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DESIGN AND PLANNED USE OF A 2-KILOTON ECCENTRIC MASS VIBRATOR

by

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Abstract

As part of the continuing seismic research program conducted by KFK at the HDR nuclear power plant, high-level dynamic tests of the containment structure are planned for early 1986. These tests will use a large eccentric mass vibrator with a maximum eccentricity of 200 ton-meters and force capacity of 2 kilotons. It is anticipated that the containment response will be on the order of 1.0 g and 10 cm at the operating floor. This vibrator is larger, by several times, than any existing unit.

1. Introduction

The purpose of the tests, supported by the German and U.S. governments, is to investigate full-scale, high-level structural response involving significant concrete and soil strains. The data will be used to benchmark containment and soil-structure interaction models and to assess the degree of nonlinearity in actual response. These tests are the third in a series of eccentric mass vibrator tests at the HDR; the first were conducted in 1975 (.01-g response) and the second in 1979 (.1-g response) [Refs. 1 and 2].

The vibrator, designated as the ANCO MK-16 (as shown in Figure 1), uses a "coast-down" design to avoid the need for a large, accurately controlled (and costly) drive system. The eccentric mass is composed of two equal sectors on a common shaft. The MK-16 is brought up to speed in a balanced condition (centers of gravity held 180 degrees apart). When at the desired speed, the drive is disconnected, an explosive bolt fired, and an eccentric cam on one sector moves the sectors to an eccentric position (center of gravity approximately 60 degrees apart); and the MK-16 is allowed to run down, exciting the structure modes in turn. Typical operating frequencies are 2 to 10 Hz with 30 seconds for run-down. The drive system consists of two hydraulic motors with four hydraulic pumps driven by dual 270-hp electric motors. The weights are composed of 7-in. (18 cm) steel plates (maximum total weight of 150 tons). This yields a maximum eccentricity of 200 ton-meters. The MK-16 is being designed to reach a force of 1 kiloton without exceeding fatigue limits (i.e., stresses are kept below the endurance limits). However, if shortened fatigue life is accepted, forces up to 2 kilotons are possible.

The MK-16 is a unique device several times larger than any previous vibrator. For sake of comparison, note that its peak thrust is equal to that of the U.S. space shuttle, its rotary inertia is ten times that of the turbine in a 1,000-MW power plant, and its centrifugal action is comparable to a locomotive making a three-meter turn at 150 kph! Its unique design, however, keeps its power requirements to 400 kW (mostly for aerodynamic drag and bearing friction). Construction is scheduled to be completed by mid-1985, checkout at the HDR by late 1985, and full testing by early 1986.

2. Discussion

A specially designed anchorage system will transfer the MK-16 forces into the HDR operating floor and reactor pit wall, as shown in Figure 2. About 200 rock bolts will attach 2-in. (5 cm) steel plates to the operating floor to create a load-distributing shear plate. Attached to the plate will be crossed, 4-ft (1.2 m) support girders. The shear plate and support girders provide the necessary strengthening of the floor so that it can react the MK-16 forces. At certain points in the floor where air spaces and plugs exist, some additional beams and plates are being added.

Extensive simulations of MK-16 operation (structural and aerodynamic) and HDR response have been carried out by ANCO [Ref. 3] and by LBF [Ref. 4]. Using a two-degrees-of-freedom model of the HDR, validated by earlier tests, ANCO predicted containment response (first mode) as detailed in Table I. Included were cases with nonlinear degradation of stiffness (to 70 percent at 5-cm response). Table II summarizes the predicted responses. Figure 3 presents a typical response. The LBF calculations have paralleled these results (and are reported in another paper in this SMiRT conference). The LBF calculations have also included analysis of the closing dynamics of the MK-16. This includes consideration of the following points:

- The sectors are held in balance (180 degrees) by a single explosive bolt. Forces on the bolt have been calculated.
- The sectors tend to move to the eccentric position (60 degrees) due to a 1-in. (2.5 cm) eccentric cam on the bearings of one sector.
- As the sectors are closing, in order to avoid excessive collision velocity (>15 kph), plastic yielding coils are used to absorb some of the energy.
- When the sectors do contact, a final set of rubber bumpers minimizes the shock, and a standard railroad coupling is used to keep the sectors together.

3. Conclusions

The MK-16 is a unique testing machine that will be available in the future for high-level testing of large manmade and natural structures, such as nuclear power plant containments, concrete and embankment dams, and pile foundations. It is also the international product of many people, organizations, and nations (including American and German researchers and ANCO, LBF, KFK, and the USNRC).

References

/ 1 / GUNDY, W.E., et al., "A Comparison of Vibration Tests and Analysis on Nuclear Power Plant Structures and Piping," 4th SMiRT, Paper K8/6, August 1977.

/ 2 / Several papers presented at the 6th SMiRT, K Session, Paris, 1981.

/ 3 / "High Level Excitation of the Heissdampfreaktor Using a Coast-Down Vibrator," ANCO Engineers, Inc., P1083-13A, revised March 1983.

/ 4 / IDELBERGER, H., and STEINHILBER, H., "Simulation of Behavior of the Modified MK-16 Coast-Down Shaker During the Transient Phase," LBF, Darmstadt, 13 September 1984.

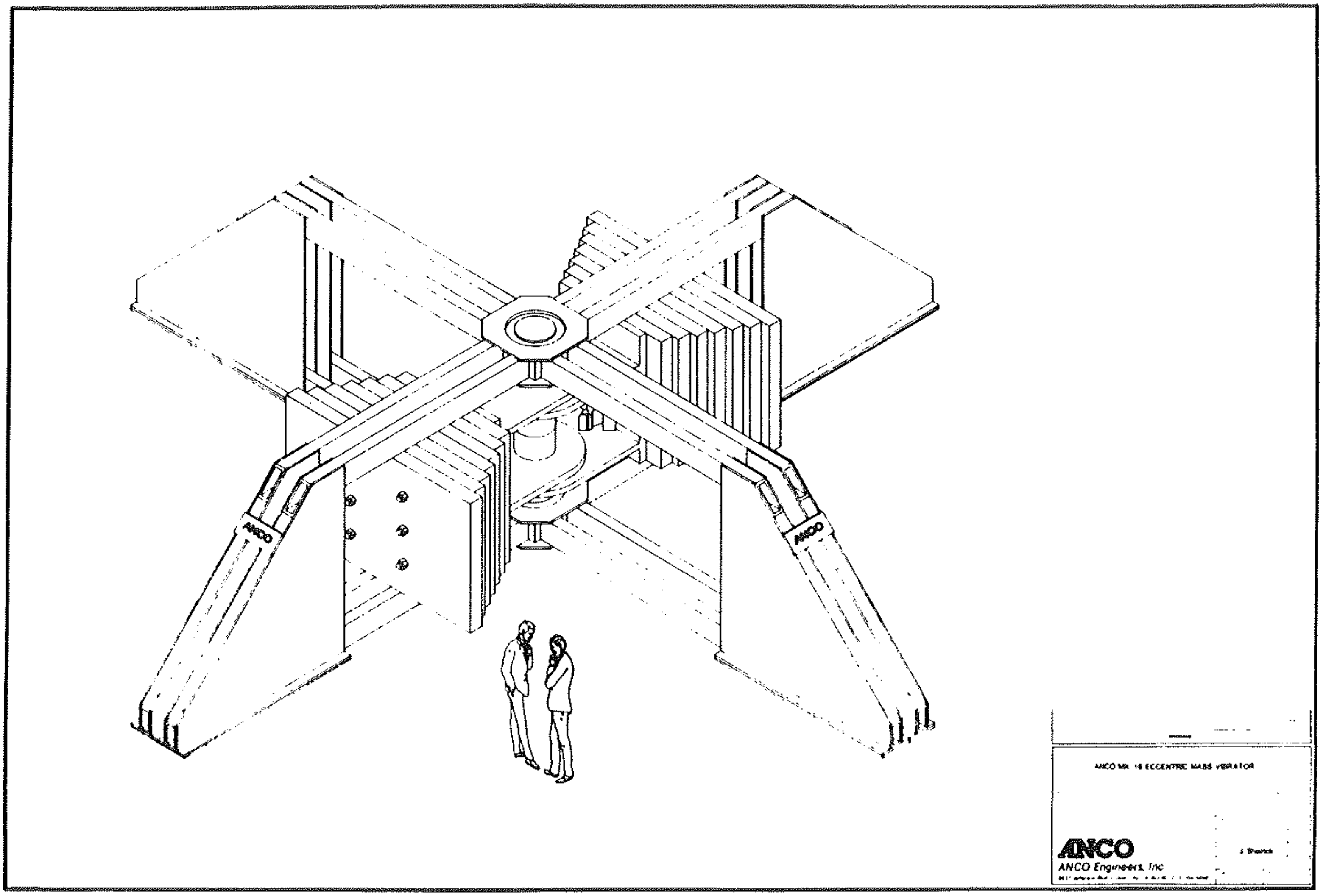

Figure 1: ANCO MK-16 Vibrator

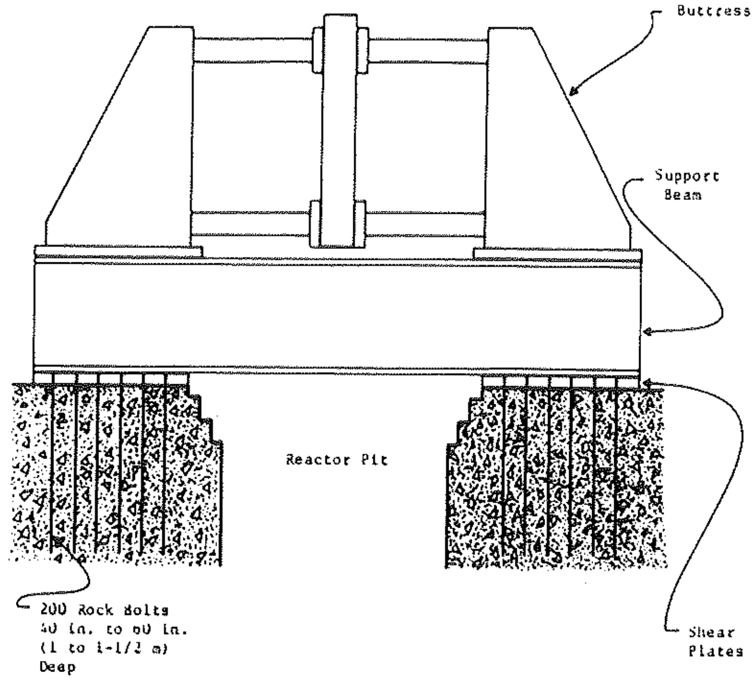

Figure 2: MK-16 Anchorage System

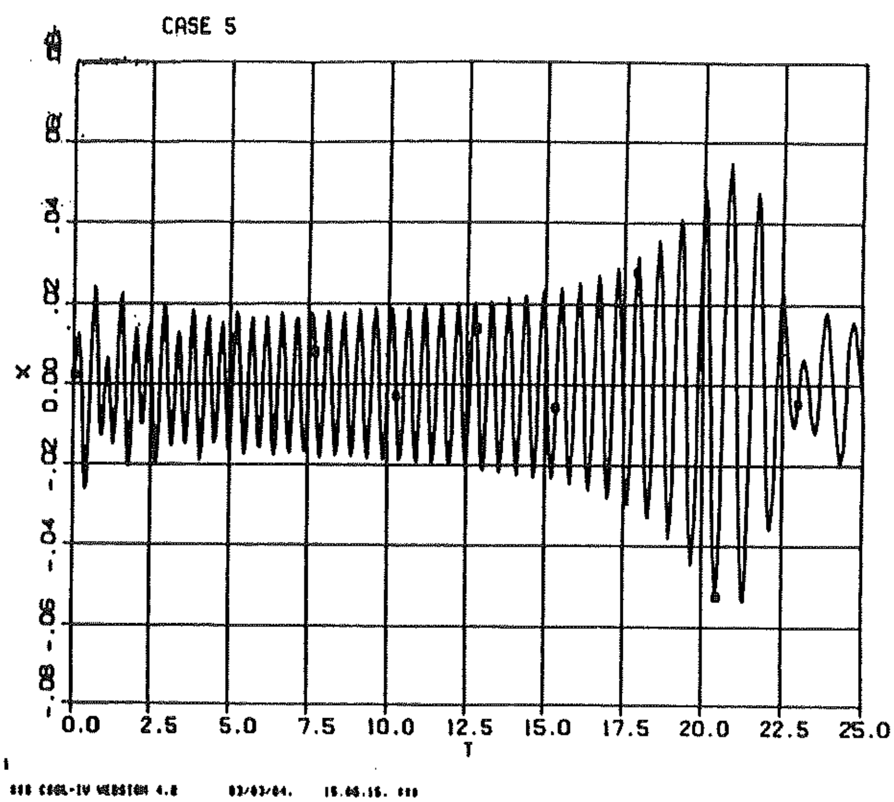

Figure 3: Displacement Time History, Case 5

TABLE I: DESCRIPTION OF CASES

Case 1	Linear structure, 10^5 kg-m eccentricity (drag coeff. 0.5, 2.4 Hz start)
Case 2	Linear structure, 10^4 kg-m eccentricity (10% forcing, else same as Case 1)
Case 3	Linear structure, 10^5 kg-m eccentricity, twice as great a moment of inertia (twice as much stored energy, else same as Case 1)
Case 4	Linear structure, 10^5 kg-m eccentricity (drag coeff. 1.5 to simulate breaking, else same as Case 1)
Case 5	Nonlinear structure, 10^5 kg-m eccentricity (else same as Case 1)
Case 6	Linear structure, 10^5 kg-m eccentricity, steady-state excitation (quasi-static sweep, calculated theoretically)

Note: "Drag coeff." refers to MK-16 weight aerodynamic drag.

TABLE II: SUMMARY OF SIMULATION RESULTS

Case	Peak Displacement (m)	Peak Acceleration (m/s^2)	Time to Peak (sec)
1. Linear Building, 100% eccentricity	.054	3.8	18.
2. Linear Building, 10% eccentricity	.008	0.6	34.
3. Linear Building, double inertia, 100% eccentricity	.062	4.3	27.
4. Linear Building, triple drag, 100% eccentricity	.054	3.8	16.
5. Nonlinear Building, 100% eccentricity	.056	2.9	21.
6. Linear Building, 100% eccentricity, steady-state driven	.080	8.8	---