STEAM PRESSURE SUPPRESSION CHARACTERISTICS OF WATER-SOLUBLE PLASTIC MEMBRANE SHIELDED ICE FOR ICE CONDENSER CONTAINMENT NUCLEAR POWER PLANTS

EPRI RESEARCH PROJECT 2125-1

FINAL REPORT

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ABSTRACT

Plastic film materials have become widely accepted for use as vapor barriers. Though not constituting an absolute vapor barrier membrane, like glass or metal foils, they usually offer more than adequate resistance to water vapor permeation. Their relative inexpensiveness, flexibility, and availability make them ideal for applications where large and/or uneven surface areas must be protected from ingress or egress of moisture.

This application would suit that of an ice condenser containment system, used in certain nuclear power plants, where ice is stored in large refrigerated compartments. This system entails a major maintenance problem in that the ice continually sublimates away. Vapor barriers have not been incorporated in the past because of the unknown effects on the heat transfer performance of the ice, that is, its ability to condense the steam generated from a postulated pipe rupture. If, however, the vapor barrier could disintegrate or dissolve away fast enough under accident conditions, then the use of such a vapor barrier might be practicable.

It was the purpose of this program, as summarized herein, to investigate and evaluate the use and possible heat transfer effects of water-soluble plastic films when used as vapor barriers around the ice stored in the ice condenser system.

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SUMMARY

Nuclear power plants using ice condenser containment systems inherently suffer from ice sublimation with resultant diminishing ice inventories. Maintaining the minimum ice inventory for containment building safety requirements necessitates periodic ice replenishment operations, with the plant shut down for the entire operation. Up to 6 months downtime and 25,000 man-hours are needed to melt out, reload, and weigh the typical plant ice inventory of 3,000,000 pounds (1,360,000 kg) and it is estimated that the process could be required as often as every 7 years. Utilities having ice condenser system plants clearly need an economical and feasible method to effectively suppress or eliminate ice sublimation losses.

Plastic film materials have become widely accepted for use as vapor barriers. Though not absolute vapor barriers, they usually offer more than adequate resistance to water vapor permeation. Further, their relative inexpensiveness, flexibility, and availability make them ideal for applications where large and/or uneven surface areas must be protected from ingress or egress of moisture.

The objective of this program was to investigate and evaluate the use and possible heat transfer effects of water-soluble plastic films when used as vapor barriers around ice stored in ice condenser systems. The following tasks were involved:

- o Determination of suitable materials for sublimation shielding, methods of application, and costs
- o Assessment of the performance of the materials through subscale tests
- o Evaluation of material characteristics such as solubility, effects of residue on drain components, maintenance and repair of the material, and effects of age and radiation

Through literature searches and discussions with the Westinghouse Chemistry Department and plastic film manufacturers, the two most likely water-soluble plastic film candidates -- methyl cellulose and polyethylene oxide -- were selected for evaluation. These materials are commercially available in liquid

form for spray-on or dipping application to ice baskets, and in 1.5- to 3.5-mil (0.038 to 0.089 mm) sheet film. Sheet film material for an ice basket column would cost from $12 to $23 to cover a column; using liquid material would cost about $200. Repairs to both shielding films could be made by bonding additional material to a damaged area with water-soluble adhesives.

Heat transfer performance was determined by using various shielding material application configurations and thicknesses on single ice baskets and performing steam blowdown tests. Testing was done by electrically heating 10 lb (4.5 kg) of water in an autoclave until steam at 1200 psig (8.27 MPa) and 580°F (304°C) was produced. When an air-operated valve in connecting piping was opened, the autoclave steam was blown into a sealed receiver vessel containing a test ice basket filled with about 140 lb (63 kg) of borated flake ice. During blowdown, pressure and temperature transients in the receiver vessel were recorded. Following blowdown and pressure and temperature stabilization in the receiver vessel, it was drained and the drain water was weighed.

The results of tests with shielded baskets were compared with those from tests using unshielded baskets under identical steam mass and energy conditions. Performance of the shielded ice baskets was based on the ability of the available ice to suppress steam pressure in the receiver vessel. An acceptance criterion, established by the Westinghouse Nuclear Safety Department, of +3.0 psig (21 Pa) above unshielded ice basket reference test conditions was used.

Chemical and radiation effect analyses were also performed on samples of the materials. Samples appeared unaffected by irradiation to 10^6 rads. The chloride content of both irradiated and unirradiated samples was evaluated and found to be acceptable based on the amount of dilution and pH of sump water. Although methyl cellulose material dissolved faster than polyethylene oxide, neither material appeared to go completely into solution. Instead, the two materials disintegrated and left small amounts of solids residue. The particles in the polyethylene oxide residue appeared to be larger than those in the methyl cellulose residue, and also somewhat sticky.

Although test results show some variation in condensing performance due to type of material, application configuration, and film thickness, the results of all shielded ice basket tests met the established acceptance criterion, and the resulting receiver vessel pressures converged to the reference (unshielded basket) test conditions in a sufficiently short time period so as not to affect the

postulated peak containment pressure from long-term heat decay after the containment ice bed is completely melted. It is believed that application of the shielding material in an actual ice condenser plant could be defended.

The overall results from this program indicate that a methyl cellulose internal basket liner made from 2.1-mil (0.053 mm) film would be the best candidate for ice basket shielding. The polyethylene oxide film material was disqualified primarily because it appears to leave sticky, larger-sized residue particles which could possibly plug containment spray nozzles. If it could be shown that this is not a problem, the 3.5-mil (0.089 mm) polyethylene oxide film could be recommended.

Recommendations for additional work include tests to determine the maximum size of residue particles that could be circulated through actual containment spray header nozzles under accident conditions without causing plugging, and analysis of heat transfer effects on the lower containment compartments under the ice condenser floor. These compartments are sensitive to the initial (first 2 seconds) pressure peak seen by the containment building.

Section 1

INTRODUCTION

BACKGROUND

Nuclear power plants which utilize ice condensers inherently suffer from ice sublimation, with resultant diminishing ice inventories. To meet the minimum ice inventory for containment building safety requirements, ice replenishment operations are periodically required. These require the plant to be shut down for the entire operation. Ice condenser plants require up to 6 months downtime to completely melt out, reload, and weigh the typical plant ice inventory of 3,000,000 lb (1,360,000 kg). It is estimated that this process could be required as often as every 7 years, and would require approximately 25,000 man-hours per unit. Utilities with ice condenser plants clearly need an economical and feasible method to effectively suppress or eliminate ice condenser ice sublimation losses.

SCOPE

The scope of this program was to (1) determine a suitable material for sublimation shielding, its application, and cost; (2) assess the performance (containment pressure transients during a LOCA blowdown) of various application configurations through subscale tests (steam blowdown on a single ice basket); and (3) evaluate material characteristics, such as solubility, effects of residue on drain components, maintenance and repairs of material, and effects of age and irradiation. The scope for future work was defined and the groundwork developed.

SUMMARY

Information gathered from literature searches, the Westinghouse Chemistry Department, and plastic film manufacturers led to identification of the two most likely candidate water-soluble plastic film shielding materials for evaluation. These were methyl cellulose and polyethylene oxide. The shielding materials are commercially available, in film thickness from 1.5 to 3.5 mils (0.038 to 0.089 mm), and in liquid form. The sheet film material could be furnished in a tubular configuration which could be applied to an ice basket as an external wrapper or as an internal basket liner. The liquid material could be applied by spraying, as with a paint sprayer, or by dipping the basket. The sheet film material can be

furnished at a cost of $12 to $23 for an individual ice basket column. Covering a basket column with liquid material would cost around $200. Repairs to the shielding film could be made by bonding additional material to damaged areas with water-soluble adhesives.

The heat transfer performance of shielded ice baskets, using the various application configurations and thicknesses, was determined by steam blowdown tests on single ice baskets. The performance of shielded ice baskets was compared against that of unshielded ice baskets under identical steam mass and energy conditions. Performance was based on the ability of the available ice to suppress steam pressure in a test receiver pressure vessel. An acceptance criterion of +3.0 psig (21 Pa) above the resulting unshielded ice basket reference test conditions was established by Westinghouse Nuclear Safety Department. This criterion was established from the fact that in accident analysis studies a maximum peak pressure of 8 psig (55 Pa) could be expected for the initial short-term containment pressure transient. An increase of 3 psig (21 Pa) would bring that initial pressure peak to 11 psig (76 Pa), which still leaves a 1.0 psig (6.9 Pa) margin for the minimum containment design pressure of 12 psig (83 Pa).

Chemical and radiation analysis was performed on samples of the test shielding materials. Irradiated samples were unaffected when subjected to 10^6 rads. The chloride content of samples was evaluated for both irradiated and nonirradiated cases, and was found to be acceptable based on the amount of dilution and pH of the water in the containment building sump. The methyl cellulose material dissolved faster than the polyethylene oxide. Neither material goes into solution completely; both appear to disintegrate and leave some small amounts of solids residue. The residue remaining from polyethylene oxide samples appeared to be in larger-sized particles than the methyl cellulose residue, and was also somewhat sticky.

Section 2

TEST PLAN DEVELOPMENT

LITERATURE SEARCH

A library literature search identified 117 reports under the description of water-soluble film or films, and vapor barriers. These reports consisted of technical journal articles, patent disclosures, and conference proceedings. Most of the reports were not available in English, and many were eliminated by review of the report summary. The following reports were identified for possible applicability and reprints were acquired:

- R. S. Lenk. "An Unsupported Water-Soluble and Heat-Sealable Film From Predominantly Nonfossil Raw Materials." Polymer, 21, pp. 371-373 (1980).
- J. J. Hatch. Water-Soluble Sulfonium Derivatives of Diphenyl Ether. U. S. Patent 3502710.
- T. S. Bianco and E. M. Dratz. Polyvinyl Alcohol Compositions Containing a Plasticizer Mixture. U.S. Patent 3374195.
- J. Friedman. Laundry Package. U. S. Patent 3322674.
- E. M. LaCombe and W. P. Miller. Water-Soluble Interpolymers of Acrylamido-Alkylsulfonates. U.S. Patent 3332904.
- M. Reintjes and L. Starr. Water-Soluble Films From Hemicellulose, Epichlorohydrin, and an Alkanolamine or Glycerol. U.S. Patent 3832313.
- A. M. Mark and C. L. Mehltretter. High-Amylose Starch Acetate. U.S. Patent 3553196.
- F. H. Ancker. Water-Soluble Biaxially Oriented Poly (Ethylene Oxide) Film. U.S. Patent 3377261.
- T. Tsuzuki. Edible Water-Soluble Collage Film. GB Patent 1219463.
- M. Freifeld and T. L. Thomas, Jr. Water-Soluble Package and Method for Making and Using Same. U.S. Patent 3277009.
- E. D. Klug. "Properties of Water-Soluble Hydroxyalkyl Celluloses and Their Derivatives." J. Polym. Sci., Pt. C,36, pp. 491-508 (1971).

MATERIAL IDENTIFICATION

As a result of the literature search and discussions with material suppliers and the Westinghouse Chemistry Department, two materials were identified for test evaluation. These were methyl cellulose, which was furnished under the Polymer Films, Inc., trade name of EDISOL M, and polyethylene oxide, Polymer Films trade name QUIK-SOL P. The materials were furnished in flat sheet stock rolls, 45 in. (1.1 m) wide, and in liquid form.

The following additional materials were identified from the information search, but were eliminated as possible candidate materials for various reasons:

- Polyvinyl alcohols
- Hemicelluloses
- Acrylamido-alkylsulfonates
- High-amylose starch acetate
- Sulfonium derivatives of diphenyl ether
- N-alkoxymethyl polypyrrolidones
- Polyacrylic acid
- Sodium polyacrylics
- Hydroxide propionate cellulose

TEST MATRIX DEVELOPMENT

The ice baskets tested were 12 in. (0.30 m) in diameter by 6 ft (1.8 m) long and made of 16 gage perforated sheet metal. The perforations were 1 in. (0.025 m) square on 1-1/8 in. (0.029 m) centers with 64 percent open area. The baskets were open on the top end and enclosed on the bottom end with 1 by 1 in. (0.025 by 0.025 m) wire screen mesh. One ice basket was required for each test run. At least six baskets were available for the test program.

The following material configurations were tested:

- Methyl cellulose - 1.5-mil (0.038 mm) thick sheet film, internal liner
- Methyl cellulose - 1.5-mil (0.038 mm) thick sheet film, external wrapper

- Methyl cellulose - 2.1-mil (0.053 mm) thick sheet film, internal liner
- Methyl cellulose - 2.1-mil (0.053 mm) thick sheet film, external wrapper
- Polyethylene oxide - 2.0-mil (0.051 mm) thick sheet film, internal liner
- Polyethylene oxide - 2.0-mil (0.051 mm) thick sheet film, external wrapper
- Polyethylene oxide - 3.5-mil (0.089 mm) thick sheet film, internal liner
- Polyethylene oxide - 3.5-mil (0.089 mm) thick sheet film, external wrapper
- Methyl cellulose - heavy spray coating

Section 3

ICE CONDENSER SUBLIMATION SHIELDING TESTING

FACILITY PREPARATION

The sublimation shielding performance test was a steam blowdown test. One autoclave [8 in. (0.20 m) in diameter by 10 ft (3.0 m) long] provided steam at 1200 psig (8.3 MPa) and 580°F (304°C). The autoclave fed the receiver vessel through 1 in. (0.025 m) diameter high-pressure stainless steel piping through a 3/4-inch (0.019 m) air-operated valve. The piping was heat traced and insulated prior to its entering the receiver vessel to reduce heat losses.

The 18 in. (0.46 m) OD by 10 ft (3.0 m) long vertical receiver vessel was rated for 150 psig (1.03 MPa) at 600°F (316°C). It was equipped with a quick-opening hatch on top and a blind flange on the bottom. A 1 in. (0.025 m) diameter pressure relief line was furnished off a side shell nozzle. The 1 in. (0.025 m) diameter blowdown inlet pipe penetrated the center of the blind flange and extended into the receiver vessel. The inlet pipe was capped off inside the receiver vessel, and numerous 1/4 in. (0.0064 m) diameter holes were furnished along the length of pipe, inside the vessel, to allow the steam to enter without directly impinging on the ice basket. A 14 in. (0.36 m) ID by 1/4 in. (0.0064 m) thick aluminum pipe extended along the entire inside length of the receiver vessel to provide an air gap next to the vessel shell for insulation purposes. Figure 3-1 is an overall schematic diagram of the test facility.

The receiver vessel instrumentation included five thermocouples and two pressure transducers. Figure 3-1 shows the location of the instrumentation. Two multichannel Visicorders recorded the temperature and pressure transients during the steam blowdown.

Figures 3-2 through 3-9 are photographs of the test facility and test operations.

TESTING

The autoclave system was loaded with 10.0 lb (4.54 kg) of water and heated electrically until steam at 1200 psig (8.3 MPa) and 580°F (304°C) was produced.

This saturated steam condition was chosen because it represented a main steam line break LOCA. Preliminary test runs showed that 10 lb (4.5 kg) of water had to be loaded into the boiler autoclave to produce a resultant receiver vessel pressure of 7.0 psig (48 Pa) with an unshielded ice basket.

The test ice basket was filled with approximately 140 lb (63 kg) of borated flake ice and loaded into the receiver vessel. This was the amount of ice necessary to completely fill the test ice basket. The receiver vessel was then sealed and the autoclave steam was blown into it by opening the air-operated valve in the connecting piping. Pressure and temperature transients were recorded during the blowdown.

Following blowdown and stabilization of pressure and temperature, the receiver vessel drain valve was opened to collect the receiver water. The drain water was weighed. The top cover was then opened and the ice basket was removed from the receiver vessel and weighed.

Appendix A sets forth the test procedure used.

TEST RESULTS

The test data sheets are presented in Appendix B, along with tabular and graphic summaries of the results.

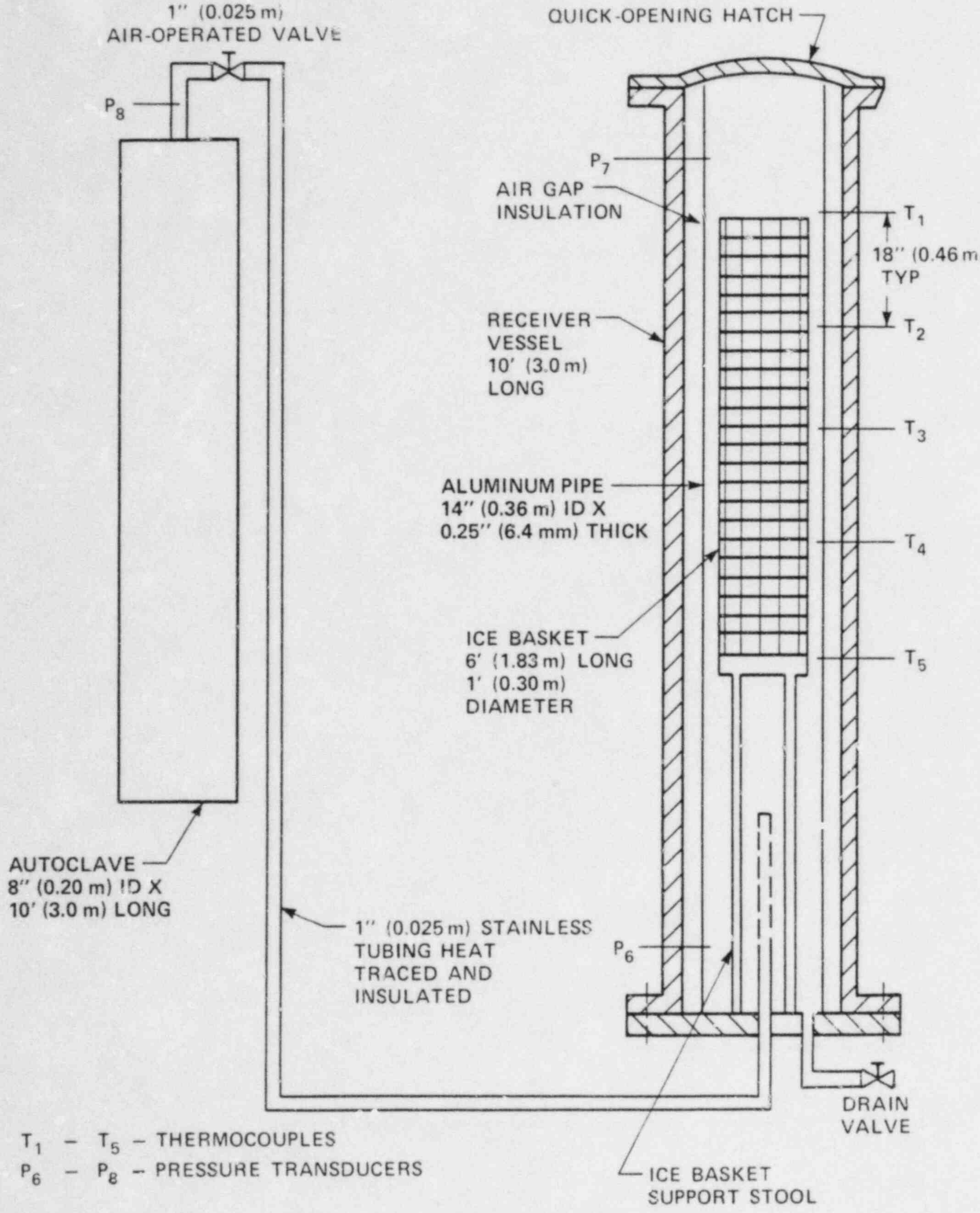


Figure 3-1. Test Facility Schematic Diagram

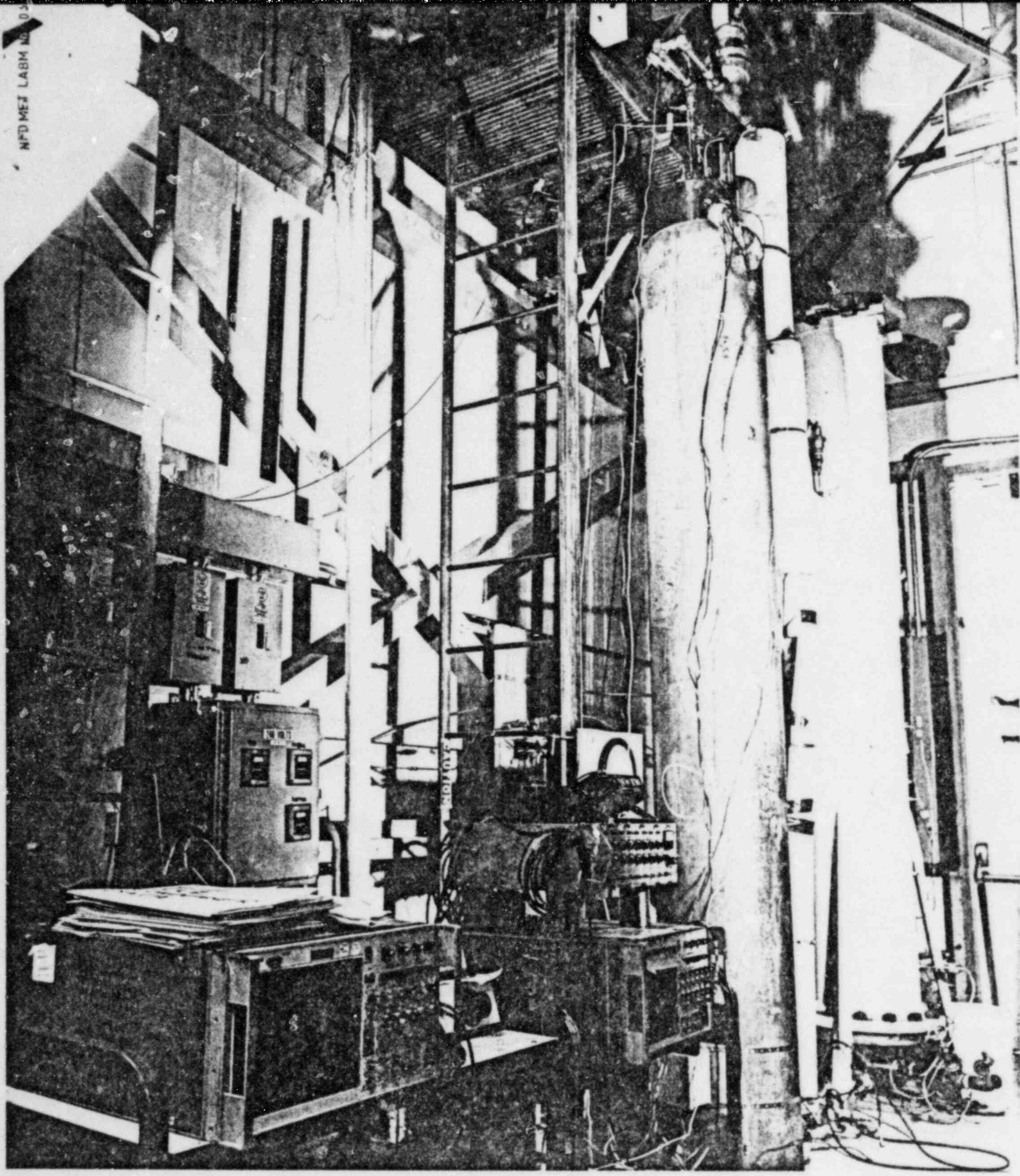


Figure 3-2. Test Facility

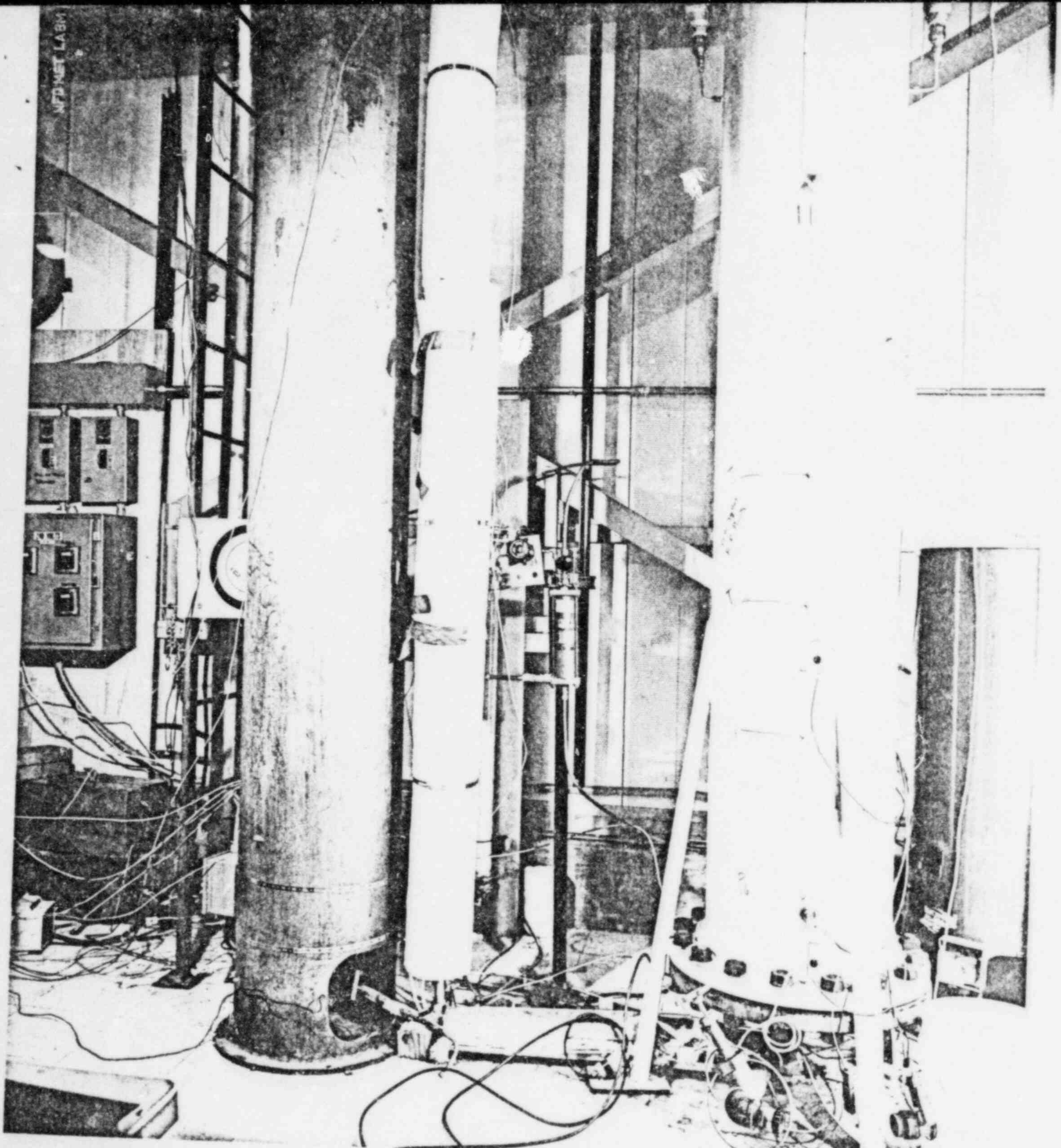


Figure 3-3. Boiler Autoclave and Receiver

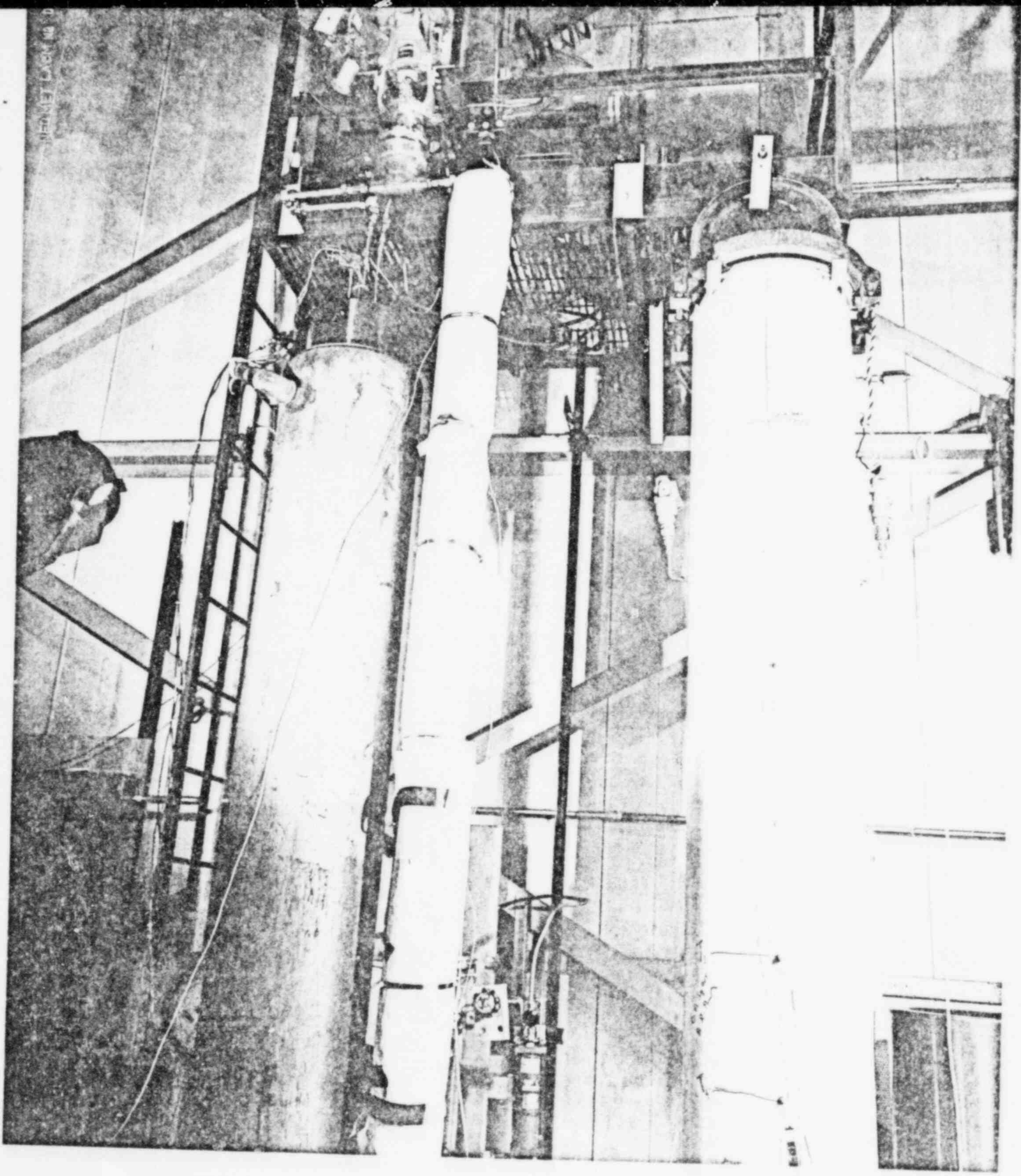
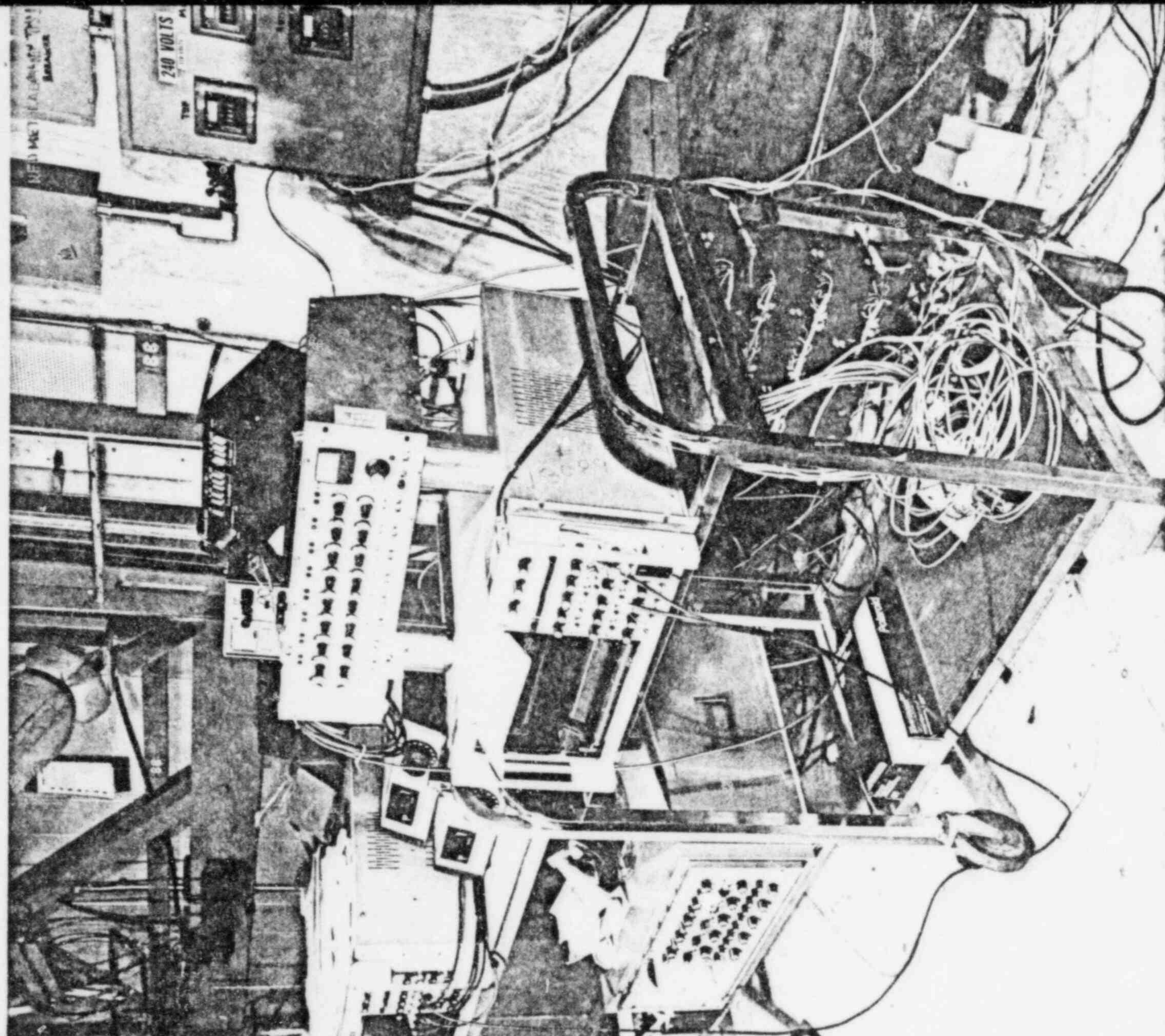


Figure 3-4. Boiler, Air-Operated Valve, and Receiver Vessel


240 VOLTS

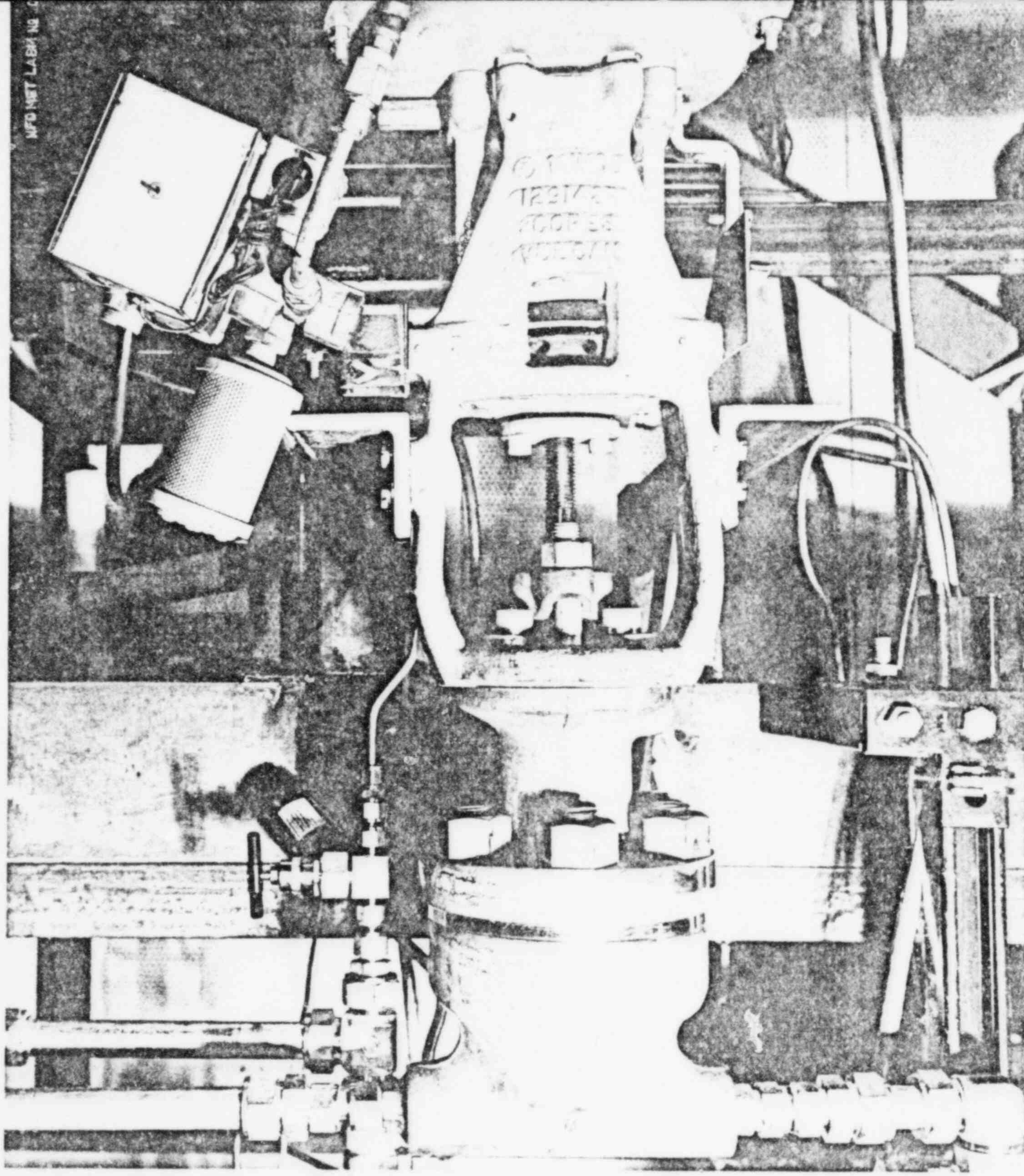


Figure 3-6. Air-Operated Valve

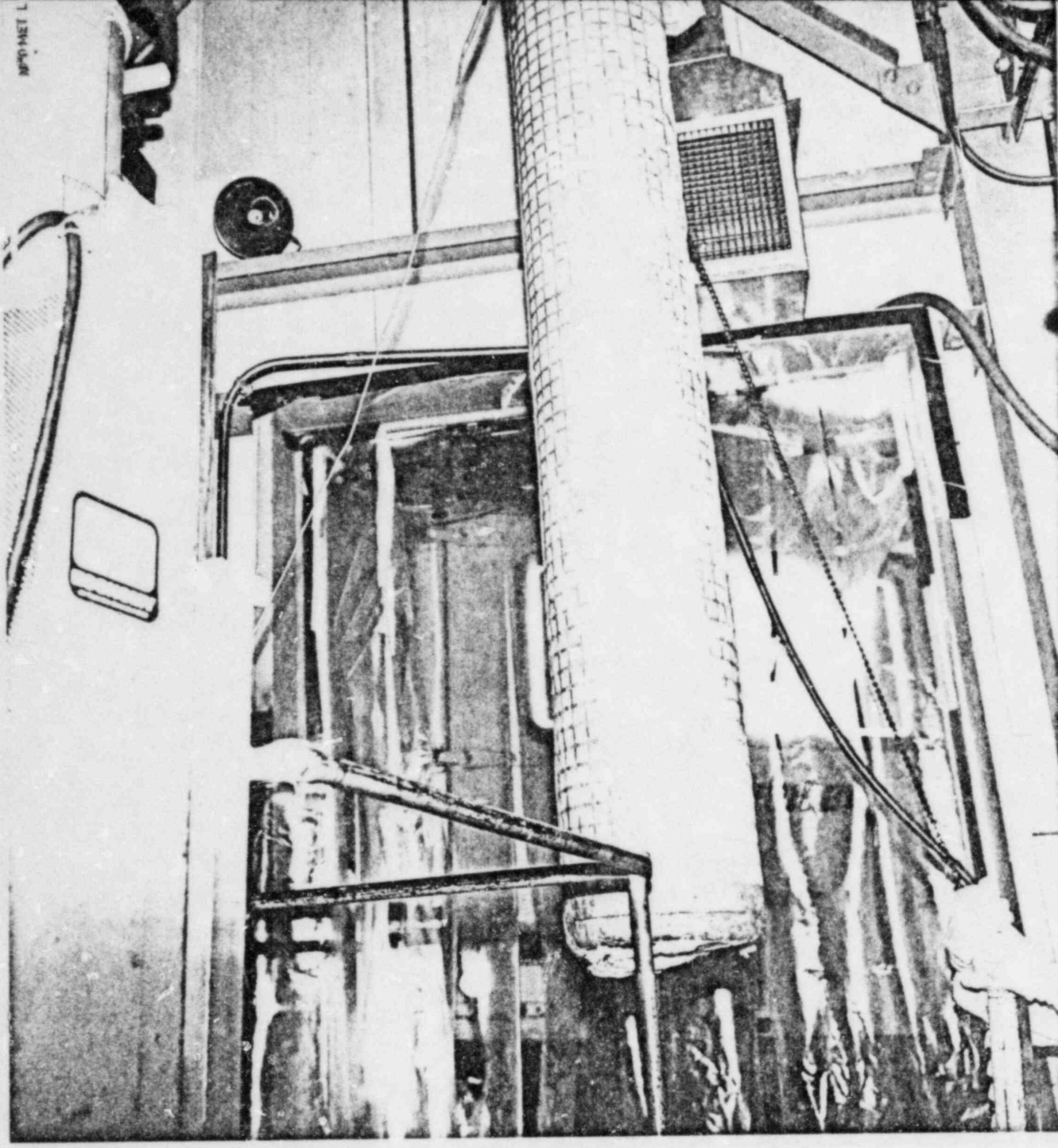


Figure 3-7. Pretest View of Ice Basket

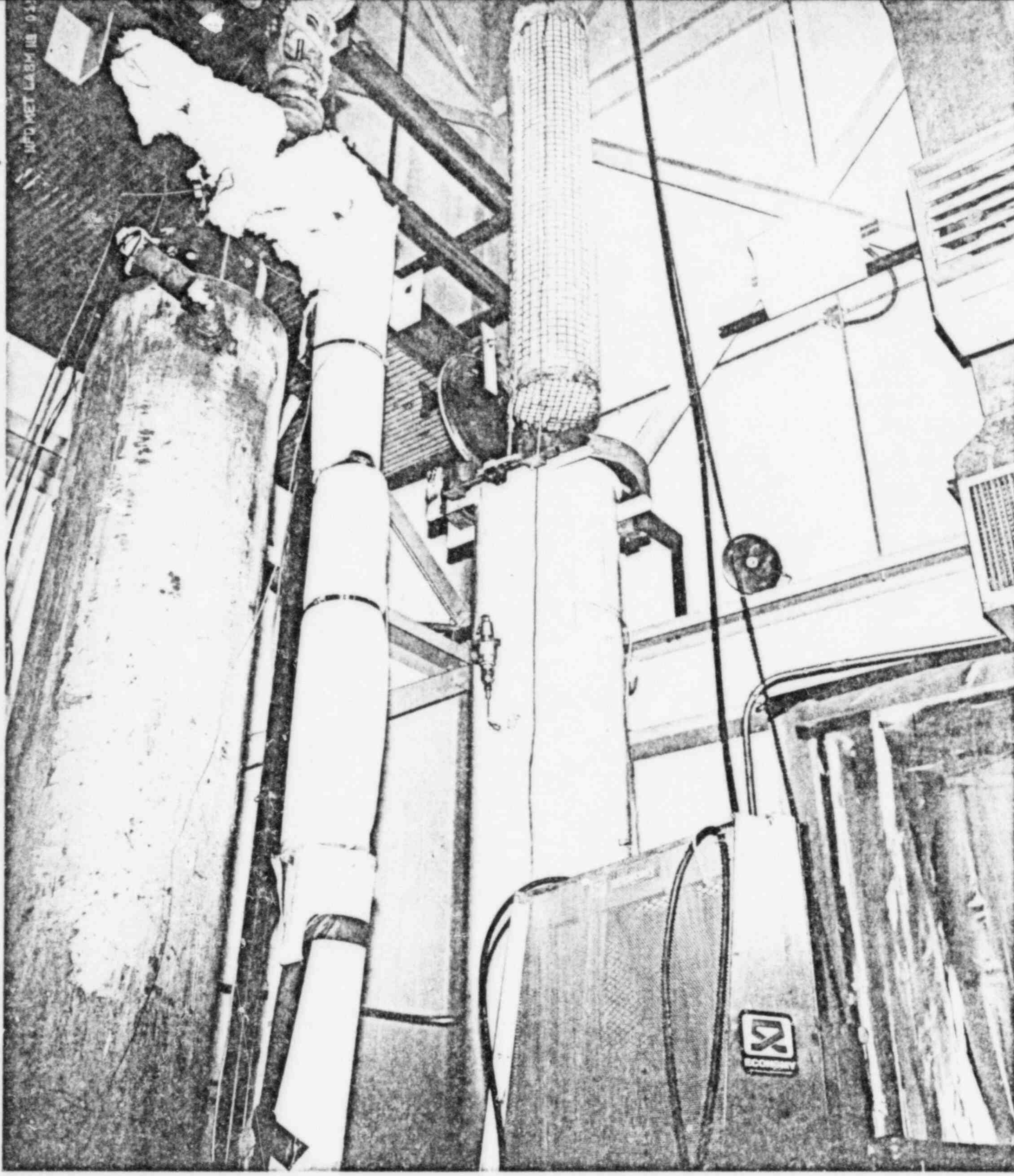


Figure 3-8. Ice Basket Being Lowered Into Receiver

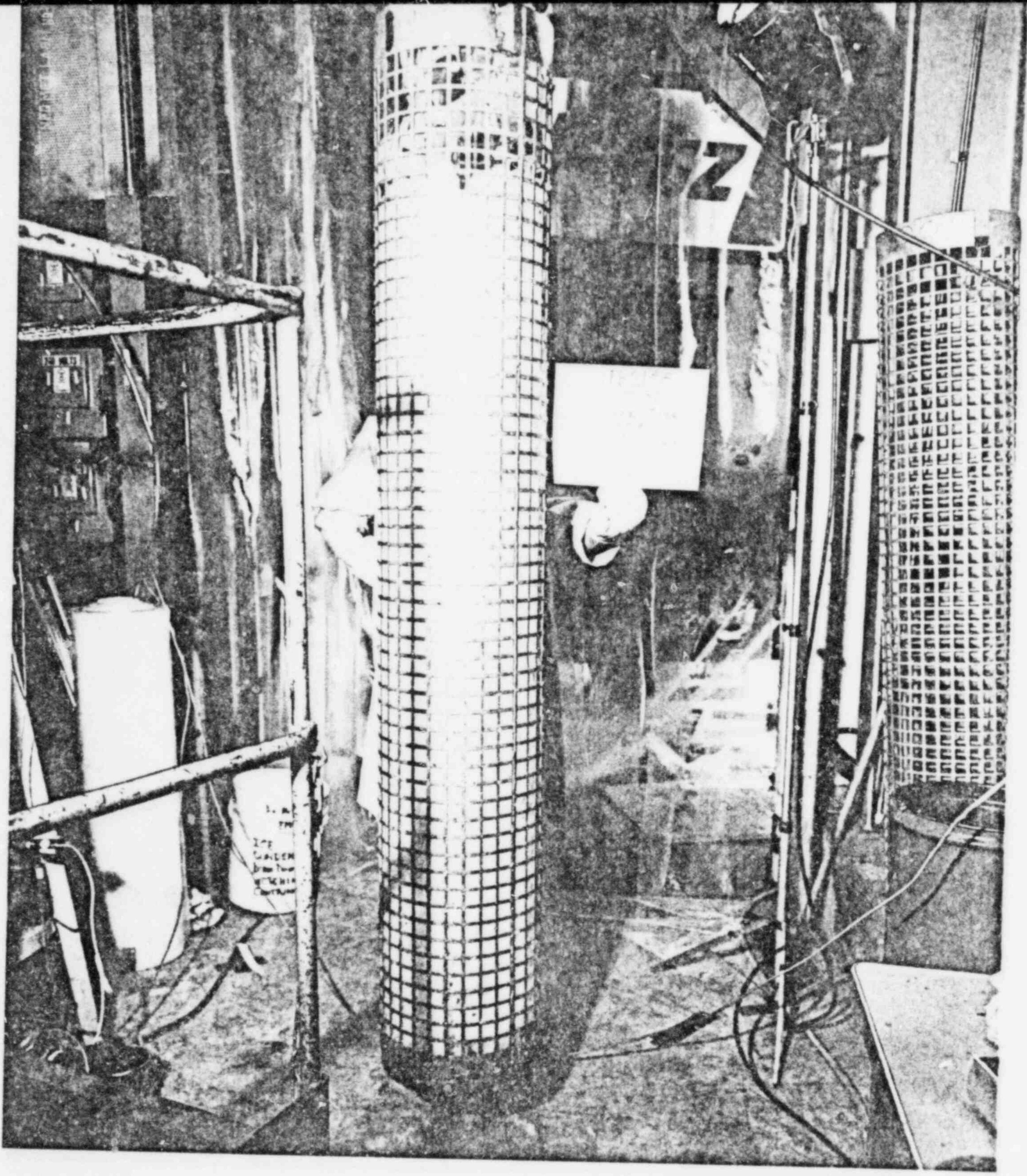


Figure 3-9. Posttest View of Ice Basket

Section 4

DATA EVALUATION

The results of the ice condenser performance test for the various water soluble shielding materials, configurations, and thicknesses are shown in comparison to the reference test case of an unshielded ice basket in Figures B-2 through B-10 (Appendix B). The generation of the reference pressure transient curve for an unshielded ice basket is shown in Figure B-1 (Appendix B). Here data from four tests are shown in relationship to the reference curve, which is an average of the plotted test points. The good repeatability of the test facility and procedure is indicated by the tight point scatter in the plot for the reference unshielded ice basket test cases.

All but one of the shielded ice basket test results met the initial criterion of 3 psig (21 Pa) above the reference test condition for the unshielded ice basket, which was established by the Westinghouse Nuclear Safety Department. Test 8 (Figure B-7), for the 3.5-mil (0.089 mm) polyethylene oxide internal liner shielded ice basket test, exceeded that criterion by 0.3 psig (2.1 Pa). However, test 13, which was a duplication of test 8, did meet the criterion. Nuclear Safety has reviewed the results of test 8 and has concluded that the results are acceptable, since the resulting initial peak pressure would still be 0.7 psig (5 Pa) below the minimum containment design pressure, and the pressure transient reduces fast enough so as not to affect the second pressure peak of 12 psig (83 Pa) which occurs about 2 hours into the LOCA accident, after the ice bed has melted out.

The only predictable pattern seen among the various film materials, thicknesses, or application configurations is that, as the peak receiver vessel pressure increased, so did the time into the transient that this peak occurred. That is, a low peak receiver vessel pressure [$\leq$7.6 psig ($\leq$52 Pa)] will occur early in the transients (<5.5 sec); the higher pressures occur later in time (up to 16.5 sec).

Film thickness and application configuration (inside liner versus outside wrapper) did not affect the pressure transient in a predictable manner. This might be explained by a comparison of Figure B-11, which is a plot of the highest pressure

points versus time from all the test cases, with Figure B-12, which is the pressure transient for an insoluble plastic film shielded ice basket. The insoluble film material was commercially available polyethylene sheet film 4.0 mil (0.10 mm) thick. The test shown in Figure B-12 (test 10) was not a scheduled test in the program, but was run to determine the effect of the shielding medium remaining intact. Both pressure transients (Figures B-11 and B-12) were similar up to approximately 12 s .onds into the steam blowdown. After this time, the pressure continued to rise for the insoluble shielded ice basket, but had peaked and started to fall for the water soluble film shielded ice basket.

The pressure transient differences before 12 seconds for all the water soluble shielded basket tests (Figures B-2 through B-10) might be an indication of how long the water soluble film material for that particular test case remained intact as a shielding medium along the length of ice basket. The pressure dip seen in Figures B-6 and B-7 could be the result of a fast disintegration of the shielding medium in the lower part of the ice basket and a slower disintegration higher up on the ice basket; in theory, the steam was condensed and the ice was melted out initially in the lower portion of the basket. Then, as the steam transient continued, the shielding film on the upper portions of the basket delayed the heat transfer and steam contact with the ice, and thus caused the pressure rise.

Figure B-9 shows the pressure transient for an ice basket which had been sprayed with methyl cellulose as a shielding film. The plot seems to indicate performance at least as good as that of the reference case (no shielding film). However, the application of the liquid methyl cellulose material was questionable in regard to producing a good continuous shielding coat over all the exposed ice surfaces.

Temperature versus time plots were recorded in five locations in the receiver vessel: at elevations corresponding to the top and bottom of the ice basket and at 1-1/2 foot (0.46 m) intervals in between. Peak temperatures and the time at which the peak temperatures occurred were recorded and are shown in Tables B-1 and B-2 (Appendix B). The actual temperature traces, from which peak temperatures were taken, appeared very erratic and spiky. The temperature information is included on the data sheets and data summary sheets (Appendix B). As expected, the lowest temperatures occurred at the top of the ice basket in all cases; the highest temperatures were at the basket bottom in most of the cases. The highest top temperature occurred in test 10, which used the insoluble plastic film shielding material. High top temperatures also occurred in those tests which exhibited the higher peak pressures. There appears to be no correlation between the times that the peak pressure and peak temperatures occurred.

Section 5

CONCLUSIONS AND RECOMMENDATIONS

The test results show some variation in performance among the types of film material, application configuration, and thickness. However, all shielded ice basket tests results are considered acceptable. The resulting receiver vessel pressures converged to the reference test conditions in a sufficiently short time period so as to not affect the postulated peak containment pressure from long-term heat decay after the ice bed is completely melted. It is believed that the application of the shielding material in an actual ice condenser plant could be defended.

Chemically, both shielding materials are acceptable on the basis of chloride content. The methyl cellulose material would be preferred because of its ability to dissolve faster and the smaller-sized, nonsticky particles in the remaining residue. However, the steam blowdown tests show lower peak pressures using thin polyethylene oxide material [2.0 mils (0.051 mm) thick] versus thin methyl cellulose material* [1.5 mils and 2.1 mils (0.038 and 0.053 mm) thick]. This appears to indicate that the polyethylene oxide material dissolves or disintegrates faster than methyl cellulose when contacted by steam.

Tables B-3 and B-4 (Appendix B) summarize the chemical analysis work performed on unirradiated and irradiated film samples, and on drain water collected after blowdown testing.

The integrity of the shielding film on the test ice baskets was greatly affected by atmospheric humidity. Several tests were cancelled because condensation formed on the plastic film surface and started to dissolve it. Shielding films sustained tears during handling operations from ice loading to lowering the basket into the receiver vessel. It was also noted that when the shielding film began to break down, the disintegration was usually more noticeable or pronounced at the bottom of the ice basket.

*Methyl cellulose is not commercially available in a thicker film at the present time.

From a handling point of view, the polyethylene oxide material was more rugged and less sensitive to moisture in the air. If actual plant application of shielding film material would be done in a dry, refrigerated environment where atmospheric humidity would not be a factor, then neither would have a handling advantage over the other.

Table 5-1 identifies the material costs associated with the incorporation of the identified shielding materials into an ice condenser plant. Based on the fact that a complete ice bed meltout and reload could cost on the order of $1,000,000, excluding costs for purchase of replacement power, the use of these materials would be very cost effective.

The internal basket liner proved to be the best method of material application on the test ice baskets. The ice basket reinforced the sheet film liner during ice loading operations and protected it during handling. The external wrapper configuration tended to blow outward during ice loading, allowing ice to be trapped between the basket exterior surface and the wrapper interior surface. Also, the external wrapper was easily damaged when the basket came into contact with other objects. The spray application of liquid material was messy and required application of a considerable amount of material to the basket surface before complete coverage appeared to be achieved. If more efficient and cost-effective techniques for spraying the liquid material were available, this application might be the most viable and attractive option for installation in an actual plant.

The results of this program indicate that a methyl cellulose internal basket liner made from 2.1-mil (0.053 mm) thick film would be the best candidate for ice basket shielding. The polyethylene oxide film material was disqualified mainly because it appears to leave sticky, larger-sized residue particles that could possibly plug containment spray nozzles. If it could be shown that this is not a problem, the 3.5-mil (0.089 mm) polyethylene oxide film material could be further considered.

RECOMMENDATIONS

The following recommendations are made on the basis of the test results:

- The possibility of the solids residue from the dissolved shielding material plugging containment spray system header nozzles has not been fully addressed. It is recommended that

this topic be evaluated by testing. Tests should be conducted to determine the maximum-sized residue particles that could be circulated through the containment spray header. Tests should be run with the maximum-sized particles pumped through actual spray nozzles under containment accident conditions.

- The heat transfer effects on the lower containment compartments under the ice condenser floor need to be addressed. These compartments are sensitive to the initial (first 2 seconds) pressure peak seen by the containment building. The short-term heat transfer computer analysis of these regions should be performed to determine its sensitivity to changes in heat transfer performance of the ice condenser.

Table 5-1

MATERIAL COSTS

Material	Cost per Pound ($)	Pounds per Column	Cost per Column ($)	Cost per Plant[a] ($ x 10^3)
METHYL CELLULOSE				
Solution	10.00	20.54	205.40	400
Film [1.5 mils (0.038 mm)]	6.66[b]	1.80	11.99	23.3
Film [2.1 mils (0.053 mm)]	6.66[b]	2.64	17.59	34.2
POLYETHYLENE OXIDE				
Solution	10.00	19.25	192.50	374.2
Film [2.0 mils (0.051 mm)]	4.84[b]	2.70	13.07	25.4
Film [2.5 mils (0.064 mm)]	4.84[b]	3.375	16.34	31.8
Film [3.5 mils (0.089 mm)]	4.84[b]	4.725	22.87	44.5

[a] 1944 columns

[b] >1000 lb

Appendix A

TEST PLAN

The test plan for the ice condenser ice basket sublimation shielding steam test is reproduced on the following pages.

Test Plan: Ice Condenser Ice Basket Sublimation Shielding Steam Test

Reference: EPRI Contract RP 2125-1

Prepared by: C.M. Scrabis, Principal Investigator
Thermal Equipment Engineering

Reviewed by: K.A. Kloes, Engineer
Thermal Equipment Engineering

P.A. Linn, Engineer
Safeguards Analysis

D.G. Agate, Project Engineer
Technology Development

Approved by: E.A. Tomasko 6/14/82
E.A. Tomasko, Manager
Q.A. Engineering

D.W. Alexander, Manager
Thermal Equipment Engineering

Rev. No. & Date		Revisions	Preparer
0	6-14-82	Original	C. M. Scrabis
1	6-23-82	Added revision page (8 pages in lieu of 7). Added Rev. No. to each page. Added IV.A.4, IV.B.9 and 10, V.5, and shielding material pre and post test weight to data sheet. Added the requirement to weigh in IV.B.4 and 7. IV.B.5 was through 13, IV.B.11 was repeat steps through 8.	C. M. Scrabis
2	10-5-82	Para. II.B.2. was 2.2 mil. Para. III.A.1.a., III.A.3.C., and IV.A.2., was 576°F. Para. III.B.3.6 was number required - 4. Para. III.B.3.d. was 2 ft spacing Para. III.B.5.b. was number reqd 7. Para. IV.A. and IV.A.15. were 8 to 10 psig. Para. IV.A.3. and IV.B.3. were 200 #. Para. IV.B. eliminated 2 steps for recovery and weighing of post test film materials. Para. V.5. eliminated post test. Figure 1 - P_7 and Air Operated Vessel, T_5 added to Receiver Vessel. Data Sheet - Removed Post test weight of film & Serial No's for thermocouples. - Added T_5 and places for Auotclave & piping temperatures. Para.IV.B.6. was Para. IV.A.14.	C.M. Scrabis

ICE BASKET SUBMLIMATION SHIELDING STEAM TEST

I. Objective

Determine the heat transfer performance of an ice filled (borated flake ice) perforated sheet metal ice basket, with 64% open area covered with a vapor barrier of water soluable plastic material, when subjected to a saturated steam blast. Evaluate and compare pressure and temperature transients of shielded versus unshielded ice baskets when subjected to comparable steam conditions.

II. Test Item

A. Ice Basket

The test baskets shall be 12 inches in diameter by 6 feet long made of 16 gauge perforated sheet metal. The perforations shall be 1 inch square on 1 1/8 inch centers with 64% open area. The baskets shall be open on the top end and enclosed on the bottom end with perforated sheet metal. One ice basket is required per each test run. At least six baskets shall be made available for the test program.

B. Water Soluable Plastic Material

Two materials have been identified for investigation in this test program; Methyl cellulose, and Polyethylene Oxide. These materials will be furnished as sheet film and as a liquid for spray application. The following material configurations will be tested:

1. Methyl Cellulose - 1.5 mil thick sheet film
2. Methyl Cellulose - 2.1 mil thick sheet film
3. Polyethylene Oxide - 2.0 mil thick sheet film
4. Polyethylene Oxide - 3.5 mil thick sheet film
5. Polyethylene Oxide - 2.5 mil thick sheet film*
6. Methyl Cellulose - light spray coating (approx. 1 mil thick)
7. Methyl Cellulose - heavy spray coating (approx. 4 mil thick)
8. Polyethylene Oxide - light spray coating (approx. 1 mil thick)
9. Polyethylene Oxide - heavy spray coating (approx. 4 mil thick)

The sheet film materials will be tested in the configurations as an external basket wrapper and as an internal basket liner.

* If test results on items 3 and 4 do not show any differences, then this item (2.5 mil thick polyethylene oxide film) can be eliminated.

III. Test Equipment and Setup

A. Mechanical (Ref. attached sketch autoclave test facility schematic)

1. Boiler Autoclave

a. 1200 psig @ 580°F
b. 8" dia. x 10' long (or equivalent)
c. Number required - 1

2. Receiver Vessel

a. 150 psig @ 600°F
b. 18" O.D. x 10' long
c. Quick opening hatch on top
d. Blind flange on bottom
e. Number required - 1

3. Air Operated Valve

a. For 1" dia. pipe line
b. Number required - 1
c. 1200 psig @ 580°F

4. Piping

a. 1" dia. high pressure stainless steel tubing

B. Instrumentation (All calibration shall be current)

1. Pressure Transducers

a. 0 to 50 psig
b. Number required - 2
c. Transducers located at the top and bottom of the ice basket location
d. Minimum response time shall be 0.090 sec.

2. Pressure Transducer

a. 0 to 2000 psig $\pm$. 2 psig
b. 32°F to 800°F temperature range
c. Minimum response time 0.001 sec.
d. Number required - 1
e. Location - steam discharge pipe to receiver vessel

3. Thermocouples

a. 32°F to 600°F
b. Number required - 5
c. Minimum response time shall be 0.090 sec.
d. One thermocouple located every 1 1/2' along the ice basket length.

4. Load Cell

   a. 0 to 250# ± 1/2#
   b. Capable of weighing in compression and tension
   c. Number required - 1

5. Graphic Data Acquisition System (Visicorder)

   a. Honeywell Model No. 1858
   b. Number of channels required - 8

IV. Test Procedure

A. Preliminary test for determining the amount of autoclave water required to produce a peak receiver vessel pressure of 7 to 10 psig.

1. Add 6.5# of water to the autoclave system.

2. Heat to saturated steam conditions (1200 psig and 580°F initially).

3. Fill the ice basket with 150# of borated flakice.

4. Weigh the ice filled ice basket.

5. Install the ice basket inside the receiver.

6. Secure the hinged cover.

7. Start visicorder.

8. Open blowdown valve.

9. Record pressure and temperature.

10. After pressure and temperature have stabilized, open drain valve and collect water from the receiver.

11. Record the weight of receiver water.

12. Open top hinged cover.

13. Remove ice basket and weigh.

14. Increase the weight of water in Step IV.A.1 in increments of 1/2 pound and repeat test IV.A until a peak receiver vessel pressure of 7 to 10 psig is reached or the weight of autoclave water reaches 11.0#.

B. Basket Performance Test

1. Add the amount of water determined in part IV.A. to the autoclave system.

2. Heat to established steam conditions.

3. Fill an ice basket with 150# of borated flakice.

4. Weigh and install material II.B.1. to the outside of the ice basket. The entire ice basket shall be enclosed in the film material.

5. Repeat steps IV.A.4. through 13.

6. Photograph the ice basket.

7. Repeat steps IV.B.1. and 2.

8. Weigh and install material II.B.1. as in internal liner to the ice basket.

9. Repeat steps IV.B.3, 5, and 6.

10. Repeat steps IV.B.1 through 8 for each of the water soluable film materials identified in paragraph II.B.2 through 5.

11. Repeat steps IV.B.1 through 5 for each of the water soluable spray coating materials identified in paragraph II.B.6 through 9.

12. Three (3) reference tests, on ice baskets without shielding materials, shall be run to verify repeatability of system transients conditions established in paragraph IV.A.14. One reference test run shall be done after testing material II.B.2, one after material II.B.5, and one after material II.B.9.

V. Data Requirements (See Attached Data Sheet)

1. Pressure transient at the bottom of the ice basket location.

2. Pressure transient at the top of the ice basket location.

3. Temperature transients along the ice basket length.

4. Description of shielding material (i.e. material, thickness, installed configuration).

5. Shielding material weight (pre test).

6. Weight of receiver vessel water after blowdown.

7. Weight of autoclave water before blowdown.

8. Pressure and temperature of autoclave before blowdown.

9. Tare weight of empty ice basket.

10. Weight of ice basket before and after steam blowdown test.

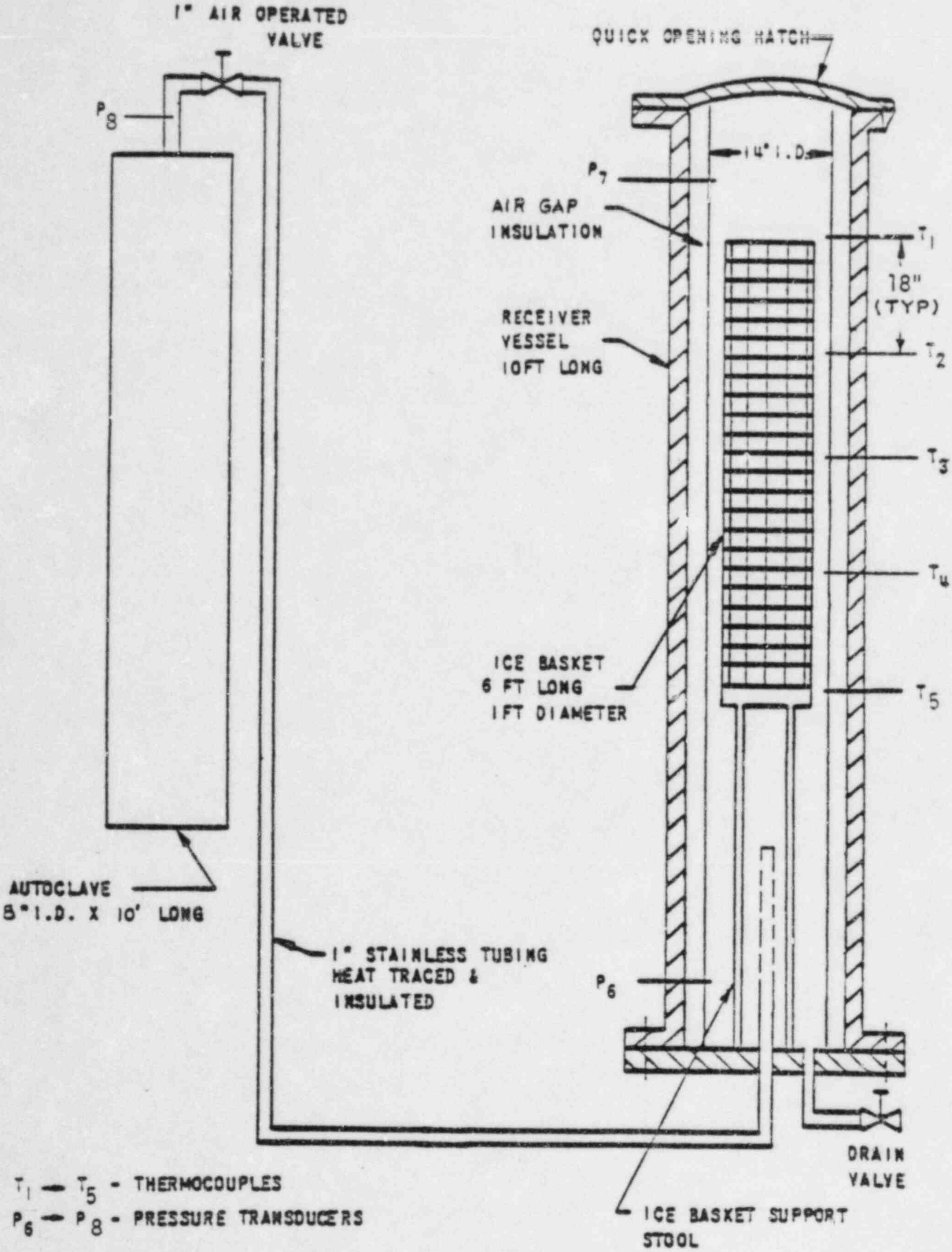


Figure 1 Autoclave Test Facility Schematic

DATA SHEET

TEST NO. ______________________

DATE ______________________

AUTOCLAVE

WEIGHT OF WATER IN AUTOCLAVES ______________________

PRESSURE (P_7) ______________ Serial No. ______________

TEMPERATURE (Autoclave) ______________ (Piping) ______________

BASKET

SHIELDING MATERIAL & THICKNESS ______________________

SHIELDING MATERIAL CONFIGURATION ______________________

SHIELDING MATERIAL PRE-TEST WEIGHT ______________________

TARE WEIGHT ______________________

ICE WEIGHT (PRE-TEST) ______________________

ICE WEIGHT (POST-TEST) ______________________

RECEIVER VESSEL

PEAK TOP P.S.I. (P_5) ______________ Serial No. ______________

PEAK BOTTOM P.S.I.(P_6) ______________ Serial No. ______________

WEIGHT OF WATER (POST-TEST) ______________________

MAX. TOP °F (T1) ______________________

MAX. MID. TOP °F (T2) ______________________

MAX. MIDDLE °F (T3) ______________________

MAX. MID. BOT. °F (T4) ______________________

MAX. BOTTOM °F (T5) ______________________

PREPARED BY: ______________ DATE ____

VERIFIED BY: ______________ DATE ____

Appendix B

TEST DATA

The results of the preliminary and reference tests are summarized in Table B-1, which is followed by the data sheets from these tests. The results of the plastic film tests are summarized in Table B-2, again followed by the appropriate data sheets. These data are presented graphically in Figures B-1 through B-3.

Chemical and radiological analysis data are given in Tables B-3 and B-4.

Table B-1

SUMMARY OF PRELIMINARY AND REFERENCE DATA
(UNSHIELDED ICE BASKETS)

Parameter	Test Number			
	Preliminary 9	Preliminary 10	Preliminary 11	6
Date	9/20/82	9/21/82	9/22/82	9/28/82
Boiler autoclave	10.0	10.0	10.0	10.0
Water weight (lb)	1200	1200	1200	1200
Pressure (psig)	580	580	581	580
Temperature (°F)				
Ice basket				
Initial ice weight (lb)	148.5	149.9	148.3	146.5
Final ice weight (lb)	133.8	134.4	130.3	126.9
Melted ice weight (lb)	14.7	15.5	18.0	19.6
Receiver vessel				
Peak pressure (psig)	7.5	7.2	7.4	7.6
Recovered water (lb)	21.2	23.1	26.5	28.2
Lost water (lb)	3.5	2.4	1.5	1.4
Maximum temperature and time (°F, sec)				
Top	75.2 @ 4.1	69.8 @ 6.2	57.2 @ 8.1	35.6 @ 10.3
Midtop	141.8 @ 7.8	132.8 @ 9.6	149 @ 7.9	44.6 @ 11.2
Middle	228.2 @ 7.0	222.8 @ 8.7	222 @ 7.5	132.8 @ 10.7
Midbottom	235.4 @ 6.4	231.8 @ 4.8	235.4 @ 7.8	197.6 @ 10.0
Bottom	249.8 @ 4.4	249.8 @ 5.5	251.6 @ 7.8	203 @ 8.8
Peak pressure time (sec)	4.0	3.5	3.0	3.4

DATA SHEET

TEST NO. Preliminary #9

DATE 9-20-82

AUTOCLAVE

WEIGHT OF WATER IN AUTOCLAVES 10.0 Lbs

PRESSURE (P_7) 1200 PSIG Serial No. 51037

TEMPERATURE (Autoclave) 580°F (Piping) 353°F

BASKET

SHIELDING MATERIAL & THICKNESS N/A

SHIELDING MATERIAL CONFIGURATION N/A

SHIELDING MATERIAL PRE-TEST WEIGHT N/A

TARE WEIGHT 29.7 Lbs.

ICE WEIGHT (PRE-TEST) 178.2 Lbs (Ice + Basket)

ICE WEIGHT (POST-TEST) 163.5 Lbs (Ice + Basket)

RECEIVER VESSEL

PEAK TOP P.S.I. (P_5) 7.5 PSIG Serial No. 66702

PEAK BOTTOM P.S.I.(P_6) 7.5 PSIG Serial No. 66703

WEIGHT OF WATER (POST-TEST) 21.2 Lbs.

MAX. TOP °F (T1) 75.2°F

MAX. MID. TOP °F (T2) 141.8°F

MAX. MIDDLE °F (T3) 228.2°F

MAX. MID. BOT. °F (T4) 235.4°F

MAX. BOTTOM °F (T5) 249.8°F

PREPARED BY: [signature] DATE 9/20/82

VERIFIED BY: [signature] DATE 9/20/82

DATA SHEET

TEST NO. Preliminary #10

DATE 9-21-82

AUTOCLAVE

WEIGHT OF WATER IN AUTOCLAVES 10.0 Lbs

PRESSURE (P_7) 1200 PSIG Serial No. 51037

TEMPERATURE (Autoclave) 580°F (Piping) 346°F

BASKET

SHIELDING MATERIAL & THICKNESS N/A

SHIELDING MATERIAL CONFIGURATION N/A

SHIELDING MATERIAL PRE-TEST WEIGHT N/A

TARE WEIGHT 29.7 Lbs

ICE WEIGHT (PRE-TEST) 179.6 Lbs (Ice + Basket)

ICE WEIGHT (POST-TEST) 164.1 Lbs (Ice + Basket)

RECEIVER VESSEL

PEAK TOP P.S.I. (P_5) 7.2 PSIG Serial No. 66702

PEAK BOTTOM P.S.I. (P_6) 7.2 PSIG Serial No. 66703

WEIGHT OF WATER (POST-TEST) 23.1 Lbs.

MAX. TOP °F (T1) 69.8°F

MAX. MID. TOP °F (T2) 132.8°F

MAX. MIDDLE °F (T3) 222.8°F

MAX. MID. BOT. °F (T4) 231.8°F

MAX. BOTTOM °F (T5) 249.8°F

PREPARED BY: [signature] DATE 9/21/82

VERIFIED BY: [signature] QE DATE 9/21/82

DATA SHEET

TEST NO. Preliminary #11

DATE 9-22-82

AUTOCLAVE

WEIGHT OF WATER IN AUTOCLAVES 10.0 Lbs

PRESSURE (P_7) 1200 PSIG Serial No. 51037

TEMPERATURE (Autoclave) 581°F (Piping) 343°F

BASKET

SHIELDING MATERIAL & THICKNESS N/A

SHIELDING MATERIAL CONFIGURATION N/A

SHIELDING MATERIAL PRE-TEST WEIGHT N/A

TARE WEIGHT 29.7 Lbs

ICE WEIGHT (PRE-TEST) 178.0 Lbs (Ice + Basket)

ICE WEIGHT (POST-TEST) 160.0 Lbs (Ice + Basket)

RECEIVER VESSEL

PEAK TOP P.S.I. (P_5) 7.4 PSIG Serial No. 66702

PEAK BOTTOM P.S.I.(P_6) DID NOT RECORD Serial No. 66703

WEIGHT OF WATER (POST-TEST) 26.5 Lbs.

MAX. TOP °F (T1) 57.2°F

MAX. MID. TOP °F (T2) 149.0°F

MAX. MIDDLE °F (T3) 222.0°F

MAX. MID. BOT. °F (T4) 235.4°F

MAX. BOTTOM °F (T5) 251.6°F

PREPARED BY: [signature] DATE 9/22/82

VERIFIED BY: [signature] QE DATE 9/22/82

Table B-2

SUMMARY OF TEST DATA
(SHIELDED ICE BASKETS)

Parameter	Test Number 2	3	4	5	7	8	9	10	11	12	13	14	15
Date	9/23/82	9/24/82	9/25/82	9/27/82	10/4/82	10/5/82	10/5/82	10/7/82	10/8/82	10/11/82	10/12/82	10/13/82	10/13/82
Boiler autoclave													
Water weight (lb)	10.0	10.0	10.0	10.0	10.0	16.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Pressure (psig)	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200
Temperature (°F)	580	580	580	580	579	580	581	580	580	580	581	580	581
Ice basket													
Initial ice weight (lb)	156.2	153.5	158.2	143.5	145.2	145.9	151.8	142.6	153.3	155.6	139.3	153.1	151.7
Final ice weight (lb)	148.4	142.7	138.3	123.8	131.0	134.4	137.8	133.9	132.3	139.4	128.6	138.3	132.8
Melted ice weight (lb)	7.8	10.8	19.9	19.7	14.2	11.5	14.0	8.7	21.0	16.2	10.7	14.8	18.9
Plastic film													
Material	EDISOL M[a]	EDISOL M	QUIK-SOL P[b]	QUIK-SOL P	EDISOL M	QUIK-SOL P	QUIK-SOL P	Insoluble polyethylene	EDISOL M	QUIK-SOL P	QUIK-SOL P	EDISOL M	QUIK-SOL P
Thickness (mils)	1.5	1.5	2.0	2.0	2.1	3.5	3.5	4.0	Heavy - 1 qt	1.5	3.5	2.1	2.0
Application	External wrap	Internal liner	External wrap	Internal liner	Internal liner	Internal liner	External wrap	Internal liner	Spray coat	External wrap	Internal liner	External wrap	External wrap
Receiver vessel													
Peak pressure (psig)	9.5	8.5	7.4	8.5	9.6	10.8	8.5	11.6	7.2	8.4	9.4	8.3	7.5
Recovered water weight (lb)	15.6	18.1	29.0	28.8	23.6	21.2	21.7	17.3	29.9	24.5	19.1	23.8	27.4
Lost water (lb)	2.2	2.7	0.9	0.9	0.6	0.3	2.3	1.4	1.1	1.7	1.6	1.0	1.5
Maximum temperature and time (°F, sec)													
Top	53.6 @ 6.7	--	--	48.2 @ 16.3	62.6 @ 9.7	74.3 @ 19.75	36.3 @ 4.9	138.2 @ 16.5	35.6 @ 29.1	36 @ 4.2	57.7 @ 13.9	32 @ 12.4	44.6 @ 4.6
Midtop	101.4 @ 5.4	159.8 @ 9.7	140 @ 5.4	168.8 @ 6.0	201.2 @ 6.5	212 @ 11.2	201.2 @ 3.4	213.8 @ 8.9	111.2 @ 28.6	180 @ 3.9	212 @ 7.9	190.4 @ 17.7	122 @ 14.1
Middle	240 @ 6.7	201.2 @ 8.1	[illegible] @ 6.3	197.6 @ 6.4	208.4 @ 8.4	208.4 @ 16.2	208.4 @ 3.3	213.8 @ 8.1	183.2 @ 5.7	203 @ 9.2	210 @ 7.9	210 @ 7.1	204.8 @ 6.6
Midbottom	239 @ 6.7	203 @ 8.7	201.2 @ 11.7	206.6 @ 6.3	217.4 @ 6.4	217.4 @ 9.2	208.4 @ 3.1	203 @ 8.0	190.4 @ 4.2	203 @ 10.9	212 @ 7.9	212 @ 4.2	206.6 @ 4.5
Bottom	257 @ 6.5	208 @ 8.6	206.6 @ 5.8	208.4 @ 6.1	212 @ 3.9	213.8 @ 6.2	213.8 @ 10.3	203 @ 7.7	197.6 @ 4.6	208.4 @ 11.7	212 @ 7.7	212 @ 3.2	207.5 @ 4.1
Peak pressure time (sec)	16.5	7.5	3.3	4.9	9.15	12.6	5.[illegible]	16.7	4.25	11.5	8.3	6.4	5.4

[a]Methyl cellulose

[b]Polyethylene oxide

DATA SHEET

TEST NO. 6

DATE 9-28-82

AUTOCLAVE

WEIGHT OF WATER IN AUTOCLAVES 10.0 Lbs

PRESSURE (P_7) 1200 PSIG Serial No. 51037

TEMPERATURE (Autoclave) 580°F (Piping) 353°F

BASKET

SHIELDING MATERIAL & THICKNESS N/A

SHIELDING MATERIAL CONFIGURATION N/A

SHIELDING MATERIAL PRE-TEST WEIGHT N/A

TARE WEIGHT 29.4 Lbs

ICE WEIGHT (PRE-TEST) 174.7 Lbs

ICE WEIGHT (POST-TEST) 155.1 Lbs

RECEIVER VESSEL

PEAK TOP P.S.I. (P_5) 7.6 PSIG Serial No. 66702

PEAK BOTTOM P.S.I. (P_6) 7.6 PSIG Serial No. 66703

WEIGHT OF WATER (POST-TEST) 28.2 Lbs

MAX. TOP °F (T1) 35.6°F

MAX. MID. TOP °F (T2) 44.6°F

MAX. MIDDLE °F (T3) 132.8°F

MAX. MID. BOT. °F (T4) 197.6°F

MAX. BOTTOM °F (T5) 203.0°F

PREPARED BY: [signature] DATE 9/29/82

VERIFIED BY: [signature] Q.E. DATE 9/28/82

DATA SHEET

TEST NO. 2

DATE 9-23-82

AUTOCLAVE

WEIGHT OF WATER IN AUTOCLAVES 10.0 Lbs

PRESSURE (P_7) 1200 PSIG Serial No. 51037

TEMPERATURE (Autoclave) 580°F (Piping) 250°F

BASKET

SHIELDING MATERIAL & THICKNESS Methyl Cellulose - 0.0015"

SHIELDING MATERIAL CONFIGURATION External Wrapper

SHIELDING MATERIAL PRE-TEST WEIGHT ———

TARE WEIGHT 29.7 Lbs

ICE WEIGHT (PRE-TEST) 186.2 Lbs (Ice + Basket + Film)

ICE WEIGHT (POST-TEST) 178.4 Lbs (Ice + Basket + Film)

RECEIVER VESSEL

PEAK TOP P.S.I. (P_5) 9.5 PSIG Serial No. 66702

PEAK BOTTOM P.S.I. (P_6) 9.5 PSIG Serial No. 66703

WEIGHT OF WATER (POST-TEST) 15.6 Lbs

MAX. TOP °F (T1) 53.6°F

MAX. MID. TOP °F (T2) 181.4°F

MAX. MIDDLE °F (T3) 240.0°F

MAX. MID. BOT. °F (T4) 239.0°F

MAX. BOTTOM °F (T5) 257.0°F

PREPARED BY: [signature] DATE 9/23/82

VERIFIED BY: E. [signature] QE DATE 9/23/82

DATA SHEET

TEST NO. 3

DATE 9-24-82

AUTOCLAVE

WEIGHT OF WATER IN AUTOCLAVES 10.0 Lbs

PRESSURE (P_7) 1200 PSIG Serial No. 51037

TEMPERATURE (Autoclave) 580°F (Piping) 345°F

BASKET

SHIELDING MATERIAL & THICKNESS METHYL CELLULOSE – 0.0015"

SHIELDING MATERIAL CONFIGURATION INTERNAL LINER

SHIELDING MATERIAL PRE-TEST WEIGHT 0.30 Lbs

TARE WEIGHT 29.7 Lbs

ICE WEIGHT (PRE-TEST) 183.5 Lbs (Ice + Basket + Film)

ICE WEIGHT (POST-TEST) 172.7 Lbs (Ice + Basket + Film)

RECEIVER VESSEL

PEAK TOP P.S.I. (P_5) 8.5 PSIG Serial No. 66702

PEAK BOTTOM P.S.I.(P_6) 8.5 PSIG Serial No. 66703

WEIGHT OF WATER (POST-TEST) 18.1 Lbs.

MAX. TOP °F (T1) DID NOT RECORD

MAX. MID. TOP °F (T2) 159.8°F

MAX. MIDDLE °F (T3) 201.2°F

MAX. MID. BOT. °F (T4) 203.0°F

MAX. BOTTOM °F (T5) 208.0°F

PREPARED BY: David Kaler DATE 9-24-82

VERIFIED BY: [signature] QE DATE 9/24/82

DATA SHEET

TEST NO. 4

DATE 9-25-82

AUTOCLAVE

WEIGHT OF WATER IN AUTOCLAVES 10.0 Lbs

PRESSURE (P_7) 1200 PSIG Serial No. 51037

TEMPERATURE (Autoclave) 580°F (Piping) 351°F

BASKET

SHIELDING MATERIAL & THICKNESS POLYETHYLENE OXIDE – 0.0020"

SHIELDING MATERIAL CONFIGURATION EXTERNAL WRAPPER

SHIELDING MATERIAL PRE-TEST WEIGHT 0.30 Lbs.

TARE WEIGHT 29.2 Lbs

ICE WEIGHT (PRE-TEST) 187.7 Lbs (Ice + Basket + Film)

ICE WEIGHT (POST-TEST) 167.8 Lbs (Ice + Basket + Film)

RECEIVER VESSEL

PEAK TOP P.S.I. (P_5) 7.5 PSIG Serial No. 66702

PEAK BOTTOM P.S.I. (P_6) 7.5 PSIG Serial No. 66703

WEIGHT OF WATER (POST-TEST) 29.0 Lbs.

MAX. TOP °F (T1) DID NOT RECORD

MAX. MID. TOP °F (T2) 140.0°F

MAX. MIDDLE °F (T3) 176.0°F

MAX. MID. BOT. °F (T4) 201.2°F

MAX. BOTTOM °F (T5) 206.6°F

PREPARED BY: David Kolo DATE 9-25-82

VERIFIED BY: [signature] QE DATE 9/25/82

DATA SHEET

TEST NO. 5

DATE 9-27-82

AUTOCLAVE

WEIGHT OF WATER IN AUTOCLAVES 10.0 Lbs

PRESSURE (P_7) 1200 PSIG Serial No. 51C37

TEMPERATURE (Autoclave) 580°F (Piping) 370°F

BASKET

SHIELDING MATERIAL & THICKNESS POLYETHYLENE OXIDE - 0.0020"

SHIELDING MATERIAL CONFIGURATION INTERNAL LINER

SHIELDING MATERIAL PRE-TEST WEIGHT 0.457 Lbs

TARE WEIGHT 27.9 Lbs

ICE WEIGHT (PRE-TEST) 171.9 Lbs (Ice + Basket + Film)

ICE WEIGHT (POST-TEST) 152.2 Lbs (Ice + Basket + Film)

RECEIVER VESSEL

PEAK TOP P.S.I. (P_5) 8.5 PSIG Serial No. 66702

PEAK BOTTOM P.S.I. (P_6) 8.5 PSIG Serial No. 66703

WEIGHT OF WATER (POST-TEST) 28.8 Lbs

MAX. TOP °F (T1) 48.2°F

MAX. MID. TOP °F (T2) 168.8°F

MAX. MIDDLE °F (T3) 197.6°F

MAX. MID. BOT. °F (T4) 206.6°F

MAX. BOTTOM °F (T5) 208.4°F

PREPARED BY: [signature] DATE 9/27/82

VERIFIED BY: [signature] QE DATE 9/27/82

DATA SHEET

TEST NO. 7

DATE 10-4-82

AUTOCLAVE

WEIGHT OF WATER IN AUTOCLAVES 10.0 Lbs

PRESSURE (P_7) 1200 PSIG Serial No. 51037

TEMPERATURE (Autoclave) 579°F (Piping) 342°F

BASKET

SHIELDING MATERIAL & THICKNESS METHYL CELLULOSE - 0.0021"

SHIELDING MATERIAL CONFIGURATION INTERNAL LINER

SHIELDING MATERIAL PRE-TEST WEIGHT ——

TARE WEIGHT 30.0 Lbs

ICE WEIGHT (PRE-TEST) 175.5 Lbs (Ice + Basket + Film)

ICE WEIGHT (POST-TEST) 161.3 Lbs (Ice + Basket + Film)

RECEIVER VESSEL

PEAK TOP P.S.I. (P_5) 9.6 PSIG Serial No. 66702

PEAK BOTTOM P.S.I. (P_6) 9.6 PSIG Serial No. 66703

WEIGHT OF WATER (POST-TEST) 23.6 Lbs.

MAX. TOP °F (T1) 62.6°F

MAX. MID. TOP °F (T2) 201.2°F

MAX. MIDDLE °F (T3) 208.4°F

MAX. MID. BOT. °F (T4) 217.4°F

MAX. BOTTOM °F (T5) 212.0°F

PREPARED BY: [signature] DATE 10/4/82

VERIFIED BY: [signature] QE DATE 10/4/82

DATA SHEET

TEST NO. 8

DATE 10-5-82

AUTOCLAVE

WEIGHT OF WATER IN AUTOCLAVES 10.0 Lbs

PRESSURE (P_7) 1200 PSIG Serial No. 51037

TEMPERATURE (Autoclave) 580°F (Piping) 332°F

BASKET

SHIELDING MATERIAL & THICKNESS POLYETHYLENE OXIDE - 0.0035"

SHIELDING MATERIAL CONFIGURATION INTERNAL LINER

SHIELDING MATERIAL PRE-TEST WEIGHT — — —

TARE WEIGHT 29.4 Lbs

ICE WEIGHT (PRE-TEST) 175.7 Lbs (Ice + Basket + Film)

ICE WEIGHT (POST-TEST) 164.2 Lbs (Ice + Basket + Film)

RECEIVER VESSEL

PEAK TOP P.S.I. (P_5) 10.8 PSIG Serial No. 66702

PEAK BOTTOM P.S.I. (P_6) 10.8 PSIG Serial No. 66703

WEIGHT OF WATER (POST-TEST) 21.2 Lbs

MAX. TOP °F (T1) 74.3°F

MAX. MID. TOP °F (T2) 212.0°F

MAX. MIDDLE °F (T3) 208.4°F

MAX. MID. BOT. °F (T4) 217.4°F

MAX. BOTTOM °F (T5) 213.8°F

PREPARED BY: [signature] DATE 10/5/82

VERIFIED BY: [signature] QE DATE 10/5/82

DATA SHEET

TEST NO. 9

DATE 10-5-82

AUTOCLAVE

WEIGHT OF WATER IN AUTOCLAVES 10.0 Lbs

PRESSURE (P_7) 1200 PSIG Serial No. 51037

TEMPERATURE (Autoclave) 581°F (Piping) 343°F

BASKET

SHIELDING MATERIAL & THICKNESS POLYETHYLENE OXIDE - 0.0035"

SHIELDING MATERIAL CONFIGURATION EXTERNAL WRAPPER

SHIELDING MATERIAL PRE-TEST WEIGHT 0.87 Lbs

TARE WEIGHT 30.0 Lbs

ICE WEIGHT (PRE-TEST) 182.7 Lbs (Ice + Basket + Film)

ICE WEIGHT (POST-TEST) 168.7 Lbs (Ice + Basket + Film)

RECEIVER VESSEL

PEAK TOP P.S.I. (P_5) 8.5 PSIG Serial No. 66702

PEAK BOTTOM P.S.I. (P_6) 8.5 PSIG Serial No. 66703

WEIGHT OF WATER (POST-TEST) 21.7 Lbs

MAX. TOP °F (T1) 36.3°F

MAX. MID. TOP °F (T2) 201.2°F

MAX. MIDDLE °F (T3) 208.4°F

MAX. MID. BOT. °F (T4) 208.4°F

MAX. BOTTOM °F (T5) 213.8°F

PREPARED BY: [signature] DATE 10/5/82

VERIFIED BY: [signature] QE DATE 10-5-82

DATA SHEET

TEST NO. 10

DATE 10-7-82

AUTOCLAVE

WEIGHT OF WATER IN AUTOCLAVES 10.0 Lbs

PRESSURE (P_7) 1200 PSIG Serial No. 51037

TEMPERATURE (Autoclave) 580°F (Piping)

BASKET

SHIELDING MATERIAL & THICKNESS Polyethylene (Non-Soluble) - 0.004"

SHIELDING MATERIAL CONFIGURATION Internal Liner

SHIELDING MATERIAL PRE-TEST WEIGHT ——

TARE WEIGHT 30.0 Lbs

ICE WEIGHT (PRE-TEST) 173.4 Lbs (Ice + Basket + Film)

ICE WEIGHT (POST-TEST) 164.7 Lbs (Ice + Basket + Film)

RECEIVER VESSEL

PEAK TOP P.S.I. (P_5) 11.6 PSIG Serial No. 66702

PEAK BOTTOM P.S.I. (P_6) 11.6 PSIG Serial No. 66703

WEIGHT OF WATER (POST-TEST) 17.3 Lbs

MAX. TOP °F (T1) 138.2°F

MAX. MID. TOP °F (T2) 213.8°F

MAX. MIDDLE °F (T3) 213.8°F

MAX. MID. BOT. °F (T4) 203.0°F

MAX. BOTTOM °F (T5) 203.0°F

PREPARED BY: David Kolo DATE 10-7-82

VERIFIED BY: E. J. Hanfee QE DATE 10-7-82

DATA SHEET

TEST NO. 11

DATE 10-8-82

AUTOCLAVE

WEIGHT OF WATER IN AUTOCLAVES 10.0 Lbs

PRESSURE (P_7) 1200 PSIG Serial No. 51037

TEMPERATURE (Autoclave) 580°F (Piping) 348°F

BASKET

SHIELDING MATERIAL & THICKNESS METHYL CELLULOSE - HEAVY APPLICATION

SHIELDING MATERIAL CONFIGURATION SPRAY COATED EXTERNAL

SHIELDING MATERIAL PRE-TEST WEIGHT ~1 QUART

TARE WEIGHT 30.0 Lbs

ICE WEIGHT (PRE-TEST) 185.7 Lbs (Ice + Basket + Film)

ICE WEIGHT (POST-TEST) 164.7 Lbs (Ice + Basket + Film)

RECEIVER VESSEL

PEAK TOP P.S.I. (P_5) 7.2 PSIG Serial No. 66702

PEAK BOTTOM P.S.I.(P_6) 7.2 PSIG Serial No. 66703

WEIGHT OF WATER (POST-TEST) 29.9 Lbs

MAX. TOP °F (T1) 35.6°F

MAX. MID. TOP °F (T2) 111.2°F

MAX. MIDDLE °F (T3) 183.2°F

MAX. MID. BOT. °F (T4) 190.4°F

MAX. BOTTOM °F (T5) 197.6°F

PREPARED BY: [signature] DATE 10/8/82

VERIFIED BY: [signature] QE DATE 10/8/82

DATA SHEET

TEST NO. 12

DATE 10-11-82

AUTOCLAVE

WEIGHT OF WATER IN AUTOCLAVES 10.0 Lbs

PRESSURE (P_7) 1200 PSIG Serial No. 51037

TEMPERATURE (Autoclave) 580°F (Piping) 338°F

BASKET

SHIELDING MATERIAL & THICKNESS POLYETHYLENE OXIDE — 0.0035"

SHIELDING MATERIAL CONFIGURATION EXTERNAL WRAPPER

SHIELDING MATERIAL PRE-TEST WEIGHT ——

TARE WEIGHT 29.7 Lbs

ICE WEIGHT (PRE-TEST) 186.4 Lbs (Ice + Basket + Film)

ICE WEIGHT (POST-TEST) 170.2 Lbs (Ice + Basket + Film)

RECEIVER VESSEL

PEAK TOP P.S.I. (P_5) 8.4 PSIG Serial No. 66702

PEAK BOTTOM P.S.I. (P_6) 8.4 PSIG Serial No. 66703

WEIGHT OF WATER (POST-TEST) 24.5 Lbs.

MAX. TOP °F (T1) 36.0°F

MAX. MID. TOP °F (T2) 180.0°F

MAX. MIDDLE °F (T3) 203.0°F

MAX. MID. BOT. °F (T4) 203.0°F

MAX. BOTTOM °F (T5) 208.4°F

PREPARED BY: [signature] DATE 10/11/82

VERIFIED BY: [signature] QE DATE 10/11/82

DATA SHEET

TEST NO. 13

DATE 10-12-82

AUTOCLAVE

WEIGHT OF WATER IN AUTOCLAVES 10.0 Lbs

PRESSURE (P_7) 1200 PSIG Serial No. 51037

TEMPERATURE (Autoclave) 581°F (Piping) 299°F

BASKET

SHIELDING MATERIAL & THICKNESS POLYETHYLENE OXIDE - 0.0035"

SHIELDING MATERIAL CONFIGURATION INTERNAL LINER

SHIELDING MATERIAL PRE-TEST WEIGHT 0.80 Lbs

TARE WEIGHT 30.0 Lbs

ICE WEIGHT (PRE-TEST) 170.1 Lbs (Ice + Basket + Film)

ICE WEIGHT (POST-TEST) 159.4 Lbs (Ice + Basket + Film)

RECEIVER VESSEL

PEAK TOP P.S.I. (P_5) 9.4 Serial No. 66702

PEAK BOTTOM P.S.I. (P_6) 9.4 Serial No. 66703

WEIGHT OF WATER (POST-TEST) 19.1 Lbs

MAX. TOP °F (T1) 57.7°F

MAX. MID. TOP °F (T2) 212.0°F

MAX. MIDDLE °F (T3) 210.0°F

MAX. MID. BOT. °F (T4) 212.0°F

MAX. BOTTOM °F (T5) 212.0°F

PREPARED BY: [signature] DATE 10/12/82

VERIFIED BY: [signature] QE DATE 10/12/82

DATA SHEET

TEST NO. 14

DATE 10-13-82

AUTOCLAVE

WEIGHT OF WATER IN AUTOCLAVES 10.0 Lbs

PRESSURE (P_7) 1200 PSIG Serial No. 51037

TEMPERATURE (Autoclave) 580°F (Piping) 352°F

BASKET

SHIELDING MATERIAL & THICKNESS METHYL CELLULOSE - 0.0021"

SHIELDING MATERIAL CONFIGURATION EXTERNAL WRAPPER

SHIELDING MATERIAL PRE-TEST WEIGHT ——

TARE WEIGHT 29.7 Lbs.

ICE WEIGHT (PRE-TEST) 183.2 Lbs (Ice + Basket + Film)

ICE WEIGHT (POST-TEST) 168.4 Lbs (Ice + Basket + Film)

RECEIVER VESSEL

PEAK TOP P.S.I. (P_5) 8.3 Serial No. 66702

PEAK BOTTOM P.S.I. (P_6) 8.3 Serial No. 66703

WEIGHT OF WATER (POST-TEST) 23.8 Lbs

MAX. TOP °F (T1) 32.0°F

MAX. MID. TOP °F (T2) 190.4°F

MAX. MIDDLE °F (T3) 210.0°F

MAX. MID. BOT. °F (T4) 212.0°F

MAX. BOTTOM °F (T5) 212.0°F

PREPARED BY: [signature] DATE 10/13/82

VERIFIED BY: [signature] QE DATE 10/13/82

DATA SHEET

TEST NO. 15

DATE 10-13-82

AUTOCLAVE

WEIGHT OF WATER IN AUTOCLAVES 10.0 Lbs

PRESSURE (P_7) 1200 PSIG Serial No. 51037

TEMPERATURE (Autoclave) 581°F (Piping) 362°F

BASKET

SHIELDING MATERIAL & THICKNESS POLYETHYLENE OXIDE 0.002"

SHIELDING MATERIAL CONFIGURATION EXTERNAL WRAPPER

SHIELDING MATERIAL PRE-TEST WEIGHT ——

TARE WEIGHT 30.0 Lbs

ICE WEIGHT (PRE-TEST) 182.1 Lbs (Ice + Basket + Film)

ICE WEIGHT (POST-TEST) 163.2 Lbs (Ice + Basket + Film)

RECEIVER VESSEL

PEAK TOP P.S.I. (P_5) 7.5 PSIG Serial No. 66702

PEAK BOTTOM P.S.I. (P_6) 7.5 PSIG Serial No. 66703

WEIGHT OF WATER (POST-TEST) 27.4 Lbs

MAX. TOP °F (T1) 44.6°F

MAX. MID. TOP °F (T2) 122.0°F

MAX. MIDDLE °F (T3) 204.8°F

MAX. MID. BOT. °F (T4) 206.6°F

MAX. BOTTOM °F (T5) 207.5°F

PREPARED BY: [signature] DATE 10/13/82

VERIFIED BY: [signature] QE DATE 10/13/82

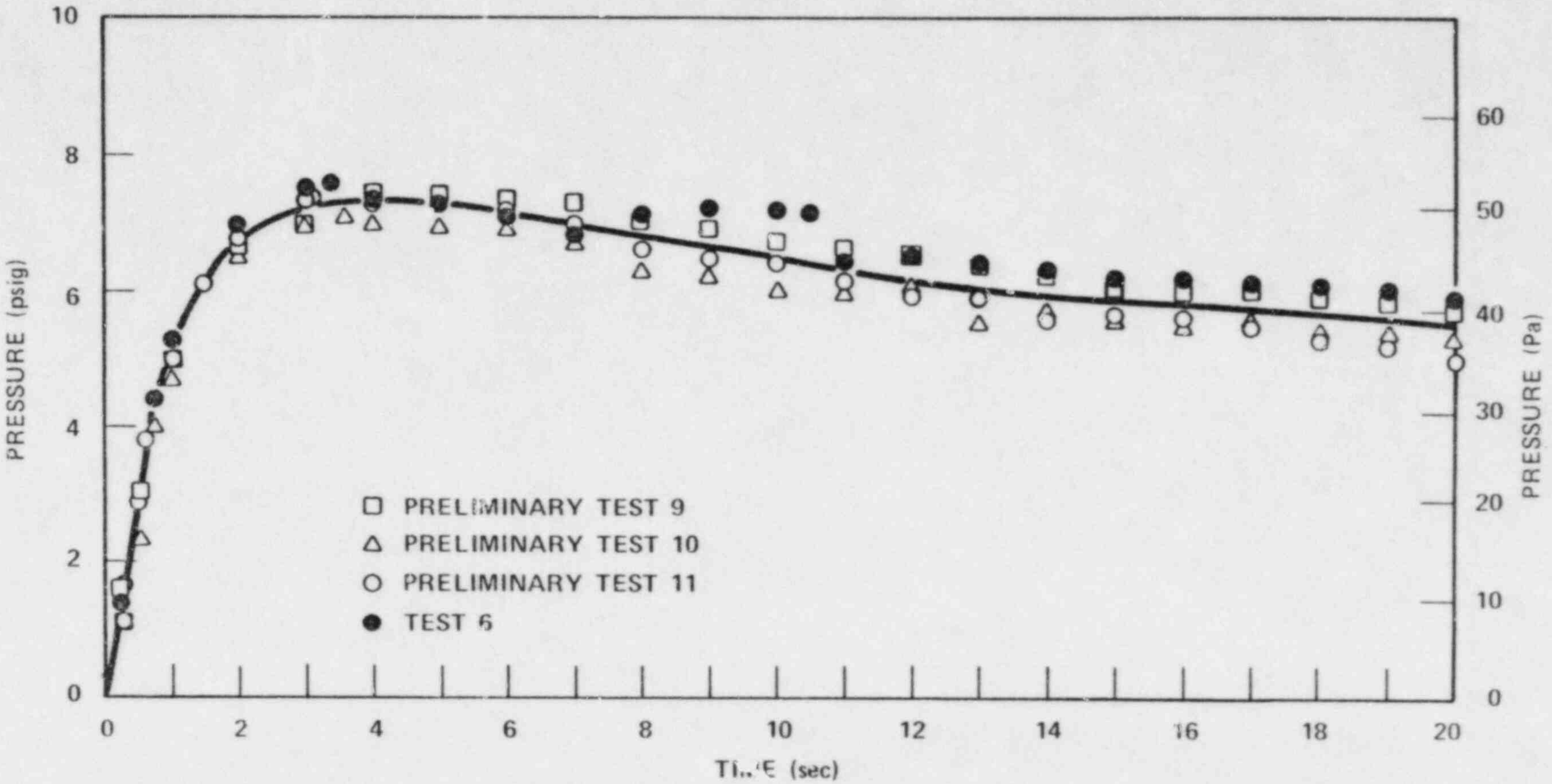


Figure B-1. Reference Tests Pressure Transient Comparison (Unshielded Ice Basket)

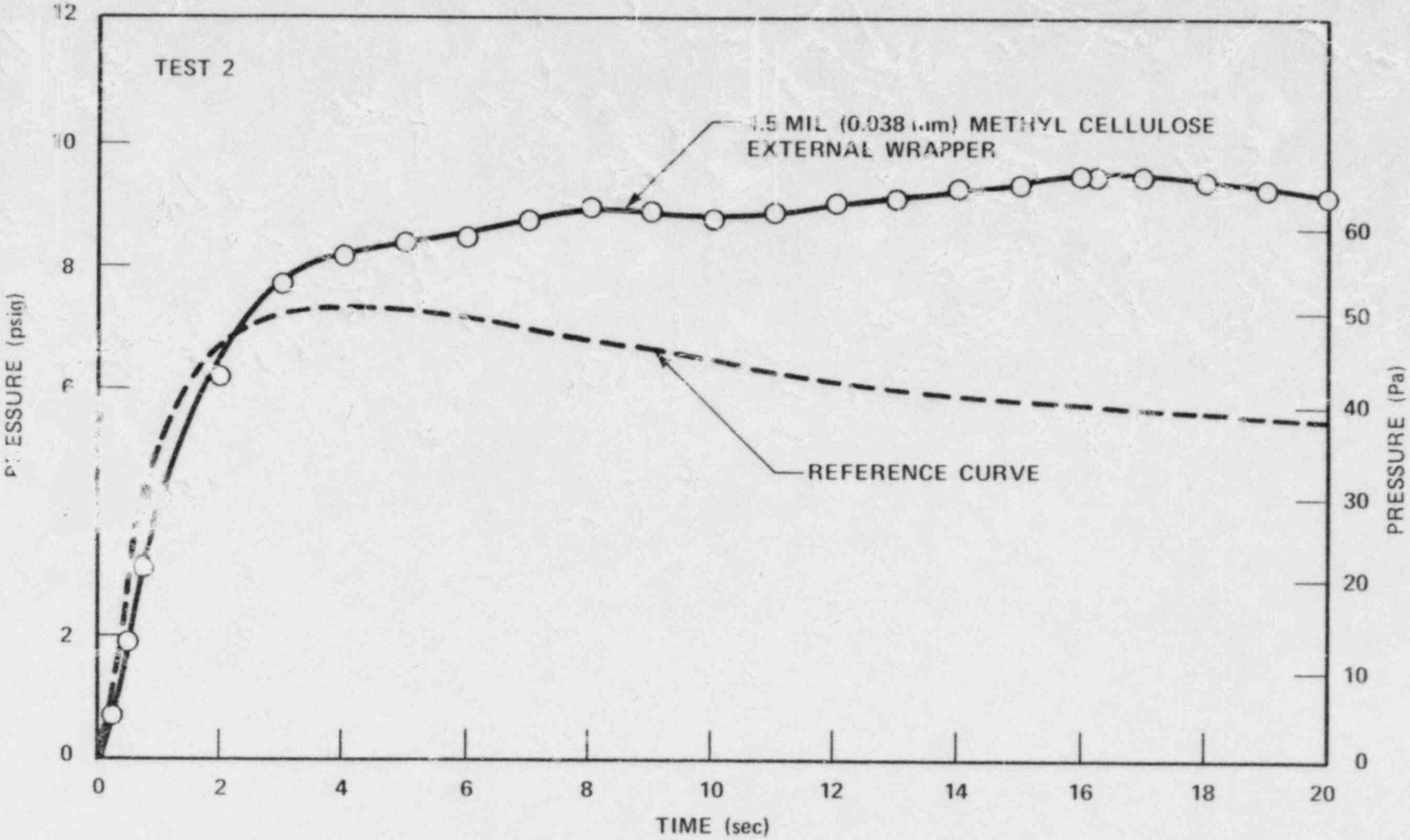


Figure B-2. Pressure Transient Comparison -- 1.5-mil (0.038 mm) External Methyl Cellulose Shielded Versus Unshielded Ice Basket

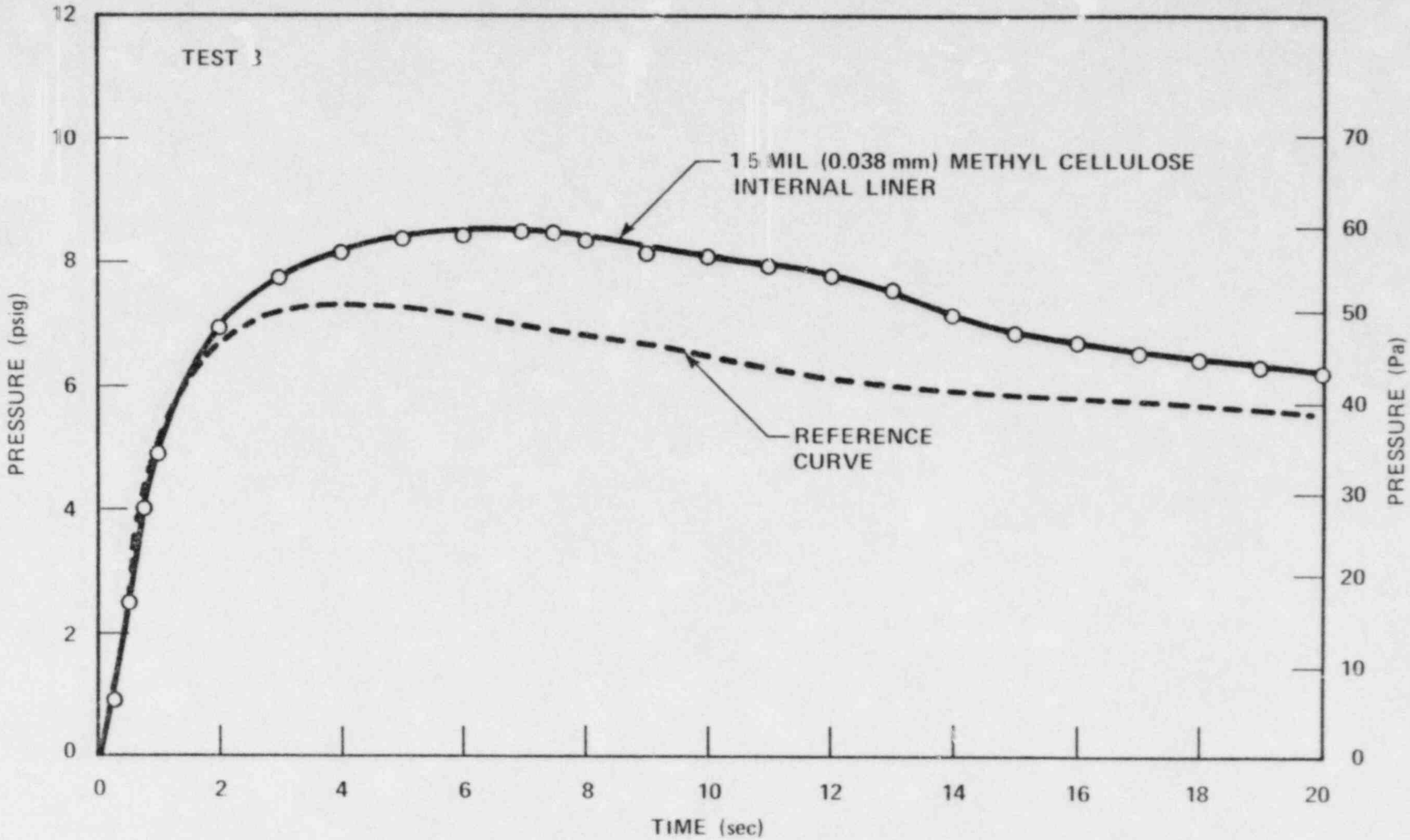


Figure B-3. Pressure Transient Comparison -- 1.5-mil (0.038 mm) Internal Methyl Cellulose Shielded Versus Unshielded Ice Basket

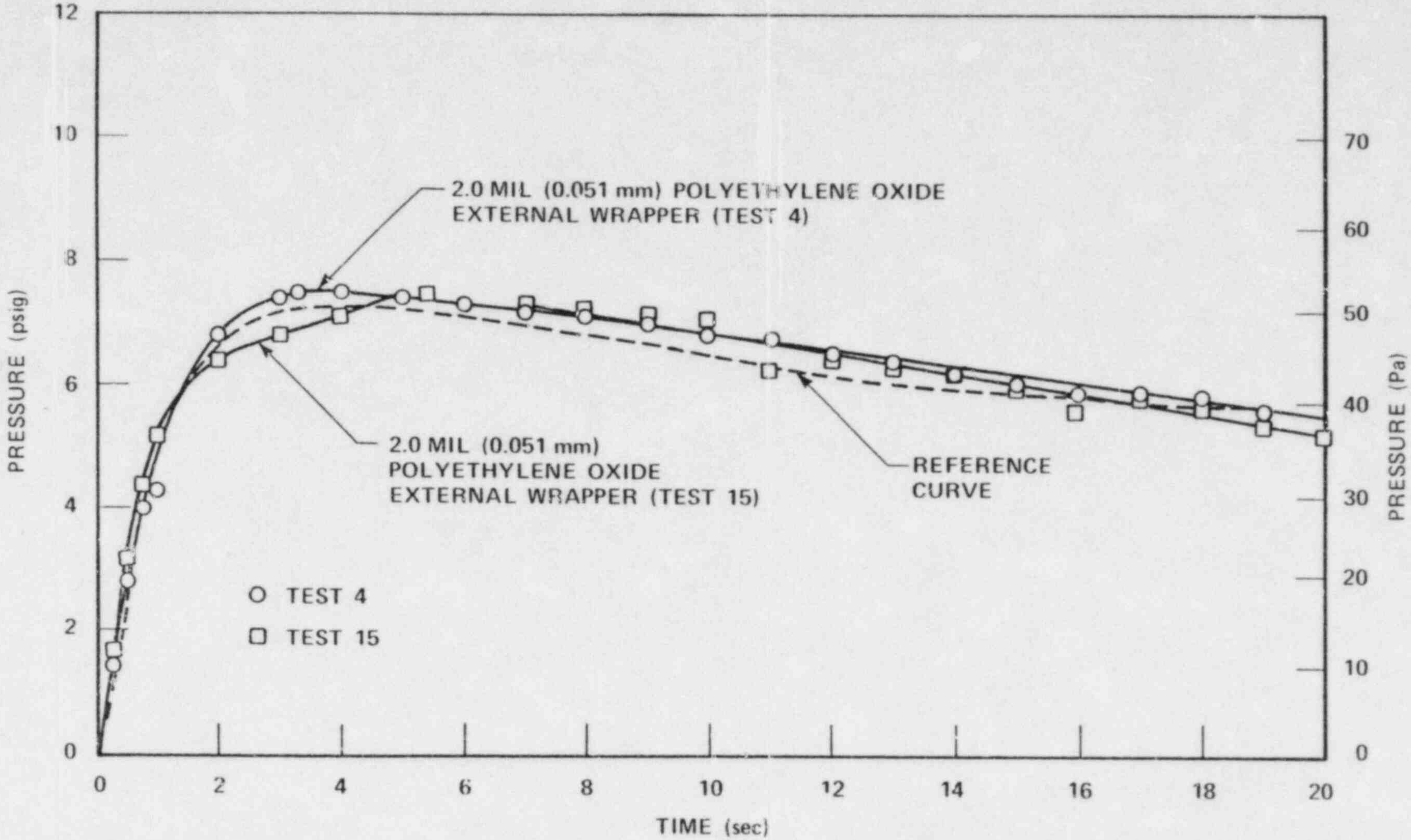


Figure B-4. Pressure Transient Comparison -- 2-mil (0.051 mm) External Polyethylene Oxide Shielded Versus Unshielded Ice Basket

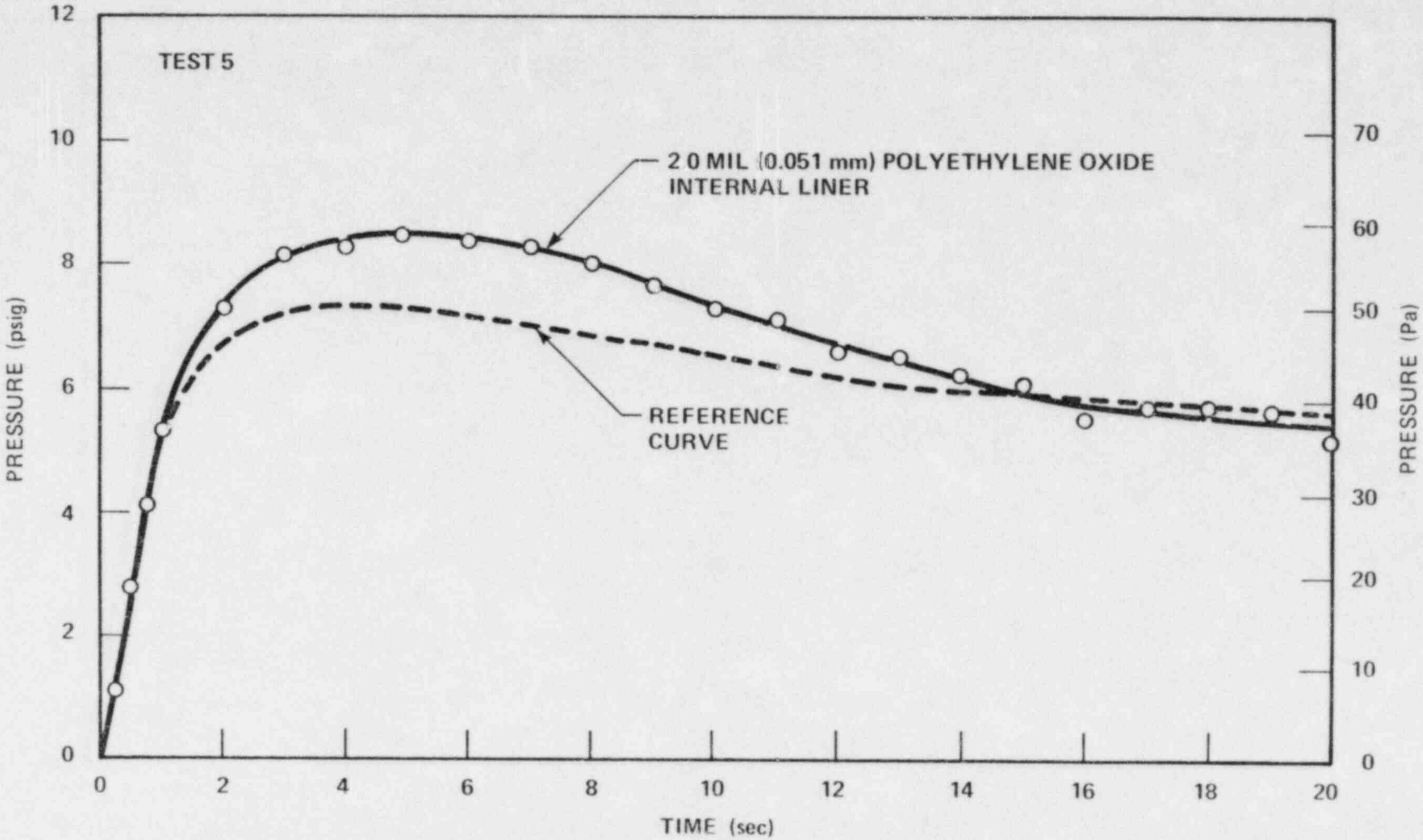


Figure B-5. Pressure Transient Comparison -- 2-mil (0.051 mm) Internal Polyethylene Oxide Shielded Versus Unshielded Ice Basket

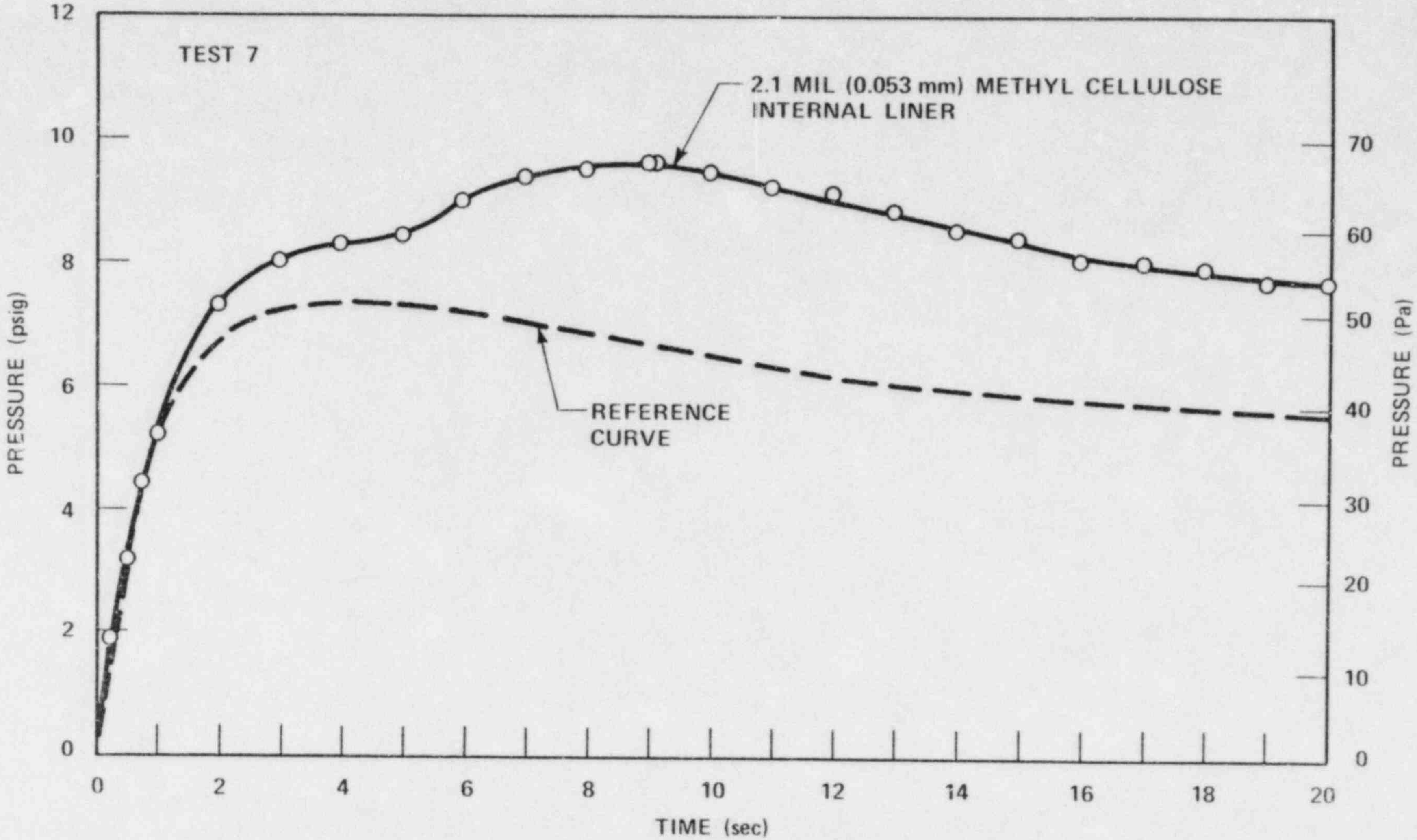


Figure B-6. Pressure Transient Comparison -- 2.1-mil (0.053 mm) Internal Methyl Cellulose Shielded Versus Unshielded Ice Basket

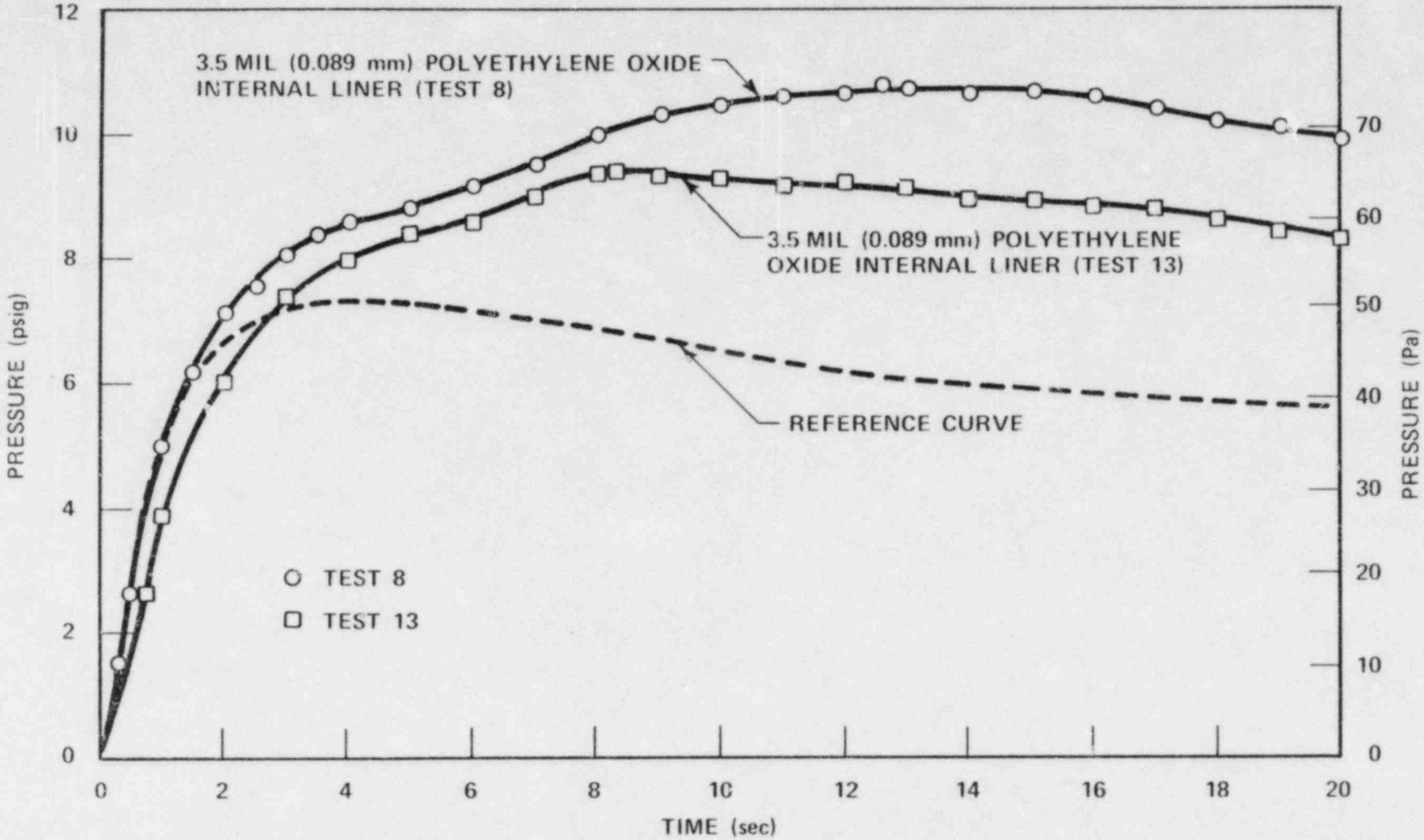


Figure B-7. Pressure Transient Comparison -- 3.5-mil (0.089 mm) Internal Polyethylene Oxide Shielded Versus Unshielded Ice Basket

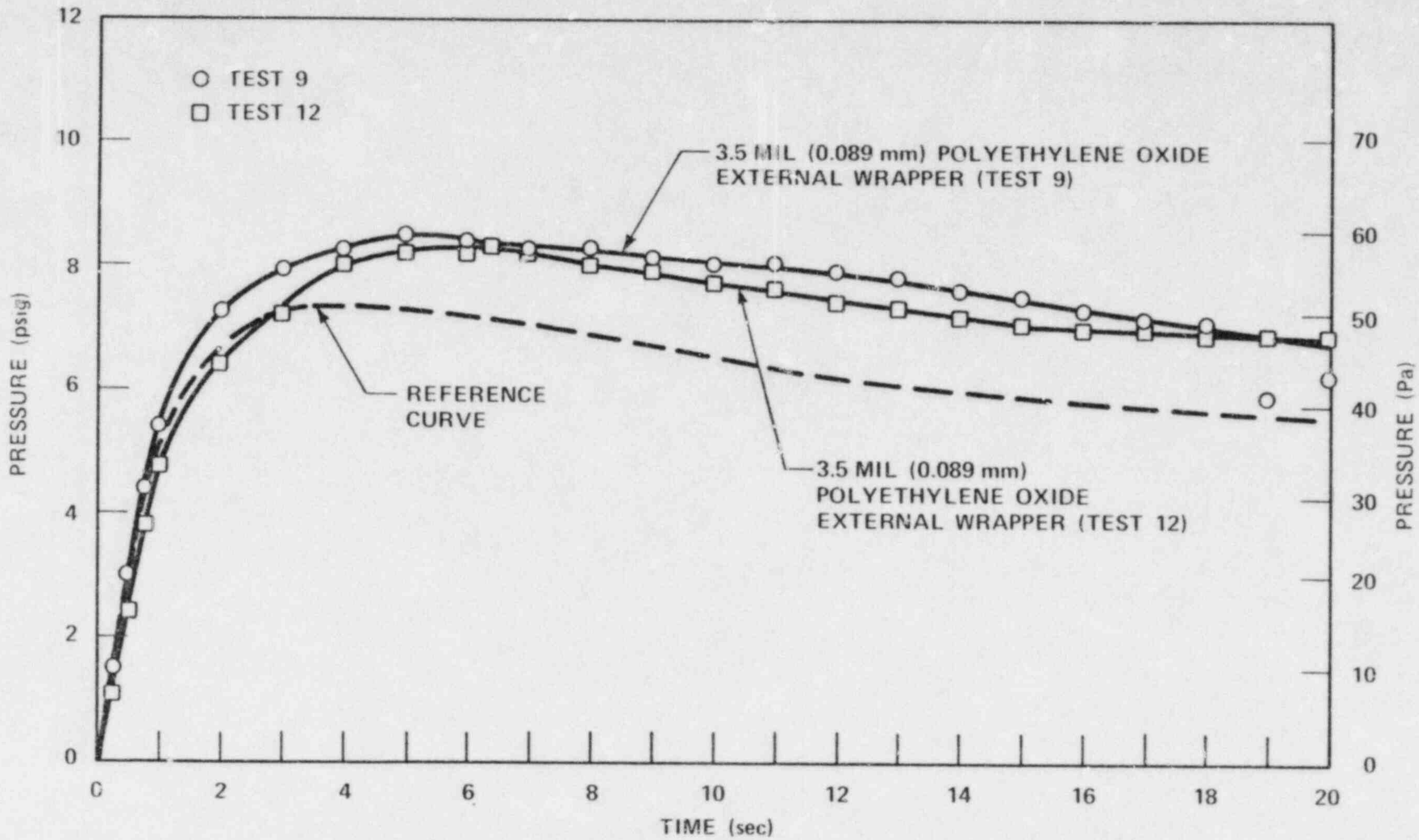


Figure B-8. Pressure Transient Comparison -- 3.5-mil (0.089 mm) External Polyethylene Oxide Shielded Versus Unshielded Ice Basket

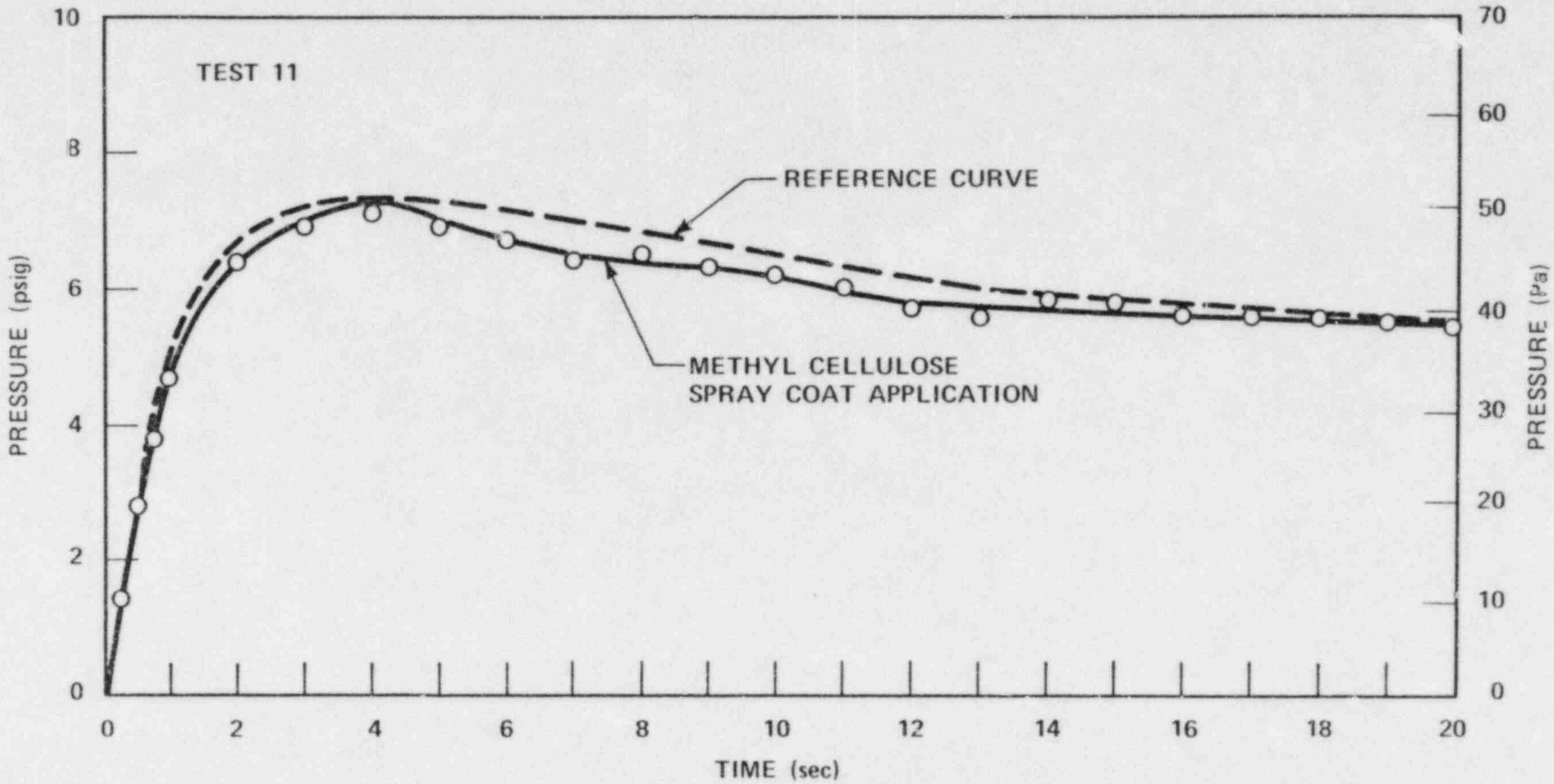


Figure B-9. Pressure Transient Comparison -- Methyl Cellulose Spray Coated Versus Unshielded Ice Basket

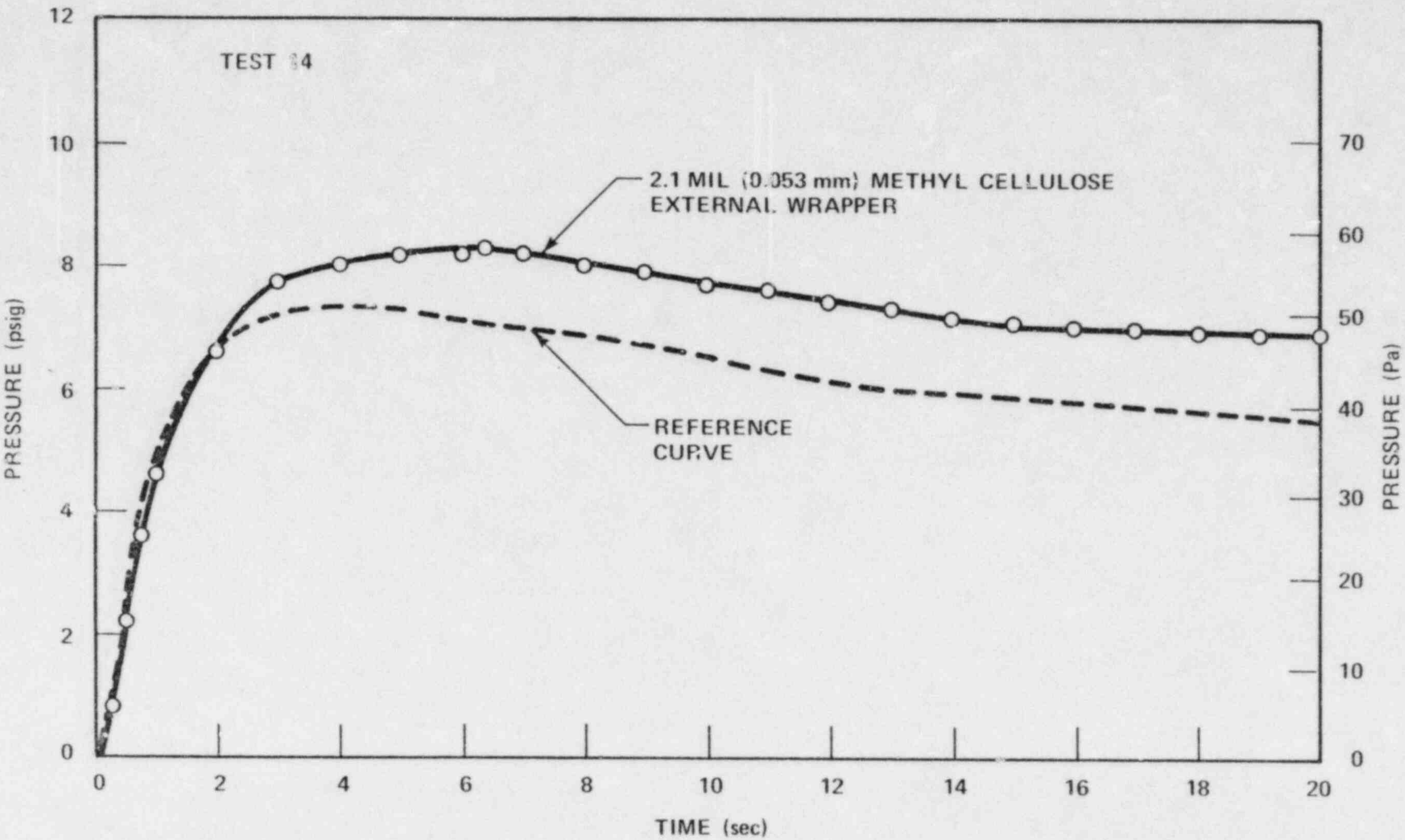


Figure B-10. Pressure Transient Comparison -- 2.1-mil (0.053 mm) External Methyl Cellulose Shielded Versus Unshielded Ice Basket

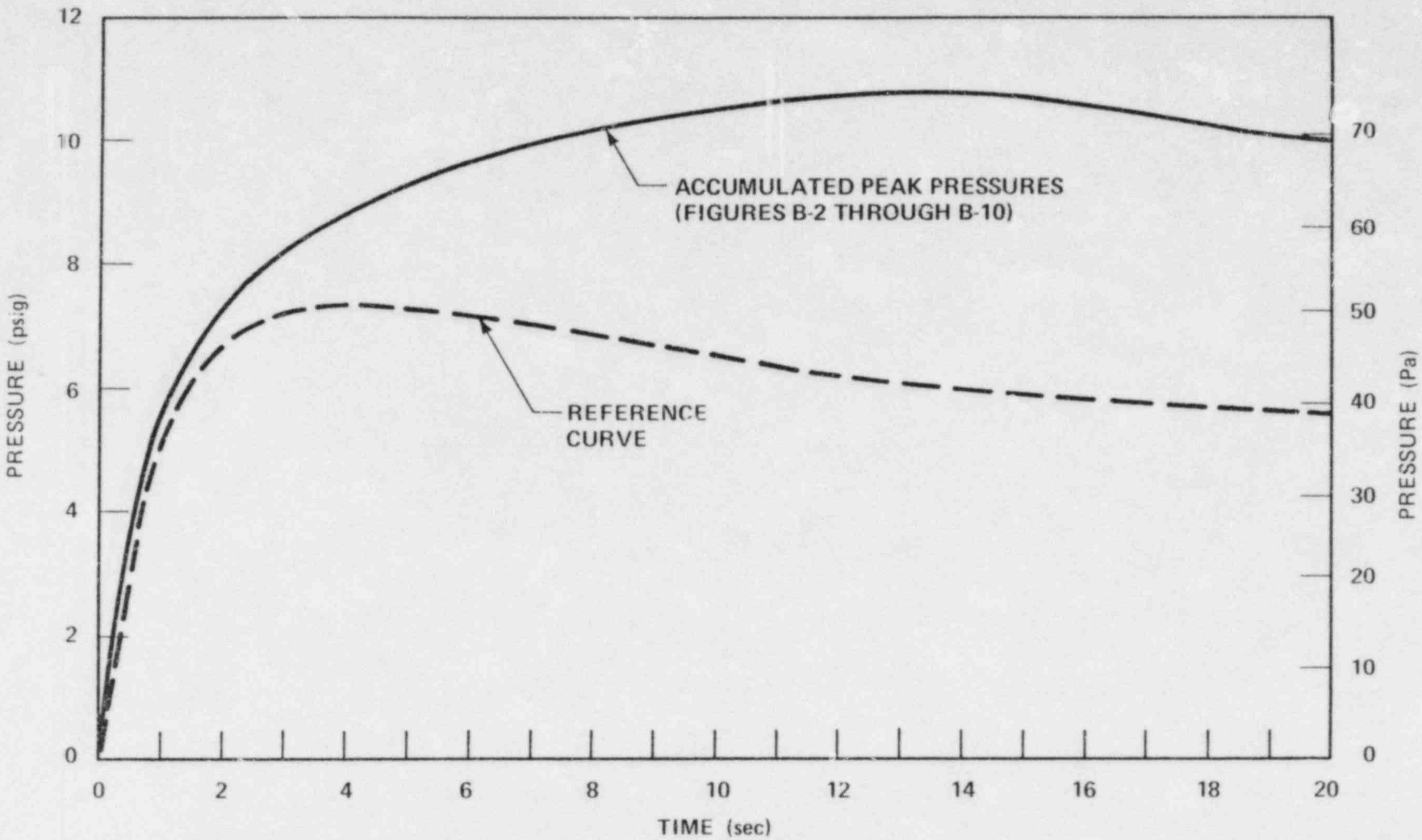


Figure B-11. Pressure Transient Comparison Summary

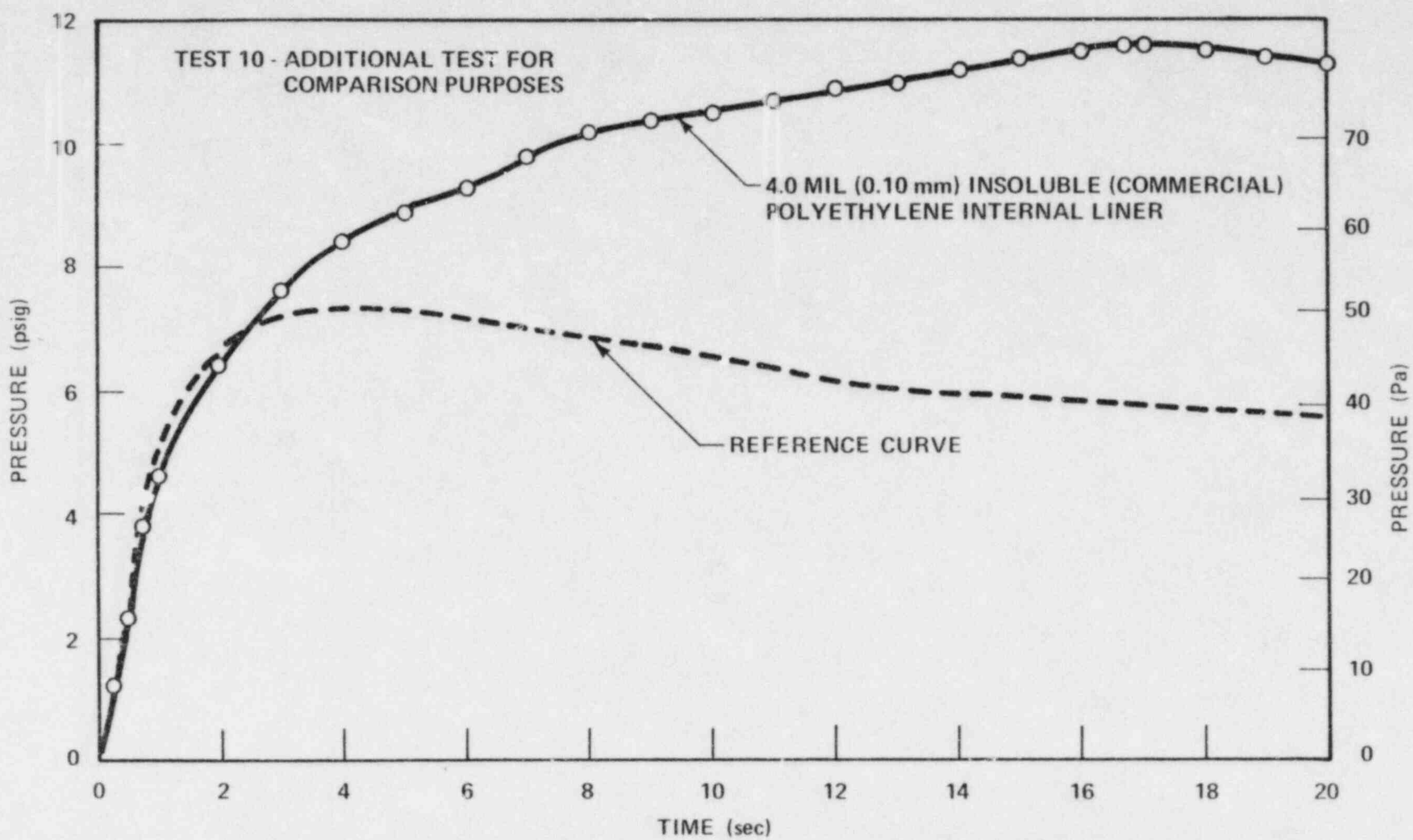


Figure B-12. Pressure Transient Comparison -- 4.0-mil (0.10 mm)
Internal Polyethylene Shielded Versus Unshielded Ice Basket

Table B-3

SAMPLE ANALYTICAL DATA

	Unirradiated Samples						Irradiated Samples[a]	
	At Room Temperature		At 180°F (82°C)		At 200°F (93°C)			
Sample	Chloride (ppm)	Dissolve Time (min)	Chloride (ppm)	Dissolve Time (min)	Chloride (ppm)	Dissolve Time (min)	Chloride (ppm)	Solids[b] (%)
QUIK-SOL P polyethylene oxide, 1.5 mils (0.038 mm)	350	>15	400	>15	500	>15	400	0.022
EDISOL M methyl cellulose, 2.1 mils (0.053 mm)	1000	<15	800	<15	1100	<15	1200	0.029
QUIK-SOL P polyethylene oxide, 2.5 mils (0.064 mm)	700	>15	400	>15	650	>15	600	0.057
QUIK-SOL P polyethylene oxide, 3.5 mils (0.089 mm)	450	>15	500	>15	600	>15	600	0.056
Methyl cellulose aged for 10 years	1000	<15	500	<15	700	>15	900	0.045

[a] 10^6 rads

[b] From centrifuge

Table B-4

RESIDUE AND CHLORIDE CONTENT FROM BASKET TEST

Sample	Test Date	Weight of Residue (g)	Solids Residue (%)	Chloride in Dried Residue (ppm)	Total Chloride in Residue (ppm)
Polyethylene oxide	10/5/82	0.5938	0.22	157	645
Polyethylene oxide	10/5/82	0.1886	0.08	789	2500
Polyethylene oxide (from stirred drain water sample)	10/5/82	1.3586	0.63	174	431
Polyethylene oxide (from stirred drain water sample)	10/5/82	0.2830	0.11	166	552

Attachment 3

Effect of Water Soluble Plastic Wrap
on the Short-Term Containment Analysis
for the Catawba Nuclear Station

In an ice condenser containment, one operational problem that exists is the sublimation of ice in the ice baskets. Due to the high heat load on the row of ice baskets nearest to the crane wall, this row of baskets experiences sublimation rates of about 5% a year. One method to eliminate this problem would be to wrap the ice with a soluble plastic film.

One effect of this plastic film is that the ice condenser performance for the first few seconds following a high energy line break will change. Thus, the short-term subcompartment pressure analysis will be affected. This study was done to determine the effect of wrapping one third of the ice condenser with a water soluble plastic.

In a review of the short-term subcompartment analysis for Catawba Units 1 and 2, it was determined that a Double-Ended Cold Leg (DECL) break in compartment 1 was the worst case. The design criterion for this analysis is that the peak pressure against the containment shell cannot exceed the design pressure of 15 psig.

Three sensitivity studies were done to bound the effect of the plastic wrap on the peak pressure against the containment shell. The first sensitivity study assumed that there was no heat transfer from those ice baskets which were wrapped. Thus, the effective heat transfer area was reduced by one third. The TMD computer code, which was used in the original FSAR analysis, was used with the only change from the FSAR case being the reduced heat transfer area. A comparison plot of pressure versus time for a compartment located against the containment shell is shown in Figure 1. This figure shows that the reduced heat transfer causes the peak pressure to rise about 1 psi and that the pressure remains below design.

The second sensitivity study was to determine the effect of increasing the empirical coefficient, ELJAC. This parameter is a pseudo-condensing length resistance. The resistance through the wrapped ice condenser section is assumed to be infinite. Therefore, the value of ELJAC will be increased by 1.5. Figure 2 shows the pressure transient against the containment shell for this revised ELJAC. This figure shows that the peak pressure is 28 psia which is below the design pressure.

The third sensitivity study was just a combination of the first two sensitivity studies. This had to be done since the ELJAC parameter was determined empirically and may be a function of the heat transfer. Therefore, this case should be the most appropriate case. Figure 3 shows a comparison of the pressure transient for this case to the pressure transient of the FSAR case. The results show that the peak pressure is still below design pressure.

Therefore, since all of the sensitivities showed a peak pressure below the design pressure, the idea of wrapping one third of the ice condenser with a soluble plastic wrap does not present a problem with any containment design pressure criteria. This analysis will allow the wrapping of any three of the nine rows in the ice condenser.

Figure 1. Reduced Heat Transfer Area Pressure Transient

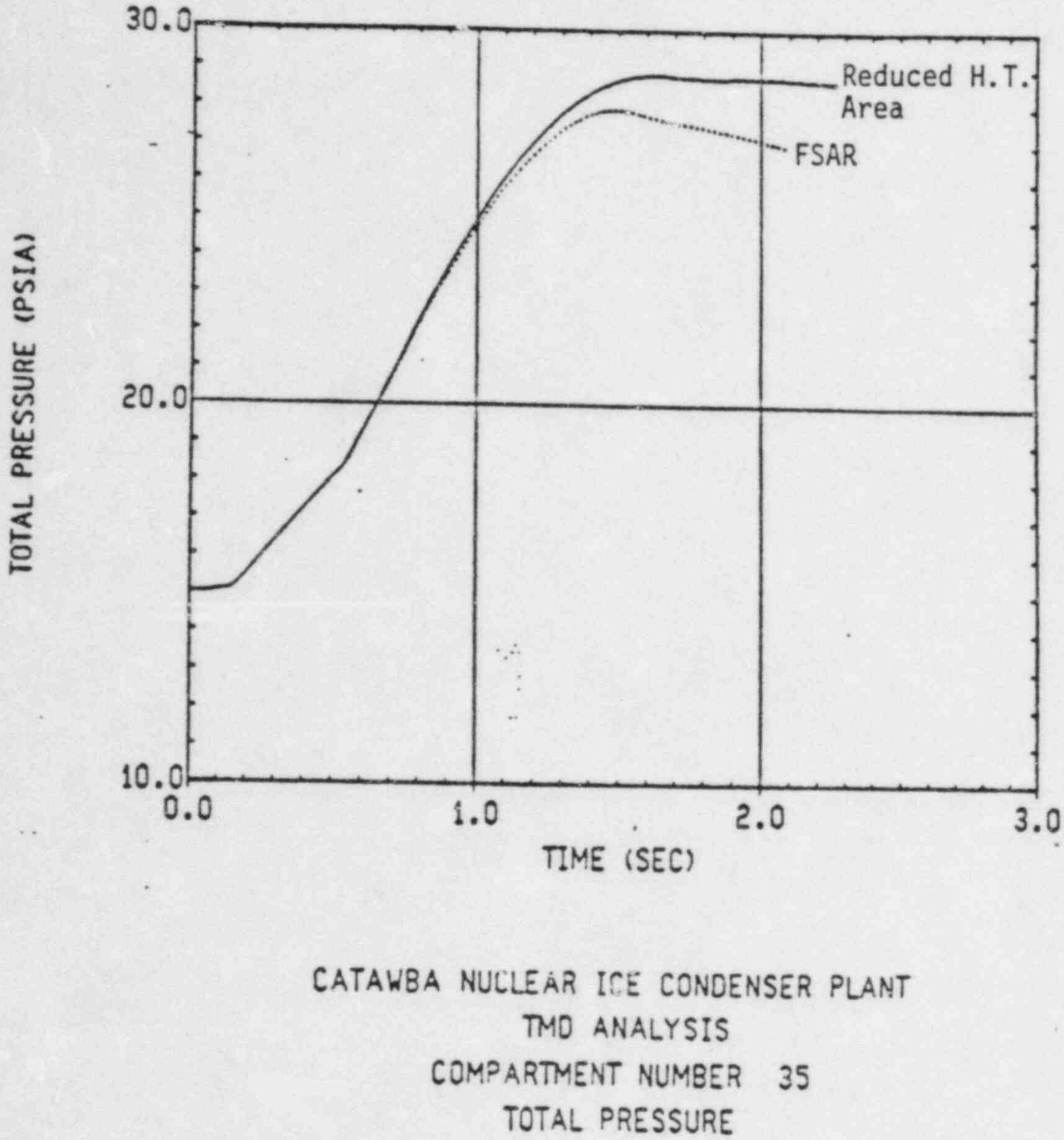
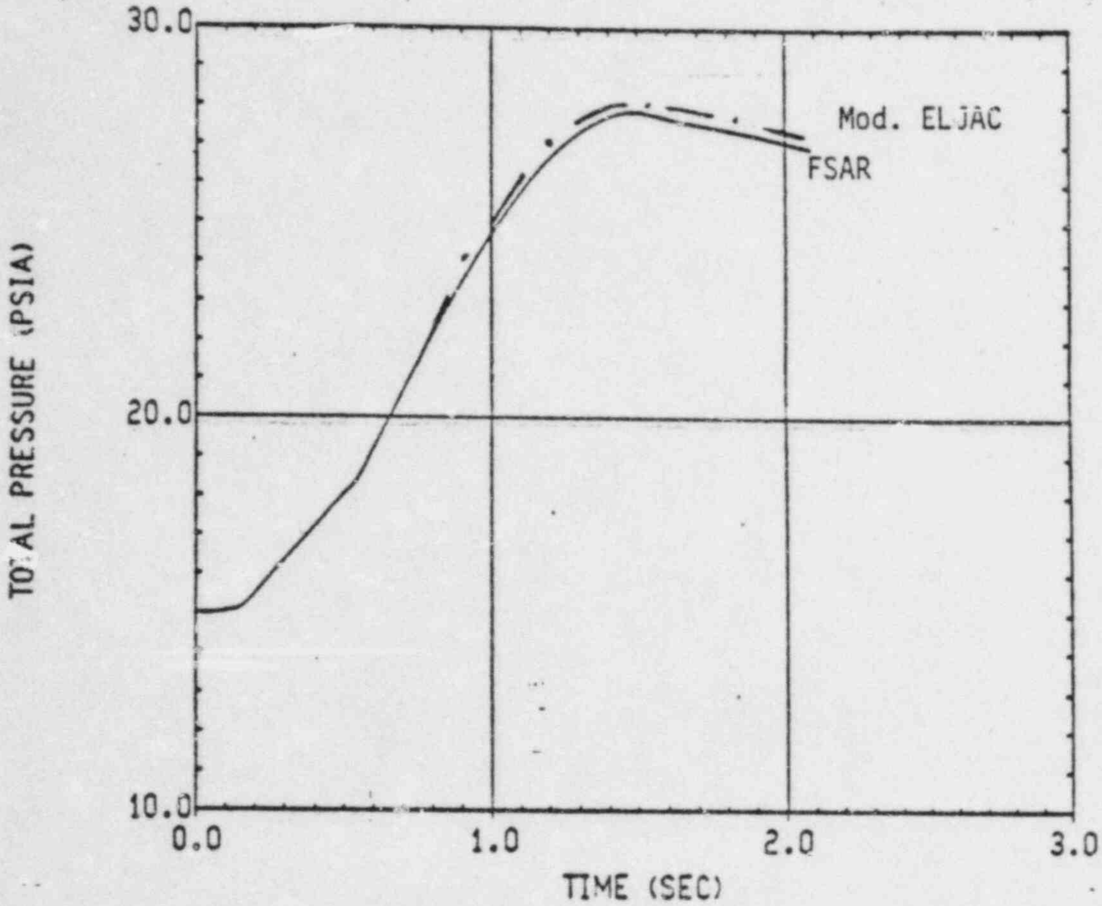
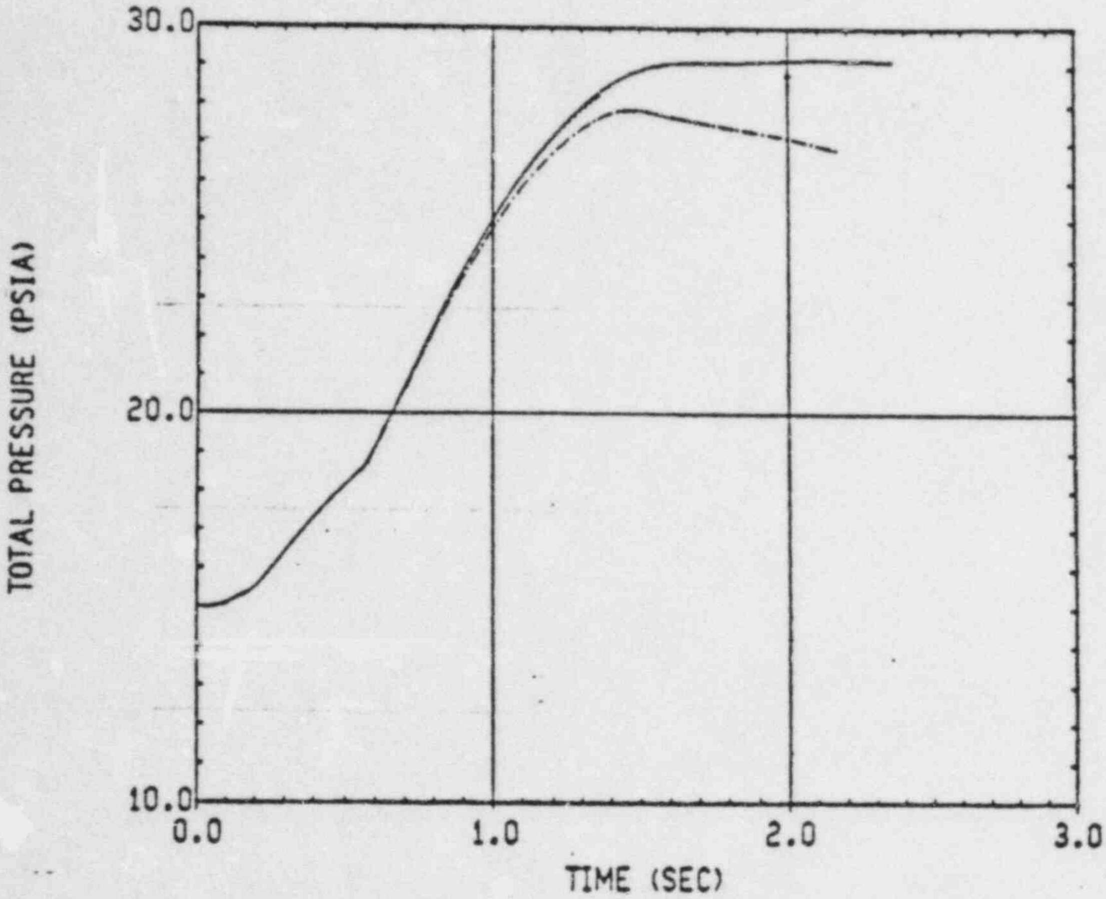


Figure 2. Modified ELJAC Pressure Transient



CATAWBA NUCLEAR ICE CONDENSER PLANT
TMD ANALYSIS
COMPARTMENT NUMBER 35
TOTAL PRESSURE

Figure 3. Combined Sensitivity Study



CATAWBA NUCLEAR ICE CONDENSER PLANT
TMD ANALYSIS
COMPARTMENT NUMBER 35
TOTAL PRESSURE

ATTACHMENT 4

DUKE-6412
CATAWBA-3540

Westinghouse Electric Corporation
Water Reactor Divisions
Nuclear Operations Division
Box 355
Pittsburgh Pennsylvania 15230

January 30, 1984

PWO No. 5

MPS #4100/#35924

S.O. No: DCP-902

Ref: CATAWBA-3512, 1/18/84

Mr. S. K. Blackley, Jr.
Chief Engineer
Mechanical and Nuclear Division
Duke Power Company
P.O. Box 33189
Charlotte, North Carolina 28242

Attn: D. L. Canup

CATAWBA/McGUIRE NUCLEAR STATION
UNITS NUMBER 1 AND 2
Ice Condenser Sublimation Shielding Spray Test Report

Dear Mr. Blackley:

Attached is a final test report entitled, "Water Soluble Sublimation Shielding Material Effects on Containment Spray Systems", January 1984. This effort was completed under contract to Duke Power and reports on the tests conducted for determining the acceptability of the coating material for the Ice Condenser Containment ice. As a result of these tests methyl cellulose is shown to be an acceptable coating material. Recommendations are made in the report for implementation of an anti-foaming material into the containment spray system.

At this time we are enclosing only one copy. Upon availability from reproduction, additional copies will be transmitted to you. A previous draft copy (January 13, 1984) was forwarded to Robert Sharpe to initiate the Duke Power NRC submittal preparation. This submittal to you and the report given in the referenced letter, regarding the containment pressure effects of the sublimation shielding, should allow your completion of a report to the NRC for implementing coating of the remaining three rows of ice baskets on Catawba Unit 1.

Please direct any questions on the attached report to Chuck Scrabis 412-374-5578 or this office.

Very truly yours,

WESTINGHOUSE ELECTRIC CORPORATION

J.C. Ratsep for

F. J. Twogood, Manager
Duke Power Projects

ICR/cm/5811D:1

Attachment

cc: H. Purcell, 1L
S. K. Blackley, Jr. 6L, 1A
E. D. Lindsay, 1L 1A
G. W. Hallman, 1L
R. O. Sharpe, 1L 1A
D. L. Canup, 1L 1A

3A

TEST REPORT: WATER SOLUBLE SUBLIMATION SHIELDING MATERIAL EFFECTS ON CONTAINMENT SPRAY SYSTEMS

Reference: Duke Power Company General Order I.D. CH-14695

Prepared by: C. M. Scrabis 1/25/84

C. M. Scrabis, Engineer
Process & Thermal Equipment Engineering

Reviewed by: P. A. Linn 1/25/84

P. A. Linn, Engineer
Operations Safeguards Analysis

K. A. Kloes 1-25-84

K. A. Kloes, Engineer
Process & Thermal Equipment Engineering

T. J. Gerlowski 1-25-84

T. J. Gerlowski, Engineer
Fluid Systems Design

B. R. Sinwell 1/26/84

B. R. Sinwell, Engineer
Test Engineering

J. J. Flaherty 1/26/84

J. J. Flaherty, Engineer
Q. A. Test Engineering

Approved by: D. W. Alexander 1/26/84

D. W. Alexander, Manager
Process & Thermal Equipment Engineering

C. E. Conway 1/26/84

C. E. Conway, Manager
Test Engineering

CONTENTS

Section 1

INTRODUCTION

All operating Ice Condenser Nuclear Power Plants are experiencing a common heat and mass transfer process called the ice sublimation. A 2.5×10^6 lb. ice inventory, which is stored in 1944 cylindrical perforated sheet metal ice baskets one (1) foot in diameter and 48 feet high, is continuously being depleted. The main mechanisms causing this sublimation are the formation of convective air currents from heat conduction through the ice bed boundaries causing ice to redistribute as frost onto cooled surfaces, and leakage of the saturated ice bed air through the lower inlet doors, which is replaced by dry air from the upper plenum area.

One method of eliminating the ice sublimation problem is to seal the ice in a vapor barrier medium, such as plastic film. This has a significant drawback, however, in that the film will reduce the rate of heat transfer from the steam to the ice in the unlikely event that a LOCA occurs.

A water soluble plastic film material minimizes the heat transfer effect. This concept has been investigated and proven feasible under a test program sponsored by EPRI in 1982. An unanswered question from that test program was the unknown effects of the dissolved sublimation shielding material, which will be washed down into the containment sump, on the spray nozzles in the containment spray system. These nozzles were selected for study since they are the limiting diameter in the Energency Core Cooling System (ECCS).

It was postulated that if the sublimation shielding material could come out of solution or if any resulting residue were circulated through the containment spray system, the potential may exist for the material to plug the spray nozzles or to reduce the effectiveness of the system for long term heat decay removal. The purpose of the test program described in this report is to determine what possible effects might occur to the containment spray system when a chemical water solution with sublimation shielding material is circulated through it.

Section 2

TEST PLAN DEVELOPMENT

MATERIAL IDENTIFICATION

Methyl Cellulose and Polyethylene Oxide were tested as sublimation shielding materials in the EPRI sponsored Steam Blowdown Test Program. Only the methyl cellulose material was used in this spray nozzle test program. Polyethylene oxide was eliminated for several reasons. The EPRI test program had shown that polyethylene oxide would not totally dissolve in water, but would leave a residue of relatively large sticky particles as compared to methyl cellulose. Subsequent information research showed that polyethylene oxide film can become insoluble if stressed by heat, radiation, or mechanical working. In addition, the supplier of these sublimation shielding materials (Polymer Films Inc.) advised that methyl cellulose has become the industry standard for water soluble plastic flims. No polyethylene oxide film material has been made by that company for nearly a year, and because of the lack in demand, no plans are being made to produce it in the near future. Investigation into other sources and users of these types of materials has revealed that no existing stocks of polyethylene oxide film material are available for procurement.

TEST MATRIX DEVELOPMENT

Spray nozzle tests were performed per the requirements of the Test Plan "Ice Condenser/Containment Spray Systems, Water Soluble Plastic Effects on Spray Systems," which is furnished as Appendix B of this report. The first test run was to establish the operational performance of the test loop and data acquisition systems. It consisted of operating the test loop for approximately 4 hours, without chemical additives or methyl cellulose material, and at whatever equilibrium temperature the system established without auxiliary heaters.

Nine (9) subsequent spray tests were conducted using 2.1 lbs. of methyl cellulose material per each 1000 lbs. of system chemical water solution. The chemical water contained 2200 ppm boron as boric acid, and/or sodium

tetraborate at temperatures of 100°F, 145°F, and 190°F. Each test was run continuously for 24 hours after reaching the required temperature and boron and methyl cellulose concentrations. The following identifies the test matrix used for this test program.

Test No.	Boron Source	Water Temp.	Time Duration
40000	N/A	Ambient	4 hrs.
40001	Boric Acid	100°F	24 hrs.
40002	"	145°F	24 hrs.
40003	"	190°F	24 hrs.
40004	Sodium Tetraborate	100°F	24 hrs.
40005	"	145°F	24 hrs.
40006	"	190°F	24 hrs.
40007	50/50 Boric Acid-Sodium Tetraborate	100°F	24 hrs.
40008	"	145°F	24 hrs.
40010	"	190°F	24 hrs.

Section 3

SPRAY SYSTEM TESTING

FACILITY PREPARATION

The test loop for this program was a closed system including a header assembly of four (4) 1-inch containment spray nozzles arranged to discharge into an open 4' x 8' x 2' stainless steel tank. A centrifugal pump drew water from the spray header tank, discharging it though a 34 KW electric heat exchanger and into the spray nozzle header assembly. A clear plexiglass hood assembly was fashioned over the header assembly and tank to reduce spray and evaporation losses. An auxiliary electric heater submerged in the spray tank furnished additional heat as required for the 190°F temperature tests.

A calibrated orifice meter with ΔP cells was installed upstream of the spray nozzle header assembly to measure the total flow to the nozzles. A separate pressure transducer between the orifice meter and spray nozzle header measured the system pressure.

Thermocouples were installed in the inlet and outlet piping across the electric heat exchanger and upstream of the spray nozzle header. Temperature control was maintained via one of the thermocouples upstream of the header. Flow control was maintained on the pressure drop across the spray nozzle header.

Sketch #BRS082983C in Appendix A is a schematic flow diagram of the spray nozzle test system.

TESTING

The testing procedures followed are described in Section VII, titled "TEST PROCEDURE," of Test Plan: Ice Condenser/Containment Spray Systems, Water Soluble Plastic Effects on Spray Systems, which is enclosed in this report as Appendix B.

The test system operating temperatures correspond to the minimum and maximum containment spray system operating temperatures of 100°F and 190°F, respectively. The additional test temperature of 145°F was arbitrarily chosen as a midpoint temperature of that range. Each test was run continuously for 24 hours in conjunction with the requirement that the containment spray system is capable of continuous operation for 24 hours after initiation of a LOCA.

The test system water chemistry, in regards to boron concentration and pH level, enveloped the expected conditions that the containment spray system will see during operation. The boron concentration should not fall below 2000 ppm, and by the addition of boron as strictly boric acid or sodium tetraborate, and as a 50/50 mix of the two chemicals, the extreme cases of an acidic or basic, and as a neutral chemical solution are examined.

Section 4

DATA EVALUATION

SPRAY DISTRIBUTION PATTERN RESULTS

The initial test run (ref. test series #40000) established the spray distribution pattern of each nozzle prior to testing with sublimation shielding material. The spray pattern was measured by collecting the sprayed water in two sets of collecting tubes. The collection tubes were laid out to collect water in a quadrant under each spray nozzle. The layout of the collection tube header system is shown on sketch BRS100783 enclosed in Appendix A.

Spray distribution data was collected after each test run to compare with the data taken in the initial test run. This data is furnished in Appendix A as part of the data sheets identified as "NOZZLE SPRAY TEST," for test series numbers 40001 through 40010. Note that test series 40009 was suspended due to excessive evaporation of the test of system fluid media, and that this test was repeated and is referenced as test series 40010. No test data is furnished for series 40009.

The variations in nozzle spray pattern distributions are acceptable and are considered to be the result of the temperature differences for each test run as compared to the initial test reference conditions, and to variations in the total system flow rates.

FOAM PHENOMENON

Introduction of the methyl cellulose material into the test system water produced a foaming action when the fluid was aerated by the spray nozzles. To reduce foaming, an antifoaming agent was gradually added to the chemical water solution until the foaming action was reduced to an acceptable level. At this point, the foam would quickly dissipate and only a light surface covering remained. The light surface covering would entirely dissappear in a few minutes after termination of the spraying.

Without the antifoaming agent, foaming was heaviest when the spray nozzles discharged into a piping cover which extended over each nozzle and down below the water level in the spray tank. These covers were installed to reduce splash and misting effects. When the piping covers were removed, and with no antifoaming agent added, the spray from the nozzles tended to beat down the foam bubbles in the spray tank.

The antifoaming agent used was Dow Corning DC-1520 silicone emulsion. The Westinghouse Chemistry Department performed a chemical evaluation of the DC-1520 material and has found it acceptable for use in the containment building. The chemistry evaluation report and a spec sheet on DC-1520 are included in Appendix A.

POST-TEST EXAMINATION

All the test spray nozzles were removed from the test loop after each test run, visually examined by engineering and quality assurance, and reinstalled into the test loop. No cleaning or other operations were performed on the spray nozzles throughout the entire test program. Each of the 4 spray nozzles was subjected to nine (9) 24-hour tests with no indication of blockage or buildup of any foreign substances. Inspection records on the spray nozzles are included in Appendix A.

At the conclusion of the test program, the centrifugal pump, electric heat exchanger, and associated piping were disassembled and visually examined by engineering and QA. No evidence of the sublimation shielding material or any other abnormalities were found. This demonstrates that the methyl cellulose did not come out of solution nor adhere to internal surfaces. A copy of the inspection report on the test equipment is included in Appendix A.

The methyl cellulose concentration in the test water was examined by performing liquid chromatographic analysis on samples taken before and after each test run. The analysis verified that the sublimation shielding remained in solution to an accuracy of $\pm 15\%$. A summary of that analysis is included in Appendix A.

SUMMARY OF TEST DATA

Plots of the test system fluid temperature, flow rate, pressure, and pump motor power, as a function of time are also included in Appendix A. All deviations from the test parameters are identified in Deviation Notices included in Appendix A. None of these deviations were significant with respect to the test results or objectives of the program.

Table 2 in Appendix A is a summary of all the test parameters. Maximum, minimum, and average water temperatures are shown in comparison to the required reference test condition, as well as boron concentration variation during the test run and the amount of antifoam agent that had to be added to the system. Variations in boron concentrations were the result of water evaporation from nozzle aeration and temperature. (As the water evaporated, the boron concentrated.) Water was added periodically to bring the boron concentration into the specified range of 2200 ppm ± 200 ppm.

Section 5

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

This test shows that both methyl cellulose and Dow Corning DC-1520 silicon emulation are acceptable for use in the containment spray system. Methyl cellulose is therefore acceptable as sublimation shielding for ice condenser applications, with no impact on balance of plant or safety systems.

Four (4) containment spray nozzles were subjected to nine (9) 24-hour tests with the maximum postulated methyl cellulose concentration. The operating conditions for spray system temperature and chemical water pH were bounded. There were no indications that the performance of the spray nozzles was degraded, that the methyl cellulose came out of solution, or that any spray system component was affected.

The form produced by aeration of the methyl cellulose solution was a concern because, if unchecked, a significant amount of water and boron could be suspended in the foam, thus decreasing the system capacity for heat removal and neutron absorption. Dow Corning DC-1520 silicon emulsion, which is available commercially, is an effective and acceptable foam suppressant. While it does not eliminate foaming, this agent does reduce foaming to an acceptable level. (See "Recommendations" for amounts and delivery methods.)

RECOMMENDATIONS

With the implementation of methyl cellulose as a water soluble plastic sublimation shielding material, it is recommended that a system be developed to introduce Dow Corning DC-1520 into the containment spray system and/or sump. A concentration of 400-625 ppm of DC-1520 in the sump water is recommended. This could be accomplished in several ways, each of which will require further study and development. The following methods for introduction of the antifoaming agent are suggested:

1. Store the antifoaming agent in the sump area such that it is released as the sump is flooded. The agent would be stored in an amount that assures the minimum required concentration would be achieved for the maximum amount of dilution during sump flooding.

2. Develop an injection system that will add the DC-1520 at a controlled rate and concentration into the sump.

3. Formulate the antifoaming agent into the sublimation shielding material. If the shielding in the ice condenser is dissolved, the antifoam agent will be available at a fixed ratio to the amount of sublimation shielding material flushed into the sump.

4. Freeze the antifoaming agent into the borated flakice in the ice bed. As the ice bed melts and drains into the sump, the concentration of the antifoaming agent will be in a fixed ratio to the amount of ice melted.

The first method would be the simplest to implement and would not require extensive development. It can be sized to assure that under all possible LOCA cases, the minimum required concentration of antifoaming agent would be present in the sump water.

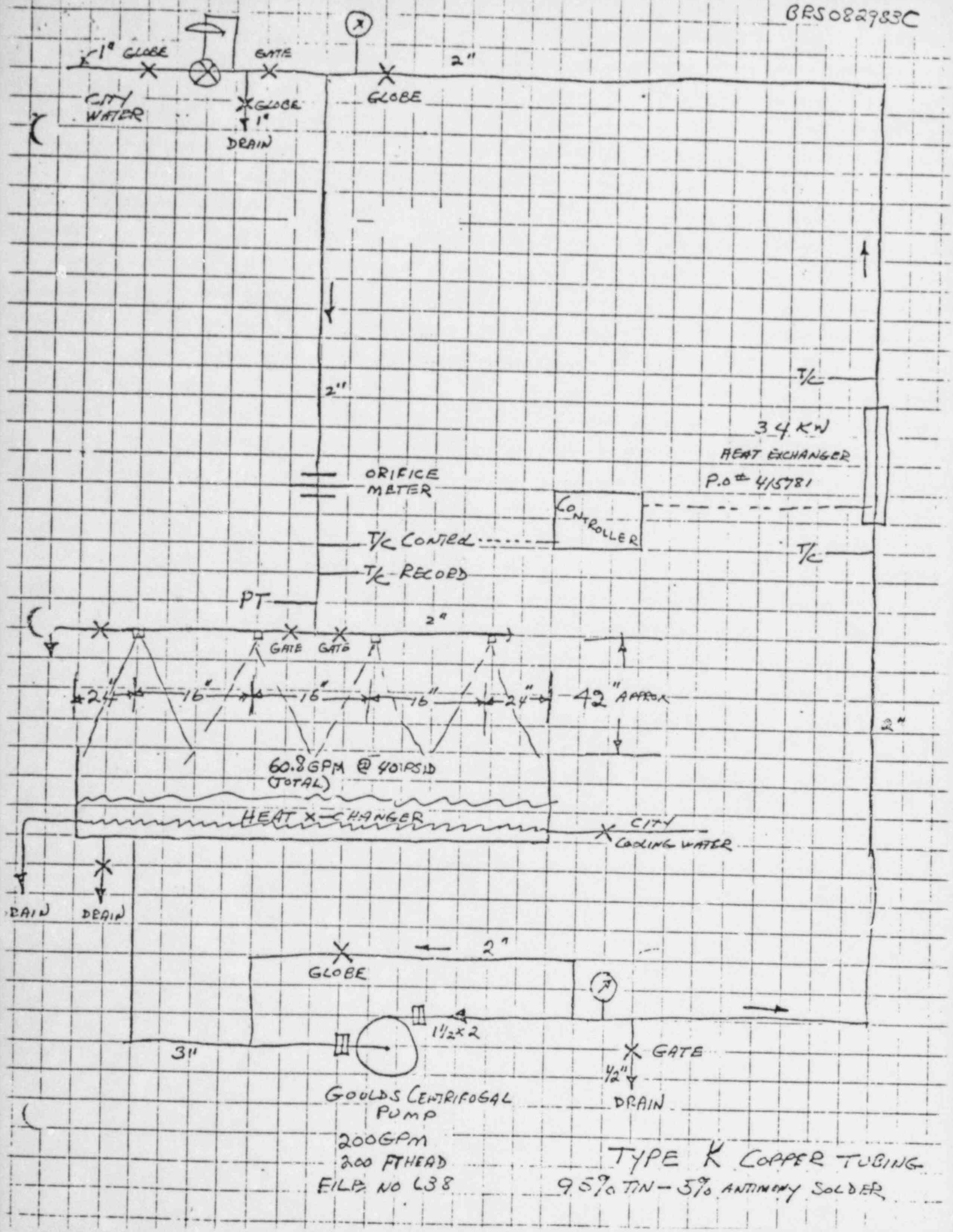
The second method will require extensive systems and equipment development and qualification. The third method will require additional development work to determine the relationship between the requirements for antifoaming agent concentrations and the different concentrations of dissolved methyl cellulose in the sump. The last method will require further study to determine the relationships between the amounts and rates in which the ice melt water and the sublimation shielding material get into the sump for different LOCA conditions.

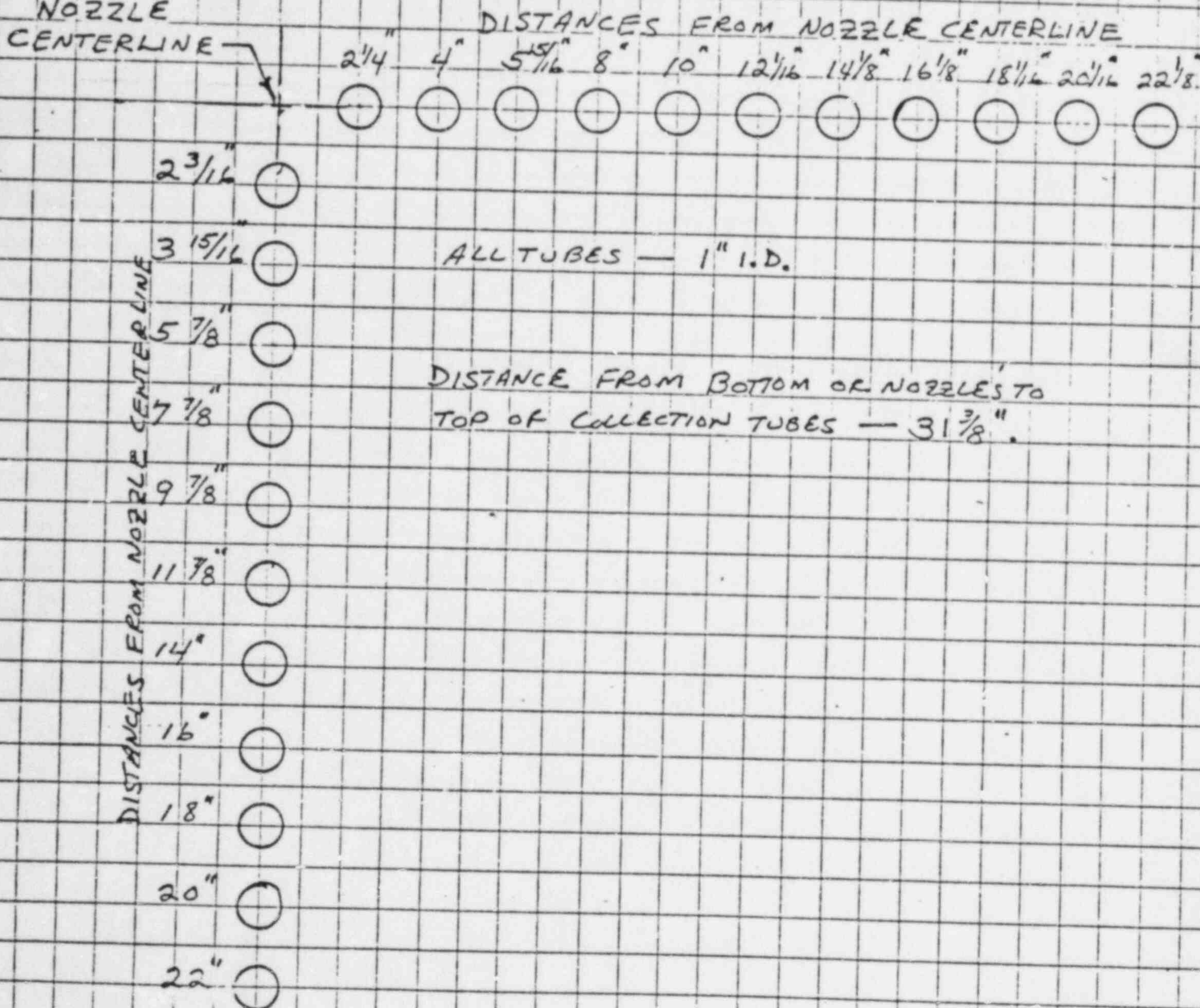
APPENDIX A

TEST DATA

The following information is furnished in this section as supporting documentation for the test program:

1. Sketch BRS082983C - Test system flow diagram
2. Sketch BRS100783 - Nozzle Spray Distribution Collection System
3, Table 1 - Test Numbering Nomenclature
4. Table 2 - Summary of Data
5. Table 3 - Summary of Data
6. Letter SGTD-7.1-23-3370 - Analysis of D.C. 1520 Silicon Emulsion
7. Westinghouse R&D Center letter dated 1-3-84 - Methyl Cellulose in Aqueous Solutions
8. Dow Corning Spec Sheet - 1500 Silocone Emulsion
9. Inspection Report - Visual Inspect Spray Nozzle
10. Inspection Report - Spray Nozzle Test
11. Test Data - Spray Nozzle test 40000
12. Test Data - Spray Nozzle test 40001
13. Test Data - Spray Nozzle test 40002
14. Test Data - Spray Nozzle test 40003
15. Test Data - Spray Nozzle test 40004
16. Test Data - Spray Nozzle test 40005
17. Test Data - Spray Nozzle test 40006
18. Test Data - Spray Nozzle test 40007
19. Test Data - Spray Nozzle test 40008
20. Test Data - Spray Nozzle test 40010
21. Spray Nozzle Test Data Plots
22. Deviation Notices


BRS082983C
1" GLOBE
GATE
2"
CITY WATER
GLOBE
1"
DRAIN
GLOBE
2"
ORIFICE METER
T/C CONTROL
T/C RECORD
PT
CONTROLLER
T/C
3.4 KW
HEAT EXCHANGER
P.O # 415781
T/C
2"
GATE
GATE
24"
16"
16"
16"
24"
42" APPROX
2"
60.8 GPM @ 40 PSID (TOTAL)
HEAT X-CHANGER
CITY COOLING WATER
DRAIN
DRAIN
2"
GLOBE
1 1/2 x 2
31"
GATE
1/2"
DRAIN
GOULDS CENTRIFOGAL PUMP
200 GPM
200 FT HEAD
EILP. NO 638
TYPE K COPPER TUBING
95% TIN - 5% ANTIMONY SOLDER



~ NOZZLE SPRAY ~
DISTRIBUTION COLLECTION SYSTEM

Test Prospectus
#83-0248
12/8/83

SPRAY NOZZLE TEST

TEST NUMBERING
NOMENCLATURE

COMP. TEST NO.	TEST PLAN NO.	TEST TEMP.	CHEMICAL ADDITION
40000.05	-	ROOM	CITY WATER
40001.02	1	100°F	BORIC ACID
40002.01	2	145	BORIC ACID
40003.01	3	190	BORIC ACID
40004.01	4	100	BORAX
40005.01	5	145	BORAX
40006.01	6	190	BORAX
40007.01	7	100	BORIC ACID & BORAX
40008.01	8	145	BORIC ACID & BORAX
40010.01 40010.02	9	190	BORIC ACID & BORAX

TABLE 1

Test Prospectus
#83-0248
12/8/83

SPRAY NOZZLE TEST
SUMMARY OF DATA

TEST NO.	REQ'D. TEST TEMP. ±2°F	AV. TEMP. °F	MAX TEMP. °F	MIN TEMP. °F	BORON CONC. PPM ±200	BORON TIME* HRS.	BORON ANTI-FOAM ADDED ML
40001.02	100°	99.4°	103.4°	96.7°	2202 2536	0 24	180
40002.01	145°	145.4°	147.3°	141.8°	2008 2229 2356 2241	0 8.5 17 24	720
40003.01	190°	187.2°	192.1°	124.4°	2119 2320 2193 2120	0 1.5 8 18.5	180
40004.01	100°	100.1°	100.8°	97.9°	1976 2065 2168	0 1.5 18.5	180
40005.01	145°	144.8°	147.2°	136.7°	2151 2376 2385	0 10 23.5	360
40006.01	190°	186.7°	194.4°	168.5°	2121 2531 2152	0 9.5 21.5	180
40007.01	100°	100.4	102.3	98.6	2023 2121 1772	0 10.5 24	180
40008.01	145°	146.3°	148.3°	143.2°	2097 2527 2201	0 13 24	360
40010.01 40010.02	190°	188.0°	193.1	180.7	2022 2375 1975 1987 2031 2548	0 8 13.2 15.2 17.8 23.8	270

* ELAPSED TIME FROM START OF 24 HOUR TEST

TABLE 2

NOZZLE INLET PRESSURE
SUMMARY OF DATA

TEST NO.	REQ'D. PRESSURE ±.4 PSI PSIA	AV PRESSURE PSIA	MAX. PRESS. PSIA	MIN. PRESS. PSIA
1	54.7	55.4	55.7	54.5
2	54.7	54.4	54.6	54.2
3	54.7	56.4	56.7	53.1
4	54.7	54.1	55.0	52.4
5	54.7	54.5	54.9	54.2
6	54.7	54.8	57.6	53.2
7	54.7	54.1	55.8	42.7
8	54.7	55.4	56.1	54.6
9	54.7	54.4	56.3	53.5

TABLE 3

SGTD-7.1-23-3370

From SGTD - Steam Generator Technology Division
WIN 244-3887
Date November 11, 1983
Subject Analyses of D. C. 1520 Silicon Emulsion for Use as a Antifoaming Agent for Ice Condenser Plants

To B. R. Sinwell FH/A200

cc: W. D. Fletcher FH/A100
M. J. Wootten FH/A200
A. S. Calderwood FH/A200
L. F. Becker FH/A200
C. M. Scrabis MNC 311
T. J. Gerlowski MNC 743

It is proposed to use Dow Dorning DC-1520 Silicon Emulsion for an antifoaming agent to counteract the foaming effect in boric acid solution of the methyl celluose. This is to be used to bag the borated ice in the reactor containment of ice condenser systems.

Chemical analyses were performed on one lot of this material. The results of these analyses and the analtyical methods used, are presented in the following table and recorded by Westinghouse Advanced Reactor Division Analytical Laboratories as Analytical Service Number 83-3360 dated 11-2-83 and in Westinghouse Notebook 137981 page 31.

TABLE 1

Impurities in DC 1520 Silicon Emulsion determined by Pyrohydralysis and Ion Chromatorgraphy.

CHLORIDE, ppm	FLUORIDE, ppm	SULFATE, ppm
65	4	155 (52 ppms)

The maximum DC 1520 antifoam agent used will be less than 625 ppm resulting in a chloride concentration of less than 0.04 ppm. This level is within the specification limit of 0.15 ppm for the reactor coolant. The sulfur level is even below this concentration and should present no corrosion problem for any of the materials of construction of the reactor system or spray system.

D. D. Whyte
D. D. Whyte, Principal Engineer
Chemistry Field Development

DDW/kr

Discard Date:

File 83-796

R&D Center - 501 3Y22
236-2232
January 3, 1984
Methyl Cellulose in
Aqueous Solutions

JAN 6 1984

C. M. Scrabis
NTD Thermal Equip. Engrg.
Nuclear Center - MS 311

cc: H. Shellaby - NTD, Forest Hills
B. Sinwell - NTD, Forest Hills
G. L. Carlson - R&D Center
K. A. Kloes - Nuclear Center - MS 311

The samples of methyl cellulose in aqueous solutions were initially examined using water and water-ethanol as elements for the samples. These analyses showed very little change in the amount of high molecular weight species present in the solutions, but the total amount of organic material was calculated to be at least twice the amount (0.2% wt.) which was supposed to be in the solutions. This variation occurred because a silicone anti-foaming agent had been added to the solution and was interfering in the determination of methyl cellulose. The interference was eliminated by using a saturated borax solution as the eluent in the liquid chromatographic analysis.

The results of this analysis again shows very little difference in the concentration of methyl cellulose in the solutions. The overall concentration is at the projected level of 0.2%, but the analytical technique is only accurate to ± 15% due to the high noise level of the detector during these tests.

John R. Ray
Senior Engineer
Analytical & Laboratory Services

/jlc

Dow Corning® [illegible]-30 Emulsion

This 30% antif[illegible]m emulsion has a long history of use in adhesive and printing inks. It contains a special formula of emulsifiers.

Typical Properties
These values are not intended for use in preparing specifications.

Color	White
Specific Gravity at 77°F (25°C)	1.0
Consistency at 77°F (25°C)	Light cream
pH	2.5
Active Defoamer, percent	30
Emulsifier Type	Nonionic
Suitable Diluent	Water

Specification Writers: Please contact Dow Corning Corporation, Midland, Michigan, before writing specifications on this product.

Dow Corning® 1500 Silicone Emulsion

This 100% antifoam compound is recommended for oil-based and solvent-based systems, for best economy. It is for food-related uses, when system will allow its use.*

Typical Properties
These values are not intended for use in preparing specifications.

Appearance	Opaque grey to white
Active Ingredient	100-percent silica-filled polydimethylsiloxane
Specific Gravity at 77°F (25°C)	1.0
Viscosity at 77°F (25°C) cps	1500
Flash Point	>200°F (93°C)

Specification Writers: Please contact Dow Corning Corporation, Midland, Michigan, before writing specifications on this product.

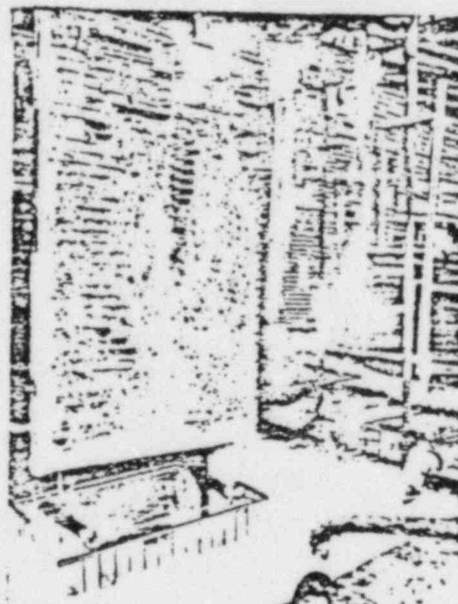
Dow Corning® DB-100

This 100% antifoam compound is for extreme conditions such as high and low pH systems. It is long-lasting and very cost effective for non-aqueous systems. Dow Corning® DB-100 is stable to freeze-thaw cycles.

Typical Properties

Active Defoamer, percent	100
Type	Compounded silicone fluid
Specific Gravity	1.03
Viscosity at 77°F (25°C), cs	2400
Color	Translucent white
Suitable Diluents	Aliphatic, aromatic and chlorinated solvents
Shelf Life, months	12

Specification Writers: Please contact Dow Corning Corporation, Midland, Michigan, before writing specifications on this product.



Metal plating

Appendix B

TEST PLAN

The test plan titled "Ice Condenser/Containment Spray Systems, Water Soluble Plastic Effects on Spray System" is reproduced on the following pages.

TEST PLAN: Ice Condenser/Containment Spray Systems Water Soluble Plastic Effects on Spray Systems

REFERENCE: Duke Power Company
General Order ID. CH-14695

Prepared By: 10/3/83
C. M. Scrabis, Engineer
Process & Thermal Equipment Engineering

Reviewed By:
T. J. Gerlowski, Engineer
Fluid Systems Design

10/5/83
B. R. Sinwell, Engineer
Test Engineering

Approved BY: 10/4/83
D. W. Alexander, Manager
Process & Thermal Equipment Engineering

10/5/83
C. E. Conway, Manager
Test Engineering

10/5/83
J. J. Flaherty, Engineer
Q.A. Engineering

Rev. No. & Date	Revisions	Preparer
0	Original	C. M. Scrabis

WATER SOLUBLE PLASTIC EFFECTS ON SPRAY SYSTEMS

I. OBJECTIVE

To determine the effects of circulating a water chemical solution with a soluble plastic dissolved in it, under simulated LOCA conditions through the Containment Spray System. Evaluate and compare post-test versus pretest flow characteristics of spray nozzles. Determine if the water soluble plastic material will come out of solution during the recirculation phase of the containment spray system, and plug or have the potential for plugging up the spray nozzles.

II. BACKGROUND

An EPRI sponsored program was completed in 1982 and documented in WCAP-2125-1 titled "Steam Pressure Suppression Characteristics of Water Soluble Plastic Membrane Shielded Ice for Ice Condenser Containment Nuclear Power Plants." This program identified two areas of questions, which required further investigation before proceeding with full implementation of the sublimation shielding material in an ice condenser plant. One area dealt with the pressure suppression characteristics of this material in the dead-ended compartments below the ice condenser floor which are sensitive to the initial phase (<2 seconds) of the pressure transients. The other question dealt with the unknown potential for this sublimation shielding material to plug or change the flow characteristics or performance of the containment spray system. It is this latter question that this test program will address.

III. TEST ITEMS

A. Spray Nozzle

Sprayco Nozzle Model No. 1707141707. Four (4) nozzles shall be used in each test run.

B. Water Soluble Plastic Material

The material Methyl Cellulose will be used for investigation. It is supplied by Polymer Films, Inc. of Rockville, Conn., under the Catalogue number of Edisol M-1100. The material will be furnished for dissolving in a chemical water solution, as a liquid form or a solid sheet film form and can be used in this test program in either form or combination of the two forms. The quantity of material used in each test will be 2.1 lbs. of methyl cellulose per every 1000 lbs. of chemical water solution.

C. Chemical Water Solution

Individual tests will be run at temperatures of 100°F, 145°F and 190°F using chemical water solution as follows:

1. 2200 ppm Boric Acid Solution
2. 2200 ppm Sodium tetraborate solution
3. 2200 ppm Boric Acid and 2200 ppm sodium tetraborate solution.

In addition, one test run using only water (city supply or tap water) will be run initially to verify that the test system operates properly.

IV. <u>TEST EQUIPMENT</u>

A. Mechanical

1. Centrifugal Pump
   a) Minimum flow - 60.8 gpm at 40 psid
   b) Number required - 1 (minimum)

2. Heat Exchanger
   a) Electric type
   b) Capable of heating and maintaining fluid temperature at 100°F, 145°F and 190°F.
   c) Number required - 1 (minimum)

3. Spray tank
   a) 4' x 8' x 2' high
   b) Stainless steel
   c) Number required -1

4. Spray Nozzles
   a) Sprayco Model No. 1707141707
   b) Required flow - 15.2 gpm @ 40 psid
   c) Number required - 4 per each test run. The nozzles may be used for multi-test runs.

B. Instrumentation

1. Calibrate Orifice Plate & ΔP cell
   a) Test flow rate 60.8 gpm at 40 psid
   b) Accuracy - $\pm$ 0.3 gpm

2. Thermocouples
   a) K type
   b) Number required - 3
   c) Accuracy $\pm$ 2.0°F

3. Pressure Gages
   a) Bordon Tube type
   b) Pressure range - 0 to 100 psig
   c) Number required - 2
   d) Accuracy $\pm$ 0.4 psi

V. <u>DATA REQUIREMENTS</u>

1. Temperature of the water upstream of the spray nozzles $\pm$ 2.0°F.

2. Flow rate through the spray nozzles $\pm$ 0.3 gpm

3. Pressure drop across the nozzles $\pm$ 0.4 psi

4. Chemical concentration of the test water ± 200 ppm

5. Time duration of the test run ± 1.0 min.

6. Water soluble plastic material concentration of the test water ± 0.1 lbs. per 1000 lbs. of water, at the start and completion of the test.

7. Identification of how the water soluble plastic material concentration was made up (i.e. lbs. of liquid material and/or lbs. of solid film material ± 0.1 lbs.)

8. Evaluation of spray nozzle spray pattern.

VI. TEST MATRIX

A total of 10 test runs are proposed per attached sketch BRS082983. The first test run will use ambient temperature or tap water with no chemical additives or water soluble material added. It will last a time duration of at least four hours and has the primary purpose to establish the operational performance of the test loop and data acquisition systems.

The remaining 9 test runs will use 2.1 lbs. of methyl cellulose material per each 1000 lbs. of chemical water. Each test run will last for 24 hours after reaching the required test temperature. The following is a listing of the 9 tests.

1. 2200 ppm Boric Acid water at 100°F
2. 2200 ppm Boric Acid water at 145°F
3. 2200 ppm Boric Acid water at 190°F
4. 2200 ppm Sodium Tetraborate at 100°F
5. 2200 ppm Sodium Tetraborate at 145°F
6. 2200 ppm Sodium Tetraborate at 190°F
7. 2200 ppm Boric Acid and 2200 ppm Sodium Tetraborate at 100°F
8. 2200 ppm Boric Acid and 2200 ppm Sodium Tetraborate at 145°F
9. 2200 ppm Boric Acid and 2200 ppm Sodium Tetraborate at 190°F

VII. TEST PROCEDURE

1. Prepare chemical water solution in the test spray tank.

2. Start up the spray test loop and establisn the proper flow rate and pressure drop through the nozzles.

3. Test each flow nozzle to establish the initial flow spray pattern characteristics.

4. Dissolve the sublimation shielding material in the chemical water solution in the ratio of 2.1 lbs. of methyl cellulose to 1000 lbs. of water.

5. Heat up test solution to proper test temperature with required flow rate and pressure drop across the spray nozzles.

6. After establishing proper test parameters, operate the test loop for prescribed test time period and record the required test parameters.

7. Before stopping the test run, retest each of the spray nozzles for flow pattern changes and comparison to the initial spray pattern check.

8. Take a sample of tne chemical water solution for chemistry evaluation of concentration level of methyl cellulose.

9. Stop tne test loop, remove the spray nozzles and visually inspect for traces of the methyl cellulose material. Record the findings.

10. Prepare for the next test run.

11. After all the test runs have been completed, the piping, orifice, valves and centrifugal pump shall be disassembled and visually examined for traces of methyl cellulose material.

ATTACHMENT 5

Proposed FSAR Changes

Insert into Section 6.2.1.3, page 6.2-4
(after topic titled Sensitivity Studies)

ICE CONDENSER

In an ice condenser containment, a concern that exists is the sublimation of ice in the ice baskets. Due to the high heat load on the row of ice baskets nearest to the crane wall, this row of baskets experiences sublimation rates of about 5-10% per year. One method to eliminate this occurrence would be to wrap the ice with a soluble plastic film (as described in Section 6.7.4.2). A side effect of this plastic film is that the ice condenser performance will change for the first few seconds following a high energy line break, and therefore, the short-term subcompartment pressure analysis will be affected. A sensitivity study was performed to determine the impact of wrapping one-third of the ice baskets with a water soluble sublimation shielding wrap. The sensitivity study assumed the following:

1) a Double-Ended Cold Leg (DECL) break in compartment 1 is the limiting case

2) a decrease in the heat transfer area

3) an increase in the condensing length resistance to account for the water soluble plastic.

The results of this study are shown in Figure 6.2.1-19a. This figure illustrates that the peak pressure, as a result of the sublimation shielding wrap, is below design pressure and hence, does not adversely impact the Short-Term Containment Analysis.

Insert into Section 6.7.4.2, page 6.7-14
(after last paragraph)

The three (3) rows of ice basket columns closest to the ice condenser crane wall incorporate a water soluble plastic sublimation shielding coating around the stored ice. Westinghouse has demonstrated the acceptability of the sublimation shielding material on all ice condenser and other interfacing equipment and systems.

Design Consideration

1. The structural stability and deformation requirements are determined to ensure no loss of function under accident and safe shutdown earthquake loads.

2. The ice baskets are designed to facilitate maintenance and for a lifetime consistant with that of the unit.

3. The structure is designed to maintain the ice in the required array to maintain the integrity of performance of the ice condenser. In particular, the hydraulic diameter and heat transfer area are maintained within the limits established by test to be consistent with the containment design pressure.

4. Any section of the ice basket is capable of supporting the total weight of the ice above that section.

General Thermal and Hydraulic Performance Requirements

The ice baskets are fabricated from perforated sheet metal which has open area to provide sufficient ice heat transfer surface. The adequacy of the design and the performance were confirmed by test and analysis.

Interface Requirements

1. Lattice Frame

The lattice frames at every 6 ft act as horizontal restraints along the length. The design provides a nominal 1/4 in. radial clearance between the ice baskets and the lattice frames. Lattice frame and basket coupling elevations coincide to prevent damage to the basket during impact.

2. Lower Support Structure

Ice basket bottoms are designed to be supported by and held down by attachments to the lower support structure. The basket supports are designed for structural adequacy under accident and safe shutdown earthquake loads and permit weighing of selected ice baskets.

3. Basket Alignment

The ice condenser crane aligns with baskets to facilitate basket weighing and/or removal. The baskets are capable of accepting basket lifting and handling tools.

4. Basket Loading

The ice baskets are capable of being loaded by a pneumatic Ice Distribution System.

5. External Basket Design

The baskets are designed to minimize any external protrusions which would interfere with lifting, weighing, removal and insertion.

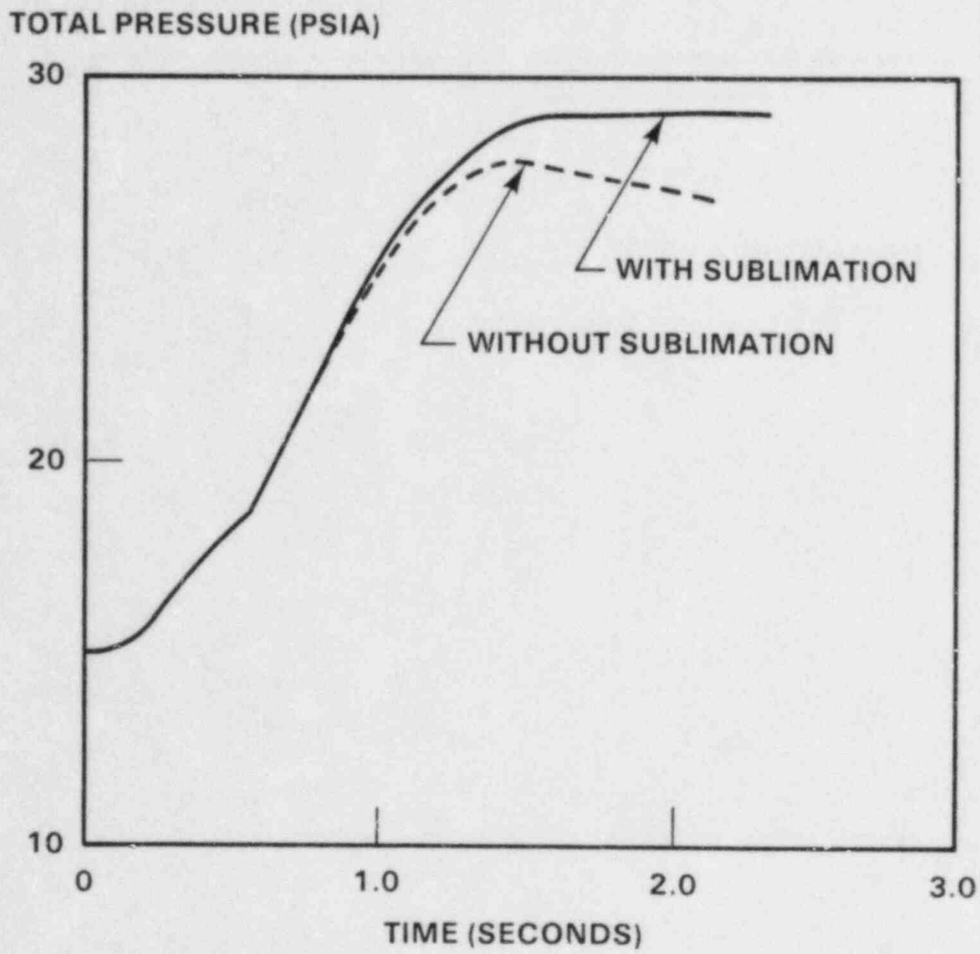


Figure 6.2.1-19a. Sensitivity to Sublimation Shielding Wrap