Sandia National Laboratories

Albuquerque, New Mexico 87185

November 30, 1982

Dr. James F. Costello
Mechanical/Structural Engineering Branch
Mail Stop NL-5650
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Jim:

During the meeting of the peer review group on June 9, 1982, we requested input on the reinforced concrete models from the members. This was reiterated in a letter to the members from Walt von Riesemann dated July 15, 1982. Responses from the members have been trickling in since shortly after the meeting. To date, six members (Ahl, Baker, Denning, Sozen, Stevenson and Ucciferro) have responded. Copies of their responses are enclosed.

I will remind the members who have not responded when they are contacted about the next peer review meeting. I will forward any responses to you shortly after we receive them.

Sincerely,

Tom

T. E. Blejwas
Systems Safety Technology
Division 9442

TEB:9442:nb

Enclosures

Copy to:
9442 W. A. von Riesemann w/o enc.
9442 File 1047.011 w/o enc.

Sandia National Laboratories
Albuquerque, New Mexico 87185

January 11, 1983

Mr. Thomas J. Ahl
Nuclear Design Group
Chicago Bridge & Iron Co.
800 Jorie Blouveard
Oak Brook, IL 60521

Dear Mr. Ahl:

By the time you receive this letter, you should be aware that I am trying to arrange a meeting of the peer review group for Sandia's Containment Integrity Program in mid-late February in Albuquerque. Prior to that meeting I would like to bring you up to date on some work on the program.

In early December we completed a test of small steel model SC-0, the fabrication checkout model. I am enclosing a copy of my quick-look letter report to Jim Costello on that test. The date of the test to failure was December 10, not December 12 as stated in the letter. Because of damage to some of the testing equipment, the test of the clean shell model, SC-1, has been delayed to about February 15.

The design of the large steel model by CB&I is complete. After our review, CB&I will begin fabrication. Enclosed is a copy of the preliminary fabrication drawings. Note that drawings Nos. 2 and 3 were not completed by CB&I; they informed me that these sheets are not required for fabrication. We are presently reviewing the drawings and plan to respond to CB&I by their requested date of February 24. We welcome any input you can provide. Certainly, important changes will be considered after the response date.

Six members of the peer review group provided responses to our request for input on the reinforced concrete models. Copies of the responses are enclosed. In addition to peer review input, we have sent out a request for proposals entitled "Experimental Modeling Techniques for Reinforced Concrete Containments." A copy of the body of the RFP as forwarded to our purchasing department is enclosed.

(A)

After arrangements for our meeting become finalized, I will forward more detailed plans. If you have any questions about the meeting or any of the enclosures, please call me at 505-846-0541. I hope to see you in Albuquerque.

Sincerely,

T. E. Blejwas

T. E. Blejwas
Systems Safety Technology
Division 9442

TEB:9442:nb

Copy to:
J. F. Costello, NRC
R. F. Reedy, R. F. Reedy, Inc.
9442 W. A. von Riesemann, w/o enc
9442 D. S. Horschel, w/o enc
9442 J. Jung, w/o enc
9442 R. L. Woodfin, w/o enc
9442 File 1047.011

CONTAINMENT INTEGRITY PEER REVIEW GROUP

July 1982

Mr. Thomas J. Ahl
Nuclear Design Group
Chicago Bridge & Iron Co.
800 Jorie Blouveard
Oak Brook, IL 60521
FTS 8-312-654-7365

Dr. Wilfred E. Baker
Dept of Ballistics & Exp. Sci.
Southwest Research Institute
6220 Culebra Rd
PO Drawer 28510
San Antonio, TX 78284
512-684-5111
FTS 8-730-5511

Dr. Richard Denning
Battelle Columbus Laborataries
505 King Ave
Columlbus, Ohio 43201
614-424-7510
FTS 8-976-7510

Dr. Asadour H. Hadjian
Bechtel Power Corporation
12400 E Imperial Highway
Norwalk, CA 90650
FTS 8-213-807-3031, Ext. 3419

Dr. George E. Howard
ANCO Engineers, Inc.
9937 Jefferson Blvd
Culver City, CA 90230
FTS 8-213-204-5050

Professor Mete A. Sozen
Dept of Civil Engineering
University of Illinois
503 W Michigan
Urbana, IL 61801
213-333-3929
FTS 8-957-3929

Dr. John D. Stevenson
Stevenson & Associates
9217 Midwest Ave
Cleveland, Ohio 44122
FTS 8-216-587-3805

Dr. Joseph J. Ucciferro
Structural Analysis Group
United Engineers & Constructors, Inc.
30 S 17th St
Philadelphia, PA 19101
FTS 8-215-422-3436

Dr. Ian Wall
Electrical Power Research Institute
3412 Hillview Avenue
PO Box 10412
Palo Alto, CA 94304
FTS 89-415-855-2935

Professor Richard N. White
School of Civil & Environ. Engr
Hollister Hall
Cornell University
Ithaca, NY 14853
607-256-3690
FTS 8-882-2611

Sandia National Laboratories

Albuquerque, New Mexico 87185

February 1, 1983

Mr. Thomas J. Ahl
Nuclear Design Group
Chicago Bridge & Iron Co.
800 Jorie Boulevard
Oak Brook, IL 60521

Dear Mr. Ahl:

Per telephone conversations with our secretary, the dates for the next meeting of the peer review group of the Containment Integrity Program are Thursday and Friday, February 24 and 25, 1983. The meeting will be at Sandia National Laboratories in Albuquerque, NM. We presently plan for Thursday's meeting to start at 9:00 a.m. and Friday's to end by 3:00 p.m. The meeting Thursday will include presentations on work to date and a tour of our test facility (weather permitting). Late Thursday and Friday we will discuss our program plans.

I am enclosing some literature that may help you in your visit to Sandia. The first, entitled "Welcome to Albuquerque, New Mexico and Sandia National Laboratories," has a map which shows the airport, freeways, etc. You may wish to refer to it in selecting a hotel/motel. The AMFAC Hotel is located on Yale Blvd., a long walk or short drive (shuttle service is available) from the airport. I've given the AMFAC a visitor list, so that, if you tell them you are here for Sandia's Containment Integrity Program, they will give you the government rate of $40 per night for a single. Other nice hotels in Albuquerque include the Marriot (near I-40 and Louisiana), the Classic (Louisiana and Menaul) and the Sheraton Old Town (north of the Old Town Historical Site). The AMFAC is the most convenient and is quite nice. Note on the map that you must enter Kirtland AFB through a military gate to reach Sandia. I am assuming that you will enter through the Gibson Gate, near the corner of Gibson Blvd. and Louisiana Blvd. I will notify the gate personnel of your visit, but you must still park and sign in. After you enter Kirtland AFB, stay on Gibson until you get to Wyoming Blvd. (the second traffic light after the military gate). Turn right (south) on Wyoming.

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The second enclosure, "Visiting Sandia National Laboratories," has a map of Sandia's Area I. I've circled Building 822 where we will hold our meeting. To reach Building 822, travel south on Wyoming to O Street (the military are very creative with names); left on O Street; left at the "T"; and then into the parking area south of Building 822. The meeting room is to your right as you enter Building 822. The meeting is outside Sandia's secure area, so you won't need a badge to enter the meeting room.

I'm also enclosing a brochure on the Sandia Peak Aerial Tramway. The restaurant at the top, High Finance, is very good and the view can be spectacular, particularly near sunset.

If I can help you in any way with your visit, please feel free to call me at 505-846-0541 (office) or 505-294-2057 (home).

Sincerely,

T. E. Blejwas
Systems Safety Technology
Division 9442

TEB:9442:nb

Enclosures

Copy to:
J. F. Costello, NRC - w/enc.
9440 D. A. Dahlgren, wo/enc.
9442 W. A. von Riesemann, wo/enc.
9442 File 1047.011, wo/enc.

Sandia National Laboratories

Albuquerque, New Mexico 87185

Mr. Thomas J. Ahl
Nuclear Design Group
Chicago Bridge & Iron Co.
800 Jorie Blouveard
Oak Brook, IL 60521 Mr. Ahl_

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503 W Michigan
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30 S 17th St
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Dr. Ian Wall
Electrical Power Research Institute
3412 Hillview Avenue
PO Box 10412
Palo Alto, CA 94304 Dr. Wall_

Professor Richard N. White
School of Civil & Environ. Engr
Hollister Hall
Cornell University
Ithaca, NY 14853 Prof. White_

AGENDA

Peer Review Group
Containment Integrity Program

February 24-25, 1983
Sandia National Laboratories
Albuquerque, New Mexico

Thursday, February 24 — Bldg 822, Room A

9:00 a.m.	Introduction	Jim Costello Walt von Riesemann
9:30 a.m.	Program Overview	Tom Blejwas
10:00 a.m.	Break	
10:15 a.m.	Small Steel Experiments	
	Models	Tom Blejwas
	Preliminary Test	Ron Woodfin
	Analysis	Dan Horschel
11:15 a.m.	Large Steel Experiment	Tom Blejwas
11:30 a.m.	Lunch - Coronado Club	
12:45 p.m	Badge Office	
1:00 p.m.	Concrete Experiments	
	Analysis	Joe Jung
	Models Schedules	Tom Blejwas
	Summary of Peer Review Written Comments	Tom Blejwas
	Questions for Overnight Consideration	Jim Costello
2:15 p.m.	Tour of Model Prep. Lab, Bldg 867	Ron Woodfin
3:00 p.m.	Tour of Containment Test Site	Ron Woodfin
4:45 p.m.	End of Day's Activities	

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Friday, February 25 Bldg 822, Room A

8:30 a.m.	Related Programs	
	EPRI Concrete Tests	Ian Wall
	Electric Penetration Assemblies	Walt von Riesemann
	Penetration Program and Isolation Valves	Jim Costello
9:30 a.m.	Far-Term Plans	Jim Costello
10:00 a.m.	Break	
10:15 a.m.	Discussion of Concrete Models	
11:15 a.m.	Lunch - Coronado Club	
12:45 p.m.	Discussion of Concrete Models	
2:15 p.m.	Break	
2:30 p.m.	Consensus of Concrete Models	
3:00 p.m.	End of Meeting	

Sandia National Laboratories
Albuquerque, New Mexico 87185

date: May 2, 1983

to: Containment Integrity Peer Review Group

R.T. Reese

from: R. T. Reese, 9442

subject: Peer Review Group Meeting, Sandia National Laboratories, Albuquerque, New Mexico, February 24-25, 1983.

Enclosed is a summary of this meeting including the discussions and agreements/action items. Also enclosed are copies of the agenda and the transparencies used in the presentations. Some of the activities described on the schedule have changed since the peer review meeting. New dates will be announced later.

Enclosures
1. Meeting Agenda
2. Copies of Transparencies Used in the Meeting
3. Y. R. Rashid, Review of the WASH-1400 Surry Containment Assessment, Draft for Comments

Copy to:
Peer Review Group; enc 1,2,3
J. Costello, NRC; enc 1,2,3
J. Burns, NRC; w/o enc
W. Anderson, NRC; w/o enc
1523 D. B. Clauss; enc 1,2
E. H. Conley; enc 1,2
9440 D. A. Dahlgren; w/o enc
9442 W. A. von Riesemann; w/o enc
9442 T. E. Blejwas; enc 1,2,3
9442 D. S. Horschel; enc 1,2,3
9442 J. Jung; enc 1,2,2
9442 R. T. Reese; enc 1,2,3
9442 W. A. Sebrell; w/o enc
9442 File 1047.011

22

Minutes of the Peer Review Group Meeting
Sandia National Laboratories
Albuquerque, New Mexico
February 24-25, 1983

Attendees

Peer Review Group

Richard S. Denning, Battelle Columbus Labs

John D. Stevenson, Stevenson & Associates

Joseph J. Ucciferro, United Engineers & Constructors, Inc.

Ian Wall, Electric Power Research Institute

Richard N. White, Cornell University

James S. Wilbeck for Wilfred Baker,
Southwest Research Institute

Nuclear Regulatory Commission

John Burns

James Costello

Sandia National Laboratories

Walter A. von Riesemann

Thomas E. Blejwas

Daniel S. Horschel

Joseph Jung

Robert T. Reese, Secretary

Wayne A. Sebrell

Ronald L. Woodfin

David B. Clauss

E. H. Conley

This summary is organized into the following sections:

Detailed summaries of each main section as follows with each of the three main sections including agreements and/or action items

a. Program Direction
b. Steel Models
c. Concrete Models

Appendixes cover presentations including copies of transparencies used and other pertinent information.

Program Direction

The Containment Integrity Program has two major objectives: to qualify analytical methods for reliably predicting the structural capability of LWR containments subjected to extreme loading conditions caused by severe accidents and extreme environments and, in conjunction with other NRC sponsored programs, to provide a basis for prediction of containment behavior including leakage. The initial loading condition considered is static internal pressure which will be applied to three small-scale (1/32) steel model containments, a large steel model (1/8 scale) and to model containments constructed of reinforced concrete.

A schedule of activities is given below (as of February 1983):

Steel Models	
Pressure Test on Steel Model SC-1	Mar 1983
Pressure Test on Steel Model SC-2	Jun 1983
Pressure Test on Steel Model SC-3	Aug 1983
Site Preparation for Large Steel Model Tests	Apr-Jul 1983
Fabrication of Large Steel Models	Mar-Jul 1983
Testing of Large Steel Model	
a. Erection/Leak Check	Jul 1983
b. Instrumentation	Jul-Oct 1983
c. Pressure Testing	Nov 1983
Concrete Models	
Modeling Studies of Reinforced Containment	Mar-May 1983
Presentation of Modeling Studies to NRC	Jun 1983
Recommendations for Designs	Jul 1983
Design of Concrete Model Containments	Aug-Oct 1983
Design Review	Nov-Dec 1983
Site Preparation, Construction of Model	Dec 1983-May 1984
Final Concrete Curing	Jun 1984
Testing of Concrete Model Containment	
a. Instrumentation	Mar-Jul 1984
b. Pressure Testing	Aug-Sept 1984

Agreement/Action Items/Major Discussion Items

There was considerable discussion regarding the possible failure modes of the steel containments subjected to internal pressure. Testing of the large steel model should provide information to address the basic questions regarding failure - either catastrophic or sustained leakage.

The other discussion centered on the concrete models. These discussions are summarized in the concrete model section.

The following agreements were made:

1. The direction of the program should be on qualification of analytical methods to predict the behavior of containments subjected to internal pressure.

2. There should be interaction with EPRI and their sponsored work and testing program at the Construction Technology Laboratories (a division of Portland Cement Association).

3. Conceptual features for concrete models were discussed and are outline in that section.

4. Leakage rates are to be measured.

5. Tests on separate features of containments are necessary.

Jim Costello raised the following question which was discussed but no firm answers were formed. The questions was: Suppose that the British do not test a SNUPPS-type containment (prestressed concrete). What can be done to bridge the gap of information between the behavior of reinforced concrete containments and prestressed containments? This question was discussed but no consensus was reached.

Steel Models

The tests on the small steel models (SC-0 through SC-3) were discussed. Tom Blejwas summarized changes on the large steel models including gussets or ring stiffeners, a constrained piping penetration, painting, and an internal support structure.

A suggestion was made regarding the constrained piping penetration in which an internal tie rod was proposed instead of an external restraint. This suggestion will be incorporated into the model.

Concrete Models

As indicated previously, one of the purposes of the peer review meeting was to discuss the concrete models. Jim Costello posed the following questions.

1. What must be included in the concrete models?

2. What can or should be done in separate tests?

3. What would be the design and construction costs for 1 and 2 above?

4. What additional tests would be required to "cover" prestressed containments?

With respect to 1, there was a lengthy discussion on the need and requirement for a liner in the concrete model. Joe Ucciferro suggested that the liners and liner-concrete interaction could be tested with separate component tests. If a liner was not used then the difficulties involved in fabricating the liner and preserving it through the construction of the containment would be eliminated, the lack of understanding on the concrete-liner interaction and the applicability of scale model tests to verify this interaction would be eliminated; and the types of liner anchorage system that should be used to represent the existing containments would not require investigation. The other approach is to have a liner because the presence of a liner will be a better simulation of real containment and the liner will, in all likelihood, affect leakage through the containment boundary as continued applications of internal pressure force yielding and failure of the containment. It was agreed that a liner is needed and that the modeling studies need to include a liner in their work.

There was also considerable discussion regarding the penetrations in the concrete model. There was no disagreement that penetrations were needed - only that the number and type need to be resolved in the modeling study.

There was also discussion in which agreement was made that separate tests are likely to be required on the following: (1) penetrations, (2) cylinder basemat interaction, and (3) confirmation of scaling laws.

The discussion on design and construction costs for concrete models resulted in various estimates. The liner alone is expected to cost between $125K and $200K. The cost for the model (without liner) depends on the scale and ranges from $250K to as large as $\$1.3 \times 10^6$ for 1/2 scale.

The similarities and differences of the prestressed and reinforced concrete containments subjected to internal pressures was discussed in some detail with emphasis on the ultimate capacity.

The major question involving the additional tests required for prestressed concrete resulted in the following concerns and likely requirements: (1) regions of the containment that are in transition from prestressed to reinforced, (2) discontinuities, (3) crack formation and propagation, and (4) evaluation inconcrete differences. Reference was made to work by Adolf Walsar (Sargent & Lundy) on cracks in prestressed concrete. It was suggested that a meeting be held in June in Chicago to review the EPRI sponsored tests and the relationships involving cracking prestressed and reinforced concrete section of modeled containments.

Separate Presentation

R. S. Denning - BCL
This presentation focused on the fission products releases to the atmosphere. Included was a discussion of four types of reactors with the comparisons to the overestimates given by WASH 1400.

The vugraphs used are included in the appendix and include a plot of pressure as a function of time which describes the various accident conditions for release of fission products (steam spike, hydrogen deflagration, hydrogen detonation, and steam explosion).

Among the conclusions are: (1) the fraction of the fission products released varies as a function of time, (2) there are differences in terms of the early and latent effects. A report summarizing this study will be available in June.

Ian Wall - EPRI
This description was of the EPRI sponsored tests at Portland Cement Association investigating the factors which will lead to substantiation of leakage which will be used to evaluate acceptable risk. In those tests a rectangular reinforced concrete block with a steel liner simulating the wall of a containment will be placed over a chamber. As described in the attached vugraphs, the test item will be loaded in two directions simulating the pressure loading. The chamber will be pressurized and include aerosol size particles. By measuring the presence of aerosol on the opposite side of chamber, a relationship can be established for the release of particulate or a function of pressure and time.

Comments were also requested on the paper by Joe Rashid which is also enclosed with the following request from Ian Wall:

"Enclosed please find a copy of a draft EPRI report entitled 'Review of the WASH-1400 Surry Containment Capability Assessment' by Dr. Y. R. (Joe) Rashid, President Anatech

Corporation. EPRI requested Dr. Rashid to critically review the structural analysis for the internal pressurization capacity of the Surry containment as presented in appendix VIII of the WASH-1400. They encouraged him to evaluate in particular the realism of the failure mode assumed in the WASH-1400 study. In this brief report, Joe argues that the Surry containment would most likely leak before it can rupture catastrophically. EPRI is sponsoring an experimental project with Portland Cement Association in order to substantiate many key points in this argument. If Joe's argument can be sustained, it would reduce the source term for LWRs with concrete containments by orders of magnitude.

An issue of this significance warrants careful review, and Dr. Ian Wall solicits your comments which should be sent to him at the Electric Power Research Institute, 3412 Hillview, P.O. Box 10412, Palo Alto, CA 94303. Please include a copy of these comments to W. A. von Riesemann, Division 9442, Sandia National Laboratories, P.O. Box 5800, Albuquerque, NM 87185. Specific questions that he would like to address include:

1. Is there merit to Dr. Rashid's argument?

2. What are the critical assumptions?

3. What experiments would your recommend to validate the calculations?

4. What additional calculations should be done?

5. How generic is the conclusion to other reactor containment types?"

Respectfully submitted,

Robert T. Reese

Robert T. Reese, Secretary

Sandia National Laboratories
Albuquerque, New Mexico 87185

date: June 17, 1983

to: Containment Integrity Peer Review Group

RTReese

from: R. T. Reese, 9442

subject: Peer Review Group Meeting, Sandia National Laboratories, Albuquerque, New Mexico, February 24-25, 1983.

Enclosed is a summary of this meeting including the discussions and agreements/action items. Also enclosed are copies of the agenda and the transparencies used in the presentations. Some of the activities described on the schedule have changed since the peer review meeting. New dates will be announced later.

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b. Steel Models
c. Concrete Models

Each section contains discussions, agreements, and/or action items. Materials used in presentations are contained in the appendixes in the order given. Other information is also contained in the appendixes.

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Separate Presentation

R. S. Denning - BCL

This presentation focused on the fission product release to the atmosphere and is based on a study funded by NRC to be reported in June. The status of the study was reported along with possible implications for the Containment Integrity Program. Included were detailed discussions on the overestimates of releases predicted in WASH 1400. In this reactor safety study, there were three sources of release of fission products: (1) from the fuel, (2) transport in the primary system, and (3) release through the containment boundary. The WASH 1400 methodology and the study presented agreed on the source terms from the fuel. WASH 1400 did not account for retention in the primary system and likely overestimated the release from the containment. These two factors will lead to a likely reduction in the overall source term.

One factor governing the potential release of materials is the relationships among pressure increases (particularly steam spikes), failure modes of the containment, and the times at which the failures could occur in terms of the introduction of possible source materials into the containment. There are significant differences in the amounts of potential source materials retained in the primary system and in the containment as a function of the timing of a failure mode.

The vugraphs used are found in Appendix 2F and describe the relationship for release fractions for cesium and other radio-nuclides in the primary system and in the development and comparisons with the results from WASH 1400.

The implications for the containment integrity program are that the failure modes of containments and their timing are important in evaluating the release fractions which are the factors in the assessment of reactor safety subjected to extreme loading conditions.

Ian Wall - EPRI

This presentation described the EPRI sponsored work on evaluating retention in the primary coolant sytem; measuring steam spikes; hydrogen deflagration and tests at the Portland Cement Association's Construction Technology Laboratories (CTL). The tests at CTL are to substantiate the source terms with a target of reducing them by a factor of 10 by 1984 from the 0.6 range outlined by R. S. Denning. Besides the expected retention of source materials in the primary cooling system and containments, Wall stated that the likely failure mode of a containment will be to leak rather than fail catastrophically.

Tests were described in which a simulated wall of a containment (a rectangular reinforced concrete block with a steel liner) will be placed over a pressurized chamber which includes aerosol size particles. The block will be loaded in biaxial tension through the reinforcing bars or prestressing tendons. Measurements of leakage and aerosols will be made on the opposite side of the block to substantiate the source term.

Comments were also requested on the paper by Joe Rashid which is also enclosed with the following request from Ian Wall:

"Enclosed please find a copy of a draft EPRI report entitled 'Review of the WASH-1400 Surry Containment Capability Assessment' by Dr. Y. R. (Joe) Rashid, President Anatech Corporation. EPRI requested Dr. Rashid to critically review the structural analysis for the internal pressurization capacity of the Surry containment as presented in appendix VIII of the WASH-1400. They encouraged him to evaluate in particular the realism of the failure mode assumed in the WASH-1400 study. In this brief report, Joe argues that the Surry containment would most likely leak before it can rupture catastrophically. EPRI is sponsoring an experimental project with Portland Cement Association in order to substantiate many key pcints in this argument. If Joe's argument can be sustained, it would reduce the source term for LWRs with concrete containments by orders of magnitude.

An issue of this significance warrants careful review, and Dr. Ian Wall solicits your comments which should be sent to him at the Electric Power Research Institute, 3412 Hillview, P.O. Box 10412, Palo Alto, CA 94303." (Please include a copy of these comments to W. A. von Riesemann, Division 9442, Sandia National Laboratories, P.O. Box 5800, Albuquerque, NM 87185.) "Specific questions that he would like to address include:

1. Is there merit to Dr. Rashid's argument?

2. What are the critical assumptions?

3. What experiments would your recommend to validate the calculations?

4. What additional calculations should be done?

5. How generic is the conclusion to other reactor containment types?"

Respectfully submitted,

Robert T. Reese

Robert T. Reese, Secretary

Enclosure 1

AGENDA

Peer Review Group
Containment Integrity Program

February 24-25, 1983
Sandia National Laboratories
Albuquerque, New Mexico

Thursday, February 24		Bldg 822, Room 8
9:00 a.m.	Introduction	Jim Costello Walt von Riesemann (2a)
9:30 a.m.	Program Overview	Tom Blejwas (2b.1)
10:00 a.m.	Break	
10:15 a.m.	Small Steel Experiments	
	Models	Tom Blejwas
	Preliminary Test	Ron Woodfin
	Analysis	Dan Horschel (2b.2)
11:15 a.m.	Large Steel Experiment	Tom Blejwas (2c)
11:30 a.m.	Lunch - Coronado Club	
12:45 p.m.	Badge Office	
1:00 p.m.	Concrete Experiments	
	Analysis	Joe Jung (2d)
	Model Schedules	Tom Blejwas (2e)
	Summary of Peer Review Written Comments	Tom Blejwas
	Questions for Overnight Consideration	Jim Costello
2:15 p.m.	Tour of Model Prep. Lab, Bldg 867	Ron Woodfin
3:00 p.m.	Tour of Containment Test Site	Ron Woodfin
4:45 p.m.	End of Day's Activities	

Friday, February 25 — Bldg 822, Room A

8:30 a.m.	Related Programs	
	BCL Studies	Richard Denning (2f)
	EPRI Concrete Tests	Ian Wall (2g & 3)
	Electric Penetration Assemblies	Wayne Sebrell (2h)
	Penetration Program and Isolation Valves	Jim Costello
9:30 a.m.	Far-Term Plans	
10:00 a.m.	Break	
10:15 a.m.	Discussions of Concrete Models	
11:15 a.m.	Lunch - Coronado Club	
12:45 p.m.	Discussion of Concrete Models	
2:15 p.m.	Break	
2:30 p.m.	Consensus of Concrete Models	
3:00 p.m.	End of Meeting	

Sandia Laboratories

Albuquerque, New Mexico 87115

July 26, 1983

Mr. Thomas J. Ahl
Nuclear Design Group
Chicago Bridge & Iron Co.
800 Jorie Blouveard
Oak Brook, IL 60521

Dear Mr. Ahl:

By now you should have received confirmation of your reservation at the Holiday Inn in Bethesda for our meeting on August 3 and 4, 1983. Please let me know if you are having difficulties with your reservations.

As I promised in my last letter, I'm enclosing a tentative agenda for the peer review meeting. The two days will be quite busy and delays may occur, but we will stick to the agenda as much as possible.

The presentations by Stone and Webster and Failure Analysis are the culmination of work performed under contract to Sandia (a copy of the statement of work is enclosed). We chose two contractors to get a larger base of information from which to design a reinforced concrete model. The two groups have worked independently. However, their presentations should not be viewed as a competition. Rather, we hope to take information from both and develop the conceptual design. This is where your help is necessary. By the end of the meeting on Thursday we hope to have a consensus from the Peer Review Group on the design/fabrication of all of the significant features of the concrete model.

Don't hesitate to call me (505-846-0541) with questions about the meeting.

Sincerely,

Tom

Thomas E. Blejwas
Systems Safety Technology
Division 6442

Enclosures

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PEER REVIEW GROUP MEETING
Bethesda, Maryland

August 3 - 4, 1983

Tentative Agenda

Wednesday, August 3, 1983

8:30 a.m.	Opening Comments	J. F. Costello T. E. Blejwas
8:40 a.m.	Presentation by Failure Analysis Associates	P. D. Moncarz J. D. Osteraas
9:30 a.m.	Break	
9:40 a.m.	Continuation of FaAA Presentation	
10:30 a.m.	Break	
10:40 a.m.	Discussion Period	
11:30 a.m.	Lunch	
1:00 p.m.	Presentation by Stone & Webster	J. W. Steere M. B. Stetson
1:50 p.m.	Break	
2:00 p.m.	Continuation of Stone & Webster Presentation	
2:50 p.m.	Break	
3:00 p.m.	Discussion Period	
4:00 p.m.	End of Wednesday's Activities	

PEER REVIEW GROUP MEETING
Bethesda, Maryland

August 3 - 4, 1983

Tentative Agenda

<u>Thursday, August 4, 1983</u>

8:30 a.m.	Discussion of Conceptual Design and Fabrication Plans for the Concrete Model	T. E. Blejwas
11:30 a.m.	Lunch	
1:00 p.m.	Recent Results from Small Steel Tests	T. E. Blejwas
1:15 p.m.	Test Philosophy for Large Steel Models	T. E. Blejwas
1:30 p.m.	Contingency Plans for Large Steel Model	R. T. Reese
1:45 p.m.	Status of U.K. Prestressed Test	W. A. von Riesemann
2:00 p.m.	Sandia Programs on Penetrations	W. A. von Riesemann
2:45 p.m.	Japanese Seismic Activities	R. White J. Stevenson
3:30 p.m.	Loading Conditions for Future Tests (Dynamic and Seismic)	
4:00 p.m.	End of Meeting	

SECTION I

ARTICLE 1 - STATEMENT OF WORK

BACKGROUND INFORMATION

The work described herein is part of a program at Sandia National Laboratories on the structural integrity of containment structures at nuclear power plants. The program is being funded by the Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission (NRC). A goal of the containment program is the qualification of methods for determining the ultimate capacity of Light Water Reactor (LWR) containment structures under severe accident and environmental conditions. Experiments with models of containment structures are being used in an attempt to qualify analytical methods. Background information and a brief description of the program are provided in the Sandia Tech Note, attached.

The testing of reinforced concrete containment models will follow the internal pressurization of steel containment models that scheduled for completion in fiscal 1983. In advance of conceptual design of the concrete experiments, a study of modeling techniques for concrete containments is required. In particular, features such as steel liners and areas of heavily congested steel reinforcement require special attention. This Contract is aimed at these modeling difficulties.

The configuration of reinforced concrete containments typically includes a basemat, a cylindrical side of about 140 to 150 feet diameter and a hemispherical dome. A simple drawing of the Surry containment structure is shown in Figure 1. The cylindrical sides of a concrete containment (Figure 2) are typically 3 to 4 feet thick with vertical and hoop reinforcement (typically No. 18 bar). Diagonal reinforcement (Figure 3) is generally used to resist seismic forces. The basemats are on the order of eight to ten feet thick and also heavily reinforced. The hemispherical domes are typically thinner than the sides with circumferential and meridional reinforcement (Figure 4). To prevent leakage to the atmosphere, the insides of all U.S. concrete containments are lined with welded steel plate that is typically 1/4 to 3/8 of an inch thick. The liners, which are fabricated before concrete placement, are attached to the concrete using embedded stud anchors and/or steel channels, such as shown in Figure 5. The areas in the cylinder around major penetrations (equipment hatches, personnel locks and large piping penetrations) are heavily reinforced as shown in Figures 6, 7, 8, and 9. The junctures between the basemat and the cylindrical side have particularly complex reinforcement patterns as seen in Figures 10 and 11.

The objective of Sandia's experiments with concrete containments is to provide data for verifying and/or developing methods for predicting structural deformations/failures that cause significant leakage during quasi-static internal pressurization. (Leakage rates greater than 10% volume per day are considered "significant" by Sandia personnel). Towards the objective, one or more prototypical models will be constructed and pressurized to rupture. Structrual response and leakage will be measured during the Test(s). Because of budget limitations,

ll replica models are not believed to be a reasonable possiblity. Adequate models, i.e. models in which accurate predictions of one or more characteristics can be made, will be used. Furthermore, where possible, conventional construction materials and practices will be utilized. A choice of model scale has not been made; however, a maximum size of from 1/8th to 1/10th scale is anticipated. Smaller scales may be cost effective and should be considered. A preliminary study of containment modeling and modeling costs is included in Chapter 5 and Appendix C of Reference 3. Table C-1 of that reference is attached. A copy of the remainder of the reference is available on request.

In addition to experiments with adequate models of an entire ontainment, separate tests of parts or sections a containment will be onsidered for the following reasons. Including all significant features in a single model may be cost prohibitive, if even possible; however, examining the effect of some features using separate tests may be cost effective. Secondly, some features, such as penetration details, vary considerably from structure to structure; separate effects experiments may provide a cost effective way to test a variety of geometries. Lastly, separate tests may be necessary to verify the modeling techniques used in the models of entire containments.

Although the usual concrete modeling concerns of reinforcement type and concrete mixture are important for this study, other features pose unusual difficulties and will require considerable attention. An ideal model liner should represent the stiffness, strength and leakage haracteristics of an actual containment liner. The attachment and concrete-liner interaction should also be representative. As noted previously, the areas around major penetrations are heavily reinforced in complex patterns. Similarly, the region at the basemat-cylinder juncture is heavily congested with rebar. Adequately modeling these areas to properly represent tension, shear and bending behavior is a particular concern in this study.

General information on the design and construction of structures at nuclear power plants is available in Reference 4.

SPECIFIC WORK TO BE PERFORMED

The contractor shall furnish all necessary personnel, service, facilities and materials and do all things necessary for and incidental to the effective performance of the work described below.

Task 1.

Develop modeling techniques for the features of a reinforced concrete containment in a prototypical model for internal pressurization tests to failure. As a minimum, the following features must be considered (1) liner, (2) major penetrations, including reinforcing in the shell, (3) reinforcement, including meridional, hoop, seismic and shear, (4) liner attachment, (5) concrete mixture, and (6) overall containment geometry, including basemat, cylindrical walls and hemispherical dome. Make

specific recommendations for including or excluding each feature. Where inclusion is recommended, specifics as to fabrication techniques must be stated.

Task 2.

Based upon the results of Task 1, recommend a scale(s) for Sandia's prototypical models.

Task 3.

Estimate the costs of a prototypical model of the scale in Task 2 incorporating all the features as recommended in Task 1. Show cost increments for any features that may be considered optional.

Task 4.

Develop separate experiments to test important characteristics that can not be evaluated in the prototypical model. Also, necessary tests to verify modeling techniques should be recommended.

Task 5.

Estimate the costs for the separate tests in Task 4.

Task 6.

The contractor shall provide Sandia (1) with a letter progress report (typed) at the end of the each month to be received by Sandia no later than the seventh day of the following month, (2) with a draft final report (typed) to be received thirty (30) days before the end of the contract and (3) with a printed final report to be received within thirty (30) days after the end of the contract. Each monthly letter report should describe in appropriate detail (a) technical results, (b) milestones achieved and milestones delayed with reasons for the delays, (c) expenditures in dollars, and (d) effort in man-months. During the project term significant problems should be reported immediately to the Sandia project manager by telephone and confirmed later by letter. Technical results may also be presented, as is appropriate, at review meetings with Sandia and/or NRC personnel, at meetings of scientific societies, or by publication in technical journals.

Mail Reports to:

Sandia National Laboratories
Attn: T. E. Blejwas Div. 9442
P.O. Box 5800
Albuquerque, NM 87185

Mail copy of cover letter accompaning all reports to the same address: Attn: L.D.L. Ellis, Div. 3721.

Task 7.

Present the important results of Tasks 1 to 5 at a meeting of Sandia and NRC personnel on or about April 15, 1983. A final date will be coordinated with all participating parties. Location of the meeting will be either Albuquerque, New Mexico, or the Washington, DC metro area. The contractor should estimate costs on the more expensive of these locations including travel from place of business.

ARTICLE 2 - PERIOD OF PERFORMANCE

EFFECTIVE DATE OF CONTRACT THROUGH MAY 31, 1983.

ARTICLE 3 - ESTIMATED COST, FIXED-FEE, AND OBLIGATION OF FUNDS

ESTIMATED COST	$51,464
FIXED FEE	4,616
TOTAL ESTIMATED COST AND FIXED FEE	$56,080
OBLIGATION OF FUNDS THROUGH May 31, 1983	$56,080

Tooling, equipment, and/or facilities acquired/fabricated for Sandia, as authorized herein, shall be separately invoiced and supported by Sandia Form SF 6110-AA, in triplicate, per Section II, Article A60, property. Costs for such items shall be segregated from other costs against this contract.

Contractor shall not incur commitments or expenditures allowable under this contract in excess of the amount shown for the period ending at the date listed. Section II, Article A32, "Estimates of Cost, Fee, and Obligation of Funds" shall apply to such amount for the stated period and thereafter to the contract total.

The Obligation of Funds shown are cumulative through the indicated time period.

ARTICLE 4 - WAIVER OF FACILITIES CAPITAL COST OF MONEY

The contractor is aware that facilities capital cost of money is an allowable cost but waives the right to claim it under this contract.

The attached letter was sent to the following people:

CONTAINMENT INTEGRITY
PEER REVIEW GROUP

July 1982

Mr. Thomas J. Ahl
Nuclear Design Group
Chicago Bridge & Iron Co.
800 Jorie Boulevard
Oak Brook, IL 60521
FTS 8-312-654-7365

Dr. Wilfred E. Baker
Dept of Ballistics & Exp. Sci.
Southwest Research Institute
6220 Culebra Rd
PO Drawer 28510
San Antonio, TX 78284
512-684-5111
FTS 8-730-5511

Dr. Richard Denning
Battelle Columbus Laboratories
505 King Ave
Columbus, Ohio 43201
614-424-7510
FTS 8-976-7510

Dr. Asadour H. Hadjian
Bechtel Power Corporation
12400 E Imperial Highway
Norwalk, CA 90650
FTS 8-213-807-3031, Ext. 3419

Dr. George E. Howard
ANCO Engineers, Inc.
9937 Jefferson Blvd
Culver City, CA 90230
FTS 8-213-204-5050

Professor Mete A. Sozen
Dept of Civil Engineering
University of Illinois
503 W Michigan
Urbana, IL 61801
217-333-3929
FTS 8-957-3929

Dr. John D. Stevenson
Stevenson & Associates
9217 Midwest Ave
Cleveland, Ohio 44122
FTS 8-216-587-3805

Dr. Joseph J. Ucciferro
Structural Analysis Group
United Engineers & Constructors, Inc.
30 S 17th St
Philadelphia, PA 19101
FTS 8-215-422-3436

Dr. George Sliter
Electrical Power Research Institute
3412 Hillview Avenue
PO Box 10412
Palo Alto, CA 94304
FTS 8-415-855-2935

Professor Richard N. White
School of Civil & Environ. Engr
Hollister Hall
Cornell University
Ithaca, NY 14853
607-256-3690
FTS 8-882-2611

Sandia National Laboratories

Albuquerque, New Mexico 87185

date: November 10, 1983

to: Containment Integrity Peer Review Committee

from: J. Jung, 6442

J. Jung

subject: Notes from the August 1983 Peer Review Meeting

Enclosed are notes from the August 2-5, 1983 Peer Review Group Meeting.

Copy to:
J. Burns, NRC
J. Costello, NRC
B. Browzin, NRC
H. Ashar, NRC
G. Lear, NRC
J. Steer, Stone & Webster
S. Martinez, Stone & Webster
P. Moncarz, Failure Analysis
J. Osteraas, Failure Analysis
1523 C. H. Conley
6442 W. A. von Riesemann
6442 T. E. Blejwas
6442 D. S. Horschel
6442 J. Jung
6442 L. N. Koenig
6442 R. T. Reese
6442 File

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NOTES FROM THE CONTAINMENT INTEGRITY PROGRAM PEER REVIEW MEETING

Bethesda, MD.

August 2-5, 1983

Notes from the Peer Review Group Meeting
Holiday Inn, Bethesda, MD
August 3-4, 1983

ATTENDEES

Peer Review Group

- T. Ahl, Chicago Bridge & Iron
- B. Baker, Southwest Research Institute
- G. Sliter, EPRI
- J. Ucciferro, United Engineers and Constructors, Inc.
- J. Stevenson, Stevenson & Associates
- M. Sozen, University of Illinois
- R. Denning, Battelle Columbus Laboratories
- D. White, Cornell University

Guest

- J. Rashid, Anatech

NRC

- J. Burns
- J. Costello
- B. Browzin
- H. Ashar
- G. Lear

Sandia

- W. A. von Riesemann
- T. E. Blejwas
- R. T. Reese
- C. H. Conley
- J. Jung

Stone and Webster

- J. Steere
- S. Martinez

Failure Analysis

- P. Moncarz
- J. Osteraas

Agenda

The initial agenda for the meeting is enclosed as Attachment 1. The primary purpose of this meeting was to obtain a Peer Review Group consensus for the design (and possibly fabrication) of all of the significant features of the concrete containment model. Work performed by Stone & Webster and Failure Analysis on the modeling of a scaled concrete containment was presented. In addition to the design of the concrete model, results from the small steel tests, the test philosophy and contingency plans for the large steel model, the status of the U.K. prestressed test, Sandia's penetration program, Japanese seismic activities and future containment program tests were discussed.

Failure Analysis Presentation (See Attachment 2 for details)

Failure Analysis proposed a scale of 1:14. There were a number of questions brought up, e.g.,

- What is the significance of the structure's own weight? Is it necessary to add weight artifically?
- Can the Diagonal seismic reinforcing be adequately modeled with more hoop and meridional reinforcement?
- Does all of the shear reinforcing in the basemat need to be included?
- Is it necessary to have one-for-one rebar replacement?
- Can liner and stud welding be modeled?
- Could the dome be explosively formed?
- How many and what kind of construction mock-ups are needed?
- Should the liner be built on site or shipped in?
- Can a "thicker" liner be used? Liners are usually thicker around penetrations anyway.

There was no indepth discussion of these questions.

Stone and Webster Presentation (See Attachment 3 for details)

Stone and Webster proposed a scale of 1:10.

Again the question of whether one-to-one rebar and stud replacements is needed was raised but there were no clear answers.

Whether a constrained penetration should be included was brought up.

General Discussion of Both Failure Analysis and Stone & Webster Work

- Cost vs. scale and quality of result vs. scale plots are needed. It is unlikely that either of these plots will be available, though.
- The notion that separate effects tests would be far more important than a scale model test was brought up by Ucciferro and Sozen.
- A possible option would be to have a higher design pressure (i.e., use thicker materials).
- The primary problem with increasing the thickness of the liner is that important failure modes may not be replicated.

The Peer Review Panel reached a general consensus that if "off the shelf" items could be used, they should be used. This thought led to considering a 1:6 to 1:8 scale model. At 1:6 scale the liner would be 1/16" thick. At this thickness the conventional welding techniques could be used for the liner and No. 3 rebar could be used as the main reinforcement.

Some advantages to building a 1/6 or 1/8 scale model would be:

1. Off the shelf material could be used.
2. The need for specially trained labor is minimized.
3. There would be larger construction tolerances than with smaller models.
4. Fewer tests would be needed to characterize steel and concrete and to validate welding techniques.
5. Modeling of cracks is more accurate with larger model.
6. The model would be easier to instrument.

Disadvantages include:

1. More material would be needed.
2. A larger model means larger loads will be needed.
3. Heavier construction equipment would be needed.
4. We are faced with shipping a liner a potentially long distance.

There was a general consensus that a scale of 1:6 should be adopted so that No. 3 rebar and a 1/16" thick liner could be used. There was some reservations expressed by Tom Ahl about scaling of welds and John Stevenson about transportation and construction of such a large model. There appeared to be a consensus that the "right" people could weld 1/16" material.

On the question of the number of studs needed, there was no general consensus. Separate testing is needed to determine if a one-to-one stud replication is needed. Some thought that some sections of the model could be built with one-to-one stud replacement and other sections need not have full replication. Certain areas of major concern (i.e., around penetrations cylinder wall basemat junctions, and wall-dome intersections) full stud replication is probably needed.

On to the question of how to fabricate the liner, there was no general agreement. Ucciferro felt that as much field welding should be used as possible. Baker felt field welding was acceptable. White would like the liner shipped in and Ahl believed field welding is dangerous.

Based on the previous discussions, Tom Blejwas presented the following description of the model:

1:6th to 1:8th scale

1/16" liner

#3 rebar

Equipment hatch

Personnel lock

Constrained penetration

Embedment Plates

Diagonal reinforcement

There was general agreement with this model description. There was also general agreement of the need for separate effects tests including:

1. Stud spacing
2. Welding procedures
3. Mock-up of wall, penetrations, rebar placement, and concrete pour
4. Panel tests for scale verification

Other Topics

Bob Reese presented contingency plans for the large steel model test (see Attachment 4).

George Sliter presented an outline of the EPRI-sponsored concrete research (see Attachment 5).

*Action Item

Walt von Riesemann asked Denning for temperature and pressure histories for BWR accidents.

*Action Item

Jim Costello asked the Peer Review Group the following questions:

What should be done with dynamic and seismic loading?

Can the test results from the reinforced concrete model be used to predict prestressed concrete containment behavior ? Do we need a prestressed concrete containment test ?

Attachment 1

AGENDA

PEER REVIEW GROUP MEETING
Bethesda, Maryland

August 3 - 4, 1983

Tentative Agenda

Wednesday, August 3, 1983

8:30 a.m.	Opening Comments	J. F. Costello T. E. Blejwas
8:40 a.m.	Presentation by Failure Analysis Associates	P. D. Moncarz J. D. Osteraas
9:30 a.m.	Break	
9:40 a.m.	Continuation of FaAA Presentation	
10:30 a.m.	Break	
10:40 a.m.	Discussion Period	
11:30 a.m.	Lunch	
1:00 p.m.	Presentation by Stone & Webster	J. W. Steere M. B. Stetson
1:50 p.m.	Break	
2:00 p.m.	Continuation of Stone & Webster Presentation	
2:50 p.m.	Break	
3:00 p.m.	Discussion Period	
4:00 p.m.	End of Wednesday's Activities	

PEER REVIEW GROUP MEETING
Bethesda, Maryland

August 3 - 4, 1983

Tentative Agenda

<u>Thursday, August 4, 1983</u>

8:30 a.m.	Discussion of Conceptual Design and Fabrication Plans for the Concrete Model	T. E. Blejwas
11:30 a.m.	Lunch	
1:00 p.m.	Recent Results from Small Steel Tests	T. E. Blejwas
1:15 p.m.	Test Philosophy for Large Steel Models	T. E. Blejwas
1:30 p.m.	Contingency Plans for Large Steel Model	R. T. Reese
1:45 p.m.	Status of U.K. Prestressed Test	W. A. von Riesemann
2:00 p.m.	Sandia Programs on Penetrations	W. A. von Riesemann
2:45 p.m.	Japanese Seismic Activities	R. White J. Stevenson
3:30 p.m.	Loading Conditions for Future Tests (Dynamic and Seismic)	
4:00 p.m.	End of Meeting	

Attachment 2

FAILURE ANALYSIS PRESENTATION

VUGRAPHS

Failure Analysis Associates
ENGINEERING AND METALLURGICAL CONSULTANTS
2225 EAST BAYSHORE ROAD
P.O. BOX 51470 PALO ALTO, CALIFORNIA 94303 (415) 856-9400

EXPERIMENTAL MODELING TECHNIQUES FOR REINFORCED CONCRETE CONTAINMENT STRUCTURES

PRESENTATION TO PEER REVIEW GROUP MEETING
BETHESDA, MARYLAND
AUGUST 3, 1983

PREPARED BY

DR. PIOTR D. MONCARZ
MR. JOHN D. OSTERAAS
MS. ANNE M. CURZON

PREPARED FOR

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE, NEW MEXICO

LOS ANGELES OFFICE 11777 MISSISSIPPI AVENUE, LOS ANGELES, CALIFORNIA 90025 (213) 479-4001
HOUSTON OFFICE 3637 WEST ALABAMA, SUITE 145, HOUSTON, TEXAS 77027 (713) 840-9460
PHOENIX OFFICE 2234 SOUTH McCLINTOCK DRIVE, TEMPE, ARIZONA 85282 (602) 929-1391

EXPERIMENTAL MODELING TECHNIQUES FOR
REINFORCED CONCRETE CONTAINMENT STRUCTURES
PRESENTATION BY
FAILURE ANALYSIS ASSOCIATES

I. DEFINITION OF GENERIC STRUCTURE

II. MODEL DESIGN - SIMPLIFICATIONS AND ACCEPTABLE DISTORTIONS
- GEOMETRY
- REINFORCEMENT
- MASS SIMULATION
- STEEL LINER
- MODEL MATERIALS

III. MODEL SCALE DEFINITION

IV. MODEL FABRICATION

V. MODEL COST ESTIMATE

VI. SUPPORT TESTS

AS A RESULT OF THE STUDY BASED ON CONSIDERATIONS OF:

- MODEL RELIABILITY
- CONSTRUCTION FEASIBILITY
- MATERIAL AVAILABILITY
- COST

FAILURE ANALYSIS ASSOCIATES PROPOSES MODEL SCALE OF 1:14

I. GENERIC STRUCTURE DEFINITION

THE STRUCTURE SHOULD BE REPRESENTATIVE OF A MAJORITY OF EXISTING R/C CONTAINMENT STRUCTURES WITH STEEL LINER. THIS INCLUDES

- OVERALL GEOMETRY
- REINFORCEMENT DETAILS
- CONCRETE - LINER ATTACHMENTS
- MATERIAL PROPERTIES

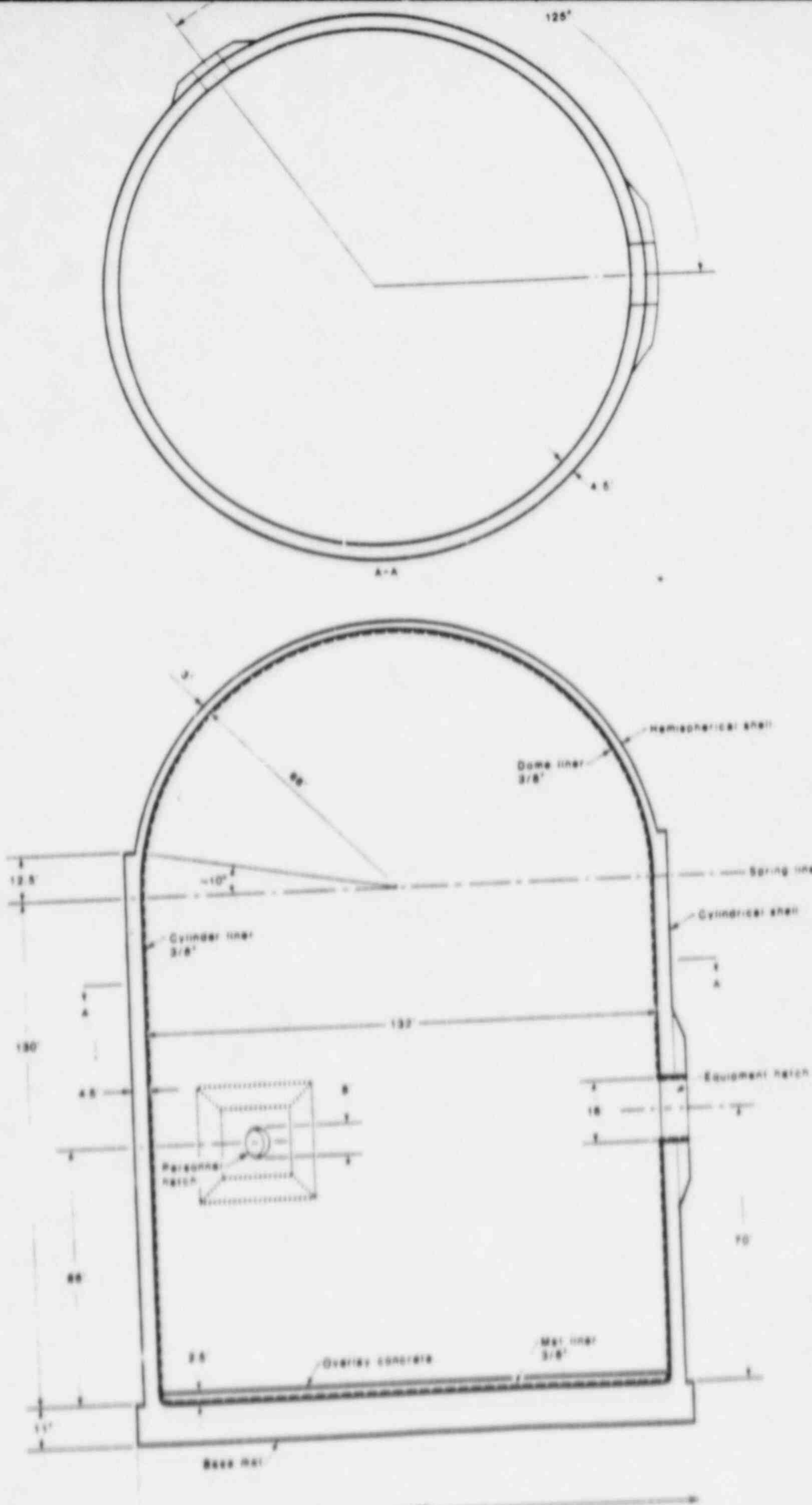


Figure 2-1. Generic containment structure geometry.

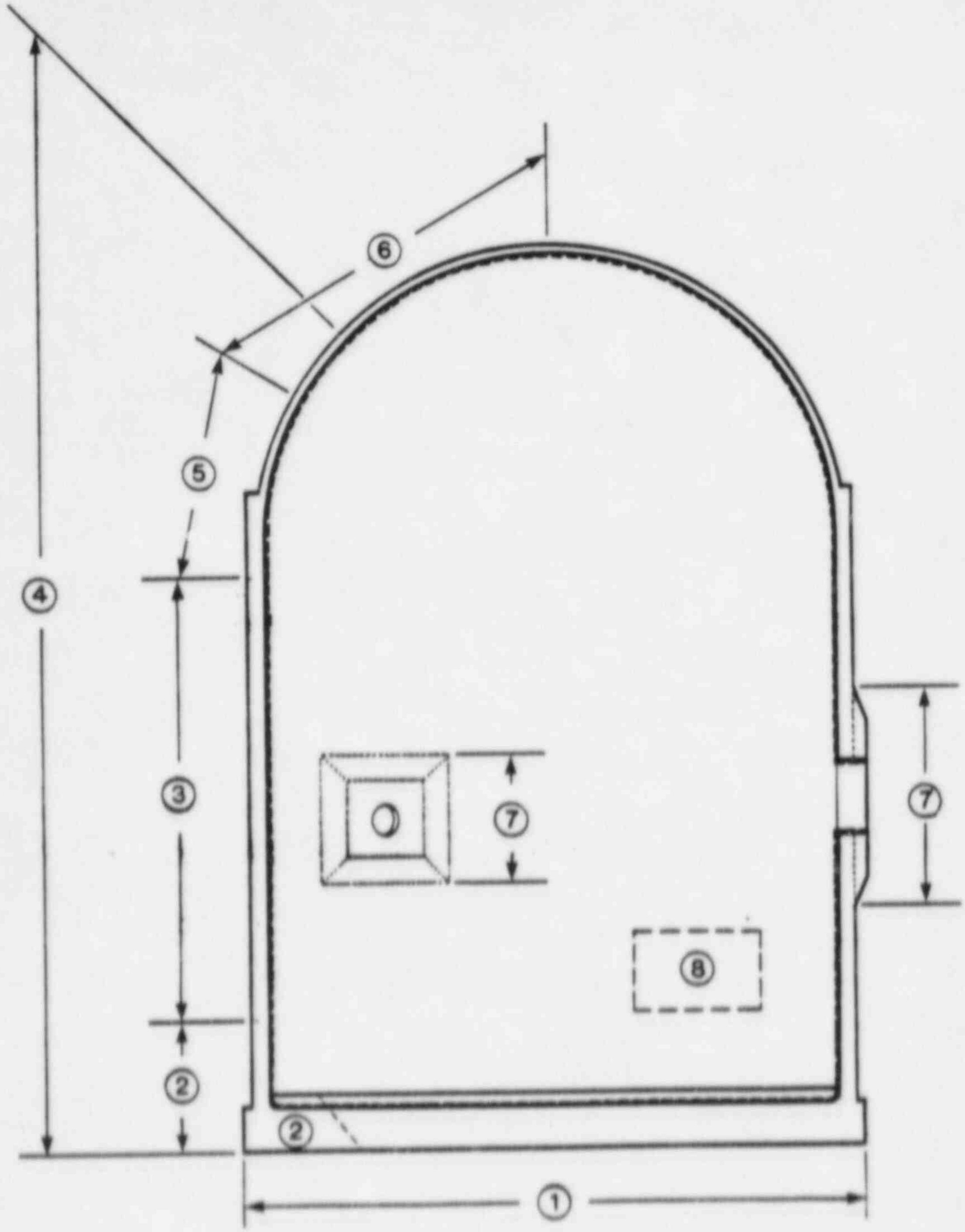


Figure 2-2. Identification key showing reinforcement zone locations.

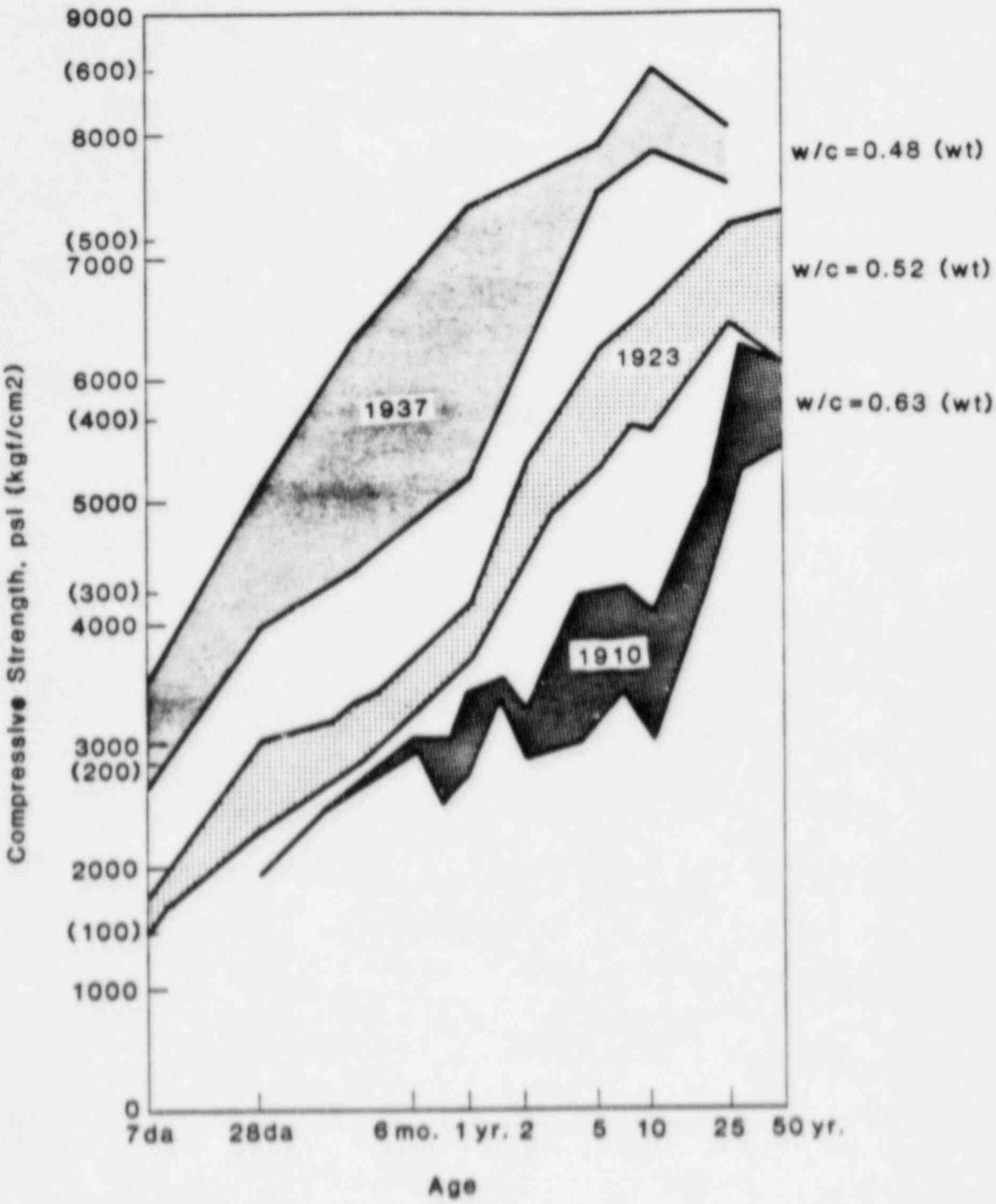


Fig. 2-14. Compressive strength-age relations for concrete (from Ref. 19).

II. MODEL DESIGN

SIMPLIFICATIONS IN MODEL GEOMETRY AND ACCEPTABLE DISTORTIONS

- MAJOR PENETRATIONS
- MINOR PENETRATIONS
- STEEL LINER
- STUD CONNECTORS
- MASS SIMULATION

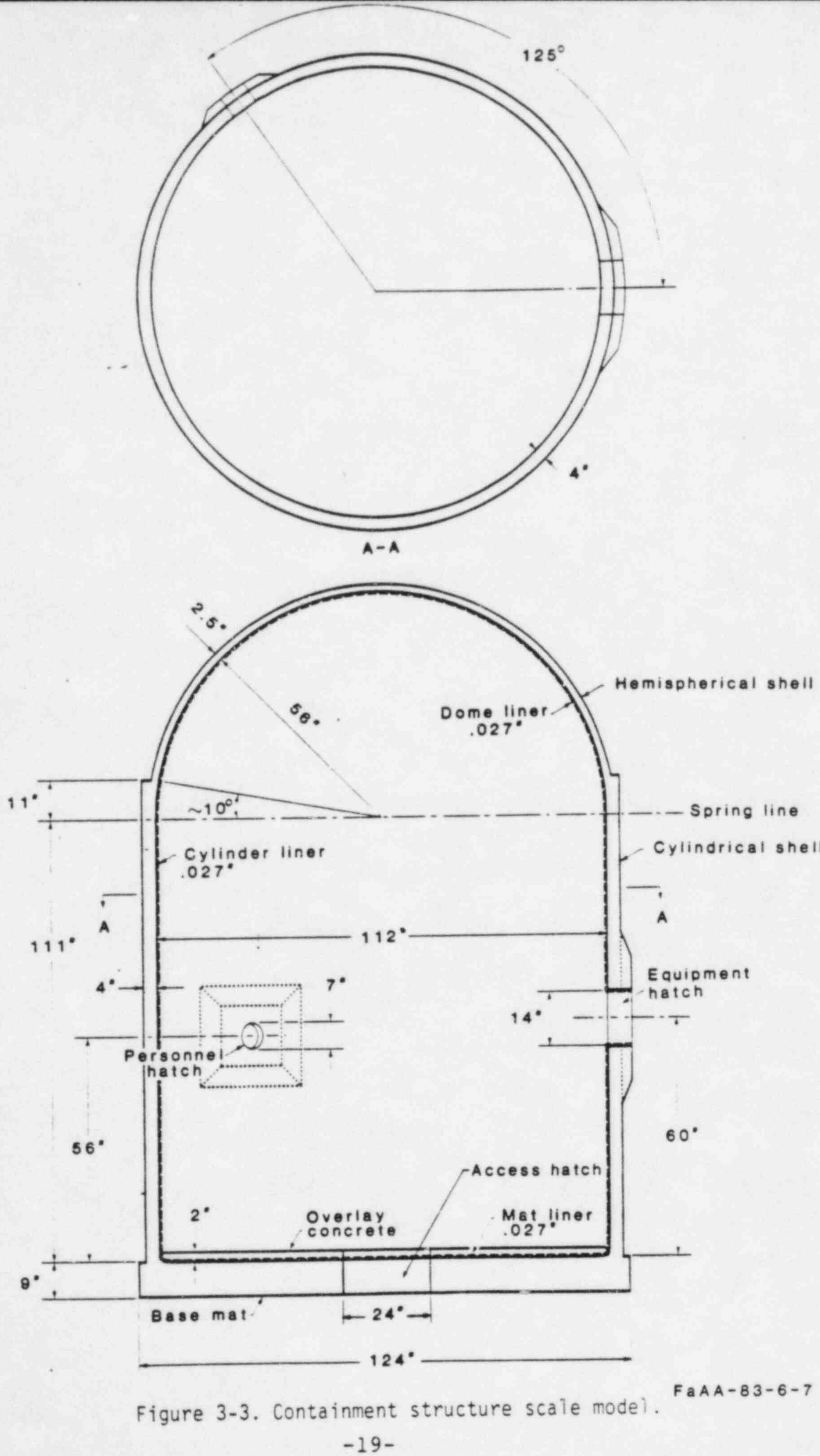


Figure 3-3. Containment structure scale model.

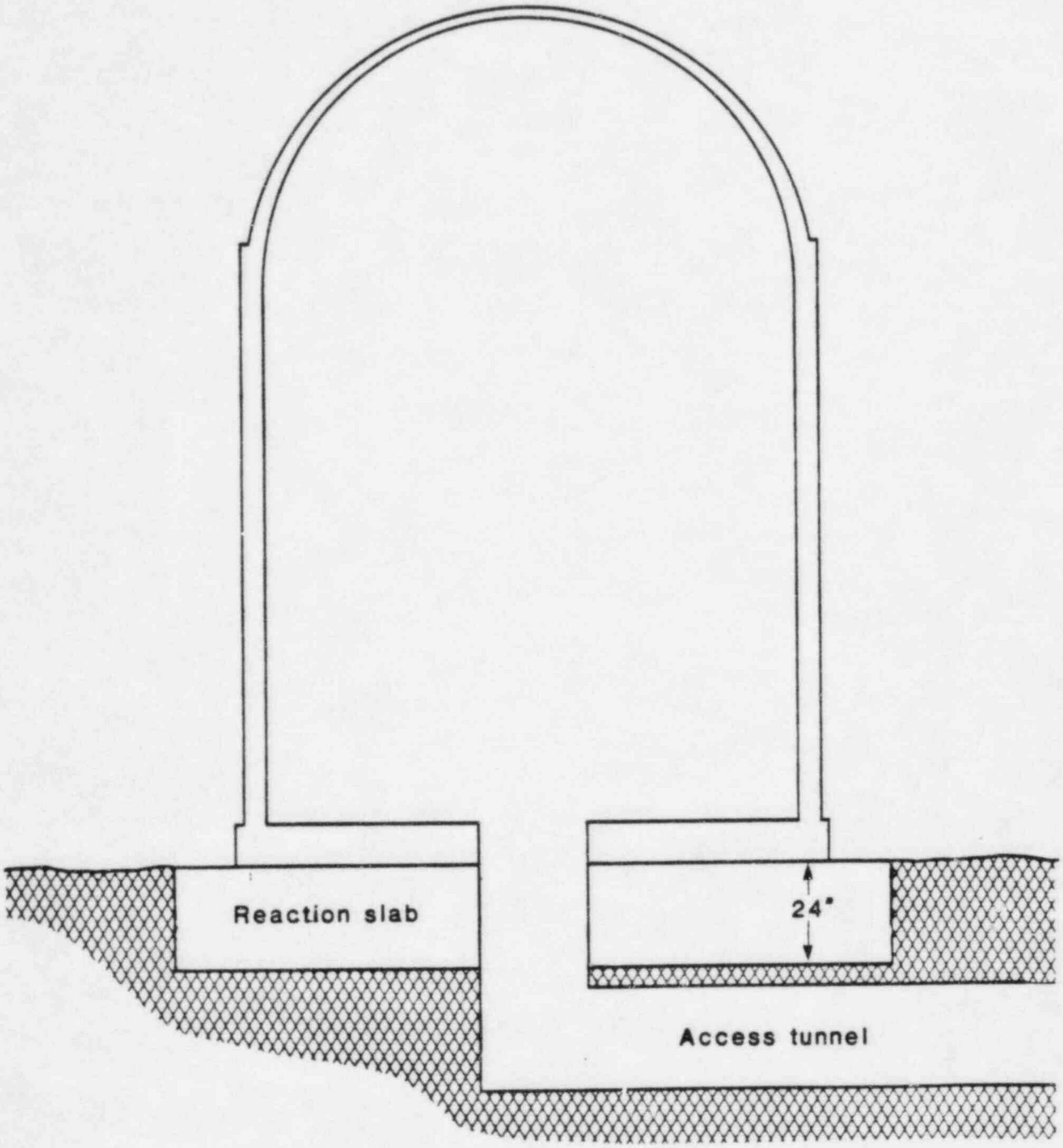


Figure 3-4. Subgrade design for model foundation.

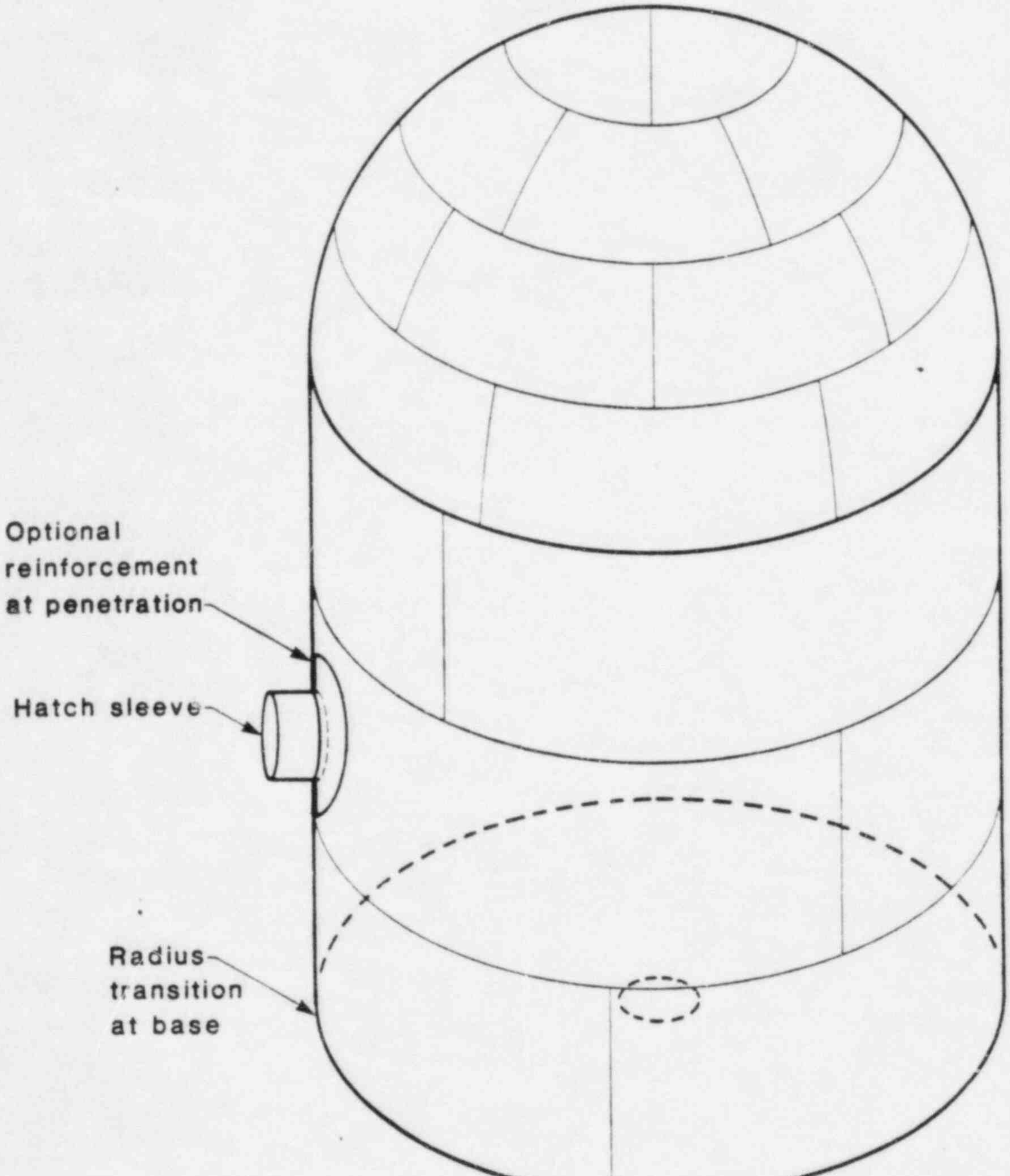


Figure 3-5. Model liner.

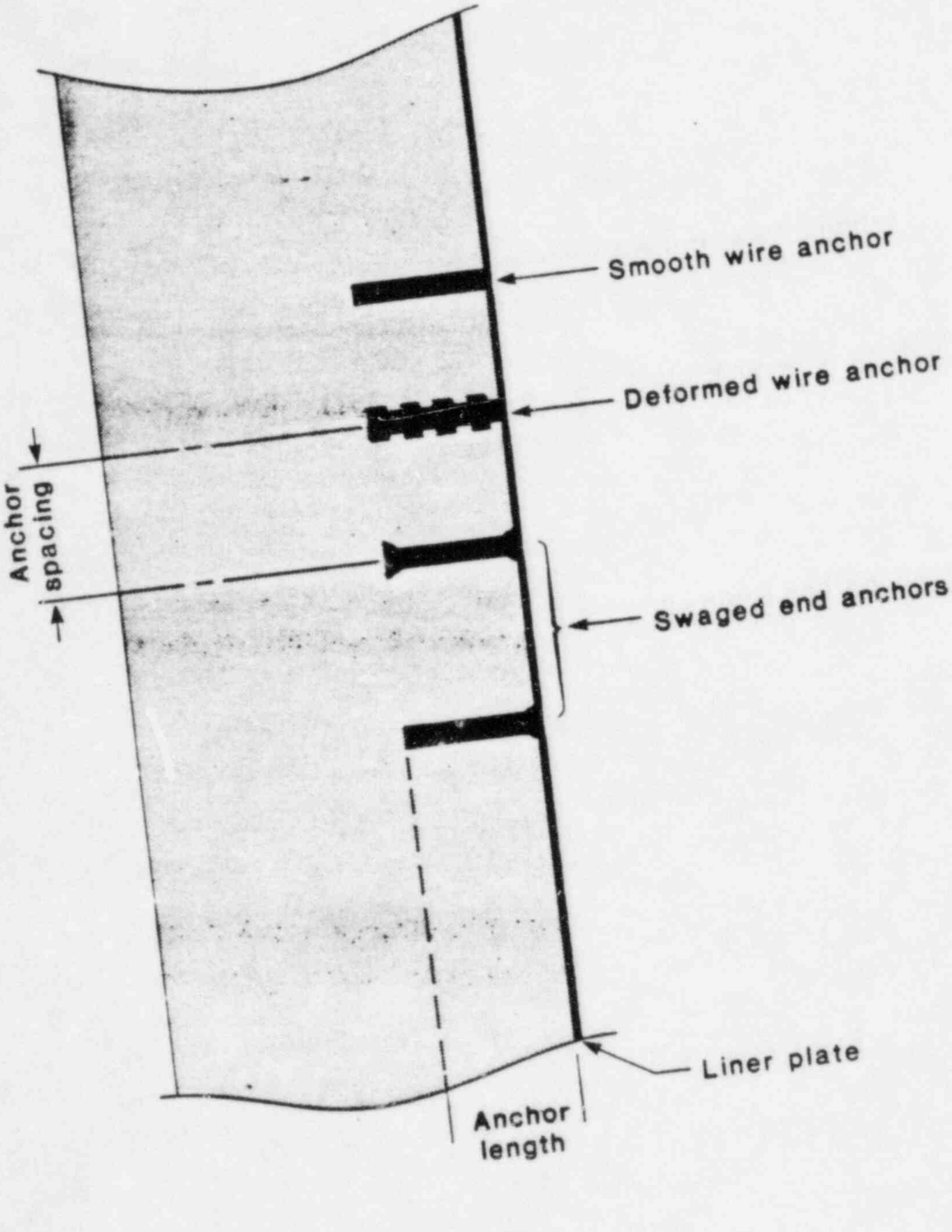


Figure 3-7. Liner anchor studs.

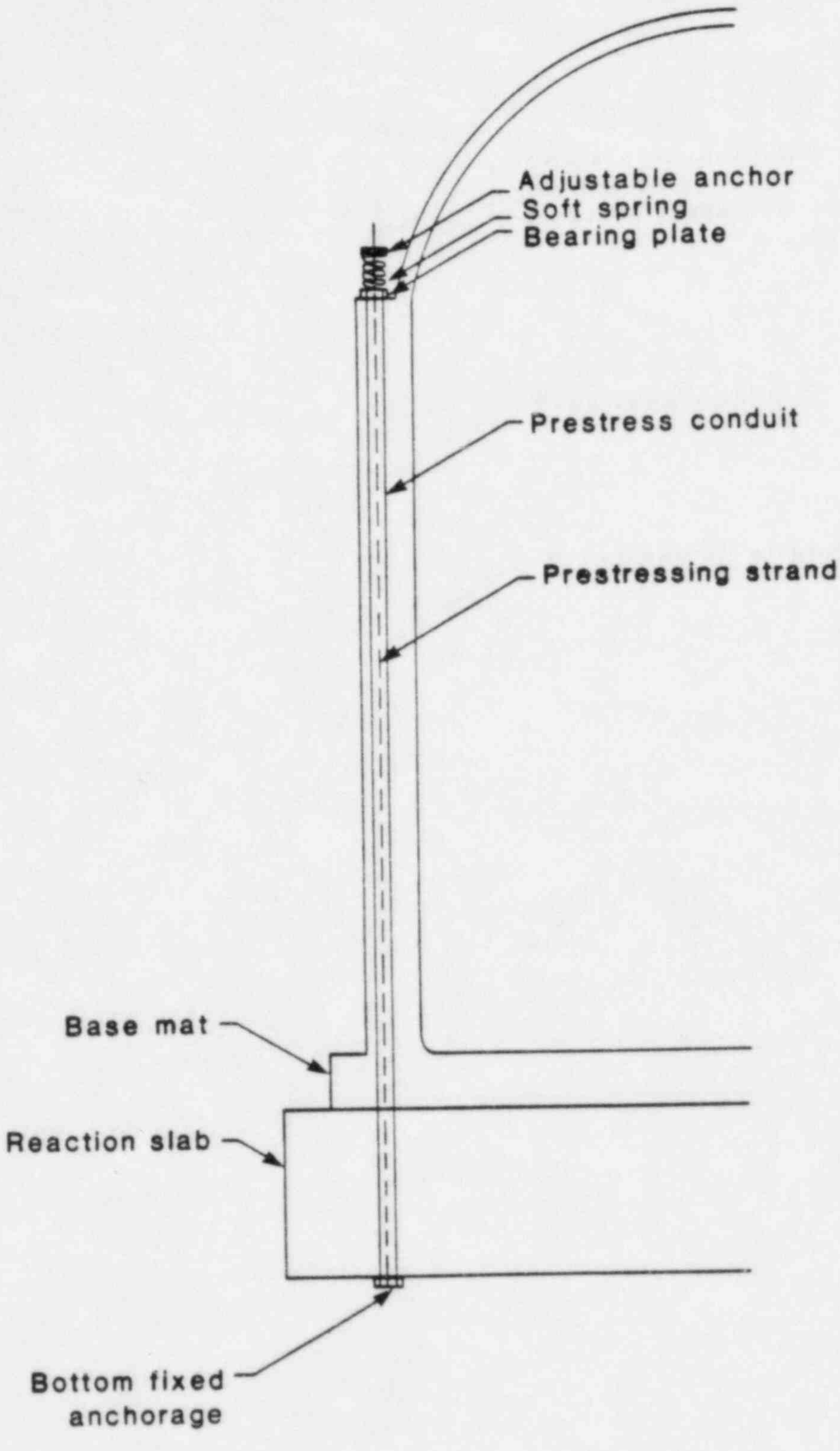


Figure 5-5. Mass simulation prestress system.

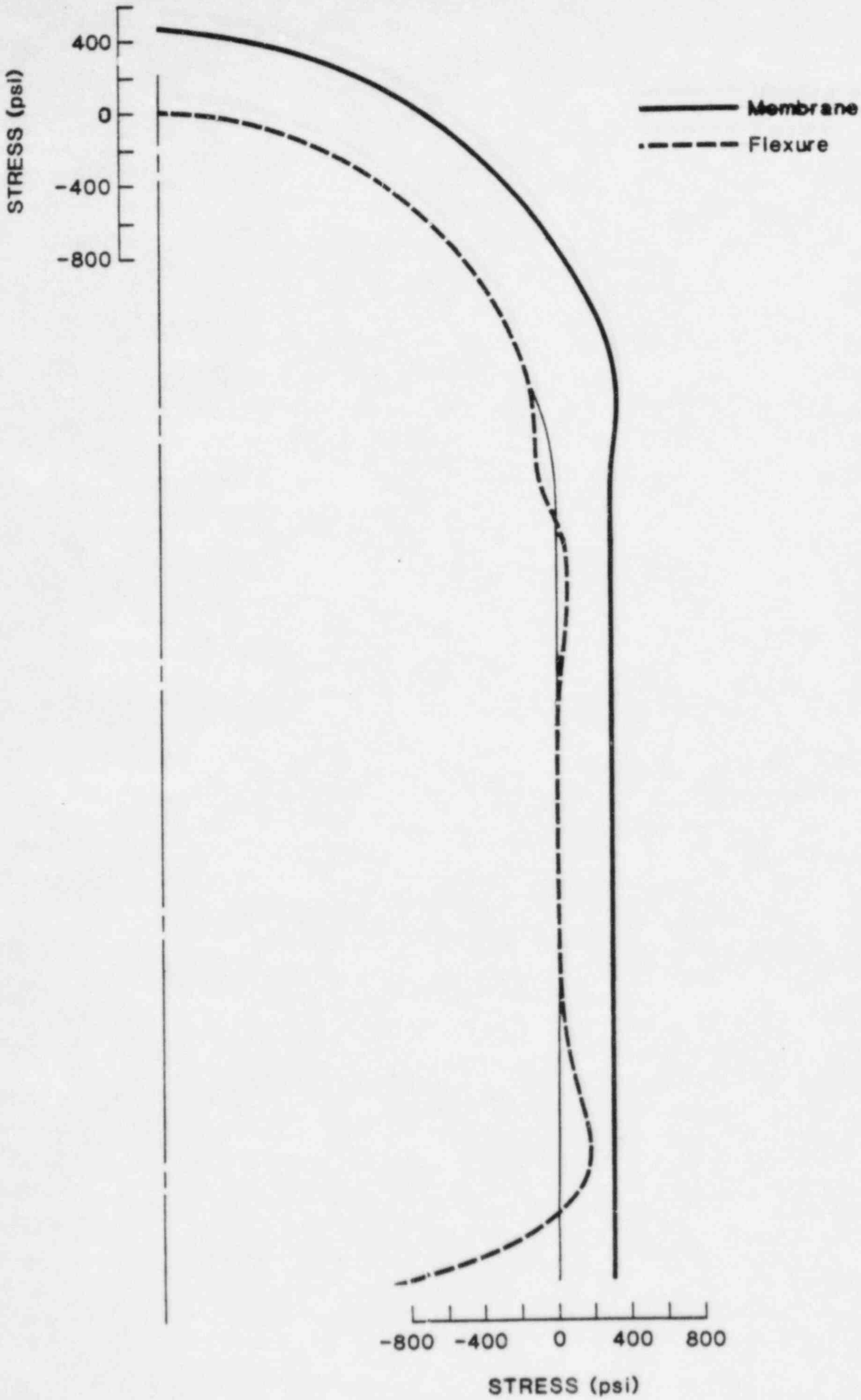


Figure 2-16. Meridional stresses at design internal pressure.

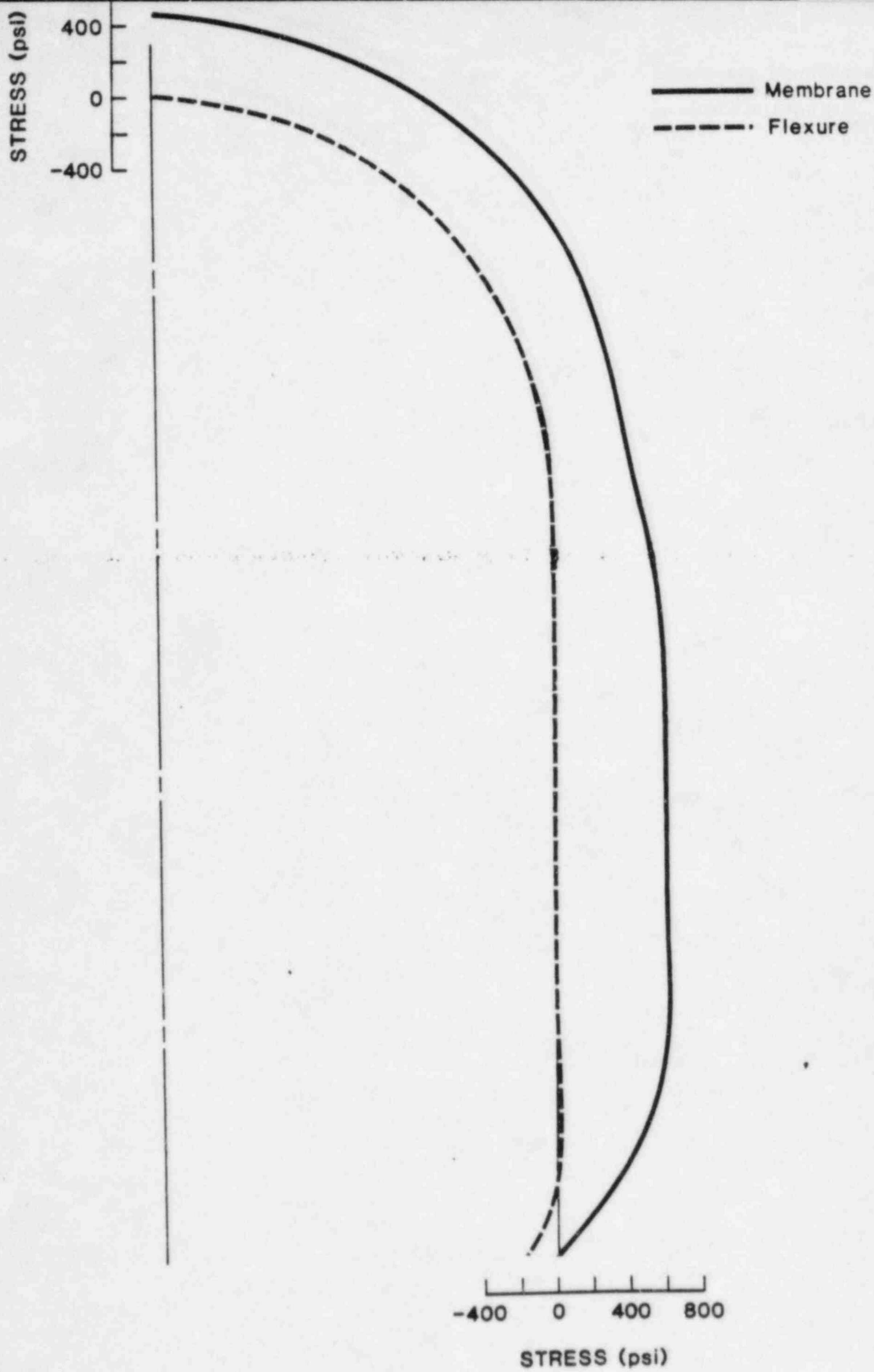


Figure 2-17. Hoop stresses at design internal pressure.

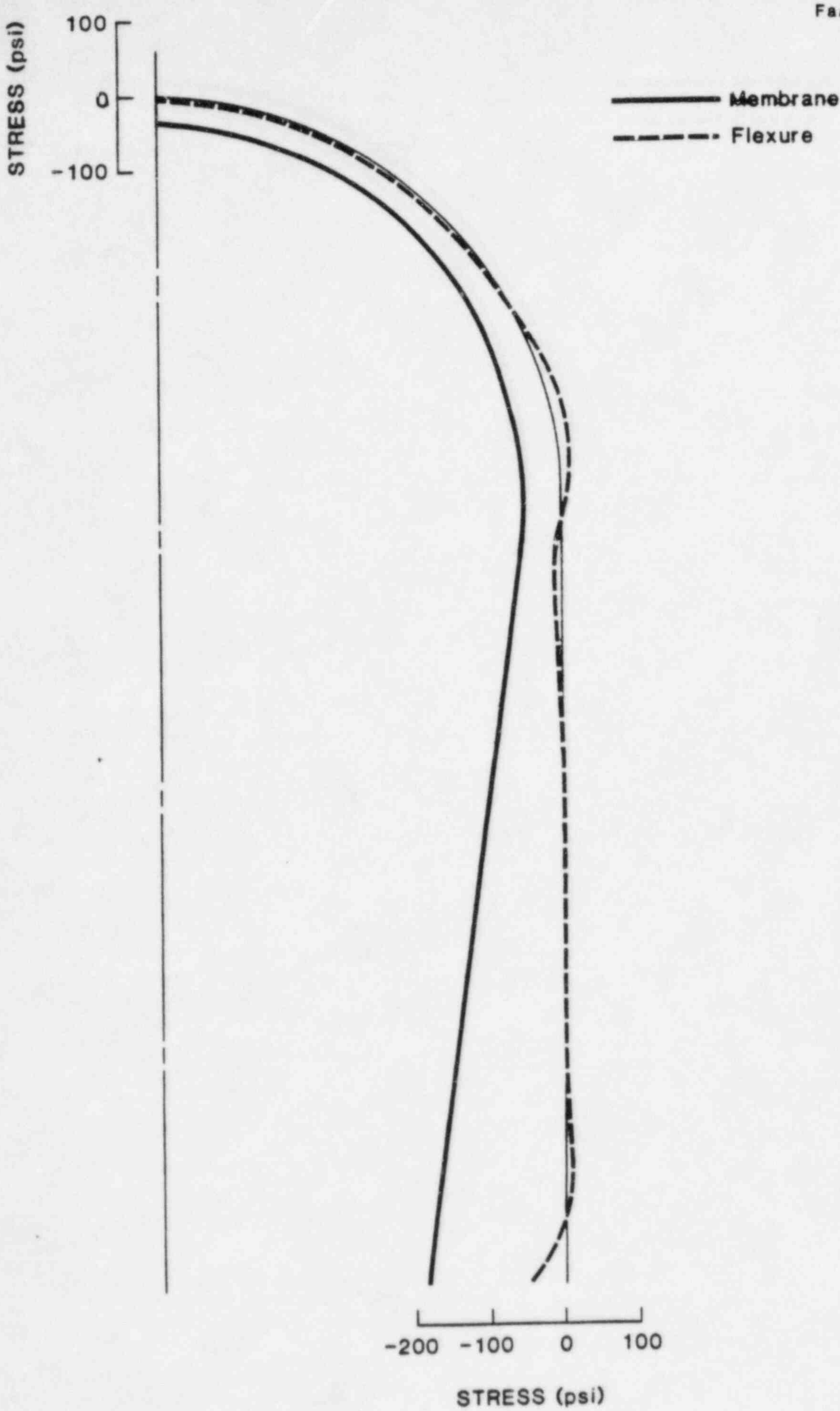


Figure 2-18. Meridional stresses due to dead load.

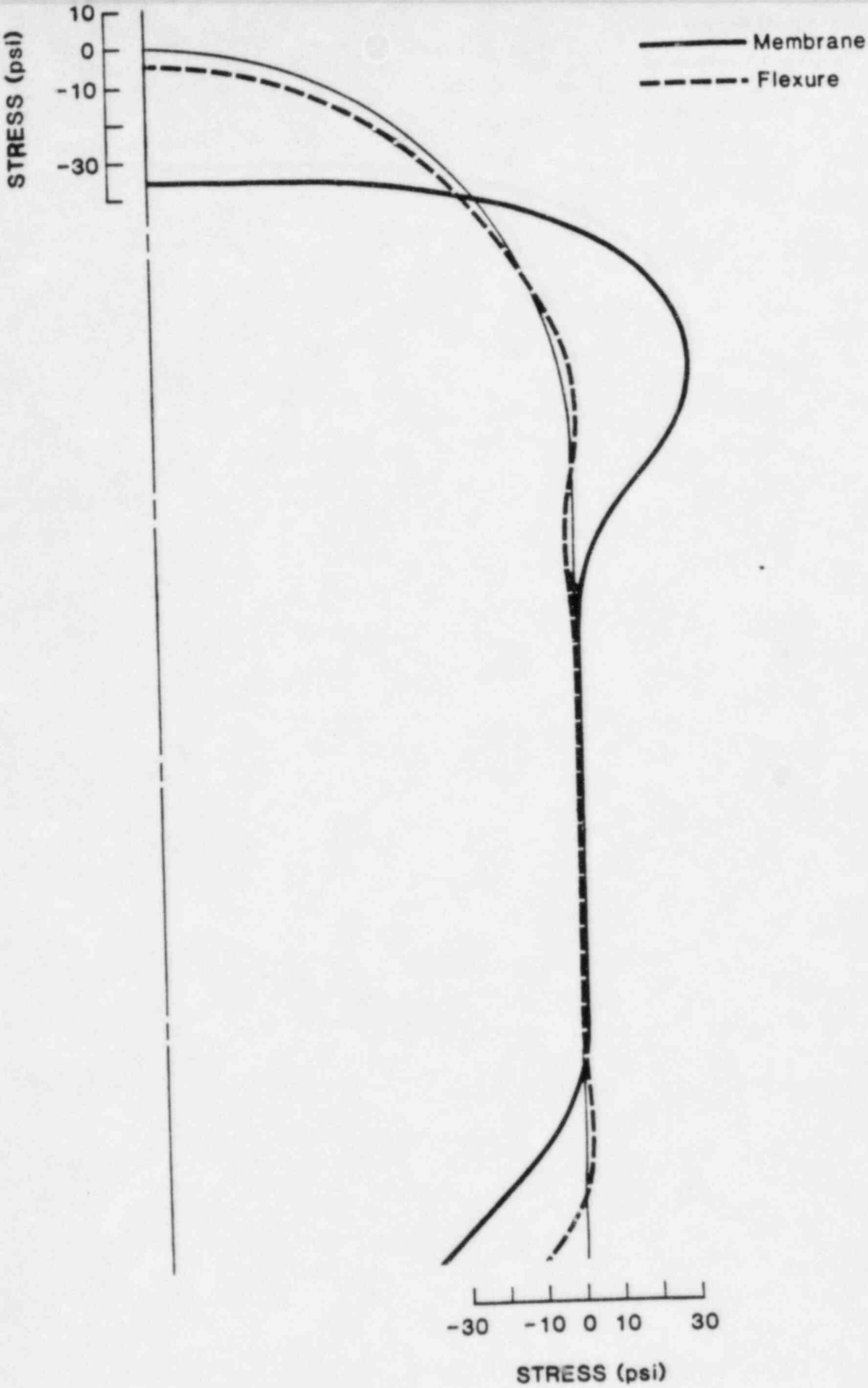


Figure 2-19. Hoop stresses due to dead load.

MODEL DESIGN

REINFORCEMENT: SIMPLIFICATIONS AND ACCEPTABLE DISTORTIONS

- TENSILE ZONE REINFORCEMENT
- HIGH SHEAR ZONE REINFORCEMENT
- SEISMIC REINFORCEMENT

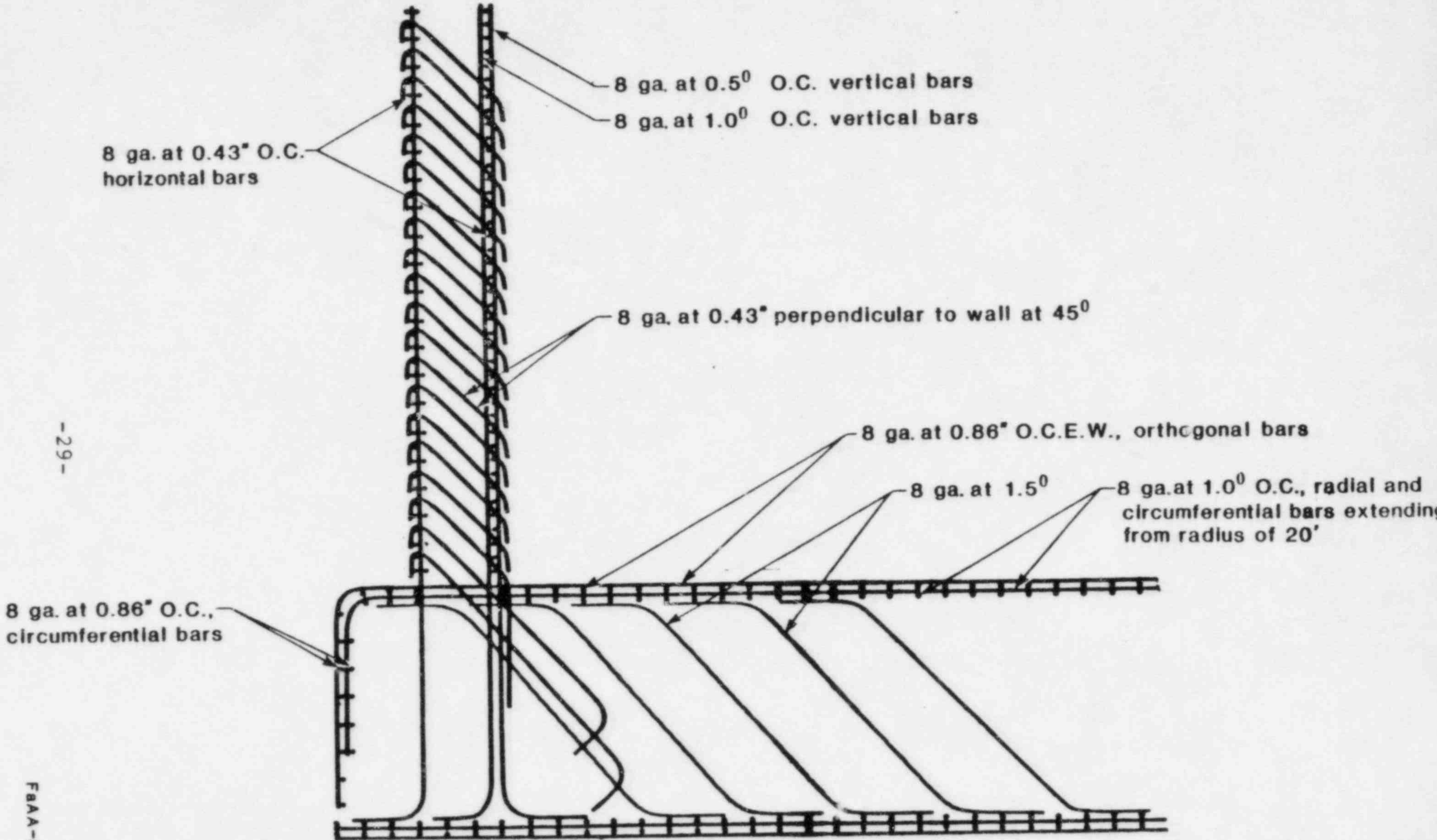


Figure 3-9. Typical model reinforcement detail at the connection of base slab and cylinder.

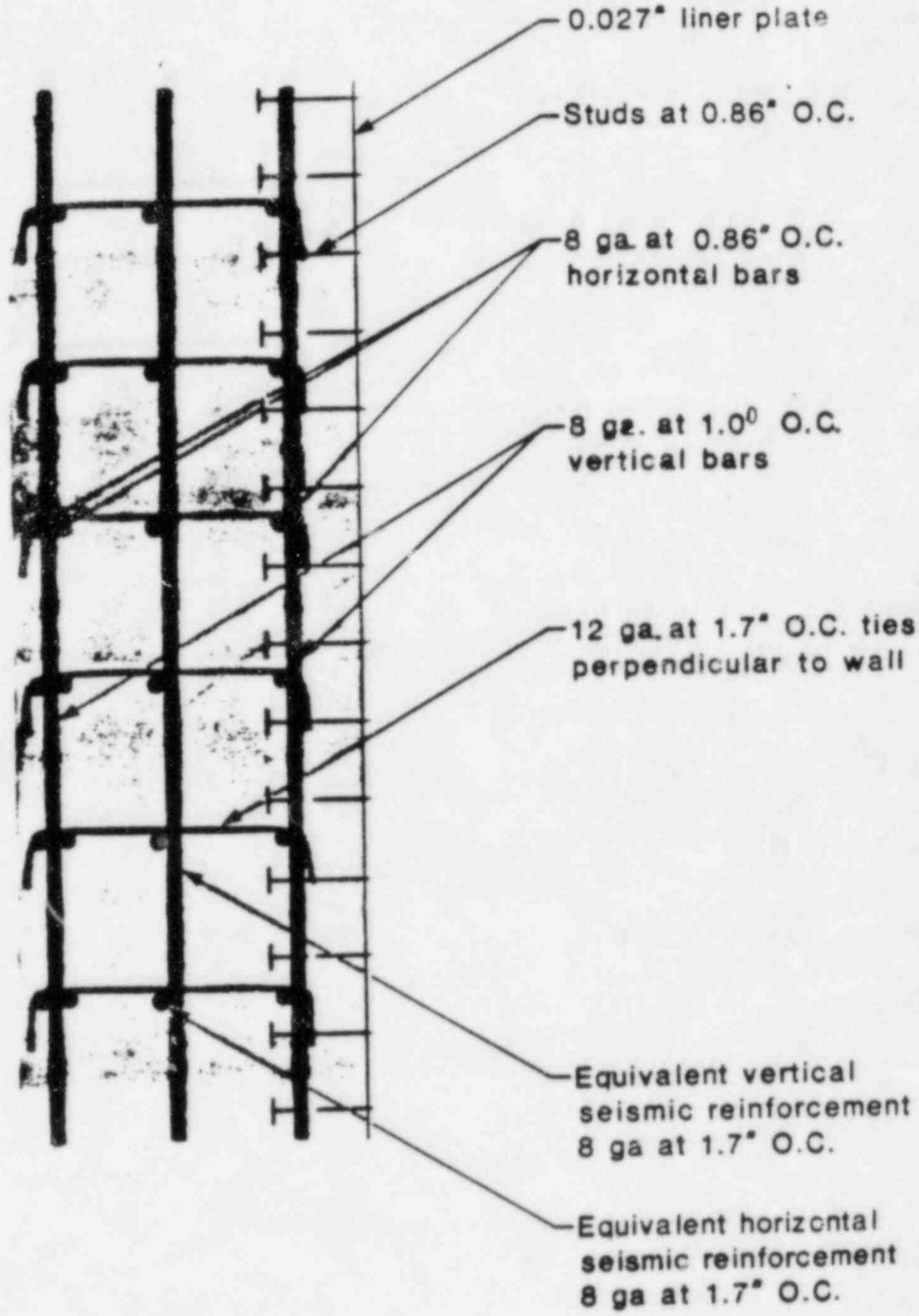


Figure 3-10. Model cylinder wall reinforcement.

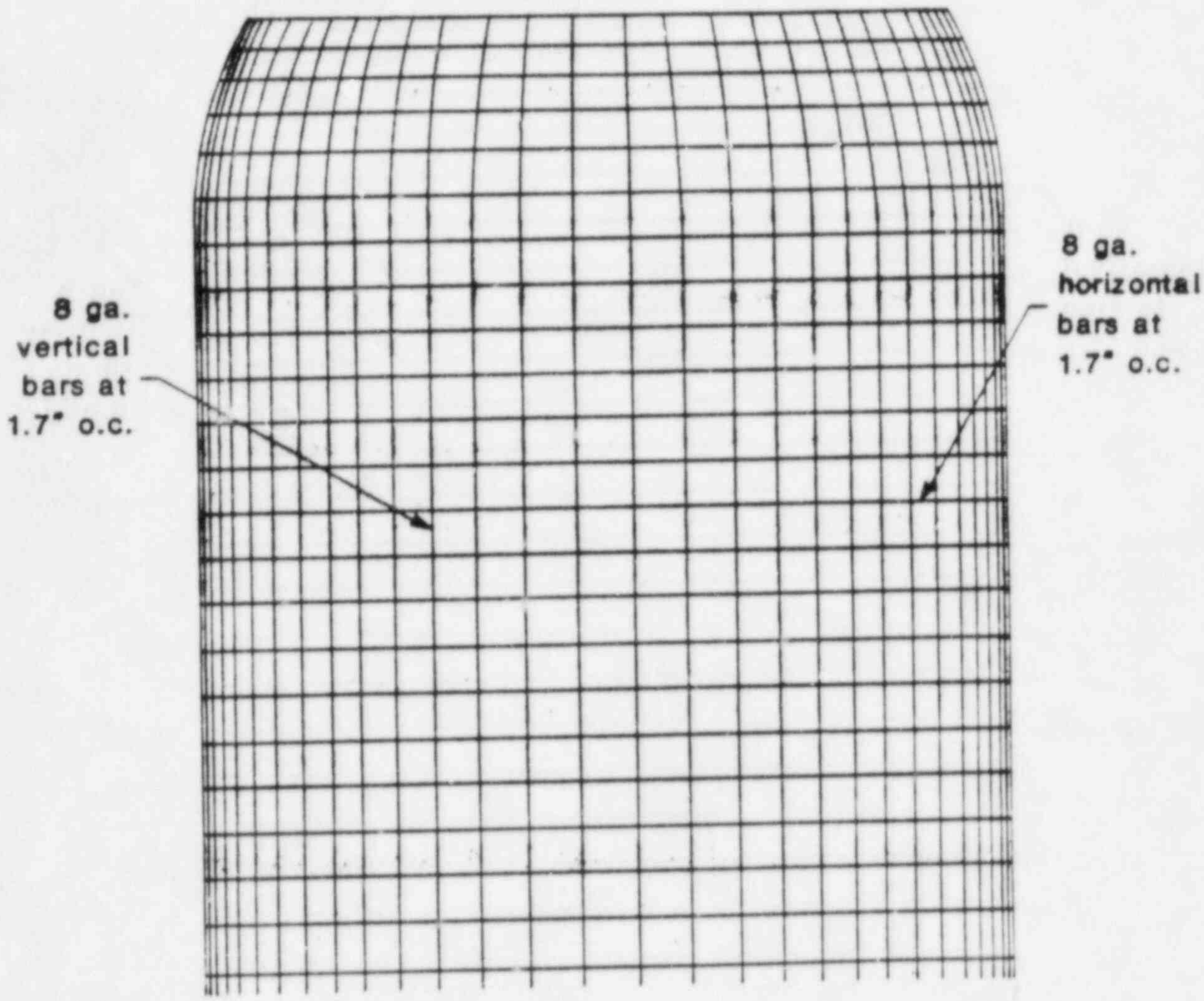


Fig. 3-13. Model seismic reinforcement.

MODEL DESIGN

MODELING MATERIALS

CONCRETE - f'_c = 3000 PSI

STRENGTH PROPERTIES

$\overline{f_c}$ = 8000 PSI

$\overline{f_T}$ = 450 PSI (?)

SHRINKAGE

REINFORCEMENT - GRADE 60

$\overline{F_Y}$ = 69 KSI

$\overline{F_U}$ = 104 KSI

LINER - ASTM A516 GRADE 60

$\overline{F_Y}$ = 48 KSI

F_U = 60 - 80 KSI

ELONGATION 25% (2") AND 21% (8")

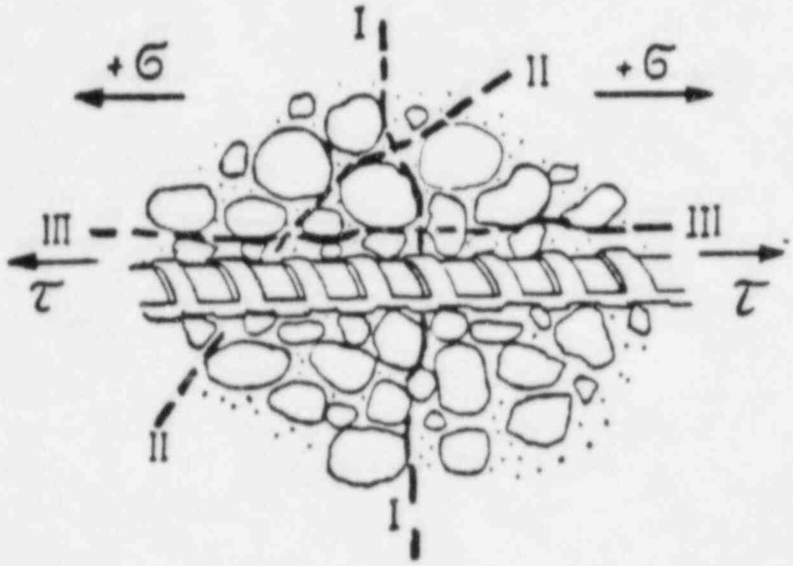


Figure 4-1. Stress transfer in reinforced concrete.

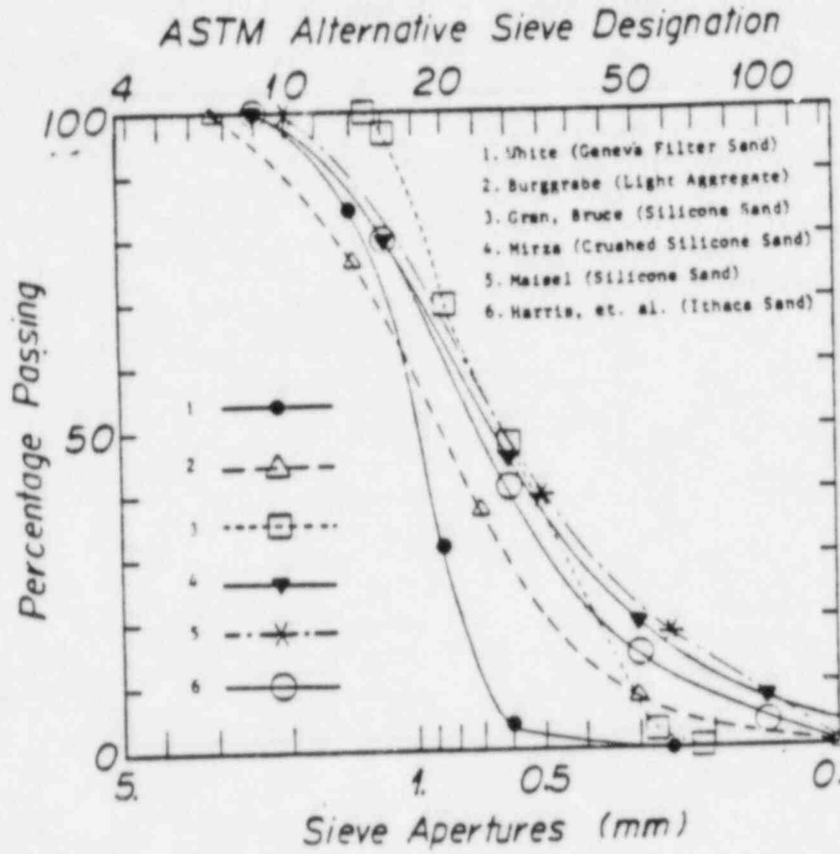


Figure 4-2. Sieve lines used by various researchers.

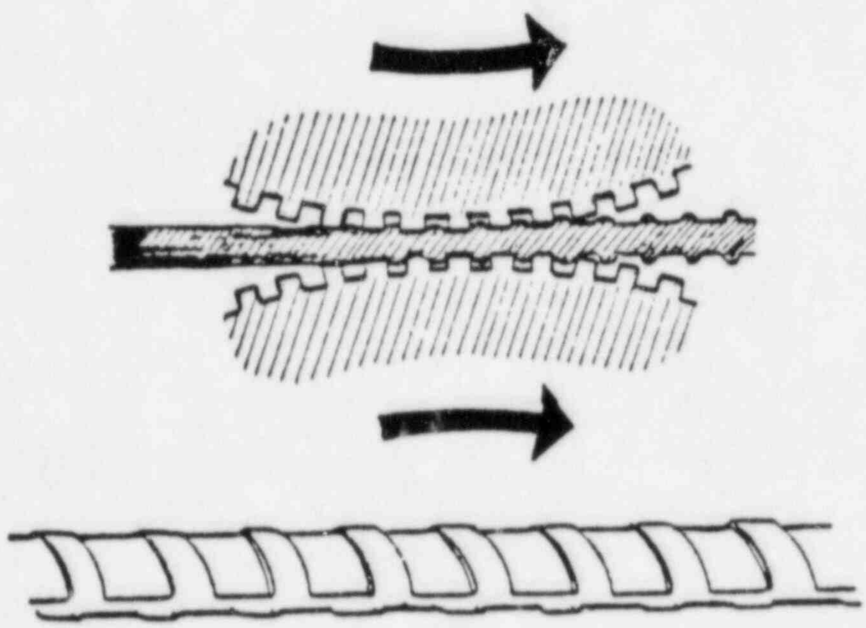


Figure 5-3. Knurling mechanism.

III. MODEL SCALE DEFINITION

MODEL SCALE DETERMINED BY:

- TEST OBJECTIVES: ULTIMATE STRENGTH MODEL 1/4 TO 1/20
- COST AND TIME: SMALLER THAN 1/8
- TEST FACILITIES: SMALLER THAN 1/8

THEREFORE, FEASIBLE RANGE OF SCALE 1/8 TO 1/20

CONSIDERATIONS WITHIN FEASIBLE RANGE

- MATERIALS

  CONCRETE: NO CONSTRAINT

  STEEL: NO CONSTRAINT

- FABRICATION

  LINER: .047 TO .019 IN.

  TRANSPORTATION - SMALLER THAN 1/11

  REINFORCEMENT: NO BAR SUBSTITUTION 1/9 TO 1/14

  1:2 BAR SUBSTITUTION 1/8.5 TO 1/20

  STUDS: POSSIBLY DOWN TO .030 INCH

  LARGER THAN 1/16

THEREFORE, DESIREABLE RANGE OF 1/11 TO 1/14

SELECT 1/14 FOR ECONOMY AND CONVENIENCE

IV. MODEL FABRICATION

- LINER
- REINFORCEMENT
- CASTING & CURING CONCRETE
- MASS SIMULATION
- PILOT FABRICATION STUDY

LINER FABRICATION

OBJECTIVE: UNIFORM LINER FREE OF STRESS CONCENTRATIONS AND FLAWS

PROBLEMS:

- THIN MATERIAL
- LARGE STRUCTURE

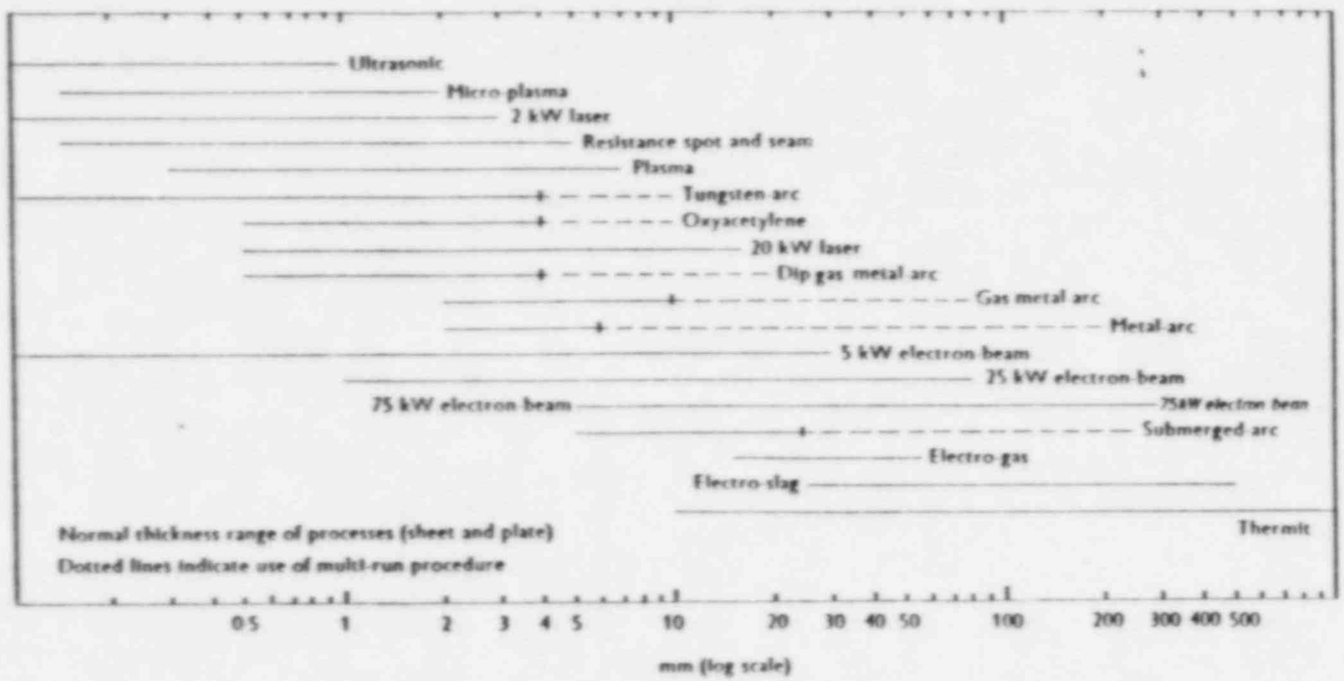
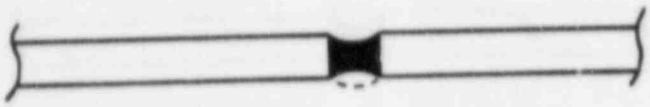
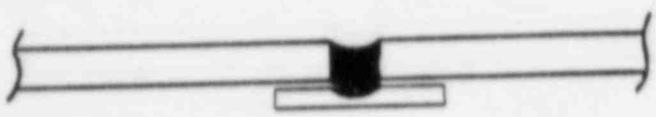


Figure 5-1. Thickness range for welding processes - log scale.

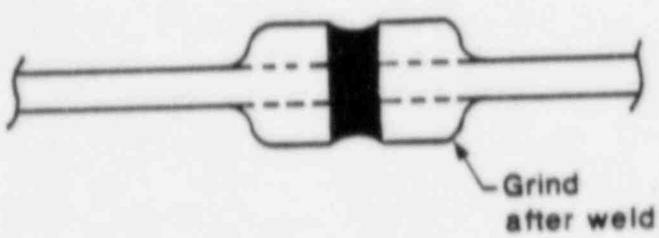
Welded joint configuration - single pass welds



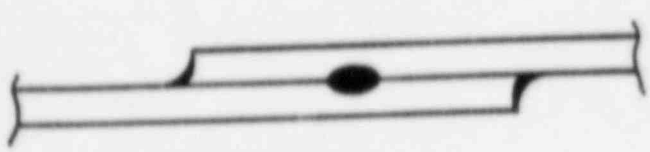
Unbacked butt weld



Butt weld with backer

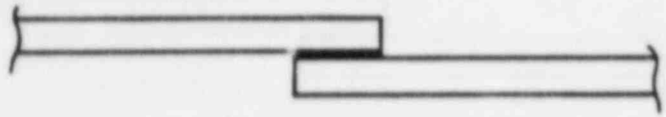


Thickened edge



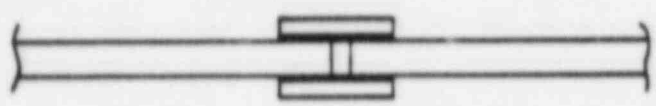
Welded lap seam

Soldered joint configurations



Simple lap

Offset lap



Symmetrical splice

LINER SIZE CONSIDERATIONS:

- CLAMPING JIG FOR ASSEMBLY
- AUTOMATED WELDING PROCEDURE
- SUPPORT STRUCTURE FOR TRANSPORTATION AND ERECTION

LINER ANCHORAGE

WALLS AND DOME:

- MODIFIED AUTOMATIC GUN DEVELOPED BY SUPPLIER
- STORED ARC WELDING PROCESS

SLAB:

- LIMITED MECHANICAL ANCHORAGE
- EPOXY GROUT

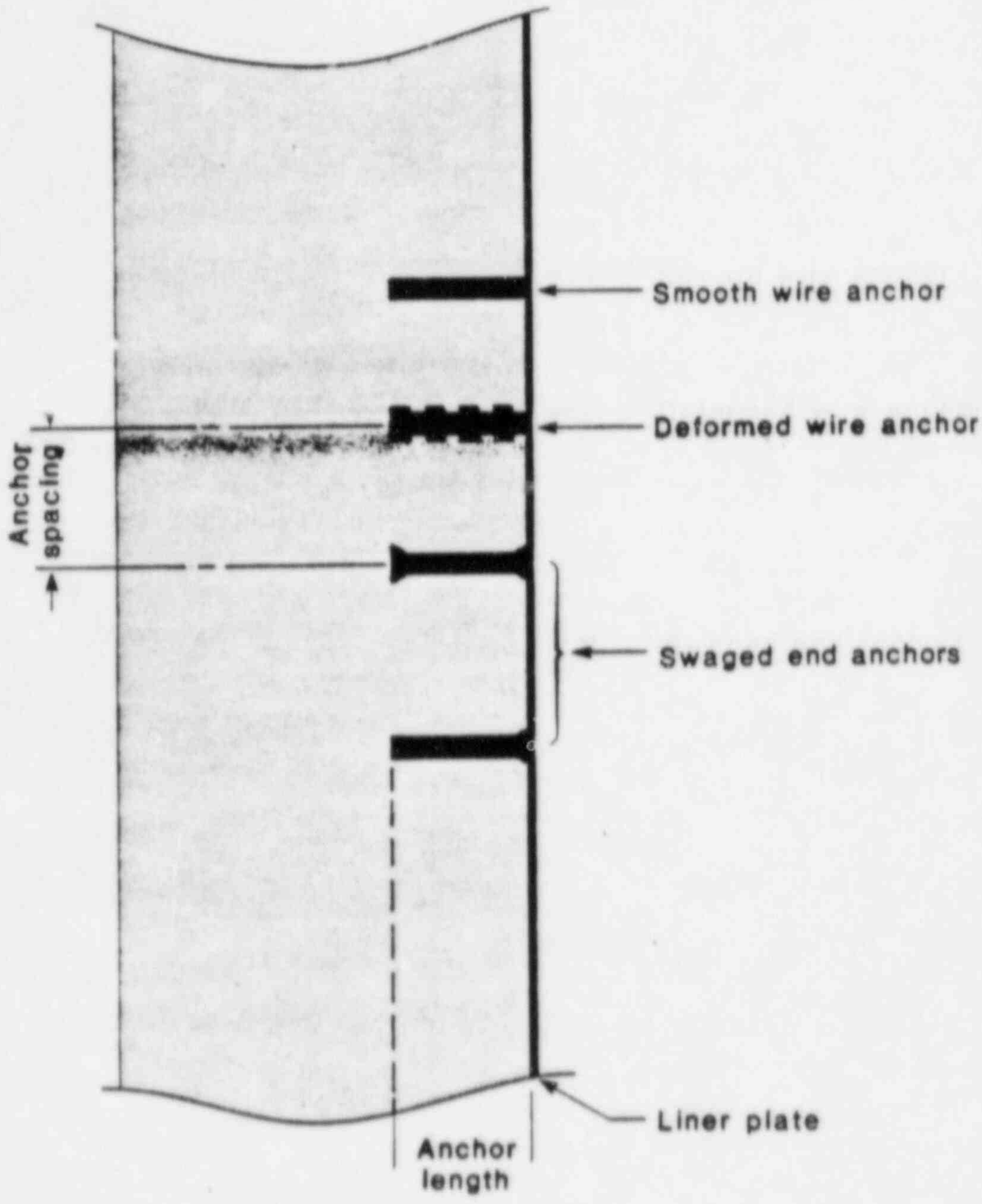


Figure 3-7. Liner anchor studs.

FaAA-83-7-9

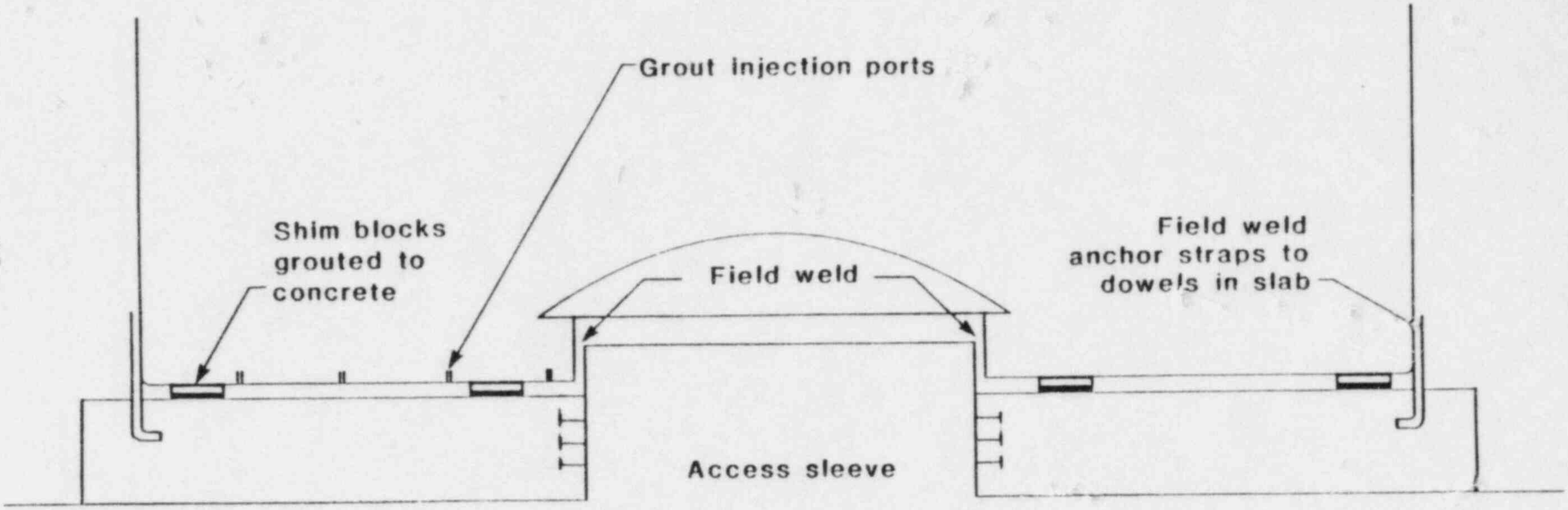


Figure 5-2. Model liner anchorage to base mat.

REINFORCEMENT MANUFACTURE

- CUSTOM ROLLING OF SOME REINFORCEMENT IS NECESSARY REGARDLESS OF SCALE
- OBJECTIVE: EMULATE MECHANICAL PROPERTIES AND GEOMETRY OF PROTOTYPE BARS AS CLOSELY AS POSSIBLE.
- PROCESS WELL DEVELOPED FOR PRODUCTION OF LABORATORY QUANTITIES
- COMMERCIALLY AVAILABLE BARS MAY REQUIRE HEAT TREATMENT

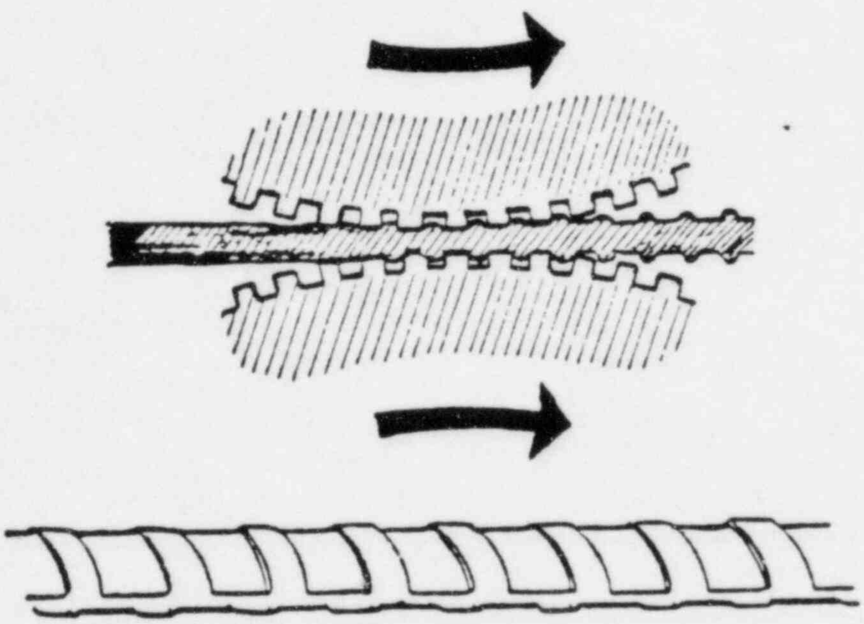
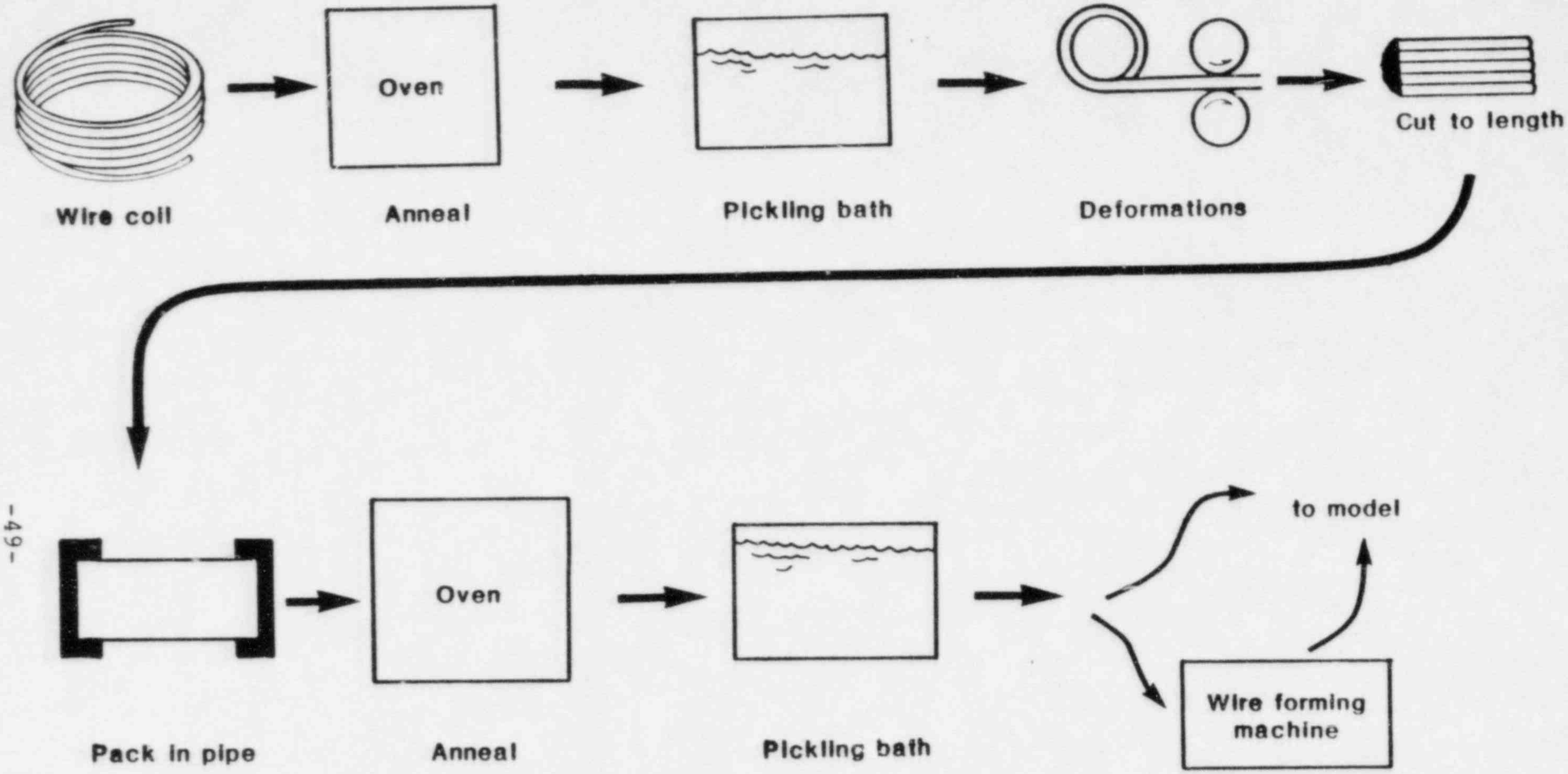


Figure 5-3. Knurling mechanism.



Model reinforcement manufacture

REINFORCEMENT ASSEMBLY

- TOLERANCES SET FORTH BY ACI AND CRSI - LINEARLY SCALED
- SPLICES SILVER SOLDERED SLEAVES
- CAGES TIED WITH WIRE (OR NYLON TIES) AND SPOT GLUED.
- DISSOLVEABLE PLASTIC TEMPLATES AT WALL BASE.

CONCRETE CASTING

- MAINTAIN SIMULITUDE OF LIFT HEIGHT
- SLIP FORM WITH MECHANICAL STRAIN RELEASE
- PUMP CONCRETE AT BASE OF FORMS
- INTERNAL PENCIL VIBRATORS
- SANDBLAST SURFACE PREPARATION

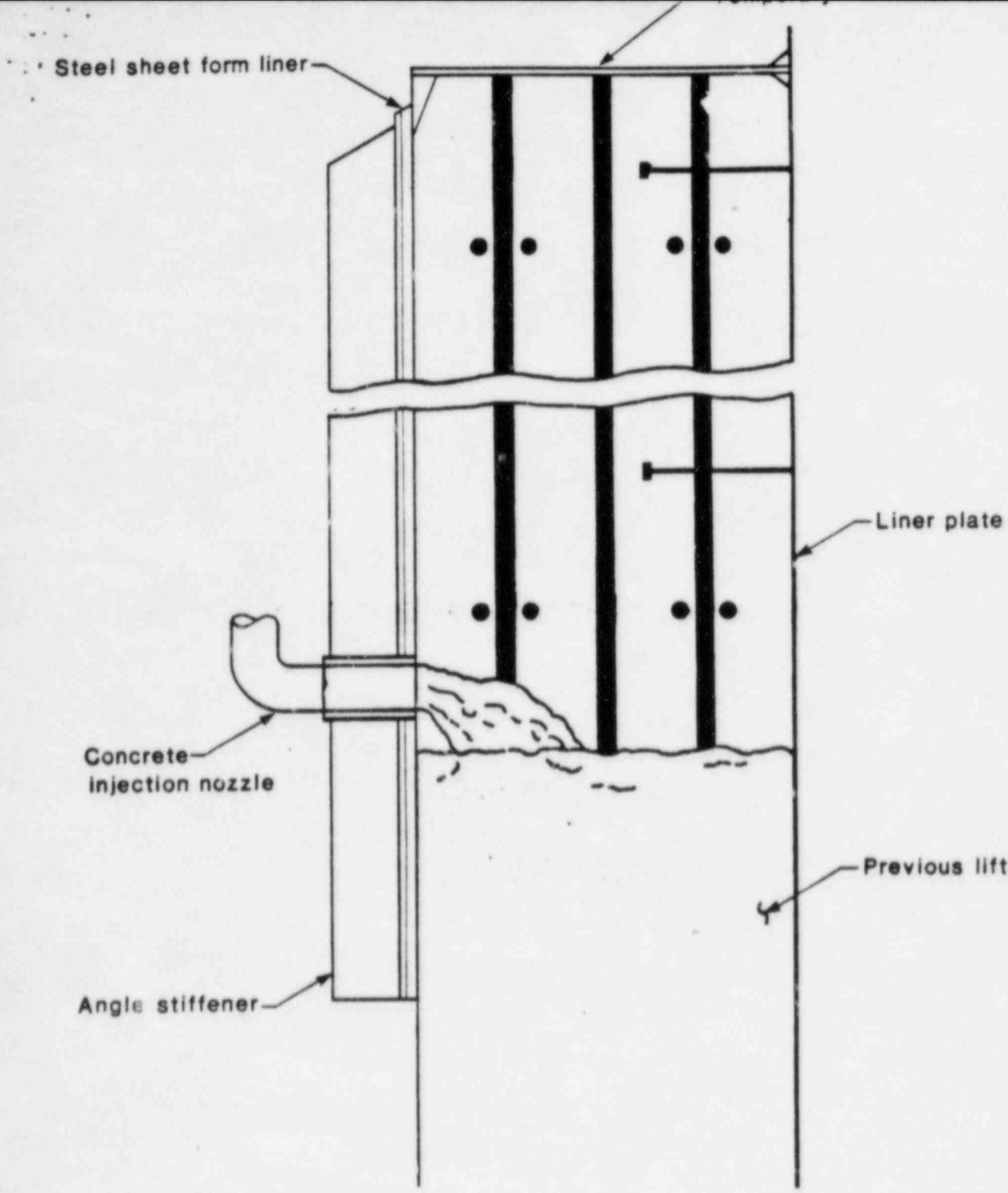


Figure 5-4. External formwork.

CONCRETE CURING

OBJECTIVE: MINIMIZE CREEP AND SHRINKAGE PROBLEMS
PRODUCE UNIFORM STRENGTH AT TIME OF TEST

PROCEDURE: MOIST CURE CONSTANTLY UNTIL UNIFORM STRENGTH

- BURLAP WRAP WITH TRICKLE FEED DURING CONSTRUCTION
- WATER SPRAY AFTER COMPLETION OF CONCRETE PLACEMENT

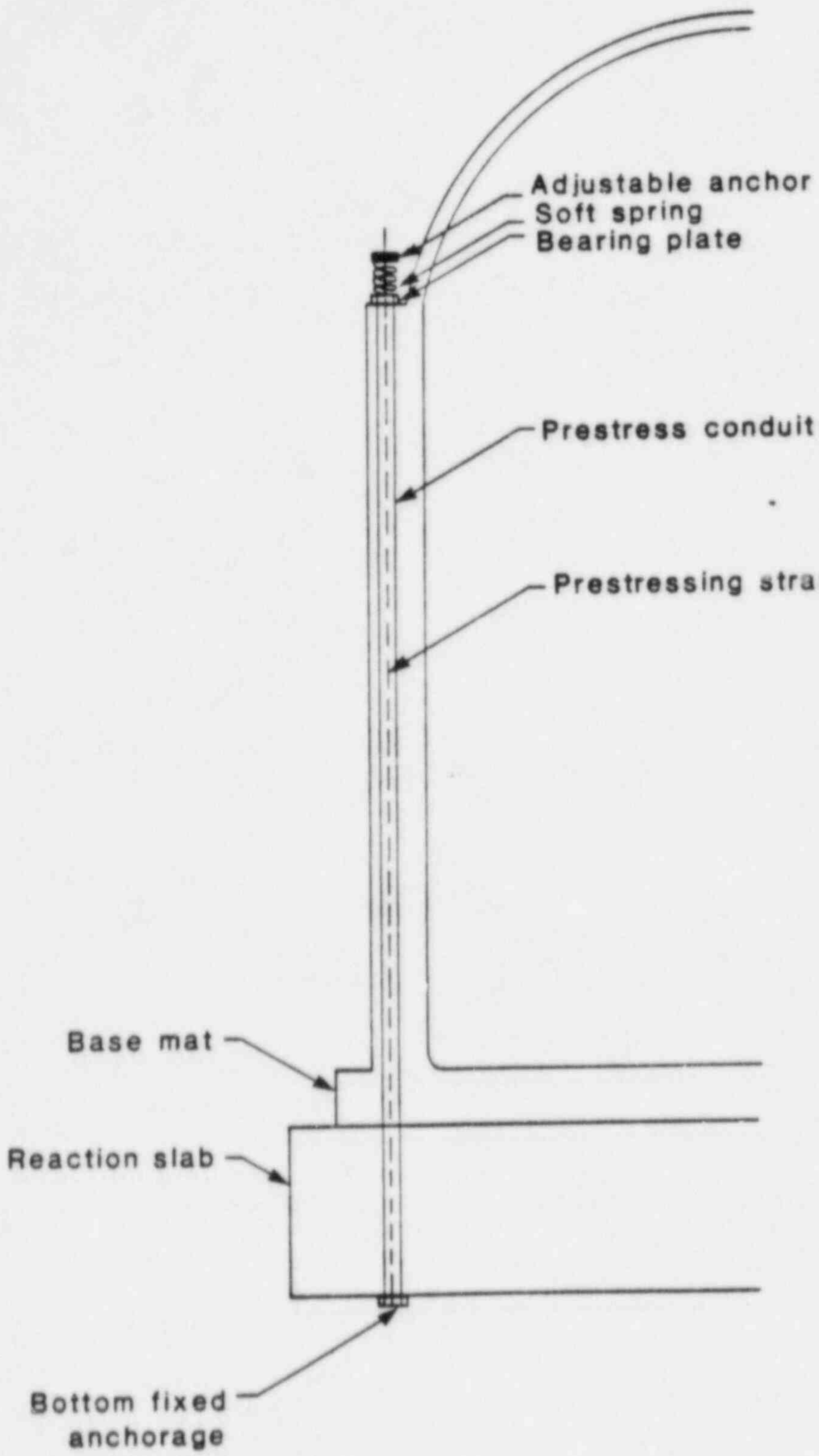


Figure 5-5. Mass simulation prestress system.

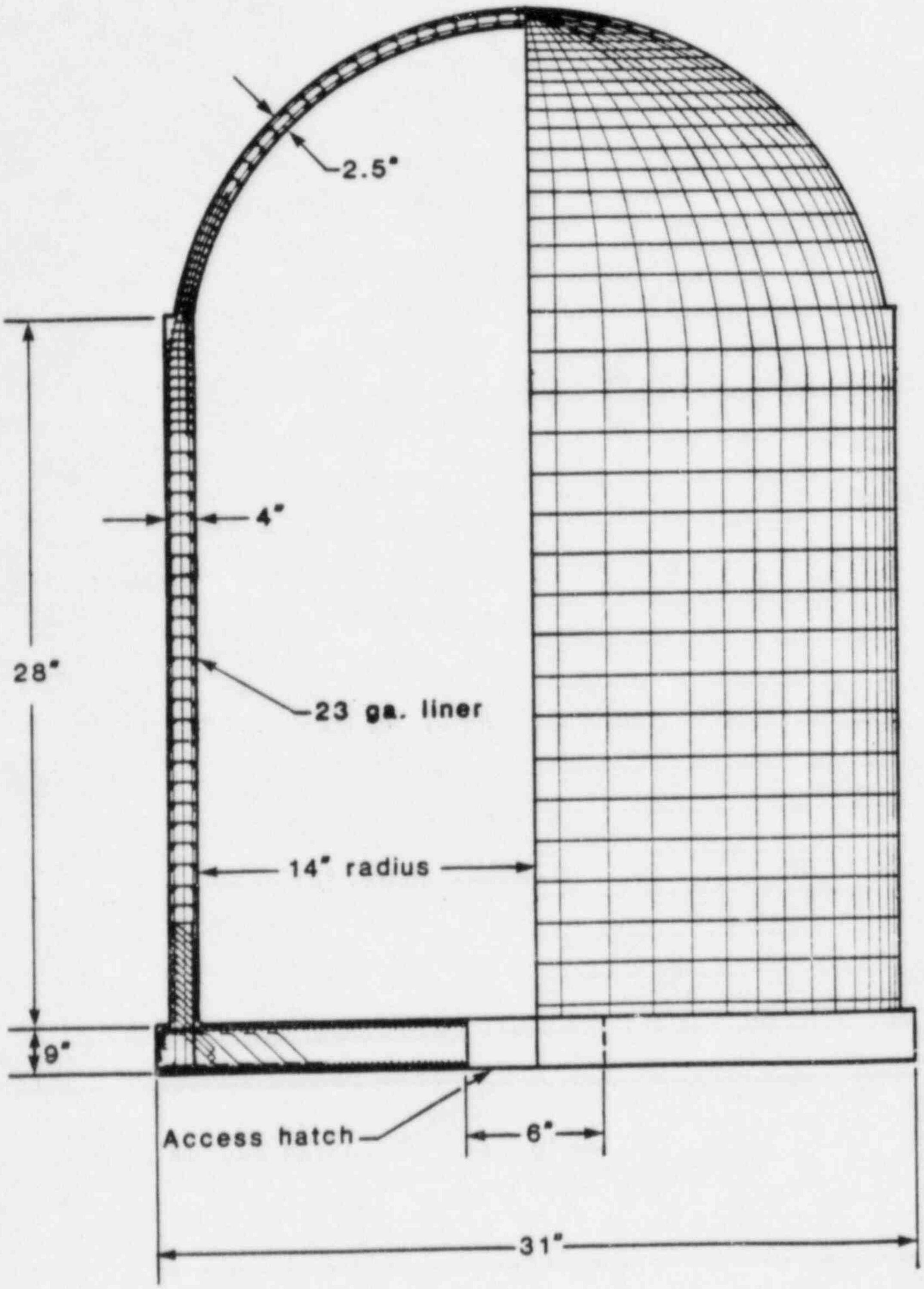


Figure 5-6. Pilot containment model.

V. MODEL COST ESTIMATE

Table 6-1

Category	Cost	Fraction of Total Cost (%)
1. Reinforcement Production	$ 60,000	6.6
2. Liner Fabrication	75,000	8.2
3. Anchor Studs	66,000	7.2
4. Reaction Mat	5,000	0.5
5. Base Mat	16,000	1.8
6. Reinforcement Fabrication	230,000	25.2
7. Prestressing	5,000	0.5
8. Concrete and Formwork	57,000	6.3
9. Interior Form Removal	2,000	0.2
10. Pilot Test Model	50,000	5.5
SUBTOTAL	$ 566,000	62.1
11. 20% Contingency	113,000	12.4
12. Management and Engineering	50,000	5.5
SUBTOTAL	729,000	80.0
13. 25% Overhead and Profit	182,000	20.0
TOTAL	$ 911,000	100%

VI. SUPPORT TESTS

- MATERIAL AND COMPONENT TESTING
- MODEL CALIBRATION AND VERIFICATION TESTS
    - CALIBRATED LEAK TESTING
    - CRACK SIMILITUDE
    - LINER/CONCRETE INTERACTION
- OMITTED SIGNIFICANT FEATURES
- DETAIL VARIATION AMONG CONTAINMENTS

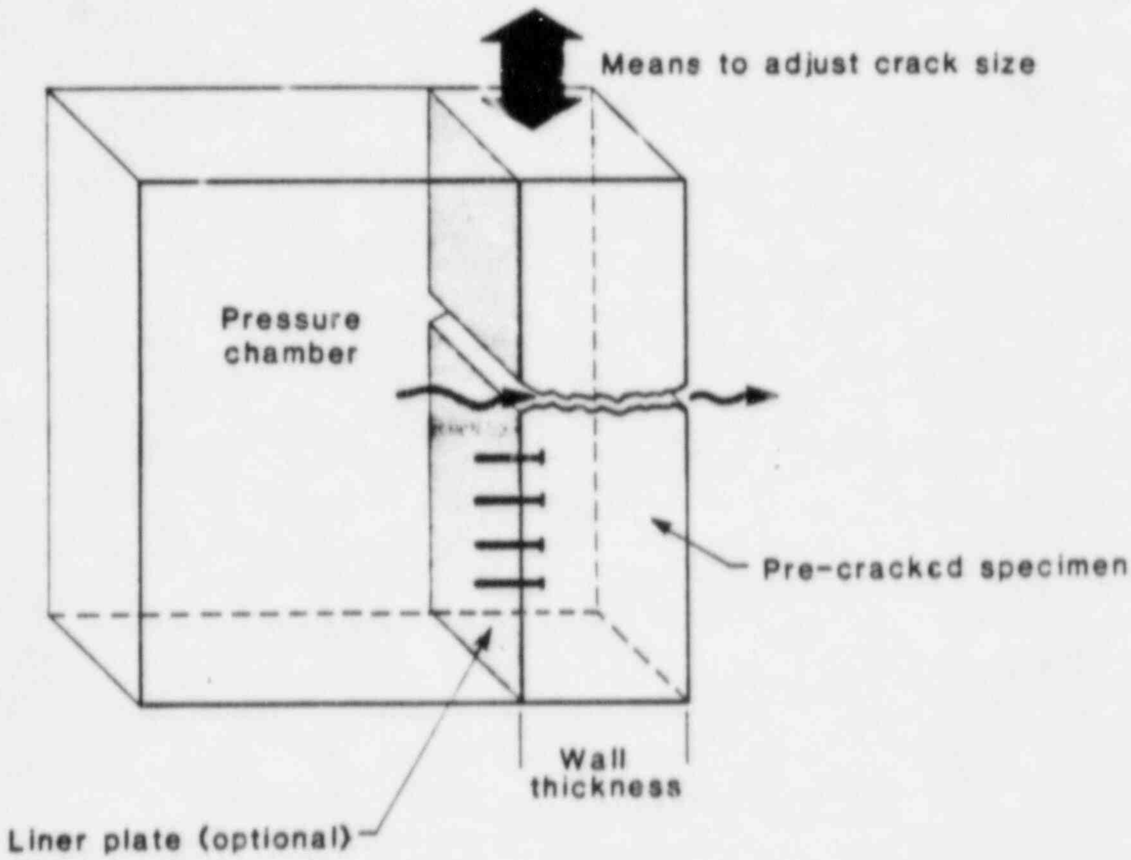


Figure 7-1. Crack leakage simulation.

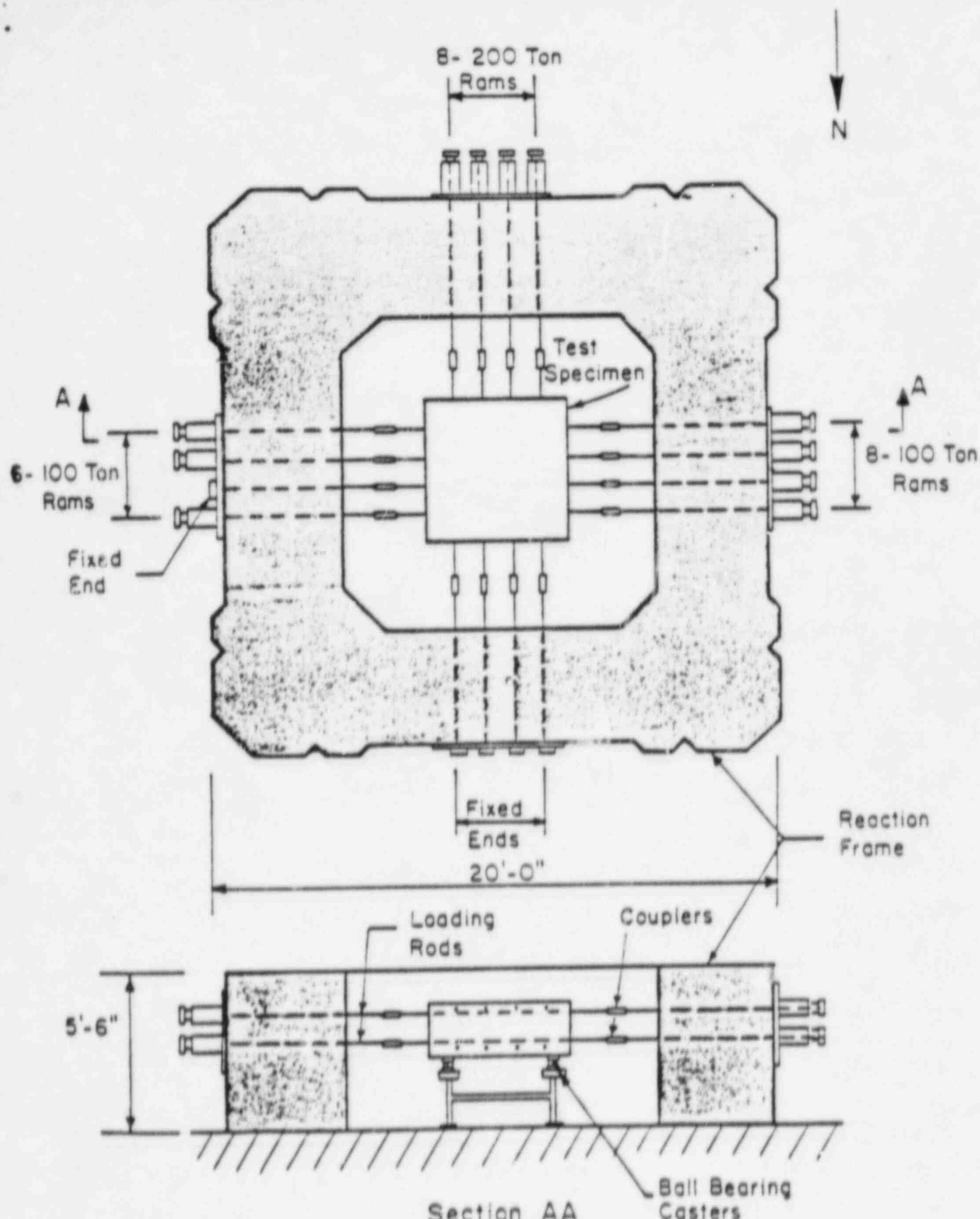
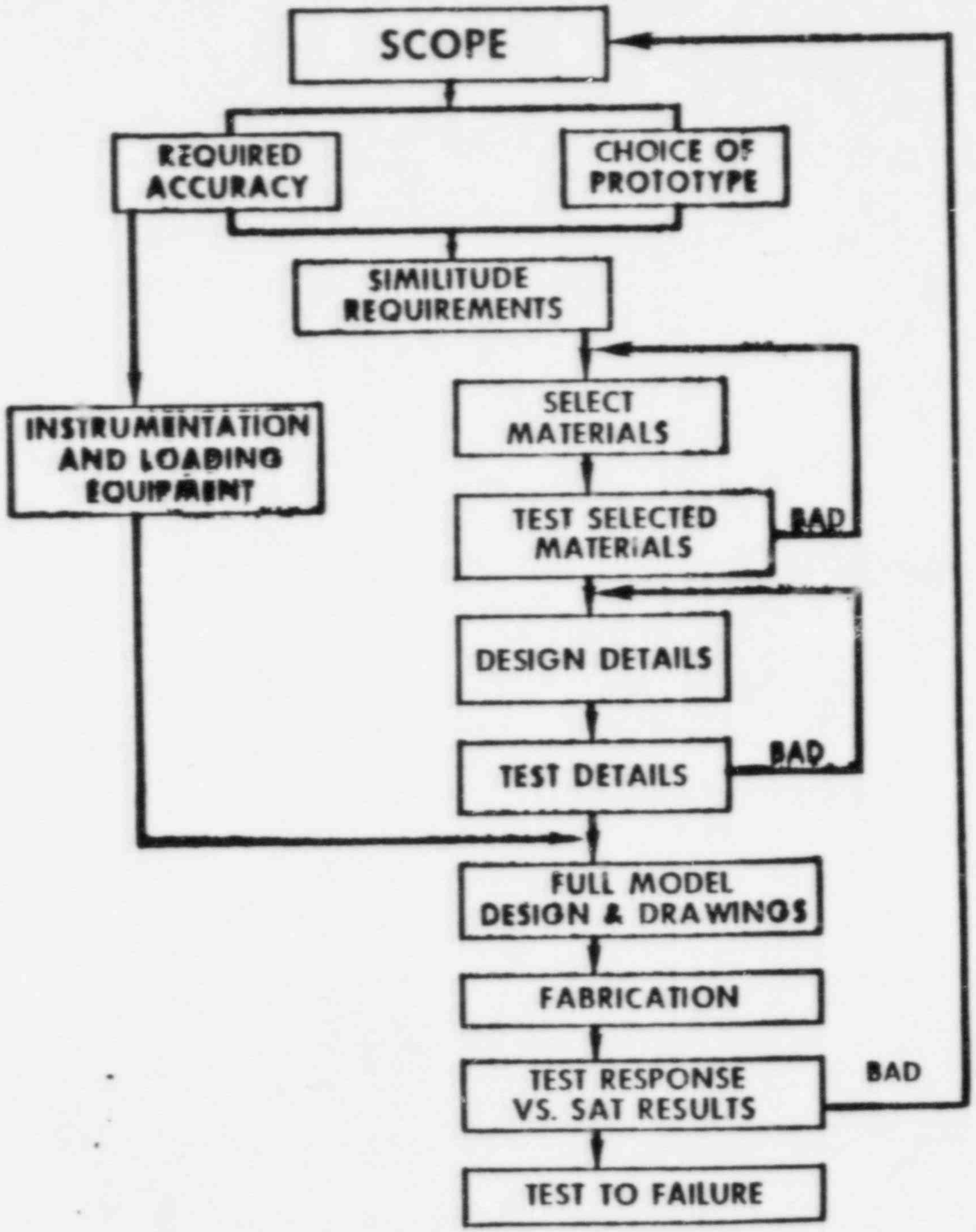


Figure 7-2. Biaxial loading system (from Oesterle and Russell 1/80).

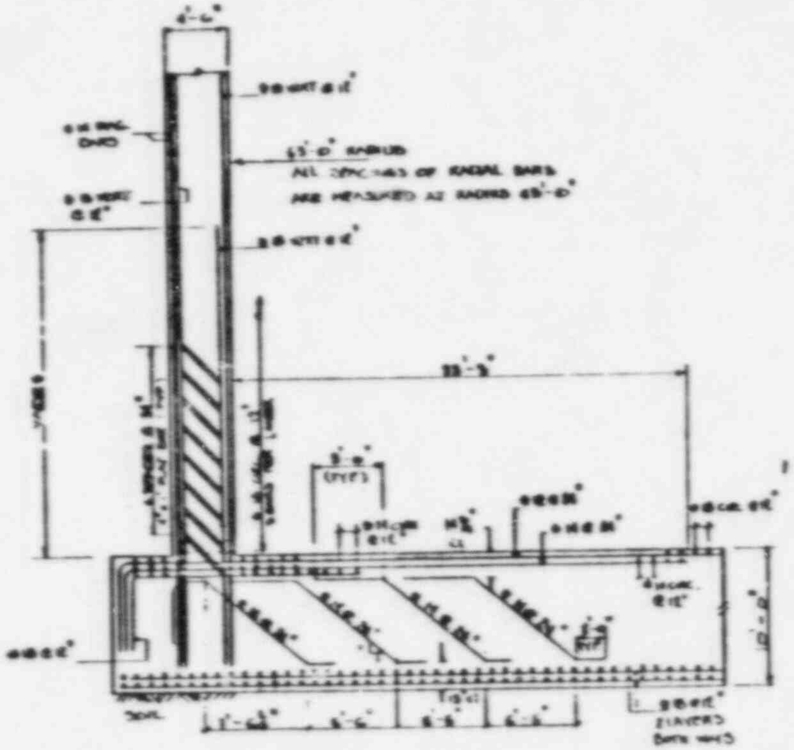
Attachment 3

STONE & WEBSTER PRESENTATION

MODELING PROCESS



WALL-MAT JOINT REINFORCEMENT DETAILS



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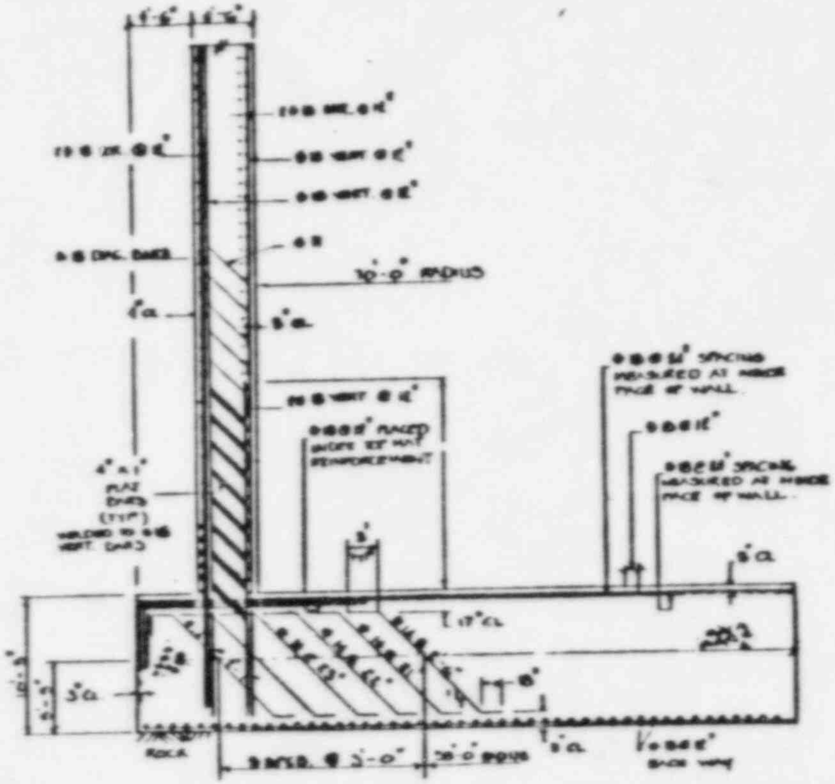

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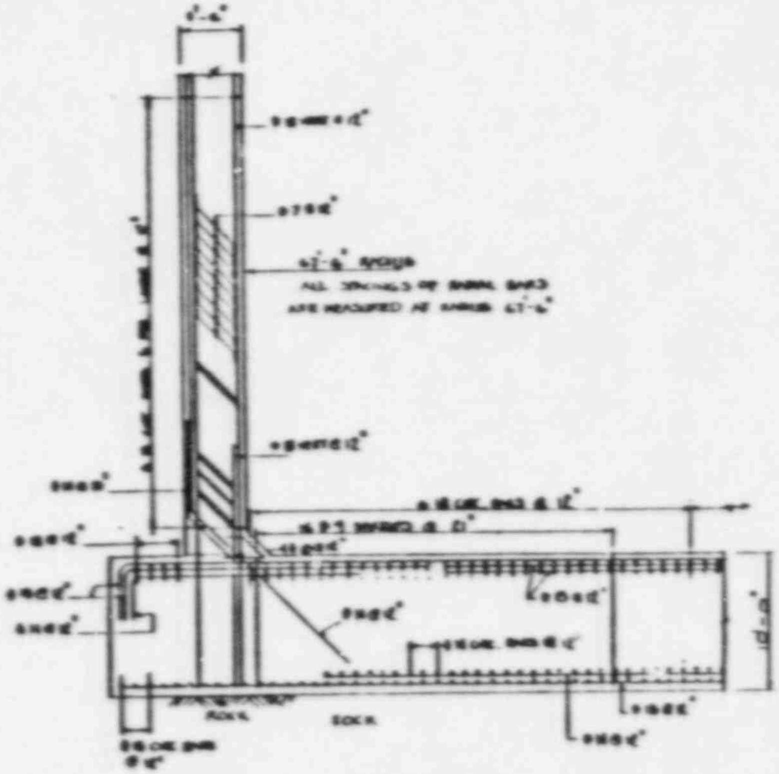
WALL-MAT JOINT REINFORCEMENT DETAILS



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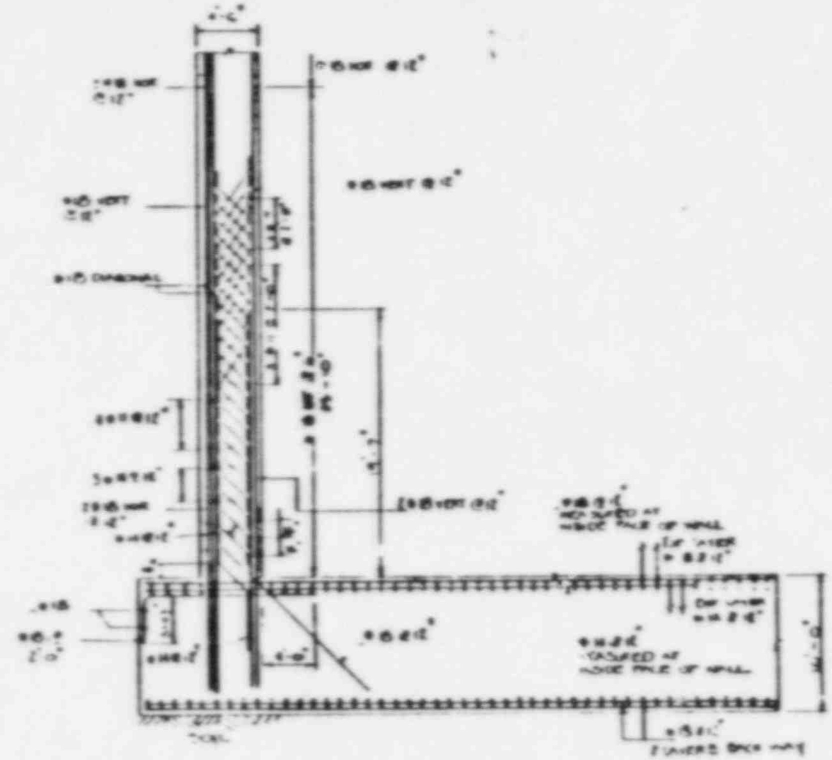

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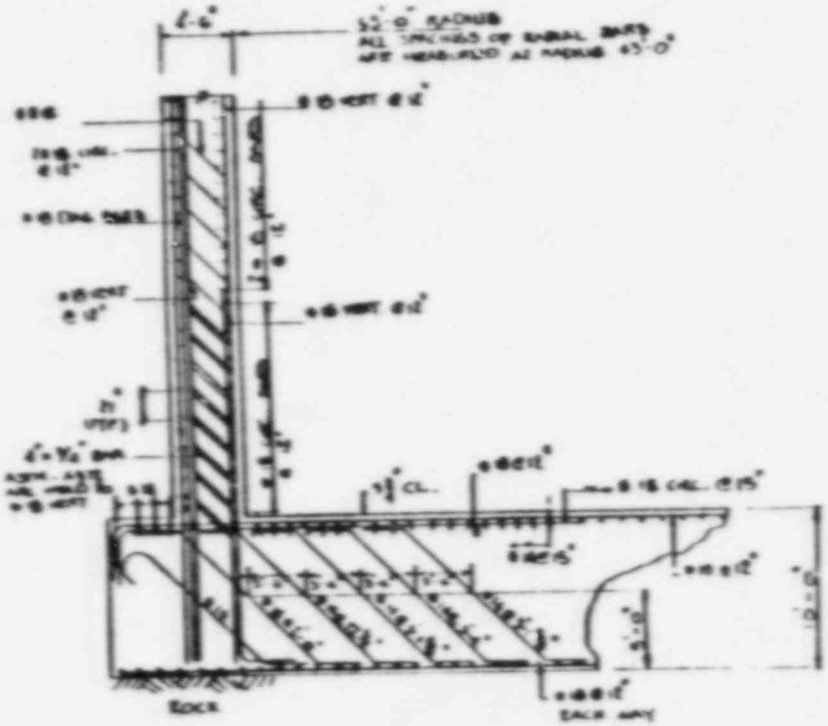
WALL-MAT JOINT REINFORCEMENT DETAILS



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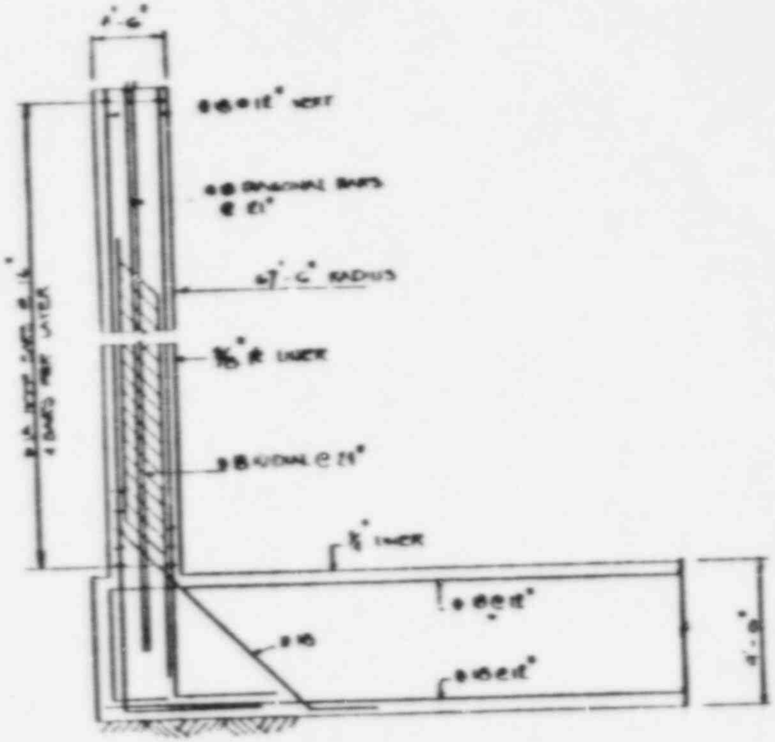

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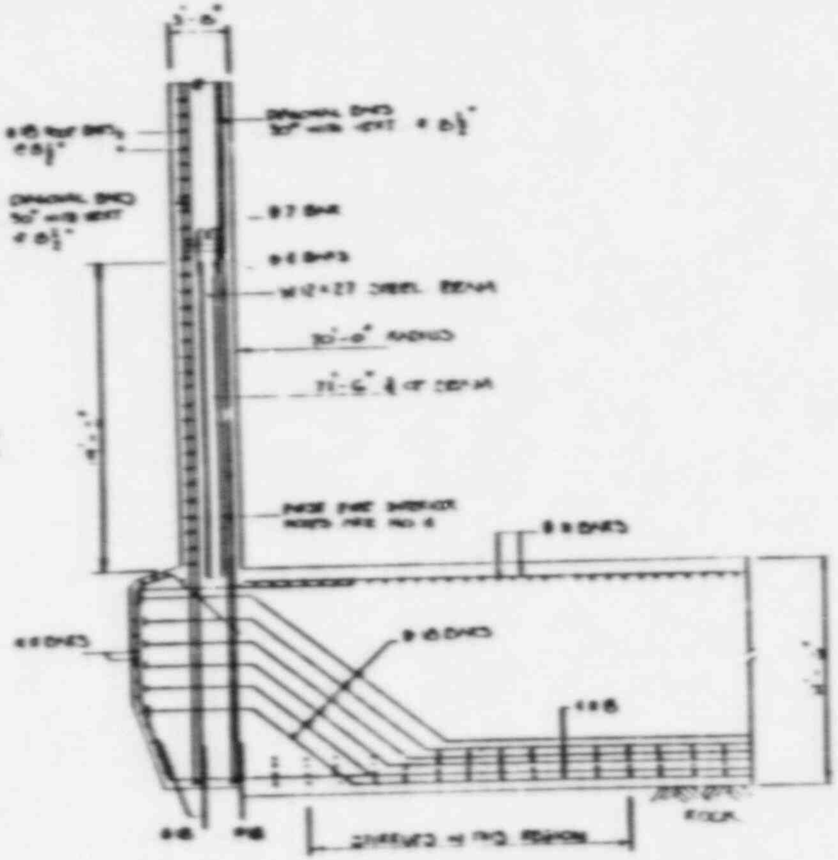
WALL-MAT JOINT REINFORCEMENT DETAILS



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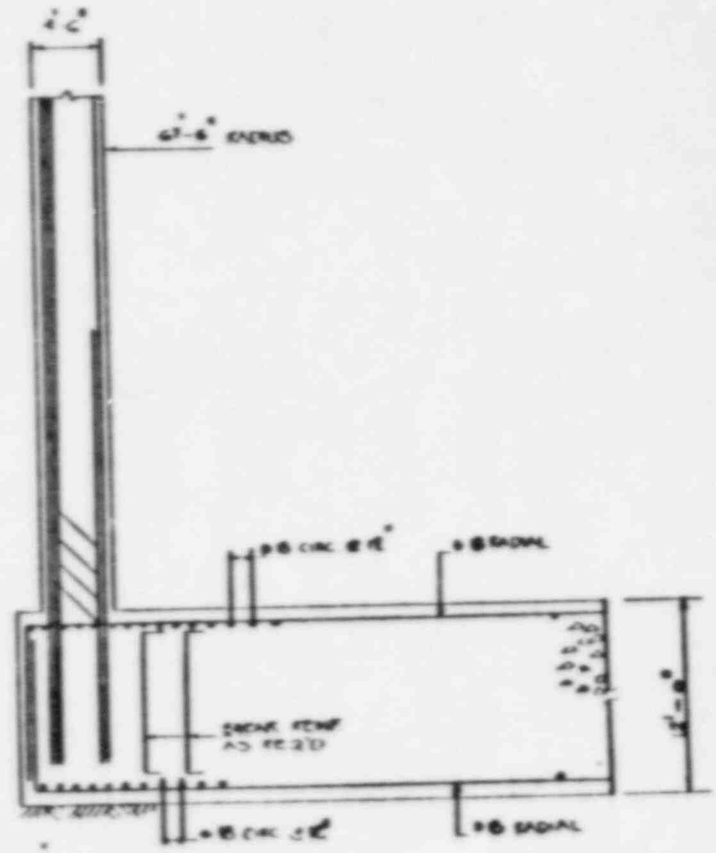

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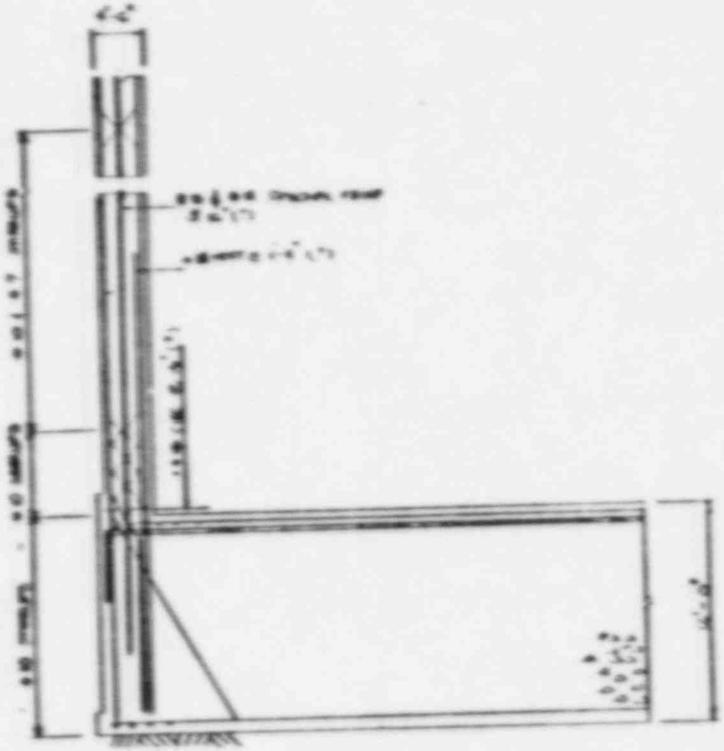
WALL-MAT JOINT REINFORCEMENT DETAILS



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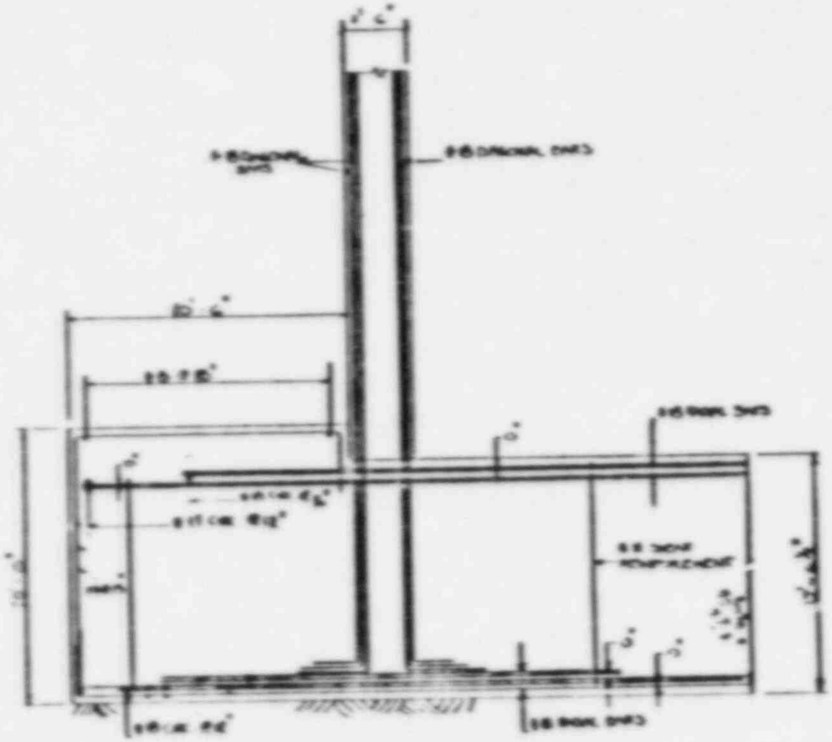

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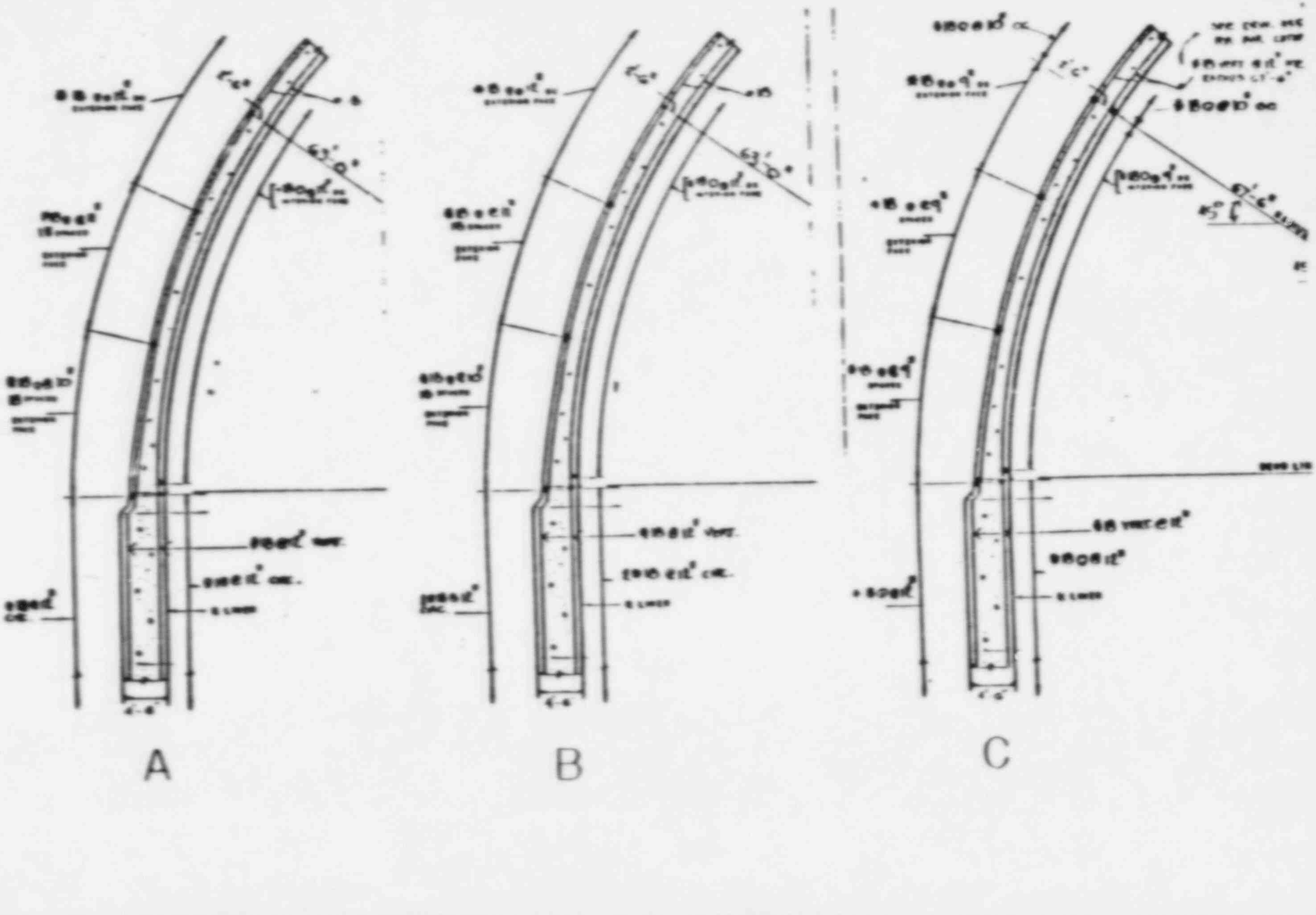
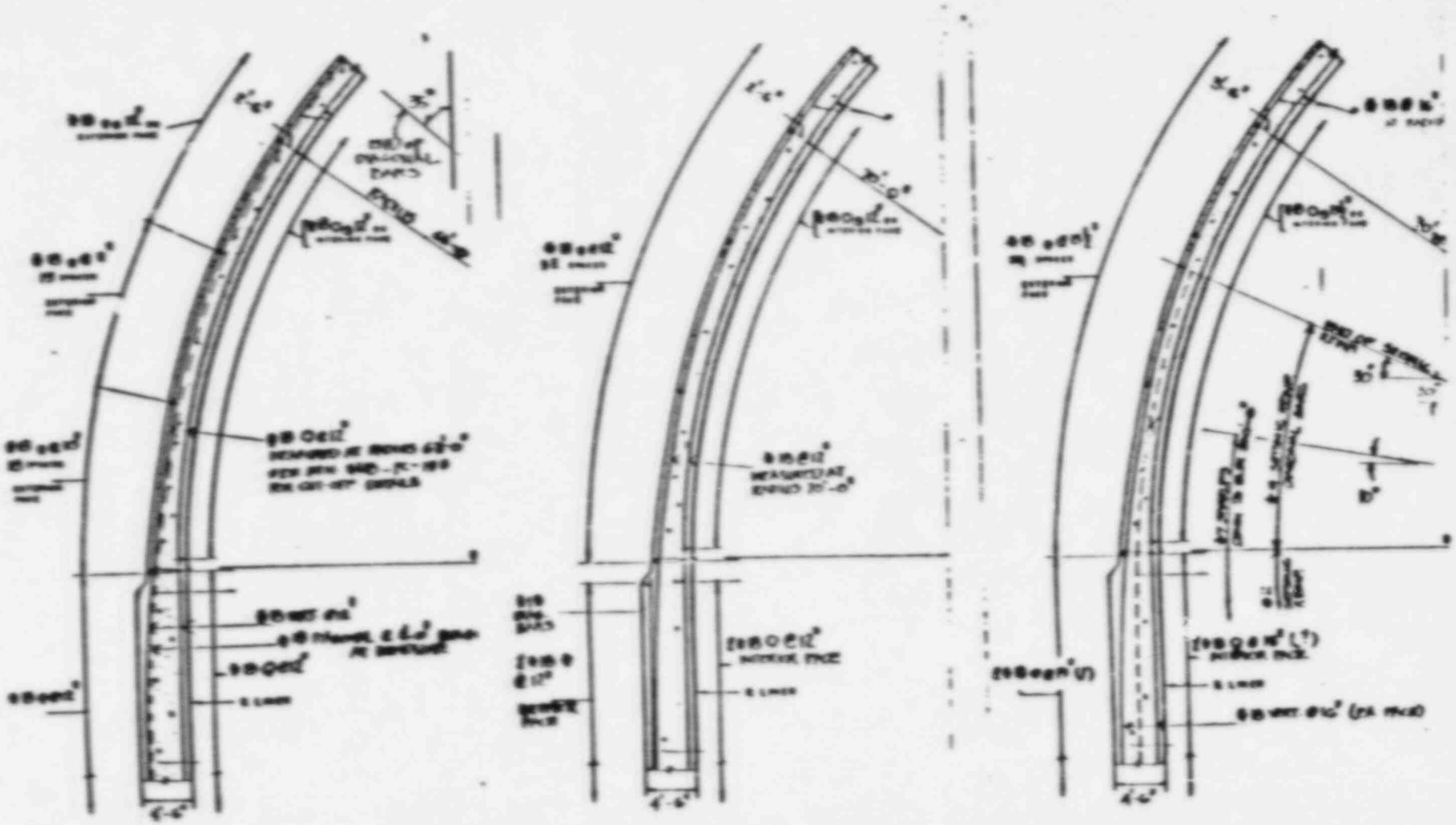
WALL AND DOME REINFORCEMENT DETAILS



WALL AND DOME REINFORCEMENT DETAILS



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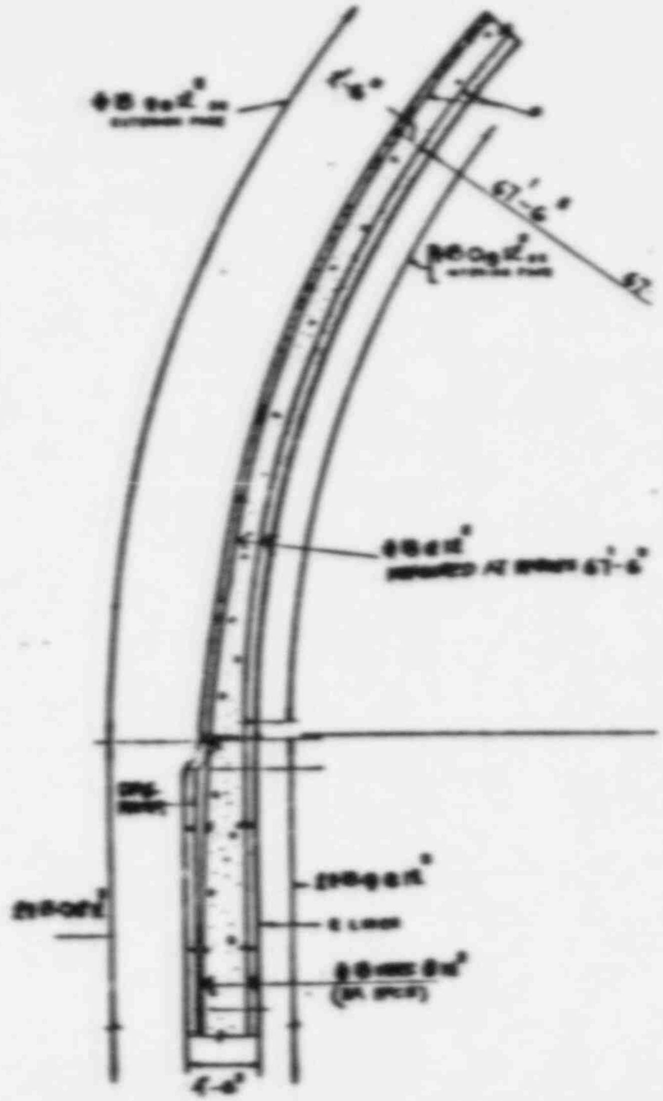
WALL AND DOME REINFORCEMENT DETAILS



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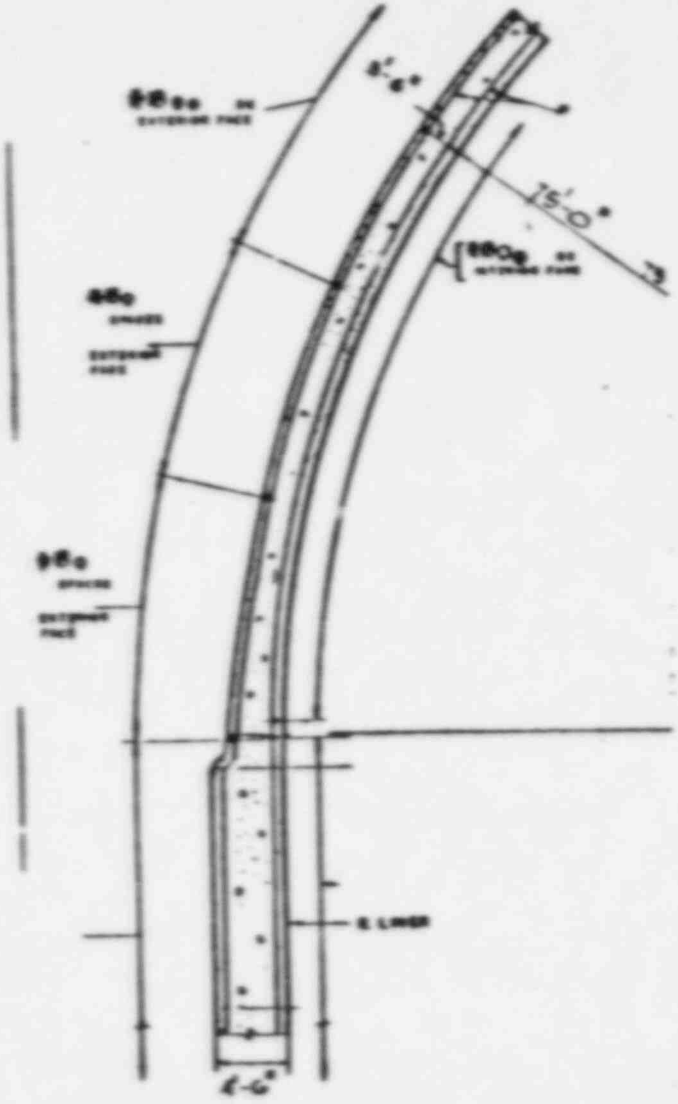

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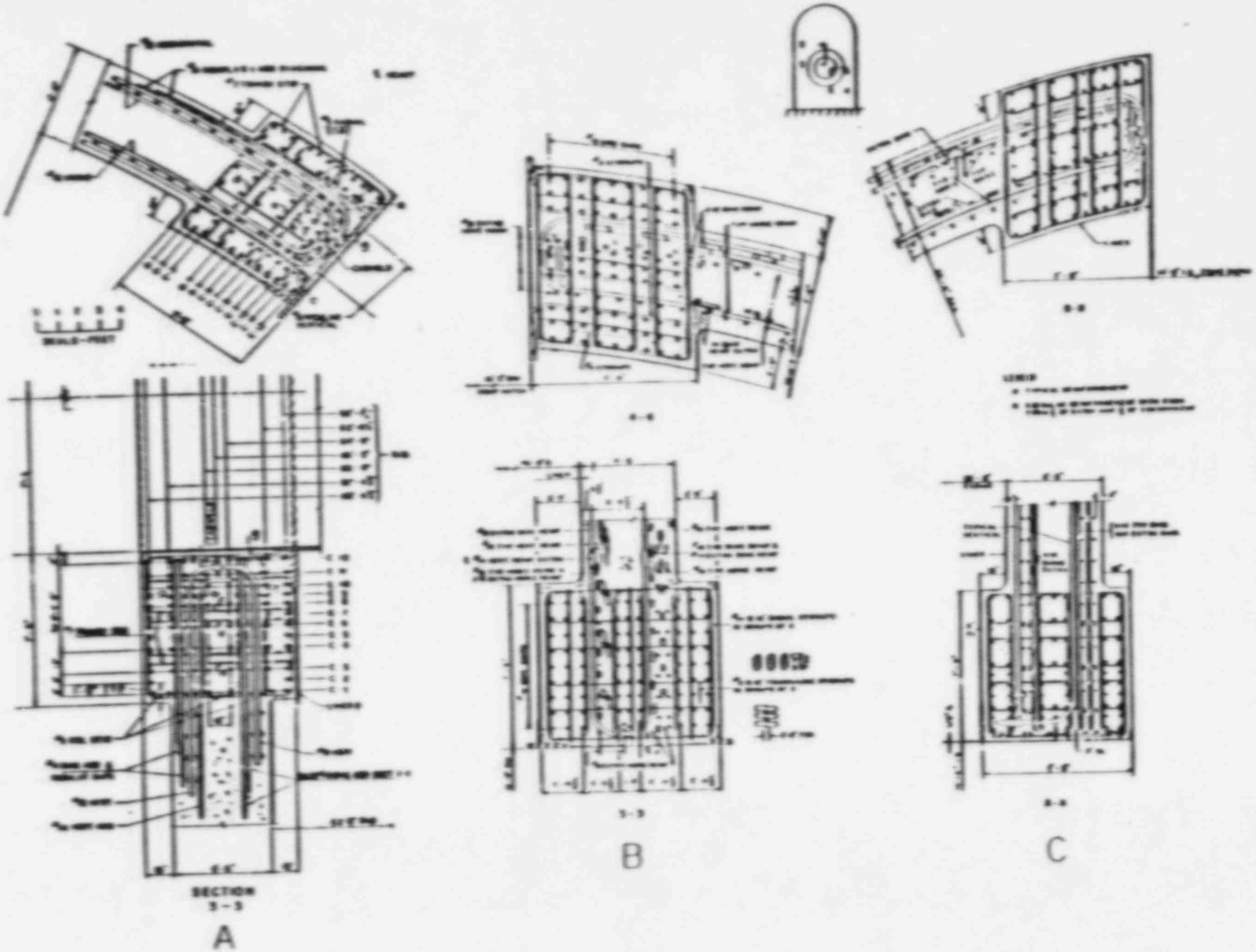
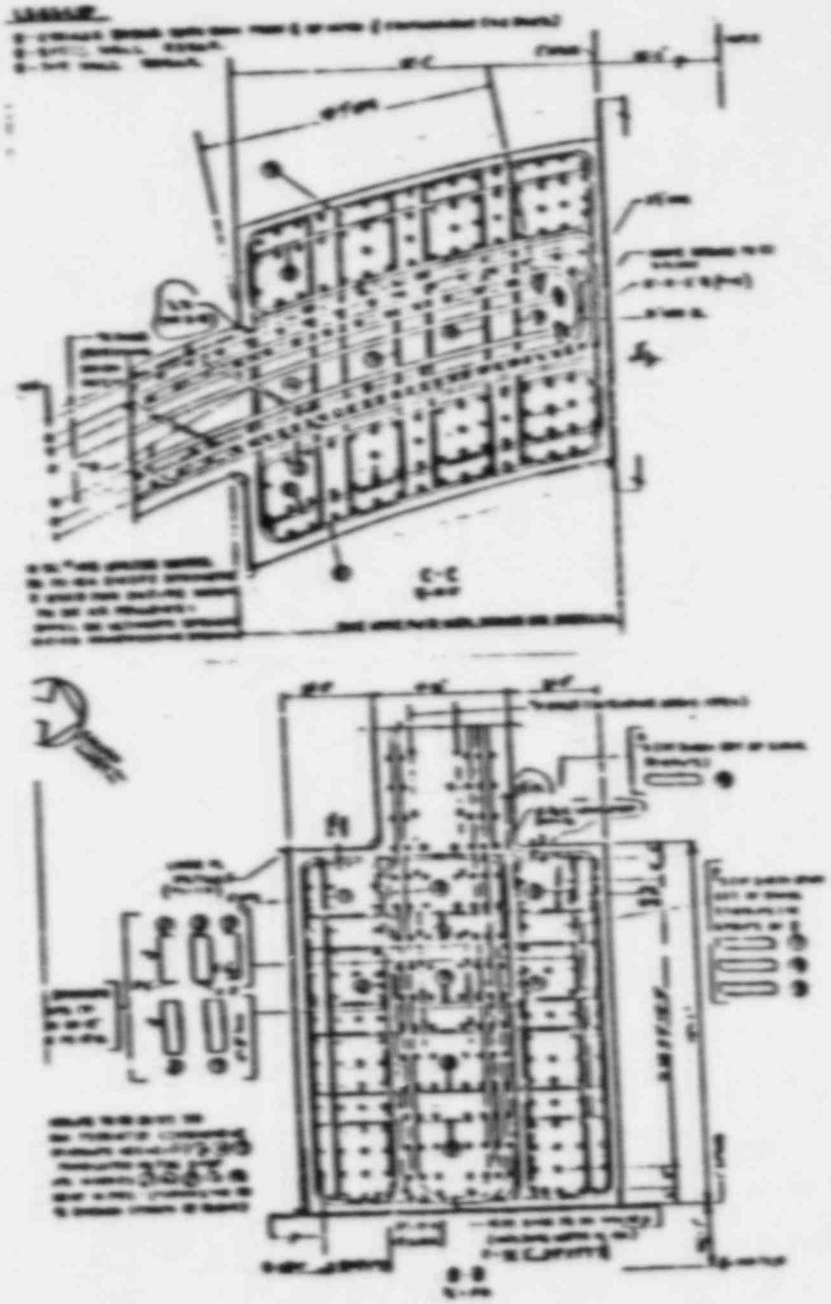
EQUIPMENT HATCH REINFORCEMENT DETAILS



EQUIPMENT HATCH REINFORCEMENT DETAILS



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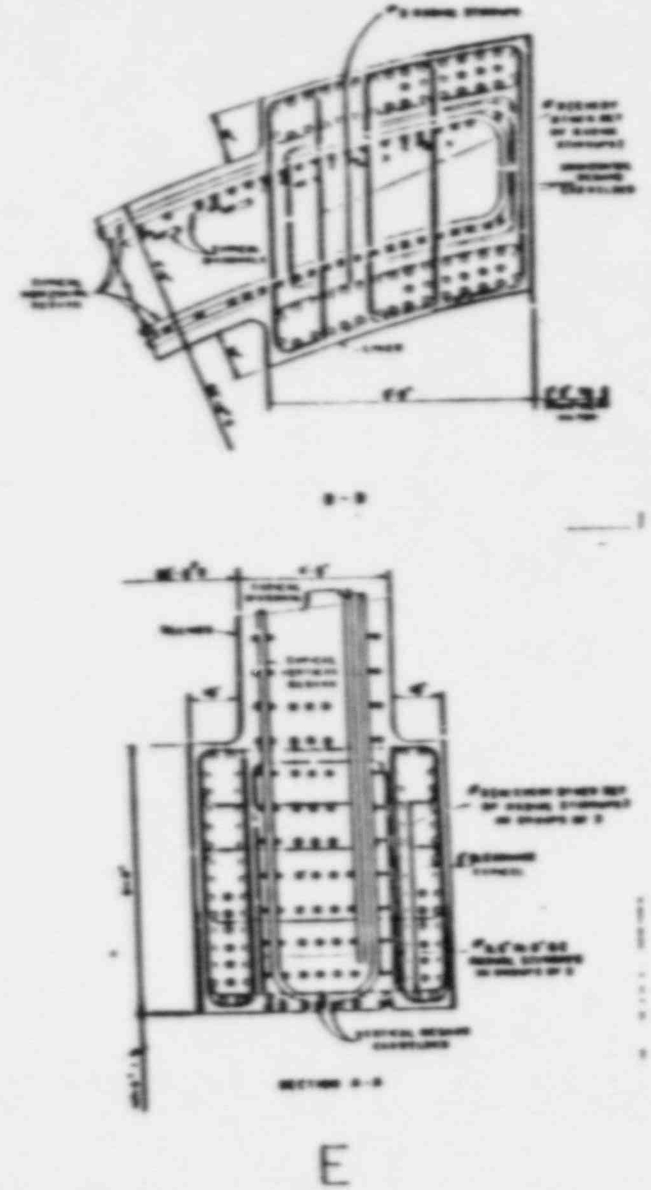

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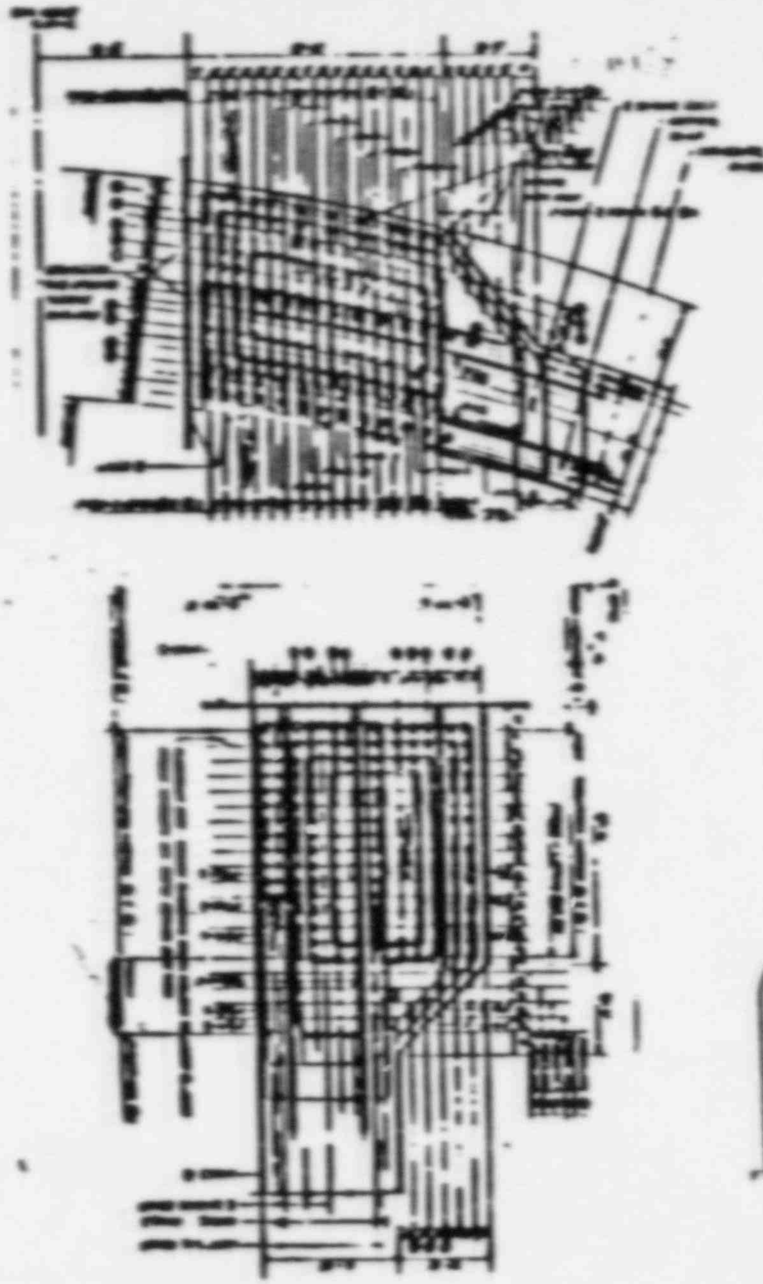
EQUIPMENT HATCH REINFORCEMENT DETAILS



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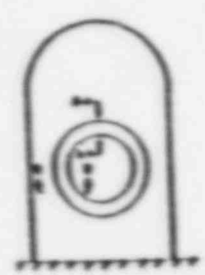
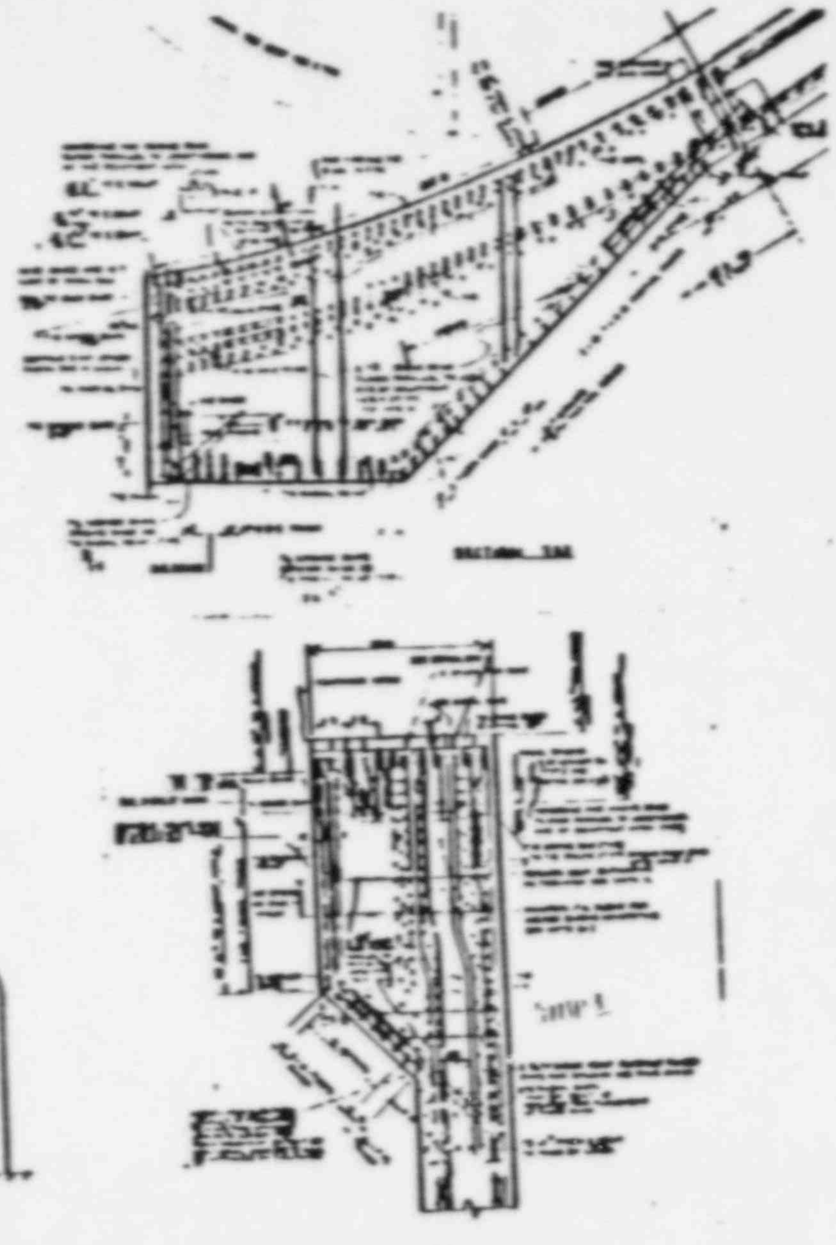
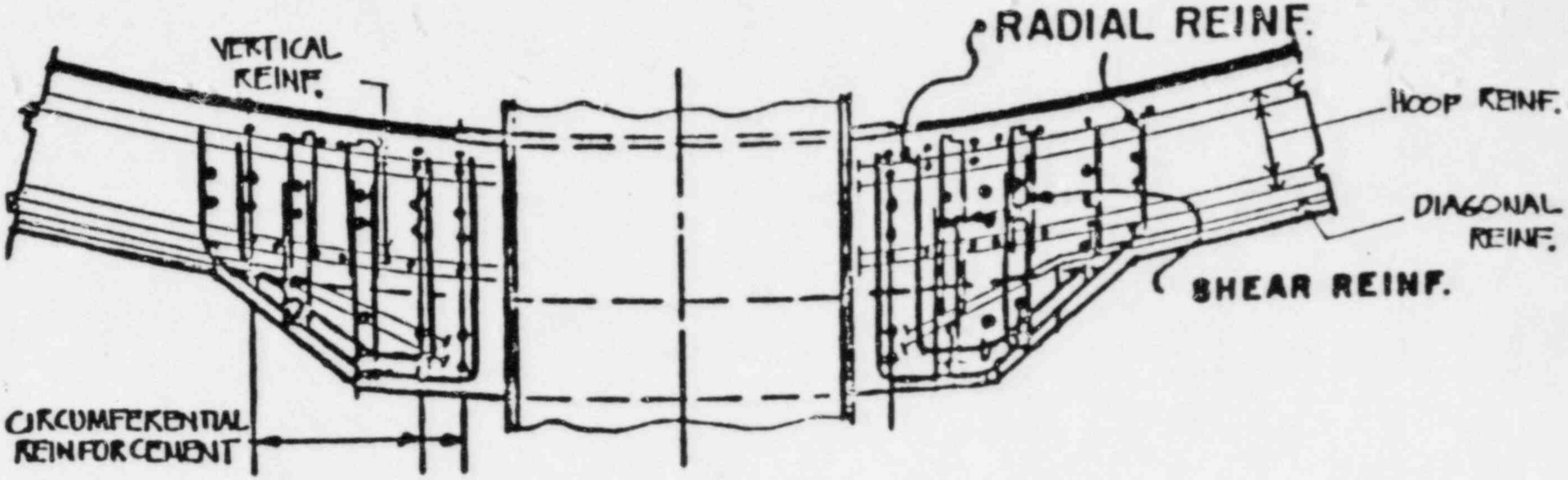




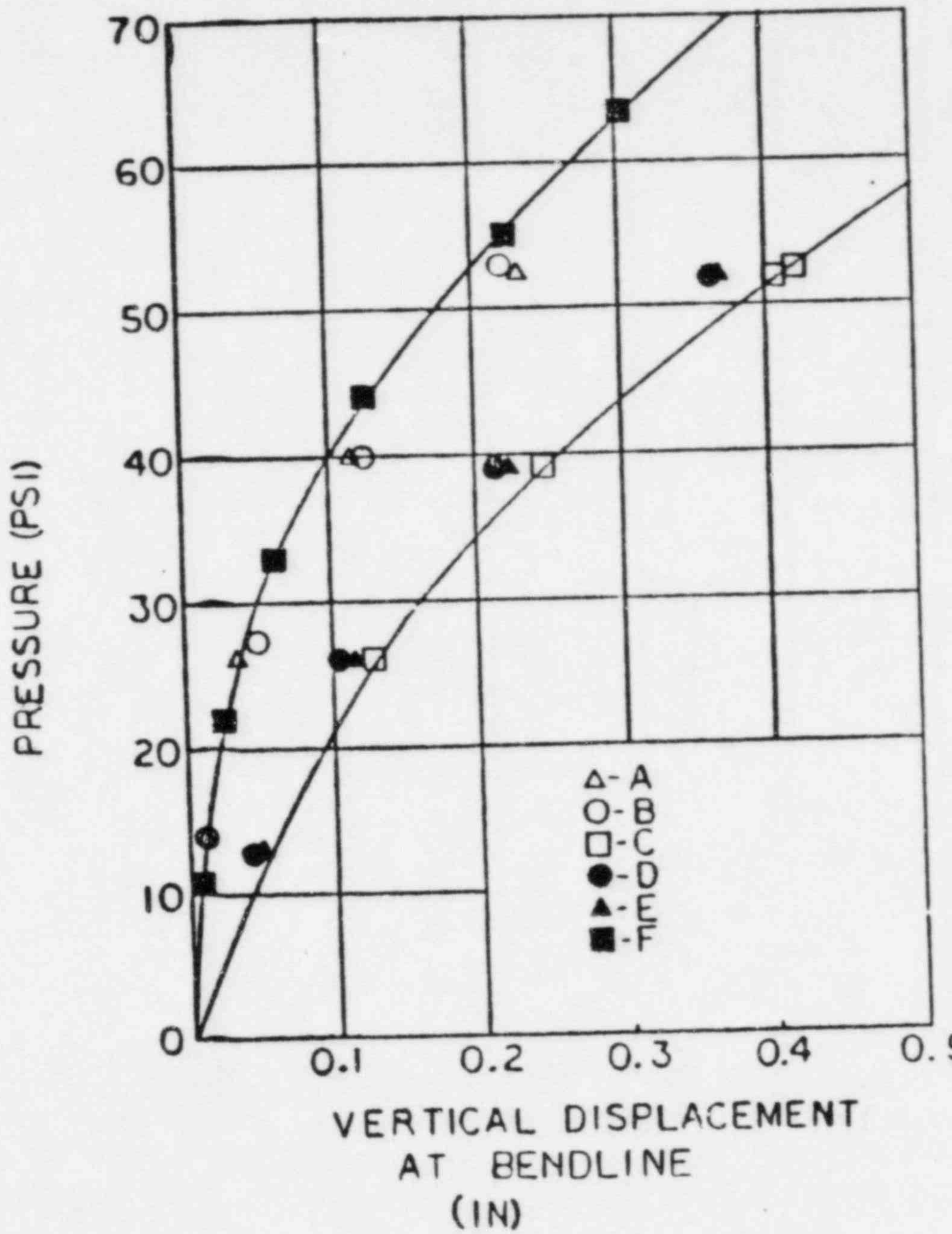
G

EQUIPMENT HATCH REINFORCEMENT DETAILS



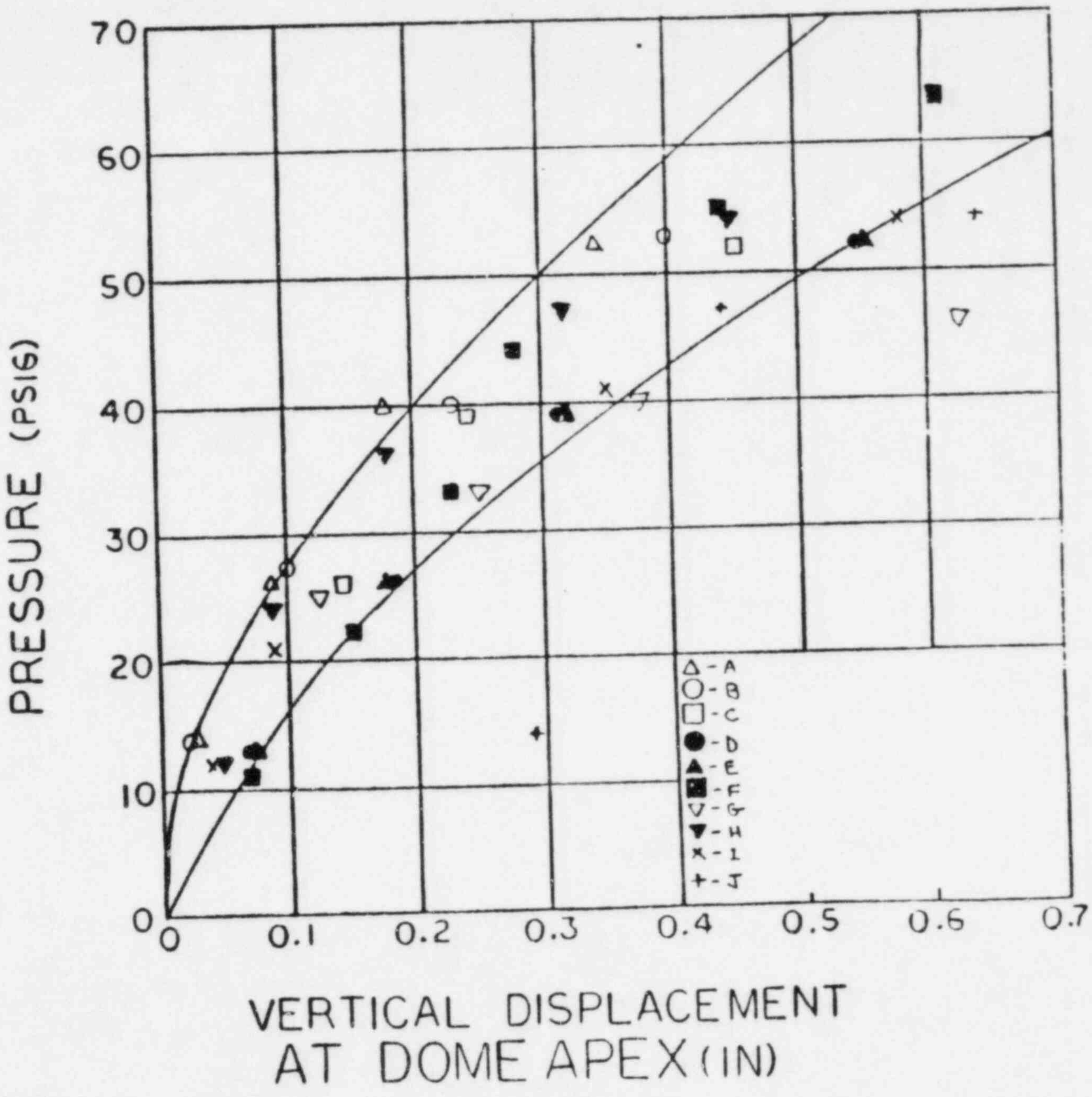
H

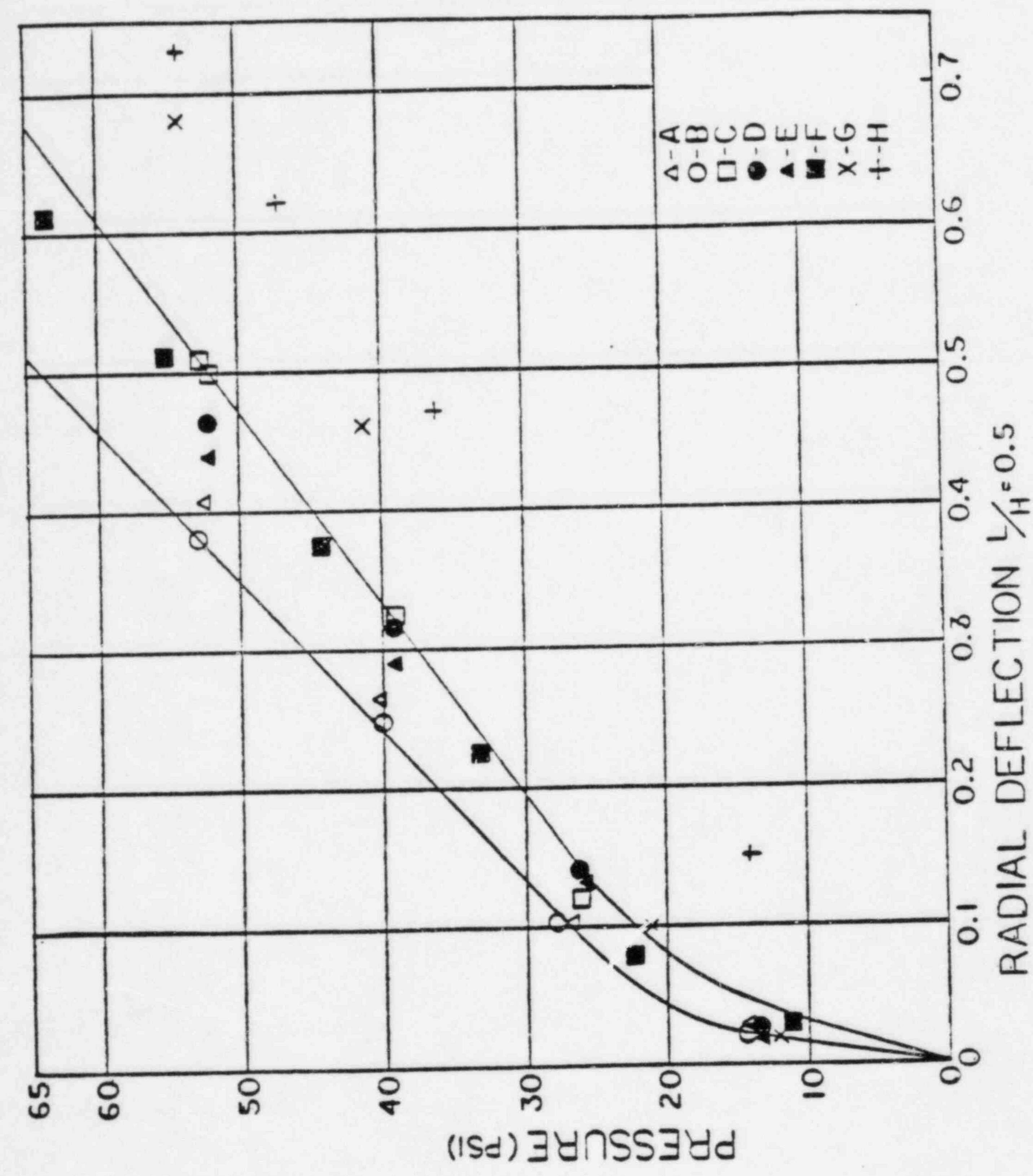
SAT RESULTS



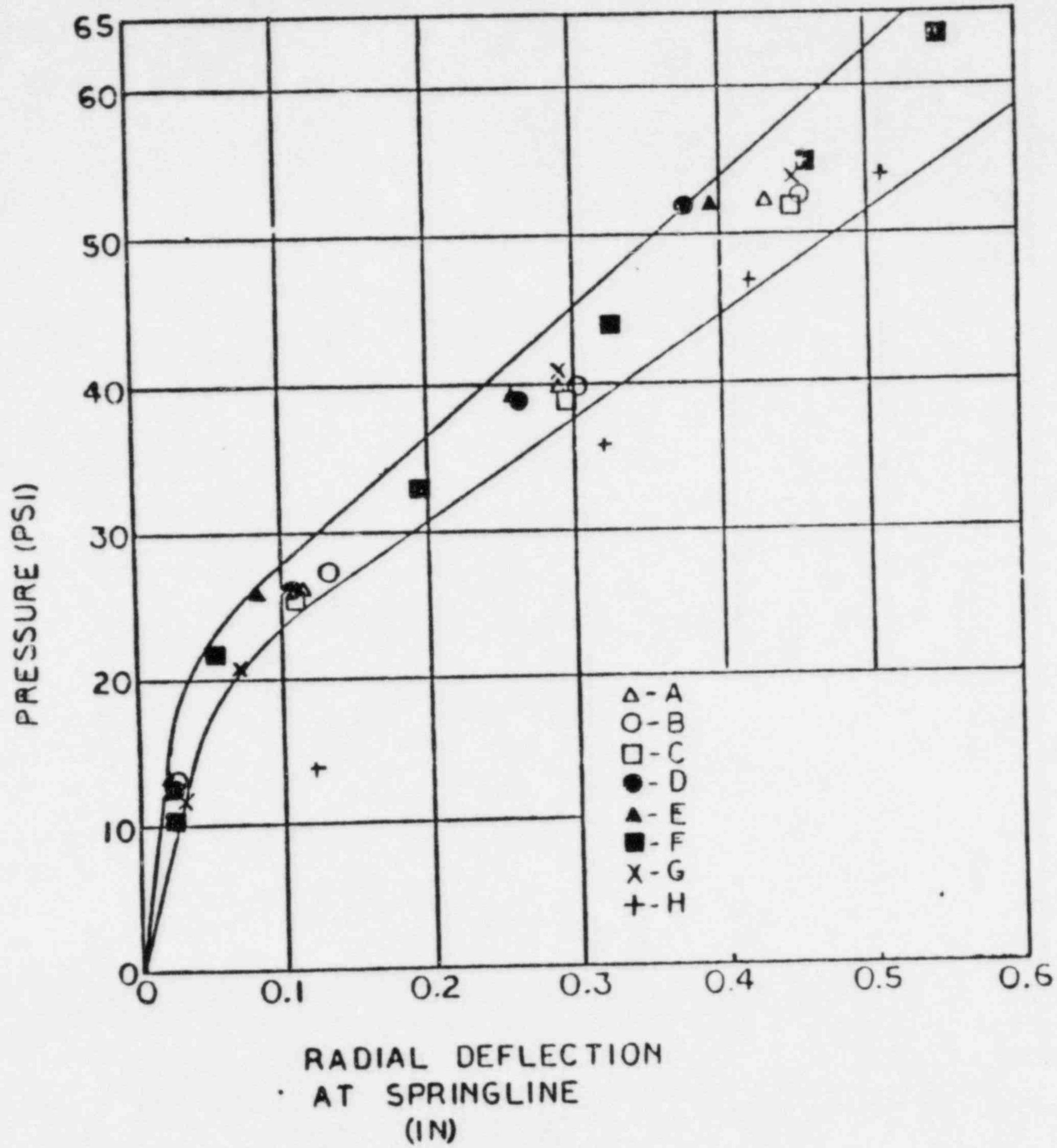
70
60
50
40
30
20
10
0
0.1
0.2
0.3
0.4
0.5
PRESSURE (PSI)
VERTICAL DISPLACEMENT
AT BENDLINE
(IN)
△- A
○- B
□- C
●- D
▲- E
■- F

SAT RESULTS

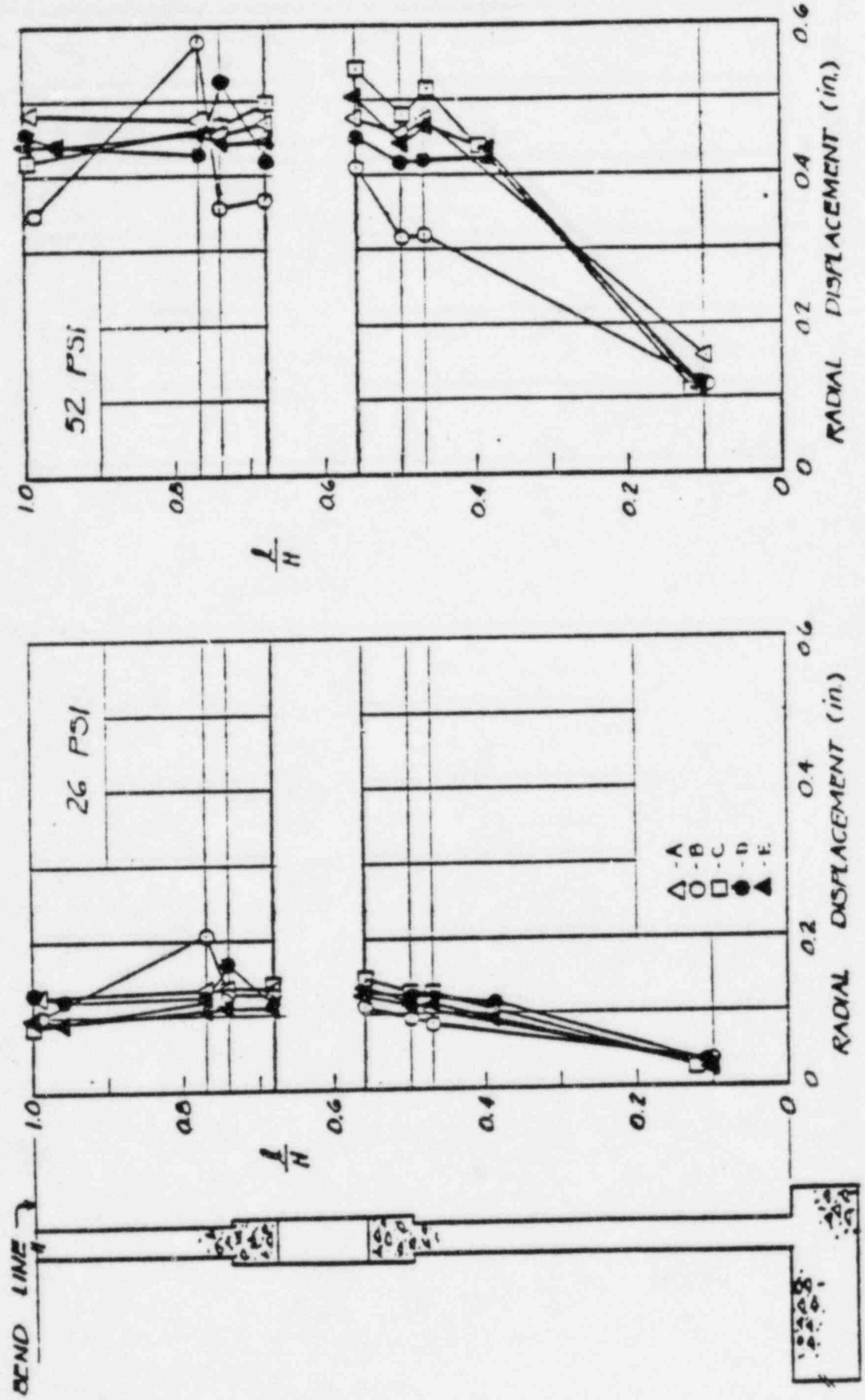

PRESSURE (PSIG)
70
60
50
40
30
20
10
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
△ - A
○ - B
□ - C
● - D
▲ - E
■ - F
▽ - G
▼ - H
× - I
+ - J
VERTICAL DISPLACEMENT
AT DOME APEX (IN)

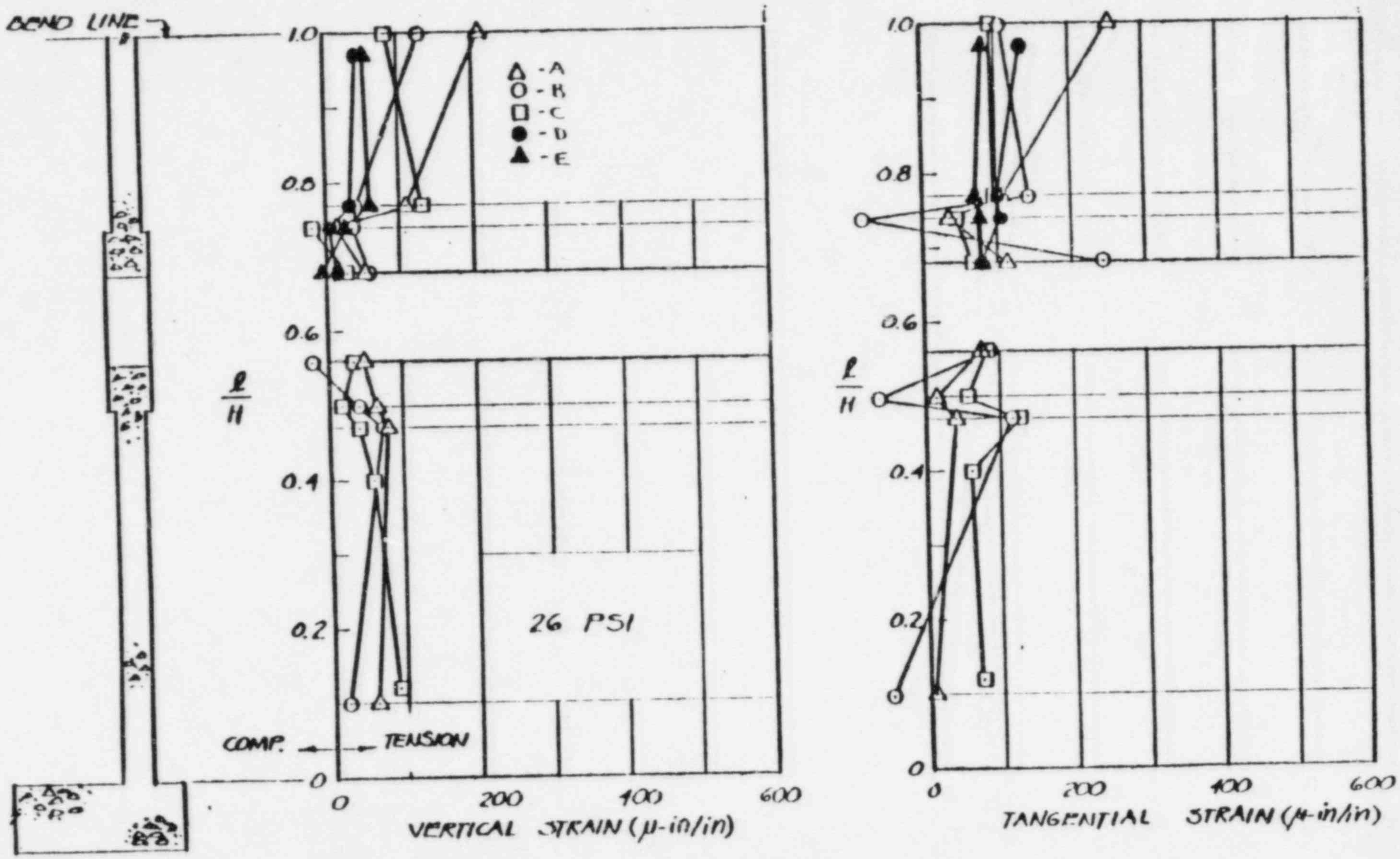

PRESSURE (PSI)
65
60
50
40
30
20
10
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
RADIAL DEFLECTION L/H = 0.5
△-A
O-B
□-C
●-D
▲-E
■-F
X-G
+-H

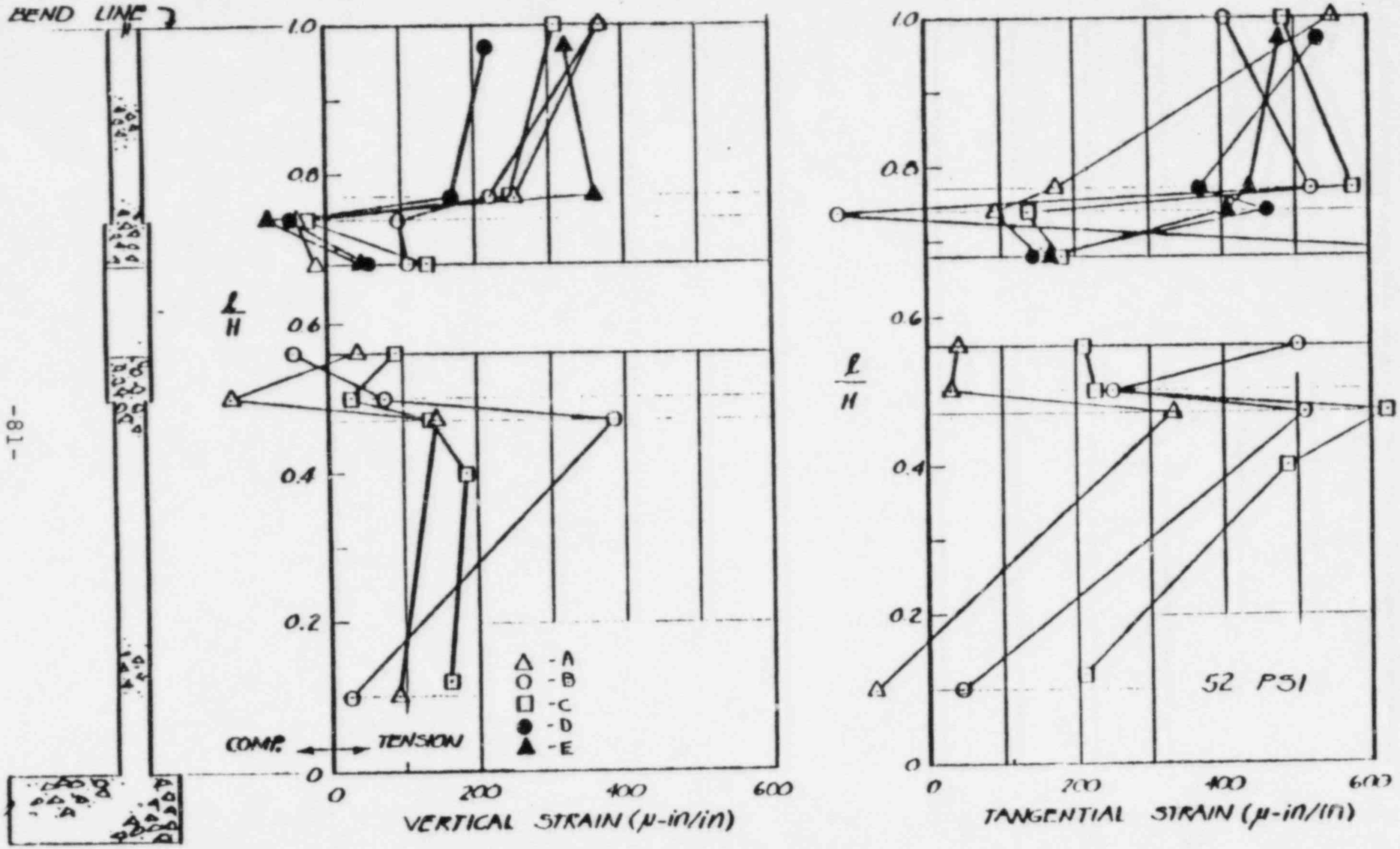
SAT RESULTS

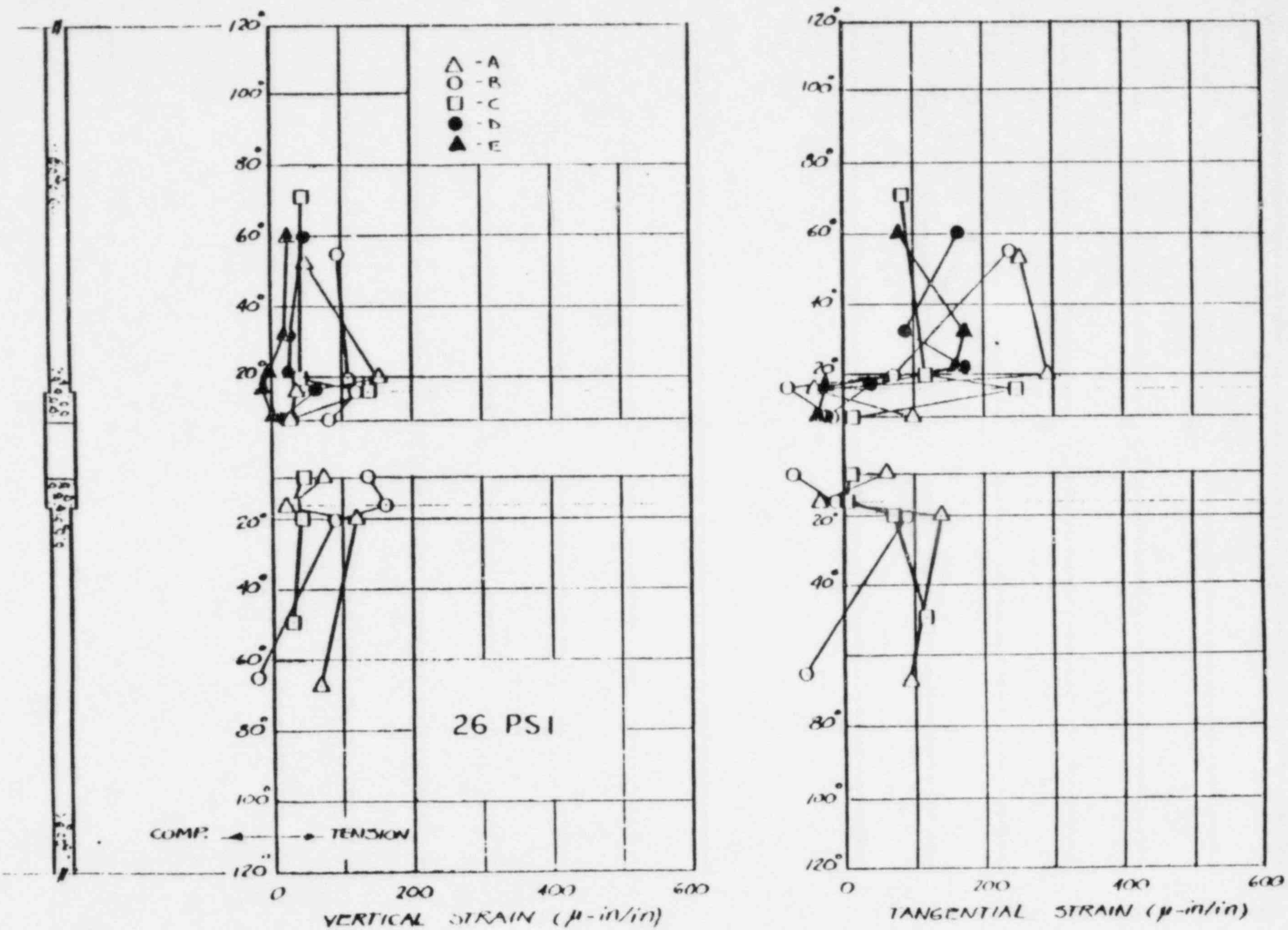


PRESSURE (PSI)
65
60
50
40
30
20
10
0
0
0.1
0.2
0.3
0.4
0.5
0.6
RADIAL DEFLECTION
AT SPRINGLINE
(IN)
△ - A
○ - B
□ - C
● - D
▲ - E
■ - F
X - G
+ - H

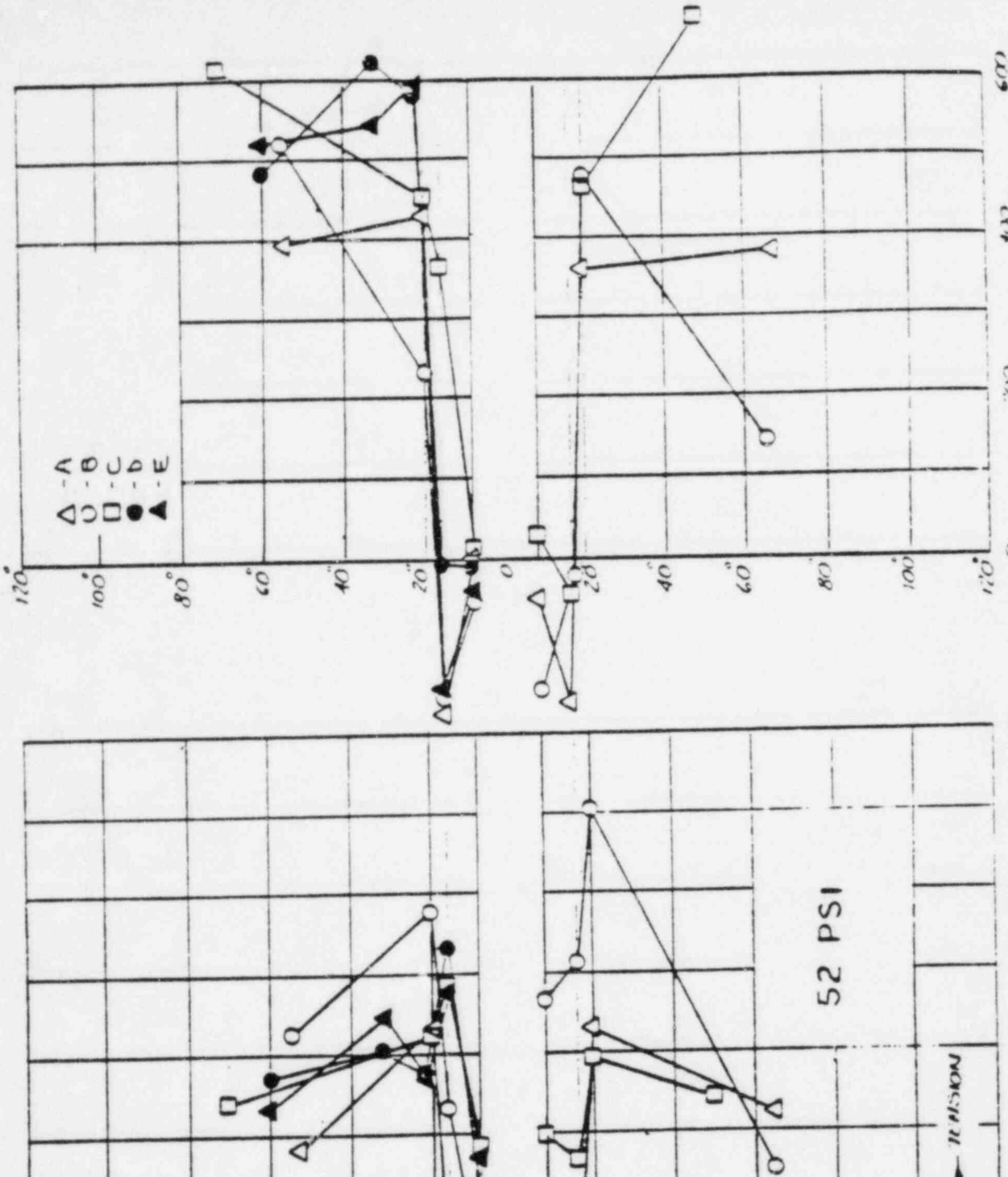

BEND LINE
26 PSI
52 PSI
ℓ/H
RADIAL DISPLACEMENT (in.)
△ - A
○ - B
□ - C
● - D
▲ - E
0
0.2
0.4
0.6
0.8
1.0


BEND LINE
l/H
1.0
0.8
0.6
0.4
0.2
0
Δ - A
O - B
□ - C
● - D
▲ - E
26 PSI
COMP. ← → TENSION
0
200
400
600
VERTICAL STRAIN (μ-in/in)
TANGENTIAL STRAIN (μ-in/in)


BEND LINE
L/H
1.0
0.8
0.6
0.4
0.2
0
COMP. ← → TENSION
0
200
400
600
VERTICAL STRAIN (μ-in/in)
△ -A
○ -B
□ -C
● -D
▲ -E
52 PSI
TANGENTIAL STRAIN (μ-in/in)

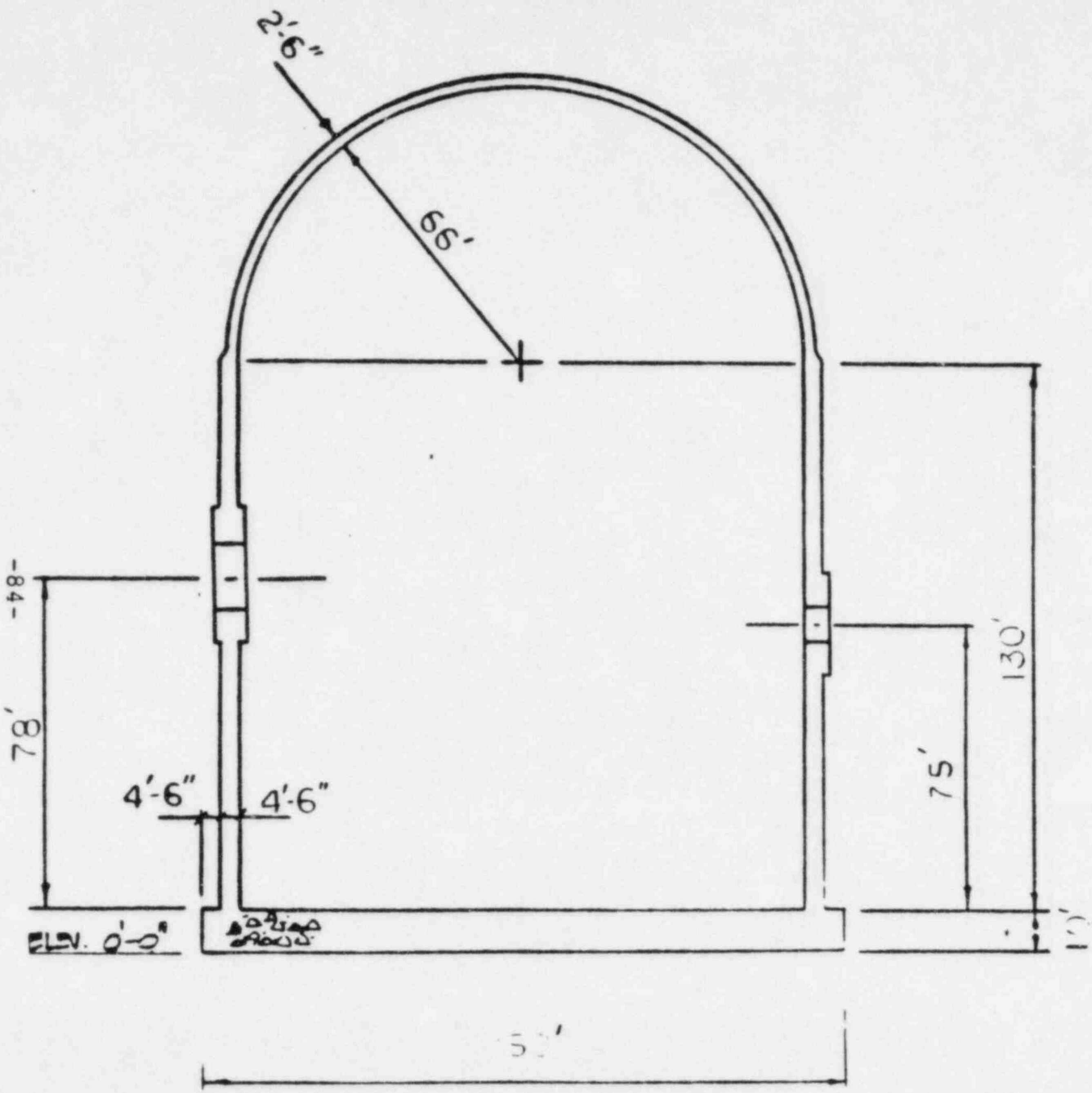


△ - A
O - B
□ - C
● - D
▲ - E
26 PSI
COMP. ← → TENSION
VERTICAL STRAIN (μ-in/in)
TANGENTIAL STRAIN (μ-in/in)

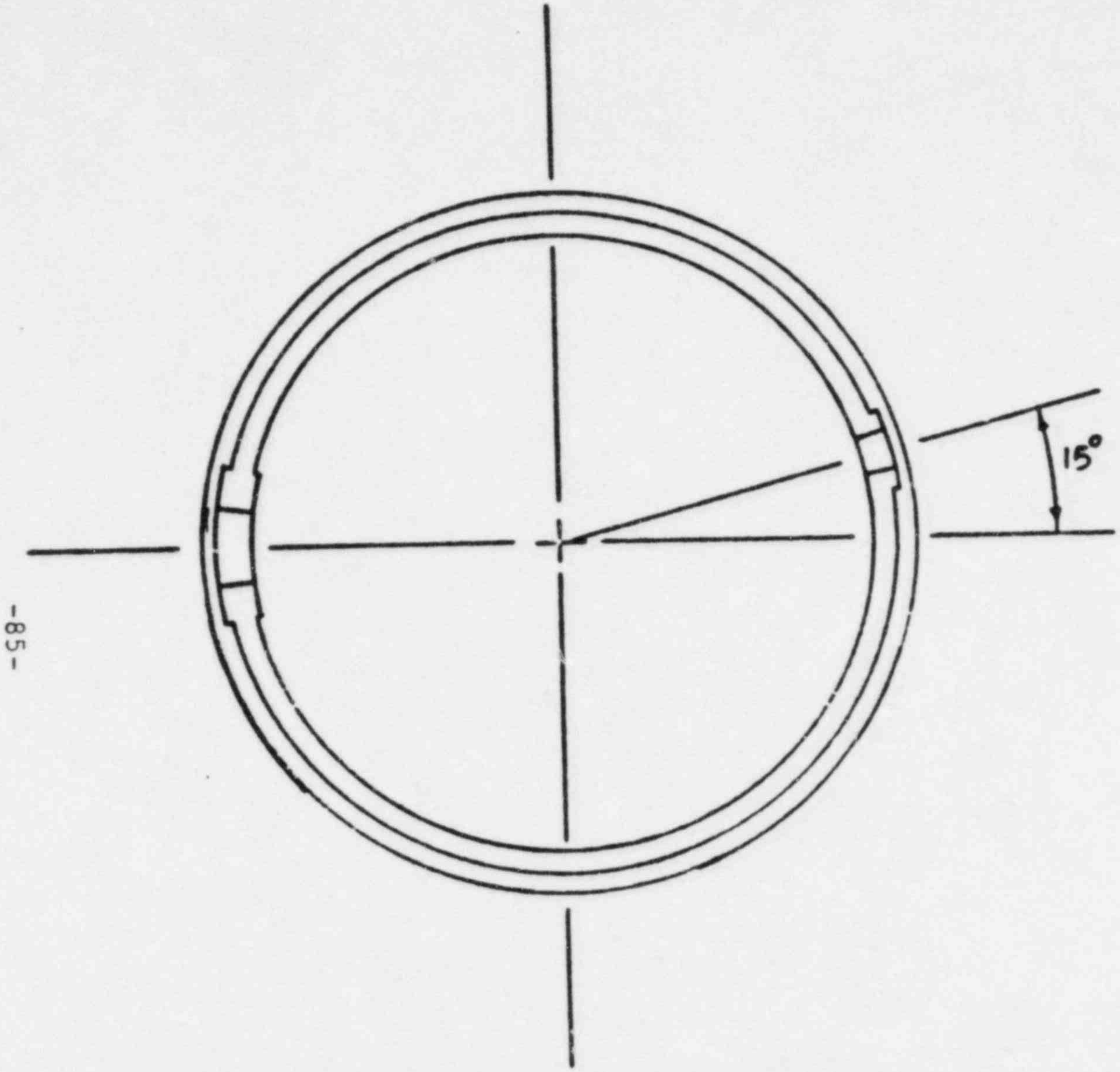


A
B
C
D
E
TANGENTIAL STRAIN (μ-in/in)
52 PSI
VERTICAL STRAIN (μ-in/in)
COMP.
TENSION

PROTOTYPE



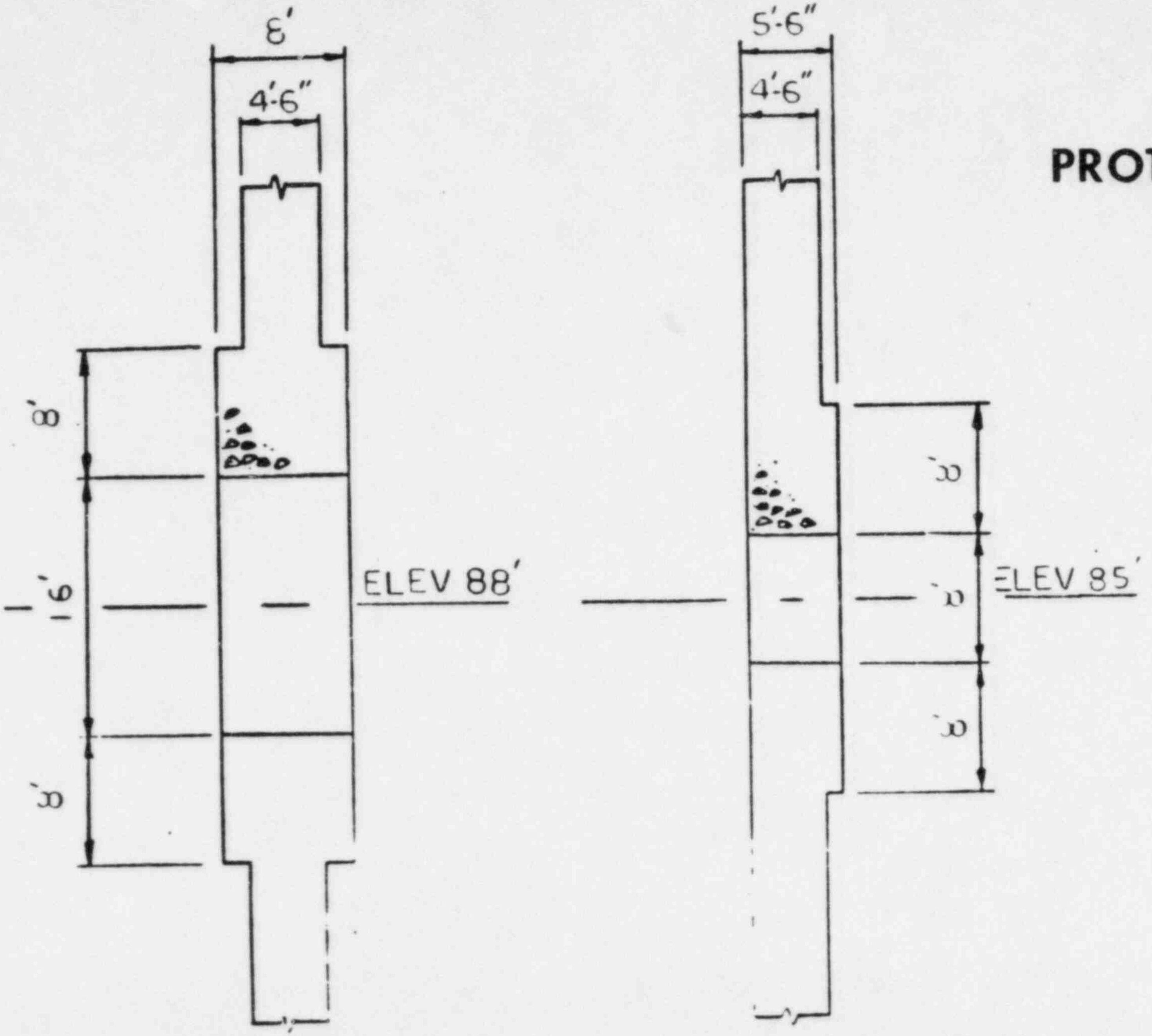
ELEVATION SECTION THRU
BOTH EQUIPMENT HATCH AND PERSONNEL AIRLOCK



PROTOTYPE

SECTION THRU EQUIPMENT HATCH AND
PERSONNEL AIRLOCK

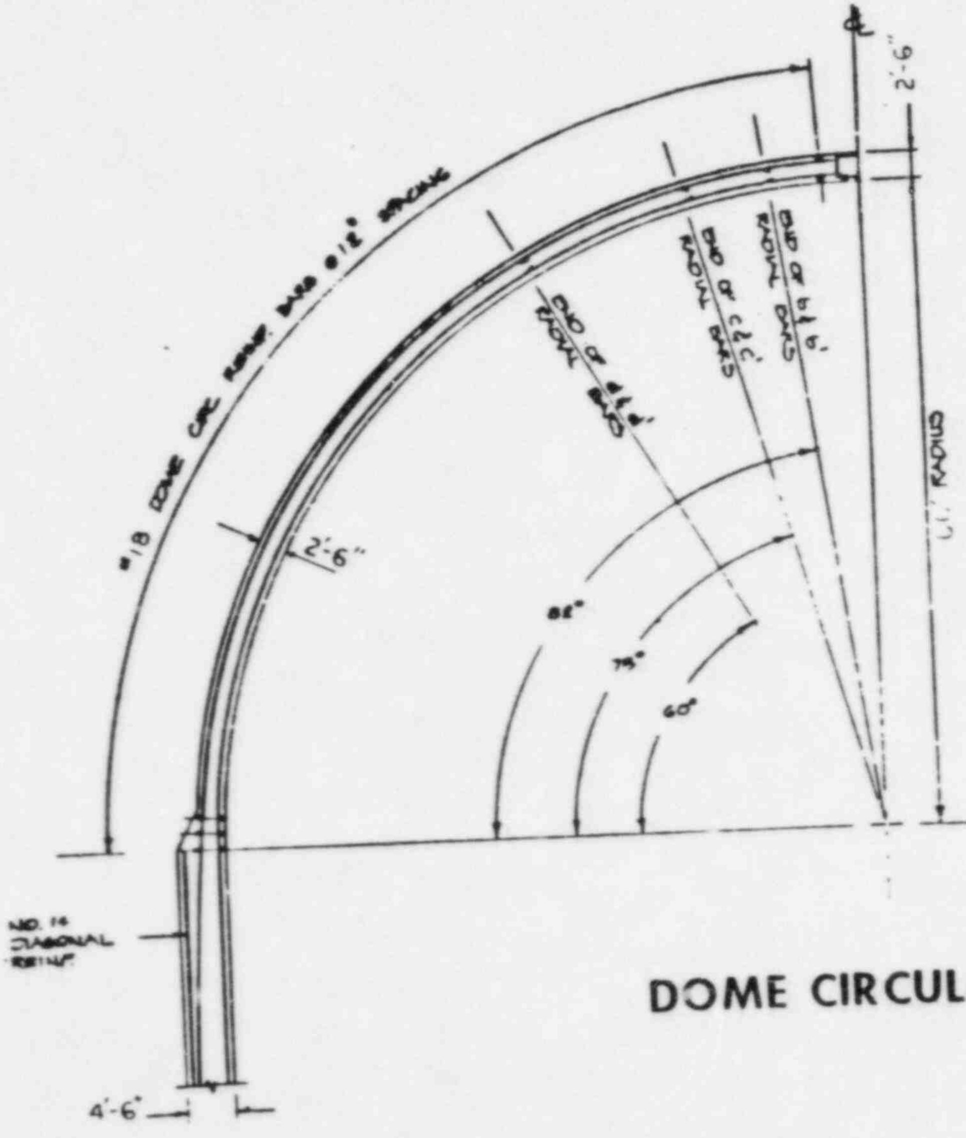
PROTOTYPE



EQUIPMENT HATCH **PERSONNEL HATCH**

CONRETE OUTLINE

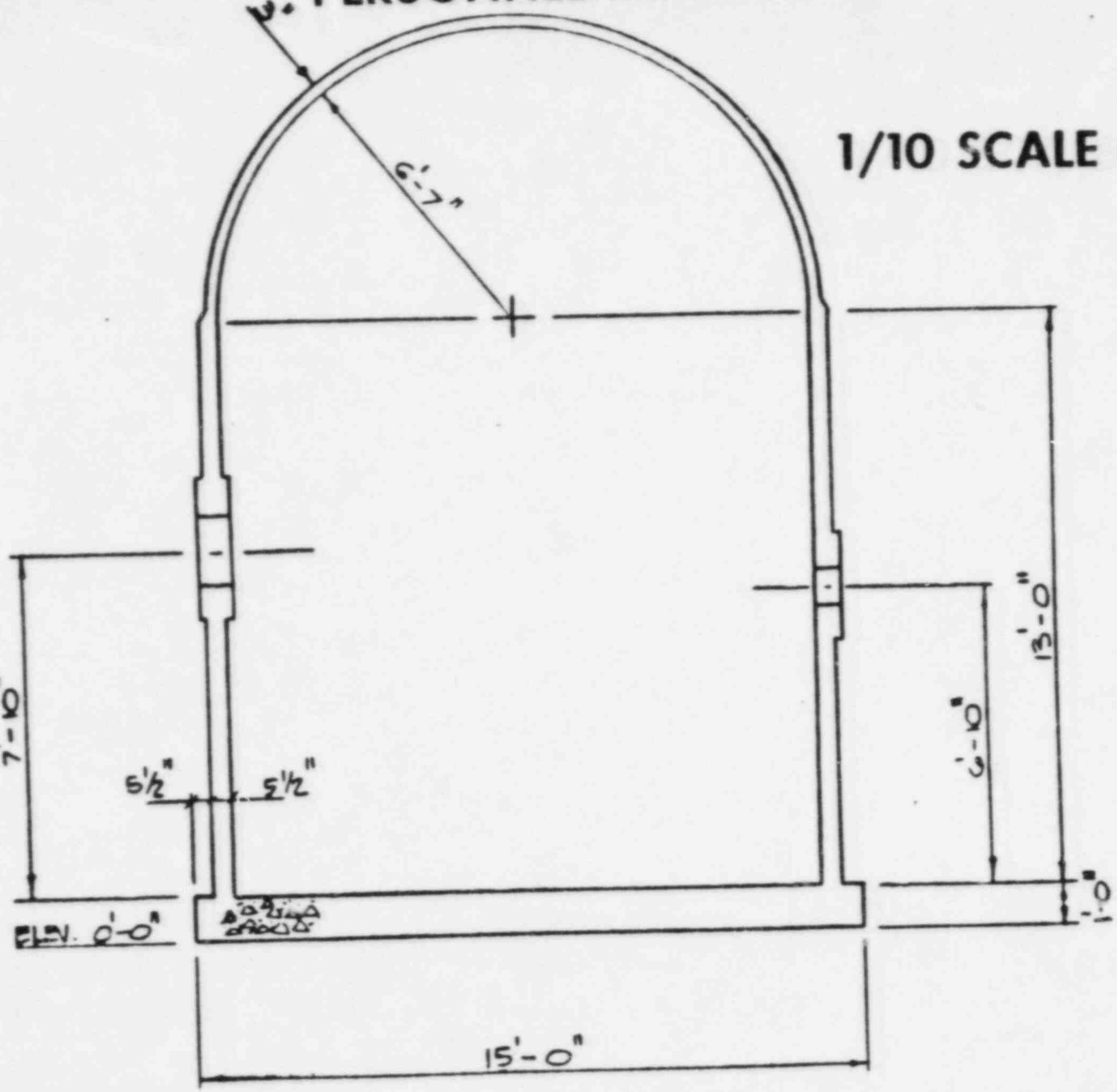
PROTOTYPE



DOME CIRCULAR REINFORCEMENT

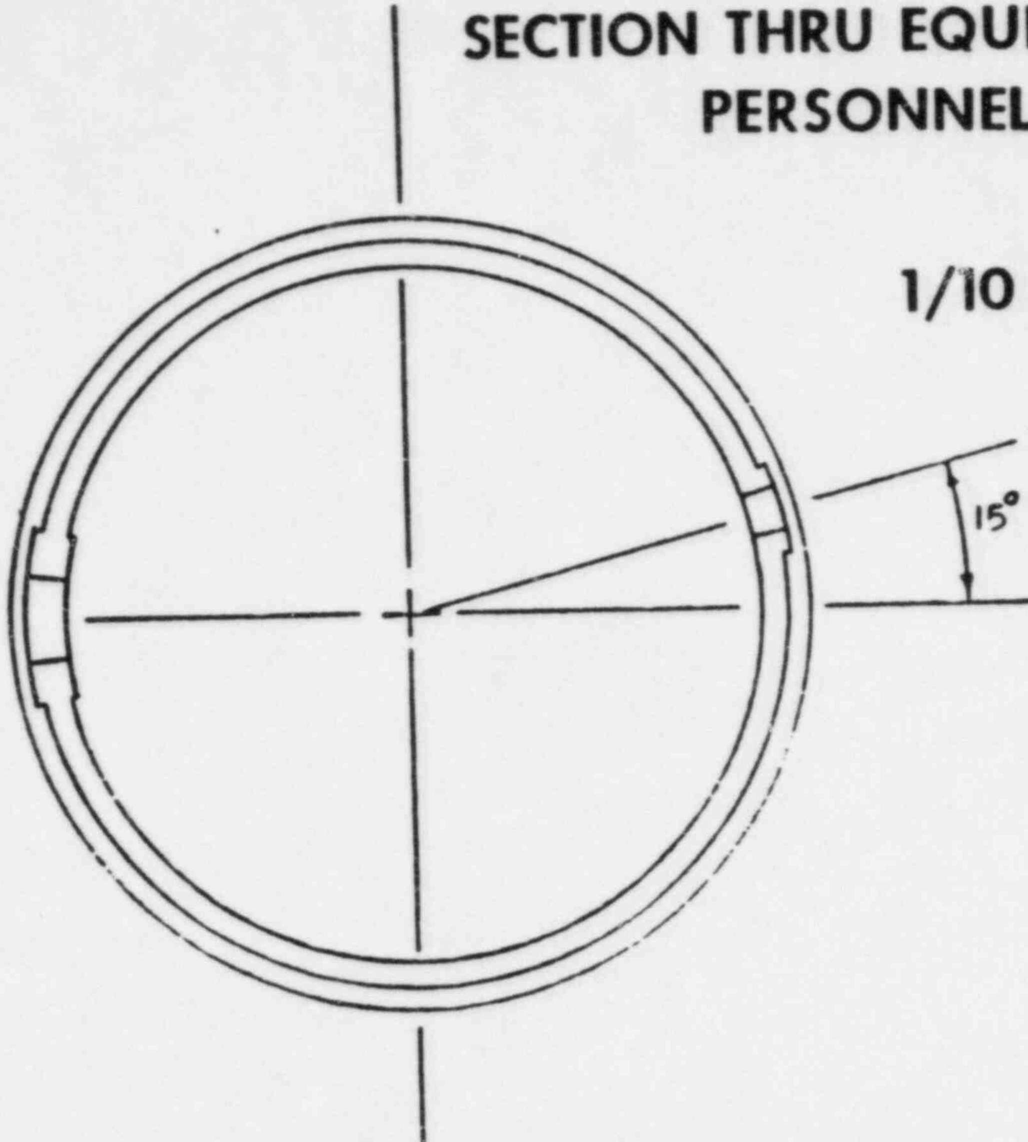
ELEVATION SECTION THRU BOTH EQUIPMENT HATCH AND PERSONNEL AIRLOCK

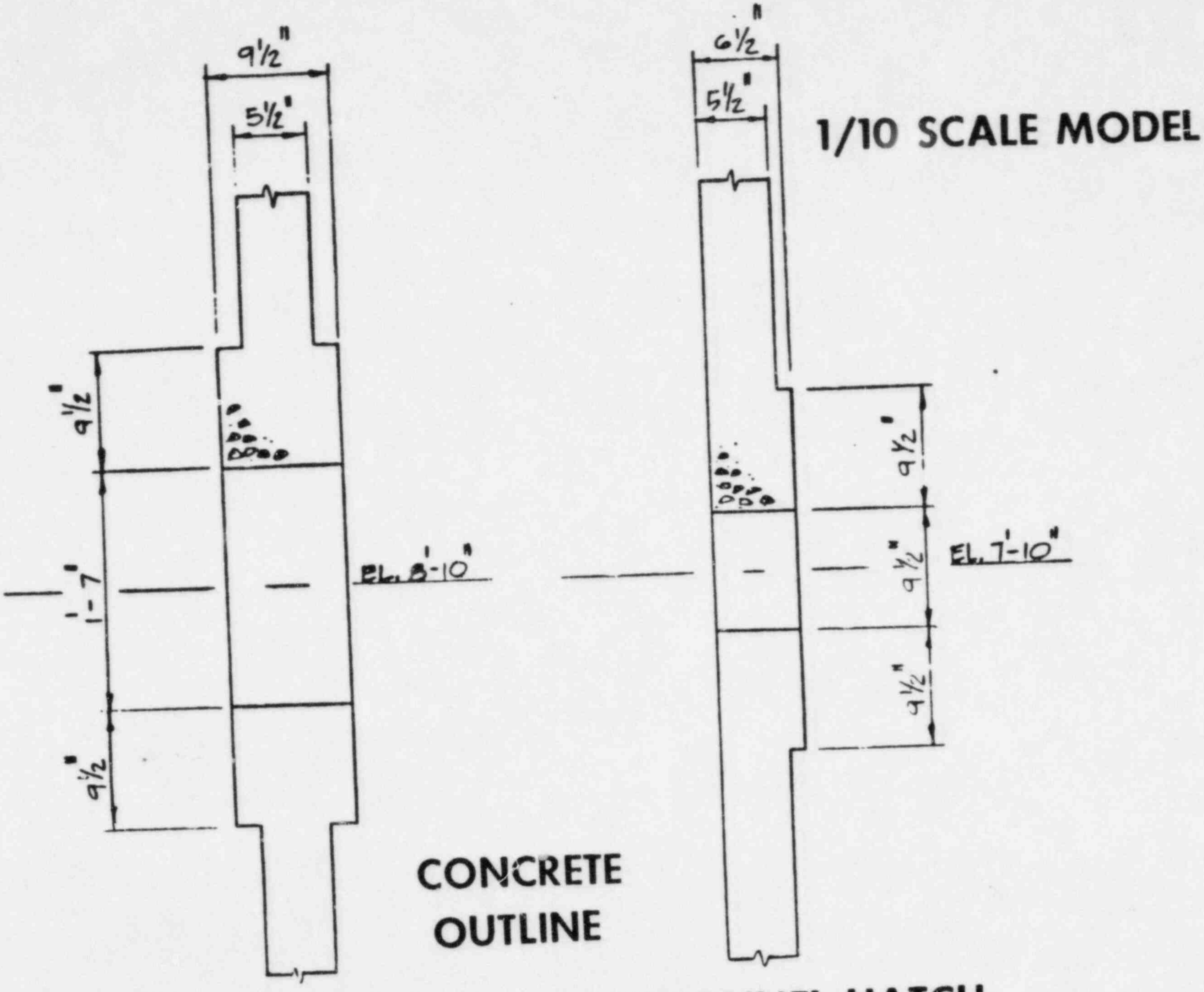
1/10 SCALE MODEL



SECTION THRU EQUIPMENT HATCH AND PERSONNEL AIR LOCK

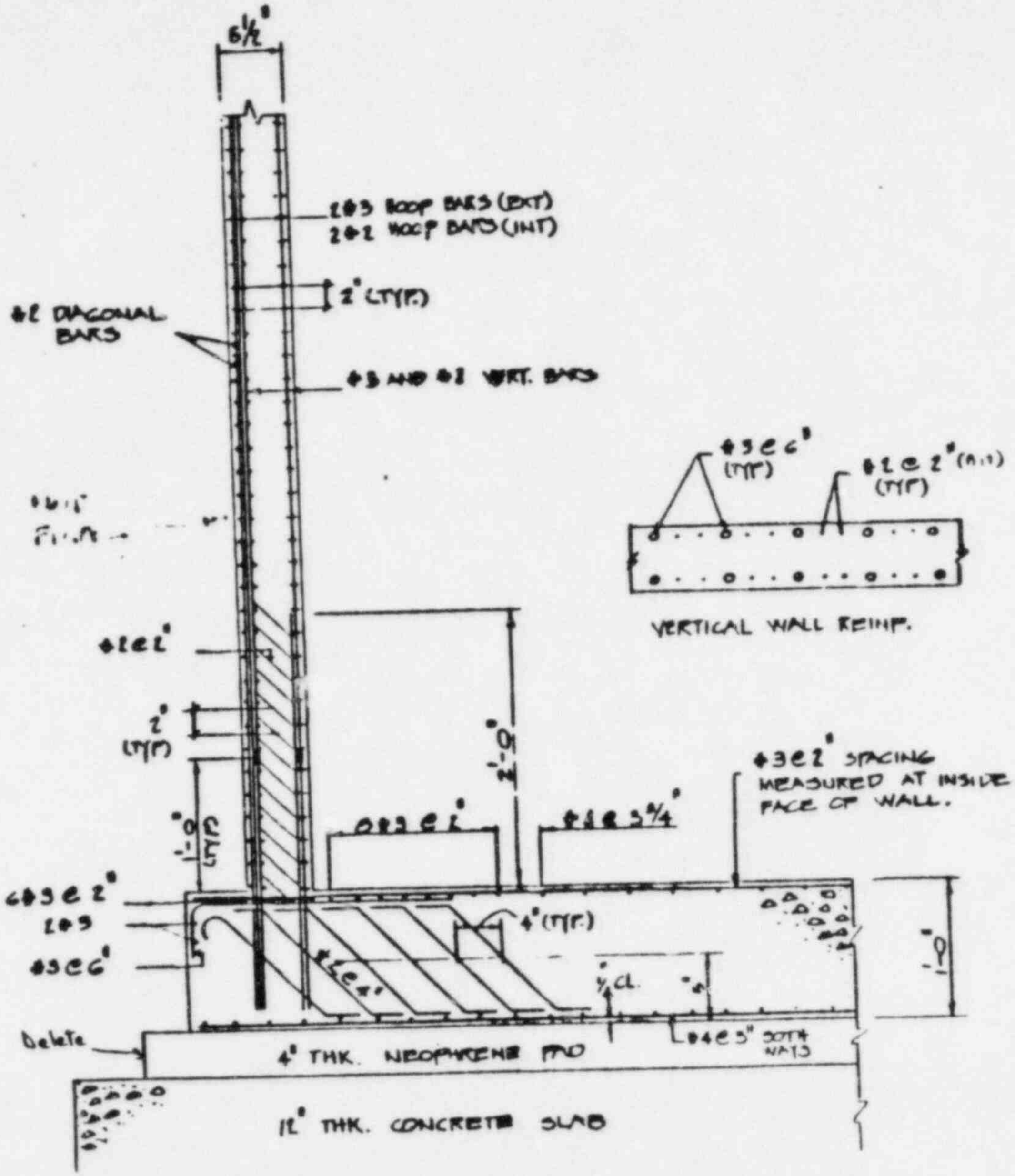
1/10 SCALE MODEL





EQUIPMENT HATCH

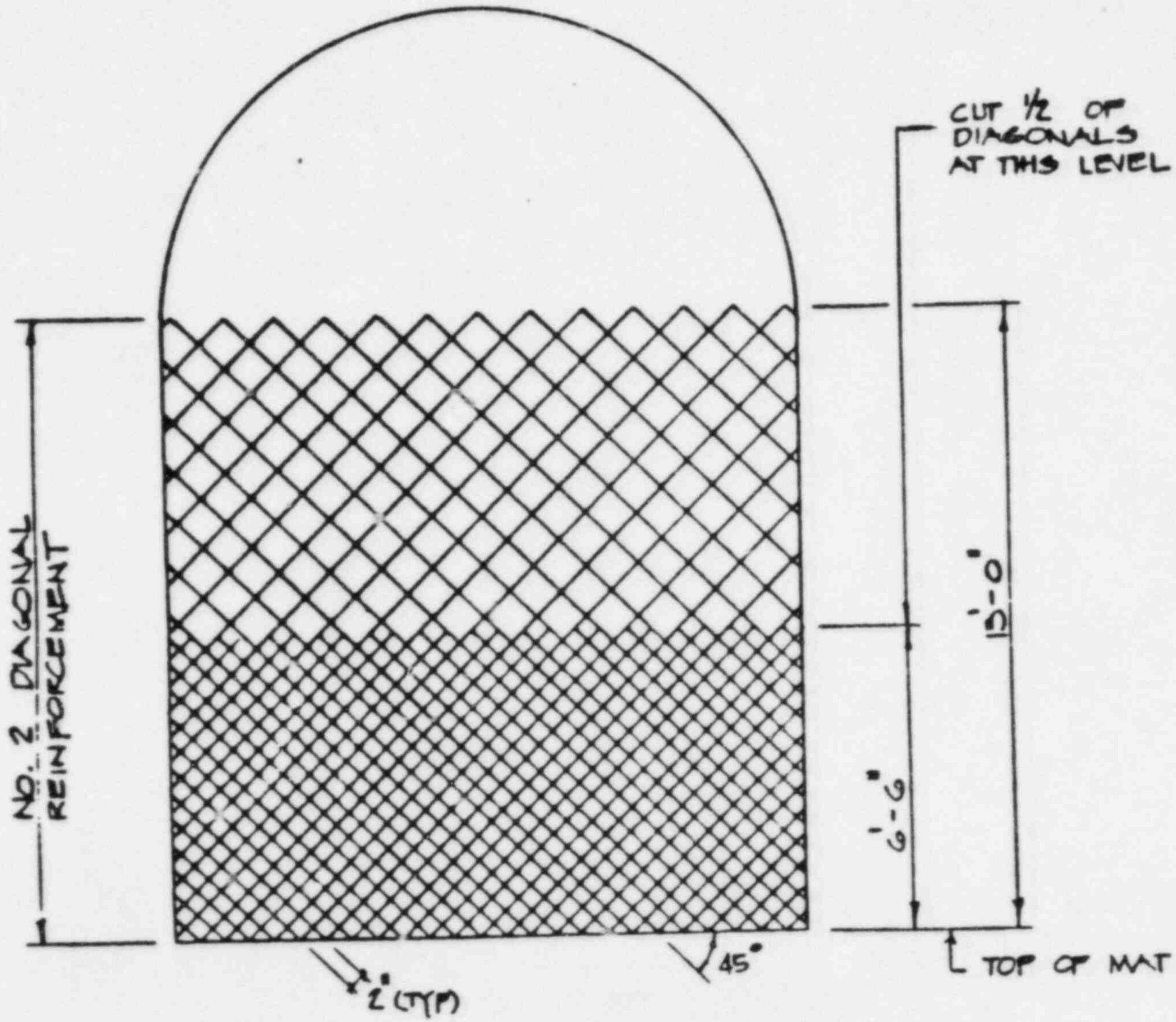
PERSONNEL HATCH

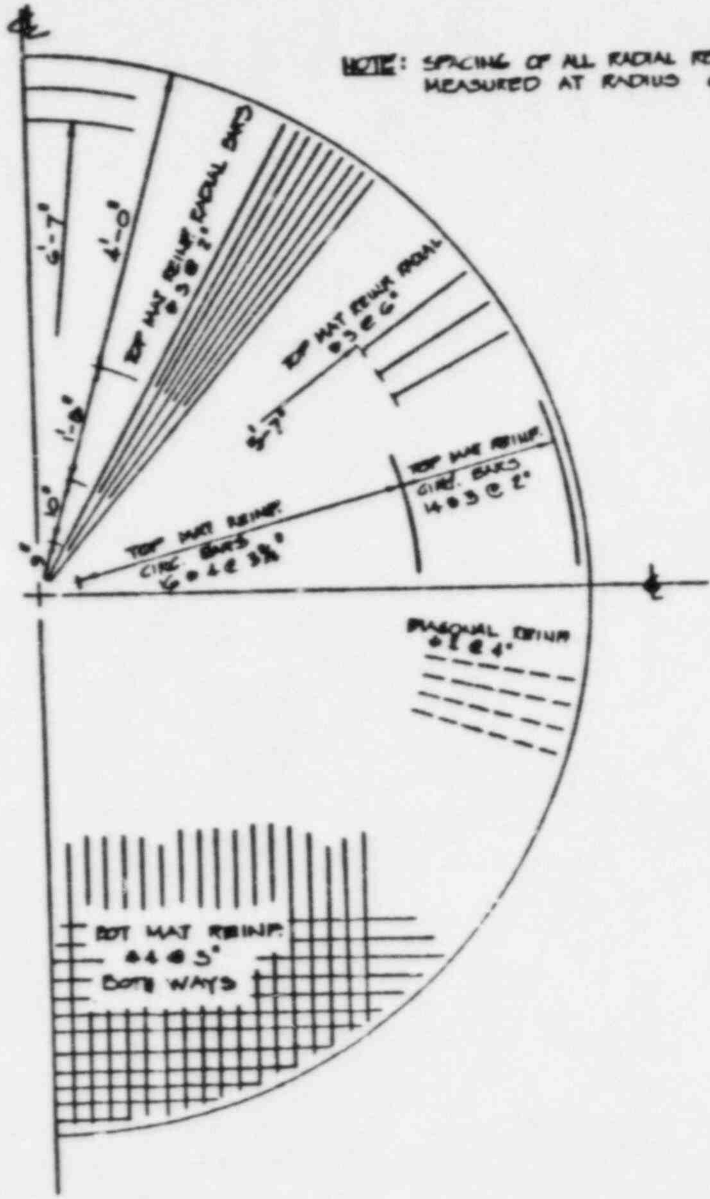


1/10 SCALE MODEL

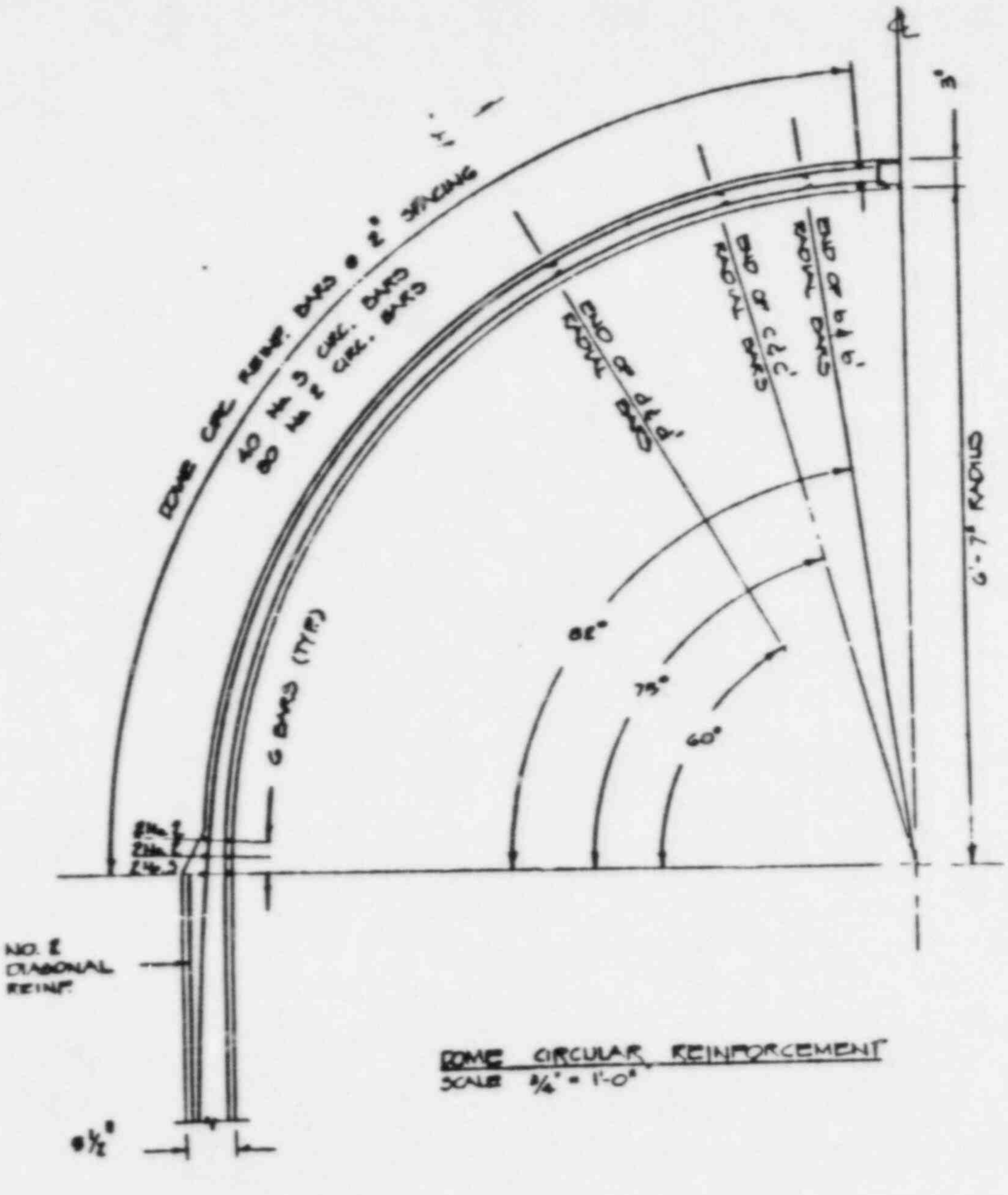
MAT-WALL JOINT REINFNORCEMENT DETAIL (ALTERNATIVE #1)

DIAGONAL REINFORCEMENT





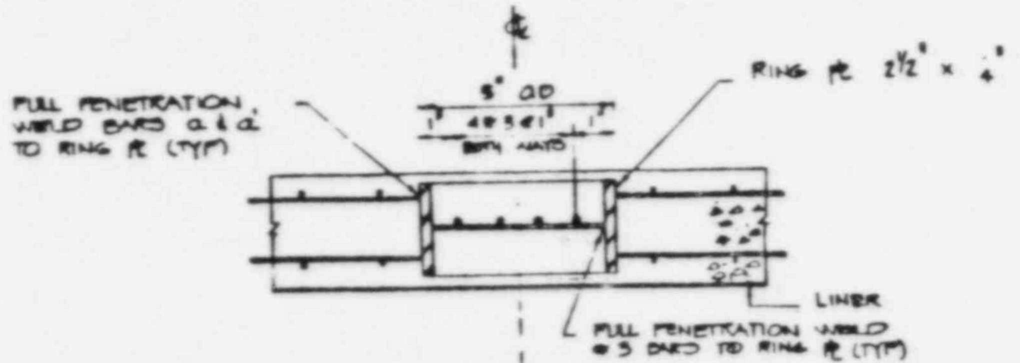
MAT FOUNDATION REINFORCEMENT



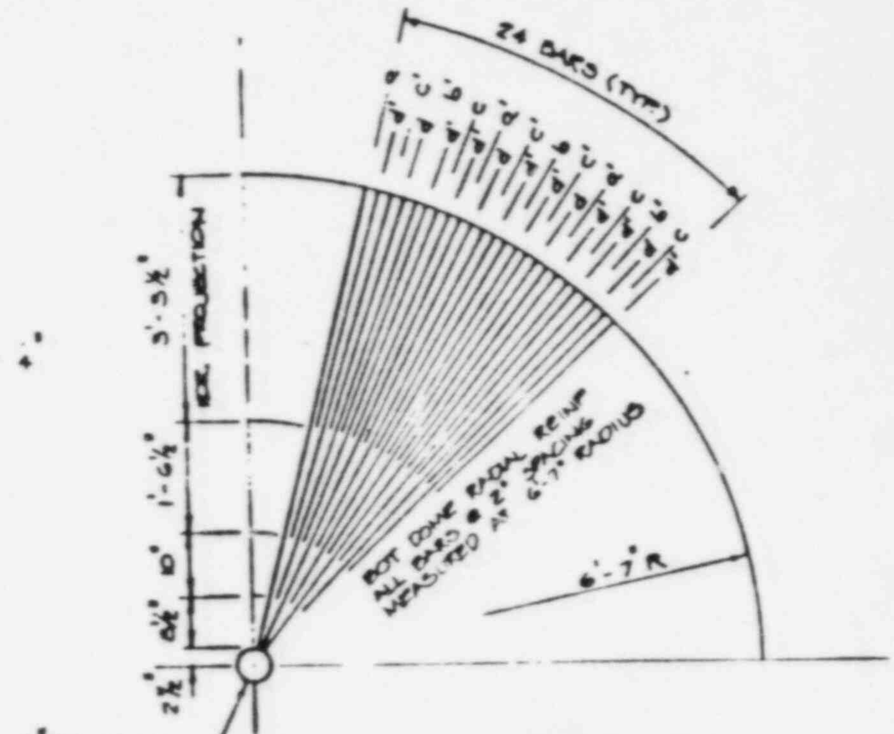
DOME CIRCULAR REINFORCEMENT SCALE ¾" 1'-0"

DOME RADIAL REINFORCEMENT DOME RING PLATE AT APEX

DOME RADIAL REINFORCEMENT
SCALE 1/2" = 1'-0"



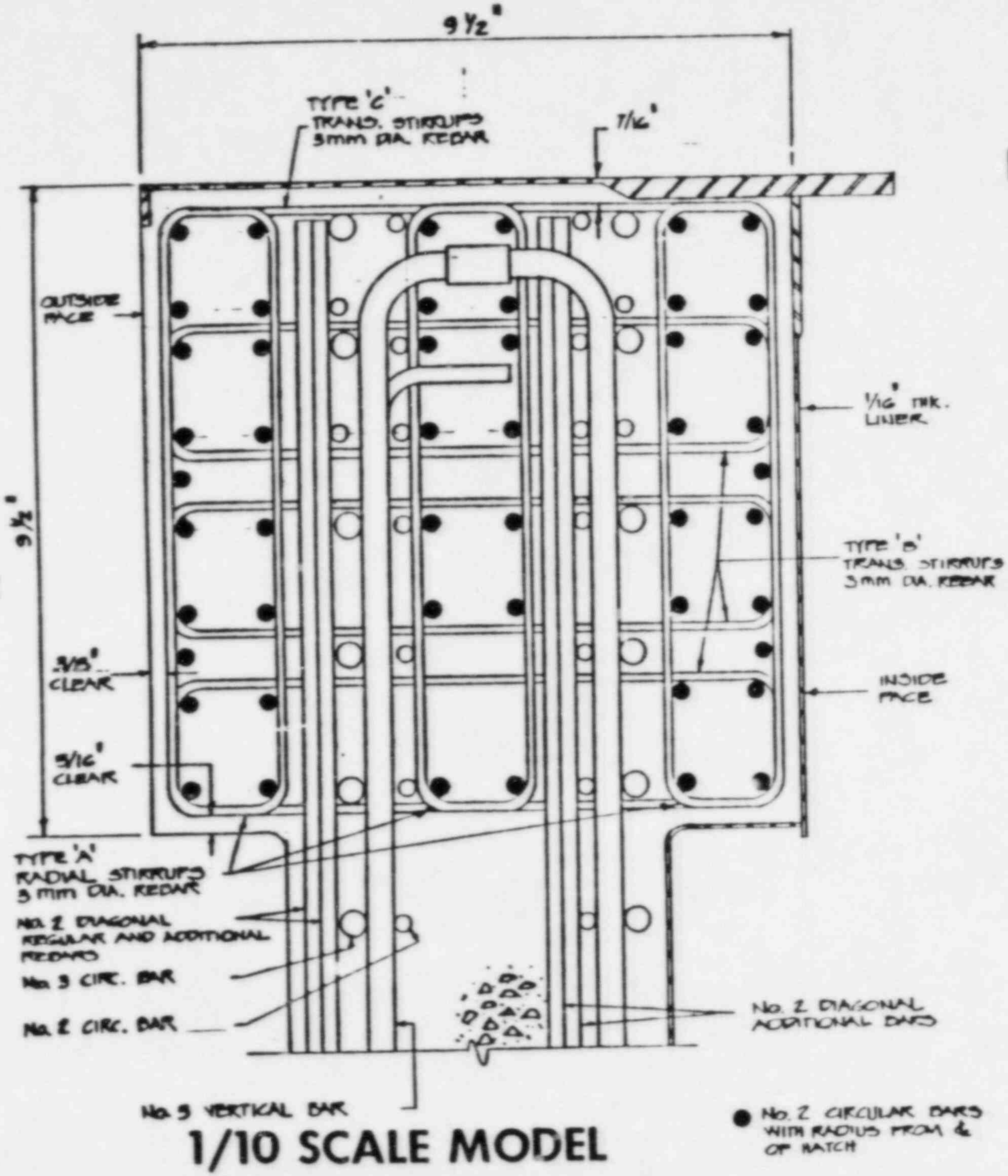
DOME RING PLATE
SCALE 3" = 1'-0"



NOTE

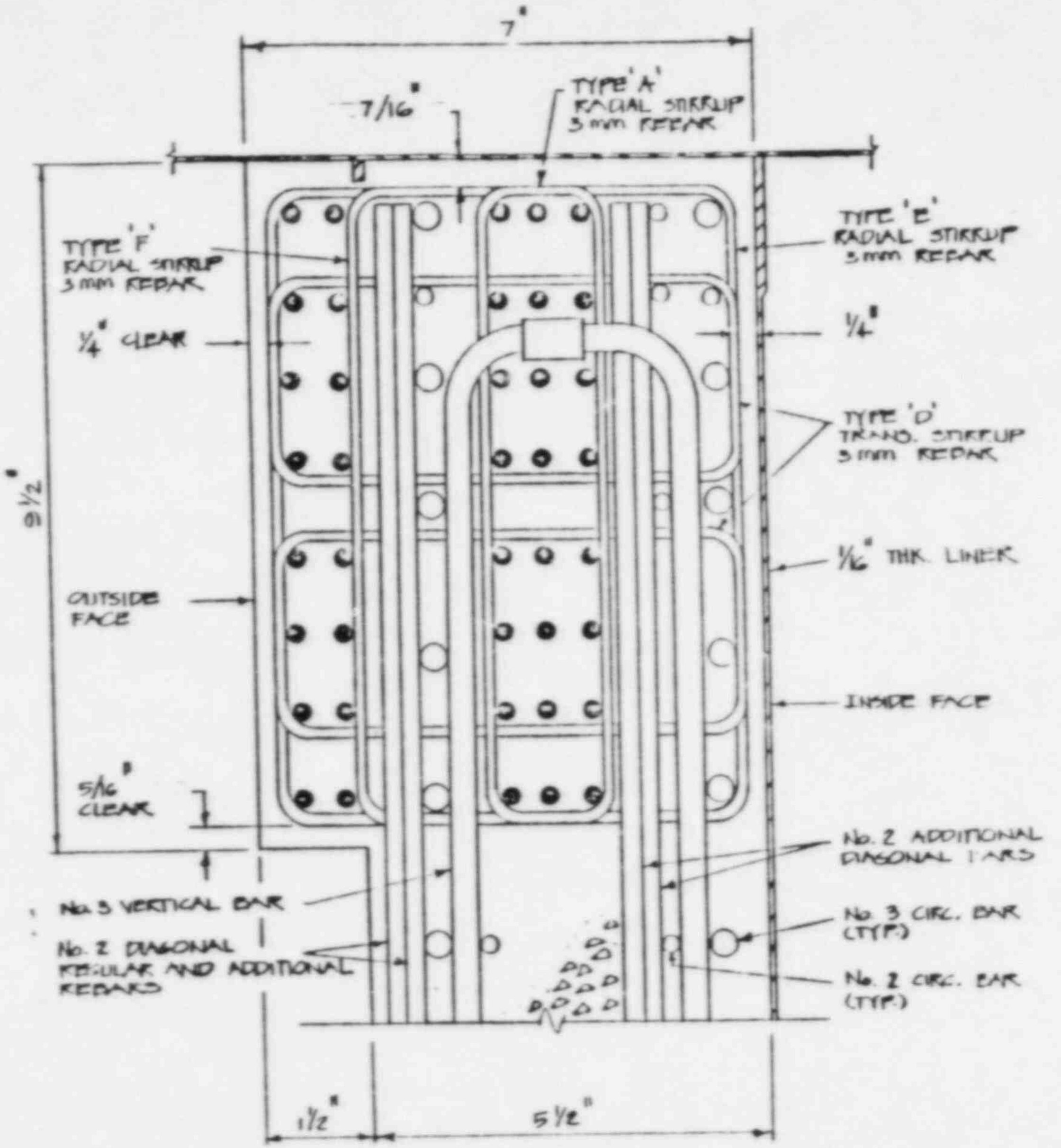
a - 10 # 3 BARS
b - 10 # 3 BARS
c - 21 # 3 BARS
d - 41 # 3 BARS
a' - 20 # 2 BARS
b' - 21 # 2 BARS
c' - 41 # 2 BARS
d' - 83 # 2 BARS

EQUIPMENT HATCH REINFORCEMENT DETAILS



1/10 SCALE MODEL

PERSONNEL HATCH REINFORCEMENT DETAILS

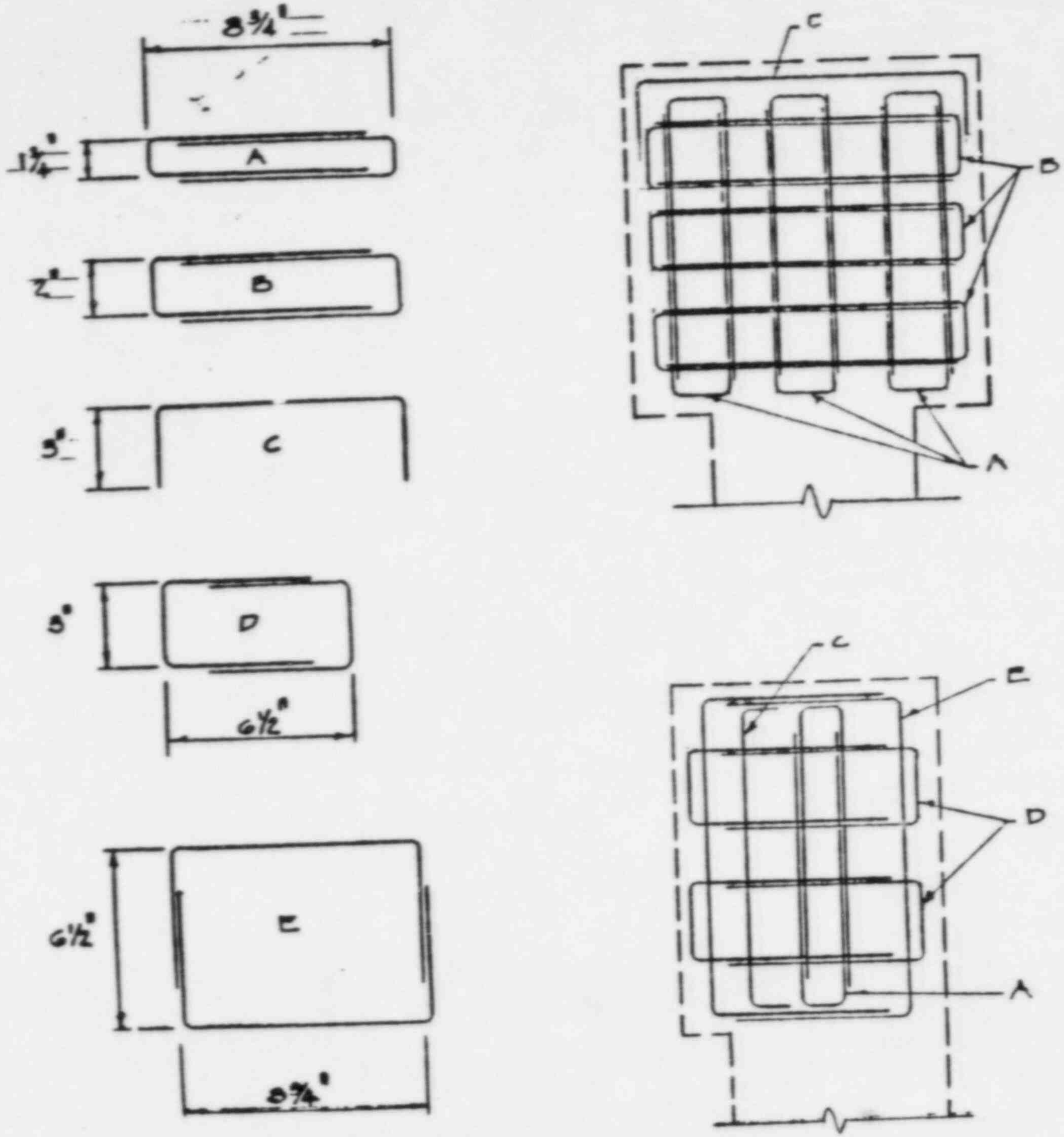


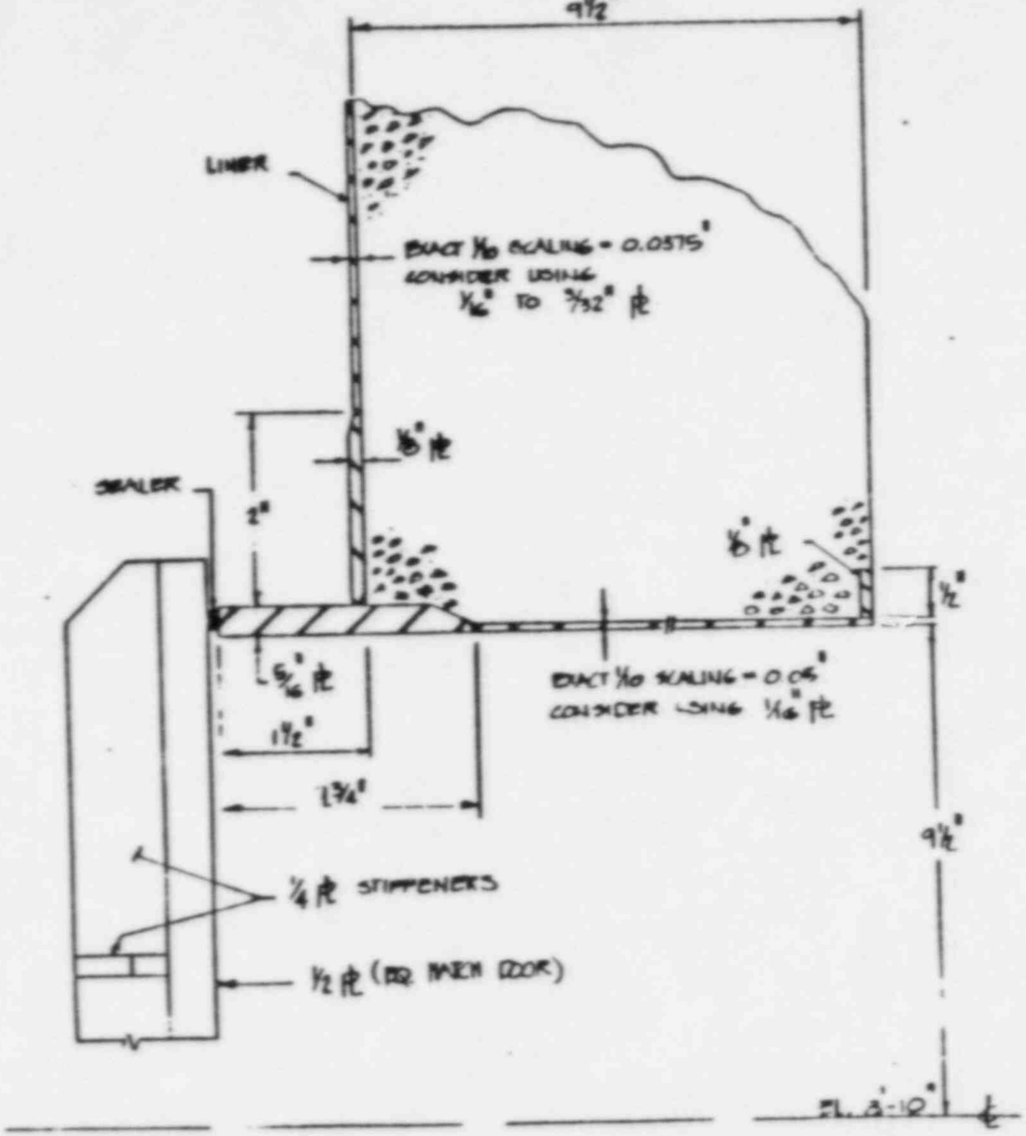
1/10 SCALE

● No. 2 CIRCULAR BARS WITH RADIUS FROM ℄ OF HATCH

83-33.456

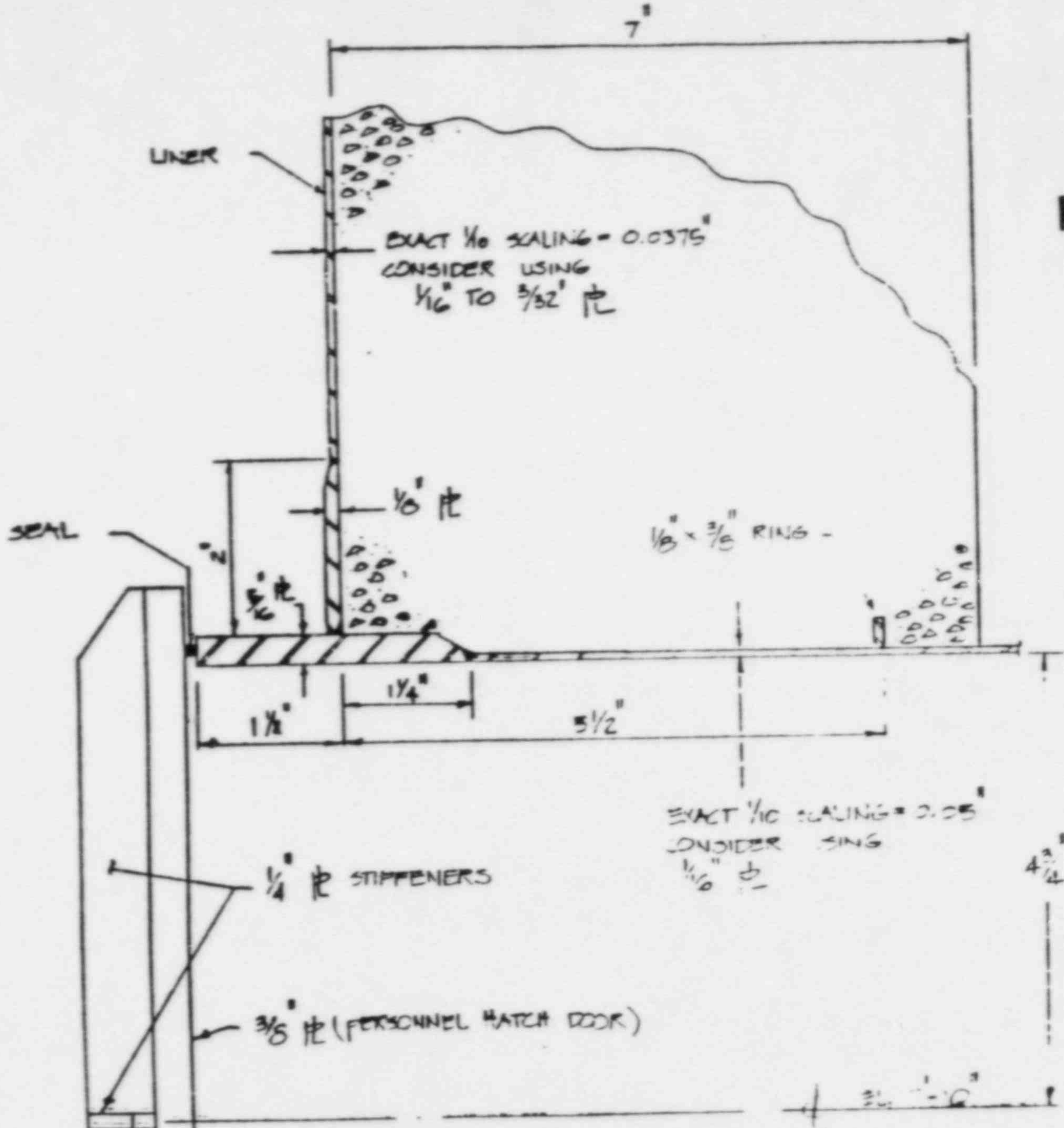
STIRRUP REINFORCEMENT DETAILS AT EQUIPMENT AND HATCH PERSONNEL PENETRATIONS





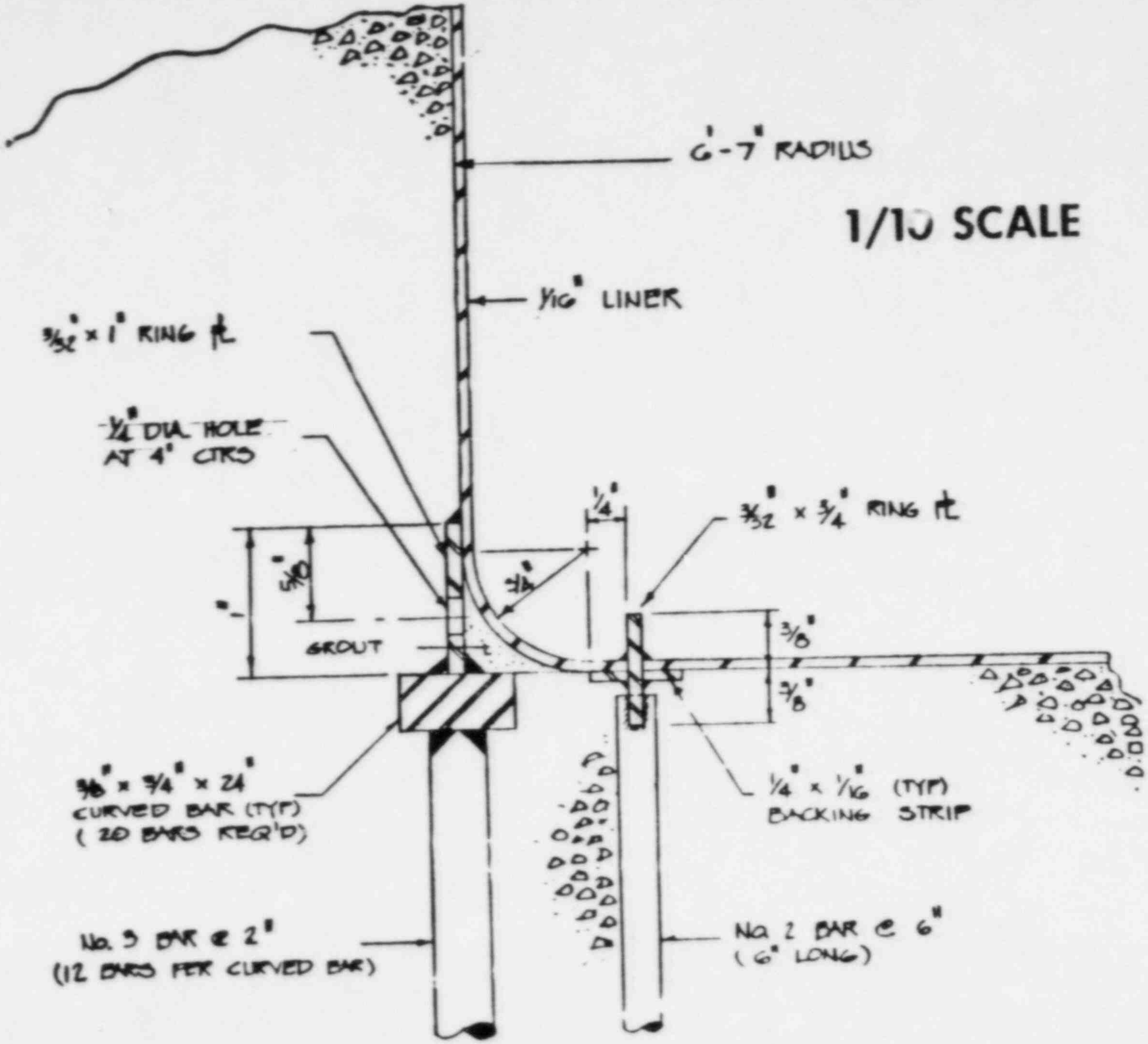
LINER DETAILS AT EQUIPMENT HATCH

LINER DETAILS AT PERSONNEL HATCH



1/10 SCALE MODEL

1/10 SCALE



LINER DETAIL AT WALL-MAT JUNCTION

SPECIAL CONSIDERATIONS

ACCESS TO MODEL

SMALL REBARS (2 + 3 MM)

INSTRUMENTATION
- LOCATION
- TYPE

MECHANICAL SPLICES

LINER MATERIAL
- BEHAVIOR
- CONSTRUCTABILITY
- WELDING
- SHIPPING
- FIELD WELDING
- STUDS

STUDS
- SPACING
- LOCATION
- DISTORTIONS

MAT
- SUBGRADE
- INTERNALS
- OVERLAY
- GEOMETRY

	TITLE	SCALE
CHECKED	-102-	DATE
CORRECT		SKETCH NUMBER
APPROVED		
REVISIONS ② ③ ④ ⑤		

SPECIAL CONSIDERATIONS

SPECIAL EFFECTS TESTS

TYPE A

- Liner Weld Tension
- Cracking Pattern
- Concrete Mix
- Bond Tension
- Construction Joint

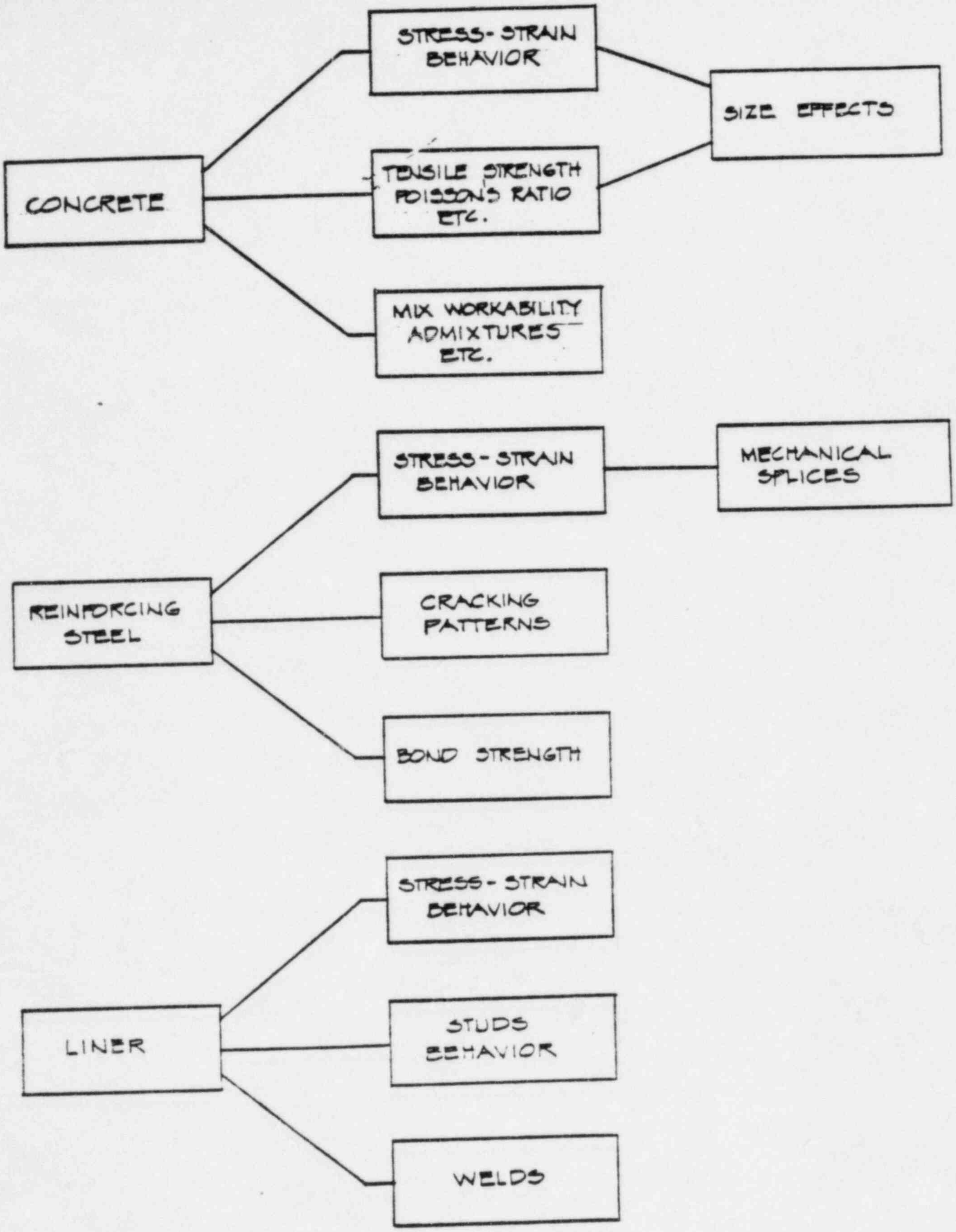
TYPE B

- Concrete at Test

TYPE C

- Smaller Penetrations
- Base Details
- Leak Rate

		TITLE	SCALE
CHECKED			DATE
CORRECT			SKETCH NUMBER
APPROVED			
REVISIONS	②	③ ④ ⑤	



TITLE MATERIALS TESTING

-104-

SCALE

DATE

CHECKED S. MARTINEZ

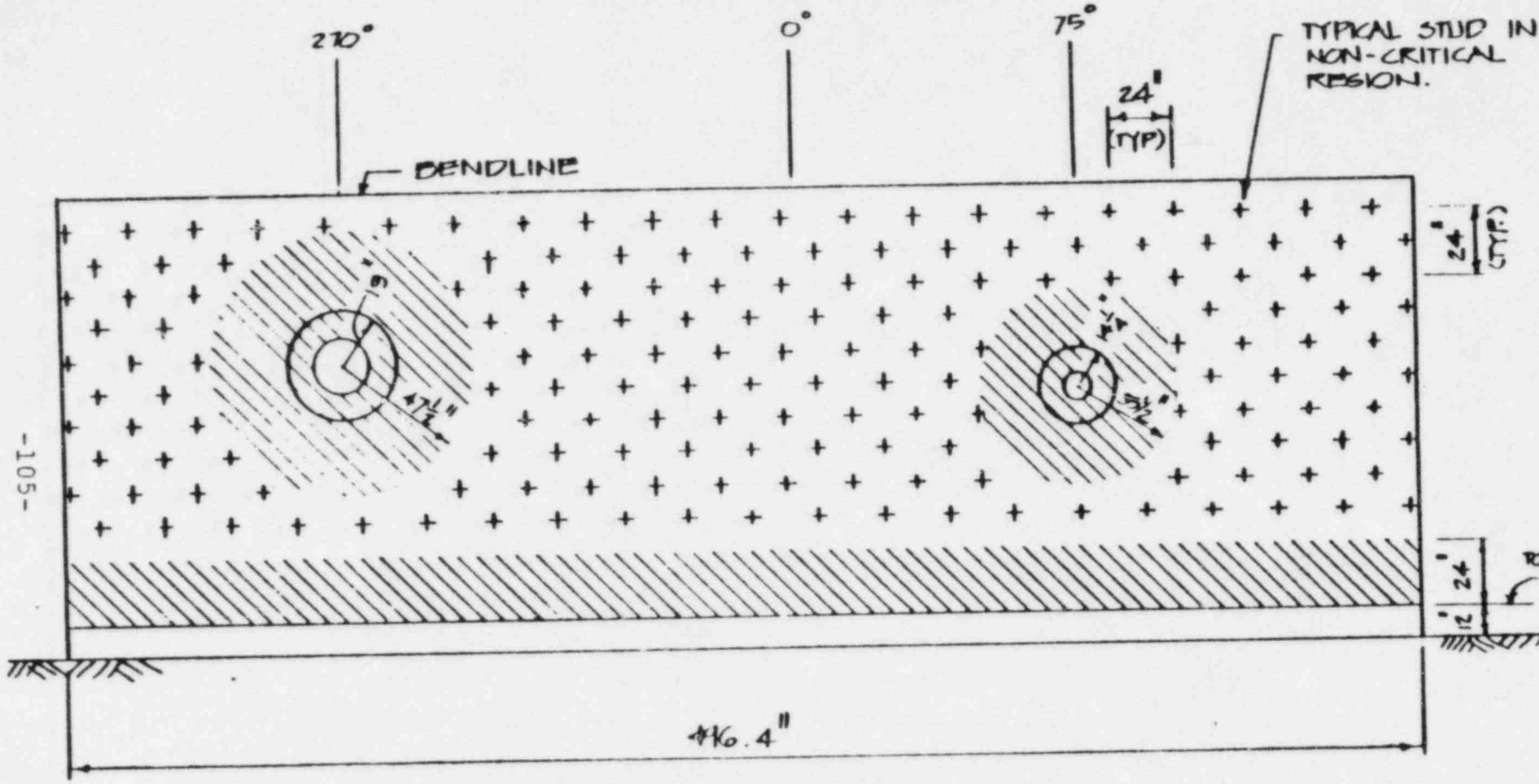
CORRECT

APPROVED

SKETCH NUMBER 14531-SK-22

REVISIONS ② ③ ④ ⑤

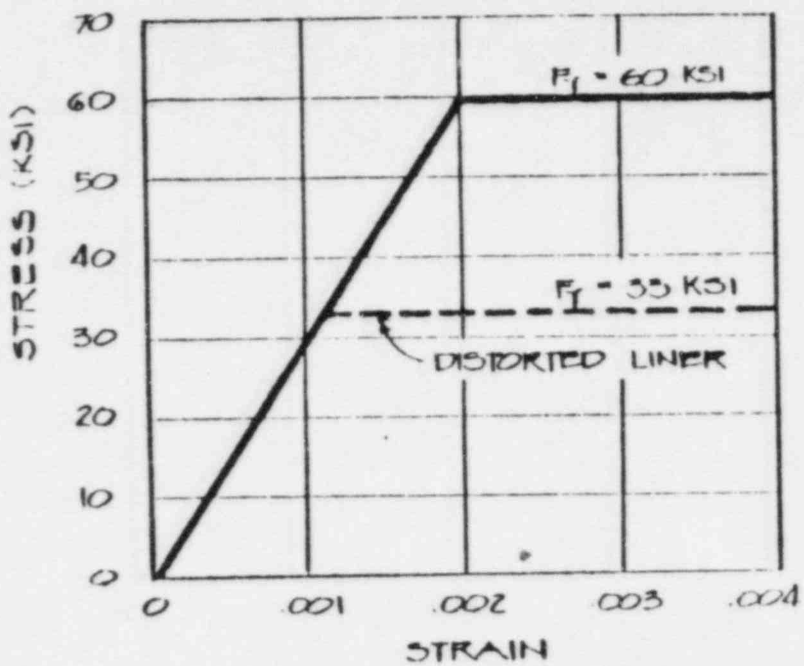
TENTATIVE PATTERN FOR LINER STUDS



1/10 SCALE MODEL

AREAS WHERE POPULATION OF STUDS SHOULD BE INCREASED. PATTERN OF STUDS TO BE SPECIFIED.

DISTORTION CREATED BY USING A THICKER LINER



PROTOTYPE

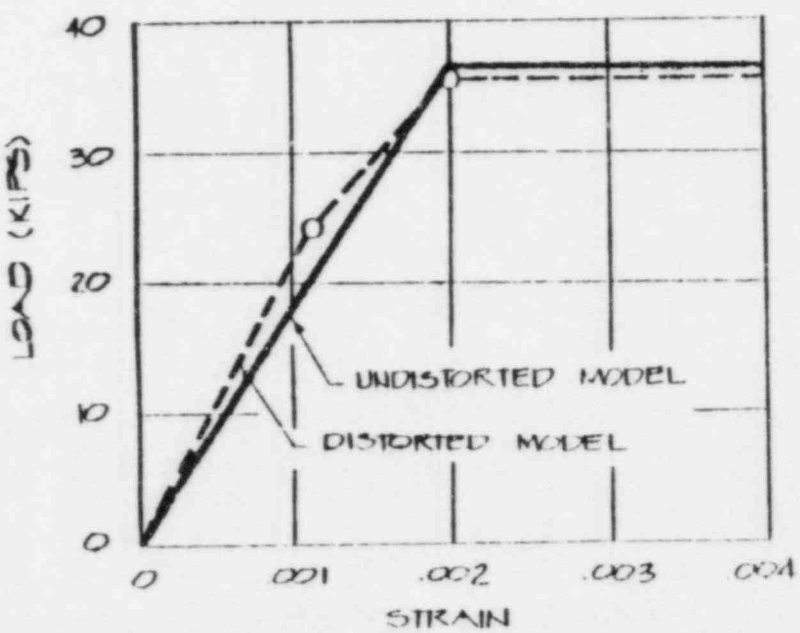
LINER THICKNESS = 3/8 in
LINER YIELD STRENGTH = 60 KSI

UNDISTORTED MODEL

LINER THICKNESS = (3/8)(1/10) = 0.038 in
LINER YIELD STRENGTH = 60 KSI

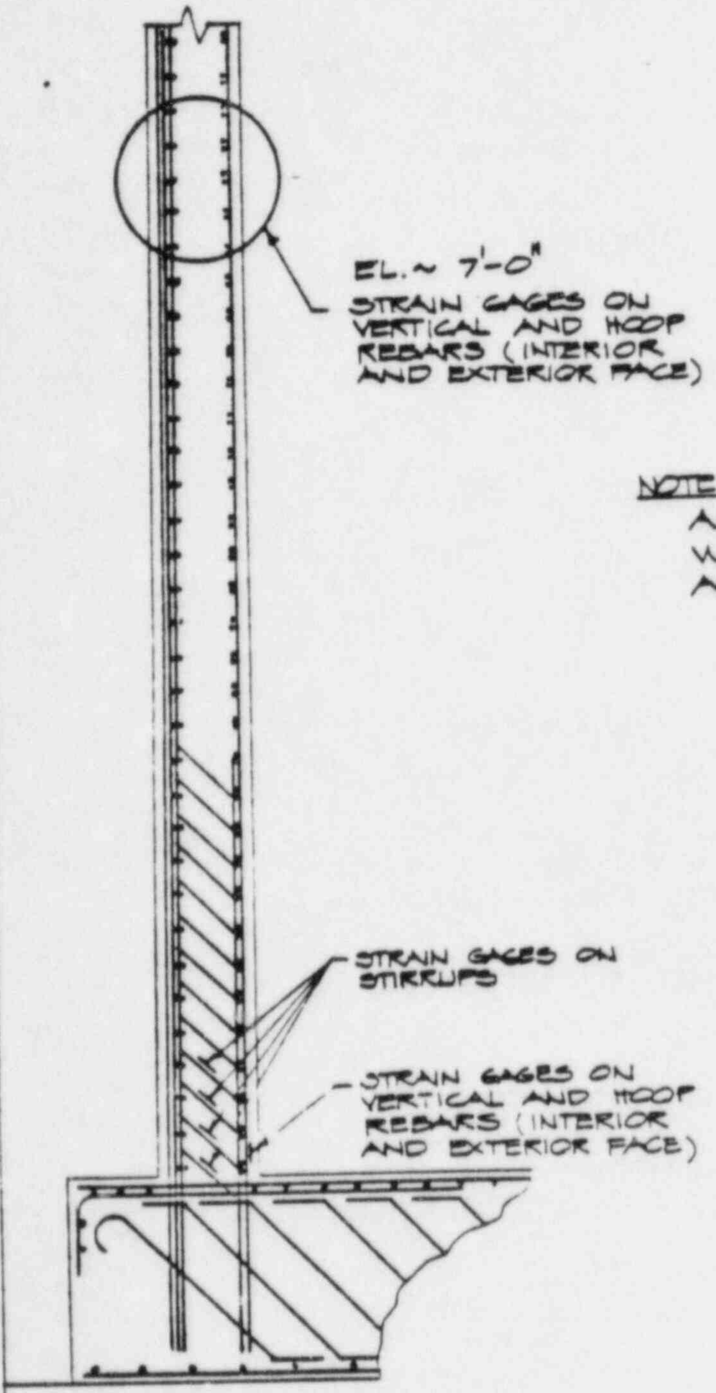
DISTORTED MODEL

LINER THICKNESS = 1/16 in = 0.063 in
LINER YIELD STRENGTH = 33 KSI



DISTORTION CREATED BY USING A THICKER LINER

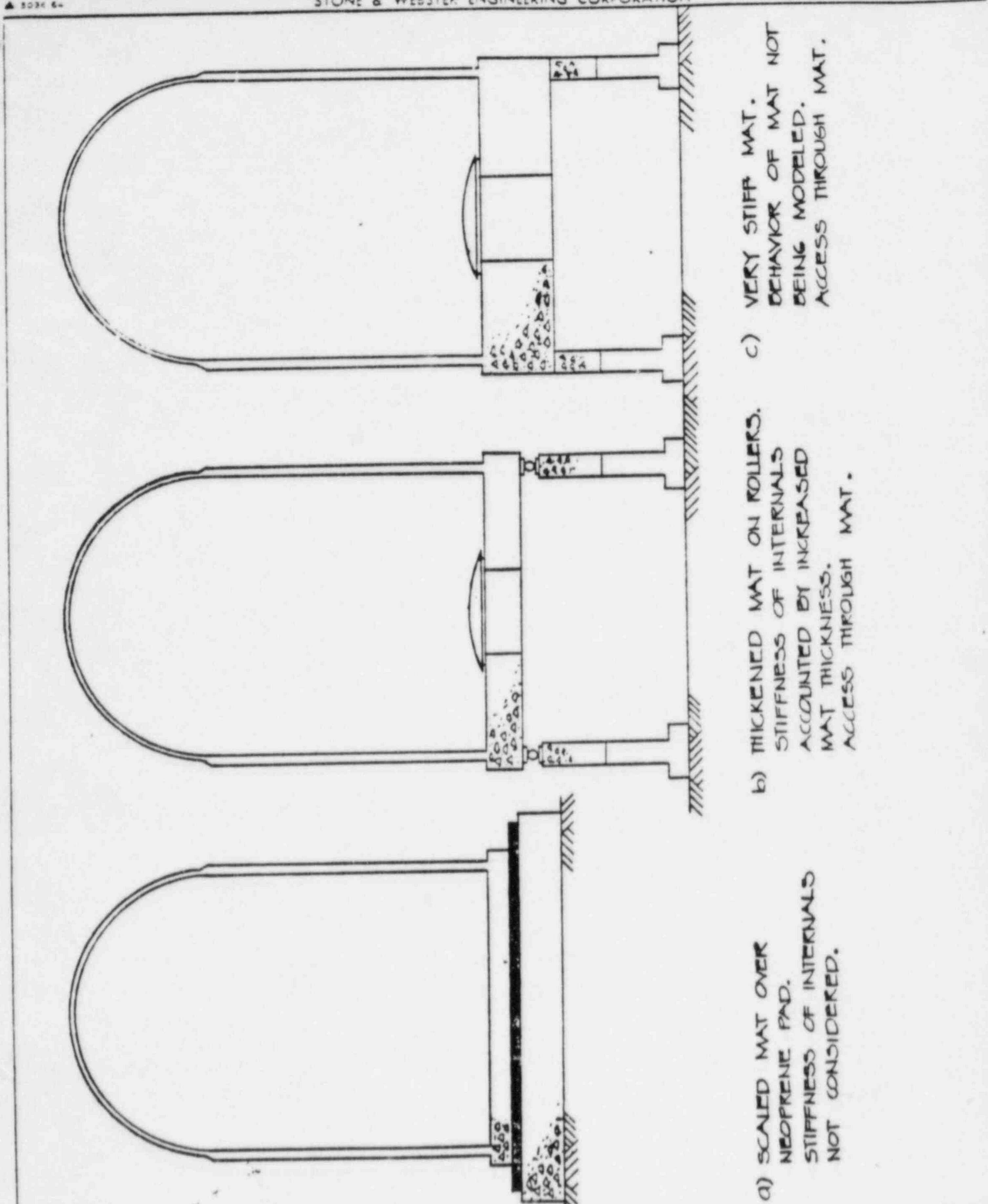
08-97 4CC



NOTE:
ADDITIONAL STRAIN GAGES ON REBARS WILL BE RECOMMENDED AT THE DOME AND PENETRATIONS.

		TITLE STRAIN GAGES ON REINFORCING REBARS	SCALE:
CHECKED	S. MARTINEZ		DATE:
CORRECT		-107-	SKETCH NUMBER 14531-SK-23
APPROVED			
REVISIONS	②	③ ④ ⑤	

STONE & WEBSTER ENGINEERING CORPORATION



		TITLE POSSIBLE FOUNDATION ARRANGEMENTS	SCALE:
CHECKED	S. MARTINEZ		DATE:
CORRECT		-108-	SKETCH NUMBER 14531- SK- 21
APPROVED			
REVISIONS	② ③ ④ ⑤		

Attachment 4

CONTINGENCY PLANS FOR LARGE STEEL MODEL TEST

CONTINGENCY PLAN FOR LARGE STEEL MODEL

PARTS

Two 5ft. by 5ft. by 3/16" Plates

Shell Stiffeners and Gussets

O-Rings

Couplings and Plugs

Oversized Plates for All Penetrations

Procedures

Field Repair for Above

Welding Equipment

Inspection

Personnel

CBI Code Qualified Welder

CBI Supervision

Inspectors

CONTINGENCY PLAN FOR LARGE STEEL MODEL

ASSUMPTIONS:

For Leakage Rate $<$ 200% Volume per day

Continue Testing

For Leakage Rate $>$ 200% Volume per day

Repair Leak

For Leakage Above Proof But Below Ultimate

Repair Leak Subject to Above

Repairs

Major, Minor } Both Made in Field

Delays in Testing Should Be Minimized

Obtain Parts   Develop Procedures

Attachment 5

EPRI RESEARCH ON CONCRETE CONTAINMENT INTEGRITY

EPRI RESEARCH ON CONCRETE CONTAINMENT INTEGRITY

G.E. SLITER

Y.K. TANG

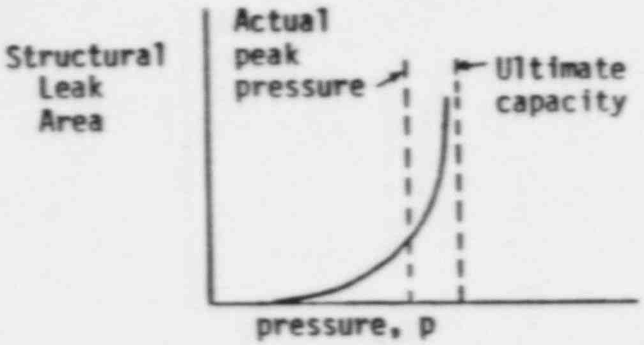
POST-SMIRT SEMINAR
"ISSUES IN CONTAINMENT ANALYSIS AND DESIGN"
CHICAGO, ILLINOIS
AUGUST 29-30, 1983

EPRI RESEARCH ON CONCRETE
CONTAINMENT INTEGRITY

OBJECTIVE: PROVIDE A DATA BASE AND A TEST-VERIFIED ANALYTICAL METHOD FOR MAKING REALISTIC EVALUATIONS OF INTEGRITY OF REINFORCED AND PRESTRESSED CONCRETE CONTAINMENTS UNDER OVERPRESSURIZATION LOADING.

ULTIMATE GOAL: CHARACTERIZE FAILURE MODES, LEAK RATE, AND RADIATION RELEASE AS FUNCTIONS OF PRESSURE AND TIME UNDER POSTULATED DEGRADED CORE CONDITIONS.

IMMEDIATE GOAL



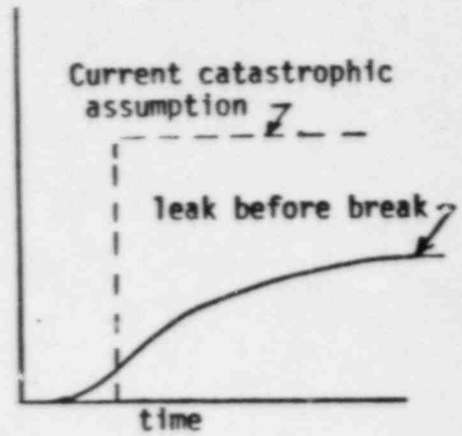
+

OTHER FACTORS

- Realistic p(t)
- Leak through penetrations
- Thermal effects
- Steam/aerosol blockage
- In-containment plate-out

→ Radiation Released

BOTTOM LINE



FAILURE MODE HYPOTHESES

TRADITIONAL (BASED ON LINEAR DESIGN AND LIMIT LOAD APPROACH)

- CATASTROPHIC FAILURE (SUDDEN TOTAL RELEASE) WHEN REINFORCEMENT/TENDONS REACH MEMBRANE YIELD/ULTIMATE.
- LINER REMAINS VIRTUALLY LEAK-TIGHT UNTIL FAILURE

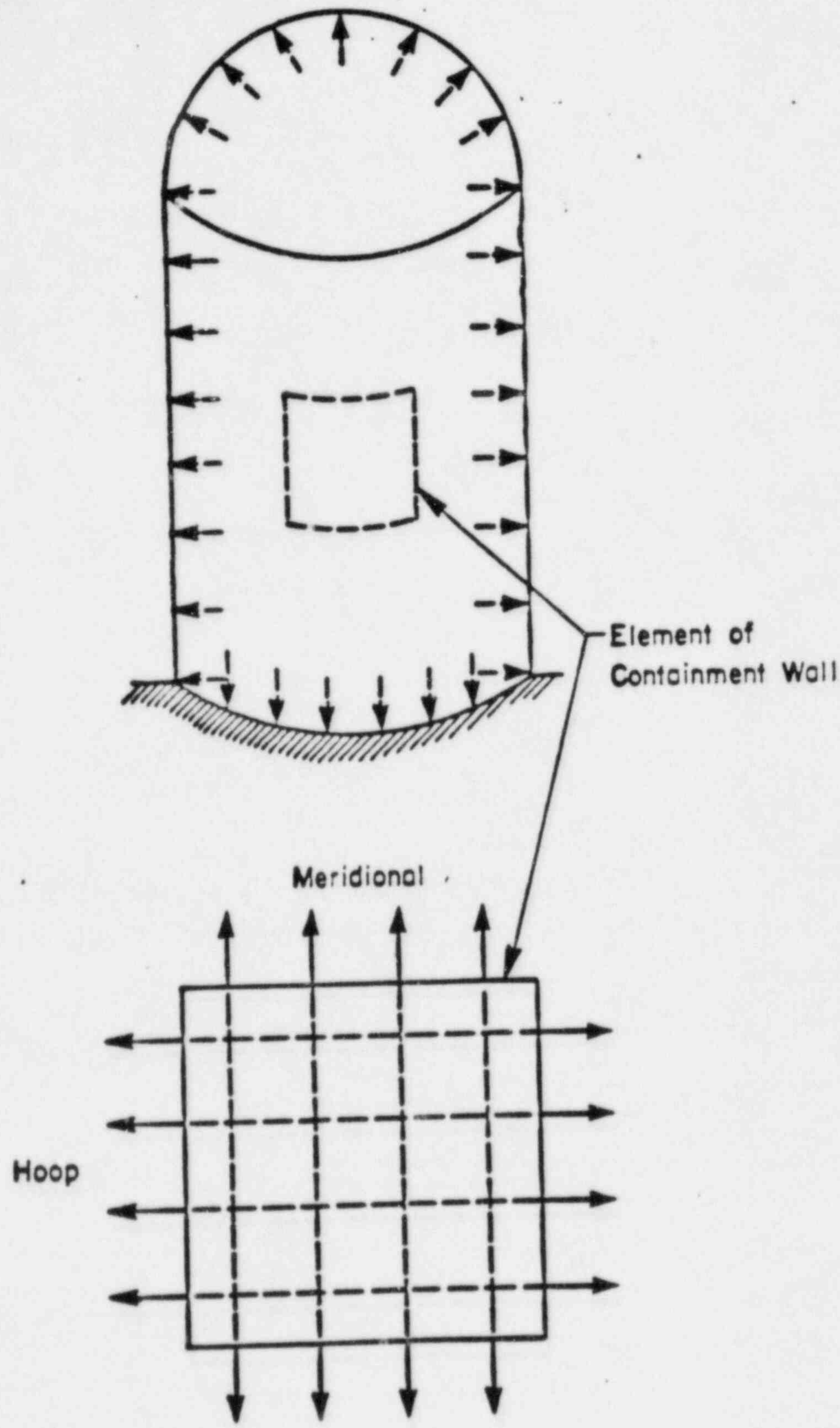
PROPOSED (BASED ON NONLINEAR BEHAVIOR/ANALYSIS)

- LINER FAILS LOCALLY (CORNERS, PENETRATIONS, WELD DEFECTS, ETC.) AT LOWER PRESSURES
- LEAKAGE (>10 IN^2) PREVENTS PRESSURE BUILD-UP AND GIVES GRADUAL RELEASE TO ATMOSPHERE

EPRI APPROACH

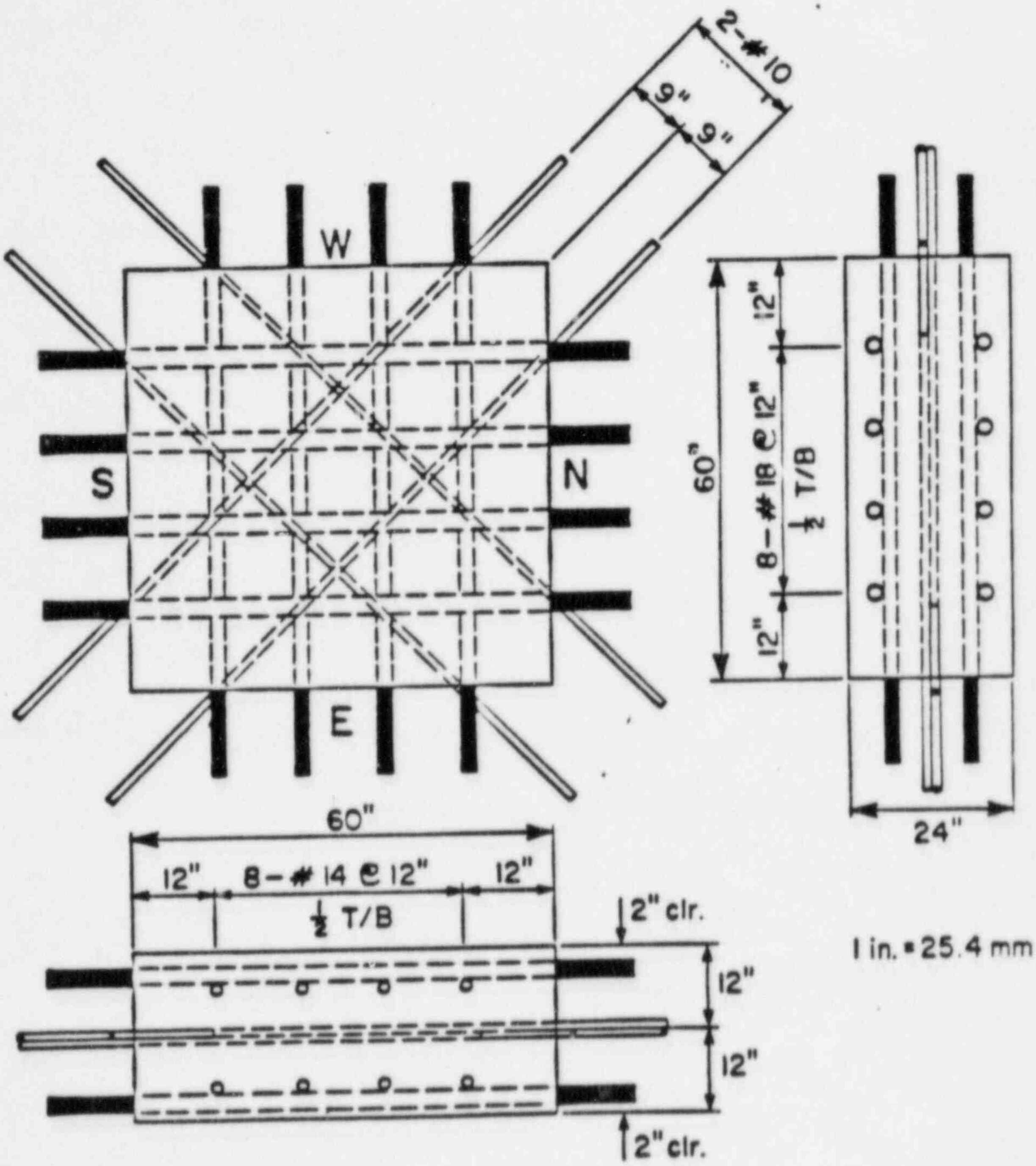
	EXPERIMENTAL	ANALYTICAL
	TEST LARGE-SCALE STRUCTURAL ELEMENTS (PCA)	BENCHMARK ABAQUS CODE WITH TEST DATA (ANATECH)
PHASE I (1982-83)	BIAXIAL TENSILE TESTS OF SIMPLE SLABS AND LINERS	APPLY EXISTING ABAQUS MATERIAL MODEL IN CALCULATION OF SLABS AND SIMPLIFIED CONTAINMENTS
PHASE II (1983-84)	LEAK RATE TESTS OF SLABS WITH LINERS AND PENETRATIONS	IMPROVE ABAQUS MATERIAL MODEL
PHASE III (1984-86)	CONTAINMENT SEGMENT TESTS (CORNERS, AREAS OF DISCONTINUITY)	QUALIFY IMPROVED METHOD WITH EPRI/SANDIA TEST DATA AND APPLY TO DETAILED PLANT CONTAINMENTS

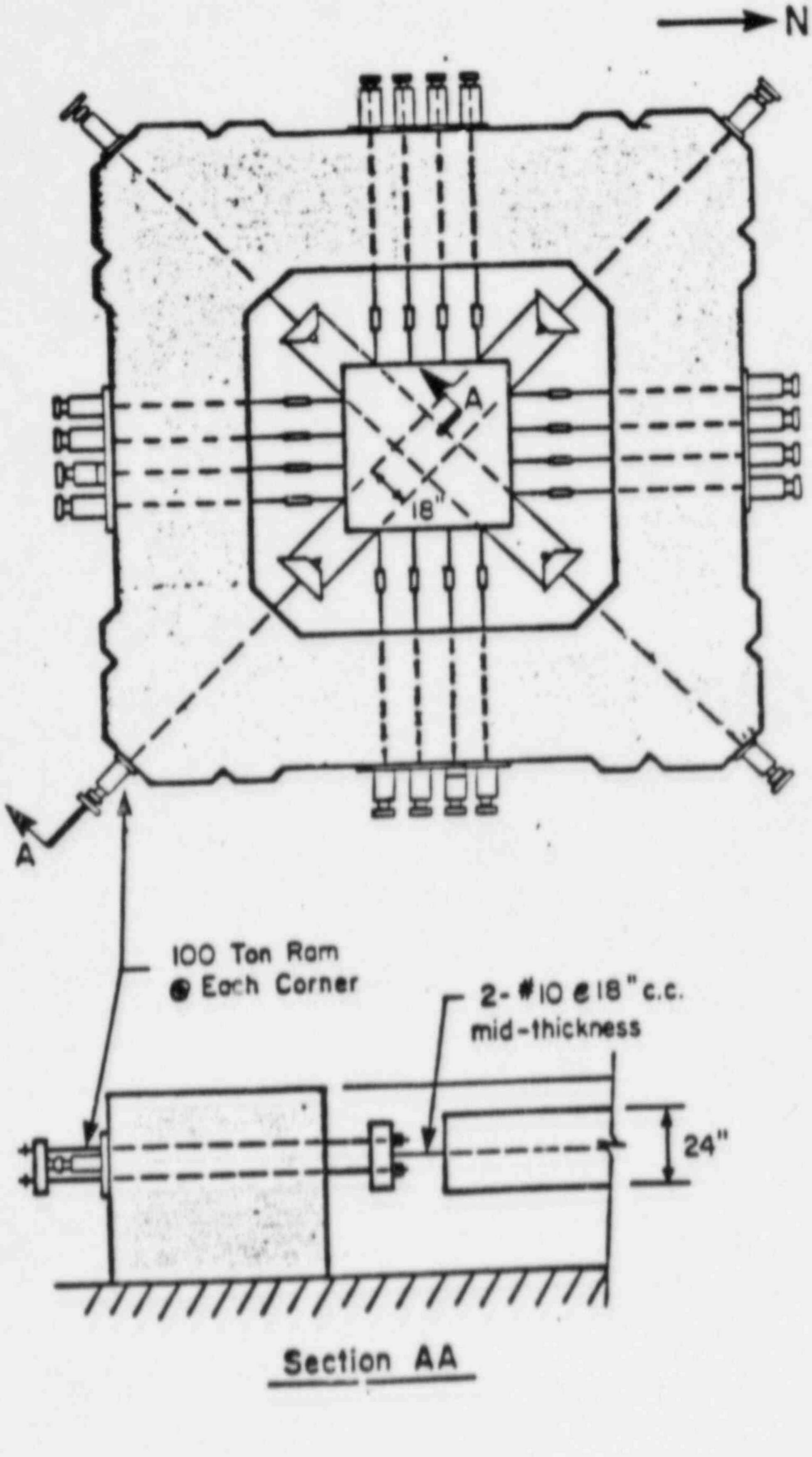
PHASE I



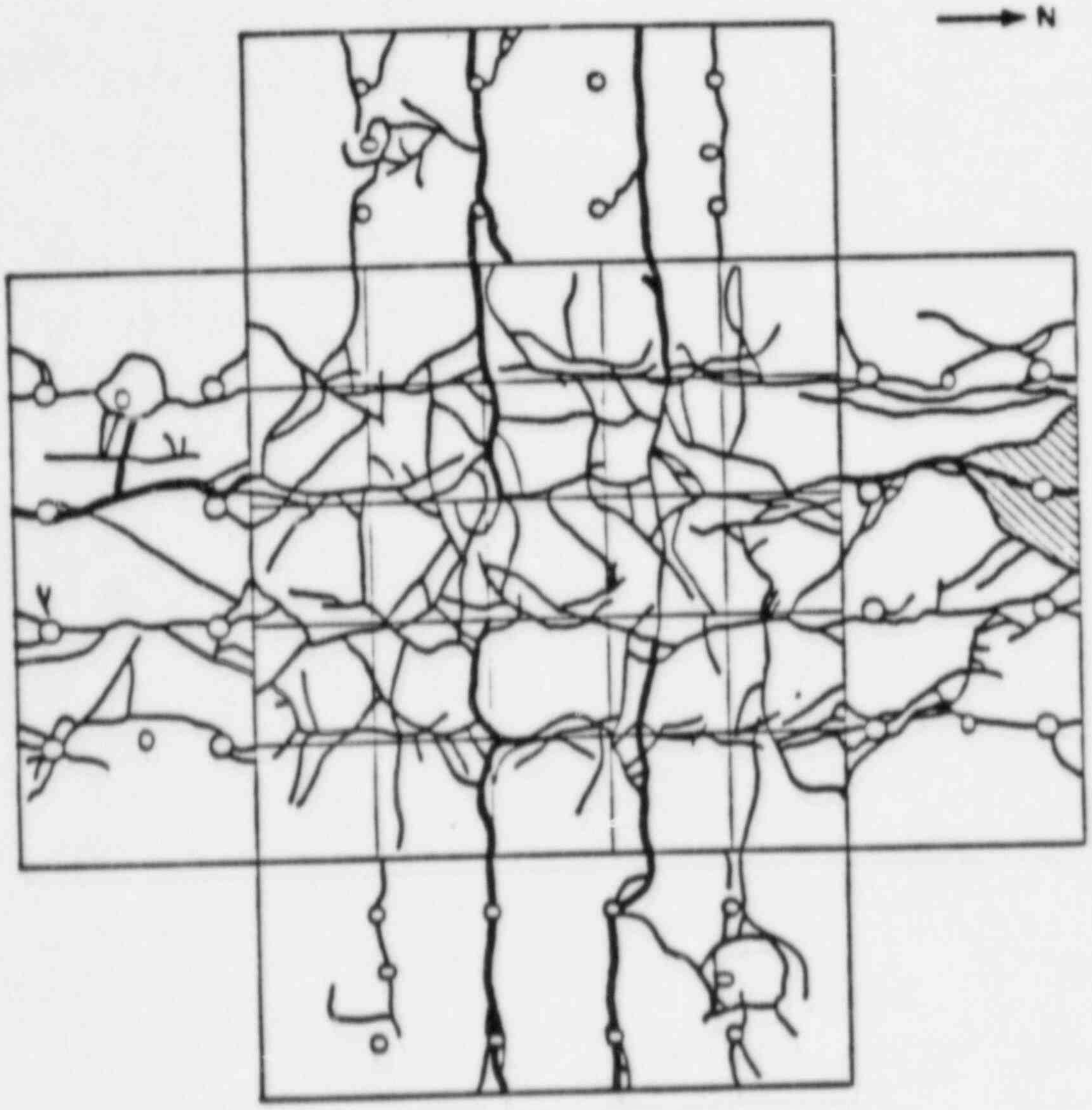
EXPERIMENTAL: PHASE I (COMPLETED)

- 8 UNIAXIAL AND BIAXIAL TESTS OF 5-FT-SQUARE BY 2-FT-THICK CONCRETE PANELS (MOST WITHOUT LINER) IN NRC TEST FIXTURE
- EXTENSIVE INSTRUMENTATION TO MEASURE LOADS, ELONGATIONS, CRACK WIDTHS, LOCAL REBAR AND CONCRETE STRAINS
- 4 BIAXIAL TESTS ON 5-FT-SQUARE LINERS (PLAIN, BUTT-WELDED, ANGLE ANCHORS, PIPE PENETRATION) TO EXAMINE STRAIN CAPABILITY

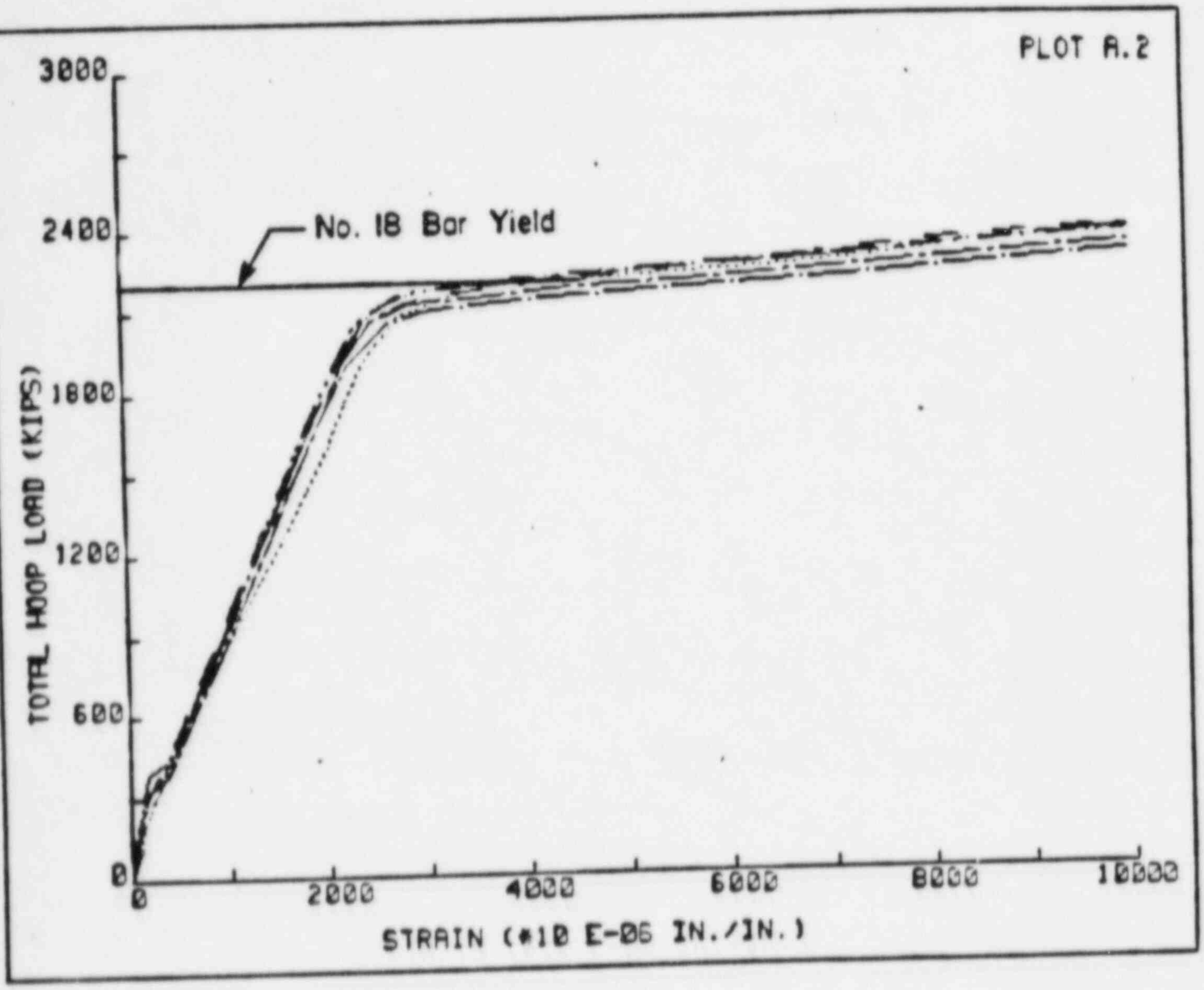

2-#10
9"
9"
W
S
N
E
60"
12"
8-#18 @ 12"
½ T/B
12"
24"
60"
12"
8-#14 @ 12"
12"
½ T/B
2" clr.
12"
12"
2" clr.
1 in. = 25.4 mm



N
A
18"
A
100 Ton Ram
@ Each Corner
2-#10 @18" c.c.
mid-thickness
24"
Section AA

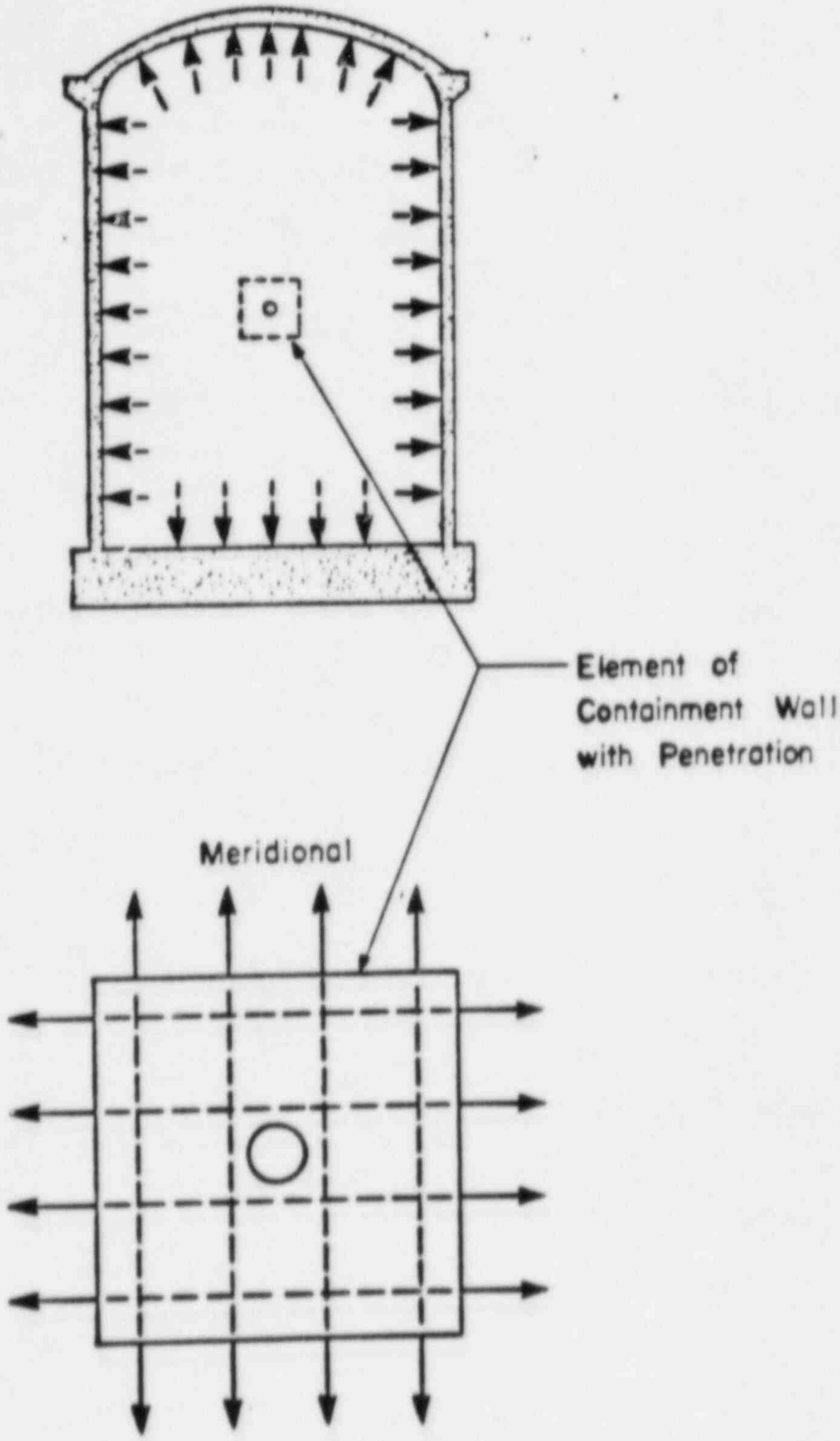


Specimen BA3: Cracking After Maximum Load



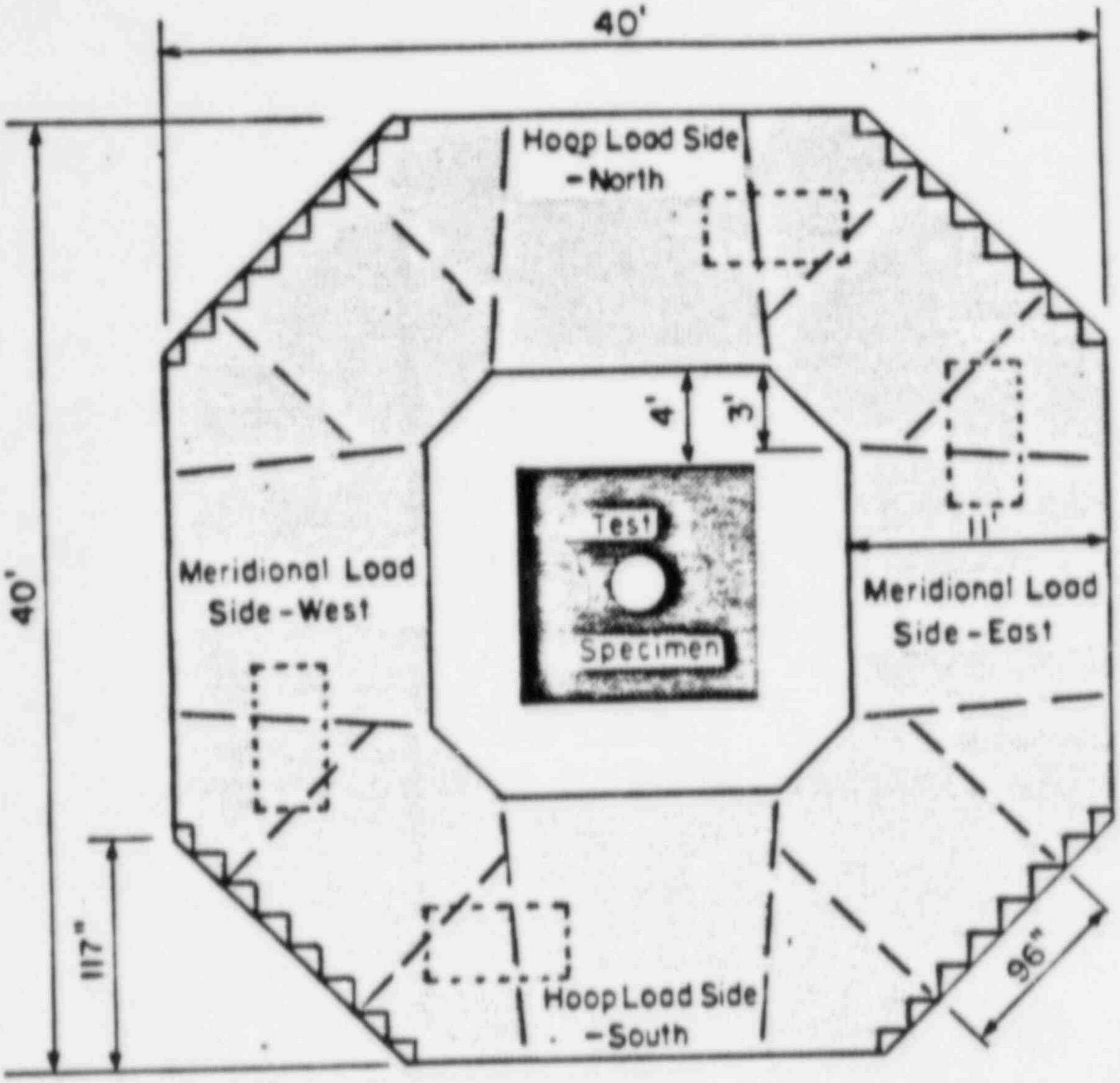
TOTAL HOOP LOAD VS OVERALL HOOP STRAIN

PHASE II

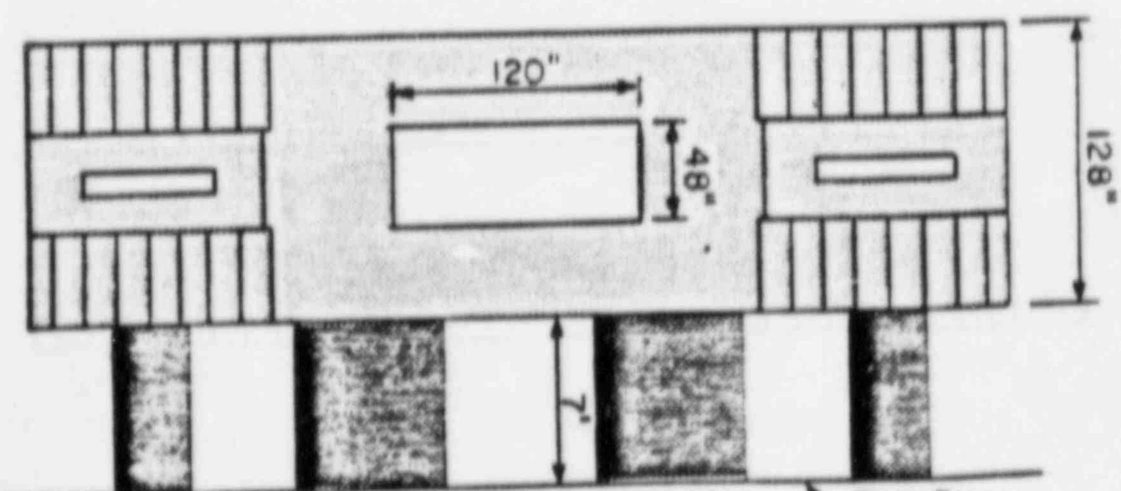

Element of
Containment Wall
with Penetration
Meridional
Hoop

EXPERIMENTAL: PHASE II

- BIAXIAL TESTS OF 3.5-FT-THICK REINFORCED CONCRETE PANELS UP TO 11-FT-SQUARE WITH LINER AND 10-IN AND 36-IN-DIAMETER PIPE/ELECTRICAL PENETRATION SLEEVES
- MEASUREMENT OF AIR LEAKAGE AS FUNCTION OF AIR PRESSURE AND APPLIED BIAXIAL LOAD
- FULL-SCALE TEST FACILITY COMPLETED -- TESTING BEGINS JANUARY 1984

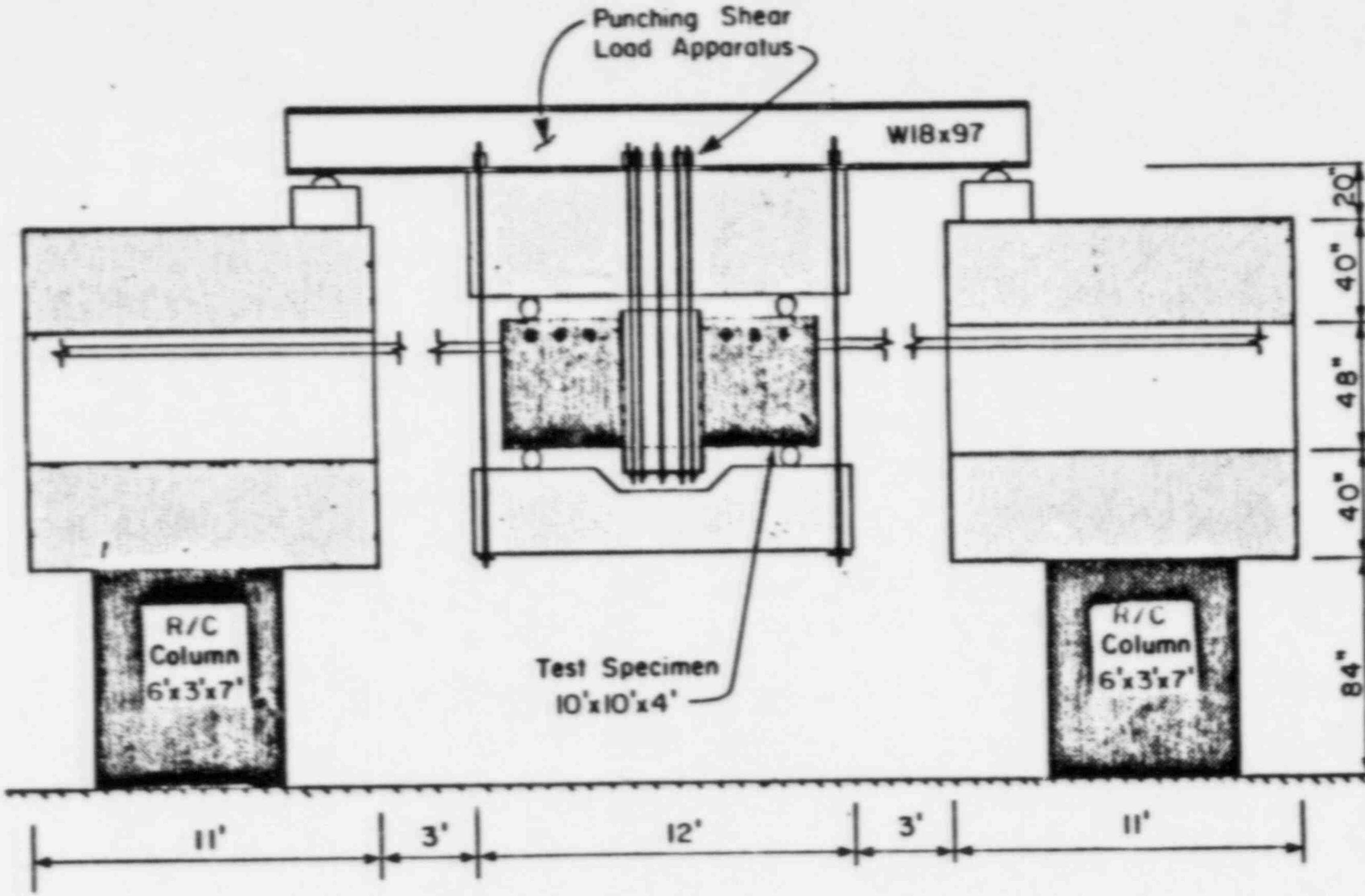


PLAN



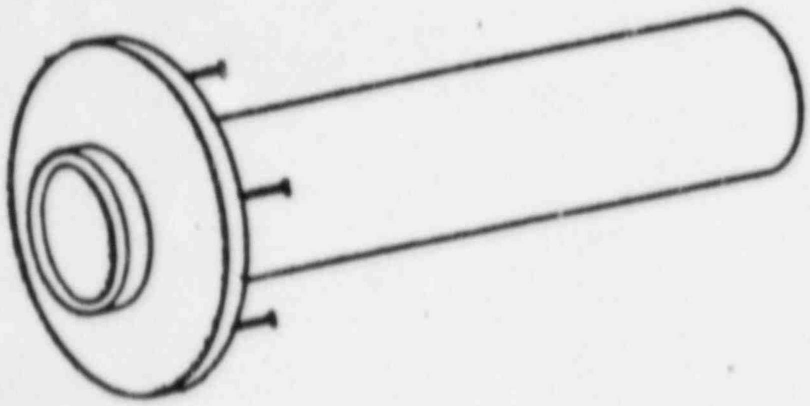
ELEVATION

Reaction Frame

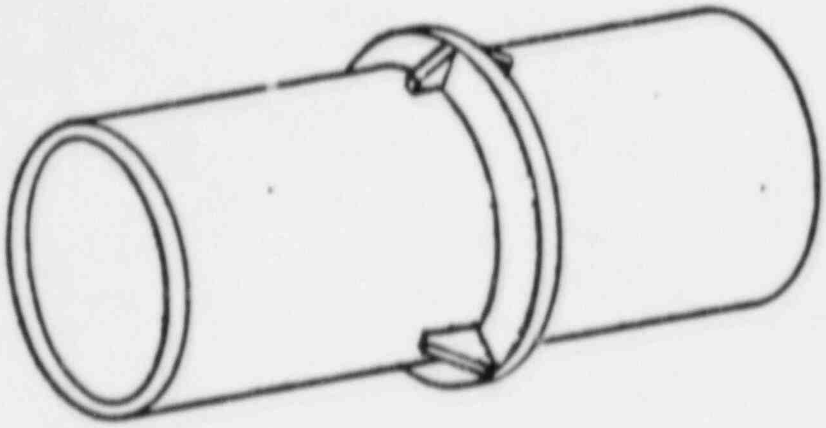


Cross-Section through Complete Test Fixture
Test Specimen: 10'x10'x4'

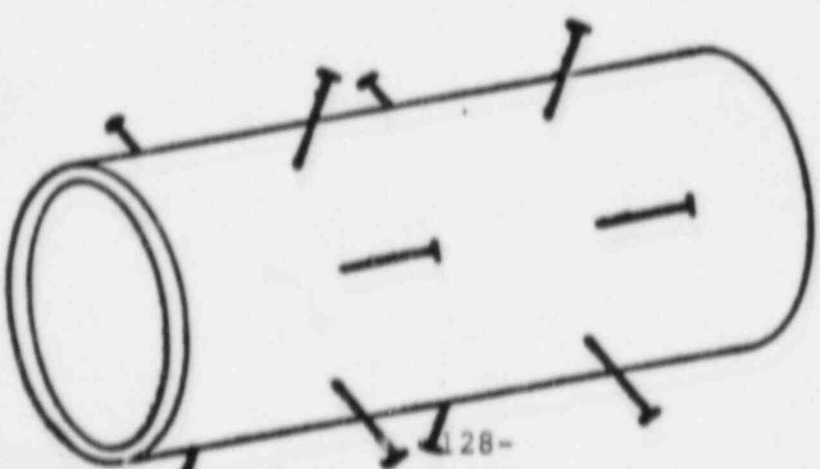
TYPES OF PENETRATION SLEEVES



THICKENED COLLAR PLATE

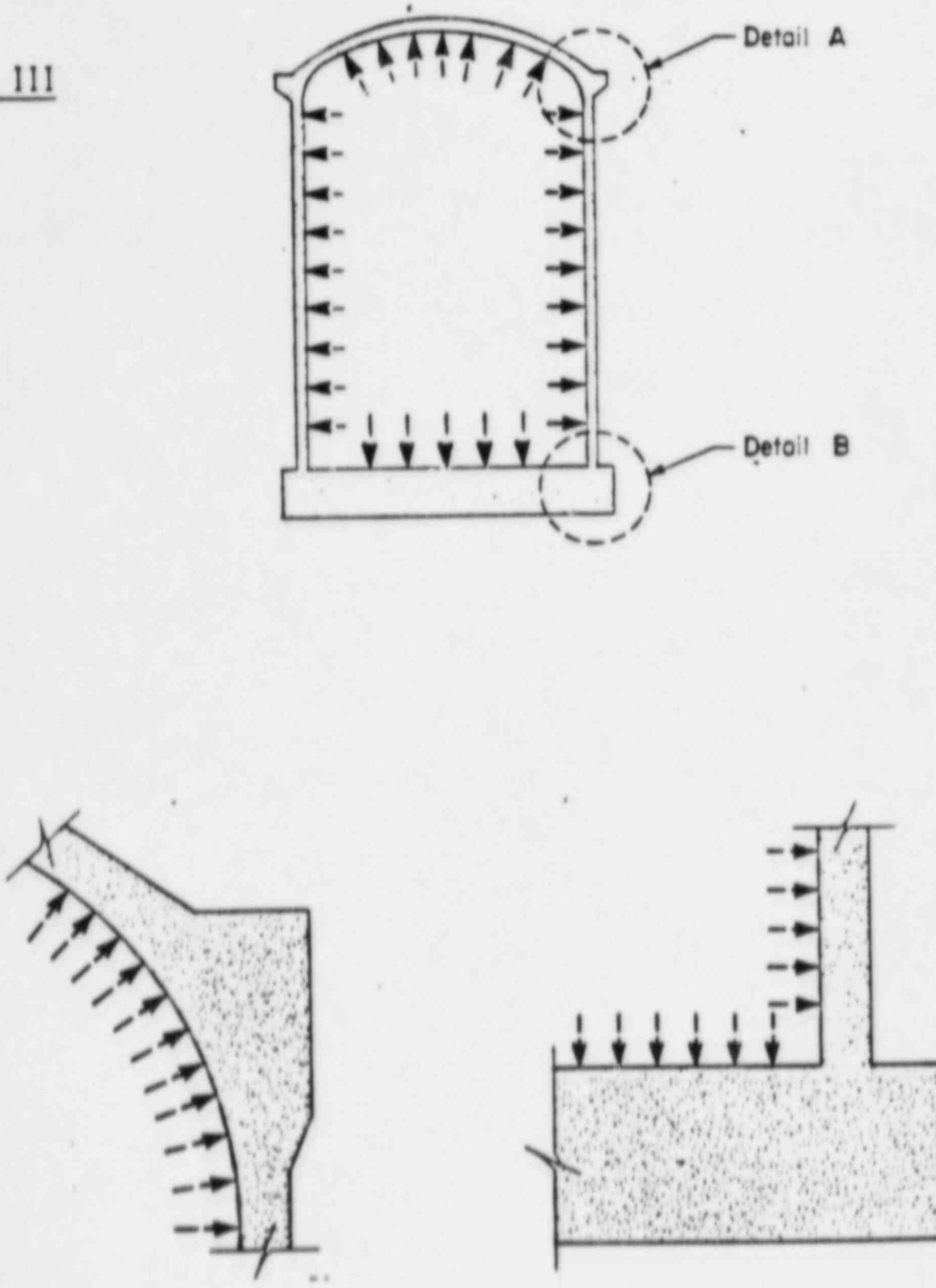


LUG PLATE



STUDS

PHASE III



EXPERIMENTAL: PHASE III

- INTERNAL PRESSURE/LEAK-RATE TESTS ON LARGE-SCALE 360° SEGMENTS REPRESENTING AREAS OF STRUCTURAL DISCONTINUITIES IN CONTAINMENTS

DEVELOPMENT OF INTEGRITY ANALYSIS OF CONCRETE CONTAINMENTS

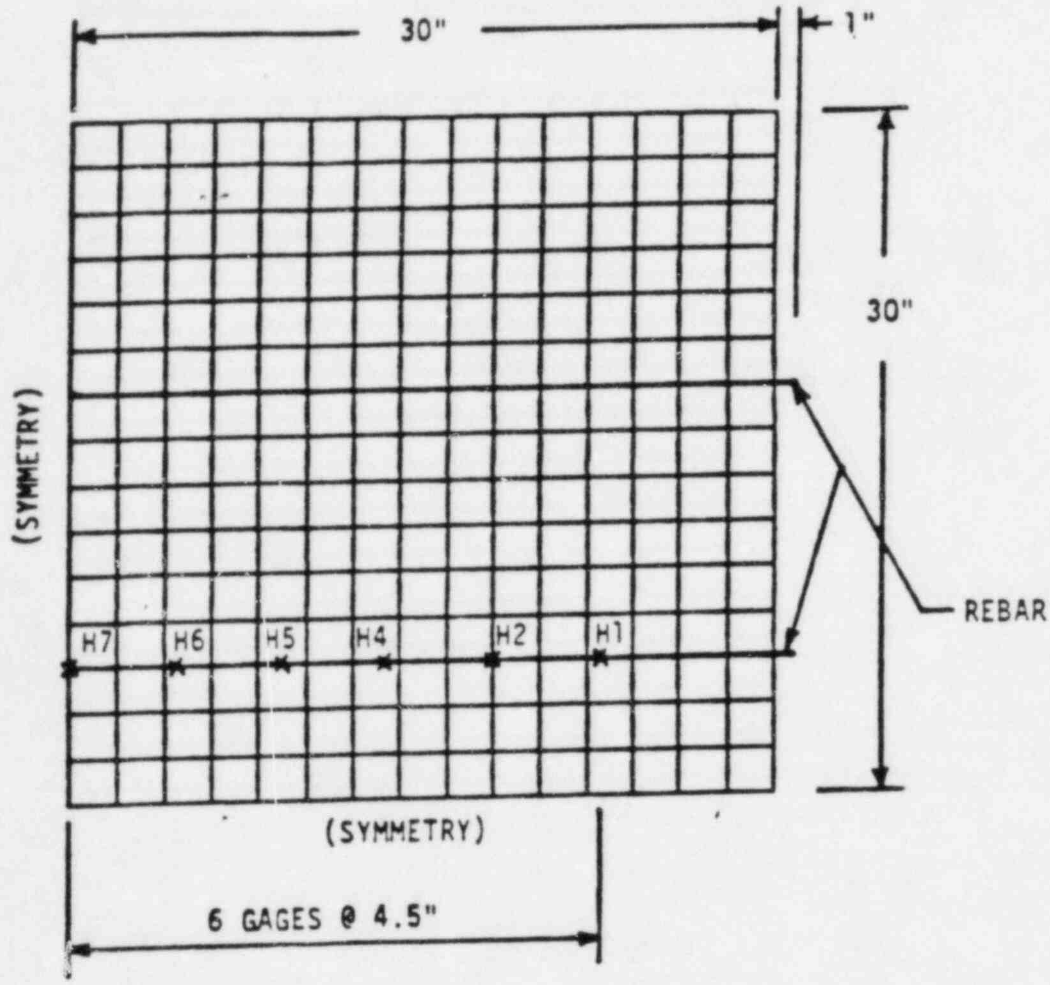
OBJECTIVE

DEVELOP AND QUALIFY AN ANALYTICAL METHODOLOGY FOR REALISTIC PREDICTION OF CONCRETE CONTAINMENT ULTIMATE INTEGRITY AND FAILURE MODES UNDER INTERNAL OVERPRESSURIZATION.

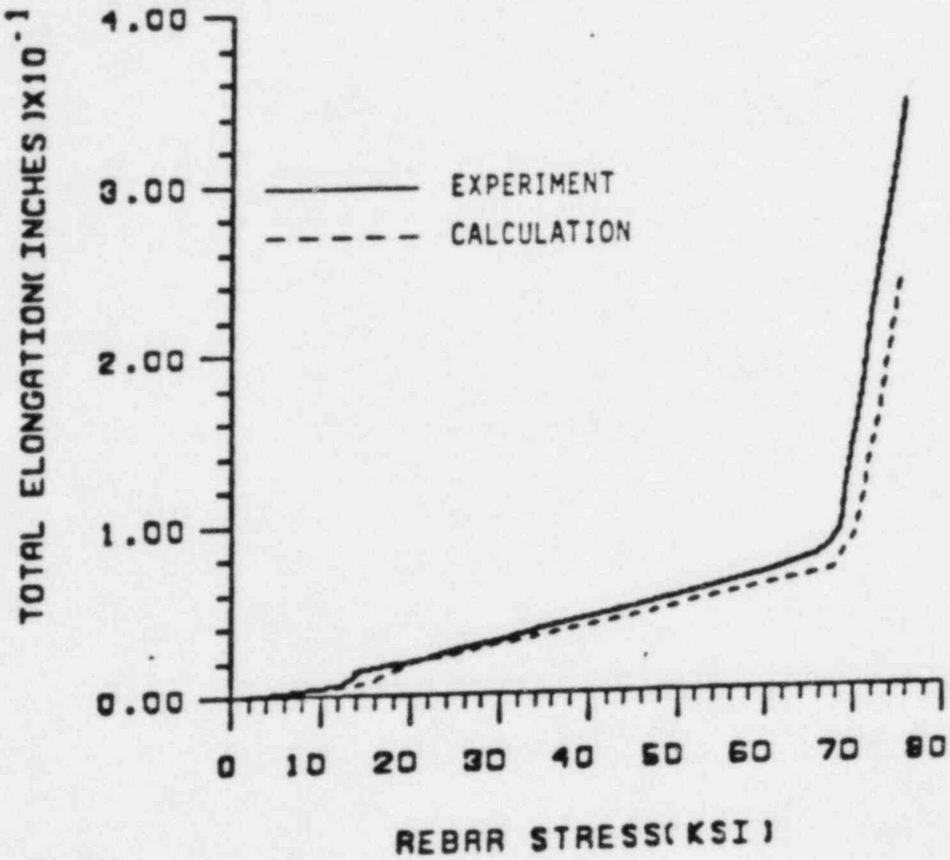
ANALYSIS: PHASE I (COMPLETED)

EXERCISE EXISTING ABAQUS CODE CAPABILITY AND IDENTIFY AREAS OF IMPROVEMENT THROUGH TEST CORRELATION

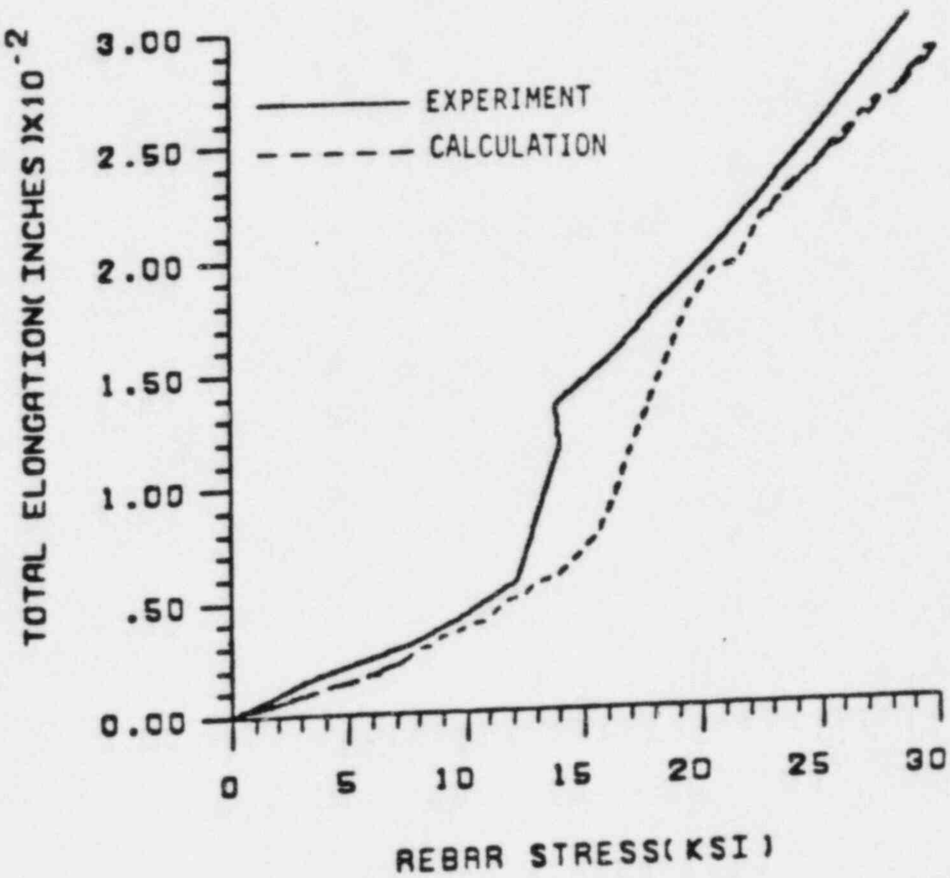
- PROTOTYPICAL CONTAINMENT
  - -- 2D AXISYMMETRIC MODEL OF TMI-2 (PRESTRESSED)
- PHASE I TEST
  - -- 2D ANALYSES OF REINFORCED DESIGN (UNIAXIAL AND BIAXIAL) AND PRESTRESSED DESIGN (BIAXIAL)



COMPUTATIONAL MODEL FOR UNIAXIAL SPECIMEN



COMPARISON BETWEEN MEASURED AND CALCULATED TOTAL ELONGATION



COMPARISON BETWEEN MEASURED AND CALCULATED TOTAL ELONGATION

ANALYSIS: PHASE II

DEVELOPMENT OF IMPROVED MATERIAL MODELS FOR THE PREDICTION OF CONCRETE CRACKING HISTORY AND CRACKING LOCATION UNDER MULTIAXIAL STRESS AND STRAIN STATES AS WELL AS THE INTERACTION OF REBAR-CONCRETE AND LINER-CONCRETE UNDER NEAR-FAILURE AND POST-FAILURE CONDITIONS.

- IMPROVEMENT OF CONCRETE FRACTURE CONSTITUTIVE MODEL
- DEVELOPMENT OF REBAR AND CONCRETE BOND-SLIP MODEL
- IMPLEMENTATION INTO ABAQUS
- CORRELATION WITH PHASE I AND II TEST DATA

Sandia National Laboratories
Albuquerque, New Mexico 87185

date: March 13, 1984

to: Containment Integrity Technical Review Panel

from: Walter A. von Riesemann

Walt

subject: April 17-18, 1984 Meeting

There will be a meeting of the Containment Integrity Technical Review Panel on April 17 and 18, 1984, in Albuquerque. We will meet in Sandia conference rooms and will also visit the large scale steel model and examine the remains of the small scale steel model tests.

I have set aside a block of rooms at the Marriott Hotel (2101 Louisiana Blvd, NE, near the Coronado Center, local telephone number is 505-881-6800, nationwide number 800-228-9290). The room rate should be $40 (before taxes) and their is a courtesy van service from the airport. Please call the hotel directly and for your reservations, please mention the Containment Integrity Panel.

Our meeting will start at 8:30 a.m. on Tuesday, April 17th in Building 822 (a map is enclosed). We will not provide transportation from the hotel to Sandia. Also you will have to stop at the military gate (i.e. stay in the right hand lane and park temporarily in the area to the right (west) of the guard shack). I am assuming you will enter the base on Wyoming Blvd. Obtain a two-day pass.

A tentative agenda is enclosed. I will mail an update and additional information shortly.

You all indicated you can make the meeting. However, if you cannot call me (505-844-2430) or my secretary (505-844-4174) as soon as possible if you cannot attend.

Copy to:
6442 File 1047.011
6442 File 1459.011

26

Distribution:
1523 D. B. Clauss
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1524 J. Jung
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6442 D. S. Horschel
6442 L. N. Koenig
6442 C. V. Subramanian
6442 Day File

Sandia National Laboratories
Albuquerque, New Mexico 87185

date: July 2, 1984

to: The Peer Review Committee

from: C. V. Subramanian - 6442

subject: Summary of Peer Review Committee Meeting held on June 15, 1984 in Crystal City, Washington, DC

A meeting was held on June 15, 1984, in the Hyatt Regency Crystal City, in which the undersigned made a presentation to the Peer Review Committee on the draft overall program plan for the "Integrity of Containment Penetrations under the Severe Accident Conditions Program". This presentation included details of the penetrations survey work and the figure of merit analyses used to select penetrations for testing (both performed by ANL), tentative test matrix and schedule for testing of large scale models of major penetrations and a tentative test matrix and schedule for testing of seals and gaskets when they are subjected to severe accident conditions. The presentation was made in order to get the Peer Review Committee's input into the overall program plan before it was finalized. There were some informative questions and discussions during the course of the presentation. It was recognized by everybody at the meeting that this program could significantly contribute to the overall containment integrity program. In general, it may be concluded that the Peer Review Committee had no major objections to the overall contents of the program plan, and in addition, felt that the task on seals and gasket testing was the most important part of the program.

CVSubramanian:6442:lc

Copy to:
NRC H. Ashar
6442 W. A. von Rieseman[redacted]
6442 File 1459.010

Final Agenda

Containment Integrity Peer Review Panel

Tuesday, April 17, 1984

Location:	Building 822, Room A Outside of Area I	
8:30 a.m.	Welcome to Sandia Introduction	von Riesemann
8:45 a.m.	Latest NRC Update	Costello Ashar
9:00 a.m.	Brief Overview of NRC Containment Programs	von Riesemann
9:20 a.m.	Containment Safety Margins Program	Blejwas
9:30 a.m.	Small Scale Steel Model Results Experimental, Analytical	Horschel
10:20 a.m.	Break	
10:45 a.m.	Large Scale Steel Model Analysis Instrumentation/Data Acquisition Test Plan Comments From Panel	 Clauss Koenig/Jung Blejwas
12:00 noon	Lunch, Coronado Club, Staff Room	
1:30 p.m.	Reinforced Concrete Model Design/Fabrication Schedule	 Jung Jung/Blejwas
2:30 p.m.	Comments From Panel	
3:00 p.m.	Tour of Test Site	Blejwas/Koenig
Evening	No-Host Dinner	

~~Tentative~~ Agenda

Containment Integrity Technical Review Panel

Wednesday, April 18, 1984

Location:	MARRIOTT HOTEL ~~To be announced~~	
8:00 ~~8:30~~ a.m.	Discussion of Unresolved Points From Tuesday	
9:00 ~~9:30~~ a.m.	Containment Penetration Program Program Plan Work To Date Test Plan	Subramanian
10:00 ~~10:30~~ a.m.	Comments From Committee	
10:15 ~~10:45~~ a.m.	Break	
10:30 ~~11:00~~ a.m.	Electrical Penetration Assemblies	Subramanian
11:30 ~~12:00~~ noon	EPRI Activities in Containment Integrity	Wall/ H. T. Tang
12:00 ~~12:30~~ p.m.	Future Directions Dynamic Pressure Loadings Seismic Loading	Costello/ von Riesemann
12:15 ~~12:45~~ p.m.	Action Items	von Riesemann
~~1:00~~ p.m. 12:30	Adjournment	

CONTAINMENT INTEGRITY
TECHNICAL REVIEW PANEL

March 1984

Mr. Thomas J. Ahl
Nuclear Design Group
Chicago Bridge & Iron Co.
800 Jorie Boulevard
Oak Brook, IL 60521
FTS 8-312-654-7365

Dr. Wilfred E. Baker
Dept of Ballistics & Exp. Sci.
Southwest Research Institute
6220 Culebra Rd
PO Drawer 28510
San Antonio, TX 78284
512-684-5111
FTS 8-730-5511

William C. Black
2650 Woodside Road
Bethlehem, PA 18017
FTS 8-215-868-9601

Ted M. Brown
Wiss, Janney, Elstner Assoc., Inc.
330 Pfingsten Road
Northbrook, IL 60062
FTS 8-312-272-7400

Dr. Richard Denning
Battelle Columbus Laboratories
505 King Ave
Columbus, Ohio 43201
614-424-7510
FTS 8-976-7510

Dr. Asadour H. Hadjian
Bechtel Power Corporation
12400 E Imperial Highway
Norwalk, CA 90650
FTS 8-213-807-3808

T. E. Johnson
Bechtel Power Corp.
777 East Eisenhower Pwy
Ann Arbor, MI 48101
FTS 8-313-994-7231

Professor Mete A. Sozen
Dept of Civil Engineering
University of Illinois
503 W Michigan
Urbana, IL 61801
217-333-3929
FTS 8-957-3929

Dr. John D. Stevenson
Stevenson & Associates
9217 Midwest Ave
Cleveland, Ohio 44122
FTS 8-216-587-3805

Dr. Joseph J. Ucciferro
Structural Analysis Group
United Engineers & Constructors, Inc.
30 S 17th St
Philadelphia, PA 19101
FTS 8-215-422-3436

Dr. Ian Wall
Electrical Power Research Institute
3412 Hillview Avenue
PO Box 10412
Palo Alto, CA 94304
FTS 8-415-855-2935

Dr. H. T. Tang
Electrical Power Research Institute
3412 Hillview Avenue
PO Box 10412
Palo Alto, CA 94304
FTS 8-415-855-2012

Professor Richard N. White
School of Civil & Environ. Engr
Hollister Hall
Cornell University
Ithaca, NY 14853
607-256-3690
FTS 8-882-2611

Sandia National Laboratories
Albuquerque, New Mexico 87185

date: April 12, 1984

to: Distribution

from: W. A. von Riesemann

subject: Containment Integrity Peer Review Panel

Attached is the "final" agenda for the Peer Review Panel meeting on April 17, 18, 1984 in Albuquerque. Please have 20 handout copies of your vugraphs/slides. Also, hang loose as there certainly will be last minute changes.

The major discussion points, as I see it, will be:

- Instrumentation and testing philosophy of the large scale steel model.
- Design of the reinforced concrete model.
- The penetration work
- Leakage measurements and extrapolation.

WAVR:6442:kl:0311Z

Distribution:

6440 D. A. Dahlgren
1523 J. Biffle
1523 D. B. Clauss
1523 C. H. Conley
6442 All Staff

Sandia National Laboratories
Albuquerque, New Mexico 87185

date: April 16, 1984

to: Containment Peer Review Committee

Walt

from: Walt von Riesemann

subject: Meeting

Welcome to Albuquerque.

As I stated in my letter we will not be providing transportation to Sandia on Tuesday the 17th. All of our meetings will be outside of the technical areas and you will not need a badge. Hence proceed directly to Building 822. I have enclosed two maps to help you find your way. By the way, you might get together ahead of time and share-a-ride.

We are on a military base and you can enter either through the Gibson or Wyoming gate. You will have to stop for a pass for your dashboard. I recommend the Wyoming gate. Stay in your right hand lane and pull into the parking area to the west (your right) of the guard shack, go into the building and get a pass. Then continue as shown on the maps. The speed limit is enforced on the base!

Our meeting is scheduled to start at 8:30 a.m., and with the stop at the gate, it should take approximately 30 minutes from your hotel.

My home phone is 884-9102.

WAVR:6442:kl:0318Z

CONTAINMENT INTEGRITY
PEER REVIEW GROUP

February 1984

Mr. Thomas J. Ahl
Nuclear Design Group
Chicago Bridge & Iron Co.
800 Jorie Boulevard
Oak Brook, IL 60521
FTS 8-312-654-7365

Dr. Wilfred E. Baker
Dept of Ballistics & Exp. Sci.
Southwest Research Institute
6220 Culebra Rd
PO Drawer 28510
San Antonio, TX 78284
512-684-5111
FTS 8-730-5511 Home 512-824-5960

William C. Black
2650 Woodside Road
Bethlehem, PA 18017
FTS 8-215-868-9601

Ted M. Brown
Wiss, Janney, Elstner Assoc., Inc.
330 Pfingsten Road
Northbrook, IL 60062
FTS 8-312-272-7400

Dr. Richard Denning
Battelle Columbus Laboratories
505 King Ave
Columbus, Ohio 43201
614-424-7510
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Dr. Asadour H. Hadjian
Bechtel Power Corporation
12400 E Imperial Highway
Norwalk, CA 90650
FTS 8-213-807-3808

T. E. Johnson
Bechtel Power Corp.
777 East Eisenhower Pwy
Ann Arbor, MI 48101
FTS 8-313-994-7231

Sandia National Laboratories

Albuquerque, New Mexico 87185

date: November 30, 1984

to: Containment Integrity Peer Review Committee

Walter A. von Riesemann

from: Walter A. von Riesemann

subject: Albuquerque Meeting, September 11, 12, 1984

There will be a meeting of the Peer Review Committee in Albuquerque on December 11 and 12, 1984. The meeting will begin at 8:30 a.m. Tuesday morning at the Amfac Hotel, 2910 Yale SE, in the Rio Grande Room. The hotel is next to the airport. The meeting will close at noon on Wednesday the 12th.

The agenda will cover:

1. The results of the large-scale steel model (1:8) experiment, including a visit to the test site, and some limited comparison of the test and analytical results.

2. An update on the penetration program.

3. The 1:6 reinforced concrete model.

4. Status report from EPRI.

We have set aside a block of rooms at the Amfac (the telephone number is 505-843-7000). The room rate should be $47, before taxes; and there is a courtesy van if you need it, though the distance is very short. Please call the hotel directly for your room reservation; please mention the Containment Integrity Panel.

If you cannot make the meeting, please call me (505-844-2430) or my secretary, Pat (505-844-4174).

Copy to:
NRC J. Burns
NRC J. F. Costello
NRC H. Ashar
1522 E. P. Chen
1523 D. B. Clauss
1523 C. H. Conley
1524 J. Jung
1832 J. A. van den Avyle
6440 D. A. Dahlgren
6442 T. E. Blejwas
6442 D. S. Horschel
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Professor Mete A. Sozen
Dept of Civil Engineering
University of Illinois
503 W Michigan
Urbana, IL 61801
217-333-3929
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Dr. John D. Stevenson
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9217 Midwest Ave
Cleveland, Ohio 44122
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Structural Analysis Group
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School of Civil & Environ. Engr
Hollister Hall
Cornell University
Ithaca, NY 14853
607-256-3690
FTS 8-882-2611

TENTATIVE AGENDA

Peer Review Committee
Containment Integrity Programs

AMFAC Hotel
Rio Grande Room

Tuesday, Dec. 11, 1984

Time	Topic/Discussion	
8:30	Opening Remarks Discussion of Agenda	Walt von Riesemann
8:45	NRC Perspective	Jim Costello
9:00	The Large Scale Steel Experiment	
	- Test Results	Tom Blejwas, Dan Horschel, Larry Koenig
	- Analytical Comparisons	Dave Clauss
	- Metallurgical Investigations	Jim Van Den Avyle
11:30	Lunch	
1:00	Tour of Test Site	Tom Blejwas, et al
3:00	Reconvene at AMFAC Hotel	
	Discussion of Test, Data Report	
4:00	Reinforced Concrete Model	Tom Blejwas

Wednesday, Dec. 12, 1984

Time	Topic/Discussion	
8:00	EPRI Status Report	H. T. Tang
9:00	Discussion of Reinforced Concrete Model	Tom Blejwas
10:00	Penetration Programs	"Subra" Subramanian
11:00	Future Plans	Jim Costello Walt von Riesemann

(32)

Sandia National Laboratories

Albuquerque, New Mexico 87185

date: December 5, 1984

to: Distribution

Walt

from: Walt von Riesemann, 6442

subject: Peer Review Meeting

Attached is a tentative agenda for the Peer Review Meeting at the AMFAC hotel on the 11th and 12th of December. There will be a Sandia bus to take us to the test site at about 12:30. Lunch on Tuesday will be at the hotel, i.e. catered.

WAVR:6442:pm

Attachment

Distribution:
1523 D. B. Clauss
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6442 T. E. Blejwas
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