METHODS OF ASSURING DESIGN

ADEQUACY OF SEISMIC III/I SUPPORTS

G. D. Summers

January 1979

Structural Mechanics in Reactor Technology

(SMIRT-5)

Berlin (West), Germany, August 13-17, 1979

HANFORD ENGINEERING DEVELOPMENT LABORATORY

Operated by Westinghouse Hanford Company, a subsidiary of

Westinghouse Electric Corporation, under the Department of

Energy Contract No. EY-76-C-14-2170

COPYRIGHT LICENSE NOTICE

By acceptance of this article, the Publisher and/or recipient acknowledges the U.S. Government's right to retain a nonexclusive, royalty-free license in and to any copyrighted covering this paper.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED
DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.
DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.
METHODS OF ASSURING DESIGN ADEQUACY
OF SEISMIC III/I SUPPORTS

G. D. Summers
Manager, Code Stress Analysis
for FFTF Project
Hanford Engineering Development Laboratory

SUMMARY

During the early design stages of the FFTF, the components necessary for the safe shutdown of the plant in the event of an earthquake were identified as Seismic Category I (SC I). These components were designed to survive the Design Basis Earthquake (DBE) and to function after the earthquake event. Such components include the reactor vessel, primary and secondary sodium piping, pumps, heat exchangers, and valves which must maintain the structural integrity of the pressure boundary to allow the removal of decay heat from the reactor. Additional piping and valves which form a part of the pressure boundary of both the sodium piping and the containment vessel are also included in the list of SC I items. Further, the electrical wiring used to initiate, monitor, and verify the safe shutdown of the plant are tabulated as SC I electrical (SCIE) conduit. Virtually thousands of items are identified as SC I. These items receive detailed analysis to demonstrate that they can survive the DBE earthquake. In cases where function has to be demonstrated, shake tests are generally performed for items such as valves and electrical panels and cabinets.

The remainder of the components in FFTF, those not required for the safe shutdown of the plant, are identified as Seismic Category III (SC III), and designed to withstand the Uniform Building Code (UBC) Zone 2 earthquake, which typically results in a low g level static equivalent load, which is superimposed onto the dead weight and operating loads.

Since there is a large increase in the magnitude of load associated with the DBE earthquake as compared to the UBC earthquake, any upgrading of components from the UBC to the DBE earthquake (SC III to SC I) has often a major impact on both the amount of analysis required and on component
configuration. Often, redesign and rework is required to affect the change from SC III to SC I.

After construction of the plant was virtually complete, special walkdown teams were sent to every cell containing SC I items. These teams, using specially derived zone of influence curves, identified those SC III items which could, if they or their supports fail, impact the SC I items. A set of generic criteria was prepared for use by the walkdown teams in the field qualifying the SC III items. These items are referred to as III/I (SC III over SC I). The generic criteria include energy based relationships that can be used to determine whether a SC III item (the missile) has sufficient potential energy to damage a SC I item (the target) even if it does fall on it. Generic criteria were developed to qualify III/I conduit, lights, ducting, piping, pipe supports, and other items. Those items which can't be field qualified with the generic criteria are given detailed analysis. In cases where numerous SC III items threaten a single SC I item or a closely grouped set of SC I items, the SC I item is sometimes protected by providing a barrier between the missile and the target.

A description of the analytical basis for the generic criteria is provided in the paper. Examples from FFTF are provided.
1.0 INTRODUCTION

During the final phases of construction of the Fast Flux Test Facility (FFTF), attention was given to identifying all items which were required for the safe shutdown of the reactor. These items were identified as Seismic Category I (SC I). Additional items which could fall and impair the function of SC I items were identified as Seismic Category III (SC III) and were classified as III/I items (SC III items which threaten SC I items). Verification of the design adequacy of a SC I item is relatively straightforward. It must be capable of withstanding design and operating conditions. As part of the loading environment, the SC I item must be capable of withstanding loads corresponding to a Design Basis Earthquake (DBE). On the other hand, a SC III item is generally designed to withstand a much reduced earthquake such as the Uniform Building Code [1]* Zone 2 (UBC Zone 2) earthquake.

There are a number of steps that were taken in FFTF to assure the design adequacy of Seismic III/I supports. This included first the identification of SC III items which could physically impact a SC I item. Secondly, an energy criteria was used to determine whether the SC III item could damage the SC I item even if it did fall. Thirdly, through the use of generic criteria, SC III item supports could be qualified for the larger DBE loads, or finally, the SC III item supports could either be redesigned to withstand the higher loads, or the SC I item could be shielded from impact by the SC III item.

In each of these four areas, specific criteria and application are contained in the official FFTF files. In this paper, the methods used to develop the criteria will be discussed.

2.0 DETERMINING THE ZONE OF INFLUENCE OF A POTENTIAL MISSILE

In this discussion, the SC III item is the missile, while the SC I item is the target.

* Numbers in brackets indicate References given at end of paper.
In order to determine whether a target is within the zone of influence of a potential missile, one can start with the equations of a projectile from basic physics as follows:

![MOTION OF A PROJECTILE](image)

Fig. 1. Trajectory of a body projected with an initial velocity $v_0$ at an angle of departure $\theta_0$. The distance $R$ is the horizontal range.

\[ X = (v_0 \cos \theta_0)t \quad \text{(1)} \]
\[ y = (v_0 \sin \theta_0)t - \frac{1}{2} gt^2 \quad \text{(2)} \]

The initial velocity $v_0$ can be related to accelerations and frequencies from specific response spectra. If one assumes a single degree of freedom system, the maximum velocity is found from the relationship

\[ v_{\text{max}} = \left| \frac{a}{f} \right|_{\text{max}} \quad \text{(3)} \]

where $a$ is the acceleration at the corresponding frequency $f$ on the response spectrum curve.

Using a factor of 1.5 to account for a real multi-degree of freedom
system, the initial velocity $v_0$ can be expressed as

$$v_0 = 1.5 \sqrt{\frac{v_{\text{max}}^2}{\text{horiz}} + \frac{v_{\text{max}}^2}{\text{vert}}}$$

(4)

For any given location in which response spectra are available, zone of influence curves similar to Figure 2 can be derived.

Figure 2. Zone of Influence Curve

Note that if a target is located anywhere within the cross-hatched region of Figure 2, it can be impacted by the missile.
3.0 USE OF ENERGY CRITERIA TO SCREEN MISSILE-TARGET COMBINATIONS

Whether a missile is capable of damaging a target is found by comparing the missile's potential energy (relative to the target) with the energy required to fail the target. Considered in this criteria are two possible modes of failure. The first is a gross distortion failure, and the second is a penetration ("punch-thru") failure. The gross distortion failure mode is a function of the material's available elongation and its yield strength. The penetration failure mode, on the other hand, is a function of missile energy, target thickness, and contact area.

The energy to produce a gross distortion failure is [2]

\[ E_g = (\mu_R - 0.5) RX_e \]  \hspace{1cm} (5)

where

\[ RX_e = \frac{F_{TY}^2}{3} \frac{I}{c^2} \frac{L}{E} \]  \hspace{1cm} (PSF)

PSF is the fully plastic shape factor, and \( \mu_R \) is the ductility ratio. The energy to produce a penetration failure is

\[ E_p = 14949 \ t_p^{3/2} \ A^{3/4} \]  \hspace{1cm} (6)

where \( t_p \) is the target thickness, and \( A \) is the contact area.

Using conservative values for the governing parameters, the potential energy of the missile is compared to the gross distortion and penetration failure energy levels computed for the missile-target combinations. If the potential energy is less, failure is not indicated even if the missile strikes the target.

As a verification of the analytical methods, impact tests were conducted on numerous potential target items including Plant Protection System (PPS) conduit components, on snubbers, rigid struts, attachment
clevises, and on small tubing sections. Several drop tests were also conducted in which a 200 lb. (90.7 kg) section of 2" (5.08 cm) pipe with a sharpened end was dropped end-on onto an insulated section of 28" (81.1 cm) pipe. These tests confirmed the adequacy of the design analyses approach.

4.0 USE OF GENERIC CRITERIA IN QUALIFYING III/I SUPPORTS

In the course of qualifying III/I supports, generic criteria were established for piping supports, conduit, ladders and lights. If the configuration meets the specified requirements, the support is qualified. Otherwise, if the configuration falls outside the specified requirements, then prequalified standard fixes are provided.

SC III conduit is used as an example. Figure 3 shows typical FFTF conduit supports. For each of the support types, test developed load ratings are available for both longitudinal and transverse loading. Based on the support load ratings, tables of maximum allowable span lengths to withstand DBE seismic loads are generated as a function of location within the plant, size of conduit, and type of conduit support. Table 1 is a typical conduit spacing table. The maximum span length is calculated as the minimum of the length needed to produce the allowable support load, or the length producing an allowable stress level in the conduit.

If a conduit span of III/I conduit is found to be less than the tabular length, it is qualified. If, however, the conduit is overspanned, the condition is rectified by either adding an intermediate support or by upgrading the type of support to a stronger clamp, thus allowing a longer span between supports. As an example, the 2-hole strap in Figure 3 will allow about twice the span length between supports as does the pipe clamp in Figure 3 for 3" (7.62 cm) and larger conduit sizes.
Figure 3. Typical FFTF Conduct Support.
### TABLE 1
MAXIMUM SPACING TABLE FOR III/I CONDUIT SUPPORTS INSIDE CONTAINMENT

<table>
<thead>
<tr>
<th>CONDUIT SIZE</th>
<th>MAXIMUM SPAN FOR CONDUIT SUPPORT TYPES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1-Hole Strap</td>
</tr>
<tr>
<td>3/4&quot; (1.905 cm)</td>
<td>10' 0&quot; (3.05 m)</td>
</tr>
<tr>
<td>1&quot; (2.54 cm)</td>
<td>10' 1&quot; (3.07 m)</td>
</tr>
<tr>
<td>1-1/2&quot; (3.81 cm)</td>
<td>7' 4&quot; (2.24 m)</td>
</tr>
<tr>
<td>2&quot; (5.08 cm)</td>
<td>11' 10&quot; (3.61 m)</td>
</tr>
<tr>
<td>3&quot; (7.62 cm)</td>
<td>--</td>
</tr>
<tr>
<td>4&quot; (10.16 cm)</td>
<td>--</td>
</tr>
<tr>
<td>5&quot; (12.70 cm)</td>
<td>--</td>
</tr>
<tr>
<td>6&quot; (15.24 cm)</td>
<td>--</td>
</tr>
</tbody>
</table>
5.0 CONCLUSIONS

A number of methods were used in the final phases of FFTF construction to identify and qualify III/I supports. Zone of influence curves were used to determine whether the missile would strike the target if it fell. Standard load ratings and SC I type design analyses were used to determine if the SC III item has potential for becoming a missile during earthquake. Energy criteria were then used to determine whether the missile could damage the target. If the target was still threatened, generic criteria were used, where possible, to qualify the supports. As alternate approaches, the target could be protected against damage by the missile, or the missile supports could be redesigned. Using one or a combination of the methods available for qualifying III/I supports, each of the III/I items was qualified and documentation provided in the FFTF files.
REFERENCES
