52-001

GE Nuclear Energy

ABWR

Date 6/1/92

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Subject ABWR Drywell Head Buckling Capability

Message Enclosed are Ai-Shen Liu's response to questions 8 and 9

D050
1/1

June 1, 1992

cc: H. E. Townsend
J. D. Duncan
C. B. Buchholz

To: J. N. Fox

From: A. S. Liu

Subject: ABWR Drywell Head Buckling Capability

Enclosed are my response to NRC's questions 8 and 9 regarding the buckling capability of the ABWR drywell head. Please fax them to the NRC for their review. Responses to other 11 questions will be provided soon.

8. The equation (19F.3-2 in Ref. 1) used in calculating the internal pressure at critical buckling is based on a paper (Ref. 2) by Galletly and Radhamohan which limits its applicability to "D/t" between 500 to 1500. The "D/t" ratio for ABWR head is 324. Provide a justification for the use of the equation. A later paper by Galletly and Blachut (Ref. 3) provides equations which could be used for "D/t" ratio of 300 to 1500. The staff's calculation based on equation 3 in the reference gives a critical buckling pressure of 203 psig at 500/F. This corresponds to ASME Level C allowable buckling pressure of 81 psig. Provide justification for using 97 psig.

Response

Galletly recently (Ref. 1) proposed a design equation for preventing buckling in fabricated torispherical shells under internal pressure. This equation is based on his previous studies (Refs. 2 and 3) and is formulated for design use with knock-down (capacity reduction) factors included. As compared to all known test results (43 in total), the ratios of the actual buckling pressure to the allowable buckling pressure predicted by this equation were found to range from 1.51 to 4.01. Hence, a minimum factor of safety of 1.5 is ensured by this equation.

The test data presented in Ref. 1 (excluding the test performed by Blenkin since no buckling was observed at the maximum test pressure) are summarized graphically in attached Fig. 8-1, showing the relationship between the test and predicated pressures. The predicted pressures, as can be seen, are at least 1.5 times lower than the test results. In order to gain more insight about the data variability, statistic analyses are performed and the results are given in Fig. 8-2. The PDF (probability density function) of the data shown by solid lines is the histogram of 42 data points expressed in terms of the ratio of test to predicted pressure. It is observed that the data can be reasonably approximated by the lognormal distribution. The median value of the test to predicted pressure ratios in the data set is 2.27 and the logarithmic standard deviation is 0.293. The resulting lognormal density and cumulative functions are shown in Fig. 8-2. The cumulative probability is 8% for the ratio up to 1.5. It means that the probability of the ratio of actual to predicted pressure being less than 1.5 is 8%. In other words, there is 92% confidence that the margin of safety against buckling is at least 1.5 when the Ref. 1 equation is used. The 1.5 factor of safety corresponding to 92th percentile is deemed sufficient for the assurance of no buckling failure against severe accident loadings of very low probabilities of occurrence. The Ref. 1 equation can be therefore used for the determination of level C buckling pressure of torispherical heads.

Using the Ref. 1 equation, the allowable buckling pressure for the ABWR drywell head is calculated to be 111 psig at 500°F. It is higher than 97 psig associated with general membrane yielding per level C stress intensity limits. Therefore, the governing level C pressure is 97 psig.

References:

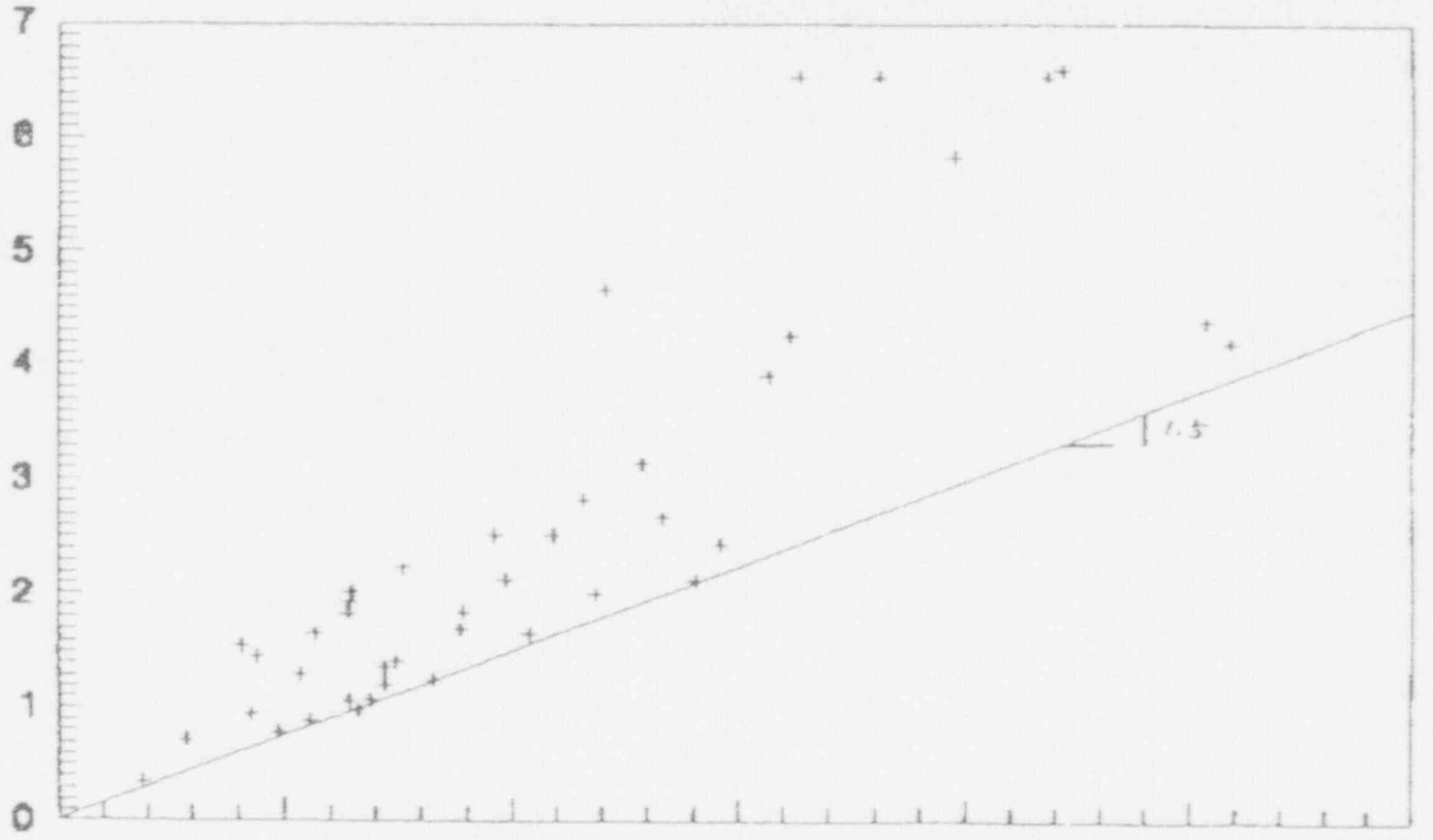
1. Galletly, G. D., A Simple Design Equation for Preventing Buckling in Fabricated Torispherical Shells under Internal Pressure, ASME Journal of Pressure Vessel Technology, Vol. 108, November 1986.

2. Galletly, G. D., and Radhamohan, S. K., Elastic-Plastic Buckling of Internally Pressurized Thin Torispherical Shells, ASME Journal of Pressure Vessel Technology, Vol. 101, August 1979.

3. Galletly, G. D., and Blachut, J., Torispherical Shells under Internal Pressure - Failure due to Asymmetric Plastic Buckling or Axisymmetric Yielding, Proc. of Institution of Mech. Engineers, Vol. 199, No. C3, 1985.

Fig. 8-1

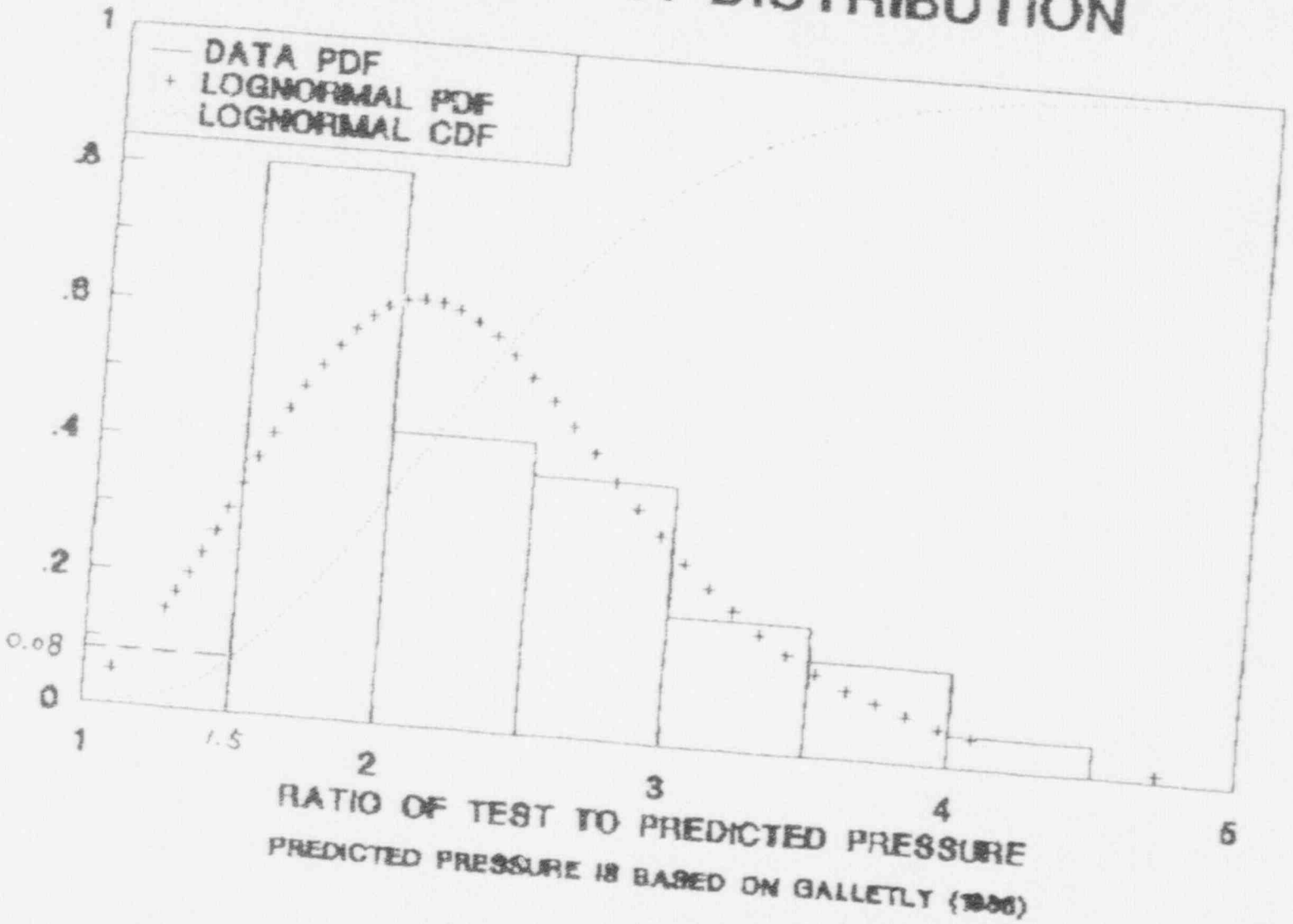
TORISPHERICAL HEAD BUCKLING TEST DATA DISTRIBUTION



PREDICTED PRESSURE IS BASED ON BALLETLY (1936)

Fig. 8-2

TORISPHERICAL HEAD BUCKLING TEST DATA DISTRIBUTION



9. The authors of the same paper (Ref. 3) have made a comparison of their own equation and with that of Shield and Drucker (Ref. 4) used in Appendix 19F for axisymmetric yielding pressure, and find that the later is conservative. Hence the head failure pressure would be dictated by ASME Level D limit for compressive buckling stress. This will correspond to 101 psig at 500/F. Provide justification for using 134 psig as the median centered failure pressure (Fig. 19FA-1) for the drywell head.

Response

The ASME level D is the design limit and should not be regarded as failure criterion for the purpose of ultimate strength prediction. As mentioned in the response to Question 8, the allowable buckling pressure of the ABWR drywell head is 111 psig at 500°F. The equation used has been shown to have a factor of safety of 1.5 as compared to the lower bound of all known test results. From a statistic study of test results (see response to Question 8), the median buckling pressure is estimated to be 2.27 times the value predicted by the reference equation. Subsequently, the critical buckling pressures of the ABWR drywell head are:

Lower bound = 1.5 * 111 = 166 psig
Best estimate = 2.27 * 111 = 252 psig

They are higher than the yielding pressure of 134 psig calculated according to the Shield and Drucker equation (Ref. 1). Buckling is thus not the controlling failure mode.

The use of 134 psig as the median centered failure pressure is conservative since a higher yielding pressure of 164 psig would be predicted when Equation 4 of Ref. 2 is used.

References:

1. Shield, R. T., and Drucker, D. C., Design of Thin-Walled Torispherical and Toriconical Pressure-Vessel Heads, Journal of Applied Mechanics, Transaction of ASME, June 1961.

2. Galletly, G. D., and Blachut, J., Torispherical Shells under Internal Pressure - Failure due to Asymmetric Plastic Buckling or Axisymmetric Yielding, Proc. of Institution of Mech. Engineers, Vol. 199, No. C3, 1985.