To AEC-NASA Space Nuclear Propulsion Office
ETS-1 SEISMIC MODIFICATIONS, SUMMARY REPORT

RN-S-0556

April 1970

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ETS-1 SEISMIC MODIFICATIONS, SUMMARY REPORT

NERVA Program

Contract SNP-1

April 1970

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ETS-1 SEISMIC MODIFICATIONS, SUMMARY REPORT

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CONTENTS

	<u>Page</u>
I. Scope	1
II. Introduction	2
III. Summary	3
IV. General Discussion	6
A. Design Criteria and Codes	6
B. Design	10
C. Construction	15
V. Postevent Facility Inspection	16
References	18

APPENDIXES

A.	0.27-g and 0.37-g, 2% and 5% PSRV Spectra
B.	Aerojet Review of Electronic Associates, Inc. (EAI) Investigation of 0.37-g PSRV Response Spectrum
C.	J. A. Blume Recommended Analytical Procedure and Design Criteria
D.	Handley Event Observation Team Location Plan
E.	Photographs

I. SCOPE

This report covers the complete seismic effort from 23 December 1968 to 31 March 1970. It is not intended as a complete single-source reference; instead, it indicates the major trend of events, provides some general factual information, and refers to other documents for detail data. Portions of some of the referenced documents are enclosed for clarity.

The analysis was conducted in a manner that resulted in the Structures Department compiling four separate files which are listed below and are included in the list of references as Items 18 through 21.

RN-S-0552, March 1970: SEISMIC RESPONSE ANALYSIS

STRUCTURES REVIEW OF ANSC SEISMIC DESIGN PACKAGE

STRUCTURES SUMMARY OF ETS-1 SEISMIC GROUND MOTION AND
RESPONSE CRITERIA

STRUCTURES REVIEW OF JOHN A. BLUME SEISMIC DESIGN PACKAGE

II. INTRODUCTION

As work required for the BENHAM seismic event was drawing to a close in January 1969, new planning was initiated for the design of permanent reinforcements for ETS-1. Aerojet's effort began officially on 23 December 1968, in accordance with Reference 1.

The design responsibility was divided between John A. Blume & Associates Engineers of San Francisco and Aerojet Nuclear Systems Company (ANSC). Their respective contracts were managed by SNPO-N and SNPO-C. The primary objective was to design facility component and structural reinforcements that could withstand, without damage, any future man-made seismic disturbance. These designs were to be based on ground-motion predictions made by the Environmental Research Corporation (ERC) of Alexandria, Virginia.

III. SUMMARY

Because seismic planning activity was initiated just prior to the final XE test series, it was expected that increasing radiation levels would become a hazard to be reckoned with during the design and scheduling phase. However, continuing uncertainty regarding seismic design criteria necessitated the preparation of numerous feasibility studies, concept sketches, and complicated construction schedules, which resulted in no field construction being accomplished before completion of the test series in mid-September 1969.

Actual design of facility reinforcements began in early March 1969 and was completed on 1 May 1969. These designs were based on a 0.27-g ground-motion prediction prepared by Environmental Research Corporation (ERC), which was made available to ANSC on 4 March 1969 (see Appendix A). ANSC and NTO activity was governed by two program directives, one for temporary installations (Reference 2) and one for permanent installations (Reference 3).

On May 7, 1970, another seismic event (PURSE) occurred that resulted in a ground motion at ETS-1 that was significantly higher than predicted. Consequently, all designs were suspended until new ground-motion predictions could be made by ERC to reflect the higher anomalous data. It was expected that the higher predictions would serve as new design criteria.

ANSC received direction on 25 September 1969 (see Reference 6) to initiate a new analysis and design effort based on the higher predicted

ground motion of 0.37-g (see Appendix A). Part of ANSC's responsibility was to develop a single-degree-of-freedom response spectrum (see Reference 18) as a backup check of the pseudo-relative-velocity (PSRV) spectrum submitted to ANSC for design. This effort was successfully accomplished when using the 0.27-g seismogram time-history tape (Reference 24). However, some difficulty was experienced in trying to match the 0.37-g PSRV spectrum. SNPO-C and ANSC agreed to bring in a third party to attempt to reconcile the differences; Electronics Associated, Inc. (EAI) of Los Angeles was selected. ANSC transmitted the ERC 0.37-g time-history data, tape No. 14354, to EAI for their use in trying to verify the accuracy of the 0.37-g design spectrum submitted to ANSC. EAI and ANSC agreed that they were able to obtain very close results from their respective single-degree-of-freedom response programs when using the same ERC analog tape of the 0.37-g Design-IV seismogram (see Appendix B).

ANSC reasoned that, when J. A. Blume generated the 2% spectrum by shifting the ERC 5% spectrum, sufficient conservatism was introduced to vary the curve so that it could be reproduced by neither the ANSC nor the EAI methods. After considering the results of J. A. Blume, ANSC and EAI, it was decided by SNPO-C that the ERC time history was correct and should continue to be used as the official criterion. SNPO-C direction (Reference 23) instructed ANSC to revert to the original ERC time-history scale factor of 0.404. ANSC had been previously instructed (see Reference 8) to use a scale factor of 0.808.

The ANSC redesign effort was started approximately 1 October 1969. All ANSC 0.27-g designs were shown to be reusable for 0.37-g motion with only minor variations. In one case, for the S1, S2, and S3 engine shields, it was possible to reuse the BENHAM braces. The new design effort was not to include the S1 or S2 engine shields because they might have required alteration during the 75K-engine modifications; it was decided to brace them temporarily for the two anticipated anomalous seismic events. The only significant new design required was for the top shield lateral braces and lines remaining after removal of PCV-449. All designs and specifications

were transmitted to SNPO-N on 1 December 1969 (see Reference 22) for implementation.

ANSC responsibility relative to J. A. Blume (JAB) was basically to review their method of analysis to verify its conformance to the requirements of SNPO-C-1. ANSC was also directed to construct a mathematical model of ETS-1 and use it in a modal and dynamic response analysis based on time-history acceleration data generated by ERC (see Reference 18). The results of ANSC's analysis were to be used to check the JAB work. The different methods used by ANSC and JAB in structural dynamics occasionally resulted in some disagreement; however, all significant discrepancies were eventually resolved with mutual satisfaction. A detailed discussion of the ANSC review of JAB design and analysis is provided in References 17 and 21.

The construction phase began approximately 7 November 1969 under management of the SNPO-N Construction Division. Working with the SNPO-N construction manager was the FEO (overall) project engineer, the ANSC project engineer, the JAB field project engineer, and several NTO personnel who provided documentation-control services and technical assistance.

All construction essential for a seismic event was completed on 12 March 1970, but considerable repair and cleanup-type work remained. The major outstanding work items were repair and redesign of false floors and ceilings and cleaning of electronic rack equipment. Numerous other work items of lesser scope must be completed as time and funding limitations permit. A complete listing of these work items has been published by NTO in References 11, 12, and 13. A final check list and punch list were published by the SNPO-N/FEO project engineer in References 9 and 10.

IV. GENERAL DISCUSSIONS

A. Design Criteria and Codes

ANSC's first official technical direction came in the form of Change Order 69-5, dated 24 January 1969 (see Reference 4). This document served as the primary basis for the discussion of design standards and criteria that took place at an NRDS meeting on 29 January 1969 with representatives of SNPO-C, SNPO-N, ANSC, NTO, and JAB present (see Reference 14).

Change Order 69-5 required that all designs and analysis be based on PSRV response data formulated by ERC. However, the PSRV response data were not yet finalized and were to be forwarded to ANSC in the near future.

Additional criteria were introduced and agreed to at the 29 January 1969 meeting. Some of the more significant ground rules and criteria were that the designs would be permanent and would not interfere with remote removal of the engine, that the facility should be considered radioactive, that the engine would remain in the stand during the event, and that construction schedules should be compatible with XE-testing downtime windows. Stresses were not to exceed 1.33 times code allowables; however, the codes had not been established, and it was left up to JAB to identify the specific aluminum design code to be used and to name all the codes and documents to be used in determining allowable stresses. A complete listing of ground rules and criteria is provided in Reference 14.

Criteria were modified by the issuance of Change Order 69-9 (see Reference 5). This document implemented the 0.27-g spectrum as formulated by ERC (see Appendix A). The ERC curve was based on 5% damping,

and JAB produced a 2% spectrum by multiplying the 5% response data by approximately 1.43. Change Order 69-9 required that the analysis be based on the assumption that the 75K engine was installed in the test stand; it further required that ANSC review the JAB design and analysis to verify conformity to SNPO-C-1 as applicable.

Final 0.27-g criteria and design codes were established at the 24 March 1969 meeting in Sacramento, attended by representatives of SNPO-N, ANSC and JAB. A copy of the JAB-proposed analytical procedure, which included their recommended design codes, was presented at the meeting and agreed to by the attendees. (SNPO-C verbal concurrence was obtained subsequent to the meeting on the same day.) Appendix C gives the JAB analytical procedure and criteria. Complete meeting minutes are given in Reference 15. In general, JAB proposed to use standard structural design codes with the previously mentioned 1/3 increase in code allowable stresses.

It was stated in the meeting that SNPO-C-1 would not be applicable for the seismic effort except in designing braces for critical systems. It was pointed out that deviation from SNPO-C-1 could be justified by applying Table II notes as appropriate. ANSC's review responsibility was to verify that the JAB design and analysis effort was in accord with SNPO-C-1 as applicable. ANSC was directed to sign the JAB drawings upon completion of review.

The next significant variation in ground rules was the decision that the test stand would not be disconnected from the shadow wall. This decision was made on 22 May 1969 at the Sacramento seismic-design review meeting (see Reference 16). Some months earlier it had been suggested by JAB that the stand and shadow wall be decoupled. In pursuing this goal, JAB hired a subcontractor (Rogers Engineering of San Francisco) to design all piping braces, including cutting of certain pipes on top of the shadow

wall. However, the consequences were so complex that effort was applied to verify analytically that decoupling was not necessary. This verification was obtained in May 1969.

On 7 May 1969, the PURSE event took place, which resulted in ground motion at ETS-1 that was significantly higher than had been predicted. This anomalous data gave rise to an entirely new response spectrum for ETS-1. The first official PSRV spectrum produced by ERC was based on a predicted ground motion of 0.36-g but was challenged by SNPO-C as possibly lacking in conservatism. To reconcile SNPO-C's concern, a meeting was held with SNPO-C, NVOO, ANSC, SNPO-N, and JAB in Las Vegas on 23 July 1969. In this meeting, it was learned that ERC had been asked to base their predictions on data most likely to result from HANDLEY, as opposed to a maximum for design purposes. Consequently, ERC was requested to prepare a new design spectrum to be available by 1 August 1969. The new design spectrum was to be based on an envelope of peaks from Rickey, Chateaugay, PURSE, and BENHAM and then scaled up for the HANDLEY event. ANSC received its copy of the ERC, 0.37-g, ground-motion, acceleration, time-history tape (see Appendix A) on approximately 1 October 1969. Another 0.37-g tape had been received earlier but apparently had been damaged and had to be replaced.

The 0.37-g spectrum was officially implemented by Change Order 69-27 (see Reference 6). This direction required that the analysis be conducted with the 75K engine in the stand, that the NES not be braced, that side-shield braces used during BENHAM be checked for reuse in HANDLEY, and that the upper facility be checked to determine the need for seismic bracing.

Shortly after receipt of Change Order 69-27, ANSC received further direction from SNPO-C by a telephone call on 2 October 1969 that directed the following:

1. ANSC was to proceed immediately with the 0.37-g design activity.

2. The test stand was to experience two more high-yield anomalous events since the device holes were already in existence. However, after the two holes were used, additional tests would not be planned that would result in ETS-1 ground motion in excess of 0.10-g; both events were to occur within the next two years. Designs were, therefore, not to be restricted to permanent braces; temporary braces were to be used wherever practical.

3. The analysis was to assume the engine was not in the test stand.

4. The facility was to be considered nonoperational.

5. Blume packages were to be prepared and submitted for construction on a piecemeal basis so field work could begin as soon as possible.

6. ANSC was to review Blume's work on an expedited basis in parallel with the construction planning, but the review was not to restrict the construction activity if it was not finished.

7. ANSC was to ultimately sign the Blume drawings, as previously agreed.

8. There were no schedules available for the testing activity, but it appeared that the AEC test would slip proportionately with SNPO-N/FEO construction time beyond the middle of January 1970.

Immediately after the telephone call, ANSC received Technical Directive 70-1, dated 7 October 1969 (see Reference 7), which basically

reiterated the telephoned information. The direction received in Technical Directive 70-1 remained as the final design ground rules throughout construction, with only one notable exception. ANSC was relieved of the responsibility to sign JAB drawings by SNPO-C direction (see Reference 25). However, the requirements for ANSC to review JAB work was not lifted; and a summary statement thereof was requested. Such a statement was forwarded to SNPO-N/FEO by ANSC (see Reference 17).

B. Design

As previously stated, the first firm ANSC design was initiated in early March 1969. During January and February, the design effort consisted mainly of feasibility studies for presentation in Washington. The purpose of the Washington meeting was to brief SNPO-W as part of its preparation for a meeting with the AEC commissioners. The intent of meeting with the commissioners was to apprise them of the serious problems that seismic events create for the NERVA program and to seek either a delay of their dates sufficient to permit completion of the XE test series or a relocation to other holes.

Some attempt at preliminary design was initiated in late January 1969, but the preponderance of unknowns precluded significant progress. Some unknowns were: (1) the degree of remote operation required because of radioactivity; for example, it was not known whether there would be temporary access to the side shields for quick brace attachment or whether completely remote operation would be required; (2) there were no reliable design loads for member sizing; (3) information was lacking on requirements to brace the NES and (4) it had not been determined whether the engine could remain in the stand. Because of these unknowns, the bulk of the initial design effort resulted in little more than conceptual sketches.

In early March 1969, enough information had been finalized to initiate

meaningful design activity. Change Order 69-9, dated 11 March 1969, gave direction to use the 0.27-g criteria and to exclude the NES and the upper facility shield. It was assumed for design purposes that all structures within ANSC responsibility would incur the maximum acceleration on the 2% damped 0.37-g PSRV spectrum. This assumption was necessary because dynamic-response values from the multiple-degree-of-freedom program were not to be available for several weeks.

A design task force was assembled and organized at NRDS by the ANSC project engineer. Designers were obtained from ANSC, NTO, and WANL. Drafting services were provided by NTO.

The design criteria required that the side-shield braces be remotely operated and that the engine be removed. (At that time, it was planned to finish construction prior to completion of the XE test series).

In late April 1969, ANSC structures personnel completed their analysis which showed it was not necessary to remove the engine; however, SNPO-C had decided previously that the chance of damaging the engine should not be taken and required that the engine be removed. The only remaining items for ANSC brace designs were the side shields and the miscellaneous facility valves.

Valve braces were designed in accordance with the following procedure:

1. This procedure applies to the valve and pipe, of which the lateral load-carrying capability was questionable from field observation.
2. The procedures consist of data collection, stress analysis of the questionable region of the piping system, design of bracings, and

calculation of stress for the bracing structure.

3. Data Collection: From the as-built drawings or field survey, or both, obtain the following information:

a. An isometric single-line sketch showing the piping layout of the region in question and covering two pipe supports on each side of the valve and the branch lines, including their first support near the valve.

b. Pipe line identification number; valve number; size and rating of flanges, elbows, and other piping elements; size and weight of valves and other components; distance between supports; and description of support structures.

c. Operating temperature and pressure of the piping system and materials of the pipe and support-structure members.

4. Stress analysis of the questionable region. The objective of this analysis is to determine (1) bracing required and (2) method of bracing and design load for the bracing. The following outlines serve as a guide only.

a. Estimate the weight of all the pipe elements, valves, and components.

b. Multiply the estimated weight by the maximum response factor (1.2) and consider the results as horizontal forces acting on the pipe center line in the direction that will induce the most unfavorable stresses in the two pipe supports (or anchor) between which the valve in question is located. Usually, this direction is lateral to the pipe line between the two supports.

c. Calculate the reactions and moments of the two supports (or anchors) due to the above horizontal forces. These forces may be treated either as uniformly distributed or concentrated on the pipe line, depending on which is a better representation of the actual weight distribution. Treat the pipe line as a beam with supported end at the pipe support, or fixed end at the pipe anchor.

d. Calculate the maximum bending and torsional stresses in the pipe section in question. If the combined stress is greater than the allowable stress for the pipe, additional lateral support is required to reduce the stress.

e. Recheck the valve analysis to determine whether the valve operator requires bracing; if it does, design to accommodate both the pipe and the valve operator by the same support.

f. Calculate the maximum stresses of structure members of the two pipe supports (or anchors) as defined in Paragraph 4.b. If the calculated stress exceeds the allowable stress, the support member in question shall be reinforced or replaced with a new design.

g. Limit the analysis to the immediate existing structural member.

5. Design of Bracings. The new bracings or the reinforcements of the existing pipe supports (or anchor) shall satisfy the following criteria.

a. Design load - as determined according to Section 4.

b. Rigidity - in both principal directions in the horizontal plane.

- c. Location of bracings - determined by compromise of effectiveness and practicality.
 - d. Connections to pipe - avoid welding as much as possible.
 - e. Connections to building structure - either bolting or welding, with special consideration, is acceptable. Reinforcement of the building structure shall be provided wherever necessary.
 - f. Material - to be compatible with each application.
 - g. Compatibility with operation - if the piping system operates at other than ambient temperature condition, special consideration shall be given to the design to allow pipe movement during operation.
6. Calculation of stress in the bracing structure. The stresses in the bracing structure member shall be calculated on the basis of worst load condition.

The final 0.27-g design drawings were completed on 1 May 1968 and were transmitted to Sacramento for review and approval by ANSC technical personnel. The PURSE event occurred during the review cycle, and all ANSC 0.27-g design activity was suspended because the PURSE data revealed a significant anomaly in the ground motion at ETS-1.

During the design suspension period ANSC and J. A. Blume were asked to concentrate more on reassessing the effect of the higher ground motion. Early ERC estimates ranged from 0.36 to 0.67-g. See Reference 20 for a summary review of criteria development during this period. As mentioned earlier, the 0.37-g PSRV spectrum was finally agreed to, and go-ahead for redesign was given by Change Order 69-27 on 22 September 1969.

The new criteria did not require that the side shields be braced remotely; removal of PCV-449 and bracing of the top shield were required. Therefore, the redesign effort (see Reference 19) consisted of verifying that the BENHAM braces for the side shields would be adequate for the 0.37-g criteria and that the 0.27-g valve brace design would be adequate for 0.37-g. A new design was generated for removing PCV-449 and for bracing the lines that were left unsupported without PCV-449. The 0.37-g design effort was conducted at both NTO and Sacramento and was cycled through the ANSC technical groups for approval. The final modification design package was completed and transmitted to SNPO-N on 1 December 1969 (see Reference 22).

C. Construction

The construction phase was initiated approximately 7 November 1969. The work was divided between CATCo and PAA, who were managed by SNPO-N, Facilities Division. CATCo was responsible for all of the test-stand structural work except piping, and Pan Am handled all other construction items. All work was implemented by the NWA form, and all changes were made with the prereleased ADCN. The ADCN could be implemented immediately with the signature of the SNPO-FEO project engineer, the ANSC project engineer (or the JAB field project engineer for JAB changes), and the facility manager. The ADCN was then processed for final approval back at the home office of ANSC or JAB, depending on which drawing was affected. During the construction activity there were 89 Pan Am and 104 CATCo confirmemos requesting field deviations; there were 190 NWAs. All the confirmemos and NWAs are located in the final seismic-modification file at NTO. A final report on all phases of the construction will be published by SNPO-N. This report will contain narrative and a complete set of all contractor documentation accumulated during construction. The

SNPO-N report will be the authoritative source on the construction activity. Construction was completed to the mutual satisfaction of all concerned on 12 March 1970. Certain repair and cleanup items remain that will be attended to in the future. References for all cleanup and repair work can be found in References 9 through 13. References 9 and 10 are the official final check lists and may not include all of the items listed in References 11, 12, and 13.

Photographs of some of the final installations are provided in Appendix D.

V. POSTEVENT FACILITY INSPECTION

The code name for the event was HANDLEY, and the event occurred on 26 March 1970.

Five observation teams were stationed at strategic locations around ETS-1 (see Appendix D). Individuals on these items were instructed to observe and record their impression of the reaction of certain assigned areas to the seismic disturbance.

It was generally agreed that the ground motion was probably less than for the BENHAM event and differed in wave characteristic. The HANDLEY event displayed two distinct shocks within the first 10 to 15 sec, followed by a continuous undulation for approximately 20 to 30 sec. The BENHAM event had two initial shocks also, but the motion subsided very soon after the second shock. The observation teams entered the facility shortly after the motion subsided to make an initial quick-look inspection to determine if significant damage had occurred. This report provides preliminary information only, and a more complete detailed file will be compiled at NTO from all the individual observer reports, from data analysis, and from a closer facility inspection. The initial inspection

showed no damage to the facility or test stand, with the minor exception of the concrete-block walls in the fill-station pumphouse. These walls were not braced prior to the event, and some cracks opened up through which daylight could be seen. These cracks indicate that the pumphouse walls should be braced prior to the next event.

REFERENCES

(NOTE: Though not in keeping with normal publication practices, unpublished documents are included in this list of references to provide the necessary traceability of activities and events.)

1. SNPO-C letter R. W. Schroeder to W. O. Wetmore, dated 23 December 1968.
2. RN-PD-MA-2015, Subject: Seismic Events Preparation for 0.37g Ground Motion, (Temporary Installation) dated 23 December 1969.
3. RN-PD-MA-2002A, Subject: Seismic Events Preparation for 0.37g Ground Motion (Permanent Installation) dated 29 December 1969.
4. SNPO-C Letter R. W. Schroeder to W. O. Wetmore, Subject: Change Order 69-5 Contract SNP-1, dated 24 January 1969.
5. SNPO-C Letter R. W. Schroeder to W. O. Wetmore, Subject: Change Order 69-9, Contract SNP-1 dated 11 March 1969.
6. SNPO-C Letter R. W. Schroeder to W. O. Wetmore, Subject: Change Order 69-27, Contract SNP-1 dated 22 September 1969.
7. SNPO-C Letter R. W. Schroeder to W. O. Wetmore, Subject: Technical Directive No. 70-1, Seismic Modifications at ETS-1, dated 7 October 1969.
8. SNPO-C Letter R. W. Schroeder to W. O. Wetmore, Subject: Technical Directive No. 70-4, Contract SNP-1, dated 20 October 1969.
9. SNPO-N Memorandum B. J. Billings to W. L. Walker, Subject: Final Check List - ETS-1 Seismic Preparation, HANDLEY Event, dated 25 February 1970.
10. SNPO-N Memorandum, B. J. Billings to W. L. Walker, Subject: Punch List - ETS-1 0.37g Seismic Modifications dated 19 February 1970.
11. NTO Memorandum, D. D. VanderMeer to D. Gray, Subject: Required Installation Work to Complete ETS-1 Seismic Modifications, PD 2002A and PD 2015, dated 12 February 1970 (NTO-M-27901).
12. NTO Memorandum D. D. VanderMeer to D. Gray, Subject: Supplemental List of Required Installation Work to Complete ETS-1 Seismic Modifications, PD 2002A and PD 2015, dated 17 February 1970 (NTO-M27902).
13. NTO Memorandum, D. D. VanderMeer to D. Gray, Subject: List of Work Items to be Accomplished after Seismic Event Hole V20, dated 20 February 1970 (NTO-M-27905).
14. ANSC Memorandum D. Holzman to W. O. Wetmore, Subject: Minutes of Seismic Meeting - 29 January 1969 dated 30 January 1969 (7050:2303M).

15. ANSC Letter C. M. Rice to R. W. Schroeder, Subject: ETS-1 Seismic Bracing Review Meeting, dated 31 March 1969 (7050:L4006).
16. ANSC Letter R. V. Evleth to R. W. Schroeder, Subject: ETS-1 Seismic Bracing Final Design Meeting Held at Sacramento on 22 May 1969, dated 27 May 1969 (7050:L4021).
17. Summary Statement of ANSC Review of the J. A. Blume Design and Analysis for ETS-1 Seismic Modifications.
18. ANSC Report, RN-S-0552, dated March 1970, Title: Seismic Response Analysis of ETS-1 Design IV (0.37g) Spectrum.
19. Structures Department Review of ANSC 0.27g and 0.37g Seismic Design Package for ETS-1.
20. Structures Department Summary Review of ETS-1 Seismic Ground Motion and Response Criteria.
21. Structures Department Summary Review of John A. Blume and Associates 0.27g and 0.37g Seismic Designs Package for ETS-1.
22. ANSC Letter, R. V. Evleth to B. J. Billings, Subject: Transmittal of ANSC ETS-1 Seismic Modification Design Package.
23. SNPO-C Letter R. W. Schroeder to A. L. Feldman, dated 2 January 1970 (MES:Jer).
24. ANSC Report, RN-S-0542, Seismic-Response Analysis of Engine Test Stand No. 1
25. SNPO-C Letter, L. C. Corrington to A. L. Feldman, Subject: AGC Drawing Sign-Off for Seismic Modifications, dated 20 January 1970 (M&S:JER).

NOTE: References 17, 19, 20, and 21 can be found in Seismic Modification file in archives at NTO.

APPENDIX A

0.27-g AND 0.37-g, 2% AND 5% PSRV SPECTRA

APPENDIX A

APPENDIX A

HANDLEY PREDICTION FOR HOLE U20_f - (ERC FIGURE 3-5% DAMPED)

APPENDIX A

APPENDIX A

APPENDIX A

APPENDIX A

APPENDIX B

AEROJET REVIEW OF ELECTRONICS ASSOCIATED, INC. (EAI)
INVESTIGATION OF 0.37-g PSRV RESPONSE SPECTRUM

APPENDIX B

ANSC STRUCTURES DEPARTMENT DETAILED DISCUSSION OF DESIGN IV SEISMOGRAM

Comparison of Spectral Response Curves Prepared by ERC, John A. Blume & Associates, EAI, and AGC for the So-Called "0.37g" Event (see page 5).

The following is a brief comparison of absolute acceleration response spectra prepared by four different sources for the so-called "0.37g" Event, together with a discussion of the methods used in deriving the spectra. There was basic agreement between all sources as far as the highest response G level was concerned (at 2% damping), namely, about 1.4g at a period of about 0.17 second. The curves prepared by AGC and EAI indicate that responses associated with this peak are in excess of 1g for a much smaller band of frequencies (periods) than indicated by the John Blume and ERC curves. A secondary peak response of about 1.15g at a period of about 0.26 second was found by both EAI and AGC, whereas the John Blume/ERC responses at the same period were less than 0.9g. Reasons are deduced for the differences noted between the responses and recommendations are made for future reporting of data.

1. The response spectra provided by both ERC and John Blume for the so-called "0.37g" event seem to be identical. The logarithmic plots furnished by John Blume & Associates appear to be Xerox copies of ERC provided originals. John Blume & Associates also provided plots of G level responses versus period, plotted on a linear scale. John Blume & Associates have stated that they have the capability to produce spectral plots from digitized ground motion data using the electronic computer; they were provided by ERC with digitized data for the "0.37g" event. However, they have stated that they derived their 2% damping response data by applying a scaling factor to the 5% response data.

2. The method used by AGC to determine response spectra avails of a computer program using digitized data (AGC Computer Program No. E13906).

APPENDIX B

The data were digitized by AGC from an ERC furnished analog FM tape of predicted ground motion acceleration, using about 30 seconds duration of raw data. The AGC digitization rate was 250 samples per second. The AGC program was checked out for numerical accuracy using exponentially decaying ground motion inputs for which the peak responses were theoretically determinable; accuracy was better than 0.1%.

3. The method used by EAI to determine response spectra avails of the electronic analog approach. AGC furnished the identical ERC tape it had used to EAI for EAI's analysis.

4. Table I and Figure 1 compare, for the case of 2% damping, the John Blume, the EAI, and the AGC values of responses.

5. a. It will be noted that there is general agreement between the EAI and the AGC results. For G levels above 0.2g (at periods up to 0.40 second) all but three of the tabulated EAI and AGC results are within $\pm 0.02g$ of one another. The differences occur where the spectral curve has a large slope -- for example, at a period of 0.17 second the EAI G level is 1.13 whereas the AGC value is 1.32. The agreement between the peak EAI and AGC values in this region is however quite good. The EAI peak response G level is 1.42g at a period of 0.172 second, whereas the AGC peak response is 1.36g at a period of 0.175 second.

b. Both EAI and AGC results show a secondary peak above 1.0g at a period of 0.26 second; the EAI G level is 1.16 as against the AGC value of 1.13.

6. a. The 2% damping spectrum curve furnished by John Blume & Associates has a peak value of 1.42g at a period of 0.17 second in general

APPENDIX B

agreement with the EAI and AGC results. It will be noted, however, that the general shape of the Blume curve in the vicinity of this peak is about two and one-half times as wide as either the EAI or AGC curves; the level of the Blume curve remains above 1g for periods between 0.14 and about 0.19 second, whereas the AGC and EAI curves remain above this level only for periods between 0.16+ and 0.18+ second. This is further discussed under Section 7.

b. The secondary peak detected by EAI and AGC, of about 1.15g, occurs in a region where the Blume furnished curve nowhere exceeds 0.90g.

c. The valleys of the EAI and AGC curves lie lower than those on the John Blume furnished curve. It is possible that ERC or John Blume deliberately flattened the secondary peak response at the same time raising the valley responses in order to get a working curve.

7. There are technical reasons supporting the accuracy of the sharpness of the EAI and AGC derived primary peak at about 1.40g, as discussed in Section 6a. As noted in Section 1, John Blume & Associates have stated that they derived their 2% damping curve by applying a constant scaling factor to the 5% damping curve. This procedure imposes the flatter sharpness of the 5% damping curve on the derived 2% curve which, however, would normally be expected to have a sharper peak. As such, this scaling procedure is conservative (in going from 5% to 2%), but it might be overly so if there were several resonances in the structure being examined in the 0.14 to 0.19 second period range.

APPENDIX B

TABLE I

COMPARISON OF ABSOLUTE ACCELERATION RESPONSES
AS BETWEEN THREE SOURCES (JOHN BLUME, EAI, AND AGC)

CYCLES	PERIOD	$\zeta=2\%$ J.B.	G LEVEL EAI	AGC	$\zeta=5\%$ J.B.	G LEVEL EAI	AGC
1.00 Hz	1.00 Sec	0.20	0.17 ₄₅	0.12 ₄	0.15	0.11 ₉₅	0.10
1.35	0.74	0.10	0.07 ₇₅	0.07 ₄	0.08	0.07 ₄₃	0.07
1.85	0.54	0.17	0.10 ₉₈	0.16	0.12	0.11 ₆₃	0.14
2.50	0.40	0.40	0.30 ₇	0.32	0.28	0.25 ₈₅	0.27
3.33	0.30	0.85	0.77 ₅	0.77	0.61	0.54 _g	0.51
3.45	0.29	0.86	0.67 ₈	0.67	0.61	0.54 _g	0.51
4.00	0.25	0.89	0.77 ₅	0.79*	0.57	0.67 ₈	0.57
4.55	0.22	0.80	0.54 _g	0.56	0.58	0.48 ₅	0.44
5.00	0.20	0.85	0.74 ₃	0.72	0.60	0.48 ₅	0.55
5.26	0.19	0.96	0.75 _g	0.76	0.69	0.54 _g	
5.55	0.18	1.05	1.05	1.15	0.95	0.58 ₁	0.78
5.88	0.17	1.40	1.13	1.32*	1.00	0.76 ₅	0.85
6.25	0.16	1.38	0.90 ₅	0.92	0.90	0.84 ₈	0.77
6.67	0.15	1.16	0.88 ₈	0.88	0.74	0.72 ₇	
7.14	0.14	1.00	0.64 ₆	0.66	0.65	0.60 ₅	0.52
7.69	0.13	0.86	0.68 ₆	0.69	0.61	0.48 ₅	0.52
8.33	0.12	0.86	0.68 ₆	0.69	0.61	0.52 ₅	0.51
9.09	0.11	0.85	0.72 ₇	0.74	0.61	0.43 ₆	0.51
11.1	0.09	0.80	0.74 ₃	0.49	0.55	0.43 ₆	0.41
100.9	0.01	0.20	0.22	0.21	0.20	0.22	0.21

EAI RESULTS FOR 2% DAMPING NEAR RESPONSE PEAKS

3.55	0.28 ₂	0.75 ₇	5.60 HZ	0.178 _g	1.26 ₂
3.65	0.74 ₄	0.88 ₄	5.65	0.177 _o	1.34 ₅
3.75	0.26 ₇	1.13 ₇	5.70	0.175 ₄	1.38 _g
3.85	0.26 _o	1.15 ₇	5.72	0.174 ₈	1.38g
3.95	0.25 ₃	0.92 ₅	5.75	0.173g	1.38g
			5.80	0.172 ₄	1.43 _o

NOTE: EAI Frequencies - per Von Hefling, they are at worst within 5% of the requested values.

* AGC peak for 2% damping is 1.36G at a period of 0.175 sec; $f = 5.72$

There is a subsidiary 2% damping peak @ 1.13G @ period 0.26 sec; $f = 3.25$.

APPENDIX B

APPENDIX C

J. A. BLUME RECOMMENDED ANALYTICAL PROCEDURE AND DESIGN CRITERIA

APPENDIX C

ETS-1 PERMANENT STRUCTURE BRACING DESIGN

CONTRACT NO. AT(28-1)-99

Procedures for Analyses of Structures and Design of Structural Modifications

I. CRITERIA

- A. Seismic Criteria: ERC Maximum Response Spectra for ETS-1 Structures (0.27g peak horizontal ground motion)
- B. Stress Criterion: 1.33 Basic Allowable Stress for Dead Load (includes equipment and piping weight) plus seismic load.

II. DYNAMIC ANALYSIS OF STRUCTURES

- A. Rigid Structures (Periods " T " $\leq$ 0.05 seconds)
 - 1. Apply the peak horizontal ground acceleration (0.27g) to mass level.
 - 2. Equivalent static force = $ma = 0.27W$.
- B. Structures with periods > 0.05 seconds
 - 1. Construct a lump mass system (mathematical model), generate flexibility and mass matrices, determine the natural periods of vibration and corresponding mode shapes, and use the spectral acceleration derived from the appropriate acceleration response spectra to determine the equivalent static, seismically induced forces. Consider a minimum of two modes for multi-mass systems and combine the modal responses by the root mean square method.

APPENDIX C

2. Damping Values

(a) Reinforced Concrete Structures = 5%

(b) Structural Steel and Aluminum Structures = 2%

C. Piping Systems

1. Modify and/or add supports to categorize systems as rigid
($T \leq 0.05$ seconds)
2. Apply maximum acceleration derived from main structure
analyses to piping systems.

D. Equipment

Analyses similar to piping system analyses.

III. DESIGN OF STRUCTURAL MODIFICATIONS

A. Design will be in accordance with UBC 1967 and accepted structural
engineering design practices.

B. Basic Allowable Stresses

Reinforced Concrete ($f'_c = 3000$ psi) - ACI-63

Structural and Miscellaneous Steel (ASTM A36) - AISC-63

Structural Aluminum (6061-T6) - Aluminum Association,
Aluminum Construction Handbook
November 1967

Drilled Caissons - NAVDOCK DM-7 and ACI-63

APPENDIX D

HANDLEY EVENT OBSERVATION TEAM LOCATION PLAN

NTO-G-0147

FIGURE 1

FIGURE 1
ETS-I SITE PLAN

HANDLEY SEISMIC EVENT OBSERVATION TEAM
LOCATION PLAN

APPENDIX D

APPENDIX E

PHOTOGRAPHS

FORWARD CONTROL ROOM TYPICAL RACK BRACES

APPENDIX E

TYPICAL CONTROL POINT BUILDING BLOCK WALL SUPPORT

APPENDIX E

TEST CELL BUILDING RACK BRACES

APPENDIX E

SIDE SHIELD AND SHADOW WALL BRACES

SHADOW WALL BRACES (SOUTHEAST)

SHADOW WALL BRACE PILING (SOUTHEAST)

S-3 SHIELD BRACE

FLARE STACK FS-5001 BRACE

TYPICAL LH₂ LINE BRACE

PCV-449 INTERFACE SUPPORT

MISC PIPE BRACE

APPENDIX E

LOX LIPE PIPE SUPPORT BRACES

MISC PIPING AND STRUCTURAL BRACES AT ELEV 3916

TYPICAL DECK BRACING

DUCT VAULT DOOR BRACES

TEST STAND TORSIONAL BRACES AND SHADOW WALL CONNECTIONS

MAIN COLUMN BASE REINFORCEMENT

TYPICAL BOX BEAM CONNECTION

TOP SHIELD DIAGONAL BRACES

APPENDIX E

FLARE STACK FS-3801 BRACE

TYPICAL VESSEL FOUNDATION SLIDE BLOCKS

APPENDIX E

HIGH PRESSURE GAS RECEIVER BRACES

32 AREA SHIELD WALL BRACES

TYPICAL WHEEL BLOCKS

NAOH TANK FOUNDATION BRACES

V-3801 DIAGONAL BRACES