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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

JUN 2 0 1975

Note to the Files

MARK III POOL SWELL IMPACT LOAD PROFILE FOR SMALL STRUCTURES

A pool swell impact load profile for plants utilizing Mark III containments (Attachment A) was developed in the course of our review of pool dynamics for the Grand Gulf plant. This profile specifies pool swell impact loads for structural design purposes as a function of elevation above the suppression pool surface and is applicable to small structures such as pipes, I-beams, and components. Use of the profile by an applicant would constitute an acceptable basis upon which to proceed at this time with design and construction of the affected structures. The development of this profile was based on the Mark III pool dynamics test data currently available to the staff; i.e., the full-scale air tests (Series 5706) and Phase A of the one-third scale steam tests (Series 5801, 5802, 5803, and 5804). Following our receipt and evaluation of additional data from GE, including that from recently proposed one-third scale air tests, the values specified in the profile could be subject to adjustment. The following discussion delineates the basis upon which the profile was developed.

The General Electric Company had previously developed a similar profile of pool swell loads which was given to A/E's as recommended values for design purposes. This is shown in Attachment B. The GE profile recognizes three zones of impact loading; the first from 0-12 feet specifies 115 psi due to solid water impact; the second from 12-19.5 feet specifies 30 psi due to solid water/froth transition impact; the final zone for above about 19.5 specifies 15 psi due to froth impingement. The justification for this profile is dependent to a large degree on test data not currently available to the staff. Therefore, our profile, while maintaining three phases of pool swell impact, does reflect different parameter values due to a difference in the data bases or interpretation of the data which is available.

In determining the loads to be used in each region of our profile, appropriate data from the full-scale air tests was identified and extrapolations of these data points were made based on pool motion characteristics determined from the one-third scale tests. The full-scale air tests were run with drywell pressure profiles simulating actual plant response and provided impact data as follows:

Tests	Submergence	Target Clearance	Load	Type
5706/1 & 2	6 ft.	8 ft.	30 psi	Transition
5706/3 & 4	10 ft.	4 ft.	1.5 psi	Solid Water
5706/5 & 6	6 ft.	18 1/2 ft.	5 psi	Froth
5706/7	6 ft.	No Target	-	-

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Recognizing certain differences in the froth conditions at impact for tests 5706/5 & 6 and those expected in an actual plant, GE recommended the application of a factor of three to the measured load, 5 psi, to arrive at a design load of 15 psi.

Phase A of the one-third scale tests were run to obtain additional froth impingement data and to provide pool motion data (surface velocity and ligament thickness) as a function of vent submergence and blowdown orifice size. GE has submitted a draft version of NEDE-13407P, Mark III Confirmatory Test Program, One-Third Scale Three Vent Tests (Test Series 5801 through 5804), which contains the data from this series.

Considering first the region of solid water impact, data from air test 5706/4 indicated a load of 115 psi at 4 feet clearance and 10 feet vent submergence. Based on level probe data the pool surface velocity at impact was found to be approximately 20 ft/sec.. For actual plant conditions we are interested in impact loads at various elevations with an initial vent submergence of 7.5 feet. Therefore our first consideration was to adjust the 115 psi data point to allow for the lesser submergence. A constant pool momentum relationship was assumed: $M_{10} V_{10} = M_{7.5} V_{7.5}$ where the subscripts refer to vent submergence. This results in a surface velocity at 4 feet elevation of $V_{7.5} = \frac{M_{10}}{M_{7.5}} V_{10} = \frac{10}{7.5} (20) = 27$ ft/sec.

GE has indicated that a general conclusion from Phase B of the one-third scale tests is that solid water impact loads are approximately a linear function of pool surface velocity. This leads to a pool swell load of $(\frac{27}{20})(115) = 155$ psi at 4 feet elevation for the higher pool velocity. Additional extrapolations must be made to determine loads as a function of elevation above the pool. Results from the one-third scale tests, which used steam blowdowns, provided the necessary data. (Air tests only provide pool motion data to about 8 feet elevation.) For a representative submergence (7.5 ft) and drywell pressure (35 psia) the following pool surface velocity data were generated:

velocity @ 4 ft. = 20 ft/sec

velocity @ 12 ft = 34 ft/sec

Assuming air only carryover to the pool these velocities would have to be increased by a factor of: $\frac{\text{pool velocity at 4 ft, air test}}{\text{pool velocity at 4 ft, steam test}} = \frac{27}{20}$

This yields a velocity profile of: 27 ft/sec @ 4 ft.
46 ft/sec @ 12 ft.

Again assuming that solid water impact load is a linear function of pool velocity, the following values are found:

load @ 4 feet	155 psi
load @ 12 feet	264 psi

Clearly, application of these assumptions results in a continuously increasing impact load from the pool surface up to the point of breakthrough. This approach has been tempered to a degree by examination of the drywell air carryover rate. Although pure air carryover might be hypothesized to occur immediately following vent clearing, significant steam/water entrainment would be expected with time due to the decreasing inventory of air in the drywell and the large masses of steam and water being added to the drywell volume. Therefore, in establishing the load profile a linear rise from 115 psi at the pool surface to 230 psi at 4 feet and a flat ceiling of 230 psi over the range of 4 to 12 feet is specified. This profile envelopes impact loads from 0-10 feet assuming pure air carryover but allows for a less severe charging rate, based on our best engineering judgment, at higher elevations.

Examination of the pool swell event indicates that the relatively high impact loads associated with solid water impact occur up to a point where the water ligament degenerates and breakthrough of the air bubble occurs. GE has selected an elevation of 12 feet (1.5 x submergence) for the onset of transition loading on the basis of air test 2. We have evaluated the data from the air test and particularly the one-third scale tests and find that our best estimate of the breakthrough data points would indicate a value of 2 times submergence while a bound of the data would require a factor of 2.5. We have selected an elevation of 17 feet which is 2.3 times the submergence as a compromise value which is reasonably conservative.

The pool impact load in the transition region was found by extrapolating air test data in a similar manner to the solid impact loads. From the previously cited one-third scale steam test, the pool velocity at 17 feet elevation was determined and then multiplied by $\frac{27}{20}$ to predict the velocity with pure air injection beneath the pool. This resulted in a velocity of about 54 ft/sec at the 17 feet elevation. Examination of air test 2 shows that the pool velocity at target impact was about 27 ft/sec, and resulted in a load of 30 psi. To adjust this load for the higher velocity the assumption was made that load was a linear function of velocity in the transition region as was the case in the solid impact region. The resultant transition load is therefore 60 psi.

The third region of pool swell impact loads is that attributable to froth impingement. As mentioned above, the results of air test six were interpreted to yield a design value of 15 psi for this condition. Further comprehensive testing for this type of impact was accomplished in Phase A of the one-third scale tests and indicated loads ranging from 2 to 7 psi. Based on these results and the margin provided by a design value of 15 psi we were able to concur in this load specification.

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A further question which arises in the specification of pool swell impact loads is the time history associated with the load in each region. The load values specified in the profiles only reflect peak values. The load magnitude versus time profile in each region is also required to determine the impulse imparted to the impacted structure and therefore the required structural capability. GE has provided such time histories for its loads based on the dynamic response of the targets used in the air tests (Attachment C).

In establishing our loads for each region it was recognized that significant extrapolations from observed data were necessary. We could accomplish this due to the comprehensive pool motion data available from the one-third scale tests. In considering the associated time history of each of these loads we found that a similar basis for extrapolation was not available. However, we concluded that a reasonable approach would be to assume that the time dependence of our load was the same as the corresponding GE load (and therefore the same as the air test data) which implies that the predominant factor governing the time profile is the fluid condition at impact - solid water, transition, or froth. Therefore the time dependence of our load specifications are also shown in Attachment C.

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Attachments:
As stated

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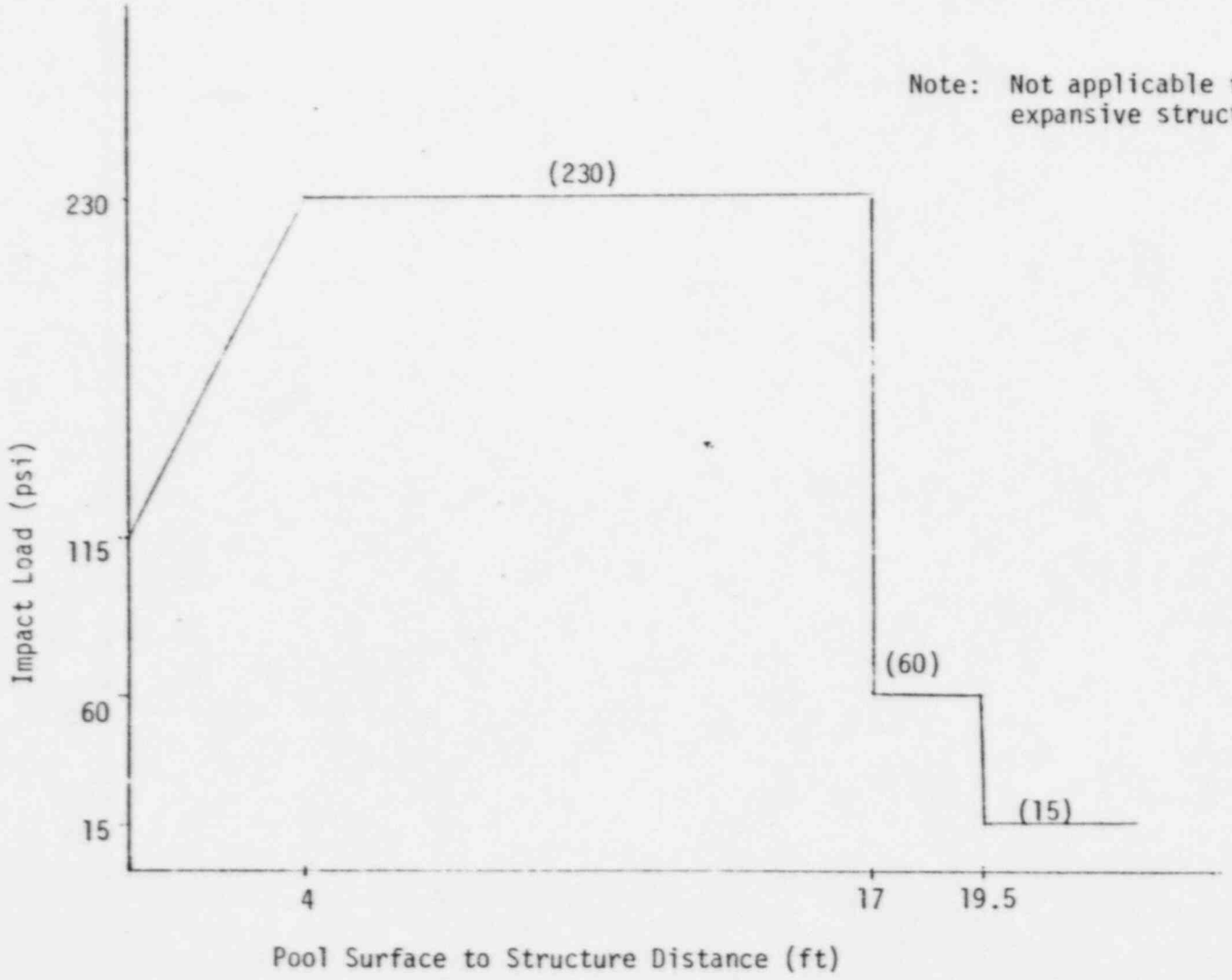
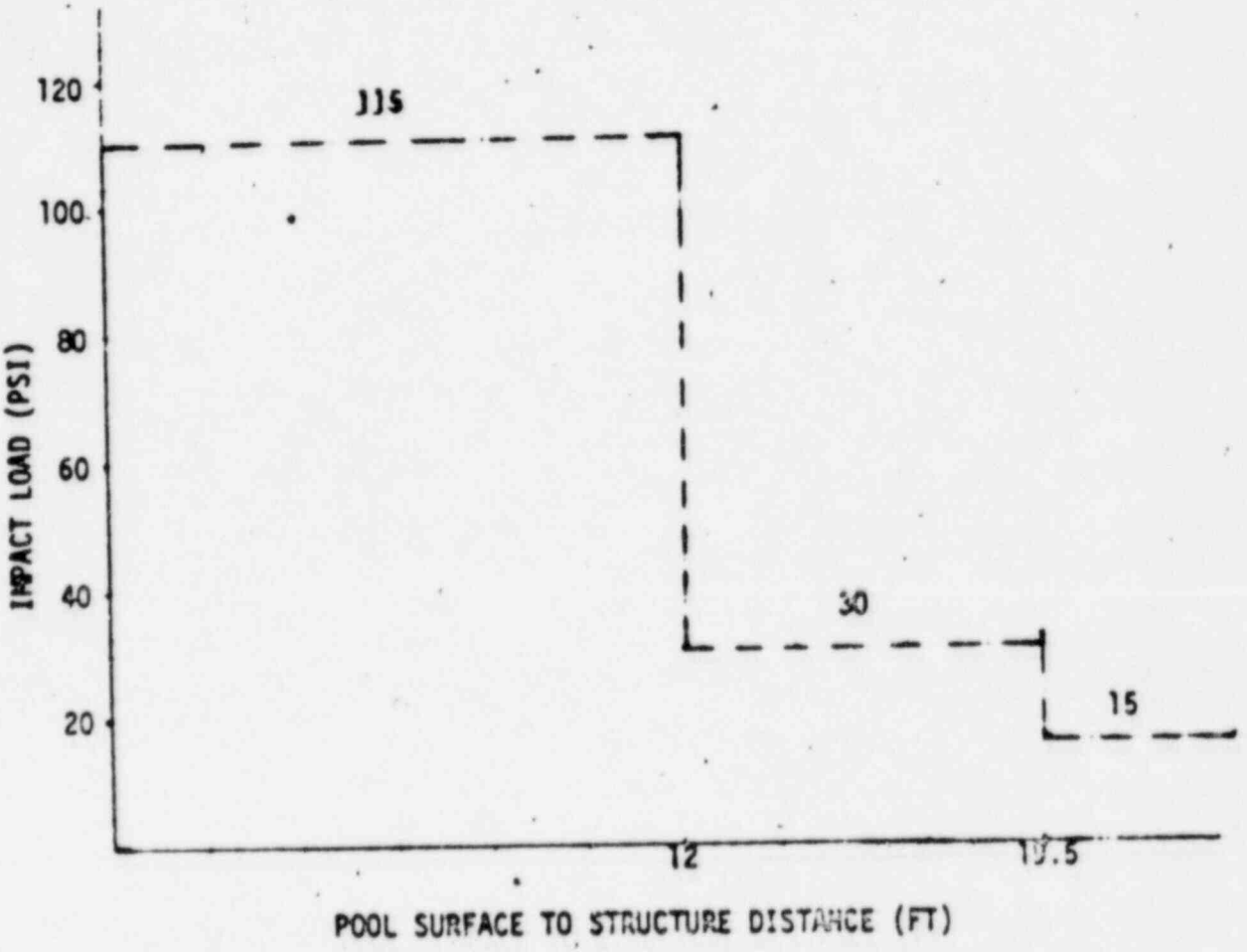
MARK III POOL SWELL IMPACT LOADS



ATTACHMENT 1

ATTACHMENT 3

MARK III POOL SHELL IMPACT LOADS
GE RECOMMENDATIONS



- APPLICABLE TO NON-EXPANSIVE STRUCTURES AT LOW (<19.5 ft) ELEVATIONS--PIPES, I-BEAMS
- APPLICABLE TO ALL STRUCTURES AT HIGH (>19.5 ft) ELEVATIONS
- STRUCTURES AT POOL SURFACE TO BE DESIGNED FOR 22 psi BUBBLE PRESSURE
- GRATINGS TO BE DESIGNED FOR DRAG LOAD ONLY

21'+ 18.5'
20.0
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ATTACHMENT C

POOL SWELL IMPACT LOAD TIME PROFILES