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22 July 1970

Mr. Edson G. Case, Director
Division of Reactor Standards
U. S. Atomic Energy Commission
Washington, D. C. 20545

Dear Mr. Case:

Enclosed are my preliminary comments and questions resulting from my review of Appendix 5A "Summary of Aircraft Impact Design", Volume 2, FSAR, Three Mile Island Nuclear Station - Unit 1, Docket No. 50-289. The requested information will facilitate my final evaluation.

Very truly yours,

JAMES F. PROCTOR
Air/Ground Explosions Division

Enclosure

Three Mile Island Nuclear Station - Unit 1
Docket No. 50-289

PRELIMINARY COMMENTS AND QUESTIONS
Review of FSAR, Volume 2, Appendix 5A
"Summary of Aircraft Impact Design"

by
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The primary concern of this review is the transient loading from the head-on crash impacts of aircraft on various reactor structures. Four cases were investigated by the applicant. Cases A and B concerned the localized impact of a lost engine on the containment structure. It was shown satisfactorily that penetration of these engines into a substantial concrete structure would not exceed several inches. However, the combined effect of localized engine impact and the plane impact of Case D was not examined explicitly. More will be said about this combined loading in a later paragraph. Impact loads from Case C (300,000-lb aircraft) do not represent a realistic crash situation and are less severe than the loadings of Case D, thus the Case C analysis was not considered essential to detail review.

The basic approach used in calculating the impact loads for Case D (realistic crash of 200,000-lb craft at 200 knots) appears to be appropriate for this problem. However, certain assumptions were made regarding loss of engines, outer portions of wings, and fuel that are open to question. In Figure 1

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it is shown that if the aircraft remains together (no loss of weight) the peak load is 18×10^6 lb. Also the area under the solid load time curve (impulse) is equal to the initial momentum of the 200,000-lb aircraft with a 200-knot velocity. The dashed curve used by the applicant (from Fig. 5A-1 and Table 5A-1 of FSAR) shows a peak load of 15×10^6 lb but loss of engines, fuel, and wing structure were assumed. (There are some internal inconsistencies between the applicant's curves Fig. 5A-1, 5A-2 and Table 5A-6 which shows a peak of 16.2×10^6 lb.) It is not clear exactly how this lost weight was handled, i.e., no criteria were presented to show when these pieces would break away from the main aircraft. Also it doesn't appear that these now free pieces of the aircraft were treated as addition colliding masses on the subject reactor structure at some location removed from the main fuselage loading. Ordinarily these types of comments could be classified as "nit picking", but they could represent 10 or 20% type deviations. When one considers that the applicant has stretched the concrete capability of the reactor dome to an absolute maximum to show its resistance to the 15×10^6-lb peak load, and additional 10 to 20% load may be the proverbial straw breaking the camel's back. My conclusion on reactor dome response is that the applicant has shown that the dome has a fair chance of surviving the unlikely head-on crash of a 200,000-lb aircraft traveling at 200 knots, but I cannot at this time fully endorse his final statement in Section 3.1.1.3 that "...the conclusion can be safely drawn that the dome will not collapse...".

This entire question of peak load magnitude influences the structural response calculations of other concrete structures which are treated as flat plates via the use of dynamic load factors (DLF) discussed in Section 2 of Appendix 5A. Depending on the loading-time curve used, we see in Figure 2 that differences of the order of 10% can occur in the calculation of DLF. Coupled with variation of peak loads, this might indicate response or stress differences of 30 to 40%. Aside from the magnitude of the load itself, questions can be raised about the method of calculating the fundamental frequency discussed in Section 3.2.1 of Appendix 5A. The frequency of a linear elastic flexural system such as that assumed by the applicant varies directly with the square root of the modulus of elasticity E. Normally E for concrete is taken to be about 1000 times its compressive strength. Actually this is an approximation of the initial slope of the non-linear stress-strain curve for concrete. Thus frequency based on such an E would hold only for relatively low stress levels. As concrete is loaded nearer its compressive capability, the slope of the stress-strain curve is substantially reduced; therefore, it would not be unexpected to find that the fundamental frequency of a concrete slab or wall would vary with the magnitude of the load. This together with the unknowns of treating a wall panel of a complex structure as a single degree of freedom system could lead to significant shifts in response frequency.

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If this is true, it would seem more prudent and certainly more conservative to assume the maximum DLF in designing exterior wall panels of structures to withstand aircraft impact. If the wall panels are designed stress-wise as marginally as the dome for aircraft impact, then I would again conclude that whereas the applicant has demonstrated that the structures can withstand large impact loads, he has not positively shown assured safety against the head-on crash of a 200,000-lb aircraft traveling at 200 knots.

In summary, the above comments lead to the following list of specific items that require additional information before a final evaluation can be made.

1. Define the criteria used to determine when the outboard engines, outer portion of wings, and fuel break away from the aircraft during impact.

2. Discuss the effect on load and building response of the combined impact of the remaining aircraft and these free separated missiles.

3. The peak impact load is given in Figure 5A-2 and other places in Appendix 5A as 15×10^6 lb, but the calculations in Table 5A-6 show 16.2×10^6. Clarify the correct peak load and include any changes that might be introduced by Items 1 and 2 above.

4. Since the crushing load of the fuselage used in the analysis is an estimate provided by Boeing Co. and the

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impact velocity is set by normal flight regulations in the area, it would be of interest to show the effect of varying these two parameters on load and building response.

5. Justify the use of a single-degree-of-freedom system to analyze the response of a multi-degree system such as the auxiliary building. To what degree, if any, does this assumption affect natural frequency and the choice of DLF.

6. What value of Young's modulus was used in calculating the natural frequency of a concrete panel. Since frequency varies with Young's modulus and concrete is a non-elastic material, discuss the possibility of a shift in frequency for a concrete panel under normal load and impact loading and the effect this might have on DLF. Also discuss the effects of variation in the assumed edge conditions for the panels on frequency and DLF.

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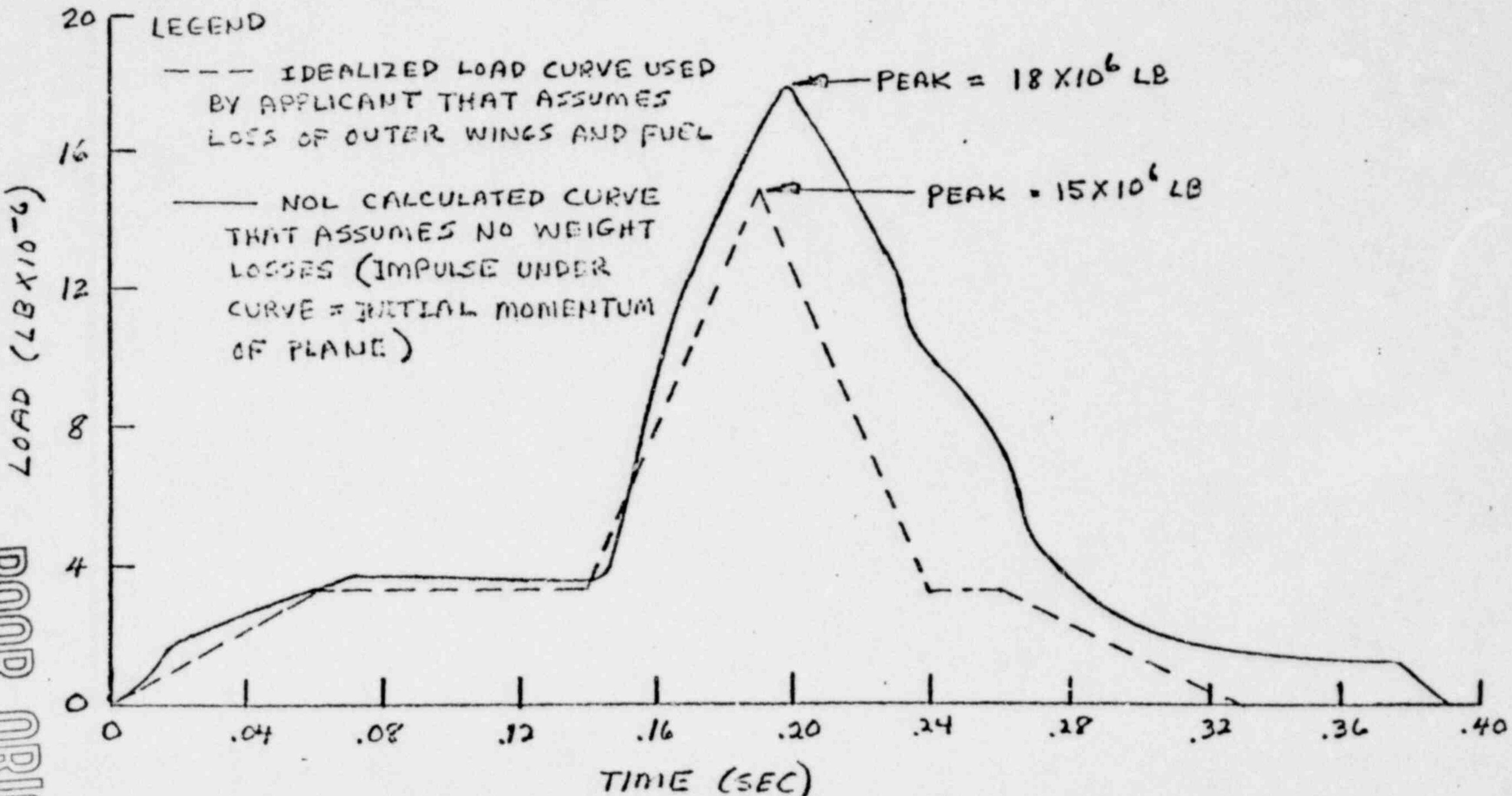
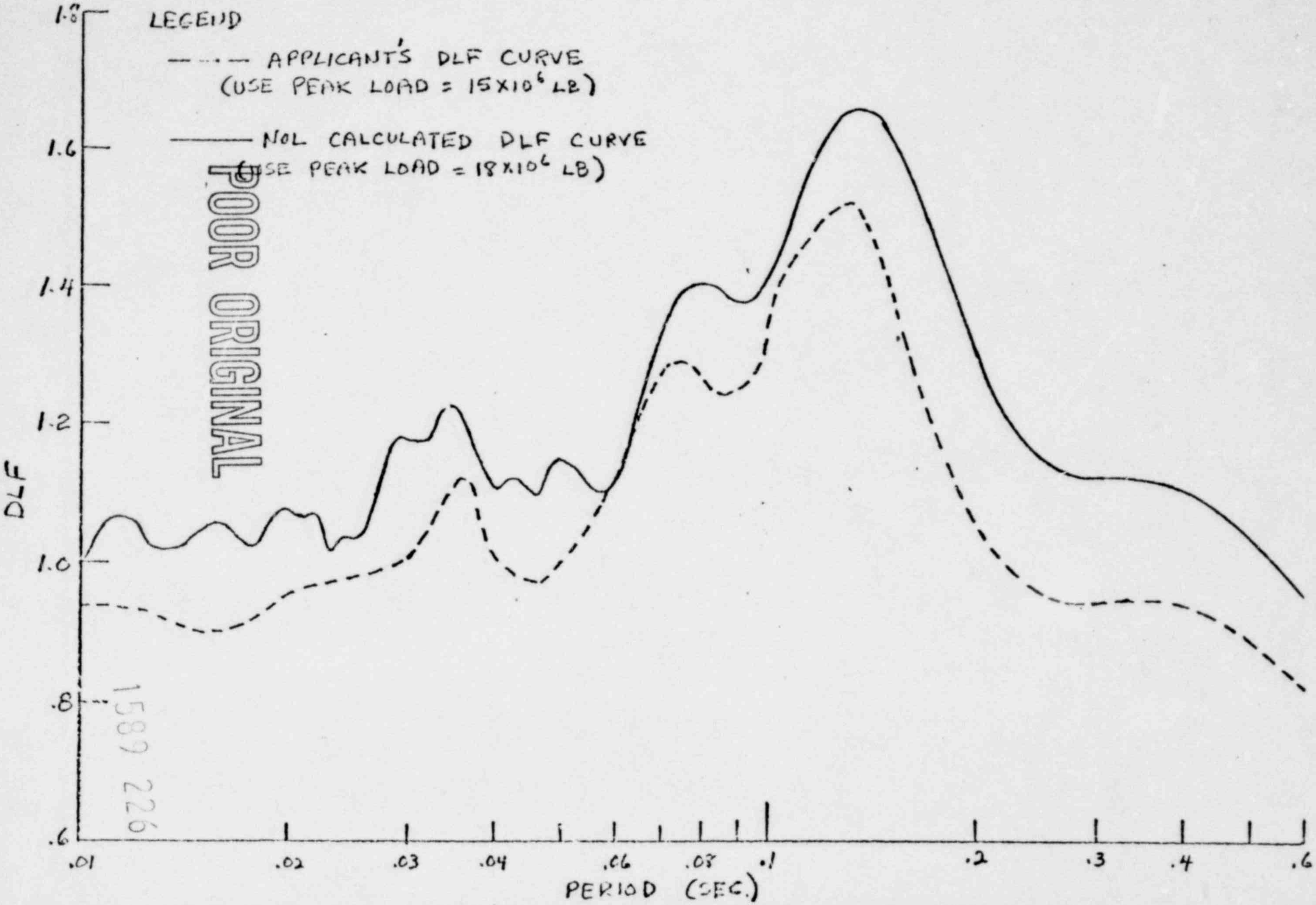


REACTION LOAD CURVES FOR B720
HEAD-ON CRASH AT 200-KNOT SPEED

FIG. 1



DYNAMIC LOAD FACTOR (DLF) VS. PERIOD OF ONE DEGREE FREEDOM SYSTEM