.478	1.002	1.404	1.226	1.303	1.384
INDEX 205	PETROBRAS TS 4.1	X60	33.1	Machined	8.880	0.713	1.488	1.010	1.414	1.239	1.314	1.400
INDEX 206	PETROBRAS TS 4.2	X60	33.2	Machined	9.398	0.733	1.511	1.005	1.446	1.264	1.339	1.442

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INDEX 207	KOREAN GAS CO DA	X65	43.5	Machined	1.732	0.251	1.172	1.192	1.220	1.147	1.209	1.179
INDEX 208	KOREAN GAS CO DB	X65	43.5	Machined	1.732	0.503	1.192	1.263	1.367	1.214	1.384	1.228
INDEX 209	KOREAN GAS CO DC	X65	43.5	Machined	1.732	0.748	1.111	1.307	1.689	1.367	1.761	1.273
INDEX 210	KOREAN GAS CO LA	X65	43.5	Machined	0.866	0.503	1.195	1.222	1.272	1.162	1.280	1.229
INDEX 211	KOREAN GAS CO LC	X65	43.5	Machined	2.598	0.503	1.149	1.247	1.377	1.236	1.387	1.225
INDEX 212	KOREAN GAS CO CB	X65	43.5	Machined	1.732	0.503	1.282	1.359	1.472	1.306	1.489	1.321
INDEX 213	KOREAN GAS CO CC	X65	43.5	Machined	1.732	0.503	1.240	1.314	1.423	1.263	1.440	1.277
INDEX 214	WATERLOO SOL-2	X46	37.4	Real	1.202	0.250	1.292	1.304	1.283	1.248	1.307	1.300
INDEX 215	WATERLOO SOL-4	X46	37.6	Real	3.858	0.346	1.407	1.484	1.344	1.471	1.557	1.495
INDEX 216	WATERLOO SOL-6	X46	37.4	Real	1.154	0.312	1.356	1.374	1.346	1.310	1.391	1.369
INDEX 217	WATERLOO SOL-10	X46	37.6	Real	2.743	0.383	1.453	1.529	1.410	1.493	1.616	1.509
INDEX 218	WATERLOO SOL-11	X46	37.5	Real	2.402	0.309	1.247	1.288	1.196	1.244	1.328	1.270
INDEX 219	WATERLOO SOL-12	X46	37.9	Real	0.967	0.256	1.141	1.148	1.152	1.101	1.146	1.151
INDEX 220	WATERLOO NOR-1	X52	52.2	Real	10.819	0.354	1.703	1.417	1.366	1.573	1.610	1.657
INDEX 221	WATERLOO NOR-2	X52	51.9	Real	3.687	0.329	1.418	1.487	1.379	1.479	1.563	1.492
INDEX 222	WATERLOO TNG-01	X46	33.1	Real	5.083	0.480	1.795	1.410	1.317	1.462	1.561	1.505
INDEX 223	WATERLOO RLK-1	X52	93.3	Real	14.246	0.504	2.240	1.830	1.627	2.076	2.129	2.215
INDEX 224	WATERLOO RLK-2	X52	95.3	Real	22.833	0.553	2.121	1.741	1.514	2.008	2.042	2.120
INDEX 225	WATERLOO RLK-3	X52	95.5	Real	21.924	0.401	1.973	1.730	1.547	1.888	1.912	1.970
INDEX 226	WATERLOO BCG-1	X42	55.2	Real	4.971	0.667	3.144	2.058	1.260	2.387	2.635	2.426
INDEX 227	WATERLOO BCG-2	X42	58.4	Real	1.351	0.560	1.353	1.431	1.197	1.373	1.598	1.397
INDEX 228	WATERLOO BCG-3	X42	57.3	Real	0.843	0.340	1.149	1.159	1.140	1.118	1.177	1.166
INDEX 229	WATERLOO BCG-4	X42	56.0	Real	2.784	0.448	1.487	1.592	1.341	1.581	1.740	1.571
INDEX 230	WATERLOO BCG-5	X42	55.6	Real	1.245	0.325	1.256	1.276	1.230	1.227	1.310	1.268
INDEX 231	WATERLOO BCG-6	X42	54.8	Real	3.360	0.431	1.289	1.384	1.176	1.390	1.507	1.386
INDEX 232	WATERLOO BCG-7	X42	60.0	Real	1.864	0.600	1.391	1.527	1.189	1.508	1.786	1.476

INDEX	Source Reference	Grade	D/t	Defect Type	$\frac{L}{\sqrt{Dt}}$	d/t	ASME B31G P_A/P_f	Mod ASME B31G P_A/P_f	RSTRENG P_A/P_f	LPC-1 P_A/P_f	SHELL 92 P_A/P_f	PCORRC P_A/P_f
INDEX 233	WATERLOO BCG-8	X42	55.1	Real	1.031	0.546	1.297	1.345	1.226	1.282	1.458	1.336
INDEX 234	WATERLOO BCG-9	X42	56.9	Real	4.327	0.437	1.298	1.406	1.156	1.441	1.541	1.449
INDEX 235	WATERLOO ESS-01	X46	63.8	Real	2.442	0.720	1.271	1.523	1.176	1.665	2.033	1.534
INDEX 236	WATERLOO NOV01	X55	88.3	Real	2.449	0.527	1.532	1.669	1.444	1.674	1.899	1.634
INDEX 237	WATERLOO NOV02-2	X55	89.1	Real	8.644	0.574	2.071	1.568	1.336	1.809	1.897	1.934
INDEX 238	WATERLOO NOV03-2	X55	89.3	Real	11.528	0.661	2.774	2.022	1.414	2.464	2.568	2.709
INDEX 239	WATERLOO NOV04	X55	88.5	Real	9.878	0.668	3.241	2.322	1.599	2.821	2.963	3.102
INDEX 240	WATERLOO NOV04-2	X55	88.5	Real	7.714	0.531	2.530	1.934	1.491	2.200	2.311	2.315
INDEX 241	WATERLOO NOV05	X55	90.5	Real	11.175	0.597	2.224	1.696	1.321	1.991	2.068	2.159
INDEX 242	WATERLOO NOV06	X55	90.1	Real	3.180	0.437	1.624	1.743	1.530	1.757	1.914	1.737
INDEX 243	WATERLOO TCP01	X46	89.7	Real	2.340	0.377	1.536	1.606	1.483	1.578	1.715	1.577
INDEX 244	WATERLOO TCP02	X46	91.2	Real	2.050	0.316	1.459	1.502	1.395	1.466	1.572	1.478
INDEX 245	WATERLOO TCP03	X46	92.1	Real	1.016	0.493	1.268	1.303	1.253	1.252	1.394	1.298
INDEX 246	ADVANTICA V1	B/X42	77.2	Machined	0.228	0.800	1.411	1.426	1.467	1.404	1.471	1.508
INDEX 247	ADVANTICA V2	B/X42	77.2	Machined	0.911	0.800	1.215	1.353	1.695	1.366	1.811	1.363
INDEX 248	BRITISH GAS RING1	X60	40.9	Machined	177.799	0.300	1.175	1.103	1.174	1.143	1.144	1.175
INDEX 249	BRITISH GAS RING2	X60	41.4	Machined	178.784	0.280	1.204	1.137	1.203	1.172	1.173	1.204
INDEX 250	BRITISH GAS RING3	X60	41.5	Machined	179.122	0.470	1.238	1.092	1.237	1.202	1.205	1.238
INDEX 251	BRITISH GAS RING4	X60	41.5	Machined	179.122	0.500	1.160	1.009	1.160	1.127	1.129	1.160
INDEX 252	BRITISH GAS RING5	X60	40.7	Machined	177.184	0.690	1.212	0.908	1.211	1.174	1.177	1.212
INDEX 253	BRITISH GAS RING6	X60	41.3	Machined	178.508	0.670	1.088	0.834	1.088	1.055	1.057	1.088
INDEX 254	BRITISH GAS RING7	X60	41.2	Machined	178.387	0.670	1.100	0.843	1.100	1.066	1.069	1.100
INDEX 255	ADVANTICA P1V1A	X80	60.1	Machined	3.890	0.775	0.693	0.903	1.304	1.152	1.341	1.114
INDEX 256	ADVANTICA P1V1B	X80	60.1	Machined	3.877	0.207	1.224	1.256	1.291	1.242	1.282	1.259
INDEX 257	ADVANTICA P1V2A	X80	60.1	Machined	3.890	0.374	1.128	1.198	1.279	1.205	1.282	1.210
INDEX 258	ADVANTICA P1V2B	X80	60.1	Machined	3.903	0.089	1.253	1.265	1.278	1.245	1.262	1.266

INDEX	Source Reference	Grade	D/t	Defect Type	$\frac{L}{\sqrt{Dt}}$	d/t	ASME B31G P_A/P_f	Mod ASME B31G P_A/P_f	RSTRENG P_A/P_f	LPC-1 P_A/P_f	SHELL 92 P_A/P_f	PCORRC P_A/P_f
INDEX 259	ADVANTICA P2V1A	X80	81.8	Machined	4.538	0.782	1.494	0.789	1.163	1.051	1.200	1.056
INDEX 260	ADVANTICA P2V1B	X80	81.8	Machined	4.450	0.167	1.168	1.193	1.220	1.186	1.214	1.200
INDEX 261	ADVANTICA P2V2A	X80	81.8	Machined	4.546	0.395	1.387	1.144	1.232	1.171	1.241	1.177
INDEX 262	ADVANTICA P2V2B	X80	81.8	Machined	4.523	0.112	1.264	1.206	1.223	1.196	1.214	1.211
INDEX 263	ADVANTICA HKL-R03	X100	57.7	Machined	146.332	0.111	1.219	1.195	1.217	1.196	1.197	1.219
INDEX 264	ADVANTICA HKL-R04	X100	57.7	Machined	146.332	0.099	1.223	1.202	1.222	1.201	1.201	1.223
INDEX 265	ADVANTICA HKL-R05	X100	57.7	Machined	146.396	0.101	1.221	1.199	1.219	1.198	1.199	1.221
INDEX 266	ADVANTICA HKL-R06	X100	57.6	Machined	146.300	0.294	1.201	1.129	1.199	1.175	1.177	1.201
INDEX 267	ADVANTICA HKL-R07	X100	57.9	Machined	146.588	0.294	1.235	1.161	1.233	1.209	1.211	1.235
INDEX 268	ADVANTICA HKL-R08	X100	57.9	Machined	146.588	0.287	1.234	1.162	1.233	1.208	1.210	1.234
INDEX 269	ADVANTICA HKL-R09	X100	57.8	Machined	146.372	0.502	1.274	1.106	1.274	1.245	1.248	1.274
INDEX 270	ADVANTICA HKL-R10	X100	57.8	Machined	146.404	0.497	1.249	1.087	1.248	1.220	1.223	1.249
INDEX 271	ADVANTICA HKL-R11	X100	57.8	Machined	146.460	0.502	1.273	1.105	1.272	1.244	1.246	1.273
INDEX 272	ADVANTICA HKL-R12	X100	57.7	Machined	146.308	0.809	Invalid	Invalid	Invalid	1.253	Invalid	Invalid
INDEX 273	ADVANTICA HKL-R13	X100	57.8	Machined	146.492	0.833	Invalid	Invalid	Invalid	1.278	Invalid	Invalid
INDEX 274	ADVANTICA HKL-R14	X100	57.8	Machined	146.372	0.814	Invalid	Invalid	Invalid	1.325	Invalid	Invalid
INDEX 275	ADVANTICA HKB-R01	X100	63.9	Machined	154.075	0.102	1.143	1.122	1.141	1.123	1.124	1.143
INDEX 276	ADVANTICA HKB-R02	X100	63.9	Machined	154.171	0.286	1.167	1.100	1.166	1.145	1.147	1.167
INDEX 277	ADVANTICA HKB-R03	X100	63.9	Machined	154.075	0.503	1.171	1.016	1.171	1.146	1.149	1.171
INDEX 278	ADVANTICA HKB-R04	X100	63.9	Machined	154.075	0.807	Invalid	Invalid	Invalid	1.137	Invalid	Invalid
INDEX 279	ADVANTICA HKL-R15	X100	57.9	Machined	146.620	0.204	1.256	1.208	1.255	1.231	1.233	1.256
INDEX 280	ADVANTICA HKL-R16	X100	58.0	Machined	146.597	0.204	1.294	1.245	1.292	1.268	1.270	1.294
INDEX 281	ADVANTICA HKL-R17	X100	57.8	Machined	146.492	0.508	1.297	1.122	1.296	1.266	1.269	1.297
INDEX 282	ADVANTICA HKL-R18	X100	57.9	Machined	146.588	0.499	1.289	1.120	1.288	1.259	1.261	1.289
INDEX 283	ADVANTICA HKL-R19	X100	57.8	Machined	146.524	0.810	Invalid	Invalid	Invalid	1.294	Invalid	Invalid
INDEX 284	ADVANTICA HKL-R20	X100	57.9	Machined	146.468	0.811	Invalid	Invalid	Invalid	1.293	Invalid	Invalid

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INDEX 285	ADVANTICA HKB-R05	X100	63.8	Machined	154.096	0.207	1.211	1.164	1.209	1.189	1.190	1.211
INDEX 286	ADVANTICA HKB-R06	X100	63.8	Machined	153.888	0.504	1.270	1.101	1.269	1.243	1.246	1.270
INDEX 287	ADVANTICA HKB-R07	X100	63.9	Machined	154.075	0.818	Invalid	Invalid	Invalid	1.211	Invalid	Invalid
INDEX 288	ADVANTICA HKL-R21	X100	57.7	Machined	146.276	0.099	1.264	1.242	1.262	1.240	1.241	1.264
INDEX 289	ADVANTICA HKL-R22	X100	57.7	Machined	146.340	0.102	1.253	1.230	1.251	1.229	1.230	1.253
INDEX 290	ADVANTICA HKL-R23	X100	57.7	Machined	146.332	0.301	1.281	1.202	1.280	1.255	1.256	1.281
INDEX 291	ADVANTICA HKL-R24	X100	57.7	Machined	146.396	0.306	1.271	1.190	1.269	1.244	1.246	1.271
INDEX 292	ADVANTICA HKL-R25	X100	57.7	Machined	146.332	0.488	1.172	1.024	1.171	1.145	1.147	1.172
INDEX 293	ADVANTICA HKL-R26	X100	57.8	Machined	146.492	0.507	1.254	1.085	1.253	1.224	1.227	1.254
INDEX 294	ADVANTICA HKL-R27	X100	57.7	Machined	146.308	0.804	Invalid	Invalid	Invalid	1.108	Invalid	Invalid
INDEX 295	ADVANTICA HKL-R28	X100	57.7	Machined	146.244	0.808	Invalid	Invalid	Invalid	1.142	Invalid	Invalid
INDEX 296	ADVANTICA HKB-R08	X100	63.7	Machined	153.851	0.111	1.218	1.194	1.217	1.198	1.198	1.218
INDEX 297	ADVANTICA HKB-R09	X100	63.8	Machined	154.059	0.309	1.238	1.159	1.237	1.214	1.216	1.238
INDEX 298	ADVANTICA HKB-R10	X100	63.4	Machined	153.444	0.493	1.225	1.068	1.224	1.199	1.201	1.225
INDEX 299	ADVANTICA HKB-R11	X100	63.8	Machined	153.888	0.769	0.976	0.651	0.976	0.952	0.955	0.976
INDEX 300	ADVANTICA HKL V01	X100	57.9	Machined	3.503	0.496	0.975	1.070	1.190	1.095	1.202	1.083
INDEX 301	ADVANTICA HKK V01	X100	57.9	Machined	6.384	0.500	1.231	0.971	1.097	1.046	1.106	1.085
INDEX 302	ADVANTICA HKL V02	X100	57.9	Machined	2.962	0.503	0.952	1.039	1.153	1.049	1.167	1.033
INDEX 303	ADVANTICA HKK V02	X100	57.8	Machined	5.825	0.500	1.200	0.940	1.060	1.005	1.068	1.034
INDEX 304	NAT GAS PCA V1	X46	76.8	Real	1.278	0.520	1.394	1.457	N/A	1.399	1.596	1.430
INDEX 305	NAT GAS PCA V2	X46	76.8	Real	2.191	0.862	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid
INDEX 306	NAT GAS PCA V3	X46	76.8	Real	0.913	0.824	Invalid	Invalid	Invalid	1.462	Invalid	Invalid
INDEX 307	TRANSGAST1	X60	70.7	Machined	3.281	0.681	1.152	1.376	1.730	1.532	1.777	1.454
INDEX 308	TRANSGAST2	X60	70.7	Machined	3.486	0.474	1.274	1.387	1.529	1.416	1.546	1.400
INDEX 309	TRANSGAST3	X60	70.7	Machined	3.486	0.681	1.138	1.365	1.722	1.534	1.766	1.467
INDEX 310	TRANSGAST4	X60	70.7	Machined	3.486	0.526	1.222	1.355	1.528	1.403	1.551	1.378

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INDEX 311	TRANSGAST5	X60	70.7	Machined	3.076	0.466	1.152	1.245	1.362	1.254	1.378	1.239
INDEX 312	TRANSGAST6	X60	70.7	Machined	3.179	0.457	1.286	1.388	1.515	1.400	1.532	1.385
INDEX 313	TRANSGAST7	X60	73.9	Real	3.040	0.432	1.436	1.536	N/A	1.539	1.678	1.525

(End of Report)