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

SEP 24 1982

Mr. George E. Howard, Principal
ANCO Engineers, Inc.
9937 Jefferson Boulevard
Culver City, CA 90230

Mr. Bruce B. Rytkonen
Manager, Contract Negotiations
Contracts Department
Electric Power Research Institute
3412 Hillview Avenue
Palo Alto, CA 94303

Gentlemen:

Letter Contract No. NRC-04-82-025, Laboratory Studies: Dynamic Response of Prototypical Piping Systems.

1. Pending negotiation of formal Contract No. NRC-04-82-025, and contingent upon your acceptance of the terms and conditions of this letter as provided below, ANCO Engineers, Inc. is authorized and directed effective September 30, 1982, to initiate work entitled "Laboratory Studies: Dynamic Response of Prototypical Piping Systems" in accordance with the Statement of Work as delineated in Attachment I of this Letter Contract.

2. Pending negotiation of a definitive contract, the applicable terms and conditions of this Letter Contract with the Nuclear Regulatory Commission (Commission) and the Electric Power Research Institute (Institute) shall be those delineated in Attachment II. It is anticipated that the said definitive contract will provide for compensation to ANCO Engineers, Inc. (Contractor) on a cost-plus-fixed-fee basis. In addition, it is a rec that in the event that a definitive contract cannot be agreed upo between the parties, that the Contractor will be reimbursed for hi actual costs in accordance with the cost principles in Federal Proc ement Regulations 1-15.2, as in effect on the effective date of this Let Contract. In the event of failure to reach agreement on a definiti e contract, the maximum liability to the Commission and the Institute will be $25,000.00.

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include $5,000.00 of Commission funding and $20,000.00 of Institute funding. It is anticipated that the total estimated cost for performance of this work under the definitive contract will not exceed $550,000.00. A cost share ratio of 50% by the Commission and 50% by the Institute will govern total expenditure of funds under both this Letter Contract and the definitive contract.

4. In the event that said definitive contract is not executed by the parties by October 31, 1982 (or by any subsequent date mutually agreed upon in writing) this Letter Contract will expire on the stated date, as the case may be.

Your acceptance of the above terms is requested by your acknowledgement and return of four (4) copies of this letter before September 30, 1982.

If you need further information, please call Levi Baisden, Contract Negotiator, on (301) 492-4289.

Sincerely,

Kellogg V. Morton, Chief
Research Contracts Branch
Division of Contracts
Office of Administration

Attachments: As stated

cc: Bruce D. Braga
Contracts Department, EPRI

GEH

ACCEPTED:

ANCO Engineers, Inc.

By: Craig B. Smith /BEH

Title: President

Date: 28 Sept 1982

ATTACHMENT 1

STATEMENT OF WORK

NRC/EPRI COOPERATIVE PROGRAM ON EXPERIMENTAL EVALUATION OF NUCLEAR POWER PLANT PIPING

A. Introduction

It is the intent of this research effort, which involves design, analysis, fabrication, erection, and dynamic testing of a 6-in. outside diameter (O.D.) piping system, to provide the following benefits:

1. increase the currently limited data base regarding damping in piping systems at response levels at and above OBE stress levels (ASME Code limits);

2. obtain a data base for benchmarking computer methods for analysis of pressurized piping systems with representative (nonlinear) supports and for response levels below and above pipe yielding and including pipe support failure; and

3. stimulate recognition of safety margins implicit in ASME Code rules for Class 2/3 piping by demonstrating the existence of large design margins for seismic response above SSE stress limits, and by providing safety margins data that could impact licensing issues involving existing nuclear power plants.

The test calls for performing seismic simulation tests at the ANCO dynamic test facility of a prototypical nuclear piping system. Tests will cover a wide range of input motions which produce stresses from below yield to above yield stress. Extensive post-test data analyses will be performed.

B. Discussion of the Research Plan

It is planned to investigate a piping system with varying complexity in overall geometry (through the inclusion of branch pipes), support layout and types and other important system variables. Support types to be considered are spring hangers, struts, and snubbers. Excitation sources may include sine dwells, random inputs, snapbacks, impulse loads and simulated earthquakes. System stiffness and mass distribution, with components being represented by concentrated offset masses or actual components, are among the other system variables. Concurrent loads include pressure. Amplitude of motion will produce peak piping stresses which vary from below to above yield stress. The test configuration will be such that for the damping studies, parameters may be systematically varied, partic larly support parameters. Actuators may be connected to the piping in a way that will permit a few or several supports to be simultaneously driven by the same actuation.

The suggested test configurations will follow the guidelines listed below:

1. Pipe sizes: Main pipe - 6" diameter
   Branch pipe - 3" to 4" diameter.

2. Pipe material & grade: ASTM A106 grade B.

3. ASME Section III criteria for fabrication and installation should be followed. No N-stamping necessary.

4. Tests should include cases with and without branch pipes.

5. Piping should be pressurized during the tests.

6. At least one valve (body & operator) should be installed along the main pipe, or a dynamic representation of the valve should be installed.

7. Vertical supports (rod hangers, or spring hangers) should be used to offset piping weight.

8. Horizontal supports will be driven by hydraulic actuators. The support system should be designed such that it can excite the piping in N-S direction for certain test cases and in E-W direction for other test cases.

It is the intent of the envisioned work to conduct an extensive test program to fully evaluate the response of actual piping system designs to seismic loads.

The data resulting from such a program, and subsequent interpretation and analytical studies, could provide the basis for addressing important questions related to pipe design and analysis. Some of these questions are given below:

1. What are the dynamic design margins inherent in nuclear power piping systems under dynamic loads, recognizing that current design limits are based upon static rather than dynamic response data?
2. How well do advanced computer models simulate response of piping to multiple independent support inputs?
3. How do snubber and other modern restraint nonlinearities affect seismic response, and how can these nonlinear effects be modeled (for analysis as well as design purposes) at OBE and SSE response levels?
4. With regard to piping system dynamic response, what are the actual failure modes of supports and the consequences of such failures?
5. What are appropriate damping values for piping systems? The use of low damping factors for typical elastic seismic design may lead to the requirement for excessive number of pipe supports.
6. What are the actual failure modes of piping.

7. How does apparent damping vary as piping systems experience large amplitude dynamic response (incipient piping yield for SSE conditions) for distributed strong motion load, that is, when inputs travel into the piping via support boundary points and result in piping excited throughout its length? Virtually all currently available piping dynamic data are for systems excited at a single location (for strains approaching and exceeding OBE response levels).

As part of the test program, it will be determined how much the pipe support system can be seismically loaded beyond the SSE level. The ultimate criteria for pipe failure will be leakage or flow restriction. However, other signs of potential failure will be looked for after each test; these will be (1) peak principal strains in the system, (2) observable exterior cracks in the pipe, (3) observation of any fracture of strain threshold detection pipe coating materials (fracture of material indicates that the local strain has exceeded a threshold value at some time during a test), (4) significant deformation, and (5) accelerations levels which would damage, or render inoperable, attached components such as valves and pumps.

After each test, all pipe supports will be examined for any malfunction.

In addition to the seismic tests (the primary test), both limited step loading and sine dwell tests will be conducted. Step loading tests will be performed only below the SSE level - about 3 tests for each support configuration. This will be done so that the log decrement damping can be determined. The sine dwell tests will be used only for obtaining response shapes - the dwelling will be done only at the natural frequencies of the system.

C. Equipment , Instrumentation and Test Sequence

The piping will be driven with three to five hydraulic actuators which are tied directly to a massive concrete strong wall construction.

The testing will entail the following sequences with three-dimensional piping:

- o. 6-in. O.D. mainline with no branch line excited to response levels ranging from well below OBE stress limits up to the SSE stress limits.
- o. 6-in. O.D. line with two branch lines (called here the "complete system") excited over similar response range, followed immediately by tests well above the SSE limits and up to inducing pipe/support failure.

The detailed test matrix is discussed in Section G.

There is need to measure the acceleration and displacement at locations on the pipe that undergo the largest motions, or motions that are greatly controlled locally by support motion. Some of these locations are midspan along long lengths of pipe. It is also of value to instrument any snubbers with a load cell (measures the snubber axial force) and displacement transducer (measures the snubber displacement). This will enable the study of the performance of the snubbers, as well as the snubber support load being transmitted to the pipe. In addition, support motion must be well defined in each of the three component directions.

As part of the pipe tests, it is important to be able to determine the stress/strain state of the pipe. It was decided to measure the strains at those points which show the highest stress for the finite element model subjected to seismic motion. Locations for instruments are tentative and subject to adjustment based on the results of model simulation. Since aspects of these tests will center around conservatisms in the ASME Code, it was decided to instrument the pipe so the total load state could be determined at several high-stress locations--i.e., determine the axial force, two shear forces, torsional moment, and two bending moments at key points. To do this, it will be necessary to instrument these key points with three strain gage rosettes and place them around the circumference of the pipe. One location will only be instrumented with one rosette and one uniaxial gage. This will allow the determination of the torsion and two bending moments, assuming that the axial and shear forces are negligible. This was done because of gage limitation.

In addition to performing seismic simulation tests, step loading and sine dwell tests will be performed. The sine dwell tests will be used only to obtain the response shapes, frequencies and damping of the system. To obtain a given mode, the system will be sinusoidally driven at the corresponding natural frequency.

A movable triaxial accelerometer array will be moved from test node point to node point. At each point the steady-state response will be captured and stored on disk. This will be done for all the modes of interest.

The type of transducers to be used will be selected so that adequate accuracy will be maintained over the entire range of strains, displacements, loads and accelerations expected. This will require instrumentation which will be appropriate for low level testing and instrumentation which will be appropriate for high level testing.

D. Pretest Planning and Types of Tests

This section describes all the work that must be done to plan for, carry out, and analyze results from, and write the final report for laboratory pipe tests to be conducted at the ANCO Engineers, Inc. dynamic test facility. The plan of attack for this test program is divided into three parts. (1) pretest planning, construction, and system check out; (2) dynamic tests, and (3) post test data processing and analysis and report writing. The tasks for the pretest work are described in Table D.1. Each task that is done will be checked by the project manager and at least one other technical person for correctness. A check out sheet will be used to keep track of who did the work, those who checked it,some of the important details of what was done, and the date of completion.

The next part is the performing of the dynamic tests. There are six types or categories of tests to be performed for each test configuration. They are given in Table D.2.

TABLE D.1

PRETEST PLANNING

Item

1. Refinement of details of tests to be performed.
2. Complete design of pipe system.
3. Procure and/or check out of necessary instrumentation and computer equipment.
4. Purchase pipe system materials/hardware.
5. [illegible]e and install pipe system, including all sleds and hydraulic actuators (ASME Code rules are to be followed for pipe fabrication).
6. Install all instrumentation (transducers plus associated equipment).
7. Set up of any computer test directories, transfer necessary software to appropriate directories.
8. Initial check out of pipe system plus instrumentation and data acquistion system.
9. Define preliminary SSE earthquake(s) based on computer model of pipe system(s).

TABLE D.2

TYPES OF TEST FOR EACH CONFIGURATION

Test Type

1. Check out system (debug system)
2. Select SSE earthquake(s) (final selection)
3. Static pressure (only)
4. Sine dwell (obtain mode shapes)
5. Step loading (similar to snapback, obtain damping)
6. Earthquake (seismic simulation)

The testing indicated in Table D.2 will be performed for different configurations. Configurations are established when branch pipes are added or supports are rearranged.

After all the tests have been performed for all the configurations, the work will progress in two stages: (1) data processing, analysis and interpretation, and (2) report writing. The data analysis and interpretation will consist of such items as (1) determination of refined values for natural frequencies, mode shapes, and modal damping, (2) calculate bending and torsional moment time histories and ultimately the ASME stress only for tests below the SSE level, and (3) determine how many times above the SSE level the pipe system could be excited without failure occurring.

E. Coordination and Contract Objectives

EPRI will utilize the results of these investigations to support its mission of providing industry and the technical community with information for the safe design of nuclear power plant piping. NRC, through its contractors Brookhaven National Laboratory and Idaho National Engineering Laboratory, will use these test results to revise Regulatory Guides and establish standards for piping analysis and design. Lawrence Livermore National Laboratory will use this information in performing seismic risk assessments of piping.

F. Deliverables

The contractor will provide EPRI and the NRC and their agents with the following:

1. data tapes of all tests and reports which in detail describes the contents of the tapes and the conditions under which the tests were performed.

2. hard copies of the reduced data for all the tests and for all the instrumentation channels including load cell, displacement gauge, strain gauges, accelerometer, etc.

3. photographic documentation (slides, movies) of the construction and performance of the tests.

4. final report documenting the results of the tests with discussion of major test findings.

All the deliverables will be provided within ~~three~~ five* months of the conclusion of the tests except that data for all the channels for each phase of the testing will be immediately processed for hard copies to be commented and reviewed by EPRI, NRC and their agents for possible test modifications.

G. Appendix

The detailed test matrix, instrumentation layout, data reduction plan, and indepth discussion of the statement of work as provided by ANCO is attached as an appendix for reference. The work performed should be corresponding to ANCO's proposal and the statement of work defined in this contract.

H. Project Management

This project will be co-managed by EPRI and the NRC.

* REF. TABLE 6.1 ATTACHED

TABLE 6.1

PROPOSED MILESTONES

1 October 1982	Contract Award; Begin Task 1 (Pretest Preparation)
1 February 1983	Have Main Piping Installed on Test Sleds
15 February 1983	Preliminary Low-Level Testing on Main Pipe (Task 2)
1 May 1983	Completion of Main Pipe Testing
1 July 1983	Completion of Main Pipe Data Reduction and Plotting
1 August 1983	Completion of Installation of Main Piping Plus 2 Branch Lines
15 August 1983	Preliminary Low-Level Testing on Main Pipe Plus 2 Branch Lines (Task 3)
15 October 1983	Completion of Main Plus 2 Branch Line Testing
15 December 1983	Completion of Main Pipe Plus 2 Branch Lines Data Reduction and Plotting
15 March 1984	Submittal of Final Report

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FROM: Bruce D. Braga

COMPANY: U.S. NRC

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c: Bruce D. Braga
Contracts Department, EPRI

ACCEPTED:

Electric Power Research Institute

By: Bruce B. Rytkonen
Bruce B. Rytkonen

Title: Manager, Contract Negotiations

Date: September 30, 1982