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BARTLETT NUCLEAR, INC.

MODIFIED PORTLAND CEMENT SOLIDIFICATION

SUBMITTED TO:

STANDARDIZATION AND SPECIAL PROJECTS BRANCH
U.S. NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555

August, 1984

By
BARTLETT NUCLEAR, INC.
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ABSTRACT

This topical report describes the system design and operation of the Bartlett Nuclear modified portland cement solidification process. The unit was developed to provide a simple, economical, and reliable method for solidification of radioactive liquids, resins, and sludges for purposes of later transportation and disposal.

The modified portland cement is a combination of portland cement type 1 and additives to produce a finely ground, nonflammable powder. The resultant solidified product is compatible with existing storage and solidification equipment throughout the industry.

The modified portland cement (MPC-1) is readily dispersible in an aqueous solution for a homogeneous mix immobilizing the radioactive nuclides into a dry free standing monolith. The MPC-1 can be used to solidify oils, evaporator bottoms, various filters/ion exchange media, and sludges. Each product to be solidified has its own special characteristics, which may inhibit or accelerate the set. The MPC-1 plus additives is used to adjust each waste stream for optimum efficiency and product compressability.

Laboratory testing process control procedures simulate the effects of a full scale solidification and verify the formulas for optimum product. The equipment used for the solidification is simple and easily transported, assembled and interfaces with existing plant equipment. The normal containers for the solidification process are 17H 55 gallon drums, which are readily available and economical.

INTRODUCTION

Bartlett Nuclear, Inc. has designed and built the portable mixing station to satisfy the needs and requirements of the nuclear power industry. The waste products are solidified using the commonly available portland I cement modified with particular additives to optimize the waste to cement ratio while at the same time forming a product which exceeds the requirements for low level waste disposal by burial.

The portable mixing station system was designed with ALARA and simplicity of operation in mind. Due to its size, it is quite flexible for use within existing structures at nuclear facilities.

This report addresses the ability of MPC-1 to meet the standards for low level waste stabilization as required by 10 CFR 61.

2.0 PROCESS DESCRIPTION

2.1 General Process Description

The Bartlett Nuclear, Inc. portable mixing station is designed to solidify all radioactive wastes to include: boric acid, evaporator bottoms, resins, sludges, oils, and various solids for immobilization. The station equipment is used to blend the MPC-1 binder and waste stream into a homogenous mix in the final burial container. Any solids (i.e. resins or diatomaceous earth) are preconditioned and once placed into the final solidification container are dewatered as necessary to provide the correct ratios of liquid to MPC-1 binder for formation of a free standing monolith with no free standing water.

Prior to transferring the waste to the drum, the process control procedure is used to verify the quantities of additives and cement necessary for proper solidification. A typical process control procedure is provided as appendix 1.

The equipment of the system is designed with built-in interlocks to provide for trouble-free operation. The control panel is simple, small and portable; and through use of various length power cables (25 feet is standard) the control panel is remote from the solification operation.

Installed plant piping, alarms, and ventilation; either temporary for infrequent use or permanent for more consistent use; are utilized within the established solidification area to prevent or minimize the spread of contamination. The agitator is hydraulically raised, lowered and operated from the remote panel.

Flushing capabilities are provided by installed plant systems. The mixing station is designed for portable application to ensure ease of transportation and set up. It can be moved anywhere within the facility, or if desired, installed as a permanent mixing station.

2.2 Subsystem Description

2.2.1 Operators Panel

The panel is equipped with pushbuttons for manual operation.

2.2.2 Waste Transfer

Waste transfer into the drum is supplied by the utility, but can be provided through an optional fill head built into the station for facilities which have sufficient volumes to be solidified to justify an installed station.

2.2.3 Dewatering System

The dewatering system is supplied by the utility.

2.2.4 Cement Transfer

The cement transfer system is variable from use of palletized bags with manual transfer to bulk storage with automated transfer to the solificiation container through an optional fill head.

2.2.5 Radiation Monitoring

Radiation monitoring is provided by the utility and the station itself is usually standard portable remote radiation monitoring equipment.

2.3 System Operation

2.3.1 Assembly

The assembly and operation of the portable solidification panel and mixing station are conducted in accordance with written procedures.

2.3.2 Waste Sampling and Conditioning

A sample of the waste is taken by the utility for use in the process control procedure to verify cement and additive quantities. After the completion of PCP, the required amount of waste is transferred to the 55 gallon drum. By remote operation the drum is placed on the mixing station. The proper amounts of cement and additives are placed in the container as the mixing station is operated. A typical PCP is provided as Appendix 1.

2.3.3 Cement Addition

Cement and additives are transferred to the waste by means of plant equipment, either installed or temporary.

2.3.4 Flushing

Flushing is accomplished by use of plant installed systems.

2.3.5 Post Solification

After completion of the cure time for the cemented waste the barrel is capped (remotely or manually depending upon activity).

3.0 EQUIPMENT DESCRIPTION

3.1 The mixing station and components are painted for ease of decontamination should this be necessary.

3.2 Ventilation, radiation alarms, and transfer equipment are all supplied by the utility. These may be a combination of installed plant area systems and portable equipment dedicated to just the solidification process.

4.0 QUALITY ASSURANCE

4.1 Quality Assurance for the processes and products is provided through the Bartlett Nuclear, Inc. Quality Assurance Program as set forth in the Quality Assurance Manual Attachment 4.

5.0 TESTING

5.1 Cement Tests

Bartlett Nuclear has done extensive testing on the solidification media to determine the reliability and regulatory compliance of the product. The testing results are attached in Appendix 2 and Appendix 3.

5.2 Mixing Station

5.2.1 The mixing station has been field tested and demonstrated. This system provides a low cost and simple operation for mixing of the cement.

6.0 DRAWINGS

6.1 A drawing of a typical mixing station is provided as Appendix 5.

BARTLETT NUCLEAR INC.

Aldrin Road, Industrial Park, Plymouth, MA 02360

Title: CEMENT SOLIDIFICATION
PROCESS CONTROL PROGRAM (P.C.P.)

APPENDIX I

REV.	DATE	ORGINATOR	DATE	Q.A.	DATE	APPROVED	DATE
---	6-08-84	R.M. Staley R.M.STALEY	6-8-84	B. Barley B. Barley	6/14/84	B.R. Bartlett B.R. Bartlett	6/15/

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1.0 SCOPE

1.1 PURPOSE

The purpose of the Process Control Program is to establish processing parameters to insure a safe and effective solidification of all low-level radioactive waste liquids, slurries and solids.

1.2 APPLICABILITY

This Process Control Program shall be used by all personnel operating the Bartlett Nuclear, Inc. portable mixing stations, cement solidification units. This is not to be used as an operating procedure.

2.0 REFERENCES

2.1 Bartlett Nuclear, Inc. Operating Procedures for Cement Solidification Units, as applicable.

2.2 NUREG 0472, "Radiological Effluent Technical Specification for PWRs".

2.3 Branch technical position - ESTB 11-3, "Design Guidance for Solid Radioactive Waste Management System Installed in Light-Water Cooled Nuclear Power Reactor Plants".

2.4 ANSI NI99, "Liquid Radioactive Waste Processing System for Pressurized Water Reactor Plants".

2.5 NRC Regulatory Guide 1.143, "Design Guides for Radioactive Waste Management System, Structure, and Components Installed in Light-Water-Cool Nuclear Power Plants".

2.6 NUREG-0133, "Preparation of Radiological Effluent Technical Specifications for Nuclear Power Plants".

2.7 NRC Regulatory Guide 8.8, "Information Relevant to Ensuring that Occupational Radiation Exposures at Nuclear Power Stations will be As Low As is Reasonably Achievable".

2.8 ANSI Standard 55.1, "Solid Radioactive Waste Processing Systems for Light-Water-Cool Reactor Plants".

3.0 REQUIREMENTS

3.1 Prerequisites

3.1.1 It is the intent of this document to be used in conjunction with the Utility Operating Procedures which govern the direct operation of the necessary equipment used to perform sampling, testing, recirculating of tank volumes, valve line-ups and safety precautions.

3.1.2 The utility operating procedure shall cover as a minimum:

3.1.2.1 Equipment Operation

Interlock for alarms, monitors, and valves.

3.1.2.2 Radiation Protection.

3.1.2.3 Administrative Controls.

3.1.2.4 Reporting documents.

3.1.3 Communication shall be established between the waste processing technicians and the utility operation via telephone or radio prior to processing any form of waste.

3.2 Contamination Releases

3.2.1 Gases

3.2.1.1 Accidental radioactive gases released during sampling and full scale solidification shall make use of the utility control negative pressure off-gas ventilation system.

3.2.2 The release of liquids, either accidental or control type, are confined by the utility physical boundry as planned under the auxiliary building design basis.

4.0 SYSTEM DESCRIPTION

4.1 PROCESS DESCRIPTION

The Bartlett Nuclear, Inc. portable mixing station is designed to solidify all radioactive waste to include: Boric acid waste, evaporator bottoms, ion exchange resin slurries, sludges, oils and various solids for encapsulation and immobilization. The waste products are solidified using the commonly available Portland I Cement modified in conjunction with particular process additives. The Modified Portland Cement (MPC-1) and additives can be transformed to varying degrees to optimize the waste to cement ratio or to perform in a specified manner. (i.e. slow cure, fast set, minimize heat generation.)

4.2 PROCESS PARAMETERS

The reactions from cement and waste form very stable hydrates from the chemical combination of calcium, silicon, and aluminum with oxides. The reactions are exothermic and are not readily produced unless strong alkalines are present in a pH of 11 to 12.

Other chemicals in the waste stream may inhibit or accelerate the set. These chemicals must be controlled by modifying the additives to ensure a controlled, free-standing monolith, dry, and with the final product able to resist penetration when probed with a spatula or similar firm object.

Bartlett Nuclear, Inc. has researched and developed the basic Modifyied Portland Cement (MPC-1) and additives to solidify radioactive waste to produce homogeneous, free-standing monolith solids with no free water. The research performed by Bartlett Nuclear, Inc. recognizes that all waste streams are not the same and the composition, density and temperature may vary from each lot of waste. This problem is addressed in Appendix 1.

4.3 CEMENT SOLIDIFICATION UNIT DESCRIPTION

4.3.1 The Bartlett Nuclear, Inc. portable mixing station contains all piping, controls, and monitoring equipment to support the solidification of radioactive waste using the MPC-1 cement process. The unit is a portable 55 gallon drum mixing unit.

4.4 SYSTEM OPERATION

4.4.1 Cement Solidification shall be performed only upon a successful sample solidification and shall be performed once for every ten full scale solidifications using a representative sample of the waste stream.

4.4.2 Sample solidification information shall be recorded on the P.C.P. Sample Test Worksheet (Appendix 2). This data shall be used to calculate the full scale values.

4.4.3 Full scale solidification shall be completed in accordance with full scale Operating Procedures (SO-OP-002) by using the formulas as defined by this procedure and the worksheet in Appendix 2.

4.4.4 Full Scale Operation General Description

The waste stream is metered into the receiving 55 gallon drum while the mixer is in operation. Any pretreatment chemical may be added to conform to the P.C.P. requirement for proper solidification. The modified Portland cement (MPC-1) is added to the waste until the required volume is reached per the P.C.P. requirement. The actual sequence of additions may vary per the P.C.P.

4.4.5 Waste-to-Cement Ration (by volume)

The waste-to-cement ratio will vary due to the chemistry of the waste stream. However, the expected ratios are approximately 2: 1 to 3: 1 for Boric Acid concentrates and other liquids to include oils, resins, powders, and other solids.

4.4.6 Cure Time

The initial cure time for P.C.P. sample is approximately 30 minutes to 4 hours; /and, for full scale solidification approximately 6 hours to 24 hours. The drum shall be vented at all times until the initial curing process is completed. The completion of the solidification process may be verified by monitoring the initial curing process temperature rise and fall; thus indicating a safe, capable product.

5.0 PRECAUTIONS AND LIMITATIONS

5.1 RADIOLOGICAL PRECAUTIONS

5.1.1 The Bartlett Nuclear, Inc. technician's activities shall be governed by the Nuclear Plant's Health Physics and safety precautions.

5.1.2 The technician shall, as required, secure a Radiological Work Permit (RWP) before handling Radioactive Waste.

5.1.3 Laboratory safety requirements per the Nuclear Plant's procedures shall be adhered to at all times.

5.1.4 The technicians shall:

5.1.4.1 Use all safety precautions necessary to eliminate hazards and injury to self and others.

5.1.4.2 Perform test with utmost care to prevent the spillage of chemicals to surrounding area.

5.1.4.3 Clean-up the area immediately upon completion of testing.

NOTE: Materials used in solidifications as described by this procedure have been regarded as safe and non-toxic to handle, however, care should be taken to minimize skin contact, inhalation, or ingestion of any chemicals used. If caustics, acids, and emulsifiers are handled, follow the safety precautions as outlined in the Safety Data Sheet in Appendix 3.

6.0 CHEMISTRY OF WASTE

The utility supplying waste shall provide waste composition and properties necessary to accurately identify the waste to be solidified. See Appendix 4 for a detailed list of properties needed for identification of the waste.

7.0 SAMPLE TESTING SOLIDIFICATION PROCEDURE

7.1 PREREQUISITES

7.1.1 The technician shall obtain an approved current Radiation Work Permit (RWP) prior to entering the work area.

7.1.2 The technician shall have on hand necessary chemicals and equipment to perform sample testing. (Table 1)

7.1.3 The waste sample to be solidified must be representative of the waste to be solidified.

7.2 WASTE RECIRCULATION

7.2.1 Waste Recirculation of batch tank (waste storage tank) shall be confirmed by utility as having been recirculated at a minimum three (3) volumes or more to insure a homogeneous mixture.

7.2.2 During the recirculation periods, if for any reasons the recirculation is stopped, the waste generating facility shall restart the recirculation period from the beginning and recirculate the volume inside the tank at least three (3) volume turnovers or more to insure a homogeneous mixture.

7.2.3 If during the recirculaion periods:

7.2.3.1 Additional waste is added to the tank,

7.2.3.2 Additional chemical is added to the tank,

7.2.3.3 Additional water is added to the tank,

7.2.3.4 If any of these conditions occur, it will be necessary to restart the recirculation process from the beginning until at least three (3) volume turnovers or more to insure a homogeneous mixture, and resample the batch tank.

7.3 DESCRIPTION OF TEST SAMPLE PROCEDURE

7.3.1 Verify the chemistry parameter of constituent, and prepare sample for solidification.

7.3.2 Measure additives and Modified Portland Cement (MPC-1) volumes and record volumes on P.C.P. sample test worksheet (Appendix 2).

7.3.3 Dispense 100 ml of the heated waste sample into a 600 ml beaker. Record pH and temperature.

7.3.4 Add the predescribed additive to adjust the pH to a 10.5 to 11.5 pH range. Record results.

7.3.5 Add the predescribed Modified Portland Cement (MPC-1) to the pretreated waste sample and mix for one (1) minute. Allow sample to cure unsealed undisturbed for 30 minutes minimum, longer if necessary.

7.3.6 Check sample for Free Standing Water (FSW) and hardness. Record observation on P.C.P. sample test worksheet (Appendix 2). Check sample as often as practical to record data necessary to verify sample under the Acceptance Criteria 6.4. Record results on sample evaluation sheet Appendix 5.

7.3.7 Perform several samples on the same waste stream varying the additive and MPC-1. Record the results in Appendix 2 and Appendix 5.

7.3.8 Select the sample that demonstrates the best: waste to binder ratios, with no free standing water and with the maximum hardness.

7.3.9 Repeat P.C.P. test sample solidification selected for repeatability.

7.3.10 Use the data sheet (Appendix 6) to scale-up the P.C.P. test sample solidification to the planned full scale solidification.

7.4 SAMPLE ACCEPTANCE CRITERIA

The verification of sample for acceptance is confirmed by the use of actual waste material used in full scale solidification plus the additives and cement to produce a homogeneous, free-standing monolithic structure. The acceptance criteria is:

7.4.1 Visually inspect for defects in structure, uniformity, free-standing water, and the free-standing monolith. Use Appendix 5 for quality assurance of the final product to be used on the full scale solidification.

7.4.2 The final cured end-product shall resist penetration when probed by hand with a spatula or a firm object, using normal limited force.

7.4.3 One representative sample shall be tested from each tenth batch of each type of wet radioactive waste to be solidified.

7.4.4 If any test samples fail to pass the acceptance criteria per Section 7.4.1 and 7.4.2, then full scale solidification of the failed batch shall be suspended until the parameters are determined and a successful test sample has met the acceptance criteria.

7.4.5 If the initial test sample from batch of waste fails to pass the acceptance criteria, then testing shall be performed until at least three (3) consecutive initial test samples have demonstrated solidification and meet Section 6.4.1 and 6.4.2 acceptance criteria.

7.5 SAMPLE REQUIREMENTS

7.5.1 A representative test sample of waste material shall be solidified prior to full scale solidification and meet the sample acceptance criteria (6.4).

7.5.2 The waste sample shall have necessary chemistry (Appendix 4) performed by the waste generating facility to adequately evaluate the parameters for test sample solidification.

7.5.3 The technician shall use the acquired skills in sampling technique, volume calculation, the number of times the volume has turned over, tank level changes and temperature changes to insure a representative homogeneous sample is received for the P.C.P.

8.0 TEST SAMPLE SOLIDIFICATION DOCUMENTATION

8.1 Using the P.C.P. sample test worksheet (Appendix 2) calculate and record the required test information for all test samples performed.

8.2 Appendix 7 Solidification Data Sheet

9.0 ADMINISTRATIVE, RECORDS AND PROCEDURES

9.1 Copies of all documentation shall be forwarded to Bartlett Nuclear, Inc. Project Manager or his designee immediately after full scale solidification.

9.2 A copy of all documentation shall be retained and maintained by the technician in charge. This record is auditable and shall be kept on file for a period of six months. After six months these records shall be forwarded to the Bartlett Nuclear, Inc. Project Manager for final disposition.

9.3 A copy of all documentation shall be forwarded to the utility Radwaste Supervisor or his designee upon completion of the solidification process.

9.4 The Bartlett Nuclear, Inc. worksheets and related documents are considered proprietary information and are not to be distributed. All documents shall be maintained in a control file by the technician, and the project manager and the utility.

- TABLE 1 -

Recommended equipment for test sample solidification

Thermometer 0-212°F

pH paper Range 0.0 to 14.0

Triple beam balance 0 to 1000 grams

Stirrer/hot plate - variable temperature control 0° to 600°

Graduate Cylinder 150 ml

Plastic disposable containers with lids

Spatula - wooden or metal

Pyrex beakers 600 to 1000 ml

MPC-1 2000 gm

NaOH 1000 ml

$Ca(OH)_2$ 1000 gm

Emulsifier 500 ml

Acceleration 500gm

APPENDIX 1

The following is a description of tests performed on the Bartlett Nuclear, Inc. radioactive liquid waste solidification cement.

TEST #	COMPOSITION	RESULTS
1-1	50% EHC oil, 50% water (H_2O)	solidified hard, no liquid
1-2	25% EHC oil, 75% water (H_2O)	solidified hard, no liquid
1-3	75% EHC oil, 25% water (H_2O)	did not solidify completely, but no free liquids present
1-4	6% Boric acid (H_3BO_3) in water (H_2O)	solidified, no liquid
1-5	24% Boric acid (H_3BO_3) in water (H_2O)	solidified, no liquid
1-6	12% Boric acid (H_3BO_3) with 10% EHC oil, 90% water (H_2O)	solidified, no liquid
1-7	30ml detergent, 30ml EHC oil, 30ml of chlorox (NaOCL) in 150ml of water (H_2O)	solidified, no liquid
1-8	15ml mineral spirits, 15ml EHC oil, 36% Boric acid (H_3BO_3) in 150ml of water (H_2O)	solidified, no liquid
1-9	57ml baking soda ($NaHCO_3$) in 150ml of water (H_2O)	started foaming in about 3 minutes, and continued to foam for about 1/2 hour; volume increased to about 300% original volume. Tested for Hydrogen - none present. Eventually solidified, very porous, alot of voids in the solid.
1-10	60ml vinegar in (CH_3COOH) in 150ml of water (H_2O)	solidified, no liquid
1-11	Baking soda ($NaHCO_3$) in EHC oil and water (H_2O)	the mixture foamed as in 1-9 but the volume increased only about 40%; then solidified very porous, solid after about 1 hour.
2-1	28.34gm salt (NaCL) in 60ml of water (H_2O)	solidified, no liquid

APPENDIX 1

TEST #	COMPOSITION	RESULTS
2-2	15ml caustic soda (NaOH 50%) in 150ml of water (H_2O)	solidified, no liquid
2-3	Carbon dust (C) and saw dust (wood particale) in 150ml of water (H_2O)	solidified, no liquid
2-4	Carbon dust (C) and water (H_2O)	solidified, no liquid
2-5	60ml alcohol (C_3H_7OH)	solidified, no liquid however, solids crumbled.

A 1 gallon container containing; floor sweepings, wax, alcohol, EHC oil, motor oil, mineral spirits, water, lye, baking soda, detergent, etc. - solidified, no liquid

APPENDIX 2

Date: ____________________
[illegible]te Tank: ____________________
[illegible] ____________________
Boron ppm: ____________________
Specific Gravity: ____________________
% Oil: ____________________
TEMP: ____________________

P.C.P. SAMPLE TEST WORKSHEET

PCP Sample Code: ____________________
PCP # USED ____________________

SAMPLE	WASTE VOLUME		CEMENT			ADDITIVE #1			ADDITIVE #2			ADDITIVE #3			ADDITIVE #4 pH-adj		
#	mL	T°	gm	pH	T°	gm	pH	T°	gm	pH	T°	gm	pH	T°	mL/gm	pH	T°
1																	
2																	
3																	
4																	
5																	
6																	
7																	
8																	
9																	
[illegible]																	

SAMPLE CONDITION

#	Time Start ______ hr			______ hr			______ hr			______ hr		
	KEY	T°	FSW	KEY	T°	FSW	KEY	T°	FSW	KEY	T°	FSW
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

P = Pourable
PT = Pourable thick
NP = Non-pourable/stirable
FS = Firm soft/cure begins
MH = MED hard/can be probed with resistance
FH = Firm hard/probe with resistance
HH = Hard hard/not probe
FSW = Free standing water

MATERIAL SAFETY DATA SHEET

APPENDIX 3

EFFECTIVE DATE: March 31, 1981

I. IDENTIFICATION

PRODUCT NAME:	NONIONIC SURFACTANT		
CHEMICAL NAME:	Alkyloxypolyethylenoxyethanol	CHEMICAL FAMILY:	Polyethylene glycol ether
FORMULA:	$C_{12-14}H_{25-29}O(CH_2CH_2O)_xCH_2CH_2OH$	MOLECULAR WEIGHT:	~596
SYNONYMS:	Nonionic Surfactant		

DEPARTMENT OF TRANSPORTATION	HAZARD CLASSIFICATION	None
	SHIPPING NAME	None

CAS # 68131-40-8 CAS NAME Alcohols, C_{11-15}-secondary, ethoxylated

II. PHYSICAL DATA

BOILING POINT, 760 mm Hg	> 250 °C (> 482 °F) Dec.	POUR POINT	6 °C (43 °F)
SPECIFIC GRAVITY (H_2O = 1)	1.006 at 20/20 °C	VAPOR PRESSURE at 20 °C	< 1 mm Hg (< 0.13 kPa)
VAPOR DENSITY (air = 1)	> 1	SOLUBILITY IN WATER, % by wt.	Miscible
PER CENT VOLATILES BY VOLUME	Nil	EVAPORATION RATE (Butyl Acetate = 1)	< 0.1
APPEARANCE AND ODOR	Essentially colorless; mild and characteristic odor.		

III. INGREDIENTS

MATERIAL	%	TLV (Units)	HAZARD
Nonionic Surfactant	100	None established	Corrosive to eye Skin irritant

IV. FIRE AND EXPLOSION HAZARD DATA

FLASH POINT [test method(s)]	380 °F, Pensky-Martens closed cup ASTM D 93 470 °F, Cleveland open cup ASTM D 92
FLAMMABLE LIMITS IN AIR, % by volume	Not determined (nonvolatile material)
EXTINGUISHING MEDIA	Use water spray, carbon dioxide, dry chemical, alcohol-type or universal-type foams applied by manufacturers' recommended technique.
SPECIAL FIRE FIGHTING PROCEDURES	Don't spray pool fires directly. A solid stream of water directed into hot, burning liquid could cause frothing.
UNUSUAL FIRE AND EXPLOSION HAZARDS	None

EMERGENCY PHONE NUMBER

304/744-3487

This number is available days, nights, weekends, and holidays.

UNION CARBIDE CORPORATION • ETHYLENE OXIDE DERIVATIVES DIVISION
OLD RIDGEBURY ROAD, DANBURY, CT 06817

APPENDIX 3

[illegible]

TLV AND SOURCE: **None established by ACGIH or OSHA**

ACUTE EFFECTS OF OVEREXPOSURE

SWALLOWING	May cause nausea and vomiting.
SKIN ABSORPTION	Heavy or prolonged exposure may result in the absorption of harmful amounts of material.
INHALATION	None currently known.
SKIN CONTACT	Trace of transient reddening of skin.
EYE CONTACT	Causes severe corneal injury.
CHRONIC EFFECTS OF OVEREXPOSURE	None currently known.
OTHER HEALTH HAZARDS	None currently known.

EMERGENCY AND FIRST AID PROCEDURES

SWALLOWING	Drink 2 glasses of water and induce vomiting by putting finger down throat. Call a physician.
SKIN	Flush with water.
INHALATION	No problems anticipated.
EYES	Immediately flush eyes with plenty of water. Call a physician.

NOTES TO PHYSICIAN

This nonionic surfactant has a relatively low order of toxicity. Treatment would be that for any mild surfactant and is primarily directed at control of symptoms. No specific antidotes are known.

APPENDIX 3

REACTIVITY DATA

STABILITY		CONDITIONS TO AVOID	None
UNSTABLE	STABLE		
--	✓		
INCCMPATIBILITY (materials to avoid)		None	
HAZARDOUS COMBUSTION OR DECOMPOSITION PRODUCTS		Burning can produce carbon monoxide and/or carbon dioxide.	
HAZARDOUS POLYMERIZATION		CONDITIONS TO AVOID	None
May Occur	Will not Occur		
--	✓		

SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IF MATERIAL IS RELEASED OR SPILLED	Wear suitable protective equipment, especially eye protection. Small spills could be flushed to a chemical sewer with large amounts of water. Larger spills should be collected for disposal. Toxic To Fish—avoid discharge to natural waters.
WASTE DISPOSAL METHOD	Incinerate in a furnace where permitted under appropriate Federal, State, and local regulations.

VII SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION (specify type)	None required		
VENTILATION	General room ventilation is satisfactory.		
PROTECTIVE GLOVES	Plastic	EYE PROTECTION	Monogoggles
OTHER PROTECTIVE EQUIPMENT	Eye bath and safety shower		

SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING

Do not get in eyes, on skin, on clothing.
Keep container closed.
Use with adequate ventilation.
Wash thoroughly after handling.

FOR INDUSTRY USE ONLY

OTHER PRECAUTIONS

None

F-43530B
3/81-25M

Printed in U.S.

MATERIAL SAFETY DATA SHEET

CORPORATE RESEARCH & DEVELOPMENT
SCHENECTADY, N. Y. 12305
Phone: (518) 385-4085 DIAL COMM 8*235-4085

MATERIALS · SERVICES · INFORMATION

No. 39

CALCIUM HYDROXIDE

Date October 1978

SECTION I. MATERIAL IDENTIFICATION

MATERIAL NAME: CALCIUM HYDROXIDE

OTHER DESIGNATIONS: Hydrated Lime, High Calcium Hydrated Lime, Caustic Lime, Calcium Hydrate, Slaked Lime, $Ca(OH)_2$, ASTM C259, C53, etc. GE Material D483, CAS# 001 305 620

MANUFACTURER: Material available from many sources, including:

	Telephone		Telephone
Harshaw Chemical Company 1945 E 97th Street Cleveland, OH 44106	(216) 721-8300	Warner Co., Ind. Mineral Division PO Box 448 Bellefonte, PA 16823	(717) 355-4761

SECTION II. INGREDIENTS AND HAZARDS

	%	HAZARD DATA
Typical Composition:*		
Calcium hydroxide, $Ca(OH)_2$	>90	8-hr TWA 5 mg/m^3**
Calcium carbonate, $CaCO_3$	<4	
Magnesium oxide, MgO	<3	
Other oxides (Al_2O_3, Fe_2O_3, SiO_2, etc.)	<3	
*Commercial material prepared by hydration of lime.		Rat, oral LD_{50} 7340 mg/kg
**The current level recommended by ACGIH (1978).		

SECTION III. PHYSICAL DATA

Decomposition point, deg C — 580

Water solubility, g/100 sat. solution:

at 0 C — 0.185

at 25 C — 0.159

at 100 C — 0.071

Specific gravity (H_2O=1) — 2.3-2.4

pH of saturated solution at 25 C — 12.5

Molecular weight $Ca(OH)_2$ — 74.1

Appearance & Odor: Crystals or soft, white powder or granules. Odorless.

SECTION IV. FIRE AND EXPLOSION DATA

Flash Point and Method	Autoignition Temp.	Flammability Limits In Air	LOWER	UPPER

Extinguishing Media: This material is nonflammable. Use extinguishing media which is appropriate for the surrounding fire.

When heated above 580 C, material can decompose to produce CaO. When this material is involved in a fire situation, firefighters should wear full protective clothing, and use eye protection and self-contained breathing apparatus.

SECTION V. REACTIVITY DATA

This is a stable solid in a sealed container at room temperature. When exposed to the air it will absorb carbon dioxide and form calcium carbonate. When heated at temperatures above 580 C, it loses water to form calcium oxide or lime.

Calcium hydroxide is a strongly alkaline material which is incompatible with acidic materials. It forms salts with nitroparaffins in the presence of water which are explosive when dried. It can cause the explosive decomposition of maleic anhydride. Boiling elemental phosphorus in a calcium hydroxide solution can liberate spontaneously flammable phosphines.

GENERAL ELECTRIC

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SECTION VI. HEALTH HAZARD INFORMATION

TLV 5 mg/m^3

This alkaline material in the presence of moisture, is irritating and can be damaging to human tissue. Excessive skin contact will irritate the skin and produce dermatitis. Eye contact gives a burning sensation with irritation and possible injury. Inhalation in dust form is irritating and can be damaging to the mucous membranes of the upper respiratory tract. Do not ingest.

FIRST AID:

Eye contact: Promptly flush with plenty of running water, including under eyelids, for at least 15 minutes; then, get prompt medical attention.

Skin contact: Wash exposed skin with plenty of water. Remove contaminated clothing promptly. Get medical help if exposed area is large or if irritation persists.

Inhalation: Remove to fresh air. Contact physician immediately.

Ingestion: Dilute by giving 2 glasses of water or milk to drink, followed by fruit juice or diluted vinegar to neutralize the alkali; then, consult physician.

SECTION VII. SPILL, LEAK, AND DISPOSAL PROCEDURES

Those involved in clean up of spills should use protective equipment (See Sect. VIII). Pick up spilled powder avoiding dusting conditions and place in a clean steel container for disposal. Safety personnel should be involved when large spills occur. Traces of residue can be flushed to the sewer, but neutralization before flushing may be required.

DISPOSAL: Follow Federal, State and local regulations for disposal. Consider the following methods of disposing of scrap material: Use to neutralize waste acid; or spread on surface of ground in an isolated, protected area to react with CO_2 from the air to form $CaCO_3$ (limestone); or disperse in water, neutralize with hydrochloric acid, precipitate with soda ash, and flush to sewer with much water to keep below 250 mg NaCl/liter.

SECTION VIII. SPECIAL PROTECTION INFORMATION

Provide general ventilation and local exhaust ventilation for dust control (or mist control if used as a water dispersion) to meet TLV requirements. Provide approved dust or mist respirators or self-contained respirators for non-routine or emergency use above the TLV.

Wear rubber gloves, protective clothing, apron, safety glasses or goggles, face shield, etc. to prevent skin or eye contact with this material as required for the conditions under which it is used. An eyewash station and safety shower must be readily available where this material, or its water dispersions, are used.

SECTION IX. SPECIAL PRECAUTIONS AND COMMENTS

Store in cool, dry area in tightly closed container. Protect container from physical damage. Keep away from acidic materials and other incompatibles (See Sect. V).

Prevent contact with the body or inhalation of dust or mist. Use due caution in mixing with water and handling the alkaline water dispersions of this material (milk of lime). Follow good personal hygiene practices.

DATA SOURCE(S) CODE: 1,2,4-9,15,~~16~~

[illegible]

APPROVALS: MIS, CTR.	
Industrial Hygiene and Safety	
Corporate Medical Staff	Geo F. Martin MD

GENERAL ELECTRIC

APPENDIX 3

MATERIAL SAFETY DATA SHEET

CORPORATE RESEARCH & DEVELOPMENT

SCHENECTADY, N.Y.

MATERIALS · INFORMATION · SERVICES

NO. 3

SODIUM HYDROXIDE

Revision A

Date September 1977

SECTION I. MATERIAL IDENTIFICATION

MATERIAL NAME: SODIUM HYDROXIDE
OTHER DESIGNATIONS: Caustic Soda, Soda Lye, NaOH, GE Material D434, ASTM D456,
DESCRIPTION: This material is an anhydrous solid (flake, pellet, etc.) CAS# 001 310 732
MANUFACTURER: Available from many suppliers.

SECTION II. INGREDIENTS AND HAZARDS

SECTION II. INGREDIENTS AND HAZARDS	%	HAZARD DATA
Typical content:		Ceiling Limit
Sodium Hydroxide (NaOH)	96	2 mg/m³
Impurities:		
Sodium Carbonate (Na_2CO_3)	0.5-2.5	
Sodium Chloride (NaCl)	0.01-2.1	
Sodium Sulfate (Na_2SO_4)	0.02-0.1	
Potassium, Calcium and Magnesium	0.1	
Silicon Dioxide (SiO_2)	0.03	
Other metals (total)	0.01	

SECTION III. PHYSICAL DATA

Boiling point, 1 atm, deg C	1388	Vapor pressure, mm Hg @ 1000 C	42
		@ 1200 C	222
Specific gravity (20/4 C)	2.13	Viscosity at 350 C, cps	4.0
Volatiles	non-volatile at room temperature	Water solubility, %, @ 0 C	29.6
		@ 100 C	77.5
Melting point, deg C	318		

Appearance & odor: White or off-white, hygroscopic solid; no odor.

SECTION IV. FIRE AND EXPLOSION DATA

Flash Point and Method	Autoignition Temp.	Flammability Limits In Air	LOWER	UPPER
None - not combustible	N/A	N/A	N/A	N/A

Although it is not combustible, it can be hazardous if present in a fire area. The following should be known for fire fighting: (1) It can melt and flow when heated (m.p. 318 C). (2) Hot or molten material can react violently with water (splattering). (3) Can react with certain metals, such as aluminum, to generate flammable hydrogen gas. (See also Reactivity Data, Section V)

SECTION V. REACTIVITY DATA

It is a stable material under normal conditions of storage. No self-polymerization. No hazardous decomposition products. Slowly it can pick up moisture from the air and react with carbon dioxide from the air to form sodium carbonate.

Sodium hydroxide can react violently with strong acids and with many organic chemicals, expecially with nitrocarbons and chlorocarbons. (Will react with trichloroethylene to form spontaneously flammable dichloroacetylene.) It generates much heat when it dissolves in water.

Avoid contact with leather and wool and with aluminum, tin, zinc, and alloys which contain these metals.

GENERAL ELECTRIC

NO. 3

SECTION VI. HEALTH HAZARD INFORMATION

TLV (Ceiling Value) 2 mg/m3

Sodium hydroxide is a strong alkali and is dangerous when improperly handled. It can be destructive to all human tissue it contacts, producing severe burns. Eye contact can produce severe or permanent injury. Dust or mist inhalation can injure the entire respiratory tract.

FIRST AID

Eye contact - Wash eyes immediately with plenty of running water for no less than 15 minutes, including under the eyelids and all surfaces. Speed in rinsing out the eyes with water after contact is extremely important if permanent injury is to be avoided. Contact physician as soon as possible.

Ingestion - Immediately dilute chemical by drinking large amounts of water or milk, then neutralize with dilute vinegar or fruit juice. Vomiting may occur spontaneously, but do not induce it. Contact a physician promptly.

Inhalation - Remove from exposure to mist or dust and get prompt medical help.

Skin contact - Wash contact area promptly with large quantities of water. (Dilute acetic acid, vinegar, can be used to neutralize.) Remove contaminated clothing under the shower. Prolong washing in serious cases until medical help arrives - even for an hour or longer. Physician should see all cases other than minor exposures to small areas of skin.

SECTION VII. SPILL, LEAK, AND DISPOSAL PROCEDURES

When solid sodium hydroxide is spilled in a dry condition, it can be promptly shoveled up for recovery or disposal. (CAUTION! Avoid dusting. Avoid contact with the skin.) Control the disposal of the waste solid. (Delay in clean up may allow absorption of moisture from the atmosphere and may increase the difficulties of clean up.) Flush contaminated surfaces with water and neutralize with dilute acid, preferably acetic acid, to remove final traces. (Sodium bicarbonate may also be used to partially neutralize.) Finally, rinse with water.

Disposal of waste is greatly dependent on local conditions and requirements. Pre-emergency plans should be made to meet legal and technical requirements. Waste caustic should never be deliberately discharged directly into sewers or surface waters. (First, convert to neutral salts and dilute well with water.)

SECTION VIII. SPECIAL PROTECTION INFORMATION

Provide adequate ventilation to meet TLV requirements, especially where dusting or misting conditions can exist. Use filter-type respirator for mist and dust protection where needed.

Use chemical safety goggles! A plastic face shield can also be used.

Use rubber gloves, rubber apron or protective clothing, rubber boots where needed to prevent contact with sodium hydroxide, especially when solutions are prepared.

Eye wash fountains and safety showers must be immediately available!

SECTION IX. SPECIAL PRECAUTIONS AND COMMENTS

Workers should not be permitted to handle this material without proper training or to work with it without protective equipment.

Store in well-sealed containers. Avoid handling conditions that may lead to spills and leaks, or to formation of mist or dust.

Wherever this material is stored, unloaded, handled or used abundant water (preferably running water) should be available for emergency use.

Drains for storage or use areas for this material should have retention basins for pH adjustment and dilution of spills and flushings before discharge.

This material is classified as a CORROSIVE by the Department of Transportation.

The pellet form is probably the safest solid form for handling and dispensing.

APPROVALS: MIS, CRD J.M.V.

Industrial Hygiene and Safety

MEDICAL REVIEW

APPENDIX 3

MATERIAL SAFETY DATA SHEET

CORPORATE RESEARCH & DEVELOPMENT
SCHENECTADY, N. Y.

MATERIALS INFORMATION SERVICES

NO. 3A
SODIUM HYDROXIDE
50% LIQUID
Date October 1977

SECTION I. MATERIAL IDENTIFICATION

MATERIAL NAME: SODIUM HYDROXIDE, 50% LIQUID
DESCRIPTION: A 50% solution of sodium hydroxide in water
OTHER DESCRIPTIONS: Liquid Caustic Soda, Lye Solution, GE Material D4E4A3
MANUFACTURE: Available from many sources

SECTION II. INGREDIENTS AND HAZARDS

SECTION II. INGREDIENTS AND HAZARDS	%	HAZARD DATA
Sodium Hydroxide (NaOH)	>48.5	TLV 2 mg/m³ (C)*
Typical Major Impurities:		
Carbonate (as Na_2CO_3)	<0.25	
Chloride (as NaCl)	<1.15	
Chorate (as $NaClO_3$)	<0.25	NaOH Solution
Sulfate (as Na_2SO_4)	<0.03	Rabbit, oral LDLo 500 mg/kg
Silica (as SiO_2)	<0.01	
Water	Balance	

*ACGIH recommends no exposure above this ceiling level (C). OSHA has the same TLV but no ceiling level at this time.

SECTION III. PHYSICAL DATA

Initial boiling pt, 1 atm, deg C — ca 140
Vapor pressure (water), mmHg:
at 60 C — ca 13
at 82 C — ca 60
Water solubility — Complete
Spec. grav., 15.6/15.6 C — 1.53
Viscosity at 20 C, cps — 50

Appearance & Odor: A clear liquid, no odor

SECTION IV. FIRE AND EXPLOSION DATA

Flash Point and Method	Autoignition Temp.	Flammability Limits In Air	LOWER	UPPER
None - not combustible				

Use water spray to cool containers of this material which are involved in a fire situation to help prevent rupture.

Sodium hydroxide will react with metals such as aluminum, tin, and zinc to generate flammable and explosive hydrogen gas.

SECTION V. REACTIVITY DATA

This material is stable under normal storage conditions in a sealed container. No polymerization will occur; there are not hazardous decomposition products.

It will react with CO_2 in the air (when exposed) to form sodium carbonate.

It will react violently with acids and with many organic chemicals, especially nitrocarbons, ~~and~~ halocarbons. (Trichloroethylene will react to form spontaneously flammable dichloroacetylene).

Avoid contact with leather and ~~wool and with aluminum,~~ tin, zinc, and alloys which contain these metals.

GENERAL ELECTRIC

NO. 3A

SECTION VI. HEALTH HAZARD INFORMATION

TLV 2 mg/m³ (ceiling for NaOH)

When improperly handled this strong alkali is dangerous. It is destructive of all human tissue it contacts, giving severe burns. Eye contact will produce severe or permanent injury. Inhalation of mist or spray can injure the entire respiratory tract.

FIRST AID:

Eye contact: Wash eyes immediately with plenty of running water for 15 minutes, including under eyelids and all surfaces. Speed in rinsing out eyes is important if permanent injury is to be avoided. Get medical help immediately.

Skin contact: Promptly wash exposed area with lots of water, (Dilute acetic acid or vinegar can be used to neutralize.) Remove contaminated clothing under the shower. Prolong washing in serious cases until doctor arrives - even for an hour or longer. Get medical help for serious exposure.

Ingestion: Immediately dilute by drinking water or milk and then neutralize with dilute vinegar or fruit juice. Contact physician promptly. Vomiting may occur spontaneously., but do not induce it.

Inhalation: Remove from exposure to mist and get prompt medical help.

SECTION VII. SPILL, LEAK, AND DISPOSAL PROCEDURES

Planning ahead essential for handling spills. Personnel working on clean up must use protective clothing and equipment to prevent body contact with the liquid. Abundant running water should be available for emergency use.

Pick up spill with vacuum equipment (alkali resistant) for disposal or flush to holding area with water. Neutralize residues with dilute acid and rinse with water.

Disposal - Dispose of scrap in accordance with pre-emergency planning and local, State and Federal regulations. Waste caustic must never be discharged directly to sewers or surface waters. First convert to neutral salts and dilute well with water. Inform legal authorities of uncontrolled spills.

SECTION VIII. SPECIAL PROTECTION INFORMATION

Provide adequate general ventilation and exhaust ventilation to meet TLV requirements, especially where possibility of mist formation exists. Consider also of mist respirators.

Use chemical safety goggles for eye protection, and, in addition, use a face shield if splashing is probable.

Use rubber gloves, apron or protective clothing, and rubber boots (tops covered by apron or clothing to prevent entrance of caustic).

Eye wash stations and safety showers must be immediately available!

SECTION IX. SPECIAL PRECAUTIONS AND COMMENTS

Do not permit workers to handle this material without proper training or without proper equipment.

Store in well-sealed containers, which are protected from physical damage. Avoid handling conditions which can lead to spills or mist formation.

Have abundant running water available where stored, unloaded or handled. Drains must have retention basins for pH adjustment and neutralization of spilled materials and flushings before discharge.

DOT classification - CORROSIVE LIQUID

[illegible]

APPROVALS: MIS. CRD

Industrial Hygiene and Safety

MEDICAL REVIEW:

APPENDIX 3

Calcium Chloride

CHARACTERISTICS:

Calcium chloride is a powder or coarse granular ("flake") product which is hygroscopic (absorbs moisture from the atmosphere) and highly deliquescent (dissolves in the water absorbed.)

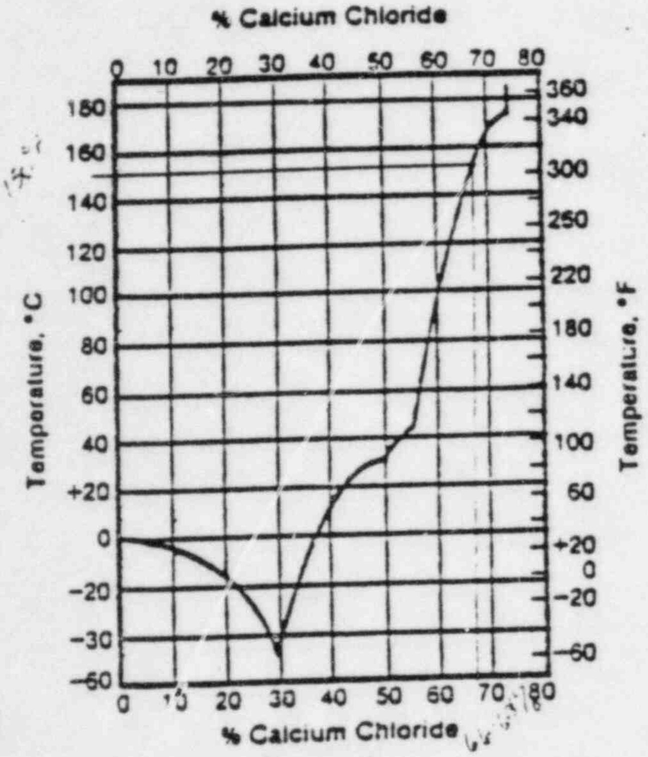
It develops considerable heat of solution when dissolved in water. It forms a eutectic (lowest freezing point) with water at a concentration of about 30% $CaCl_2$ that has a freezing point of about −65° F. It drastically lowers the melting temperature of ice.

PRODUCT MARKETS AND USES:

Market	Use	Reason for use
Building maintenance	Freezeproofing water in fire-pails	Lowers freezing point
Chemical manufacture	Production of calcium salts	Source of calcium
Construction	Cold-weather concrete additive	Accelerates set
	Soil solidification	Solidifies loose, sandy soils when injected together with sodium silicate
	Tractor tire weighting	Freezeproofs water put in tires to improve traction by increasing weight
Drying air and gases	Direct drying compound	Removes moisture by hygroscopicity
Highway construction	Shoulder and base stabilization	Retains moisture which improves compaction of soil
Highway maintenance	Dustlaying	Moisture absorbed from the air prevents dust formation
	Snow and ice control	Melts ice
Mining	Dustproofing and freezeproofing ore and coal	Retains moisture; lowers freezing point of residual water
Paper manufacture	Increases web strength of corrugating media	Provides artificial water hardness that allows web to drain better
Petroleum	Additive to oil well completion fluids	Increases density
	Cementing finished oil wells	Accelerates set of cement
	Drilling mud additive	Reduces shale swelling
	Drying petroleum fractions	Absorbs water
Portland cement manufacture	Additive to kiln feed or fuel to volatilize alkalies	Reduce alkali content of cement to eliminate expansive reactions in finished concrete
Railroad right-of-way maintenance	Weed-killer additive	Prevents weed-killer from drying out and becoming flammable
Refrigeration	Brine ingredient	Calcium chloride brines have low freezing points
Rubber manufacture	Coagulating latex emulsions	Coagulant
Steel and pig iron manufacture	Treatment of pelletized ore and blast furnace additive	Elimination of alkalies that attack furnace refractory
Waste water treatment	Removal of fluorides	Precipitant
	Treatment of oily wastes	Breaks oil emulsions
	Removal of silicates	Densifies floc

PROPERTIES:

	Flake	SUPER FLAKE
Formula	$CaCl_2 \cdot 2H_2O$	$CaCl_2$
Molecular weight	147.02	110.99
Solubility	See Graph	
Heat of solution (approx.), Btu/lb	130	292
pH of 10% solution (approx.)	10.3	10.3



Solubility of Pure Calcium Chloride in Water

METHOD OF MANUFACTURE:

Calcium chloride is a co-product of the ammonia-soda process for the manufacture of soda ash. A process liquor containing calcium chloride is purified, concentrated and solidified on water-chilled rolls to produce the flake product. This is then further processed in a dehydrator to produce SUPER FLAKE™ Anhydrous Calcium Chloride.

GRADES AND FORMS:

Powdered, 77-80%
Flake, 77-80%
SUPER FLAKE, 94-97%
Liquor, 40-45%
Not for food or drug use

TYPICAL ANALYSES:

	Flake	SUPER FLAKE
% Calcium chloride ($CaCl_2$)	77.3	94.9
% Alkali chlorides (as NaCl)	2.4	2.8
Screen analyses (cumulative % on):		
U.S. No. 4	2.4	9.
20	97.0	94.0
30	99.0	95.5

PACKAGES AND SHIPPING CONTAINERS:

Grade	Container	Net Wt.
Powdered	Paper bag	100 lbs
Flake	Paper bag Bulk truck Hopper car Sparger car	25 lbs; 100 lbs
SUPER FLAKE	Paper bag Bulk truck Hopper car Sparger car	80 lbs
Liquor	Tank truck Tank car	

SHIPMENTS:

FOB Syracuse, N.Y.

SHIPPING REGULATIONS:

None

ADDITIONAL INFORMATION AVAILABLE:

Technical and Engineering Service Bulletin No. 16, "Calcium Chloride", Form No. 75-36.
"Better Concrete with SOLVAY Calcium Chloride", Form No. 75-22.

PRODUCT SAFETY INFORMATION:

As with any chemical, calcium chloride requires care in handling. Anyone responsible for the procurement, use, or disposal of the product or its container should familiarize himself and those handling the product with the appropriate safety and handling precautions involved. Such information may be obtained by writing to:

Technical Service
Industrial Chemicals Division
Allied Chemical Corporation
P.O. Box 6
Solvay, New York 13209

In the event of an emergency with this product, call the 24-hour Allied Chemical emergency number: 201-455-2000.

APPENDIX 3

MATERIAL SAFETY DATA SHEET PAGE: 1
DOW CHEMICAL U.S.A. MIDLAND MICHIGAN 48640 EMERGENCY PHONE: 517-636-4400

EFFECTIVE DATE: 06 OCT 80 PRODUCT CODE: 13906

PRODUCT NAME: CALCIUM CHLORIDE 77-80%, DOWFLAKE (R) BULK MSD: 0517

INGREDIENTS (TYPICAL VALUES-NOT SPECIFICATIONS) : % :

CALCIUM CHLORIDE, (CACL2) : 78 :

SECTION 1 PHYSICAL DATA

BOILING POINT: 347F, 175C : SOL. IN WATER: VERY SOLUBLE
VAP PRESS: 1.0 MMHG @ 20C, 68F : SP. GRAVITY: 2. DENS. 55LBS/CU.FT.
VAP DENSITY (AIR=1): ---- : % VOLATILE BY VOL: ABSORBS MOISTURE
APPEARANCE AND ODOR: WHITE TO OFF-WHITE, ODORLESS SOLID FLAKE.

SECTION 2 FIRE AND EXPLOSION HAZARD DATA

FLASH POINT: NOT APPLICABLE : FLAMMABLE LIMITS (STP IN AIR)
METHOD USED: ---- : LFL: NOT APPL. UFL: NOT APPL.
EXTINGUISHING MEDIA: NON-COMBUSTIBLE.
SPECIAL FIRE FIGHTING EQUIPMENT AND HAZARDS: NONE.

SECTION 3 REACTIVITY DATA

STABILITY: WHEN EXPOSED TO ATMOSPHERE CALCIUM CHLORIDE WILL PICK
UP WATER AND FORM A SOLUTION.
INCOMPATIBILITY: METALS WILL SLOWLY CORRODE IN AQUEOUS SOLUTIONS.
HAZARDOUS DECOMPOSITION PRODUCTS: ----
HAZARDOUS POLYMERIZATION: WILL NOT OCCUR.

SECTION 4 SPILL, LEAK, AND DISPOSAL PROCEDURES

ACTION TO TAKE FOR SPILLS (USE APPROPRIATE SAFETY EQUIPMENT): NO SPECIAL
PRECAUTIONS NECESSARY - SWEEP UP AND RETURN TO CONTAINER OR DISCARD.
DISPOSAL METHOD: WASH AWAY WITH LARGE EXCESS OF WATER OR BURY. KEEP
OUT OF DRINKING WATER SOURCES. COMPLY WITH GOVERNMENTAL REGULATIONS.

SECTION 5 HEALTH HAZARD DATA

INGESTION: LOW SINGLE DOSE ORAL TOXICITY. LD50 (RATS) 1300 MG/KG.
EYE CONTACT: MODERATE IRRITATION AND POSSIBLE TRANSIENT CORNEAL INJURY.
SKIN CONTACT: SOLID -- MILD IRRITATION ON DRY SKIN; STRONG SOLUTIONS
CAPABLE OF CAUSING MARKED IRRITATION, EVEN A SUPERFICIAL BURN.

(CONTINUED ON PAGE 2)

(R) INDICATES A TRADEMARK OF THE DOW CHEMICAL COMPANY

MATERIAL SAFETY DATA SHEET PAGE: 2
DOW CHEMICAL U.S.A. MIDLAND MICHIGAN 48640 EMERGENCY PHONE: 517-636-4400

EFFECTIVE DATE: [illegible] OCT 90 PRODUCT CODE: 13906
PRODUCT (CONT'D): CALCIUM CHLORIDE 77-80%, DOWFLAKE (R) BULK MSD: 0517

SECTION 5 HEALTH HAZARD DATA (CONTINUED)

SKIN ABSORPTION: NOT LIKELY TO BE ABSORBED THROUGH THE SKIN IN TOXIC AMOUNTS.
INHALATION: DOW IHG 10 MG/M3 FOR CALCIUM CHLORIDE SOLUTIONS.
EFFECTS OF OVEREXPOSURE: DUSTS MAY BE IRRITATING.

SECTION 6 FIRST AID--NOTE TO PHYSICIAN

FIRST AID PROCEDURES:

EYES: IRRIGATION OF THE EYE IMMEDIATELY WITH WATER FOR FIVE MINUTES IS GOOD SAFETY PRACTICE.
SKIN: IN CASE OF CONTACT, IMMEDIATELY FLUSH SKIN WITH PLENTY OF WATER FOR AT LEAST 15 MINUTES WHILE REMOVING CONTAMINATED CLOTHING. CALL A PHYSICIAN. WASH CLOTHING BEFORE REUSE.
INHALATION: REMOVE TO FRESH AIR IF EFFECTS OCCUR. CONSULT MEDICAL PERSONNEL.
INGESTION: IF SWALLOWED, INDUCE VOMITING IMMEDIATELY BY GIVING TWO GLASSES OF WATER AND STICKING FINGER DOWN THROAT. CALL A PHYSICIAN.
NOTE TO PHYSICIAN:
EYES: MAY CAUSE CORNEAL INJURY OR BURN. STAIN FOR EVIDENCE OF CORNEAL INJURY. IF CORNEA IS BURNED, INSTILL ANTIBIOTIC STEROID PREPARATION FREQUENTLY. CONSULT OPHTHALMOLOGIST.
SKIN: MAY CAUSE MODERATE IRRITATION. TREAT AS ANY CONTACT DERMATITIS. IF BURN IS PRESENT, TREAT AS ANY THERMAL BURN.
RESPIRATORY: MAY CAUSE MILD IRRITATION.
ORAL: LOW IN TOXICITY.
GENERAL: CONSULT STANDARD LITERATURE. NO SPECIFIC ANTIDOTE. TREATMENT BASED ON THE SOUND JUDGMENT OF THE PHYSICIAN AND THE INDIVIDUAL REACTIONS OF THE PATIENT.

SECTION 7 SPECIAL HANDLING INFORMATION

VENTILATION: RECOMMEND CONTROL OF DUST TO COMFORT LEVEL IN WORK AREA OR SOLUTION TO SUGGESTED GUIDE.
RESPIRATORY PROTECTION: IF REQUIRED, USE AN APPROVED DUST RESPIRATOR.
PROTECTIVE CLOTHING: CLEAN, BODY-COVERING CLOTHING. IN ADDITION, GLOVES, BOOTS, APRON DEPENDING UPON THE EXTENT AND SEVERITY OF EXPOSURE LIKELY.
EYE PROTECTION: SAFETY GLASSES WITHOUT SIDE SHIELDS. FOR SEVERE EXPOSURE - CHEMICAL WORKERS GOGGLES.

SECTION 8 SPECIAL PRECAUTIONS AND ADDITIONAL INFORMATION

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE: AVOID EYE AND PROLONGED SKIN CONTACT. ALWAYS USE COOL WATER (TEMPERATURE LESS THAN 80F, 27C) WHEN DISSOLVING CALCIUM CHLORIDE.

(CONTINUED ON PAGE 3)
(R) INDICATES A TRADEMARK OF THE DOW CHEMICAL COMPANY

MATERIAL SAFETY DATA SHEET PAGE: 3
DOW CHEMICAL U.S.A. MIDLAND MICHIGAN 48640 EMERGENCY PHONE: 517-636-4400

EFFECTIVE DATE: 08 OCT 80 PRODUCT CODE: 13906
PRODUCT (CONT'D): CALCIUM CHLORIDE 77-80%, DOWFLAKE (R) BULK MSD: 0517

SECTION 8 SPECIAL PRECAUTIONS AND ADDITIONAL INFORMATION (CONTINUED)

ADDITIONAL INFORMATION: 08 OCT 80 REVISIONS OF 31 MAY 78 --
SECTIONS 1, 4, 5, 6, AND 7.

LAST PAGE

(R) INDICATES A TRADEMARK OF THE DOW CHEMICAL COMPANY

CONSULT THE DOW CHEMICAL COMPANY FOR FURTHER INFORMATION.

THE INFORMATION HEREIN IS GIVEN IN GOOD FAITH, BUT NO WARRANTY,
EXPRESSED OR IMPLIED, IS MADE

APPENDIX 4

WASTE STREAM CHEMISTRY

Date:	Time Sampled:	Tank Sampled:	
Chemistry Tech:	ppm	mg/l	other
Chlorides			
Boron as (H_3BO_3)			
Ammonia			
Soap/Detergents			
Oils			
rganic solvents			
Decontamination solutions			
Neutralized waste (Name of neutralizer)			
Other			

SAMPLE EVALUATION FOR QUALITY ASSURANCE

SAMPLE NUMBER:

DATE:

WASTE STREAM:
(E)

INITIAL TEMP: 0 F C

ppm Boron:

INITIAL pH:

TEMP: 0 F C

ADJUSTED pH:

TEMP: 0 F C

pH adjusted with:

		AMOUNTS gm/ml	TEMP. °F	APPEARANCE Thick, thin lumps, separation	pH Before	pH After			
PORTLAND TYPE I									
MPC-1/OS-1									
LIME									
SODIUM HYDROXIDE									
EMULSIFIER									
ACCELATOR									

VOLUME: START ____________ ML END ____________ ML

RATIOS: $\frac{\text{Liquid Vol}}{\text{Final Vol}}$ x contain vol = Waste vol

$\frac{\text{LV}}{\text{FV}}$ ________ x cv == wv

NOTE: See Appendix 6 for detail

COMPLETE PRODUCT ACCEPTANCE CRITERIA:

DEFECTS IN STRUCTURE:

1. CRACKS: ____________ 2. LUMPS: ____________
3. FOAM: ____________ 4. DRY SPOTS: ____________

UNIFORMITY:

1. COLOR: ____________ 2. GRAININESS: ____________
3. TEXTURE: ____________ 4. ____________

MOISTURE:

1. DRY APPEARANCE: ____________ 2. VOL. ____________ ML

MONOLITH:

1. RESISTANCE TO PENETRATION: ____________
2. FREE STANDING: ____________

NOTES:

A PTED
PRODUCT BY: ______________________________ ____________________
Technician Date

To convert the P.C.P. sample formulas to full scale solidification use the following calculation.

SUMMARY:

A = The volume of P.C.P. liquid additives, to include total volumes of waste, NaOH and other liquid used.

B = The total volume after completed mixing of liquids and dry additive.

C = The VOLUME OF SOLIDIFICATION CONTAINER LESS the freeboard volume. I.E., 55 gal drums contain 54 gal of liquid at 31" height less freeboard height of 1" = 31"-1" = 30" x 1.74 gallon per inch = 52.25 gallons of liquid volume.

D = The volume of accelerator used in test.

E = Total grams of MPC-1, dry product.

F = A ÷ B x C = The total allow waste volume per 55 gallon container 100ml ÷ 144ml x 52.25 gal = 36.28 gal of waste.

WASTE VOLUME

Waste Liquid + Liquid Additives A: ________ML

Final Mixture Volume B: ________ML

Container Volume C: ________gal

Accelerator D: ________grams

MPC-1 E: ________grams

FORMULAS

$$\frac{A:\_\_\_\_\_\_\ \text{ml}}{B:\_\_\_\_\_\_\ \text{ml}} \times C:\_\_\_\_\_\_\ \text{gal} = F:\_\_\_\_\_\_\ \text{gal of waste}$$

$$\frac{F:\ 36.28\ \text{gal} \times E:\ 260\ \text{gm}}{A:\ 100\ \text{ml}} \times 8.33\ \text{conversion factor} = G:\_\_\_\_\_\_\ \text{Total pounds of MPC-1}$$

D: ______gm x 1.700 lb/gm = H: ________lb of Accelerator

Full Scale Volume and Weight

gallons of waste = F: ____________

MPC-1 pounds = G: ____________

Accelerator Pound = H: ____________

APPENDIX 7

SOLIDIFICATION DATA SHEET

LINER DRUM #

DATE OF REQUEST

LINER/DRUM SERIAL #

PCP DATA

TANK

PCP DATE

OF

BATCH #

PCP SAMPLE CODE

OTHER

SAMPLE # USED

* CHEMISTRY DATA

TANK SAMPLED

TEMP OF TANK °C/F

NO. OF VOL. TURNOVERS

TEMP OF SAMPLE °C/F

DATE/TIME SAMPLE PLACED IN REC.

pH (TEMP CORRECTED)

DATE/TIME OF SAMPLE

BORIC ACID CONC PPM

SPECIFIC GRAVITY

ADDITIVE DATA

VOL. OF WASTE

WT OF MPC-1

WT OF WASTE

WT OF ADDITIVE

WT OF LINER

WT OF ADDITIVE #

WT OF ADDITIVE #

TOTAL WEIGHT

DATE WASTE RECEIVED

DATE SOLIDIFIED

* CHEMISTRY DEPT. ANALYSIS DATA

APPENDIX II

Franklin Institute Research Laboratory, Inc.
A Subsidiary of The Franklin Institute

21 December 1983

Bartlett Nuclear, Inc.
P.O. Box 810
10 Aldrin Rd.
Plymouth Industrial Pk.
Plymouth, MA 02360

Attn: Mr. Bruce Bartlett

Dear Mr. Bartlett:

Enclosed please find Technical Report on Concrete Analysis for use as a Matrix for Solidification of Low-Level Radioactive Waste. The four tests indicated that in all cases, the concrete samples supplied by your organization met or far surpassed the criteria boundaries set by the U.S. Nuclear Regulatory Commission.

It is unfortunate that time would not allow us to conduct the remaining three tests required. It is my understanding that the radiation resistance test is to be conducted by a university. Franklin Research Institute Laboratories would like to submit a quote for the remaining two tests, Leachability and Free Liquid Tests. Under separate cover we will propose testing the remainder of the requirements. Thank you for allowing FIRL to be of service to you and hopefully to be able to be of service in the future.

Please accept our holiday greetings for all members of your staff and their families.

Sincerely,

Andrew J. Cassell

Andrew J. Cassell
Sr. Staff Scientist

Enc.

AJC:rm

The Benjamin Franklin Parkway, Philadelphia, Pa. 19103 (215) 448-1000 TWX-710 670 1889

TECHNICAL REPORT

Final Report
A5889

CONCRETE TESTING FOR SOLIDIFICATION OF LOW LEVEL RADIOACTIVE WASTE

by

Andrew J. Cassell

December 15, 1983

Prepared for

Bartlett Nuclear, Inc.
Plymouth, Mass.

Agreement No. 23381-I

Franklin Institute Research Laboratory, Inc.
A Subsidiary of The Franklin Institute

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FIGURES

SECTION A

INTRODUCTION

In accordance with the U.S. Nuclear Regulatory Commission (NRC) technical position (TP) with regard to waste classification and waste form, and the implementation of 10CFR Part 61, solidification of class B and C, wastes may be deemed acceptable by test methods outlined by the NRC.

The seven tests denoted in the notice supplied by the NRC include 1) compression test in accordance with ASTM C39(1) or D621 test methods, 2) radiation stability in the presence of 10^8 rads, 3) biodegradation in accordance with ASTM G21(2) and G22(3), 4) Leachability in accordance with ANS section 16.1, 5) immersion test for a 90 day test and compression stability, 6) thermal cycling in accordance with ASTM B553(4) test method, and 7) free liquid in accordance with ANS 55.1.

In accordance with the TP issued by the NRC, the Bartlett Nuclear Corp. of Plymouth, Mass. and Columbia, S.C. approached FIRL, Inc. of Philadelphia, PA to undertake the testing of special concrete material to be used as the matrix for solidifying class A, B and C low level rad waste which will be acceptable for near-surface disposal. Discussion of the test samples of the concrete matrix will be covered in the section of this report titled Procedure. It is the intention of this testing to report on the final results of each test performed and in no way issue a certification of acceptance.

Of the total of seven tests recommended by the Nuclear Regulatory Commission, Franklin Research Laboratory, Inc. has undertaken the analysis of four of these tests. The remaining three, #2-Radiation stability, #4-Leachability and #7 Free Liquid could not be performed in the allotted time period required by Bartlett Nuclear. It is recommended that these three tests be conducted some time in the near future under the guidance of FIRL, Inc.

The report is divided into three sections, (A) Introduction, (B) Procedures and (C) Results for the following examinations:

1) Compression Test per ASTM-C39
2) Biodegradation - Resistance of concrete to fungi per ASTM-G21
2A) Biodegradation - Resistance of concrete to bacterial growth per ASTM-G22

3) Immersion Test - Compression after 90 days immersion
(Procedure provided per FIRL, Inc.)

4) Thermal Cycling - per ASTM B553

Appendix A of this report contains copies of each of the ASTM recommended practices utilized in the testing of concrete samples. Photographs taken of each test performed are located at the end of each section, (C) Results.

(1), (2), (3), (4) Recommended practices outlined in ASTM Publications are located in Appendix A, of this report.

SECTION B

PROCEDURE:

1) Compression test for the concrete matrix was performed in accordance with ASTM C39-79. Three molded cylinders were prepared by Bartlett Nuclear. Each cylinder measured 6" dia. x 12" long and were aged for not less than 10 days prior to testing. Specimens were identified as 1-1, 1-2 and 1-3. Accurate measurements of the specimens were determined by micrometric method. Average values of the three specimens are stated in results section. A copy of ASTM specification C-39 appears in Appendix A. Two of the three specimens were moisture cured for a period of 72 hours prior to the compression test, specimens 1-1 and 1-2. Following the curing period the two specimens were then tested for compression capabilities. The third specimen was maintained as control (1-3). During the compression testing, the relative humidity, surrounding the specimens, was maintained between 75-85%. Each specimen undergoing compression test was tested with a load of 50 psi (0.3MPa) and visual examination conducted. Additional loading on each specimen was made and the point where failure occurred was noted in the section on results. The type of failure and general appearance of the concrete has been noted. A copy of ASTM specificiation C-39 appears in Appendix A.

2) Determination of the resistance of concrete material to fungi according to ASTM G21. A total of twenty (20) specimens were selected for this test. Each of the specimens are rectangular casts, 7" long x 1" wide x 3/8" high. All twenty sample are conditioned in an ethylene oxide atmosphere for 2 hours, to remove any inhibited fungi which may be present during manufacturing of the cement.

Five of the specimens are set aside as control (in air) for comparison of the final test specimens. Fifteen of the specimens are then placed in contact with agar solution which were obtained from a biological supply house and was prepared according to the formula in ASTM G-21. The agar is placed in a glass dish and allowed to solidify. Following solidification of the agar, place 5 specimens onto the surface of the agar and inoculate the surface of the specimens with the composite spore suspension which was purchased from the American Type Culture Collection, Wash., D.C., and prepared, according to procedures in ASTM G21, 2 days prior to fungi testing and held in refrigeration. Inoculation of the test specimens, in contact with the agar, is obtained by spraying the spore suspension onto the exposed surface of the specimens, assuring that all surfaces are moistened with the fungi spores.

The glass dish is then covered and the five inoculated test specimens are allowed to incubate at 28°-30°C, and relative humidity not less than 85%, for a period not less than 21 days. Recording of any growth shall be reported weekly. Since this is a go-no go growth determination, recorded growth observation shall be rated from "0", no growth to "4", heavy growth, as described in the results.

Results shall include, a) organisms used, time of incubation, visual rating of fungus growth, description of any physical changes, and the number of observations and the time of observation from the onset of the test. Five specimens are placed on a solidified surface with no inoculation with the fungus spores. These 5 specimens are a control lot to assure that a non-growth of the specimen, while in contact with the agar, does not take place. A copy of ASTM specification G21 is located in Appendix A of this report.

2A) Determination of the resistance of concrete to bacteria in accordance with ASTM-G22.

Five specimens are selected at random for testing of resistance to bacteria. Five additional samples are selected as control specimens. Each of the specimens used is a rectangular casted piece, with dimensions of 7" long x 1" wide by 3/8" high. Test specimens and control specimens are placed in a suitable desiccator and the air evacuated. A cylinder of ethylene oxide is attached to the desiccator and the gas allowed to fill the volume occupied by the evacuated air. The specimens are allowed to be exposed to the ethylene oxide for two hours in order to destroy any residual bacteria that may have been present under normal conditions. Preparation of agar solution shall be the same as test No. 2 for fungi resistance testing. The bacterial cell suspension was prepared by obtaining the required organism from a suitable biological supply house and prepared according to required culture media in ASTM G-22. The bacterial specimens and control test specimens are placed in sterile glass dishes which have sufficient seeded agar layers (1/4" to 1/2" thick) that has been allowed to solidify. The uninoculated control specimens are placed in an environmental chamber along with the glass dish containing the inoculated specimens. A volume of bacterial cell suspension sufficient to yield approximately 50,000 viable cells/ml. constitutes the culture inoculant. The culture dishes are covered and incubated at 35°C (98°F) in a relative humidity atmosphere of not less than 85% for a minimum of twenty-one days. Observations are made during the incubation period. Results shall include organism used, time of incubation, visual rating of bacterial growth (judged as growth or no growth), number of observations made during incubation period, and any observed changes other than bacterial growth by comparison to control specimens. (A copy of ASTM-G22 is located in Appendix A of this report).

3) Immersion - Six specimens of the precasted concrete, in rectangular form, are selected for this test and examination. The specimens are carefully weighed within 0.001 grm accuracy. The six specimens are then cut in half representing six immersion test specimens to be tested and six control specimens. The pieces are identified and reweighed again. The test specimens are placed in a glass dish which will accommodate the 6 specimens. Water is added to the dish to a level where the water covers the specimens to a point not less than 1/4" above the specimens.

The glass dish is covered and allowed to stand, maintaining surveillance so that the water level does not go below the 1/4" coverage. The specimens are allowed to be immersed for a period of not less than 90 days. At the end of the 90 day immersion, the specimens are removed, stood on one end for period of 2 hours and then measured for final weight. Comparison of dry weight and final weight, against control specimens, will give a value of absorptivity. A compression test is then conducted to assure the specimens will withstand 50 psi (0.3MPa). Apply load to the specimens until failure occurs noting the type of failure and appearance of the concrete, if failure occurs.

) Thermal Cycling - Three specimens were precasted by Bartlett Nuclear Corp. The specimens shall be 6" right cylinders which have been allowed to age for a period of 10 days. Accurate measurements are taken of the three specimens including average diameter and average height. Existing conditions of the three cylinders shall be made and any preexisting conditions shall be noted.

The thermocouples to be used in the environmental chambers shall be calibrated prior to starting thermal tests. Each thermocouple shall be immersed in boiling water and ice water for 100°C and 0°C calibration. The environmental chamber shall be calibrated during one complete cycle. An accurate precalibrated centigrade thermometer is placed in the chamber and readings taken at +22°C, +60°C and -40°C for accuracy determination.

Two of the three cement test specimens shall be identified for visual identification during the test cycles and introduced into the environmental chamber and allowed to rest on a stainless steel meshed plate. The chamber temperature is then increased to 60°C and maintained at this temperature for 1 hour. Allow the test chamber to return to 22°C, as quickly as possible and hold at this temperature for 1 hour. Reduce the specimen temperature to -40°C and hold for one hour. This procedure constitutes one (1) full thermal cycle. The test for this evaluation shall consist of 30 full cycles. At the end of the 30 cycle period remove the samples from the environmental chamber and remeasure the physical size of each specimen. Following this step in the evaluation, prepare the three samples for compression testing. Determination shall be made that the test specimens maintain integrity under compression of 50 psi (0.3MPa). Results of this test shall include, the number of cycles performed, chamber loading calibration of controller and recorder, and physical distortions following compression test (Copy of ASTM B553 may be found in Appendix A of this report).

SECTION C

C. RESULTS

1.0 Test #1 - Compression Strength of Cylindrical Concrete Specimens

1.1 The test performed on concrete specimens supplied by Bartlett Nuclear Corporation was conducted in accordance with American National Standards Institute/American Society for Testing and Materials (ANSI/ASTM) 39-72.

1.2 The three specimens were identified and physical measurements taken as follows:

#1 (Test Specimen)	#2 (Test Specimen)	#3 (Control)
Bottom Dia. = 6.10" (15.49 cm)	Bottom Dia. = 6.01"(15.26 cm)	Bottom Dia. = 6.05" (15.37 cm)
Middle Dia. = 6.13" (15.57 cm)	Middle Dia. = 6.01"(15.26 cm)	Middle Dia. = 6.03" (15.32 cm)
Top Dia. = 6.09" (15.46)	Top Dia. = 6.04" (15.34 cm)	Top Dia. = 6.02" (15.29 cm)

1.3 Cylinder length = Avg. of ten readings per specimen = 11.98 inches (30.43 cm) control
11.92 inches (30.28 cm) #2
11.90 inches (30.23 cm) #3

1.4 Cross-sectional Area -

#1	#2	#3
Top - 29.2 in^2(188.4 cm^2)	Top - 28.27 in^2(182.4 cm^2)	Top - 23.27 in^2(182.39cm^2)
Bottom -29.2 in^2(188.4cm^2)	Bottom -28.65 in^2(184.8cm^2)	Bottom-28.75in^2(192.41cm^2)

1.5 Compression load for USNRC acceptance:

#1	#2
1460 lbs.	1425.5 lbs.
(equivalent to 50 psi)	(equivalent to 50 psi)

Results: Neither specimen, #1 nor #2, failed at 50 psi. Compression was continued until physical defects were observed:

Specimen #1		Specimen #2	Specimen #3
1st crack indication	34,000 lbs. (1164 psi)	1st crack indication	36,000 lbs. (1264 psi)
Spalling	41,000 lbs. (1404 psi)	Spalling	49,000 lbs. (1721 psi)
Total Failure	74,600 lbs. (2555 psi)	Total failure	69,800 Lbs. (2453 psi)

1.6 Specimens were aged 18 days prior to compression test.

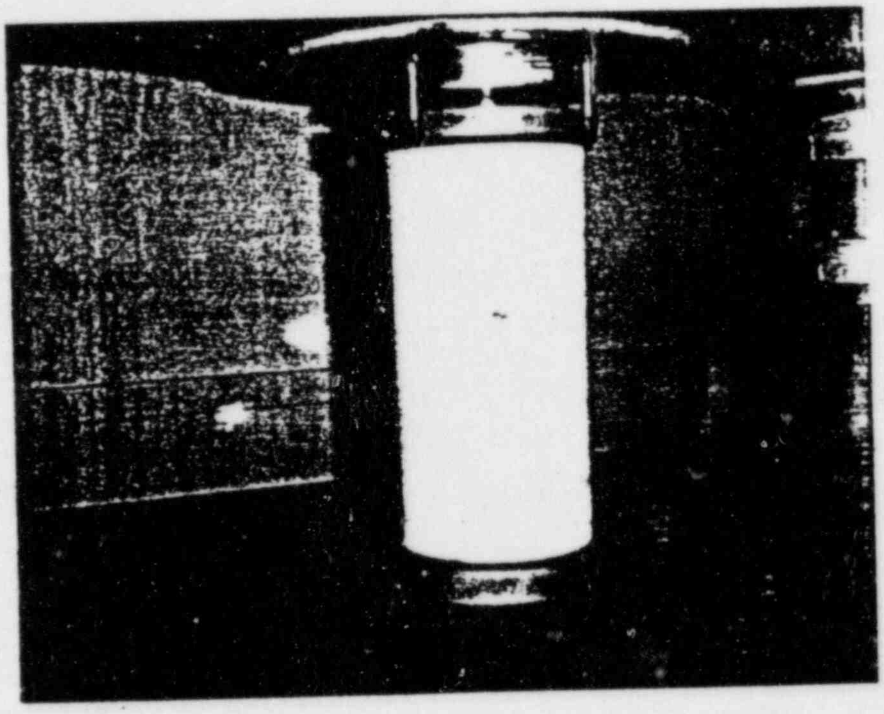

Fig. 1-1 Test Specimen #1 at 50 PSI

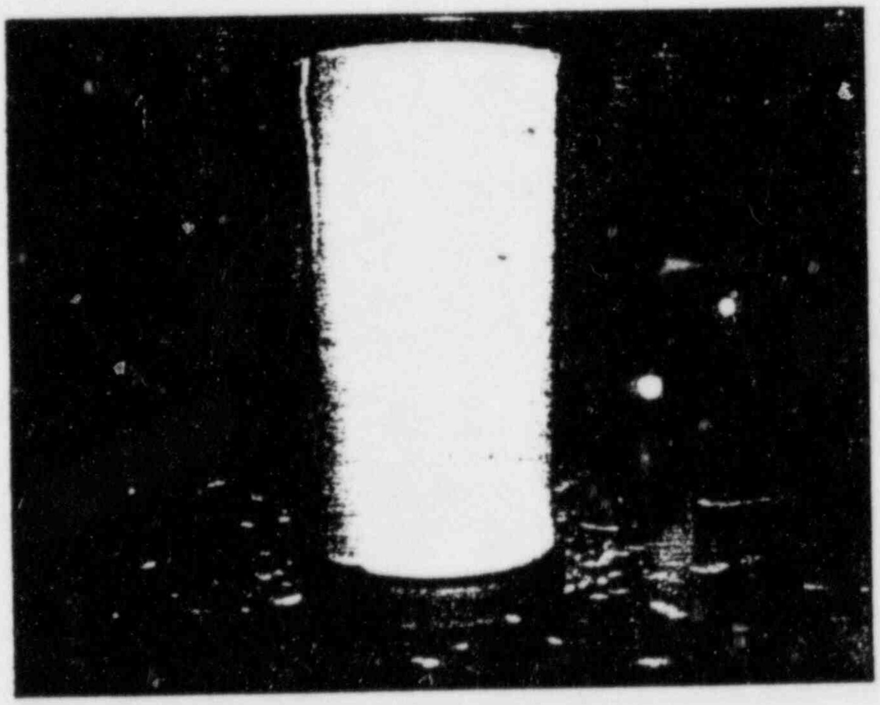

Fig. 1-2 Test Specimen #1 Spalling Indication

Fig. 1-3 Test Specimen #2 at 50 PSI

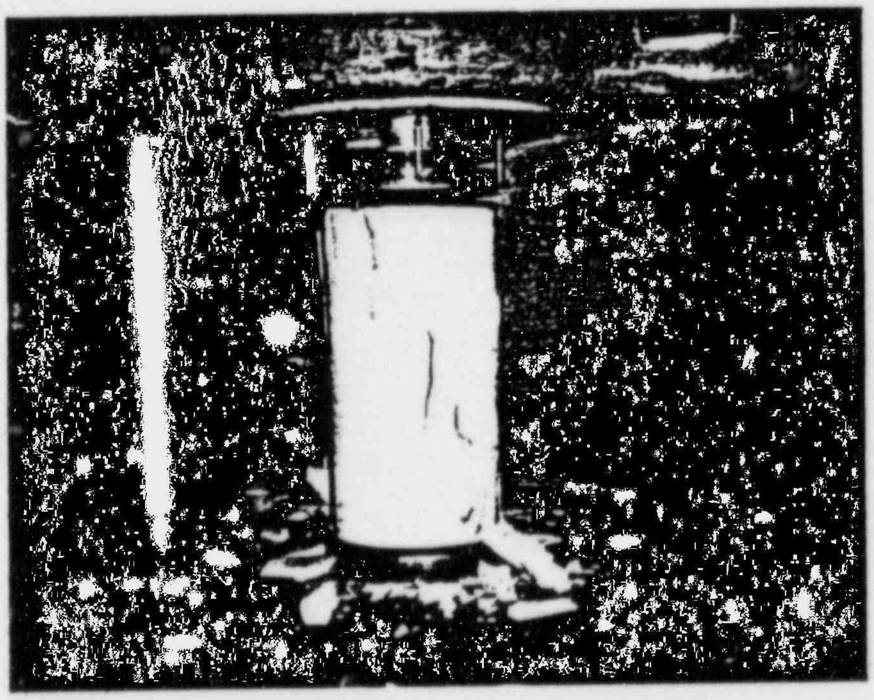

Fig. 1-4 Test Specimen #2 Total Failure

C. RESULTS

2.0 Test #2 - Determination of resistance of concrete to fungi.

2.1 The tests performed on concrete specimens supplied by Bartlett Nuclear Corp. was conducted in accordance with American Society of Testing and Materials (ASTM) G21-70.

2.2 Preconditioning - twenty specimens were exposed to ethylene oxide gas for 3 days. The preconditioning was conducted in a chemical dessicator by evacuating the dessicator and introducing the ethylene oxide which was allowed to react on any natural fungi which may have been present during casting and solidification of the concrete specimens.

2.3 The following test fungi were ordered from the American Type Culture Collection, Washington, D.C.:

Nomenclature	ATCC No.
1. ASPERGILLUS NIGER	9642
2. PENICILLIUM FUNICULOSUM	9644
3. CHAETOMIUM GLOBOSUM	6205
4. TRICHODERMA SP	9645
5. PULLULARIA PULLULANS	9348

2.4 Preparation of Nutrient-salts agar was made according to the following chemical compound formula:

Potassium dihydrogen orthophosphate (KH_2PO_4)	0.7 grm
Potassium monohydrogen phosphate ($KHPO_4$)	0.7 grm
Magnesium Sulfate ($MgSO_4.7H_2O$)	0.7 grm
Ammonium Nitrate (NH_4NO_3)	1.0 grm
Sodium Chloride (NaCl)	0.005 grm
Ferrous Sulfate ($FeSO_4.7H_2O$	0.002 grm
Zinc Sulfate . $7H_2O$	0.002 grm
Manganous Sulfate ($MnSO_4.7H_2O$)	0.001 grm
Agar	15.000 grms

pH adjusted to 6.35

Sufficient Nutrient-Salt agar prepared for both fungi and bacterial resistance tests.

2.5 Each test fungi was prepared according to ASTM-G21 procedures and spore suspension content measured for concentration. The five spore solutions averaged $1.02 \times 10^6 \pm 0.2 \times 10^6$ spores/ml.

2.6 Five control fungi dishes were prepared for viable control observation. Hardened nutrient-salts agar were inoculated with the mixed spores solution and incubated at 30°C (86°F) at a relative humidity of not less than 85%. Control specimen dishes were observed after 14 days incubation period. Fungi growth was observed in all cases. (See photo at end of this result analysis).

2.7 A single specimen test dish was prepared for the test specimens. Solidified nutrient-salts agar was prepared and 5 concrete specimens positioned on the hardened agar surface. Each specimen was inoculated with the mixed spore suspension, assuring that all surfaces including nutrient-salts agar were adequately covered with mixed spore suspension.

2.8 Observation:

	Sample Tray #1 (control)	Sample Tray #2 (test specimens)
Day 2	No growth	No growth
Day 8	No growth	No growth
Day 15	No growth	No growth
Day 21	No growth	No growth

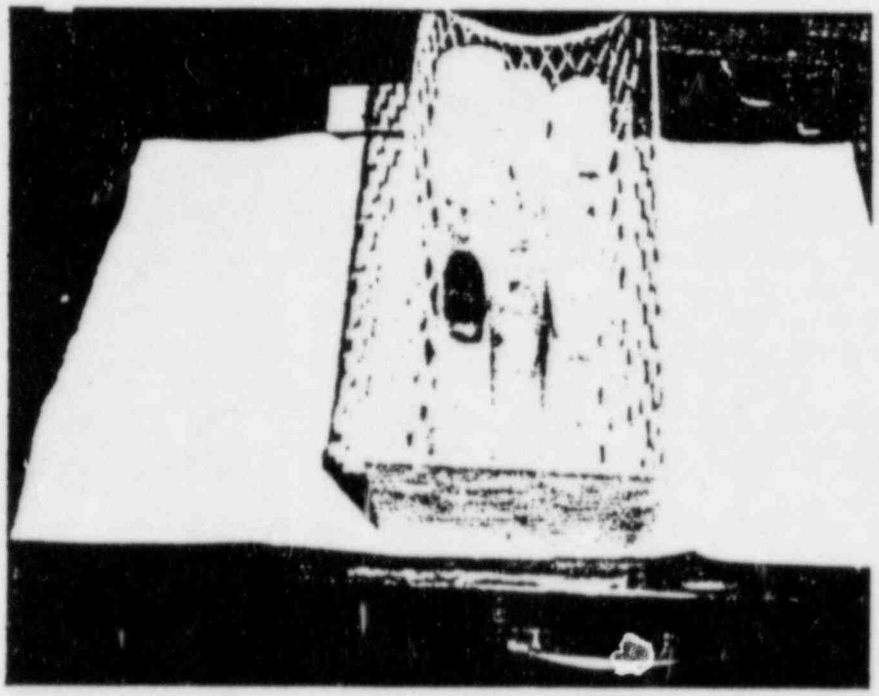

Fig. 2-1 Viable Fungus Spore Slants
Spores Nos. 1, 2 and 3

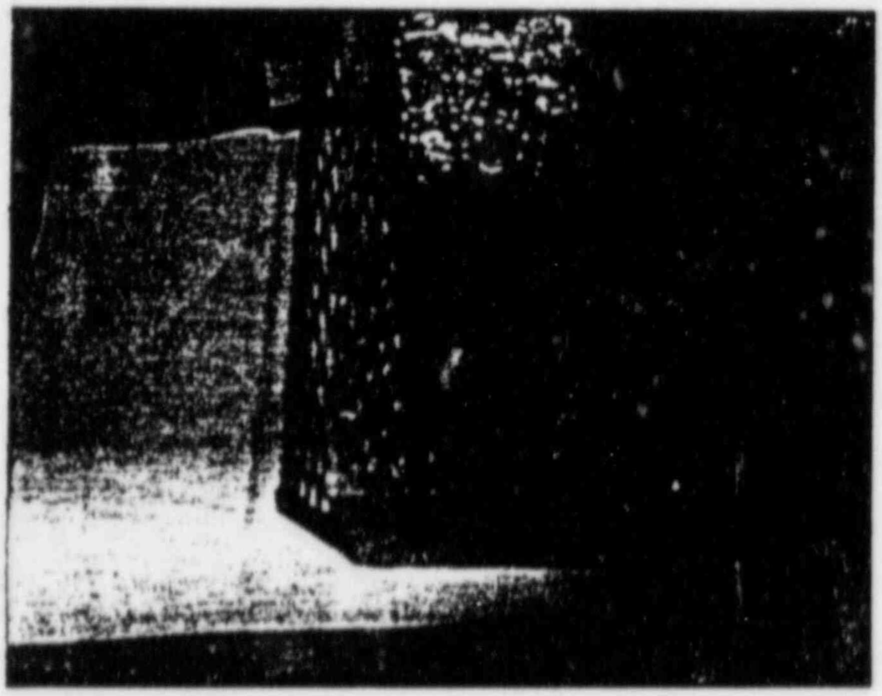

Fig. 2-2 Viable Fungus Spore Slants
Spore Nos. 1, 4 and 5

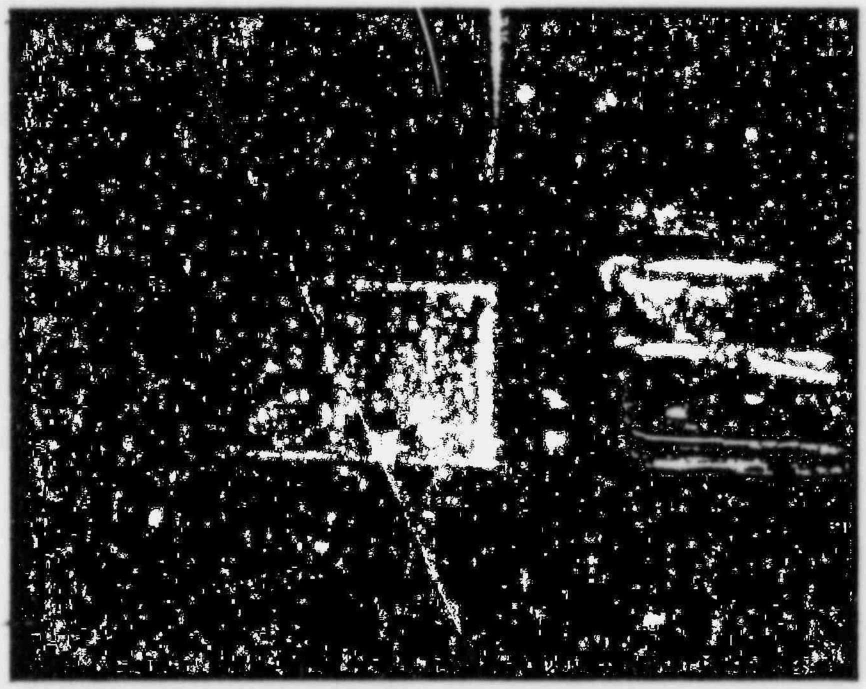

Fig. 2-3 Incubation Dish with Viable Fungus Growth in Separate Dishes

A5889

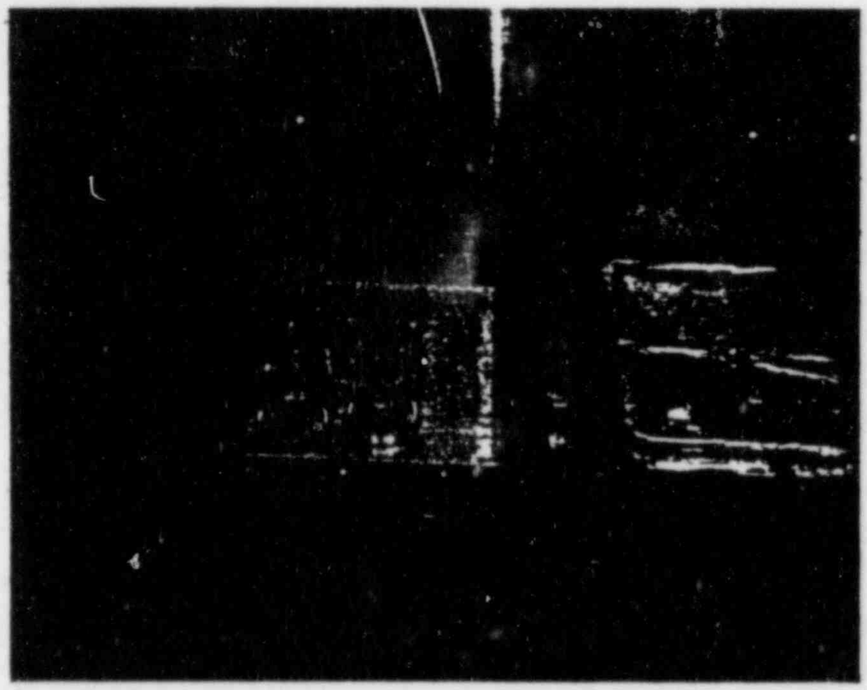

Fig. 2-3 Incubation Dish with Viable Fungus Growth in Separate Dishes

#1, #2 and #3 sample dishes were covered with plate glass, taped. Closed and maintained at 35 to 37°C (95 to 98.6°F) for a period of twenty-one days. Required humidity, not less than 85%, should be present in the elevated temperature while the sample dishes are maintained with a sealed cover.

A.4.4 Observation:

	Tray #1 (Control)	Tray No. 3 (Test Specimens)
Nov. 8	No growth	No growth
Nov. 10	Slight growth	No growth
Nov. 12	Moderate growth	Very slight growth (on agar base only)
Nov. 18		No growth
Nov. 25		No growth
[illegible]c. 1		No growth

2A.4.5 Observations were taken on surfaces and beneath specimens. The major observation was made at the contact point between specimens and the nutrient-salts agar gel. Observation of the potential effected area in the test specimens dish was made with a 10X magnification. Observation of the control dish was made with no magnification.

2A.4.6 Conclusion:

The concrete test specimens did not support bacterial growth under the recommended conditions. Control dish assured that bacterial suspension was active and supported growth.

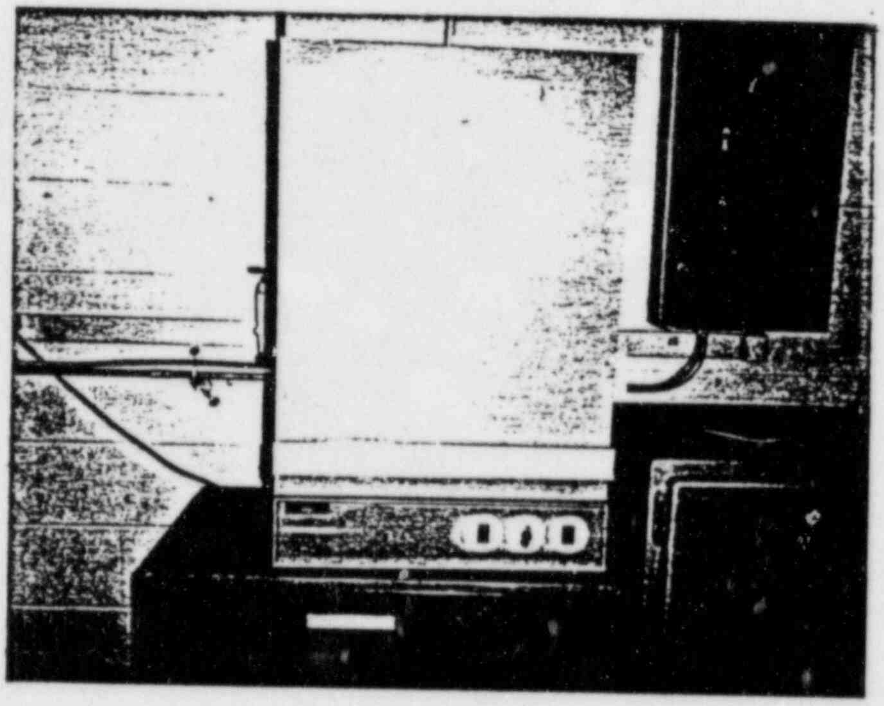

Fig. 2A-1 Humidity Chamber for Bacterial Degradation Test

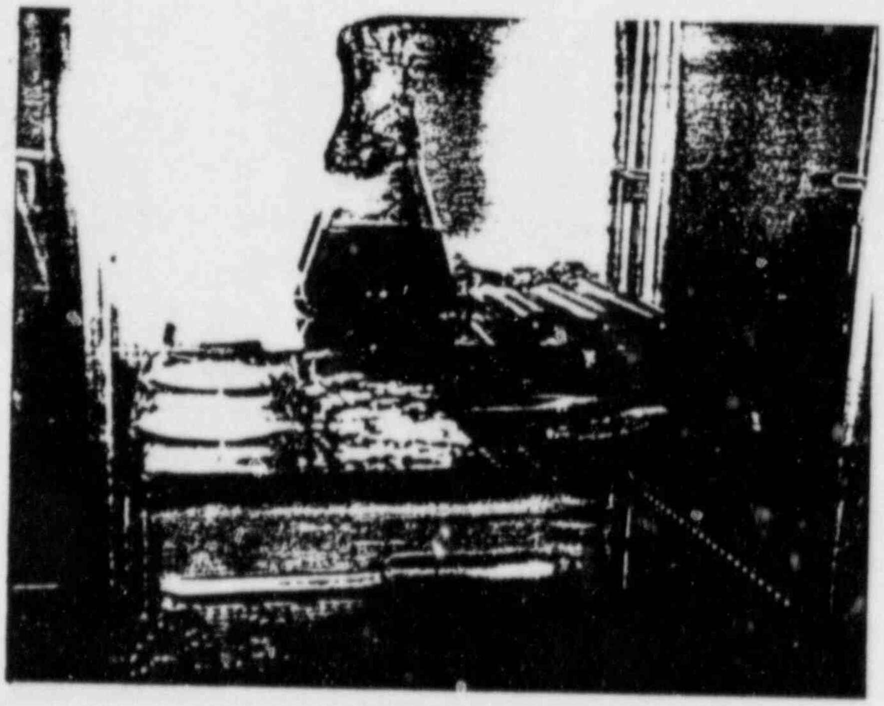

Fig. 2A-2 Nutrient Agar Salt - Media for Bacterial Growth

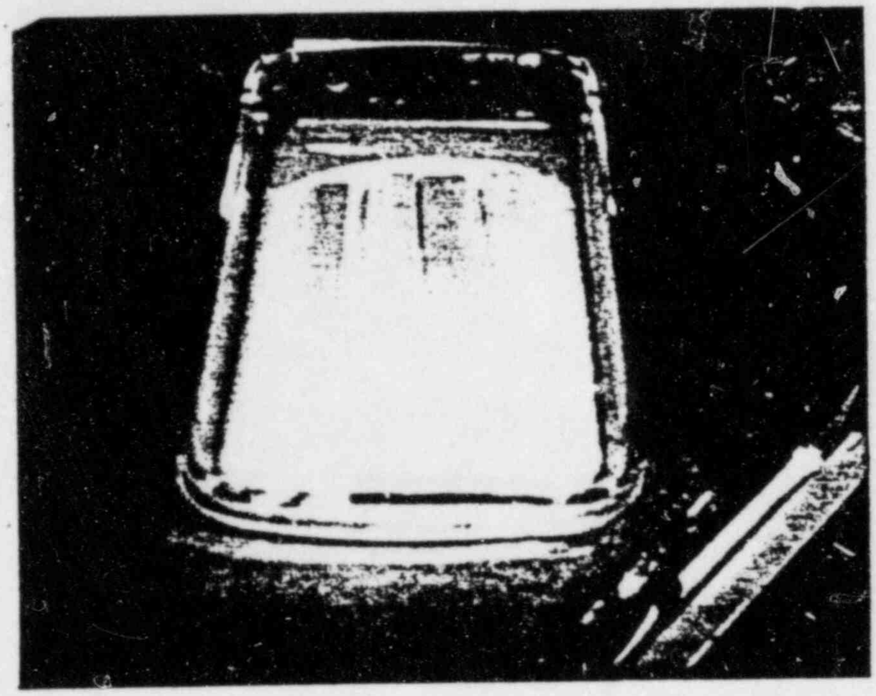

Fig. 2A-3 One Week Bacterial Culture Growth on Test Specimens

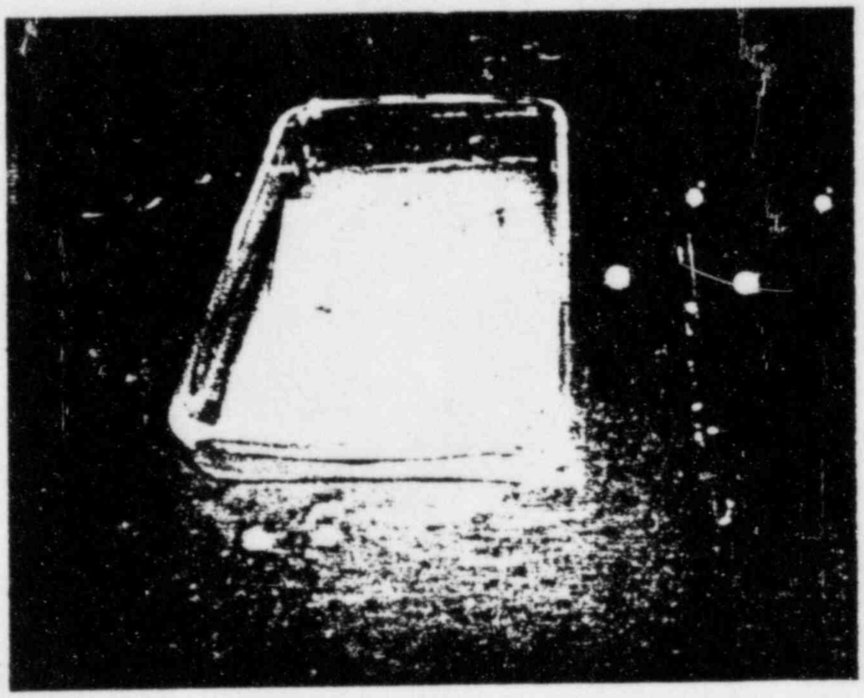

Fig. 2A-4 Two Week Bacterial Culture Growth on Test Specimens

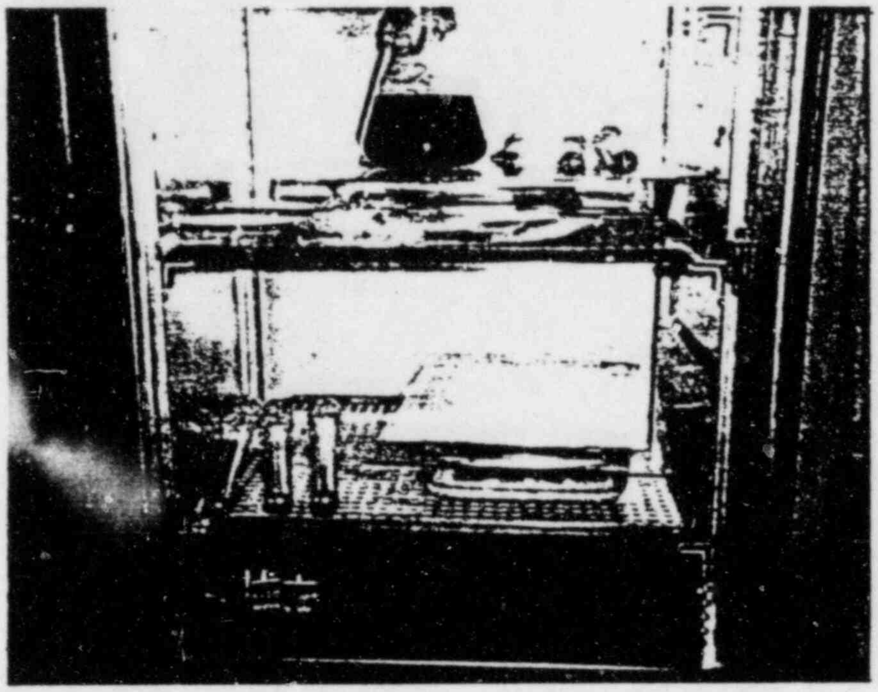

Fig. 2A-5 Viable Growth Slant Sample with Test Specimen Trays

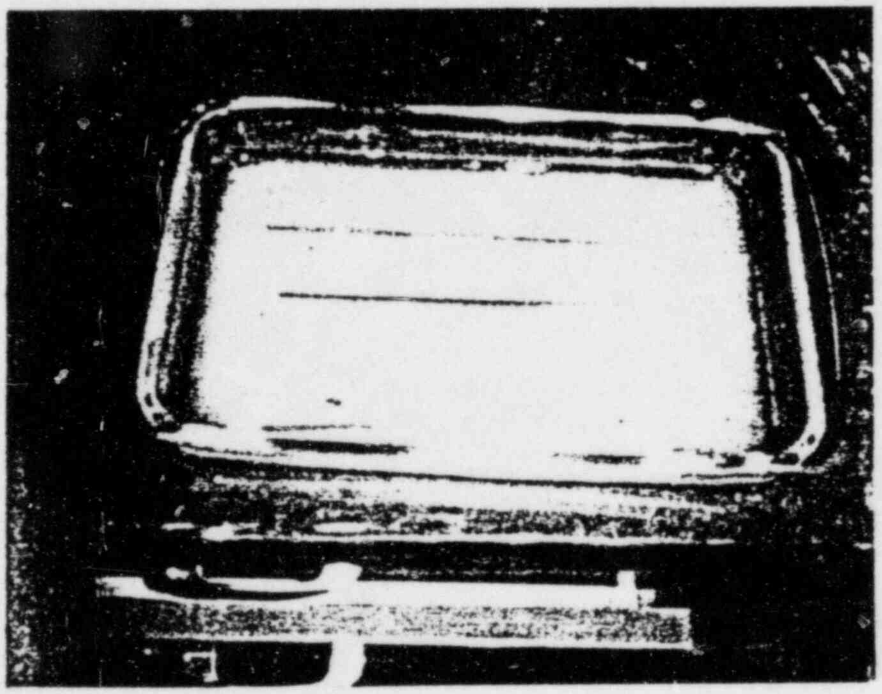

Fig. 2A-6 Three Week Bacterial Culture Growth on Test Specimens

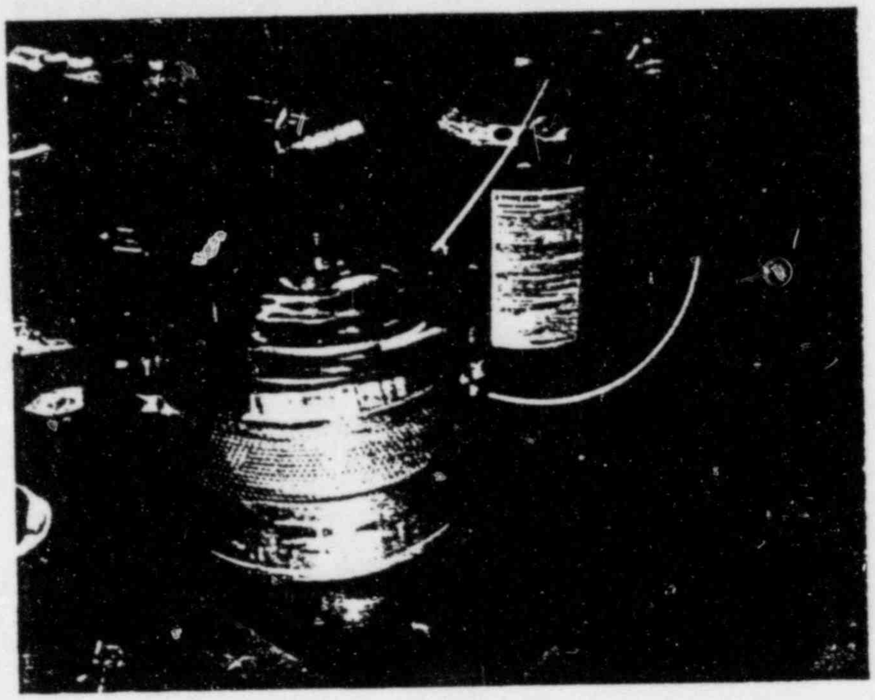

Fig. 2A-7 Sterilization of Test Specimens - Ethylene Oxide Treatment

C. RESULTS

3.0 Test #3 Immersion Test

Since USNRC does not provide guidance for immersion testing in their technical position for implementation of 10CFR Part 61, FIRL, Inc. has conducted this test according to previous recommended tests performed on other cement matrix for immersion testing.

3.1 Test specimens (6 total) were identified from #1 thru #6.
Control specimens were identified as A thru F.

Wt. of Control Specimens	Wt. of Test Specimens
A. 34.656 grms	1. 34.624 g
B. 34.915 grms	2. 34.957 g
C. 34.424 grms	3. 34.393 g
D. 33.905 grms	4. 33.873 g
E. 39.259 grms	5. 39.227 g
F. 39.505 grms	6. 39.534 g

3.2 Observation during immersion testing

Sept. 9 1st week - small particulates floating on water surface
Sept.16 2nd week - slight increase in particulate matter
Oct. 7 5th week - filtered water solution and collected particulate matter. Immersion bath, 100% new supply of water
Oct.20 7th week - very small particle suspension on water surface
Nov. 4 9th week - no obvious change in immersion bath
Nov.17 11th week -no obvious change
Dec. 2 13th week -no obvious change

3.3 pH measurement during immersion testing:

1st week - pH = 7.6
5th week - pH = 7.85
10th week - pH = 7.95
13th week - pH = 7.90

3.4 Particulate matter removed from immersion bath during 5th week visual examination, filtered, dried and weighed:

wt. of particulate matter - 1.43 grms

% loss of total mass of concrete in immersion bath - 0.67%

11th week - Particulate matter removed during visual examination:

wt. of particulate matter - 0.255 grms

total % loss of mass of concrete after 11 weeks

immersion testing - 0.11 + 0.67 = 0.78%

loss during 5 weeks immersion - 0.67%

loss after 11 weeks immersion = 0.11%

Total loss after 11 weeks = 0.78%

Calculated weight after 11 weeks immersion (accounting for avg. loss)

Test Samples	Loss	Final Wt.
1. 34.624 x 0.0078 =	0.270 grm =	34.354 grms
2. 34.957 x 0.0078 =	0.273 grm =	34.684 grms
3. 34.393 x 0.0078 =	0.286 grm =	34.107 grms
4. 33.873 x 0.0078 =	0.264 grm =	33.609 grms
5. 39.227 x 0.0078 =	0.306 grm =	38.921 grms
6. 39.534 x 0.0078 =	0.308 grm =	39.226 grms

3.5 Wt of specimens after 90 days immersion test.

(Test Specimens)	(Control)
1 35.067 grams	A. 34.657
2 35.76[illegible] gms.	B. 34.915
3 35.302 gms.	C. 34.425
4 34.580 gms.	D. 33.906
5 40.145 gms.	E. 38.259
6 40.391 gms.	F. 39.505

Observation: All specimens were unchanged in their physical appearance. No swelling, no deformity of size, no surface changes; only obvious change was coloration. Specimens appeared to be slightly darker in gray color than previously observed prior to immersion in water.

3.6 Moisture Retention after 72 hrs. AIR drying:

	Final Wt. cms.	Calculated Avg. Wt. (with particulate loss)	Water Retention (gms.)	% Retention
1.	35.067	34.354	0.7137	2.08
2.	35.750	34.684	1.071	3.08
3.	35.302	34.107	1.195	3.50
4.	34.580	33.609	0.971	2.89
5.	40.145	38.921	1.224	3.14
6.	40.391	39.226	1.165	2.97

3.7 Compression test on 90 day immersion specimens

	Surface Area of Specimen	(50 psi)
1	3.591" x 0.981" = 3.523 in^2	176.2 lbs. load
2	3.464" x 0.987" = 3.419 in^2	171.0 lbs. load
3	3.497" x 0.980" = 3.427 in^2	171.4 lbs. load
4	3.502" x 0.989" = 3.463 in^2	173.2 lbs. load
5	3.526" x 0.985" = 3.473 in^2	173.7 lbs. load
6	3.500" x 0.989" = 3.462 in^2	173.1 lbs. load

All specimens passed the compression test at 50 psi (0.3MPa)

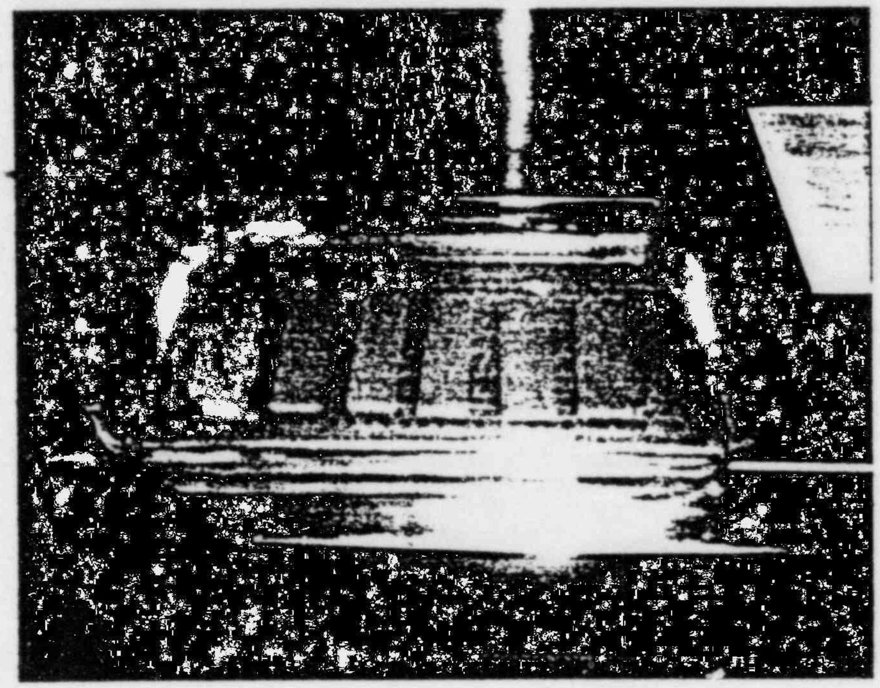

Fig. 3-1 Immersion Bath After Fifth Week

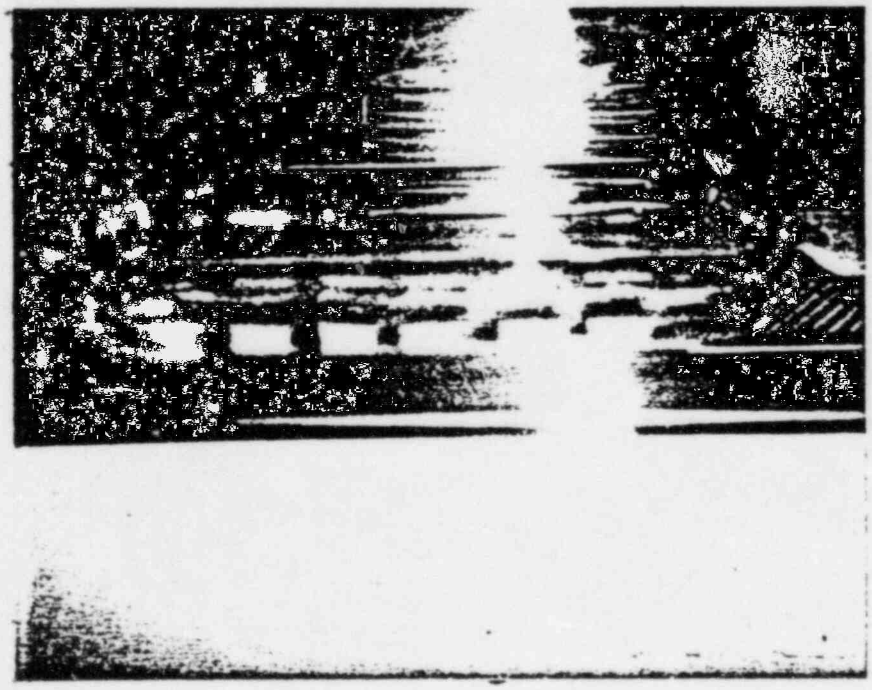

Fig. 3-2 Immersion Bath After Eleventh Week

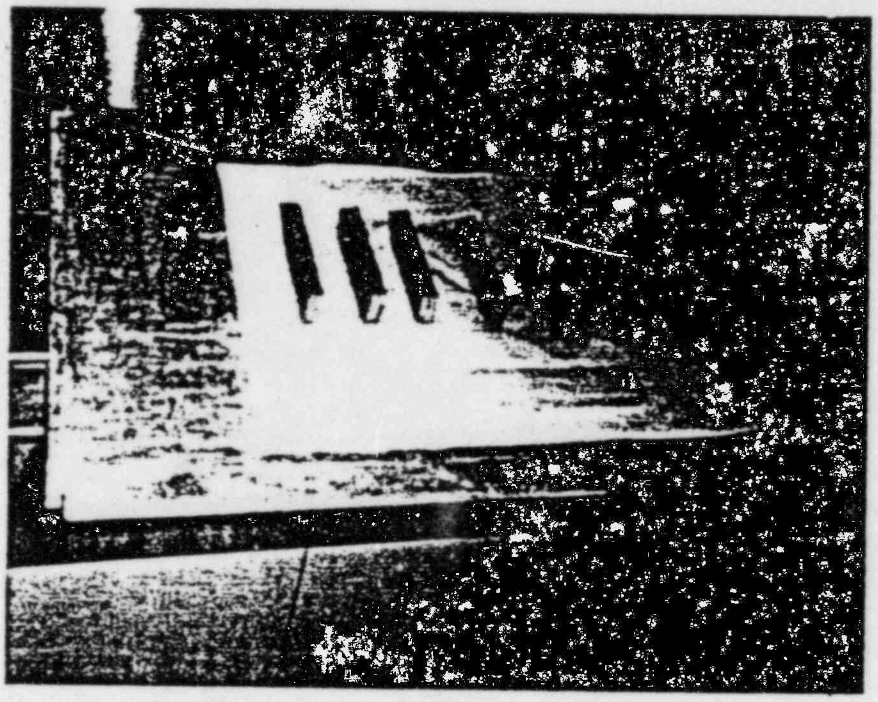

Fig. 3-3 Two Hours After Draining Specimens

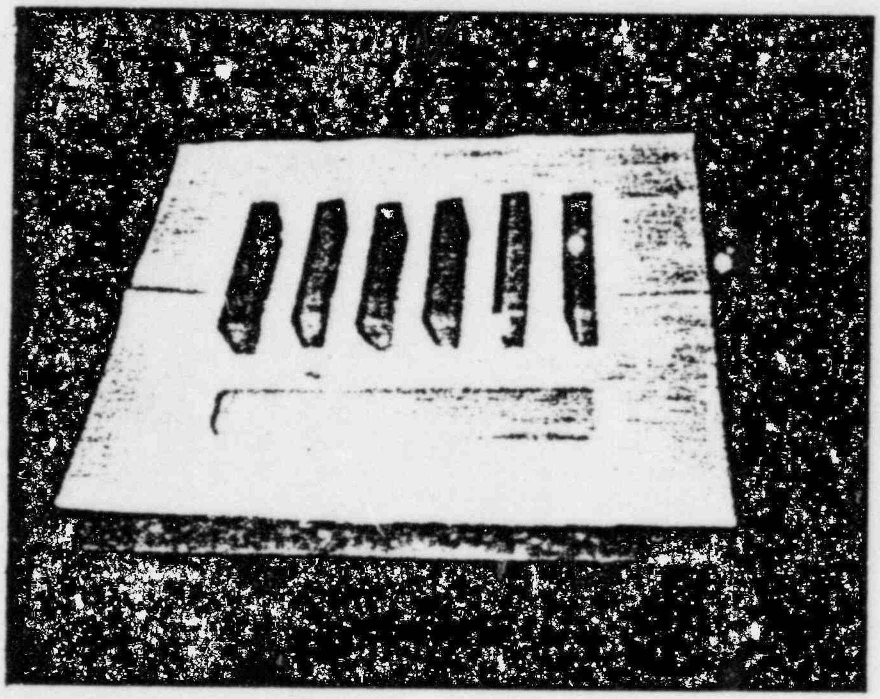

Fig. 3-4 Twelve Hours After Air Drying

C. RESULTS

4.0 Test #4 Thermal Cycling Test for Evaluation of Cylindrical Cement Specimens

4.1 The tests performed on concrete specimens supplied by Bartlett Nuclear Corp. was conducted in accordance with the American Society for Testing and Materials (ASTM B553-71).

4.2 Physical size of test specimens:

#1 (Control)	#2 (Test)	#3 (Test)
Dia - Rt. Cylinder	Dia - Rt. Cylinder	Dia. Rt. Cylinder
Top - 6.12 in (15.54 cm)	Top - 6.13 in (15.57 cm)	Top - 6.11 in (15.52 cm)
Middle - 6.11 in (15.52 cm)	Middle - 6.14 in (15.49 cm)	Middle - 6.09 in (15.47 cm)
Bottom - 6.13 in (15.57 cm)	Bottom - 6.16 in (15.65 cm)	Bottom - 6.13 in (15.57 cm)
Length - 6.03 in (15.22 cm)	Length - 6.01 in (15.24 cm)	Length - 5.98 in (15.19 cm)

4.3 Chamber Calibration: (Calibrated thermometer inside environmental chamber

Calibrated Thermometer (°C)		Chamber Chart Recorder
+ 20°C (+ 68°F)	+ 20.5°C	68.2°F (20.1°C)
+ 60°C (+ 140°F)	+ 60.75°C	141.5°F (60.8°C)
- 40°C (-40°F)	- 39.8°C	-39°F (-39.4°C)

The environmental chamber was then measured for temperature comparison to chart recorder:

Environmental Chamber	Chart Recorder
+ 20.5°C	+ 20.2°C
+ 60°C	+ 60.75°C
- 40°C	- 39.5°C

4.4 Two test specimens, #2 and #3, were placed on a stainless steel fine mesh screen within the environmental chamber in order to allow the temperature change to effect all surfaces of the concrete cylindrs. The two specimens were then exposed to 30 cycles of temperature change from + 60°C to - 40°C, in accordance with procedures, 2 cycles per day were performed for a total of 15 days.

4.5 At the end of cycling period, the two specimens were removed and visually examined for defects.

Visual Examination

#2	#3
No physical changes observed	One slight fine crack on bottom surface of specimen #3, Cracking occurred at the indent formation of the cylinder and appeared to be approximately 3/8" long.

4.6 Post measurement following temperature cycle and precompression testing:

a) Physical Size:

#2	#3
Dia:	Dia:
Top - 6.09 in. (15.47 cm)	Top: - 6.08 in. (15.44 cm)
Middle - 6.11 in. (15.52 cm)	Middle - 6.06 in. (15.39 cm)
Bottom - 6.14 in. (15.60 cm)	Bottom - 6.10 in. (15.49 cm)
Length - 6.00 in. (15.24 cm)	Length - 5.96 in. (15.14 cm)

4.7 Compression Test:

Surface Area:

#2	#3
$6.11/2 = N$	$6.09/2 = r$
$A = N^2 = (3.055)^2$	$A = r^2 = (3.045)^2$
$A = (9.33)$	$A = (9.27)$
$A = 29.31\ in^2$	$A = 29.12\ in^2$

Compression required for 50 psi

#2	#3
1465.5 lbs. Load	1456 lbs. Load

Results: Neither specimen, #2 and #3, failed at 50 psi (0.3MPa)

4.8 Failure Indication

#2 Specimen		#3 Specimen	
1st crack indication	15,225 lbs.(519.6 psi)	1st crack indication	14,790 lbs. (505 psi)
Failure Load	47,760 lbs.(1630 psi)	Failure Load	52,200 lbs.(1782 psi)

4.9 Because specimens were less than 12" or D/L ratio less than 1, correction factor of 0.87 had to be applied in accordance with ASTM C42-79, Part 14 titled "Obtaining and Testing Drilled Cores and Sawed Beams of Concrete", page 32. Compression tests were conducted on specimens with no previous humidity conditions being applied (Dry condition).

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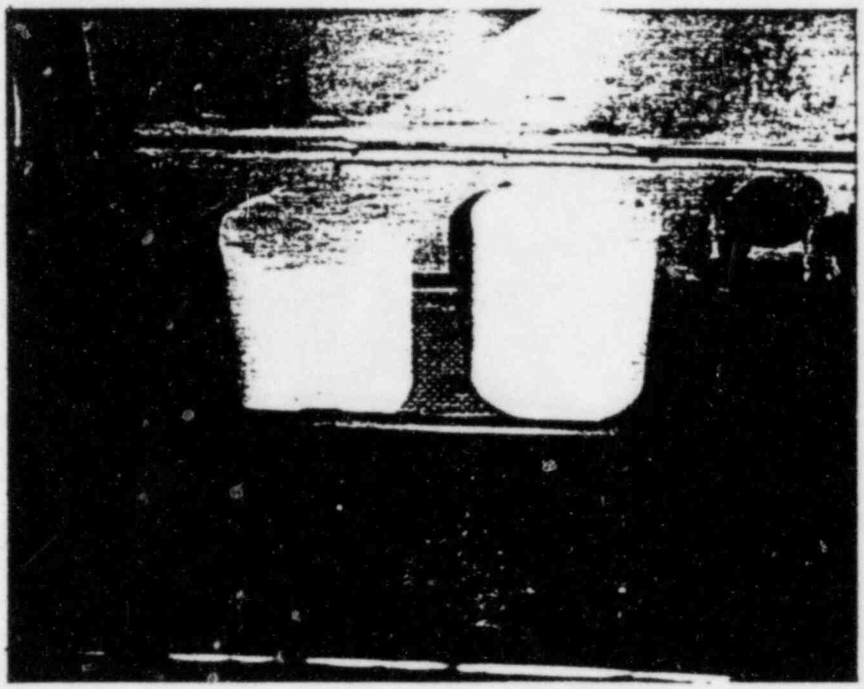

Fig. 4-3 Positioning of Test Specimens in Environmental Chamber

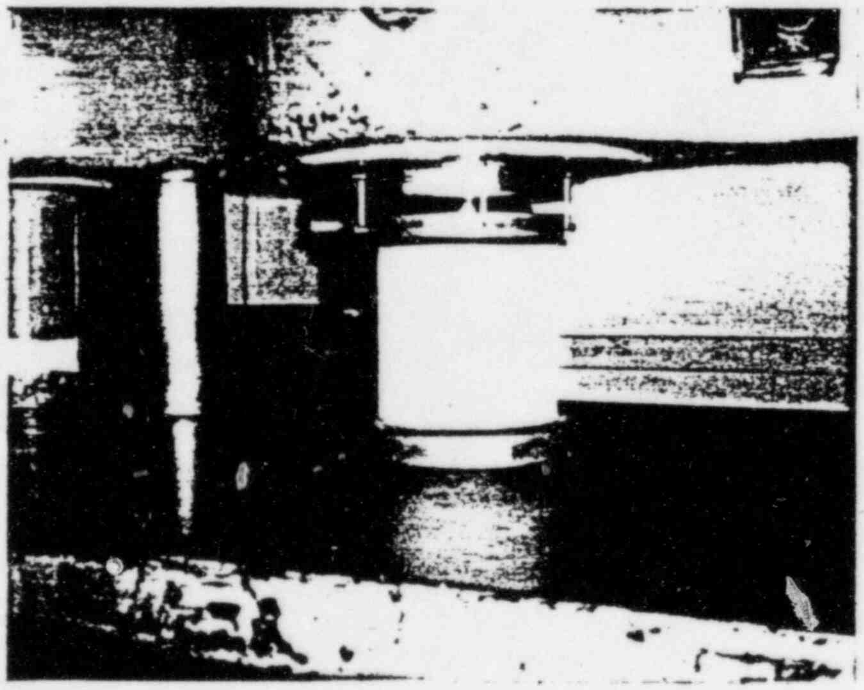

Fig. 4-4 Test Specimen #1 with 50 PSI

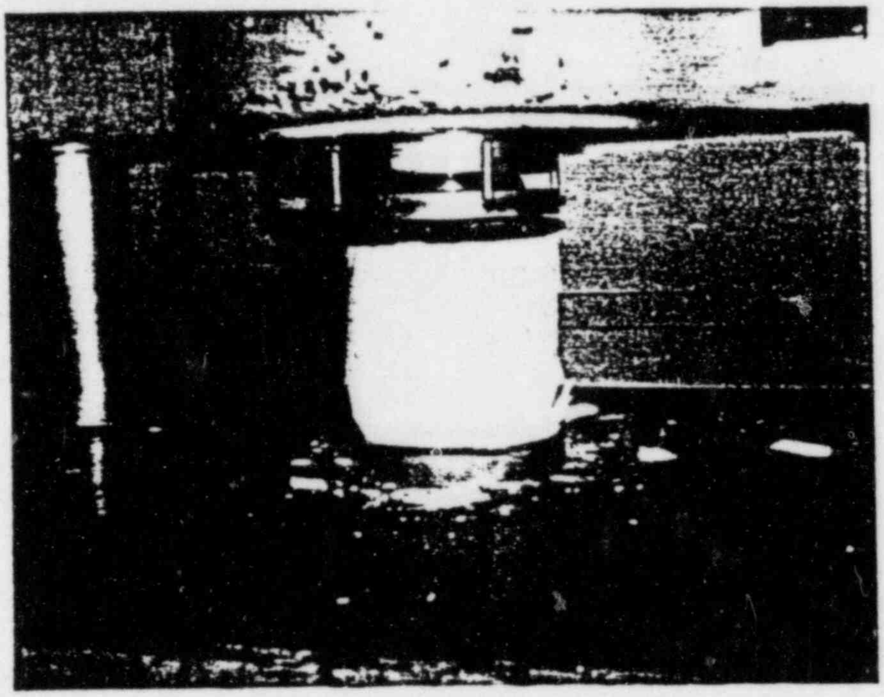

Fig. 4-5 Test Specimen #1 Bursting Failure

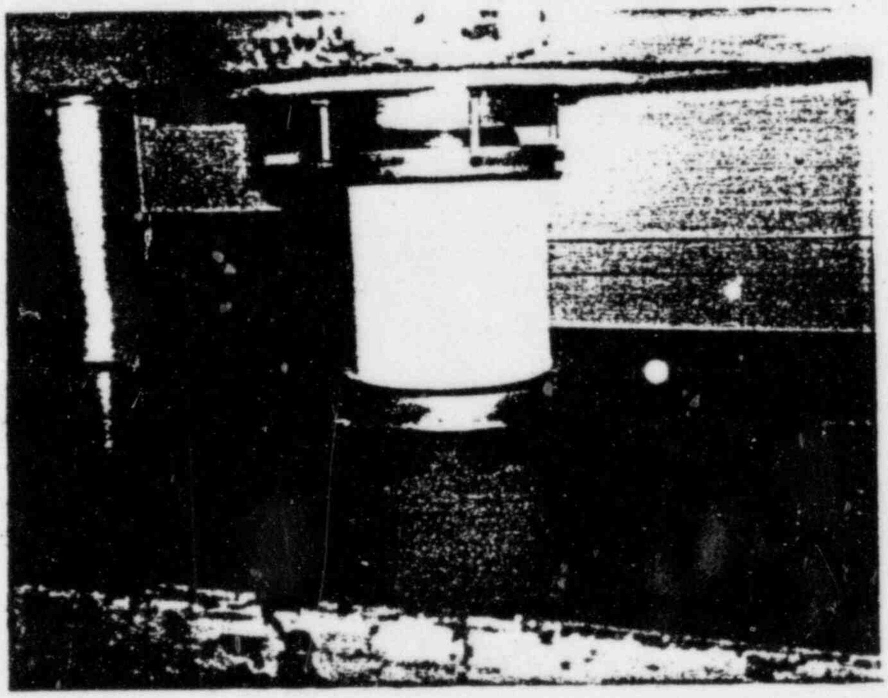

Fig. 4-6 Test Specimen #2 with 50 PSI

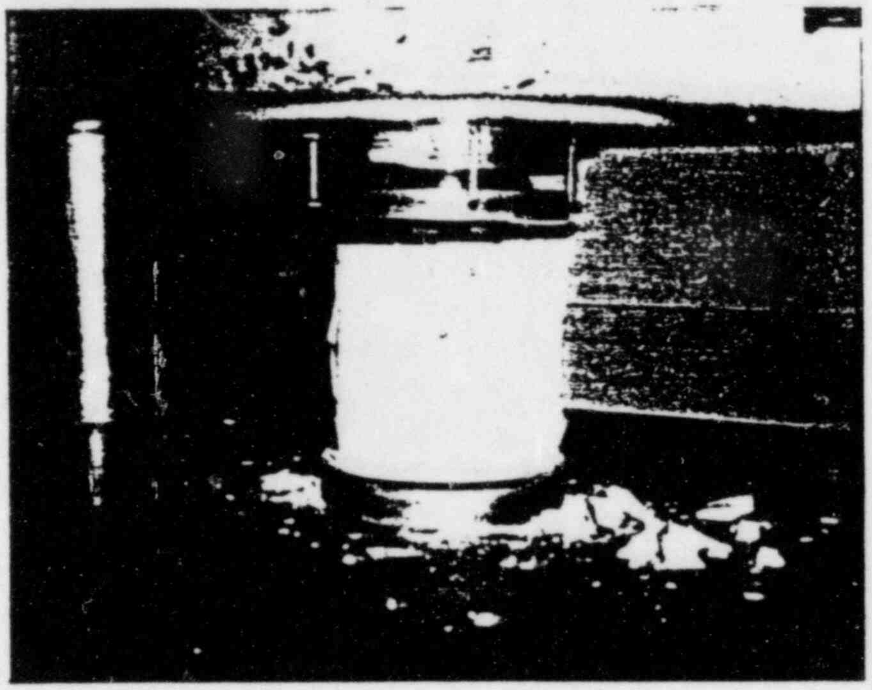

Fig. 4-7 Test Specimen #2 Bursting Failure

APPENDIX A

ASTM REQUIREMENTS

TEST # 1 - COMPRESSION TEST

AMERICAN NATIONAL STANDARD ANSI/ASTM C 39 - 72
(Reapproved 1979)

American Association State
Highway and Transportation Officials Standard
AASHTO No.: T 22

Standard Test Method for
COMPRESSIVE STRENGTH OF CYLINDRICAL CONCRETE SPECIMENS[1]

This Standard is issued under the fixed designation C 39; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval.

1. Scope

1.1 This method covers determination of compressive strength of cylindrical concrete specimens such as molded cylinders and drilled cores.

NOTE 1—For methods of molding concrete specimens see ASTM Method C 192, Making and Curing Concrete Test Specimens in the Laboratory[2] and ASTM Method C 31, Making and Curing Concrete Test Specimens in the Field.[2] For methods of obtaining drilled cores see ASTM Method C 42, Obtaining and Testing Drilled Cores and Sawed Beams of Concrete.[2]

2. Apparatus

2.1 The testing machine may be of any type of sufficient capacity, and shall be capable of providing the rate of loading prescribed in 4.2. It must be power operated and must apply this load continuously rather than intermittently, and without shock.

2.2 It shall conform to the requirements of Sections 16, 17, and 18 of ASTM Methods E 4, Verification of Testing Machines.[3] If it has only one loading rate (meeting the requirements of 4.2), it must be provided with a supplemental means for loading at a rate suitable for calibration. This supplemental means of loading may be power or hand operated. The space provided for test specimens shall be large enough to accommodate, in readable position, an elastic calibration device which is of sufficient capacity to cover the loading range of the testing machine and which complies with the requirements of ASTM Methods E 74, Calibration of Force-Measuring Instruments for Verifying the Load Indication of Testing Machines.[3]

NOTE 2—The type of elastic calibration device most generally available and most commonly used for this purpose is the circular proving ring.

2.3 The testing machine shall be equipped with two steel bearing blocks with hardened faces (Note 3), one of which is a spherically seated block that will bear on the upper surface of the specimen, and the other a solid block on which the specimen shall rest. Bearing faces of the blocks shall have a minimum dimension at least 3 percent greater than the diameter of the specimen to be tested. Except for the concentric circles described below, the bearing faces shall not depart from a plane by more than 0.001 in. (0.025 mm) in any 6 in. (152 mm) of blocks 6 in. in diameter or larger, or by more than 0.001 in. in the diameter of any smaller block; and new blocks shall be manufactured within one half of this tolerance. When the diameter of the bearing face of the spherically seated block exceeds the diameter of the specimen by $\frac{1}{2}$ in. (13 mm) or more, concentric circles not more than $\frac{1}{32}$ in. (0.8 mm) deep and not more than $\frac{3}{64}$ in. (1.2 mm) wide shall be inscribed to facilitate proper centering.

NOTE 3—It is desirable that the bearing faces of blocks used for compression testing of concrete have a Rockwell hardness of not less than HRC 55.

2.4 Bottom bearing blocks shall conform to the following requirements:

2.4.1 The bottom bearing block is specified

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[1] This method is under the jurisdiction of ASTM Committee C-9 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.03.01 on Methods of Testing Concrete for Strength.

Current edition approved Sept. 29, 1972. Published October 1972. Originally published as C 39 – 21T. Last previous edition C 39 – 71.

[2] *Annual Book of ASTM Standards*, Part 14.

[3] *Annual Book of ASTM Standards*, Part 41.

for the purpose of providing a readily machinable surface for maintenance of the specified surface conditions (Note 4). The top and bottom surfaces shall be parallel to each other. The block may be fastened to the platen of the testing machine. Its least horizontal dimension shall be at least 3 percent greater than the diameter of the specimen to be tested. Concentric circles as described in 2.3 above are optional on the bottom block.

2.4.2 When the lower bearing block is used to assist in centering the specimen, the center of the concentric rings, when provided, or the center of the block itself must be directly below the center of the spherical head. Provision shall be made on the platen of the machine to assure such a position.

2.4.3 The bottom bearing block shall be at least 1 in. (25 mm) thick when new, and at least 0.9 in. (22.5 mm) thick after any resurfacing operations.

NOTE 4—If the testing machine is so designed that the platen itself can be readily maintained in the specified surface condition, a bottom block is not required.

2.5 The spherically seated bearing block shall conform to the following requirements:

2.5.1 The maximum diameter of the bearing face of the suspended spherically seated block shall not exceed the values given below:

Diameter of Test Specimens, in. (mm)	Maximum Diameter of Bearing Face, in. (mm)
2 (51)	4 (102)
3 (76)	5 (127)
4 (102)	6½ (165)
6 (152)	10 (254)
8 (203)	11 (279)

NOTE 5—Square bearing faces are permissible, provided the diameter of the largest possible inscribed circle does not exceed the above diameter.

2.5.2 The center of the sphere shall coincide with the surface of the bearing face within a tolerance of ±5 percent of the radius of the sphere. The diameter of the sphere shall be at least 75 percent of the diameter of the specimen to be tested.

NOTE 6—The preferred contact area is in the form of a ring (described as preferred "bearing" area) as shown on Fig. 1. The ball and the socket must be so designed by the manufacturer that the steel in the contact area does not permanently deform under repeated use, with loads up to 8000 psi (55.2 MPa) on the test specimen.

2.5.3 The curved surfaces of the socket and of the spherical portion shall be kept clean and shall be lubricated with a petroleum type oil such as conventional motor oil, not with a pressure type grease. After contacting the specimen and application of small initial load, further tilting of the spherically seated block is not intended and is undesirable.

2.5.4 If the radius of the sphere is smaller than the radius of the largest specimen to be tested, the portion of the bearing face extending beyond the sphere shall have a thickness not less than the difference between the radius of the sphere and radius of the specimen. The least dimension of the bearing face shall be at least as great as the diameter of the sphere (see Fig. 1).

2.5.5 The movable portion of the bearing block shall be held closely in the spherical seat, but the design shall be such that the bearing face can be rotated freely and tilted at least 4 deg in any direction.

2.6 If the load of a compression machine used in concrete tests is registered on a dial, the dial shall be provided with a graduated scale that can be read to at least the nearest 250 lbf (1110 N) of load (Note 7). The dial shall be readable within 1 percent of the indicated load at any given load level within the loading range. In no case shall the loading range of a dial be considered to include loads below the value which is 100 times the smallest change of load which can be read on the scale. The scale shall be provided with a graduation line equal to zero and so numbered. The dial pointer shall be of sufficient length to reach the graduation marks; the width of the end of the pointer shall not exceed the clear distance between the smallest graduations. Each dial shall be equipped with a zero adjustment which is easily accessible from the outside of the dial case, and with a maximum load indicator.

NOTE 7—As close as can reasonably be read is considered to be 1/32 in. (0.8 mm) along the arc described by the end of the pointer.

3. Test Specimens

3.1 Compression tests of moist-cured specimens shall be made as soon as practicable after removal from the curing room. Neither end of compressive test specimens when tested shall depart from perpendicularity to the axis by more than 0.5 deg (approximately equivalent to $\frac{1}{8}$ in. in 12 in. (3 mm in 300 mm)). The ends of compression test specimens that are not plane within 0.002 in. (0.050 mm) shall be capped (Note 8). Test specimens shall be kept moist by any convenient method during the period between removal from moist storage and testing. They shall be tested in a moist condition. The diameter of the test specimen shall be determined to the nearest 0.01 in. (0.25 mm) by averaging two diameters measured at right angles to each other at about midheight of the specimen. This average diameter shall be used for calculating the cross-sectional area. When the length of the specimen is less than 1.8*D*, or more than 2.2*D*, the length shall be measured to the nearest 0.05*D*.

NOTE 8—For methods of capping compression specimens see ASTM Method C 617, Capping Cylindrical Concrete Specimens.[3]

4. Procedure

4.1 *Placing the Specimen*—Place the plain (lower) bearing block, with its hardened face up, on the table or platen of the testing machine directly under the spherically seated (upper) bearing block. Wipe clean the bearing faces of the upper and lower bearing blocks and of the test specimen and place the test specimen on the lower bearing block. Carefully align the axis of the specimen with the center of thrust of the spherically seated block. As the spherically seated block is brought to bear on the specimen, rotate its movable portion gently by hand so that uniform seating is obtained.

4.2 *Rate of Loading*—Apply the load continuously and without shock. In testing machines of the screw type the moving head shall travel at a rate of approximately 0.05 in. (1.3 mm)/min when the machine is running idle. In hydraulically operated machines apply the load at a constant rate within the range 20 to 50 psi/s (0.14 to 0.34 MPa/s). During the application of the first half of the anticipated load a higher rate of loading shall be permitted. Make no adjustment in the controls of the testing machine while a specimen is yielding rapidly immediately before failure.

4.3 Apply the load until the specimen fails, and record the maximum load carried by the specimen during the test. Note the type of failure and the appearance of the concrete.

5. Calculation

5.1 Calculate the compressive strength of the specimen by dividing the maximum load carried by the specimen during the test by the average cross-sectional area determined as described in Section 3 and express the result to the nearest 10 psi (69 kPa).

6. Report

6.1 The report shall include the following:

6.1.1 Identification number,

6.1.2 Diameter (and length, if outside the range of 1.8*D* to 2.2*D*), in inches (or millimeters),

6.1.3 Cross-sectional area, in square inches (or square centimeters),

6.1.4 Maximum load, in pounds-force (or newtons),

6.1.5 Compressive strength calculated to the nearest 10 psi (69 kPa),

6.1.6 Type of fracture, if other than the usual cone,

6.1.7 Defects in either specimen or caps, and,

6.1.8 Age of specimen.

TEST # 2 - BIODEGRADATION - FUNGI RESISTANCE

Designation: G 21 – 70

Standard Recommended Practice for
DETERMINING RESISTANCE OF SYNTHETIC POLYMERIC MATERIALS TO FUNGI[1]

This Standard is issued under the fixed designation G 21; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval.

1. Scope

1.1 This recommended practice covers determination of the effect of fungi on the properties of synthetic polymeric materials in the form of molded and fabricated articles, tubes, rods, sheets, and film materials. Changes in optical, mechanical, and electrical properties may be determined by the applicable ASTM methods.

NOTE 1—The values stated in U.S. customary units are to be regarded as the standard.

2. Summary of Method

2.1 The procedure described herein consists of (*1*) selection of suitable specimens for determination of pertinent properties, (*2*) inoculation of the specimens with suitable organisms, (*3*) exposure of inoculated specimens under conditions favorable to growth, (*4*) examination and rating for visual growth, and (*5*) removal of the specimens and observations or testing, either before cleaning or after cleaning and reconditioning.

NOTE 2—Since the procedure involves handling and working with fungi, it is recommended that personnel trained in microbiology perform the portion of the procedure involving handling of organisms and inoculated specimens.

3. Significance

3.1 The resin portion of these materials is usually fungus-resistant in that it does not serve as a carbon source for the growth of fungi. It is generally the other components, such as plasticizers, cellulosics, lubricants, stabilizers, and colorants, that are responsible for fungus attack on plastic materials. It is important to establish the resistance to microbial attack under conditions favorable for such attack, namely, a temperature of 2 to 38 C (35 to 100 F) and a relative humidity of 60 to 100 percent.

3.2 The effects to be expected are as follows:

3.2.1 Surface attack, discoloration, loss of transmission (optical).

3.2.2 Removal of susceptible plasticizers, modifiers, and lubricants, resulting in increased modulus (stiffness), changes in weight, dimensions, and other physical properties, and deterioration of electrical properties such as insulation resistance, dielectric constant, power factor, and dielectric strength.

3.3 Often the changes in electrical properties are due principally to surface growth and its associated moisture and to pH changes caused by excreted metabolic products. Other effects include preferential growths caused by nonuniform dispersion of plasticizers, lubricants, and other processing additives. Attack on these materials often leaves ionized conducting paths. Pronounced physical changes are observed on products in film form or as coatings, where the ratio of surface to volume is high, and where nutrient materials such as plasticizers and lubricants continue to diffuse to the surface as they are utilized by the organisms.

3.4 Since attack by organisms involves a large element of chance due to local accelerations and inhibitions, the order of reproducibility may be rather low. To assure that estimates of behavior are not too optimistic, the greatest observed degree of deterioration should be reported.

3.5 Conditioning of the specimens, such as exposure to leaching, weathering, heat treatment, etc., may have significant effects on the

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[1] This recommended practice is under the jurisdiction of ASTM Committee G-3 on Deterioration of Nonmetallic Materials.

Current edition effective April 13, 1970. Originally issued 1961 as D 1924. Replaced D 1924 – 63. Redesignated G 21 in 1970.

TEST # 2 - (Cont.)

resistance to fungi. Determination of these effects is not covered in this recommended practice.

4. Apparatus

4.1 *Glassware*—Glass vessels are suitable for holding specimens when laid flat. Depending on the size of the specimens, the following are suggested:

4.1.1 For specimens up to 76 mm (3 in.) in diameter, 152-mm (6-in.) covered Petri dishes.

4.1.2 For 76-mm (3-in.) and larger specimens, such as tensile and stiffness strips, large Petri dishes, trays of borosilicate glass, or baking dishes up to 408 by 508 mm (16 by 20 in.) in size, covered with squares of window glass.

4.2 *Incubator*—Incubating equipment for all test methods shall maintain a temperature of 28 to 30 C (82.4 to 86 F) and a relative humidity not less than 85 percent. Automatic recording of wet- and dry-bulb temperature is recommended.

5. Reagents and Materials

5.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.[2] Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

5.2 *Purity of Water*—Unless otherwise indicated, references to water shall be understood to mean distilled water or water of equal purity.

5.3 *Nutrient-Salts Agar*[3]—Prepare this medium by dissolving in 1 liter of water the designated amounts of the following reagents:

Potassium dihydrogen orthophosphate (KH_2PO_4)	0.7 g
Potassium monohydrogen orthophosphate (K_2HPO_4)	0.7 g
Magnesium sulfate ($MgSO_4 \cdot 7H_2O$)	0.7 g
Ammonium nitrate (NH_4NO_3)	1.0 g
Sodium chloride ($NaCl$)	0.005 g
Ferrous sulfate ($FeSO_4 \cdot 7H_2O$)	0.002 g
Zinc sulfate ($ZnSO_4 \cdot 7H_2O$)	0.002 g
Manganous sulfate ($MnSO_4 \cdot 7H_2O$)	0.001 g
Agar	15.0 g

Sterilize the test medium by autoclaving at 121 C (250 F) for 20 min. Adjust the pH of the medium by the addition of 0.01 N NaOH solution so that after sterilization the pH is between 6.0 and 6.5. Prepare sufficient medium for the required tests.

5.4 *Mixed Fungus Spore Suspension:*

NOTE 3—Since a number of other organisms may be of specific interest for certain final assemblies or components, such other pure cultures of organisms may be used if agreed upon by the purchaser and the manufacturer of the plastics. Reference (1) illustrates such a choice.

5.4.1 Use the following test fungi in preparing the cultures:

Fungi	ATCC No.[4]	QM No.[5]
Aspergillus niger	9642	386
Penicillium funiculosum	9644	391
Chaetomium globosum	6205	459
Trichoderma sp	9645	365
Pullularia pullulans	9348	279c

[4] American Type Culture Collection, 2112 M St., N. W., Washington 7, D. C.

[5] Quartermaster Culture Collection, QMR & E Command, Natick, Mass.

Maintain cultures of these fungi separately on an appropriate medium such as potato dextrose agar. The stock cultures may be kept for not more than 4 months at approximately 3 to 10 C (37.4 to 50 F). Use subcultures incubated at 28 to 30 C (82.4 to 86 F) for 7 to 20 days in preparing the spore suspension.

5.4.2 Prepare a spore suspension of each of the six fungi by pouring into one subculture of each fungus a sterile 10-ml portion of water or of a sterile solution containing 0.05 g/liter of a nontoxic wetting agent such as sodium dioctyl sulfosuccinate. Use a sterile platinum or nichrome inoculating wire scrape gently the surface growth from the culture of the test organism.

5.4.3 Pour the spore charge into a sterile 125-ml glass-stoppered Erlenmeyer flask containing 45 ml of sterile water and 10 to 15 solid glass beads, 5 mm in diameter. Shake the flask vigorously to liberate the spores from the fruiting bodies and to break the spore clumps.

5.4.4 Filter the shaken suspension through

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[2] "Reagent Chemicals, American Chemical Society Specifications," Am. Chemical Soc., Washington, D.C. For suggestions on the testing of reagents not listed by the American Chemical Society, see "Reagent Chemicals and Standards," by Joseph Rosin, D. Van Nostrand Co., Inc., New York, N.Y., and the "United States Pharmacopeia."

[3] Agar and nutrient-salts agar are obtainable from biological laboratory supply sources.

TEST # 2 - (Cont.)

a thin layer of sterile glass wool in a glass funnel into a sterile flask in order to remove mycelial fragments.

5.4.5 Centrifuge the filtered spore suspension aseptically, and discard the supernatant liquid. Resuspend the residue in 50 ml of sterile water and centrifuge.

5.4.6 Wash the spores obtained from each of the fungi in this manner three times. Dilute the final washed residue with sterile nutrient-salts solution (Note 4) in such a manner that the resultant spore suspension shall contain 1,000,000 ± 200,000 spores/ml as determined with a counting chamber.

5.4.7 Repeat this operation for each organism used in the test and blend equal volumes of the resultant spore suspension to obtain the final mixed spore suspension.

NOTE 4—Nutrient salts solution is identical with the composition for nutrient salts agar given in 5.3 except that the agar is omitted.

5.4.8 The spore suspension may be prepared fresh each day or may be held in the refrigerator at 3 to 10 C (37.4 to 50 F) for not more than 4 days.

6. Viability Control

6.1 With each daily group of tests place each of three pieces of sterilized filter paper, 25.4 mm (1 in.) square, on hardened nutrient-salts agar in separate Petri dishes. Inoculate these with the spore suspension by spraying the suspension from a sterilized atomizer[6] so that the entire surface is moistened with the spore suspension. Incubate these at 28 to 30 C (82.4 to 86 F) at a relative humidity not less than 85 percent and examine them after 14 days' incubation. There shall be copious growth on all three of the filter paper control specimens. Absence of such growth requires repetition of the test.

7. Test Specimens

7.1 The simplest specimen may be a 51 by 51-mm (2 by 2-in.) piece, a 51-mm (2-in.) diameter piece, or a piece (rod or tubing) at least 76 mm (3 in.) long cut from the material to be tested. Completely fabricated parts or sections cut from fabricated parts may be used as test specimens. On such specimens, observation of effect is limited to appearance, density of growth, optical reflection or transmission, or manual evaluation of change in physical properties such as stiffness.

7.2 Film-forming materials such as coatings may be tested in the form of films at least 51 by 25.4 mm (2 by 1 in.) in size. Such films may be prepared by casting on glass and stripping after cure, or by impregnating (completely covering) filter paper or ignited glass fabric.

7.3 For visual evaluation, three specimens shall be inoculated. If the specimen is different on two sides, three specimens of each, face up and face down, shall be tested.

NOTE 5—In devising a test program intended to reveal quantitative changes occurring during and after fungal attack, an adequate number of specimens should be evaluated to establish a valid value for the original property. If five replicate specimens are required to establish a tensile strength of a film material, the same number of specimens shall be removed and tested for each exposure period. It is to be expected that values of physical properties at various stages of fungal attack will be variable; the values indicating the greatest degradation are the most significant (see 3.4). The *ASTM Manual on Quality Control of Materials, STP 15-C*, may be used as a guide.

8. Procedure

8.1 *Inoculation*—Pour sufficient nutrient-salts agar into suitable sterile dishes (see 4.1) to provide a solidified agar layer from 3.2 to 6.4 mm (1/8 to 1/4 in.) in depth. After the agar is solidified, place the specimens on the surface of the agar. Inoculate the surface, including the surface of the test specimens, with the composite spore suspension by spraying the suspension from a sterilized atomizer[6] with 110 kPa (16-psi) air pressure so that the entire surface is moistened with the spore suspension.

8.2 *Incubation*—Cover the inoculated test specimens and incubate at 28 to 30 C (82.4 to 86 F) and not less than 85 percent relative humidity for a minimum of 21 days, recording the growth each week.

NOTE 6—Covered dishes containing nutrient agar are considered to have the desired humidity. Covers on large dishes may be sealed with masking tape.

8.3 *Observation for Visible Effects*—If the test is for visible effects only, remove the three specimens from the incubator and judge

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[6] DeVilbiss No. 154 atomizer or equivalent has been found satisfactory for this purpose.

them as follows:

Observed Growth on Specimens	Rating
None	0
Traces of growth (less than 10 percent)	1
Light growth (10 to 30 percent)	2
Medium growth (30 to 60 percent)	3
Heavy growth (60 percent to complete coverage)	4

NOTE 7—Traces of growth may be defined as scattered, sparse fungus growth such as might develop from (*1*) a mass of spores in the original inoculum, or (*2*) extraneous contamination such as fingermarks, insect feces, etc. Continuous cobwebby growth extending over the entire specimen, even though not obscuring the specimen, should be rated as 2.

NOTE 8—Considerable physical change in plastics may occur without much visual growth, hence some measure of change in physical property selected from those cited in the Appendix is recommended.

8.4 *Effect on Physical, Optical, or Electrical Properties*—Wash the specimens free of growth, immerse in an aqueous solution of mercuric chloride (1+1000) for 5 min, rinse in tap water, air dry overnight at room temperature, and recondition at the standard laboratory conditions defined in ASTM Methods D 618, Conditioning Plastics and Electrical Insulating Materials for Testing,[2] 23 ± 1.1 C (73.4 ± 2 F) and 50 ± 2 percent relative humidity, and test according to the respective methods used on control specimens (see the Appendix).

NOTE 9—For certain electrical tests, such as insulation resistance and arc resistance, specimens may be tested in the unwashed, humidified condition. Test values will be affected by surface growth and its associated moisture.

9. Report

9.1 The report shall include the following:

9.1.1 Organisms or organism used,

9.1.2 Time of incubation (if progressive),

9.1.3 Visual rating of fungus growth according to 8.3, and

9.1.4 Tabulation of progressive change in physical, optical, or electrical property against time of incubation. Give the number of observations, the mean, and the maximum observed change.

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[2] *1974 Annual Book of ASTM Standards*, Part 35.

REFERENCES

(1) Bagdon, V. J., Military Specification Mil-P-43018(CE), "Plastic Sheets: Polyethylene Terephthalate, Drafting, Coated," June 13, 1961.

(2) Baskin, A. D., and Kaplan, A. M., "Mildew Resistance of Vinyl-Coated Fabrics," *Applied Microbiology*, APMBA, Vol 4, No. 6, November 1956.

(3) Berk, S., "Effect of Fungus Growth on Plasticized Polyvinyl Chloride Films," *ASTM Bulletin*, ASTBA, No. 168, September 1950, p. 53 (TP 181).

(4) Berk, S., Ebert, H., and Teitell, L., "Utilization of Plasticizers and Related Organic Compounds by Fungi," *Industrial and Engineering Chemistry*, IECHA, Vol 49, No. 7, July 1957, pp. 1115-1124.

(5) Brown, A. E., "Problem of Fungal Growth on Synthetic Resins, Plastics, and Plasticizers," *Modern Plastics*, MOPLA, Vol 23, 1946, p. 189.

(6) F ss, S. H., "Biocides for a Strippable Vinyl Plastic Barrier Material," Report PB-151-119, U. S. Department of Commerce, Office of Technical Services.

APPENDIX

A1. TEST METHODS FOR EVALUATION OF EFFECT OF FUNGI ON SYNTHETIC POLYMERIC MATERIALS

A1.1 For evaluation of the effect of fungi on mechanical, optical, and electrical properties, the following ASTM and other test methods are recommended.

Property	Methods
Tensile strength	D 638, D 882, D 1708[a]
Stiffness	D 747[a] TAPPI Test Method T 451-M-45 Federal Specification Textile Test Methods CCC-T-191b Method 5204 (Clark Stiffness Test) Federal Specification Textile Test Methods CCC-T-191b Method 5206 (Cantilever Bend Method)
Hardness	D 785[a]
Optical transmission	D 791[a]
Haze	D 1003[a]
Water vapor transmission	E 96[a]
Dielectric strength	D 149[a]
Dielectric constant-power factor	D 150[a]
Insulation resistance	D 257[a]
Arc resistance	D 495[a]

[a] These designations refer to the following ASTM methods:

D 149, Tests for Dielectric Breakdown Voltage and Dielectric Strength of Electrical Insulating Materials at Commercial Power Frequencies[4]

D 150, Tests for A-C Loss Characteristics and Dielectric Constant (Permittivity) of Solid Electrical Insulating Materials[4]

D 257, Tests for D-C Resistance or Conductance of Insulating Materials[4]

D 495, Test for High-Voltage, Low-Current Arc Resistance of Solid Electrical Insulating Materials[4]

D 638, Test for Tensile Properties of Plastics[4]

D 747, Test for Stiffness of Plastics by Means of a Cantilever Beam[4]

D 785, Test for Rockwell Hardness of Plastics and Electrical Insulating Materials[4]

D 791, Test for Luminous Reflectance, Transmittance, and Color of Materials[4]

D 1003, Test for Haze and Luminous Transmittance of Transparent Plastics[4]

D 1708, Test for Tensile Properties of Plastics by Use of Microtensile Specimens[4]

E 96, Test for Water Vapor Transmission of Materials in Sheet Form[4]

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[4] *1974 Annual Book of ASTM Standards*, Part 41.

TEST # 2A - BIODEGRADATION - BACTERIA RESISTANCE

ASTM Designation: G 22 – 67 T

Tentative Recommended Practice for DETERMINING RESISTANCE OF PLASTICS TO BACTERIA

This Tentative Recommended Practice has been approved by the sponsoring committee and accepted by the Society in accordance with established procedures, for use pending adoption. Suggestions for revisions should be addressed to the Society at 1916 Race St., Philadelphia, Pa. 19103.

1. Scope

1.1 This recommended practice covers two procedures, A and B, for determining the effect of bacteria on the properties of plastics in the form of molded and fabricated articles, tubes, rods, sheets, and film materials. Procedure B provides a more extensive contact between the test bacteria and the specimens than does Procedure A. Changes in optical, mechanical, and electrical properties may be determined by the applicable ASTM methods.

Note 1—The values stated in U.S. customary units are to be regarded as the standard.

2. Summary of Method

2.1 The procedure described herein consists of the following steps:

2.1.1 Selection of suitable specimens for determination of pertinent properties,

2.1.2 Inoculation of specimens with suitable organisms,

2.1.3 Exposure of inoculated specimens under conditions favorable to growth,

2.1.4 Examination and rating for visual growth, and

2.1.5 Removal, sterilization, and evaluation of specimens.

Note 2—Since the procedure involves handling and working with bacteria that may be capable of infecting man, it is essential that personnel trained in microbiology perform the portion of the procedure involving handling of bacterial organisms and inoculated specimens.

3. Significance

3.1 The resin portion of plastic materials is usually resistant to bacteria, in that it does not serve as a carbon source for the growth of bacteria. It is generally the other components, such as plasticizers, lubricants, stabilizers, and colorants that are responsible for bacterial attack on plastic materials. It is important to establish the resistance of plastics to microbial attack when plastics are used under conditions of high temperature and humidity favorable for such attack.

3.2 The effects to be expected are:

3.2.1 Surface attack, discoloration, and loss of transmission (optical).

3.2.2 Removal of susceptible plasticizers, modifiers, and lubricants, resulting in increased modulus (stiffness), changes in weight, dimensions, and other physical properties, and deterioration of electrical properties such as insulation resistance, dielectric constant, power factor, and dielectric strength.

3.3 Often the changes in electrical properties are due principally to surface growth and associated moisture, and to pH changes caused by products of bacterial metabolism. Other effects include preferential growths caused by nonuniform dispersion of plasticizers, lubricants, and other processing additives. Pronounced physical changes may be observed on products in film form or as coatings where the ratio of surface to volume is high, and where nutrient materials such as plasticizers and lubricants continue to diffuse

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[1] This recommended practice is under the jurisdiction of ASTM Committee G-3 on Deterioration of Nonmetallic Materials.

Current edition effective Nov. 1, 1967. Originally issued as D 2676. Redesignated G 22 in 1970.

to the surface as they are utilized by the organisms.

3.4 Since attack by organisms involves a large element of change due to local accelerations and inhibitions, the order of reproducibility may be rather low. To assure that estimates of behavior are not too optimistic, the greatest observed degree of deterioration should be reported.

3.5 Conditioning of specimens such as exposure to leaching, weathering, heat treatment, etc., may have significant effects on the resistance of plastics to bacteria. Determination of these effects is not covered in this document.

4. Apparatus

4.1 *Glassware*—Glass vessels are suitable for holding specimens when laid flat. Depending on the size of the specimens, the following are suggested:

4.1.1 For specimens up to 75 mm (3 in.) in diameter, 150-mm (6-in.) covered petri dishes.

4.1.2 For 75-mm (3-in.) and larger specimens, such as tensile and stiffness strips, large petri dishes, trays of borosilicate glass; or baking dishes covered with squares of window glass or other suitable covering.

4.2 *Incubator*—Incubating equipment for all test methods shall maintain a temperature of 35 to 37 C (95 to 98.6 F) and a relative humidity of not less than 85 percent. Automatic recording of wet and dry bulb temperature is recommended.

5. Reagents and Materials

5.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.[2] Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

5.2 *Purity of Water*—Unless otherwise indicated, references to water shall be understood to mean distilled water.

5.3 *Nutrient-Salts Agar*[3]—This is a carbon-free culture medium used in ASTM Recommended Practice G 21, for Determining Resistance of Synthetic Polymeric Materials to Fungi.[4] Although intended for the cultivation of fungi, nutrient-salts agar will support growth of the test bacteria when carbon requirements are supplied by susceptible plastic materials. Prepare this medium by dissolving in 1 liter of water the designated amounts of the following reagents:

Potassium dihydrogen orthophosphate (KH_2PO_4)	0.7 g
Potassium monohydrogen orthophosphate (K_2HPO_4)	0.7 g
Magnesium sulfate ($MgSO_4 \cdot 7H_2O$)	0.7 g
Ammonium nitrate (NH_4NO_3)	1.0 g
Sodium chloride (NaCl)	0.005 g
Ferrous sulfate ($FeSO_4 \cdot 7H_2O$)	0.002 g
Zinc sulfate ($ZnSO_4 \cdot 7H_2O$)	0.002 g
Manganese sulfate ($MnSO_4 \cdot H_2O$)	0.001 g
Agar	15.0 g
Distilled water	1000.0 ml

Sterilize the test medium by autoclaving at 121 C (250 F) for 20 min. Prepare sufficient medium for the required tests including uninoculated controls.

NOTE 3—Nutrient-salts agar readily supports growth of fungi which may be present on the test specimens. Fungal contamination can be controlled by either (*1*) the addition of 0.15 percent cycloheximide[5] to nutrient-salts agar or (*2*) sterilization of the specimens by some suitable means such as exposure to ethylene oxide.

5.4 *Bacterial Cell Suspension:*

5.4.1 The following test organism shall be used, or a suitable bacterium as agreed upon among parties concerned: *Pseudomonas aeruginosa* ATCC 13388[6] QM B 1468.[7]

5.4.2 Cultures of the organism shall be maintained on slants of nutrient agar.[3] To prepare nutirent agar slants suspend 0.3 percent beef extract, 0.5 percent peptone, and 1.5 percent agar in distilled water and heat until dissolved. Tube, plug, and autoclave for

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[2] "Reagent Chemicals, American Chemical Society Specifications," Am. Chemical Soc., Washington, D.C. For suggestions on the testing of reagents not listed by the American Chemical Society, see "Reagent Chemicals and Standards," by Joseph Rosin, D. Van Nostrand Co., Inc., New York, N.Y., and the "United States Pharmacopeia."

[3] Agar, nutrient-salts agar, and nutrient broth are obtainable from biological laboratory supply sources.

[4] *1974 Annual Book of ASTM Standards*, Parts 35 and 41.

[5] Similar or equivalent to "Actidione," a product of the Upjohn Co.

[6] American Type Culture Collection, 12301 Parklawn Drive, Rockville, Md. 20852.

[7] NLABS Culture Collection (QM), U.S. Army Natick Laboratories, Natick, Mass.

15 min at 103 kPa (15 psi) steam pressure at 121 C. The tubed and sterilized media shall be allowed to cool and gel in a slanted position to afford an appropriate surface on which the bacteria may be cultured.

5.4.3 The inoculum shall be prepared from not less than two successive transfers in nutrient broth.[7] To prepare nutrient broth dissolve 0.3 percent beef extract and 0.5 percent peptone in distilled water and dispense in suitable test tubes or flasks. Plug and autoclave at 103 kPa (15 psi) steam pressure at 121 C. Transfer the bacteria with a flame-sterilized needle from the nutrient agar slant to nutrient broth. Incubate for 24 h. Transfer this broth culture to the sterile nutrient broth medium and culture as before. Centrifuge the broth culture. Decant the broth and resuspend the bacteria cells in sterile normal saline solution (0.8 percent NaCl). Centrifuge, decant the saline solution, and resuspend the bacteria cells in fresh normal saline. Determine the bacterial cell concentration.

5.4.4 The concentration of the bacterial cells may be estimated turbidimetrically using a photoelectric colorimeter. The turbidimetric standard is obtained by concurrent plate counts and turbidimetric measurements of a serially diluted bacterial cell suspension. Reference to a calibration curve of cell count versus absorption will give a measure of concentration. The cell count need be done only once to establish the calibration curve.

5.5 *Viability Control*—Streak onto sterile nutrient agar poured into a sterile petri dish a loop-full of the bacterial suspension at the start and end of the bacterial inoculation procedure. Contamination of this inoculum must be avoided. Incubate the viability culture at 35 to 37 C (95 to 98.6 F) at a relative humidity not less than 85 percent for 48 to 72 h. The inoculum shall be reported as viable only if typical growth occurs in this culture with no contamination. Absence of growth or the presence of atypical growth requires repetition of the test.

6. Test Specimens

6.1 The simplest specimen may be a 50 by 50-mm (2 by 2-in.) piece, a 50-mm (2-in.) diameter piece, or a piece (rod, tubing) at least 75 mm (3 in.) long cut from the material to be tested. Completely fabricated parts or sections cut from fabricated parts may be used as test specimens. On such specimens, observation of effect is limited to appearance, density of growth, optical reflection or transmission, or manual evaluation of change in physical properties such as stiffness.

6.2 Film-forming materials such as coatings may be tested in the form of films, at least 50 by 50 mm (2 by 2 in.) in size. Such films may be prepared by casting on glass and stripping after cure, or by impregnating ignited glass fabric.

6.3 For visual evaluation, three specimens shall be inoculated. If the specimen is different on two sides, three specimens of each, face up and face down, shall be tested.

NOTE 4—In devising a test program intended to reveal quantitative changes occurring during and after bacterial attack, an adequate number of specimens should be evaluated to establish a valid value for the original property. If five replicate specimens are required to establish a tensile strength of a film material, the same number of specimens shall be removed and tested for each exposure period. It is to be expected that values of physical properties at various stages of bacterial attack will be variable; the values indicating the greatest degradation are the most significant (see 3.4).[8]

7. Procedure A

7.1 *Inoculation*—Melt sufficient sterile nutrient salts agar and cool to about 45 C. Pipet into the melted and cooled agar a volume of bacterial cell suspension sufficient to yield a concentration of about 50,000 viable cells/ml of agar. The cell concentration does not appear to be critical, and satisfactory results have been obtained over the range from 20,000 to 150,000 cells/ml. Pour sufficient seeded agar into suitable sterile dishes to provide an agar layer from 6 to 12 mm (¼ to ½ in.) in depth and allow to harden. After the agar is solidified, place the specimens on the surface of the agar.

7.2 *Uninoculated Controls*—Prepare uninoculated control specimens as above using uninoculated nutrient salts agar. This is imperative if measurements of physical or electrical properties are to be used in assessing

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[8] *ASTM Manual on Quality Control of Materials, STP 15 C.*

changes in the exposed specimens.

7.3 *Incubation*—Cover the culture dishes and incubate at 35 to 37 C (95 to 98.6 F) and not less than 85 percent relative humidity for a minimum of 21 days.

NOTE 5—Covered dishes containing nutrient agar are considered to have the desired humidity. Covers on large dishes may be sealed with masking tape.

NOTE 6—Since the test organism may be a pathogen, standard bacteriological procedures must be observed to ensure against infection.

8. Procedure B

8.1 This procedure provides more intimate contact between bacteria and specimens when the geometry of the specimens will permit. Prepare the required volume of nutrient-salts agar in two equal lots. Inoculate each as in 7.1 just prior to using. Pour one lot of seeded agar into the culture dish, allow to solidify, and position specimens on the agar surface. Pour the second lot of seeded agar over the specimens and allow to gel. Prepare uninoculated control specimens as in 7.2 and incubate as in 7.3.

NOTE 7—Specimens of low density material may tend to float in the still-liquid agar. This can be controlled mechanically until the agar has solidified using suitable aseptic techniques.

9. Observations

9.1 *Observation for Visible Effects*—Bacterial attack is not visible in the form of apparent growth on the specimen surface. However, in Procedure A visible bacterial growth occurs beneath susceptible samples on the agar surface. With Procedure B bacterial growth on all surfaces of susceptible specimens may be observed. Judge as growth or no growth.

NOTE 8—Considerable physical change in plastics may occur without much visual growth; hence, some measure of change in physical property is recommended. See Appendix of Recommended Practice G 21.

9.2 *Effect on Physical, Optical and Electrical Properties*—Wash the specimens free of growth in an aqueous solution of mercuric chloride (1 + 1000) for at least 5 min before handling, rinse in tap water, air-dry overnight at room temperature, and recondition at the standard laboratory conditions defined in ASTM Methods D 618, Conditioning Plastics and Electrical Insulating Materials for Testing,[9] in accordance with the respective methods used on control specimens.

10. Report

10.1 The report shall include the following:

10.1.1 Procedure used,

10.1.2 Organism used, identified to strain,

10.1.3 Time of incubation (if progressive),

10.1.4 Visual rating of bacterial growth according to 9.1, and

10.1.5 Tabulation of change in physical, optical or electrical property. Give number of observations, the mean, and maximum observed change.

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[9] *1974 Annual Book of ASTM Standards*, Parts 35 and 39.

TEST # 4 - THERMAL CYCLING

Designation: B 553 – 71

American National Standard G53.42-1972
Approved April 20, 1972
By American National Standards Institute

Standard Recommended Practice for

THERMAL CYCLING TEST FOR EVALUATION OF ELECTROPLATED PLASTICS[1]

This Standard is issued under the fixed designation B 553; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval.

1. Scope

1.1 This recommended practice covers the thermal cycling procedure and apparatus used to test electroplated plastics for evaluation of serviceability. The thermal cycle test covers four service conditions which simulate the environmental extremes to which such parts may be subjected, either in shipping or use.

NOTE 1—This document is not intended as a standard method of test which can be used to predict serviceability of electroplated plastics. Rather, it is a recommended practice for testing parts for such evaluation.

2. Apparatus

2.1 The apparatus shall consist of a circulating air heating chamber and cooling chamber sufficiently powered, insulated, and controlled so as to maintain closely the preset temperature. The two chambers may be separate, or may be built so as to constitute a single piece of apparatus. The controller and recorder used for chamber control, calibration, and records shall be accurate to ±1 C. All points within the working area of the test chamber shall remain within ±3 C of the set temperature when tested by the procedures described below. The rate of air circulation shall be controlled so as to permit a consistent rate of heating or cooling of the parts under test.

2.1.1 Install 24-gage (0.511-mm) thermocouples 25 mm from each corner of the test chamber.

2.1.2 Each thermocouple should be previously calibrated in boiling water (100 C) and in ice water (0 C).

NOTE 2—Further details may be found in ASTM Method E 220, Calibration of Thermocouples by Comparison Techniques.[2]

3. Sampling

3.1 Draw the samples randomly from the parts under evaluation.

3.1.1 Test methods are time-consuming and often destructive; therefore, 100 percent inspection is usually impractical. The purchaser should select a suitable sampling plan for the acceptance testing of lots of coated items. In order that the manufacturer know the quality standard he is expected to meet, the plan selected should be made a part of the purchase contract.

3.1.2 General information on sampling procedures is given in ASTM Recommended Practice E 105, for Probability Sampling of Materials,[3] and ASTM Recommended Practice E 122, for Choice of Sample Size to Estimate the Average Quality of a Lot or Process.[4] Standard sampling plans are suggested in Military Standards MIL-STD 105, Sampling Procedures and Tables for Inspection by Attributes, and MIL-STD 414, Sampling Procedures and Tables for Inspection by Variables for Per Cent Defective.

4. Elapsed Time After Plating

4.1 The elapsed time between completion of the plating operation and thermal cycling affects test results obtained. The elapsed time shall be 24 ± 2 h, unless otherwise agreed

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[1] This recommended practice is under the jurisdiction of ASTM Committee B-8 on Electrodeposited Metallic Coatings and Related Finishes.

Effective Aug. 30, 1971.

[2] *1974 Annual Book of ASTM Standards*, Part 17, and *1973 Annual Book of ASTM Standards*, Part 30.

[3] *1974 Annual Book of ASTM Standards*, Parts 15 and 41, and *1973 Annual Book of ASTM Standards*, Part 24.

[4] *1974 Annual Book of ASTM Standards*, Parts 15 and 41.

TEST # 4 - (Cont.)

upon between purchaser and seller.

5. Procedure

5.1 The parts may be introduced into the chamber unmounted, or mounted in a manner simulating assembly, if so agreed upon between purchaser and seller.

5.2 Load the chamber with the desired quantity and type of parts to be tested.

5.3 Record the location of parts within the chamber, the loading, and the size of the parts being tested.

5.4 Subject the sample to a thermal cycle procedure as follows:

Service Condition	High Limit	Low Limit
1 (mild)	60 C	−30 C
2 (moderate)	75 C	−30 C
3 (severe)	85 C	−30 C
4 (very severe)	85 C	−40 C

Each thermal cycle begins with either placing the samples in a room-temperature chamber and heating the chamber up to the high limit or placing the samples directly into a chamber at the high limit.

NOTE 3—Suggested definitions of service conditions appear in the Appendix. Alternatively, the definition may be one agreed upon between the purchaser and seller.

5.4.1 Expose the parts for 1 h at the high limit.

5.4.2 Allow the parts to return to 22 ± 3 C, as quickly as possible and maintain at this temperature for a total cooling period of 1 h. This is frequently accomplished by removing the parts from the chamber, however, some types of apparatus are so constructed that the parts need not be removed during this step.

5.4.3 Expose the part for 1 h at the lower limit.

5.4.4 Repeat 5.4.2. This constitutes one full thermal cycle.

6. Recording of Test Results

6.1 Parts submitted for this test shall be subjected to the following requirements for reporting of test data:

6.1.1 A statement that this recommended practice was followed. Regarding 5.2.4, the number of cycles, as agreed upon between the purchaser and the seller.

6.1.2 The tray construction (if a tray is used) and chamber loading.

6.1.3 The particular temperature limits specified in 5.4. The time required for the specified heating and cooling of the parts for the particular loading and type of parts selected.

6.1.4 The last calibration date of the controller and recorder.

6.1.5 Upon the completion of the test, the part shall be examined and a record made of the extent, nature, and location of any defect.

NOTE 4—The interpretation of 6.1.5 is beyond the scope of this recommended practice.

APPENDIX

A1. DESCRIPTION OF SERVICE CONDITIONS

A1.1 *Service Condition 1 (mild)*—Indoor exposure in normally warm, dry atmospheres with plated coating subjected to a minimum of wear or abrasion.

A1.2 *Service Condition 2 (moderate)*—Indoor exposure in places where condensation of moisture may occur, for example, kitchens and bathrooms.

A1.3 *Service Condition 3 (severe)*—Exposure likely to include occasional or frequent wetting by rain or dew or possibly strong cleaners and saline solutions; for example, outdoor furniture and hardware components, bicycle parts, and hospital fixtures.

A1.4 *Service Condition 4 (very severe)*—Outdoor exposure likely to include the requirements of SC 3, along with damage from denting, scratching, and abrasive wear; for example, exterior components of automobiles and boat fittings.

APPENDIX III

STABILITY OF CEMENT MATRIX USED FOR LOW-LEVEL RADIOACTIVE WASTE SOLIDIFICATION

FIRL REPORT F-A5959

Prepared for

Bartlett Nuclear Corporation
Plymouth, MA 02360

July 13, 1984

Franklin Institute Research Laboratory, Inc.
20th and Race Streets. Phila., Pa. 19103 (215) 448-1000

CONTENTS

1. SUMMARY OF PERTINENT FACTS

FIRL Report No.

F-A5959

Report Title:

Qualification of Cement Matrix Used for Low-Level Radioactive Waste Solidification

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Conducted and Reported by:

Franklin Institute Research
Laboratory, Inc.
Twentieth and Race Streets
Philadelphia, PA 19103

Conducted for:

Bartlett Nuclear Corporation
10 Aldrin Rd.
Plymouth Industrial Park
Plymouth, MA 02360

Report Date:

May 23, 1984

Period of Program:

March 1 through April 25, 1984

Objective:

To demonstrate the capability of a specific solidification matrix to comply with the requirements of 10CFR61 for leachability and radiation stability.

Material Tested:

Cement identified as MP-1, modified Portland cement.

Elements of Program:

Raw MP-1 cement, supplied by Bartlett Nuclear Corp., was used to solidify simulated borated waste and ion exchange resin beads by interposing radioactive material in the matrix mix. A leachability index number was determined by laboratory means for comparison to the accepted value. The cement matrix was also subjected to 10^8 rads (100 megarads) gamma radiation, when formed into a solid mass containing the two waste streams: borate and ion exchange resin beads. Compression tests were conducted to determine the comparison of values established by implementation of 10CFR61 (Draft).

Summary of Test Results:

a. Leachability index: For each of the two different isotopes used to simulate waste streams, the cement matrix produced a leachability index numerically higher than the minimum value stated in 10CFR61 (Draft).

b. Radiation stability: For each of the two different isotopes used to simulate waste streams, the compression test demonstrated values considerably higher than the minimum value stated in 10CFR61 (Draft).

c. Free-standing liquid: During preparation of all eight specimens, there was no free-standing liquid either 5 minutes after specimen molding or 48 hours after curing specimens.

2. OBJECTIVE AND ACCEPTANCE CRITERIA

2.1 OBJECTIVE

The objective of this program was twofold: (1) to determine the leachability index of a specific cement material used as a solidification agent in the permanent in-ground storage of low-level radioactive waste and (2) to demonstrate the stability of the same cement material when exposed to a high radiation dose over a short period of time. The radiation accumulated dose of 10^8 rads is based on the upper limits of current routinely generated waste. These objectives are based on the implementation of 10CFR Part 61.

2.2 ACCEPTANCE CRITERIA FOR STABILITY

The leachability index is calculated using the method described in the American Nuclear Society publication ANS 16.1, entitled "Measurement of the Leachability of Solidified Low-Level Radioactive Waste," Third Draft of a Standard, dated November 16, 1982. A value of 6 is the minimum acceptable value.

The compression strength, following high dose exposure, is based on an abstract published by the U.S. Nuclear Regulatory Commission titled "Implementation of 10CFR Part 61 Abstract" and authored by T. C. Johnson, P. H. Lottaus, and G. W. Roles (no date). A subtitle included in the abstract is "Waste Classification and Waste Form Requirements." The criterion for this test is a compression resistance, following dose exposure, of not less than 0.3 MPa (50 psi).

2.3 PERFORMANCE OF QUALITY ASSURANCE

The performance of quality assurance was in accordance with the FIRL Quality Assurance Manual, dated April 5, 1982 and inspected by the U.S. Nuclear Regulatory Commission via a site visit (dated August 8-12, 1983), and the NRC acceptance letter dated December 6, 1983.

3. DESCRIPTION OF CEMENT MATRIX

3.1 LEACHING STABILITY

The specimen materials used in the leachability index number determination are described as follows. The solidification matrix contained modified Portland cement, ion exchange resin beads, and sufficient water to make a slurry. Specimens were also prepared with borate solution and an accelerator for quick setting time. Eight specimens were molded; two contained resin beads with cesium-137 isotope, two used the cobalt-60 isotope, two contained borate material with a cesium-137 isotope, and two had borate material and the cobalt-60 isotope. Duplicate specimens were run to verify test results. Each specimen was a right cylinder measuring 2-cm diameter by 4-cm long.

3.2 RADIATION STABILITY

For radiation stability, two of each of the following mixtures were prepared for stability test: cement matrix plus ion exchange resin beads and cement matrix plus borate stream waste. Each of the four cylinders was cast in Teflon-lined tubes giving an overall dimension of 6-in diam by 6-in long. The weights and dimensions of each specimen were recorded prior to gamma radiation exposure. Preparation of samples was according to applicable field use instructions as supplied by Bartlett Nuclear Corp.

4. TEST PROCEDURES

4.1 LEACHABILITY INDEX DETERMINATION

The leachability index determination was conducted according to the American Nuclear Society publication ANS 16.1, entitled "Measurement of the Leachability of Solidified Low-Level Radioactive Waste," Third Draft of a Standard, dated November 16, 1982. Each of the eight specimens prepared for testing was submerged in demineralized water for a specific period of time. Seven leaching cycles were conducted over a period of 6 days for a set of four specimens and an additional 6 days for a second set of four specimens. The eight specimens were molded in specially designed molds made of Teflon. After removal of cured solidification matrix, the specimens were rinsed and all equipment used as mixing vessels was rinsed. The specimens were placed in dry, empty glass jars which were cap-sealed. The rinse solutions were then tested for isotopic content. The difference between amounts detected in the rinse and original activity received constituted A_o, the amount of isotope contained in each specimen. Each specimen was then placed in 314 ml of demineralized water for a cycle period of 2, 5, 17, 24, 24, and 24 hours (see Figure 1). The leachant (fresh demineralized water) was replaced at the end of each cycle with the same volume as originally used, 314 ml. The leachate (water containing leached out isotope) was then tested for isotopic content (see Appendix A for test data). At the completion of each cycle, three 1-ml aliquots were taken from each of the 314-ml leachate solutions and isotopically counted using the Gamma 4000 counting system. The data were analyzed, and the leachability index numbers were determined (see Appendix A for test data). The specimens were identified in the following manner:

Sample ID No.	Waste Stream	Isotopic Content	Date Prepared
1A1	Resin beads	200 uCi Cs-137	3/15/84
1A2	Resin beads	200 uCi Cs-137	3/15/84
1B1	Borate	200 uCi Cs-137	3/15/84
1B2	Borate	203 uCi Cs-137	3/15/84

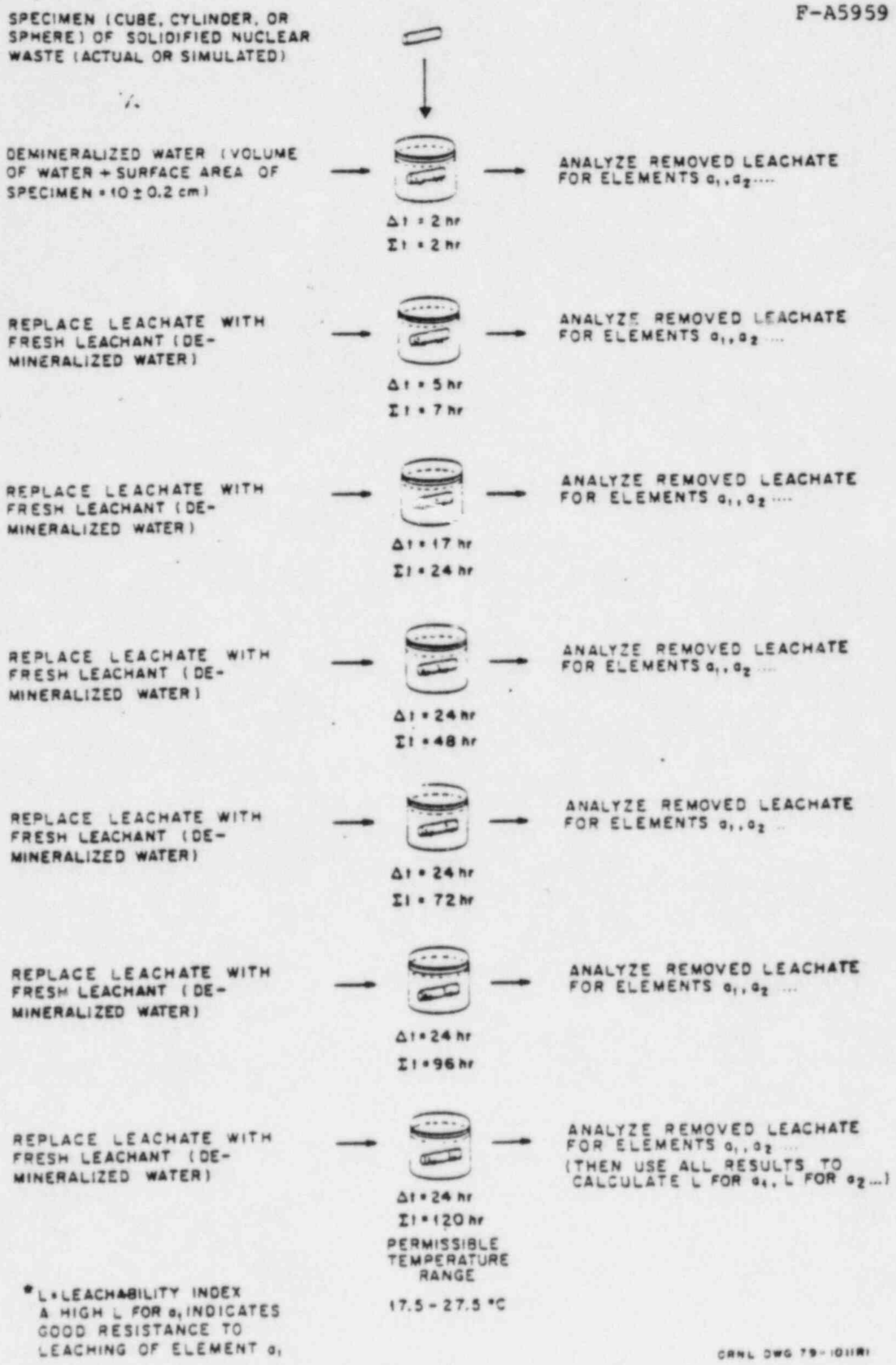

Figure 1. Schematic of the Standard Leach Test

Sample ID No.	Waste Stream	Isotopic Content	Date Prepared
2A1	Resin beads	202 uCi Co-60	3/29/84
2A2	Resin beads	205 uCi Co-60	3/29/84
2B1	Borate	202 uCi Co-60	3/29/84
2B2	Borate	199 uCi Co-60	3/29/84

Included in this test was the visual determination of free-standing liquid after solidification had taken place. Observations were conducted immediately after each specimen was poured in the Teflon molds, at the conclusion of the 48-hour curing period, and during the dry storage of the specimens prior to leach tests.

4.2 RADIATION STABILITY

Each of the two selected waste streams, ion exchange resin and borate solution, was homogeneously mixed and solidified in the cement matrix (MP-1). Six specimens of 6-in right cylinders were molded, three containing ion exchange resin beads and three containing borate solutions. Preparation of the solidification matrix is illustrated in Appendix B, which contains photographs of test apparatus. Two specimens of each simulated waste were selected and packaged for shipment to Neutron Products, Dickenson, MD, which performed the gamma dose exposure. Specimens 1 and 3 each contained 22.5% by weight of ion exchange resin beads. Specimens 6 and 7 contained borated compound as boric acid in a 10.3% solution to simulate the borate waste stream at a utility site. The total amount of boron in the solidified waste form was 4.74% by weight. Certification of radiation exposure is found in Appendix A, page A-1, as supplied by Neutron Products, Inc. Following the required radiation dose exposure of 10^8 rads, the four specimens were returned to FIRL, and compression tests were conducted on all four specimens. Results of these tests are found in Section 5 of this report. Photographs of the solidified matrix and the compression testing are presented in Appendix B, Figures B-9 through B-15.

5. TEST RESULTS

5.1 LEACH TEST RESULTS

The test results for leaching stability contained in Section 5, pages 8 through 31, were prepared in accordance with recommendations made in ANS 16.1, "Measurements of the Leachability of Solidified Low-Level Radioactive Waste," dated November 16, 1982, and requested by Bartlett Nuclear Corp. A summary of test results, page 32, demonstrates that the average of seven leaching cycles' leachability index numbers (LIX) for all of the eight specimens tested exceeded the minimum value of 6 as stated in "Implementation of 10CFR Part 61." Leach test results are based on pertinent data sheets which are presented in Appendix A of this report. Test data sheets are numbered in accordance with actual laboratory notebook numbered pages.

5.2 RADIATION STABILITY RESULTS

Test results for radiation stability are summarized on page 34 of this report. The results demonstrate that the matrix supplied by Bartlett Nuclear Corp. exceeds the minimum pressure load of 50 psi, as stated in "Implementation of 10CFR Part 61," by a factor of between 7.5 and 21.7 times the minimum value.

5.3 PRESENCE OF FREE-STANDING LIQUIDS

Test results for determination of the presence of free-standing liquids were based on visual observations made during test proceedings. No test data exist. Therefore, conclusions made in Section 6 of this report are based solely on observations.

LEACH TEST RESULTS

LEACH TEST IDENTIFICATION NUMBER 1 A

LABORATORY WHERE TESTS PERFORMED Franklin Research Center

ANALYST A.J. Cassell

DATE RESULTS REPORTED 27 April 1984

Part A. Description of Leach Specimen

Specimen Identification Number 1 A 1

Proportion of Waste Incorporated in Mixture 35.7 Weight %

4.49 cc Volume %

(Based on initial volumes)

Type of Waste, Chemical and Radioisotopic Composition, and Specific Activity of the Waste Ion exchange resin beads containing Cs-137 isotope. 200 uCi of Cs-137 gives a specific activity of 11.68 uCi/gram of specimen.

Type and Composition of the Solidification Agent Solidification material is basically Portland cement (modified) - MP-1.

Preparation of Specimen Specimen was prepared according to sponsor's normal use in the field. Each component was weighed out and mixes in teflon cups. Radioactive tracer was added as last ingredient. Slurry was then poured into teflon mold, 2 cm diad. and 4 cm high. By previous trial the correct volume of matrix was determined and used to completely fill the mold.

Shape and Dimensions of Specimen

Sphere, diameter, d (cm) =

Cylinder, diameter, d (cm) = 2 cm diameter &

length, ℓ (cm) = 4 cm long

Parallelepiped, length, ℓ (cm) = ,

width, w (cm) = , &

height, h (cm) =

Other, Shape

Dimensions

Initial Weight of Specimen, W_i (g) = 17.12 grams

Volume of Specimen*, V (cm^3) = 12.56 cubic centimeters

Surface Area of Specimen, S* (cm^2) = 31.40 square centimeters

Storage Conditions After solidification, the specimen was placed in an empty glass jar which was cap sealed.

Appearance

The specimen was excellent in shape and surface condition. Removal of the sample from the mold was accomplished by splitting the mold.

Description of Leachant

Leach Interval (n)	Electrical Conductivity (umho/cm)	Volume, V_L (ml)
1	1.4	314
2	1.2	314
3	1.2	314
4	1.1	314
5	1.3	314
6	1.4	314
7	1.2	314

---

*Calculated from dimensions of specimen.

LEACH TEST RESULTS

F-A5959

LEACH TEST IDENTIFICATION NUMBER 1 A 1

LABORATORY WHERE TESTS PERFORMED Franklin Research Center

ANALYST A.J. Cassell

DATE RESULTS REPORTED 27 April 1984

Part B. Description of Leach Test Procedure

Specimen Preparation*

Diagram of Leach Apparatus:

(See Photos on Page B-1)

Leachate Sampling Procedure Following each leaching cycle, the specimen was removed from the 314 ml. leachant solution. The specimen was rinsed in 157 ml. of distilled water for 20-30 sec. From the leachate, three(3) aliquoits of one(1) ml. each were placed in counting vials and each vial identified as to the specimen number. The leachate was not discarded unless the three samples gave counting statisticts within acceptable standard deviations.

Analytical Techniques:

Counting Instrument Identification and Calibration Gamma counting of the leachate was accomplished by using a Gamma 4000 unit, manufactured by Beckman Instrument Co. The unit contains a three inch sodium iodide, thallium activated , scintillation crystal.

Constituent a_1, Analytical Procedure, Standard Deviation of Method Cs-137, 0.1 uCi, ± 3%, traceable to NBS Standard, was used to determine counting efficiency. A normal or Maxwellian distribution was used in Standard Deviation detrmination

Constituent a_2, Analytical Procedure, Standard Deviation of Method

Constituent a_i, Analytical Procedure, Standard Deviation of Method

*If different from "Preparation of Specimen" in Part A.

LEACH TEST RESULTS

LEACH TEST IDENTIFICATION NUMBER 1 A 1

LABORATORY WHERE TESTS PERFORMED Franklin Research Center

ANALYST A.J. Cassell

DATE RESULTS REPORTED 27 April 1984

Part C. Experimental Data

Constituent Analyzed, = Cesium-137

Free Standing Water in Leach Specimen Container: Yes X No
If Yes, Volume (ml) = ____; Radioactivity (uCi) = ____; and % of A_o = ____

Specimen Rinse Before Initiation of Leaching: *Do not include with results in the table below.*
Volume (ml) = 120 ; Radioactivity (uCi) = 6 ; and % of A_o = 2.91

Initial Amount in Specimen, A_o (uCi) [after 30-s rinse] = 200 uCi

Leach Interval (n)	Temp. (°C)	Time and Date*		$(\Delta t)_n$ (s)	$t=\Sigma(\Delta t)_n$ (s)	An Analyzed (uCi) **	Blank ( )	Corrected Conc. (uCi)	a_n***	a_n/A_o	$(a_n/A_o)[1/(\Delta t)_n]$ (fraction/s)	$\Sigma_1^n a_i/A_o$
		In	Out									
1	20	3-19-84 0800	3-19-84 1005	7.5×10^3	7.30×10^3	9.20	—	18.4	18.4	0.092	1.23×10^{-5}	0.092
2	20	3-19-84 1005	3-19-84 1510	1.83×10^4	2.58×10^4	23.2	—	46.4	46.4	0.232	8.99×10^{-6}	0.324
3	20	3-19-84 1510	3-20-84 0815	6.15×10^4	8.73×10^4	21.6	—	43.2	43.2	0.216	2.47×10^{-6}	0.540
4	20	3-20-84 0815	3-21-84 0825	8.7×10^4	1.74×10^5	12.8	—	25.6	25.6	0.128	7.36×10^{-7}	0.668
5	20	3-21-84 0825	3-22-84 0825	8.64×10^4	2.60×10^5	8.00	—	16.0	16.0	0.080	3.08×10^{-7}	0.748
6	20	3-22-84 0825	3-23-84	8.73×10^4	3.47×10^5	3.44	—	6.88	6.88	0.034	9.80×10^{-8}	0.782
7	20	3-23-84 0845	3-24-84 0845	8.67×10^4	4.34×10^5	2.48	—	4.96	4.96	0.025	5.76×10^{-8}	0.807

*Date, hour, and minute

**Concentration in leachate, show units

***a_n = corrected concentration x V_L x factor to convert to same units as A_o. The value of a_n must include any radioactivity rinsed from the specimen and the leachate apparatus at the end of the renewal period.

LEACH TEST RESULTS

F-A5959

LEACH TEST IDENTIFICATION NUMBER 1 A

LABORATORY WHERE TESTS PERFORMED Franklin Research Center

ANALYST A.J. Cassell

DATE RESULTS REPORTED 27 April 1984

Part A. Description of Leach Specimen

Specimen Identification Number 1 A 2

Proportion of Waste Incorporated in Mixture 35.7 Weight %

4.49 Volume %

(Based on initial volumes)

Type of Waste, Chemical and Radioisotopic Composition, and Specific Activity of the Waste Ion exchange resin beads containing Cs-137 isotope, 200 uCi of Cs-137 gives a specific activity of 11.68 uCi/grm of specimen

Type and Composition of the Solidification Agent Solidification material is basically Portland cement, MP-1, modified.

Preparation of Specimen Specimen was prepared according to sponsor's normal use in the field. Each component was weighed out and mixed in teflon cup. Radioactive tracer was added as last ingredient. Slurry was then poured into a teflon mold, 2 cm dia. X 4 cm long. By previous trial the correct volume of the matrix was determined and used to completely fill the mold.

Shape and Dimensions of Specimen

Sphere, diameter, d (cm) =

Cylinder, diameter, d (cm) = 2 cm &

length, ℓ (cm) = 4 cm

Parallelepiped, length, ℓ (cm) = ,

width, w (cm) = , &

height, h (cm) =

Other, Shape

Dimensions

Initial Weight of Specimen, W (g) = 17.14

Volume of Specimen*, V (cm^3) = 12.56

Surface Area of Specimen, S* (cm^2) = 31.40

Storage Conditions Specimen was stored on a teflon saddle inside of a clean dry jar and the jar cap sealed.

Appearance

The specimen was excellent in shape and size. Surface condition was very good, due to the ability of removining specimen from the mold.

Description of Leachant

Leach Interval (n)	Electrical Conductivity (umho/cm)	Volume, V_L (ml)
1	1.3	314
2	1.5	314
3	1.2	314
4	1.3	314
5	1.2	314
6	1.3	314
7	1.4	314

---

*Calculated from dimensions of specimen.

LEACH TEST RESULTS

LEACH TEST IDENTIFICATION NUMBER 1 A 2

LABORATORY WHERE TESTS PERFORMED Franklin Research Center

ANALYST A.J. Cassell

DATE RESULTS REPORTED 27 April 1984

Part B. Description of Leach Test Procedure

Specimen Preparation*

Diagram of Leach Apparatus:

(See Photos on Page B-1)

Leachate Sampling Procedure Following each leaching cycle, the specimen was removed from the 314 ml leachate solution. The specimen was rinsed in 157 ml. of distilled water for 20-30 sec. From the leachate, three(3) aliquoits of one(1) ml. each were placed in counting vials and each vial identified as to the specimen number. The leachate was not discarded unless the three samples gave counting statistics within acceptable standard deviations.

Analytical Techniques:

Counting Instrument Identification and Calibration

Constituent a_1, Analytical Procedure, Standard Deviation of Method

Constituent a_2, Analytical Procedure, Standard Deviation of Method

Constituent a_i, Analytical Procedure, Standard Deviation of Method

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*If different from "Preparation of Specimen" in Part A.

LEACH TEST RESULTS

LEACH TEST IDENTIFICATION NUMBER I A 2

LABORATORY WHERE TESTS PERFORMED Franklin Research Center

ANALYST A.J. Cassell

DATE RESULTS REPORTED 27 April 1984

Part C. Experimental Data

Constituent Analyzed, = Cesium-137

Free Standing Water in Leach Specimen Container: ___ Yes X No
If Yes, Volume (ml) = ____; Radioactivity (μCi) = ____; and % of A_o = ____

Specimen Rinse Before Initiation of Leaching: *Do not include with results in the table below.*
Volume (ml) = 120 ; Radioactivity (μCi) = 6 ; and % of A_o = 2.91

Initial Amount in Specimen, A_o (μCi) [after 30-s rinse] = 200 uCi

Leach Interval (n)	Temp. (°C)	Time and Date*		$(\Delta t)_n$ (s)	$t=\Sigma(\Delta t)_n$ (s)	As Analyzed (uCi) **	Blank ( )	Corrected Conc. (uCi)	a_n***	a_n/A_o	$[a_n/A_o][1/(\Delta t)_n]$ (fraction/s)	$\Sigma_1^n a_i/A_o$
		In	Out									
1	20	3-19-84 0800	3-19-84 1005	7.50×10^3	7.50×10^3	7.36	—	14.72	14.72	0.074	1.01×10^{-5}	0.074
2	20	3-19-84 1005	3-19-84 1510	1.83×10^4	2.58×10^4	18.40	—	36.80	36.80	0.184	7.13×10^{-6}	0.258
3	20	3-19-84 1510	3-20-84 0815	6.15×10^4	8.73×10^4	16.80	—	33.60	33.60	0.168	1.88×10^{-6}	0.426
4	20	3-20-84 0815	3-21-84 0825	8.70×10^4	1.74×10^5	10.40	—	20.80	20.80	0.104	5.98×10^{-7}	0.530
5	20	3-21-84 0825	3-22-84 0825	8.64×10^4	2.60×10^5	6.40	—	12.80	12.80	0.064	2.46×10^{-7}	0.594
6	20	3-22-84 0825	3-23-84 0840	8.73×10^4	3.47×10^5	2.72	—	5.44	5.44	0.027	7.78×10^{-8}	0.621
7	20	3-23-84 0840	3-24-84 0845	8.67×10^4	4.34×10^5	2.00	—	4.00	4.00	0.020	4.61×10^{-8}	0.641

*Date, hour, and minute

**Concentration in leachate, show units

*** a_n = corrected concentration x V_L x factor to convert to same units as A_o. The value of a_n must include any radioactivity rinsed from the specimen and the leachate apparatus at the end of the renewal period.

LEACH TEST RESULTS

LEACH TEST IDENTIFICATION NUMBER 1 B

LABORATORY WHERE TESTS PERFORMED Franklin Research Center

ANALYST A.J. Cassell

DATE RESULTS REPORTED 27 April 1984

Part A. Description of Leach Specimen

Specimen Identification Number 1 B 1

Proportion of Waste Incorporated in Mixture 10.4 **Weight %**

1.31 **Volume %**

(Based on initial volumes)

Type of Waste, Chemical and Radioisotopic Composition, and Specific Activity of the Waste Simulated borate stream consisted of boric acid (10.4% concentration) containing 200 uCi of Cs-137. Specific activity of Cs-137 was 11.59 uCi/gram of the specimen

Type and Composition of the Solidification Agent Solidification agent is basically modified Portland cement (Type MP-1)

Preparation of Specimen Specimen was prepared according to sponsor's normal use in the field. Each component was weighed out and mixed in a teflon cup. Radioactive tracer, Cs-137 was added as the next to last ingredient. The accelerator was added last. Slurry was then added to the teflon mold, which was 2 cm. dia. X 4 cm. long.

Shape and Dimensions of Specimen

Sphere, diameter, d (cm) =

Cylinder, diameter, d (cm) = 2 cm. &

length, ℓ (cm) = 4 cm.

Parallelepiped, length, ℓ (cm) = ,

width, w (cm) = , &

height, h (cm) =

Other, Shape

Dimensions

Initial Weight of Specimen, W (g) = 16.47

Volume of Specimen*, V (cm^3) = 12.56

Surface Area of Specimen, S* (cm^2) = 31.40

Storage Conditions Specimen was removed from mold after curing at 130°F for 48 hours. The specimen was then placed in a dry, empty storage jar, to be held until leachability test started.

Appearance

The specimen was in excellent shape and surface condition was very good. Specimen measured 2 cm. X 4 cm. after removal from mold.

Description of Leachant

Leach Interval (n)	Electrical Conductivity (umho/cm)	Volume, V_L (ml)
1	4.0	314
2	3.8	314
3	3.8	314
4	4.1	314
5	4.0	314
6	4.2	314
7	3.9	314

*Calculated from dimensions of specimen.

LEACH TEST RESULTS

F-A5959

LEACH TEST IDENTIFICATION NUMBER 1 B 1

LABORATORY WHERE TESTS PERFORMED Franklin Research Center

ANALYST A.J. Cassell

DATE RESULTS REPORTED 27 April 1984

Part B. Description of Leach Test Procedure

Specimen Preparation*

Diagram of Leach Apparatus:

(See photos on Page B-1)

Leachate Sampling Procedure Following each leaching cycle, the specimen was removed from the 314 ml. of leachate solution. The specimen was rinsed in 157 ml. of fresh distilled water. From the leachate, three(3) aliquoits of one(1) ml. each were placed in counting vials and each vial identified as to the specimen number. The leachate was not discarded unless the three samples gave counting statistics within acceptable standard deviations.

Analytical Techniques:

Counting Instrument Identification and Calibration Gamma counting was accomplished by using a Gamma 4000 automatic sampler, manufactured by by Beckman Instrument Co. The unit contains a three inch sodium iodide, thallium activated, scintillation crystal.

Constituent a_1, Analytical Procedure, Standard Deviation of Method Cs-137, 0.1 uCi, ± 3% accuracy, traceable to NBS Standard was used as the source for determining instrument efficiency. A normal or Maxwellian distribution was used in the standard deviation determination.

Constituent a_2, Analytical Procedure, Standard Deviation of Method

Constituent a_i, Analytical Procedure, Standard Deviation of Method

---

*If different from "Preparation of Specimen" in Part A.

LEACH TEST RESULTS

LEACH TEST IDENTIFICATION NUMBER 1 B 1

LABORATORY WHERE TESTS PERFORMED Franklin Research Center

ANALYST A.J. Cassell

DATE RESULTS REPORTED 27 April 1984

Part C. Experimental Data

Constituent Analyzed, = Cesium-137

Free Standing Water in Leach Specimen Container: X Yes ___ No
If Yes, Volume (ml) = ___; Radioactivity (μCi) = ___; and % of A_o = ___

Specimen Rinse Before Initiation of Leaching: *Do not include with results in the table below.*
Volume (ml) = 120; Radioactivity (μCi) = 6; and % of A_o = 2.91

Initial Amount in Specimen, A_o (μCi) [after 30-s rinse] = 200 uCi

Leach Interval (n)	Temp. (°C)	Time and Date*		$(\Delta t)_n$ (s)	$t=\Sigma(\Delta t)_n$ (s)	As Analyzed (uCi) **	Blank ( )	Corrected Conc. (uCi)	a_n***	a_n/A_o	$[a_n/A_o][1/(\Delta t)_n]$ (fraction/s)	$\sum_{1}^{n} a_j/A_o$
		In	Out									
1	20	3-19-84 0800	3-19-84 1005	7.50×10^3	7.50×10^3	6.00	——	12.00	12.00	0.060	8.00×10^{-6}	0.060
2	20	3-19-84 1005	3-19-84 1510	1.83×10^4	2.58×10^4	16.32	——	32.64	32.64	0.163	6.30×10^{-6}	0.223
3	20	3-19-84 1510	3-20-84 0815	6.15×10^4	8.73×10^4	13.20	——	26.40	26.40	0.132	1.50×10^{-6}	0.355
4	20	3-20-84 0815	3-21-84 0825	8.70×10^4	1.74×10^5	6.96	——	13.92	13.92	0.070	4.00×10^{-7}	0.425
5	20	3-21-84 0825	3-22-84 0825	8.64×10^4	2.60×10^5	3.20	——	6.40	6.40	0.032	1.23×10^{-7}	0.457
6	20	3-22-84 0825	3-23-84 0840	8.73×10^4	3.47×10^5	1.36	——	2.72	2.72	0.014	4.03×10^{-8}	0.471
7	20	3-23-84 0840	3-24-84 0845	8.67×10^4	4.34×10^5	0.80	——	1.60	1.60	0.008	1.84×10^{-8}	0.479

*Date, hour, and minute

**Concentration in leachate, show units

***a_n = corrected concentration × V_L × factor to convert to same units as A_n. The value of a_n must include any radioactivity rinsed from the specimen and the leachate apparatus at the end of the renewal period.

F-A5959

LEACH TEST RESULTS

F-A5959

LEACH TEST IDENTIFICATION NUMBER 1 B

LABORATORY WHERE TESTS PERFORMED Franklin Research Center

ANALYST A.J. Cassell

DATE RESULTS REPORTED 27 April 1984

Part A. Description of Leach Specimen

Specimen Identification Number 1 B 2

Proportion of Waste Incorporated in Mixture 10.4 Weight %

1.31 Volume %

(Based on initial volumes)

Type of Waste, Chemical and Radioisotopic Composition, and Specific Activity of the Waste Simulated borate waste stream consisting of boric acid (10.4% concentration) with 203 uCi of Cs-137 as tagged contaminate. Specific activity of Cs-lct was 12.39 uCi/gram of the specimen.

Type and Composition of the Solidification Agent Solidification agent was modified Portland cement (MP-1).

Preparation of Specimen Specimen was prepared according to sponsor's normal use in the field. Each component was weighed out and mixed in a teflon cup. The radioactive tracer, Cs-137, was added as the next to last ingredient. The accelerator was added last. The slurry was then added to teflon mold which I.D. was 2 cm. and 4 cm. long.

Shape and Dimensions of Specimen

Sphere, diameter, d (cm) = ______

Cylinder, diameter, d (cm) = 2 cm &

length, ℓ (cm) = 4 cm

Parallelepiped, length, ℓ (cm) = ______,

width, w (cm) = ______, &

height, h (cm) = ______

Other, Shape ______

Dimensions ______

Initial Weight of Specimen, W (g) = 16.39

Volume of Specimen*, V (cm^3) = 12.56

Surface Area of Specimen, S* (cm^2) = 31.40

Storage Conditions Specimen was removed from mold after curing at 130°F for 48 hours. The specimen was placed in a clean , dry, empty storage jar., to be held until leachability test started.

Appearance

Specimen was in excellent condition and surface condition was very good. There were no obvious voids from a visual inspection.

Description of Leachant

Leach Interval (n)	Electrical Conductivity (umho/cm)	Volume, V_L (ml)
1	3.2	314
2	3.0	314
3	2.8	314
4	3.0	314
5	2.7	314
6	3.1	314
7	3.0	314

*Calculated from dimensions of specimen.

LEACH TEST RESULTS

F-A5959

LEACH TEST IDENTIFICATION NUMBER 1 B 2

LABORATORY WHERE TESTS PERFORMED Franklin Research Center

ANALYST A.J. Cassell

DATE RESULTS REPORTED

Part B. Description of Leach Test Procedure

Specimen Preparation*

Diagram of Leach Apparatus:

(See Photo on Page B-1)

Leachate Sampling Procedure Following each leaching cycle, the specimen was removed from the 314 ml. leachate solution. The specimen was rinsed in 154 ml. of fresh demilineralized water. From the lechate, three(3) aliquoits of one (1) ml. each were placed into counting vials and the vials identified as to the specimen number. The leachate was not discarded unless the three samples gave counting statistics within acceptable standard deviations.

Analytical Techniques:

Counting Instrument Identification and Calibration Gamma counting was accomplished by using a Gamma 4000 automatic sampler, manufactured by Beckman Instrument Co. The unit contains a three-inch sodium iodide, thallium activated, scintillation crystal.

Constituent a_1, Analytical Procedure, Standard Deviation of Method Cs-137, 0.1 uCi, ± 3% accuracy, traceable to NBS Standard was used as the source to determine the instrument efficiency. A normal or Maxwellian distribution was used in the standard deviation determinatic

Constituent a_2, Analytical Procedure, Standard Deviation of Method

Constituent a_i, Analytical Procedure, Standard Deviation of Method

---

*If different from "Preparation of Specimen" in Part A.

LEACH TEST RESULTS

LEACH TEST IDENTIFICATION NUMBER 1 B 2

LABORATORY WHERE TESTS PERFORMED Franklin Research Center

ANALYST A.J. Cannell

DATE RESULTS REPORTED 27 April 1984

Part C. Experimental Data

Constituent Analyzed, = Cesium-137

Free Standing Water in Each Specimen Container: ___ Yes X No
If Yes, Volume (ml) = ___; Radioactivity (μCi) = ___; and % of A_o = ___

Specimen Rinse Before Initiation of Leaching: *Do not include with results in the table below.*
Volume (ml) = 120 ; Radioactivity (μCi) = 3 ; and % of A_o = 1.46

Initial Amount in Specimen, A_o (μCi) [after 30-s rinse] = 203 uCi

Leach Interval (n)	Temp. (°C)	Time and Date*		$(\Delta t)_n$ (s)	$t=\Sigma(\Delta t)_n$ (s	As Analyzed (uCi) **	Blank ( )	Corrected Conc. (uCi)	a_n***	a_n/A_o	$[a_n/A_o][1/(\Delta t)_n]$ (fraction/s)	$\sum_1^n a_1/A_o$
		In	Out									
1	20	3-19-84 0800	3-19-84 1005	7.50×10^3	7.50×10^3	8.22	——	16.44	16.44	0.081	1.08×10^{-5}	0.081
2	20	3-19-84 1005	3-19-84 1510	1.83×10^4	2.58×10^4	19.26	——	38.52	38.52	0.190	7.36×10^{-6}	0.271
3	20	3-19-84 1510	3-20-84 0815	6.15×10^4	8.73×10^4	17.25	——	34.50	34.50	0.170	1.95×10^{-6}	0.448
4	20	3-20-84 0815	3-21-84 0825	8.70×10^4	1.74×10^5	12.43	——	24.86	24.86	0.122	7.01×10^{-7}	0.570
5	20	3-21-84 0825	3-22-84 0825	8.64×10^4	2.60×10^5	7.22	——	14.44	14.44	0.071	2.73×10^{-7}	0.641
6	20	3-22-84 0825	3-23-84 0840	8.73×10^4	3.42×10^5	2.41	——	4.82	4.82	0.024	6.92×10^{-8}	0.665
7	20	3-23-84 0840	3-24-84 0845	8.67×10^4	4.34×10^5	2.01	——	4.02	4.02	0.020	4.61×10^{-8}	0.685

*Date, hour, and minute

**Concentration in leachate, show units

***a_n = corrected concentration x V_L x factor to convert to same units as A_o. The value of a_n must include any radioactivity rinsed from the specimen and the leachate apparatus at the end of the renewal period.

F-A5959

LEACH TEST RESULTS

F-A5959

LEACH TEST IDENTIFICATION NUMBER 2 A

LABORATORY WHERE TESTS PERFORMED Franklin Research Center

ANALYST A.J. Cassell

DATE RESULTS REPORTED 27 April 1984

Part A. Description of Leach Specimen

Specimen Identification Number 2 A 1

Proportion of Waste Incorporated in Mixture 35.7 **Weight %**

4.49 **Volume %**

(Based on initial volumes)

Type of Waste, Chemical and Radioisotopic Composition, and Specific Activity of the Waste Ion exchange resin beads containing Co-60 isotope. 202 uCi of Co-60 produced a specific activity of 11.85 uCi/gm of the specimen.

Type and Composition of the Solidification Agent The solidification matrix was a modified Portland cement (MP-1) supplied by the sponsor.

Preparation of Specimen Specimen was prepared according to sponsor's normal use in the field. Each component was weighed out and mixed in a clean teflon cup. The radioactive tracer, Co-60, was added as the last component. The slurry was then poured into a clean teflon mold, which inside measurements produced the desired specimen size.

Shape and Dimensions of Specimen

Sphere, diameter, d (cm) =

Cylinder, diameter, d (cm) = 2.0 &

length, ℓ (cm) = 4.0

Parallelepiped, length, ℓ (cm) = ,

width, w (cm) = , &

height, h (cm) =

Other, Shape

Dimensions

Initial Weight of Specimen, W (g) = 17.05

Volume of Specimen*, V (cm^3) = 12.56

Surface Area of Specimen, S* (cm^2) = 31.40

Storage Conditions Following a 48 hour curing period at 130°F, the specimen was removed from the mold and placed in a dry, empty, glass jar and maintained with a sealed cap until the leachability test was started.

Appearance

The specimen appeared excellent in shape and sondition. There were no surface void determined while visual inspection was being conducted.

Description of Leachant

Leach Interval (n)	Electrical Conductivity (μmho/cm)	Volume, V_L (ml)
1	2.0	134
2	1.8	134
3	2.1	134
4	2.0	134
5	2.2	134
6	2.0	134
7	2.0	134

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*Calculated from dimensions of specimen.

LEACH TEST RESULTS

F-A5959

LEACH TEST IDENTIFICATION NUMBER 2 A 1

LABORATORY WHERE TESTS PERFORMED Franklin Research Center

ANALYST A.J. Cassell

DATE RESULTS REPORTED 27 April 1984

Part B. Description of Leach Test Procedure

Specimen Preparation*

Diagram of Leach Apparatus:

See Photos on Page B-1)

Leachate Sampling Procedure Following each leaching cycle, the
specimen was remove from the 314 ml. of leachate. The specimen was
rinsed in 157 ml. of fresh demineralized water. From the leachate,
three (3) aliquoits of one(1) ml. were placed into separate counting
vials and the vials identified as to the specimen number. The leachate
was not discarded unless the three samples gave counting statistics
within acceptable standard deviations.

Analytical Techniques:

Counting Instrument Identification and Calibration A Gamma 4000, automatic
sampler, containing a three (3) inch sodium iodide, thallium activated
scintillation crystaldetector was used for counting the leachate
samples.

Constituent a_1, Analytical Procedure, Standard Deviation of Method
Co-60, 0.4 uCi, ± 3%, traceable to NBS standard, was used to determine
counting efficiency. A normal or Maxwellian distribution was used
in standard deviation determination.

Constituent a_2, Analytical Procedure, Standard Deviation of Method

Constituent a_i, Analytical Procedure, Standard Deviation of Method

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*If different from "Preparation of Specimen" in Part A.

LEACH TEST RESULTS

LEACH TEST IDENTIFICATION NUMBER 2 A 1

LABORATORY WHERE TESTS PERFORMED Franklin Research Center

ANALYST A.J. Connell

DATE RESULTS REPORTED 27 April 1984

Part C. Experimental Data

Constituent Analyzed, = Cobalt-60

Free Standing Water in Leach Specimen Container: ___ Yes X No
If Yes, Volume (ml) = ___; Radioactivity (µCi) = ___; and % of A_o = ___

Specimen Rinse Before Initiation of Leaching: *Do not include with results in the table below.*
Volume (ml) = 120 ; Radioactivity (µCi) = 4 ; and % of A_o = 1.94

Initial Amount in Specimen, A_o (µCi) [after 30-s rinse] = 202 uCi

Leach Interval (n)	Temp. (°C)	Time and Date*		$(\Delta t)_n$ (s)	$t=\Sigma(\Delta t)_n$ (s)	As Analyzed (uCi) **	Blank ( )	Corrected Conc. (uCi)	a_n***	a_n/A_o	$[a_n/A_o][1/(\Delta t)_n]$ (fraction/s)	$\sum_{1}^{n} a_j/A_o$
		In	Out									
1	20	4-02-84 0800	4-02-84 1015	8.10×10^3	8.10×10^3	4.00	——	8.00	8.00	0.039	4.81×10^{-6}	0.039
2	20	4-02-84 1015	4-02-84 1525	1.86×10^4	2.67×10^4	11.22	——	22.44	22.44	0.111	4.16×10^{-6}	0.150
3	20	4-02-84 1525	4-03-84 0835	6.18×10^4	8.85×10^4	13.63	——	27.26	27.26	0.135	1.52×10^{-7}	0.285
4	20	4-03-84 0835	4-04-84 0845	8.70×10^4	1.76×10^5	10.02	——	20.04	20.04	0.099	5.62×10^{-7}	0.384
5	20	4-04-84 0845	4-05-84 0850	8.67×10^4	2.63×10^5	8.42	——	16.84	16.84	0.083	3.16×10^{-7}	0.467
6	20	4-05-84 0850	4-06-84 0855	8.67×10^4	3.50×10^5	4.00	——	8.00	8.00	0.039	1.11×10^{-7}	0.506
7	20	4-06-84 0855	4-07-84 0855	8.64×10^4	4.36×10^5	3.21	——	6.42	6.42	0.032	7.34×10^{-8}	0.538

*Date, hour, and minute

**Concentration in leachate, show units

***a_n = corrected concentration × V_L × factor to convert to same units as A_o. The value of a_n must include any radioactivity rinsed from the specimen and the leachate apparatus at the end of the renewal period.

F-A5959

LEACH TEST RESULTS

F-A5959

LEACH TEST IDENTIFICATION NUMBER 2 A

LABORATORY WHERE TESTS PERFORMED Franklin Research Center

ANALYST A.J. Cassell

DATE RESULTS REPORTED 27 April 1984

Part A. Description of Leach Specimen

Specimen Identification Number 2 A 2

Proportion of Waste Incorporated in Mixture 35.7 Weight %
4.49 Volume %
(Based on initial volumes)

Type of Waste, Chemical and Radioisotopic Composition, and Specific Activity of the Waste Ion exchange resin beads containing Co-60 isotope, 205 uCi of Co-60 produced a specific activity of 11.86 uCi/gm of the specimen.

Type and Composition of the Solidification Agent The solidification matrix was a modified Portland cement (MP-1) supplied by the sponsor.

Preparation of Specimen The specimen was prepared according to the sponsor's normal use in the field. Each component was weighed out and mixed in a clean teflon cup. The radioactive tracer, Co-60, was added as the last component. The matrix slurry was poured into a clean, teflon mold, the iside measurements producing the required specimen size.

Shape and Dimensions of Specimen

Sphere, diameter, d (cm) = ______ &
Cylinder, diameter, d (cm) = 2.0
length, ℓ (cm) = 4.0
Parallelepiped, length, ℓ (cm) = ______,
width, w (cm) = ______, &
height, h (cm) = ______

Other, Shape ______
Dimensions ______

Initial Weight of Specimen, W (g) = 17.28
Volume of Specimen*, V (cm^3) = 12.56
Surface Area of Specimen, S* (cm^2) = 31.40

Storage Conditions Following a 48 hour curing period at 130°F, the specimen was removed from the mold and placed in a dry, empty, glass jar and maintained with a sealed cap until the leachability test was started.

Appearance
The specimen appeared to be excellent in shape. The surface exhibited a very smooth homogeneous surface.

Description of Leachant

Leach Interval (n)	Electrical Conductivity (umho/cm)	Volume, V_L (ml)
1	1.4	314
2	1.2	314
3	1.2	314
4	1.3	314
5	1.25	314
6	1.4	314
7	1.2	314

*Calculated from dimensions of specimen.

LEACH TEST RESULTS

LEACH TEST IDENTIFICATION NUMBER 2 A 2 **F-A5959**

LABORATORY WHERE TESTS PERFORMED Franklin Research Center

ANALYST A.J. Cassell

DATE RESULTS REPORTED 27 April 1984

Part B. Description of Leach Test Procedure

Specimen Preparation*

Diagram of Leach Apparatus:

(see Photos on Page B-1)

Leachate Sampling Procedure Following the leaching cycle, the specimen was removed from the 314 ml. of leachate. The specimen was rinsed in 15 of fresh demineralized water. From the leachate, three (3) aliquoits of one(1) ml. each were placed into separate counting vials and the vials identified as to the specimen number. The leachate was not discarded unless the three samples gave counting statistics within acceptable standard deviations.

Analytical Techniques:

Counting Instrument Identification and Calibration A Gamma 4000, automatic sampler, containing a three inch sodium iodide, thallium activated, scintillation crystal detector was used for counting the leachate samples.

Constituent a_1, Analytical Procedure, Standard Deviation of Method Co-60, ± 3%, traceable to NBS standard, was used as the standard for determining counting efficiency. A normal or Maxwellian distributic was used in the standard deviation determination.

Constituent a_2, Analytical Procedure, Standard Deviation of Method

Constituent a_i, Analytical Procedure, Standard Deviation of Method

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*If different from "Preparation of Specimen" in Part A.

LEACH TEST RESULTS

LEACH TEST IDENTIFICATION NUMBER 2 A 2

LABORATORY WHERE TESTS PERFORMED Franklin Research Center

ANALYST A.J. Cassell

DATE RESULTS REPORTED 27 April 1984

Part C. Experimental Data

Constituent Analyzed, = Cobalt-60

Free Standing Water in Leach Specimen Container: _ Yes X No
If Yes, Volume (ml) = ___; Radioactivity (μCi) = ___; and % of A_o = ___

Specimen Rinse Before Initiation of Leaching: *Do not include with results in the table below.*
Volume (ml) = 120 ; Radioactivity (μCi) = 1.0 ; and % of A_o = 0.49

Initial Amount in Specimen, A_o (μCi) (after 30-s rinse) = 205 uCi

Leach Interval (n)	Temp. (°C)	Time and Date*		$(\Delta t)_n$ (s)	$t=\Sigma(\Delta t)_n$ (s)	An Analyzed ( )**	Blank ( )	Corrected Conc. (uCi)	a_n***	a_n/A_o	$(a_n/A_o)[1/(\Delta t)_n]$ (fraction/s)	$\sum_1^n a_n/A_o$
		In	Out									
1	20	4-02-84 0800	4-02-84 1015	8.10×10^3	8.10×10^3	2	——	4	4	0.020	2.47×10^{-6}	0.020
2	20	4-02-84 1015	4-02-84 1525	1.86×10^4	2.67×10^4	8.84	——	17.68	17.68	0.086	3.21×10^{-6}	0.105
3	20	4-02-84 1525	4-03-84 0835	6.18×10^4	8.85×10^4	10.45	——	20.9	20.9	0.102	1.15×10^{-6}	0.207
4	20	4-03-84 0835	4-04-84 0845	8.70×10^4	1.76×10^5	7.64	——	15.28	15.28	0.074	4.20×10^{-7}	0.281
5	20	4-04-84 0845	4-05-84 0850	8.67×10^4	2.63×10^5	5.22	——	10.44	10.44	0.051	1.94×10^{-7}	0.312
6	20	4-05-84 0850	4-06-84 0855	8.67×10^4	3.50×10^5	3.22	——	6.44	6.44	0.031	8.86×10^{-8}	0.361
7	20	4-06-84 0855	4-07-84 0855	8.64×10^4	4.36×10^5	2	——	4	4	0.020	4.59×10^{-8}	0.383

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[*] Date, hour, and minute

[**] Concentration in leachate, show units

[***] a_n = corrected concentration x V_L x factor to convert to same units as A_o. The value of a_n must include any radioactivity rinsed from the specimen and the leachate apparatus at the end of the renewal period.

LEACH TEST RESULTS

LEACH TEST IDENTIFICATION NUMBER 2 B F-A5959

LABORATORY WHERE TESTS PERFORMED Franklin Research Center

ANALYST A.J. Cassell

DATE RESULTS REPORTED 27 April 1984

Part A. Description of Leach Specimen

Specimen Identification Number 2 B 1

Proportion of Waste Incorporated in Mixture 10.4 Weight %
1.31 Volume %
(Based on initial volumes)

Type of Waste, Chemical and Radioisotopic Composition, and Specific Activity of the Waste Simulated borate waste stream consisting of boric acid, (10.4% concentration) with 202 uCi of Co-60 as the tagged contaminate 12.27 uCi/gm. of the specimen

Type and Composition of the Solidification Agent The solidification agent was modified Portland cement (MP-1) as supplied by the sponsor.

Preparation of Specimen Specimen was prepared according to sponsor's normal use in the field. Each componenet was weighed out and mixed in a clean teflon cup. The isotope, Co-60, was added next to last, and the accelerator was added last. The slurry was then poured into a teflon mold which measured 2 cm. ID, and 4 cm. long.

Shape and Dimensions of Specimen

Sphere, diameter, d (cm) =
Cylinder, diameter, d (cm) = 2.0 &
length, ℓ (cm) = 4.0
Parallelepiped, length, ℓ (cm) = ,
width, w (cm) = , &
height, h (cm) =
Other, Shape
Dimensions

Initial Weight of Specimen, W (g) = 16.46
Volume of Specimen*, V (cm^3) = 12.56
Surface Area of Specimen, S* (cm^2) = 31.40

Storage Conditions Specimen was removed from the mold following a 48 ho curing period at 130°F. The specimen was placed in a dry, empty glass jar and cap sealed until the leachability test started.

Appearance

Specimen appeared in excellent shape. Surface condition exhibited 2 very small conical indentations in the surface, otherwise the surface was completely homogeneous.

Description of Leachant

Leach Interval (n)	Electrical Conductivity (umho/cm)	Volume, V_L (ml)
1	1.4	314
2	1.4	314
3	1.3	314
4	1.3	314
5	1.25	314
6	1.4	314
7	1.4	314

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*Calculated from dimensions of specimen.

LEACH TEST RESULTS

LEACH TEST IDENTIFICATION NUMBER 2 B 1 F-A5959

LABORATORY WHERE TESTS PERFORMED Franklin Research Center

ANALYST A.J. Cassell

DATE RESULTS REPORTED 27 April 1984

Part B. Description of Leach Test Procedure

Specimen Preparation*

Diagram of Leach Apparatus:

(See Photos on Page B-1)

Leachate Sampling Procedure Following each of the seven leaching cycles, the specimen was removed from the leachate and rinsed in 157 ml.of fresh demineralized water. From the lechate, three(3) aliquoits of of one (1) ml. each were placed into individual vials and the vials identified as to the specimen number. The leachate solution was not discarded unless the aliquoit samples gave counting statistics within acceptable standard deviations.

Analytical Techniques:

Counting Instrument Identification and Calibration A Gamma 4000, automatic sample changer, containing a three inch sodium iodide, thallium activated, scintillation crystal detector was used to count the leachate samples.

Constituent a_1, Analytical Procedure, Standard Deviation of Method Co-60, 0.4 uCi, ± %, traceable to NBS standard, was used as the standard to determine counting efficiency. A normal or Maxwelliam distribution was used in the standard deviation determination.

Constituent a_2, Analytical Procedure, Standard Deviation of Method

Constituent a_i, Analytical Procedure, Standard Deviation of Method

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*If different from "Preparation of Specimen" in Part A.

LEACH TEST RESULTS

LEACH TEST IDENTIFICATION NUMBER 2 B 1

LABORATORY WHERE TESTS PERFORMED Franklin Research Center

ANALYST A.J. Cassell

DATE RESULTS REPORTED 27 April 1984

Part C. Experimental Data

Constituent Analyzed, = Cobalt-60

Free Standing Water in Leach Specimen Container: ___ Yes X No
If Yes, Volume (ml) = ___; Radioactivity (μCi) = ___; and % of A_o = ___

Specimen Rinse Before Initiation of Leaching: *Do not include with results in the table below.*
Volume (ml) = 120; Radioactivity (μCi) = 4; and % of A_o = 1.94

Initial Amount in Specimen, A_o (μCi) (after 30-s rinse) = 202 uCi

Leach Interval (n)	Temp. (°C)	Time and Date*		$(\Delta t)_n$ (s)	$t=\Sigma(\Delta t)_n$ (s)	As Analyzed (uCi) **	Blank ( )	Corrected Conc. (uCi)	a_n***	a_n/A_o	$[a_n/A_o][1/(\Delta t)_n]$ (fraction/s)	$\sum_{i=1}^{n} a_i/A_o$
		In	Out									
1	20	4-02-84 0800	4-02-84 1015	8.10×10^3	8.10×10^3	3.21	___	6.42	6.42	0.032	4.00×10^{-6}	0.032
2	20	4-02-84 1015	4-02-84 1525	1.86×10^4	2.67×10^4	10.42	___	20.84	20.84	0.103	3.86×10^{-6}	0.135
3	20	4-02-84 1525	4-03-84 0835	6.18×10^4	8.85×10^4	12.42	___	24.84	24.84	0.123	1.39×10^{-6}	0.258
4	20	4-03-84 0835	4-04-84 0845	8.70×10^4	1.76×10^5	9.22	___	18.44	18.44	0.091	5.17×10^{-7}	0.349
5	20	4-04-84 0845	4-05-84 0850	8.67×10^4	2.63×10^5	6.41	___	12.82	12.82	0.063	2.40×10^{-7}	0.412
6	20	4-05-84 0850	4-06-84 0855	8.67×10^4	3.50×10^5	5.21	___	10.42	10.42	0.052	1.48×10^{-7}	0.464
7	20	4-06-84 0855	4-07-84 0855	8.64×10^4	4.36×10^5	2.81	___	5.62	5.62	0.028	6.05×10^{-8}	0.492

*Date, hour, and minute

**Concentration in leachate, show units

***a_n = corrected concentration x V_L x factor to convert to same units as A_o. The value of a_n must include any radioactivity rinsed from the specimen and the leachate apparatus at the end of the renewal period.

F-A5959

LEACH TEST RESULTS

F-A5959

LEACH TEST IDENTIFICATION NUMBER 2 B

LABORATORY WHERE TESTS PERFORMED Franklin Research Center

ANALYST A.J. Cassell

DATE RESULTS REPORTED 27 April 1984

Part A. Description of Leach Specimen

Specimen Identification Number 2 B 2

Proportion of Waste Incorporated in Mixture 5.10 Weight %

1.31 Volume %

(Based on initial volumes)

Type of Waste, Chemical and Radioisotopic Composition, and Specific Activity of the Waste Simulated borate waste stream consisting of boric acid, (15% concentration) with 199 uCi of Co-60 as the tagged contaminate. This produced a specific activity of 12.12 uCi/gm of the specimen.

Type and Composition of the Solidification Agent The solidification agent was modified Portland cement (MP-1) as supplied by the sponsor.

Preparation of Specimen Specimen was prepared according to sponsor's normal use in the field. Each component was weighed out and mixed in a clean teflon cup. The tagged isotope, Co-60, was the next to last component added. The last component to be added was the accelerator. The slurry was poured into a clean teflon mold, 2 cm. X 4m. inside measurements.

Shape and Dimensions of Specimen

Sphere, diameter, d (cm) =

Cylinder, diameter, d (cm) = 2.0 &

length, ℓ (cm) = 4.0

Parallelepiped, length, ℓ (cm) = ,

width, w (cm) = , &

height, h (cm) =

Other, Shape

Dimensions

Initial Weight of Specimen, W (g) = 16.42

Volume of Specimen*, V (cm^3) = 12.56

Surface Area of Specimen, S* (cm^2) = 31.40

Storage Conditions Specimen was removed from the mold following a 48 hour curing at 130°F. The specimen was placed in a dry, empty, glass jar and cap sealed until the start of the leachability test.

Appearance

Specimen appeared in excellent shape . The surface condition of the specimen was also excellent, having a complete homogeneous condition.

Description of Leachant

Leach Interval (n)	Electrical Conductivity (umho/cm)	Volume, V_L (ml)
1	2.1	314
2	2.4	314
3	2.0	314
4	2.2	314
5	2.2	314
6	2.3	314
7	2.2	314

*Calculated from dimensions of specimen.

LEACH TEST RESULTS

LEACH TEST IDENTIFICATION NUMBER 2 B 2

LABORATORY WHERE TESTS PERFORMED Franklin Research Center

ANALYST A.J. Cassell

DATE RESULTS REPORTED 27 April 1984

Part B. Description of Leach Test Procedure

Specimen Preparation*

Diagram of Leach Apparatus:

(See Photos on Page B-1)

Leachate Sampling Procedure Following each of the seven leaching cycle the specimen was removed from the leachate and rinsed in 157 ml. of fresh demineralized water. From the 314 ml. of leachate, three (3) aliquoits of one(1) ml. each were placed into individual vials and the vials identified as to the specimen number. The leachate soluti was not discarded unless the aliquoit samples gave counting statist within acceptable standard deviations.

Analytical Techniques:

Counting Instrument Identification and Calibration A Gamma 4000, automati sampling gamma detector, manufactured by Beckman Instruments, and containing a three inch, sodium iodide, thallium activated, scintillation crystal, was used for gamma counting.

Constituent a_1, Analytical Procedure, Standard Deviation of Method Co-60, 0.4 uCi, ± 3%, traceable to NBS Standard, was used to determine the counting efficiency. A normal or Maxwellian distribut was used in the standard deviation determination.

Constituent a_2, Analytical Procedure, Standard Deviation of Method

Constituent a_i, Analytical Procedure, Standard Deviation of Method

---

*If different from "Preparation of Specimen" in Part A.

LEACH TEST RESULTS

LEACH TEST IDENTIFICATION NUMBER 2 B 2

LABORATORY WHERE TESTS PERFORMED Franklin Research Center

ANALYST A.J. Cassell

DATE RESULTS REPORTED 27 April 1984

Part C. Experimental Data

Constituent Analyzed, n Cobalt-60

Free Standing Water in Leach Specimen Container: _ Yes X No
If Yes, Volume (ml) = ___; Radioactivity (µCi) = ___; and % of A_o = ___

Specimen Rinse Before Initiation of Leaching: *Do not include with results in the table below.*
Volume (ml) = 120; Radioactivity (µCi) = 7; and % of A_o = 3.40

Initial Amount in Specimen, A_o (µCi) [after 30-s rinse] = 199 uCi

Leach Interval (n)	Temp. (°C)	Time and Date*		$(\Delta t)_n$ (s)	$t=\Sigma(\Delta t)_n$ (s)	As Analyzed (uCi) **	Blank ( )	Corrected Conc. (uCi)	a_n***	a_n/A_o	$(a_n/A_o)[1/(\Delta t)_n]$ (fraction/s)	$\sum_1^n a_j/A_o$
		In	Out									
1	20	4-02-84 0800	4-02-84 1015	8.10×10^3	8.10×10^3	2.00	——	4.00	4.00	0.020	2.47×10^{-6}	0.020
2	20	4-02-84 1015	4-02-84 1525	1.86×10^4	2.67×10^4	7.59	——	15.18	15.18	0.076	2.85×10^{-6}	0.096
3	20	4-02-84 1525	4-03-84 0835	6.18×10^4	8.85×10^4	8.79	——	17.58	17.58	0.088	9.94×10^{-7}	0.184
4	20	4-03-84 0835	4-04-84 0845	8.70×10^4	1.76×10^5	6.00	——	12.00	12.00	0.060	3.41×10^{-7}	0.244
5	20	4-04-84 0845	4-05-84 0850	8.67×10^4	2.63×10^5	3.60	——	7.20	7.20	0.036	1.37×10^{-7}	0.280
6	20	4-05-84 0850	4-06-84 0355	8.67×10^4	3.50×10^5	1.60	——	3.20	3.20	0.016	4.57×10^{-8}	0.296
7	20	4-06-84 0855	4-07-84 0855	8.64×10^4	4.36×10^5	0.80	——	1.60	1.60	0.008	1.83×10^{-8}	0.304

*Date, hour, and minute

**Concentration in leachate, show units

***a_n = corrected concentration × V_L × factor to convert to same units as A_o. The value of a_n must include any radioactivity rinsed from the specimen and the leachate apparatus at the end of the renewal period.

SUMMARY OF TEST RESULTS

Specimen I.D. - 1A1

n	1	2	3	4	5	6	7
a_n	18.4	46.4	43.2	25.6	16.0	6.88	4.96
a_n/A_o	0.092	0.232	0.216	0.128	0.080	0.034	0.025
$\{\Sigma(a_n/A_o)\}$	0.092	0.324	0.540	0.668	0.748	0.782	0.807
$\{a_n/A_o\}\{1/t_n\}$	1.23×10^{-6}	8.99×10^{-6}	2.47×10^{-6}	7.36×10^{-7}	3.08×10^{-7}	9.80×10^{-8}	$5.76\times10^{-}$
LIX	5.23	5.20	5.60	6.20	6.80	7.50	7.90
D	5.8×10^{-6}	6.9×10^{-6}	2.6×10^{-6}	6.4×10^{-7}	1.6×10^{-7}	3.1×10^{-8}	1.2×10^{-8}

Specimen I.D. - 1A2

n							
a_n	14.72	36.80	33.60	20.80	12.80	5.44	4.00
a_n/A_o	0.074	0.184	0.168	0.104	0.064	0.027	0.020
$\{\Sigma(a_n/A_o)\}$	0.074	0.258	0.426	0.530	0.594	0.621	0.641
$\{a_n/A_o\}\{1/t_n\}$	1.01×10^{-5}	7.13×10^{-6}	1.88×10^{-6}	5.98×10^{-7}	2.46×10^{-7}	7.78×10^{-8}	4.61×10
LIX	5.30	5.30	5.75	6.30	6.90	7.60	8.10
D	4.80×10^{-6}	5.48×10^{-6}	1.99×10^{-6}	5.16×10^{-7}	1.30×10^{-7}	2.46×10^{-8}	9.65×10

Specimen I.D. - 1B1

n							
a_n	12.00	32.64	26.40	13.92	6.40	2.72	1.6
a_n/A_o	0.060	0.163	0.132	0.073	0.032	0.014	0.00
$\{\Sigma(a_n/A_o)\}$	0.060	0.223	0.355	0.425	0.457	0.471	0.47
$\{a_n/A_o\}\{1/t_n\}$	8.00×10^{-6}	6.30×10^{-6}	1.50×10^{-6}	4.00×10^{-7}	1.23×10^{-7}	4.03×10^{-8}	1.84×1
LIX	5.40	5.30	5.80	6.40	7.20	7.90	8.4
D	3.8×10^{-6}	4.8×10^{-6}	1.6×10^{-6}	3.8×10^{-7}	6.6×10^{-8}	1.3×10^{-8}	3.9×1

Specimen I.D.- 1B2

n							
a_n	16.4	38.52	34.50	24.86	14.44	4.82	4.
a_n/A_o	0.081	0.190	0.170	0.122	0.071	0.024	0.0
$\{\Sigma(a_n/A_o)\}$	0.081	0.271	0.448	0.570	0.641	0.665	0.6
$\{a_n/A_o\}\{1/t_n\}$	1.08×10^{-5}	7.36×10^{-6}	1.95×10^{-6}	7.01×10^{-6}	2.73×10^{-7}	6.92×10^{-8}	$4.61\times$
LIX	5.30	5.25	5.67	6.22	6.83	7.66	8.0
D	5.11×10^{-6}	5.66×10^{-6}	2.15×10^{-6}	6.06×10^{-7}	1.47×10^{-7}	2.18×10^{-8}	$9.66\times$

Specimen I.D. - 2A1

n	1	2	3	4	5	6	
a_n	8.00	22.44	27.26	20.04	16.84	8.00	6.
a_n/A_o	0.039	0.111	0.135	0.099	0.083	0.039	0.
$\{\Sigma(a_n/A_o)\}$	0.039	0.150	0.285	0.384	0.467	0.506	0.
$\{a_n/A_o\}\{1/t_n\}$	4.81×10^{-6}	4.16×10^{-6}	1.52×10^{-6}	5.62×10^{-7}	3.16×10^{-7}	1.11×10^{-7}	7.43
LIX	5.91	5.82	5.98	6.43	6.70	7.28	7
D	1.22×10^{-6}	1.52×10^{-6}	1.03×10^{-6}	3.69×10^{-7}	1.99×10^{-7}	5.18×10^{-8}	2.65

SUMMARY OF TEST RESULTS (cont.)

Specimen I.D. - 2A2

n	1	2	3	4	5	6	7	AVG.
a_n	4.00	17.68	20.90	15.28	10.44	6.44	4.00	
a_n/A_o	0.020	0.086	0.102	0.074	0.051	0.031	0.020	
$(\Sigma(a_n/A_o))$	0.020	0.105	0.207	0.281	0.332	0.363	0.383	
$(a_n/A_o)(1/t_n)$	2.47×10^{-6}	3.21×10^{-6}	1.15×10^{-6}	4.20×10^{-7}	1.94×10^{-7}	8.86×10^{-8}	4.59×10^{-8}	
LIX	6.20	5.93	6.11	6.53	6.91	7.39	7.78	6.7
D	6.25×10^{-7}	1.18×10^{-6}	7.79×10^{-7}	2.96×10^{-7}	1.22×10^{-7}	4.12×10^{-8}	1.65×10^{-8}	

Specimen I.D. - 2B1

n								
a_n	6.42	20.84	24.84	18.44	12.82	10.42	5.62	
a_n/A_o	0.032	0.103	0.123	0.091	0.063	0.052	0.028	
$(\Sigma(a_n/A_o))$	0.032	0.135	0.258	0.349	0.412	0.464	0.492	
$(a_n/A_o)(1/t_n)$	4.00×10^{-6}	3.86×10^{-6}	1.39×10^{-6}	5.17×10^{-7}	2.40×10^{-7}	1.48×10^{-7}	6.05×10^{-8}	
LIX	6.00	5.90	6.10	6.40	6.80	7.20	7.60	6.6
D	1.00×10^{-6}	1.41×10^{-6}	8.83×10^{-7}	3.64×10^{-7}	1.51×10^{-7}	6.91×10^{-8}	2.32×10^{-8}	

Specimen I.D. - 2B2

n								
a_n	4.00	15.18	17.58	12.00	7.20	3.20	1.60	
a_n/A_o	0.020	0.076	0.088	0.060	0.036	0.016	0.008	
$(\Sigma(a_n/A_o))$	0.020	0.096	0.184	0.244	0.280	0.296	0.304	
$(a_n/A_o)(1/t_n)$	2.47×10^{-6}	2.85×10^{-6}	9.94×10^{-7}	3.41×10^{-7}	1.37×10^{-7}	4.57×10^{-8}	1.83×10^{-8}	
LIX	6.20	6.00	6.20	6.60	7.10	7.70	8.20	6.9
D	6.25×10^{-7}	1.04×10^{-6}	6.72×10^{-7}	2.40×10^{-7}	8.62×10^{-8}	2.12×10^{-8}	6.62×10^{-9}	

5.2 RADIATION STABILITY RESULTS

Pre-gamma dose exposure:

Specimen No.	1	3	6	7
Specimen Wt.	8.9(lbs)	9.03	8.79	8.80
Physical Size				
1. Length	5.99(in)	6.00	6.01	6.01
2. Diameter	6.00	6.00	6.00	6.00

Post-gamma dose exposure:

Specimen No.	1	3	6	7
Physical Size				
Specimen Wt.(lbs)	8.85	8.98	8.75	8.76
Physical Size(in.)				
1. Length	5.99	6.00	6.01	6.01
2. Diameter	6.00	6.00	6.00	6.00

Compression Test:

Specimen No.	1	3	6	7
Break Load(lbs.)	25,200	30,600	11,500	10,600

Load Applied: 1413 lbs.=50 psi for minimum requirement

#1	25,200/1413 = 17.8 times minimum acceptable value
#3	30,600/1413 = 21.7 times minimum acceptable value
#6	11,500/1413 = 8.1 times minimum acceptable value
#7	10,600/1413 = 7.5 times minimum acceptable value

6. CONCLUSIONS

6.1 LEACHABILITY INDEX NUMBER DETERMINATION

It can be concluded from the summary of test results in Section 5 of this report that the solidification material, MP-1 cement, as supplied by Bartlett Nuclear Corp., has met the requirements of the USNRC for implementing 10CFR Part 61 by exhibiting a leachability index number greater than 6.

6.2 RADIATION STABILITY

It can be concluded from the radiation stability test results in Section 5 of this report that the cement material MP-1, as supplied by Bartlett Nuclear Corp., has met the requirements of the USNRC for implementing 10CFR Part 61 by exhibiting a compression stability greater than 0.3 MPa (50 psi) after being subjected to a high gamma dose.

6.3 PRESENCE OF FREE-STANDING LIQUIDS

It is concluded that no free liquid was present in any of the 12 specimens tested following the solidification process. This conclusion is based on observations made following waste solidification in the cement matrices.

7. CERTIFICATION

The undersigned certifies that this report is a true account of the tests conducted and the results obtained.

Andrew J. Cassell

Andrew J. Cassell
Project Manager
Senior Staff Scientist

5/23/84
Date

APPENDIX A

TEST CERTIFICATION AND TEST DATA

IRRADIATION DATE April 6-14, 1984

DICKERSON I
CERTIFICATION OF IRRADIATION

NPI LOT NUMBER: 4N20194B

CUSTOMER

Franklin Research Center
20th and Race Streets
Philadelphia, Pa. 19103

PURCHASE ORDER NO.:
B72488

PRODUCT DESCRIPTION AND CUSTOMER LOT NUMBERS

Cement Cores (6" X 6")
Nos. 1, 3, 6 & 7

NUMBER OF PIECES IN NPI LOT
Four

IRRADIATION DOSE

MINIMUM 97.3 MEGARADS.

MAXIMUM 102.7 MEGARADS.

☒ EXPOSED DOSE

☐ MINIMUM DOSE CORRECTED FOR ______% ESTIMATED ATTENUATION

☐ MINIMUM DOSE CORRECTED FOR ______% ATTENUATION BASED ON PROCESS VALIDATION DOSIMETRY

☒ REPORTED DOSES CONFIRMED USING FAR WEST DOSIMETERS

COMMENTS

Elizabeth L. Baker

Elizabeth L. Baker
Manager, Product Testing

neutron products inc

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By A. Cassell	Date 3/17/84	Ch'k'd P.H.	Date 3/18/84	Rev.

Title SOLIDIFICATION CAPABILITIES OF CEMENT(MP-1) MATRIX - LEACH STABILITY

Preparation of resin bead waste samples

Determination of isotopic content in specimen 1A1

specimen 1A1 contained 206 µCi Cs-137 except amounts contain in three (3) washes.

wash #1	25cc 3N HCl (teflon mixing vessel)
wash #2	75cc 3N HCl (teflon mold)
wash #3	20cc 3N HCl (mixing tools)

wash #1 - 1ml. removed and placed in counting vial. = 1589 c/m

wash #2 1ml removed and placed in counting vial = 1165 c/m

wash #3 1ml removed and placed in counting vial: = 1589 c/m

sample #1 contained:
$1589 \frac{c/m}{cc} \times 25 cc = 3.972 \times 10^{4} c/m / 0.02386 (EFF.) = 1.665 \times 10^{6} c/m / 1.11 \times 10^{6} = 1.$

Sample #2 contained:
$1165 \times 75 = 8.738 \times 10^{4} / 0.02386 = 3.662 \times 10^{6} / 1.11 \times 10^{6} =$ 3.

Sample #3 contained:
$1589 \times 20 = 3.178 \times 10^{4} / 0.02386 = 1.332 \times 10^{6} / 1.11 \times 10^{6} =$ 1

TOTAL 6

206 µCi original
− 6 µCi from wash
200 µCi in specimen 1A1

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Title SOLIDIFICATION CAPABILITIES OF CEMENT(MP-1)MATRIX - LEACH STABILITY

Preparation of borated waste stream specimen

Determination of isotopic content in Specimen 2B2

Specimen 2B2 contained 206 μCi Co-60 except amounts contained in three (3) washes

Wash #1 25cc 3N HCl (teflon mixing vessel)

Wash #2 75cc 3N HCl (teflon mold)

Wash #3 20cc 3N HCl (mixing tools)

wash #1 1ml removed and placed in counting vial. = 10,023 c/m

Wash #2 1ml removed and placed in counting vial = 1632 c/m

Wash #3 1 ml removed and placed in counting vial = 1749 c/m

wash #1 contained:
$10{,}023 \times 25 = 2.506 \times 10^5 / 0.05249 = 4.774 \times 10^6 / 1.11 \times 10^6 =$ 4.3 μCi

wash #2 contained:
$1632 \times 75 = 1.224 \times 10^5 / 0.05249 = 2.332 \times 10^6 / 1.11 \times 10^6 =$ 2.1 μCi

wash #3 contained:
$1749 \times 20 = 3.498 \times 10^4 / 0.05249 = 6.664 \times 10^5 / 1.11 \times 10^6$ 0.6 μCi

Total 7.0 μCi

206 μCi original
7.0 in waste
199.0 μCi

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Title SOLIDIFICATION CAPABILITIES OF CEMENT(MP-1)MATRIX - LEACH STABILITY

Leach Testing:

specimen 1A1 - resin bead waste - Cs^{137} isotope - 200μCi

n size: 2 cm. dia. x 4 cm. Long

START: 0800 - 3/19/84 314 ml. Leachant

1. STOP: 1005 - 3/19/84

Three one(1) ml. aliquoits removed:

#1 752 c/m
#2 786 c/m
#3 790 c/m
} AVG. 776 c/m/ml = 9.2 μCi

START: 1005 3/19/84 314 ml. Leachant

2. STOP: 1510 3/19/84 (3 aliquoit samples taken)

#1 1983 c/m
#2 1952 c/m
#3 1932 c/m
} AVG. 1956 c/m/ml = 23.2 μCi

START: 1510 3/19/84 314 ml. leachant

3. STOP: 0815 3/20/84 (3 aliquoits taken)

#1 1801 c/m
#2 1839 c/m
#3 1824 c/m.
} AVG. 1821 c/m/ml. = 21.6 μCi

START: 0815 3/20/84 314 ml. Leachant

4. STOP: 0825 3/21/84 (3 aliquoits taken)

#1 1045 c/m
#2 1092 c/m
#3 1103 c/m
} AVG. 1080 c/m/ml = 12.8 μCi

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Title SOLIDIFICATION CAPABILITIES OF CEMENT(MP-1) MATRIX - LEACH STABILITY

Specimen 1A1 (cont.)

n

START: 0825 3/21/84 314 ml. Leachant

5. STOP: 0840 3/22/84 (3 aliquoits taken)

#1 702 c/m
#2 631 c/m } AVG. 675 c/m/ml = 8.0 μCi
#3 692 c/m

START: 0840 3/22/84 314 ml. Leachant

6. STOP: 0840 3/23/84 (3 aliquoits taken)

#1 287 c/m
#2 272 c/m } AVG. 290 c/m/ml = 3.44 μCi
#3 211 c/m

START: 0840 3/23/84 314 ml. Leachant

7. STOP 0845 3/24/84 (3 aliquoits taken)

#1 230 c/m
#2 187 c/m } AVG. 20º c/m/ml = 2.48 μCi
#3 210 c/m

END test on Specimen 1A1

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By A. Cassell	Date 4/3/84	Ch'k'd R.H.	Date 4/4/84	Rev.

Title SOLIDIFICATION CAPABILITIES OF CEMENT(MP-1) MATRIX - LEACH STABILITY

Specimen 2B2

Specimen 2B2 - Borate waste stream -
Co-60 isotope · 199 μCi - Size: 2cm dia x 4cm. long

n

START: 0800 4/2/84 314 ml Leachant

1. STOP: 1015 4/2/84 Three-one (1) ml. aliquoits taken)

#1 396 c/m
#2 355 c/m
#3 362 c/m
} AVG 371 c/m/ml = 2.0 μCi/314 ml

START: 1015 4/2/84 314 ml Leachant

2. STOP: 1525 4/2/84 (3 aliquoits taken)

#1 1379 c/m
#2 1465 c/m
#3 1383 c/m
} AVG. 1409 c/m/ml. = 7.59 μCi/314 ml

START: 1525 4/2/84 314 ml Leachant

3. STOP: 0835 4/3/84 (3 aliquoits taken)

#1 1632 c/m
#2 1654 c/m
#3 1607 c/m
} AVG. 1631 c/m/ml. = 8.79 μCi/314 ml.

START: 0835 4/3/84 314 ml. Leachant

4. STOP: 0845 4/4/84 (3 aliquorts taken)

#1 1090 c/m
#2 1098 c/m
#3 1154 c/m
} AVG. 1114 c/m/ml = 6.0 μCi/314 ml.

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By	Date	Ch'k'd	Date	Rev.	Date
A. Cassell	4/7/84	P.H.	4/9/84		

Title SOLIDIFICATION CAPABILITIES OF CEMENT(MP-1) MATRIX - LEACH STABILITY

Specimen 2B2 (cont.)

START: 0845 4/4/84 314 ml. Leachant

5. STOP: 0850 4/5/84 (3 aliquoits taken)

#1 640 c/m
#2 667 c/m
#3 687 c/m

AVG. 668 c/m/ml. = 3.60 μCi/314 ml.

START: 0850 4/5/84 314 ml. Leachant

6. STOP: 0855 4/6/84 (3 aliquoits taken)

#1 289 c/m
#2 280 c/m
#3 312 c/m

AVG. 297 c/m/ml. = 1.6 μCi/314 ml.

START: 0855 4/6/84 314 ml. Leachant

7. STOP: 0855 4/7/84 (3 aliquoits taken)

#1 141 c/m
#2 168 c/m
#3 135 c/m

AVG. 148 c/m/ml. = 0.80 μCi/314 ml.

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Title SOLIDIFICATION CAPABILITIES OF CEMENT(MP-1) MATRIX - LEACH STABILITY

Calculations of number of microcuries per leach cycle for each specimen.

1A1	c/m/ml / Eff. = c/m/2π / c/m/μCi × ml		μCi
1)	$776/0.02386 = 3.252\times10^4/1.11\times10^6 \times 314$ ml.	=	9.20
2)	$1956/0.2386/1.11\times10^6 \times 314$	=	23.20
3)	$1821/0.02386/1.11\times10^6 \times 314$	=	21.60
4)	$1080/0.02386/1.11\times10^6 \times 314$	=	12.80
5)	$675/0.02386/1.11\times10^6 \times 314$	=	8.00
6)	$290/0.02386/1.11\times10^6 \times 314$	=	3.44
7)	$209/0.02386/1.11\times10^6 \times 314$	=	2.48

1A2			
1)	$620/0.02386/1.11\times10^6 \times 314$	=	7.36
2)	$1552/0.02386/1.11\times10^6 \times 314$	=	18.40
3)	$1417/0.02386/1.11\times10^6 \times 314$	=	16.80
4)	$877/0.02386/1.11\times10^6 \times 314$	=	10.40
5)	$540/0.02386/1.11\times10^6 \times 314$	=	6.40
6)	$230/0.02386/1.11\times10^6 \times 314$	=	2.72
7)	$169/0.02386/1.11\times10^6 \times 314$		2.00

1B1			
1)	$506/0.02386/1.11\times10^6 \times 314$	=	6.00
2)	$1377/0.02386/1.11\times10^6 \times 314$	=	16.32
3)	$1113/0.02386/1.11\times10^6 \times 314$	=	13.20
4)	$587/0.02386/1.11\times10^6 \times 314$	=	6.96
5)	$270/0.02386/1.11\times10^6 \times 314$	=	3.20
6)	$115/0.02386/1.11\times10^6 \times 314$	=	1.36
7)	$68/0.02386/1.11\times10^6 \times 314$	=	0.80

1B2			
1)	$693/0.02386/1.11\times10^6 \times 314$	=	8.22
2)	$1624/0.02386/1.11\times10^6 \times 314$	=	19.25
3)	$1455/0.02386/1.11\times10^6 \times 314$	=	17.25
4)	$1048/0.02386/1.11\times10^6 \times 314$	=	12.43
5)	$609/0.02386/1.11\times10^6 \times 314$	=	7.22
6)	$203/0.02386/1.11\times10^6 \times 314$	=	2.41
7)	$170/0.02386/1.11\times10^6 \times 314$	=	2.01

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Title SOLIDIFICATION CAPABILITIES OF CEMENT(MP-1) MATRIX - LEACH STABILITY

Calculation of microcuries (cont.)

μCi

2A1
1) 742/0.05249 (Eff)/1.11x10^6 c/m/μCi x 314 ml = 4.00
2) 2082 c/m = 11.22
3) 2530 c/m = 13.63
4) 1860 c/m = 10.02
5) 1563 c/m = 8.42
6) 742 c/m = 4.00
7) 596 c/m = 3.21

2A2
1) 371/0.05429/1.11x10^6 x 314 = 2.00
2) 1641 c/m = 8.84
3) 1939 c/m = 10.45
4) 1418 c/m = 7.64
5) 969 c/m = 5.22
6) 598 c/m = 3.22
7) 371 c/m = 2.00

2B1
1) 596/0.05429/1.11x10^6 x 314 = 3.21
2) 1934 c/m = 10.42
3) 2305 c/m = 12.42
4) 1711 c/m = 9.22
5) 1190 c/m = 6.41
6) 967 c/m = 5.21
7) 522 c/m = 2.81

2B2
1) 371 c/m/0.05429/1.11x10^6 x 314 = 2.00
2) 1409 c/m = 7.59
3) 1631 c/m = 8.79
4) 1114 c/m = 6.00
5) 668 c/m = 3.60
6) 297 c/m = 1.60
7) 148 c/m = 0.80

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By A Cassell	Date 4/13/84	Ch'k'd RH	Date 4/13/84	Rev.

Title SOLIDIFICATION CAPABILITIES OF CEMENT(MP-1) MATRIX - LEACH STABILITY

Calculation of "D_i"

D = effective diffusivity

$$= \pi\left[\frac{\overline{a_n/A_0}}{(\Delta t)_n}\right]^2\left[\frac{V}{S}\right]^2 T$$

where $T = \left[\frac{1}{2}\left(t_n^{1/2} + t_{n-1}^{1/2}\right)\right]^2$

1A1

1) 5.8×10^{-6}
2) 6.9×10^{-6}
3) 2.6×10^{-6}
4) 6.4×10^{-7}
5) 1.6×10^{-7}
6) 3.1×10^{-8}
7) 1.2×10^{-8}

1A2

1) 4.8×10^{-6}
2) 5.5×10^{-6}
3) 1.99×10^{-6}
4) 5.16×10^{-7}
5) 1.3×10^{-7}
6) 2.46×10^{-8}
7) 9.65×10^{-9}

1B1

1) 3.80×10^{-6}
2) 4.80×10^{-6}
3) 1.6×10^{-6}
4) 3.8×10^{-7}
5) 6.6×10^{-8}
6) 1.3×10^{-8}
7) 3.9×10^{-9}

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	By A. Carosell	Date 4/18/94	Ch'k'd PH	Date 4/19/84	Rev. Date

Title SOLIDIFICATION CAPABILITIES OF CEMENT(MP-1) MATRIX - LEACH STABILITY

Calculation of D_i value (cont.)

$$\left[\frac{a_n/A_o}{(\Delta t)_n}\right]^2 \left[\frac{V}{S}\right]^2 T$$

$$T = \left[\frac{1}{2}\left(t_n^{1/2} + t_{n-1}^{1/2}\right)\right]^2$$

1 B 2

1) 5.11×10^{-6}
2) 5.66×10^{-6}
3) 2.15×10^{-6}
4) 6.07×10^{-7}
5) 1.47×10^{-7}
6) 2.18×10^{-8}
7) 9.66×10^{-9}

2 A 1

1) 1.22×10^{-6}
2) 1.52×10^{-6}
3) 1.03×10^{-6}
4) 3.69×10^{-7}
5) 1.99×10^{-7}
6) 5.18×10^{-8}
7) 2.65×10^{-8}

2 A 2

1) 6.25×10^{-7}
2) 1.18×10^{-6}
3) 7.79×10^{-7}
4) 2.96×10^{-7}
5) 1.22×10^{-7}
6) 4.12×10^{-8}
7) 1.65×10^{-8}

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By A. Caswell	Date 4/19/84	Ch'k'd P.H.	Date 4/19/84	Rev.

Title SOLIDIFICATION CAPABILITIES OF CEMENT(MP-1)MATRIX - LEACH STABILITY

Calculation of D_i value (cont.)

$$\left[\frac{a_n/A_o}{(\Delta t)_n}\right]^2 \left[\frac{V}{S}\right]^2 T$$

$$T = \left[\tfrac{1}{2}\left(t_n^{1/2} + t_{n-1}^{1/2}\right)\right]^2$$

2B1

1) 1.00×10^{-6}
2) 1.41×10^{-6}
3) 8.83×10^{-7}
4) 3.64×10^{-7}
5) 1.51×10^{-7}
6) 6.91×10^{-8}
7) 2.32×10^{-8}

2B2

1) 6.25×10^{-7}
2) 1.04×10^{-6}
3) 6.72×10^{-7}
4) 2.40×10^{-7}
5) 8.62×10^{-8}
6) 2.12×10^{-8}
7) 6.62×10^{-9}

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By A. Casoeli	Date 4/24/84	Ch'k'd PH. Date 4/25/84	Rev. Date

Title SOLIDIFICATION CAPABILITIES OF CEMENT(MP-1) MATRIX - LEACH STABILITY

Calculation of Leachability INDEX (L_x)

$L_x = \log \beta / D_i$

where β = constant = 1 cm²/sec.

	1	2	3	4	5	6	7	AVG. $\left(\frac{\Sigma L_x}{7}\right)$
1 A 1	5.23	5.2	5.6	6.2	6.8	7.5	7.9	6.3
1 A 2	5.3	5.3	5.8	6.3	6.9	7.6	8.1	6.5
1 B 1	5.4	5.3	5.8	6.4	7.2	7.9	8.4	6.6
1 B 2	5.3	5.25	5.67	6.22	6.83	7.66	8.02	6.4
2 A 1	5.91	5.82	5.98	6.43	6.70	7.28	7.58	6.5
2 A 2	6.20	5.93	6.11	6.53	6.91	7.39	7.78	6.7
2 B 1	6.0	5.9	6.1	6.4	6.8	7.2	7.6	6.6
2 B 2	6.2	6.0	6.2	6.6	7.1	7.7	8.2	6.9

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By P. Hackett	Date 3/21/84	Ch'k'd ajc	Date 3/21/84	Rev.

Title SOLIDIFICATION CAPABILITIES OF CEMENT(MP-1) MATRIX - RADIATION STABILITY

Preparation of Cement cylinder #1 (Simulated Resin Bead waste) DATE

Materials used:

Cement (MP-1): 3294 grams (7.25 lbs)
Resin Beads: 2196 ml. (2.80 lbs)
water: 1098 ml. (2.42 lbs.)

Ion exchange resin beads were presoaked in 2N NaOH solution over-night, until a constant pH value of 10.5 was obtained. (normal bacidity of resin bead waste) 3/21/84

The one liter of water was used to rinse the resin beads down the walls of the mixing vessel.

Cement and resin beads were mixed for a period between 4-5 minutes. A longer mixing cycle tends to produce setting of the slurry in the mixing vessel.

As the slurry congels, the mixture on the vessel wall must be scraped into the slurry.

Pour slurry into cardboard mold, using proper scraping tool to remore all of the matrix from mixing vessel.

An exothermic reaction can be detected. Proper stirring of the matrix in the mold, must be performed to dissallow formation of entrapped air bubbles.

Place mold in preregulated oven - 55°C, and allow a 48 hour curing cycle maintain a constant temperature of 55°C. 3/21/

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By P. Hackett	Date 3/22-84	Ch'k'd ajc	Date 3/22/84	Rev. Date

Title SOLIDIFICATION CAPABILITIES OF CEMENT(MP-1) MATRIX - RADIATION STABILITY

Preperation of Cement Cylinder #1 (cont.) DATE

Remove mold from oven - following Curing time. 3/22/84
Allow mold to cool to ambient Temperature
before attempt is made to remove cement
cylinder.

Cylinder weighed at 1645 on 3/22/84 8.90 lbs.

Cylinder reweighed at 0945 3/26/84 8.90 lbs.

Measurement of cylinder taken: 3/22/84

DIA. 6.000 inches Length 6.002 inches

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By P. Hackett	Date 3/23/84	Ch'k'd	Date 3/23/84	Rev.

Title SOLIDIFICATION CAPABILITIES OF CEMENT(MP-1) MATRIX - RADIATION STABILITY

DATE

Preperation of cement Cylinder #3

3/23

Presoaked resin beads - pH 10.67

Materials Used:

cement (MP-1)	3294 grems (7.25 lbs)
Ion exchange Resin Beads	2196 ml (2.8 lbs)
water	1098 grems (2.4 lbs.)

No free standing liquid following casting of cylinder

Placed in oven at 11:59 on 3/23/84

Removed from oven on 3/26/84 - 72 hr. curing -

Mold allowed to cool for two hours prior to removing cylinder.

wt. of Cylinder 9.03 lbs.

3.

Measurements of cylinder size taken

Dia. 6.000" Length 5.992"

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By	Date	Ch'k'd	Date	Rev.	Date
P. Hackett	3/26/84	AJC	3/26/84		

Title SOLIDIFICATION CAPABILITIES OF CEMENT(MP-1) MATRIX - RADIATION STABILITY

Preperation of Cement Cylinder #6 3/26/84
(Simulated borate waste Stream)

Materials Used:

(Borate waste Stream) 206 grams Boric Acid in 2 Liters of H_2O - heated to 165°F to place in solution.

4000 grams cement (8.8 lbs)
2000 ml. Boric Acid Solution (10.3% by wt.)
140 grams Accelerator (Supplied by Bartlett)

Place cement and borate solution in mixing vessel.
Mix Thoroughly -

Add accelerator slowly - do not exceed 30-60 seconds for total mix. more mixing time will cause setting of matrix in mixing vessel.

Pour into cardboard mold.

Specimen #6 cured in oven at 55°C, for 48 hours

Removed specimen from oven, and allowed to cool to ambient temperature, for 2 hours 3/28/84

Physical characteristics taken on specimen #6

Specimen wt. 8.79 lbs

Specimen size:

DIA. - 6.000 inches Length: 5.997 inches

<u>No Free standing liquid after casting cement cylinder</u>

Title SOLIDIFICATION CAPABILITIES OF CEMENT(MP-1) MATRIX - RADIATION STABILITY

3/28/

Preparation of cement Cylinder #7

Materials Used:

Cement (MP-1) - 4000 g (8.8 lbs)

Borate Solution - 2 Liters of Boric Acid solution (206 g)

Accelerator - 100 grams (0.22 lbs)

To prepare borate solution:
Weighed out 206 grams boric acid. Dissolved in 2 liter of water. Heated solution to 74°c and held at this Temperature until mixed in cement mixture vessel.

Preparation of Cylinder #7 - was conducted the same as Cylinder No. 6.
Time of accelerator mix - 45 sec.

No standing water detected.

Physical Measurement:
Specimen #7 weight - 8.80 lbs.
SIZE: Dia. - 6.000 inches
Length - 6.008 inches

3/31

(Note): The four specimens were packaged in special wooden crate for shipment To Neutron Products for gamma dose exposure - (see photos in Appendix B)

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Title SOLIDIFICATION CAPABILITIES OF CEMENT(MP-1) MATRIX - RADIATION STABILITY

Post-gamma dose exposure 4/26/84

Four specimens, #1, #3, #6 and #7 returned from Neutron Products after 10^8 Rad gamma exposure

Post exposure specimen wt.

#1	8.8 lbs
#3	8.98 lbs
#6	8.75 lbs
#7	8.76 lbs

Compression test on 4 cement specimens

#1 } Ion exchange resin beads waste
#3 }

#6 } Borate waste stream
#7 }

	#1	#3	#6	#7	
Stress Indication	8000	7000	8100	8800	lbs-Load
Break Point	25,200	30,600	11,500	10,600	lbs-Load

LOAD applied = 1413 lbs = 50PSI (acceptable minimum limit)

Load comparison to test specimens

#1 25,600/1413 = 17.8 (Times > 50PSI)

#3 30,600/1413 = 21.7 (Times > 50PSI)

#6 11,500/1413 = 8.1 (Times > 50PSI)

#7 10,600/1413 = 7.5 (Times > 50PSI)

APPENDIX B

PHOTOGRAPHS OF TEST APPARATUS

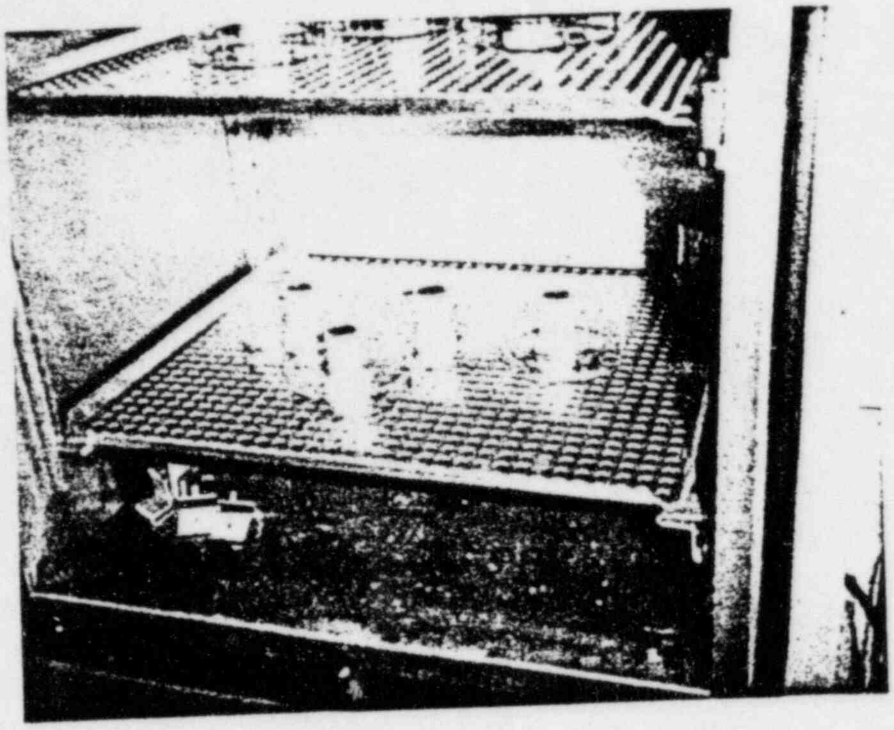

Figure B-1. Cured Specimens Containing Cesium-137

Figure B-2. Cured Specimens - Four Containing Cesium-137 and Four Containing Cobalt-60

Figure B-3. Specimens Under Leachant for Leachability Test, Saddle Supports Demonstrated

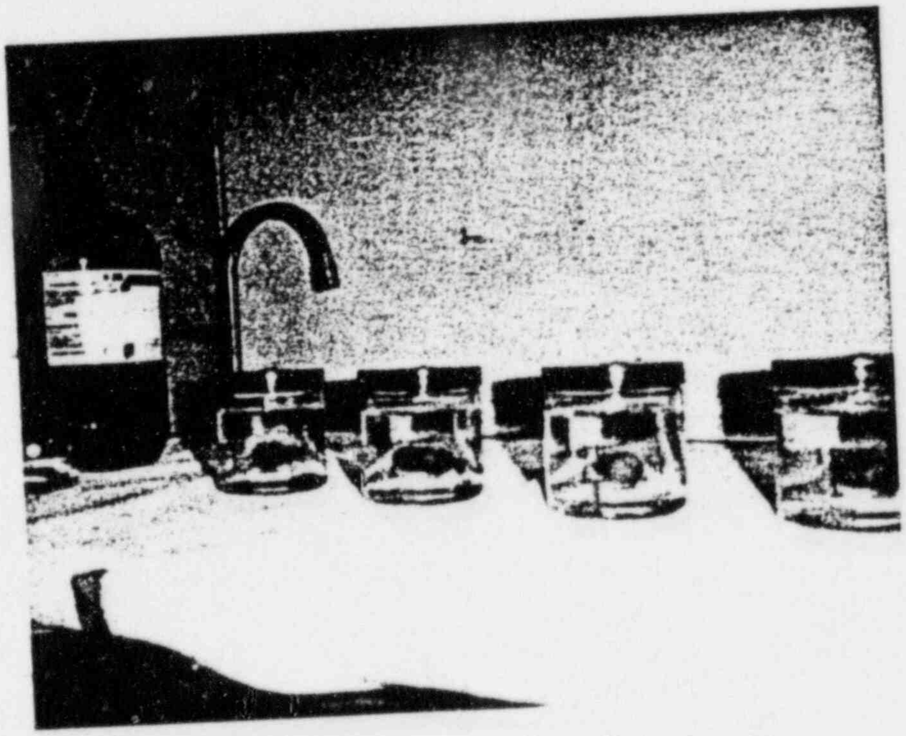

Figure B-4. Specimens Under Leachant, End of First Leaching Cycle (2 hours)

Figure B-5. Specimens Containing Borate Waste Stream with Cobalt-60

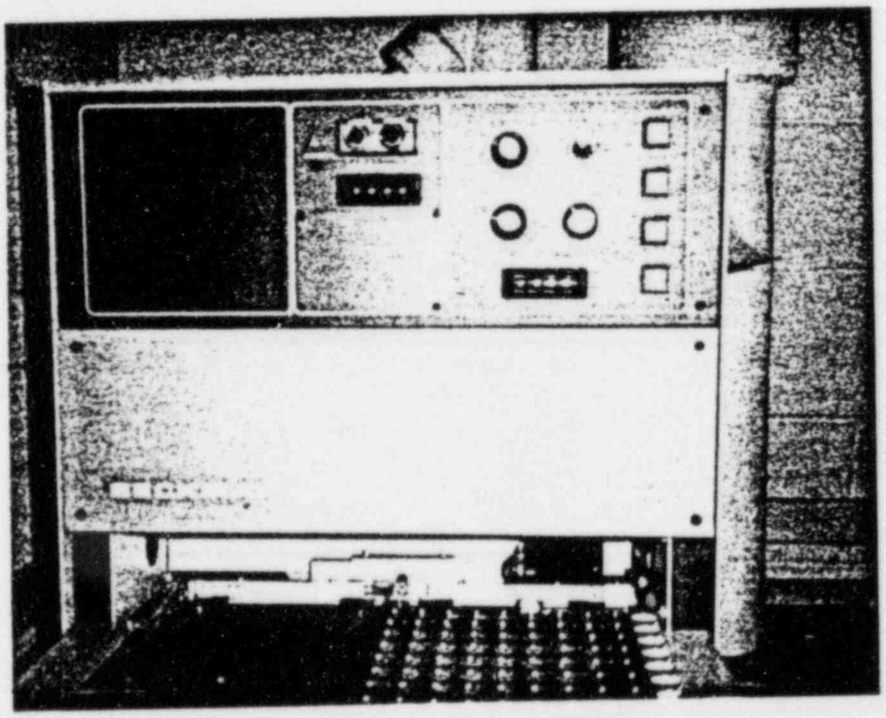

Figure B-6. Gamma 4000 Automatic Counting System

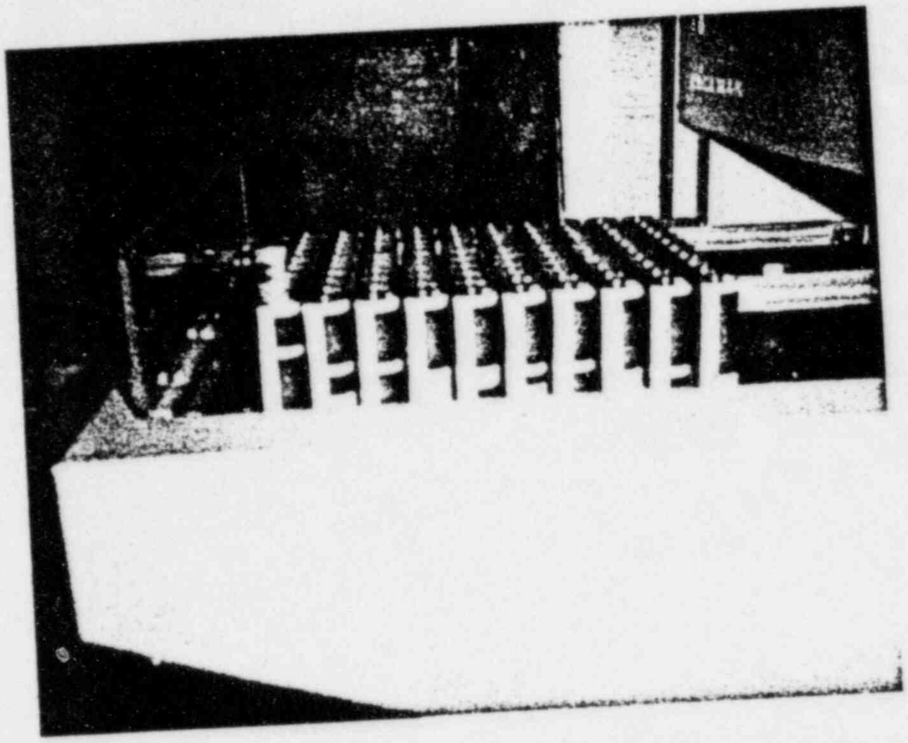

Figure B-7. Aliquot Samples Aligned for Isotopic Counting

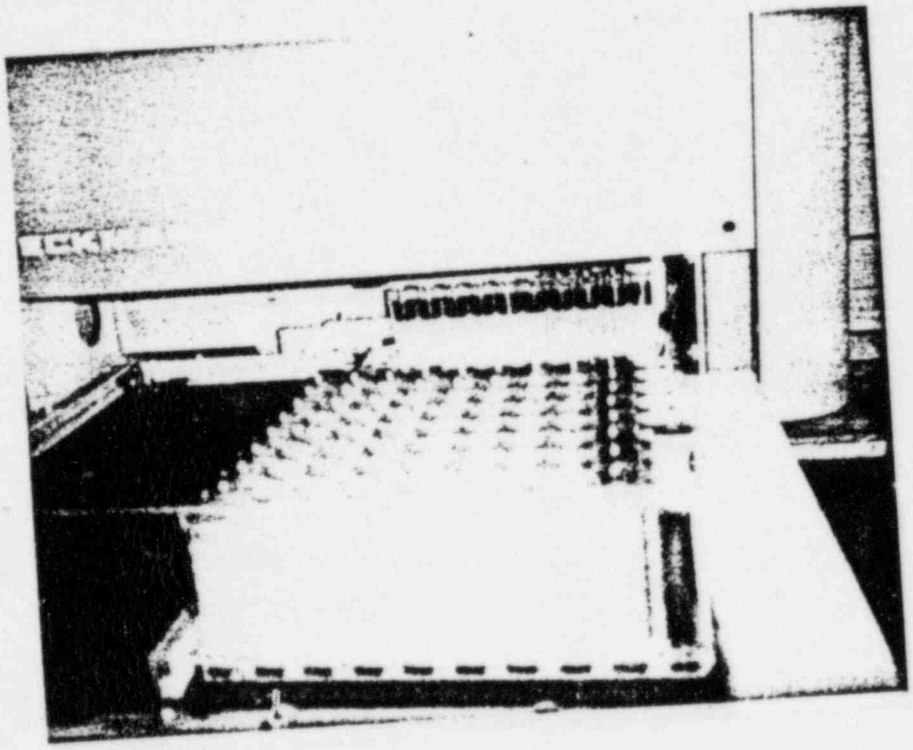

Figure B-8. Aliquot Samples In-Line for Counting of First Ten Samples

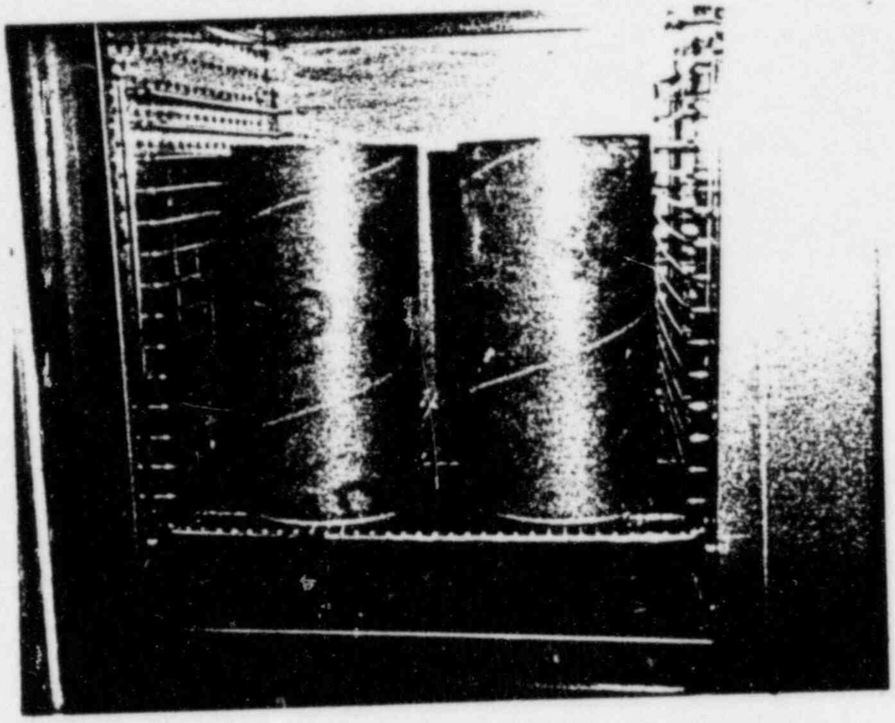

Figure B-9. Molds for Casting 6-inch Cylinders
Curing of Two Molded Specimens

Figure B-10. Molded Cylinders Following 48-hour Curing Cycle

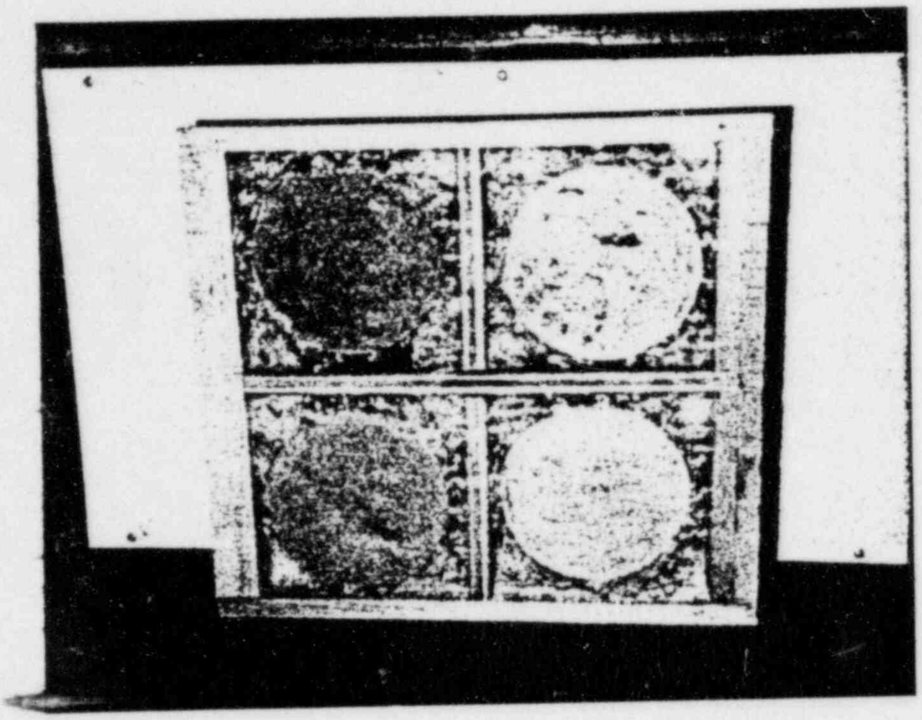

Figure B-11. Four Cement Cylinders Packaged for Gamma Dose Exposure

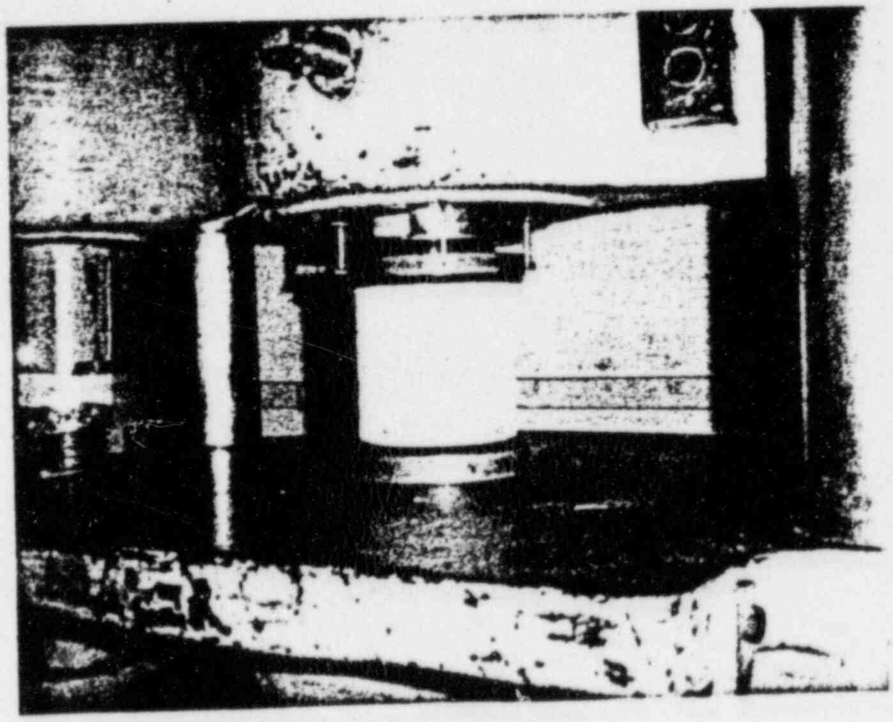

Figure B-12. Compression Test for Cement Matrix Containing Ion-Exchange Resin Beads

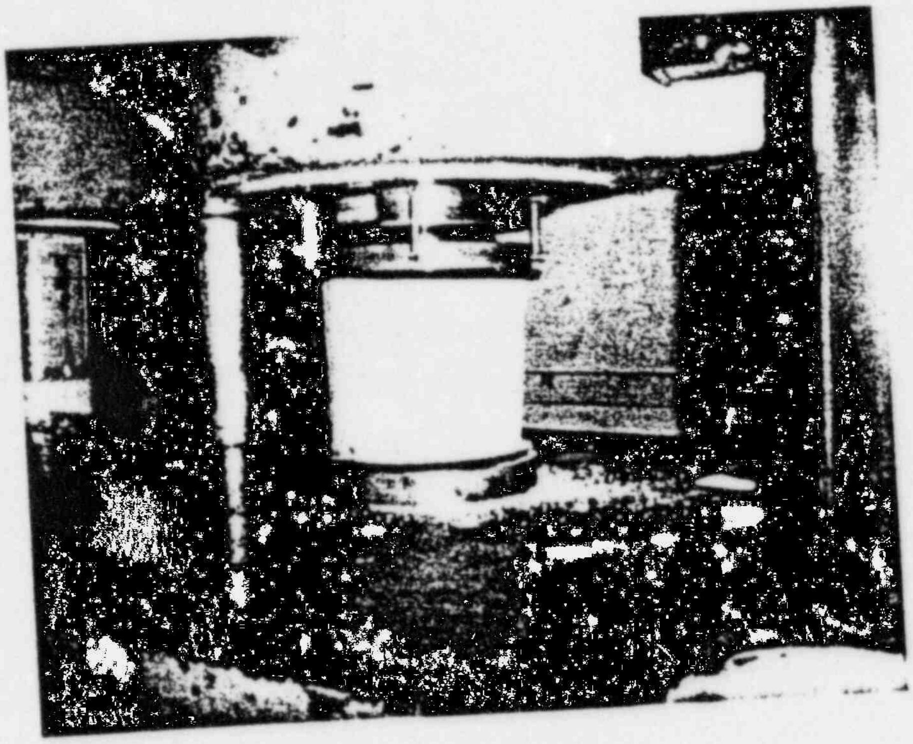

Figure B-13. Breaking Point of Specimen Containing Ion-Exchange Resin Beads

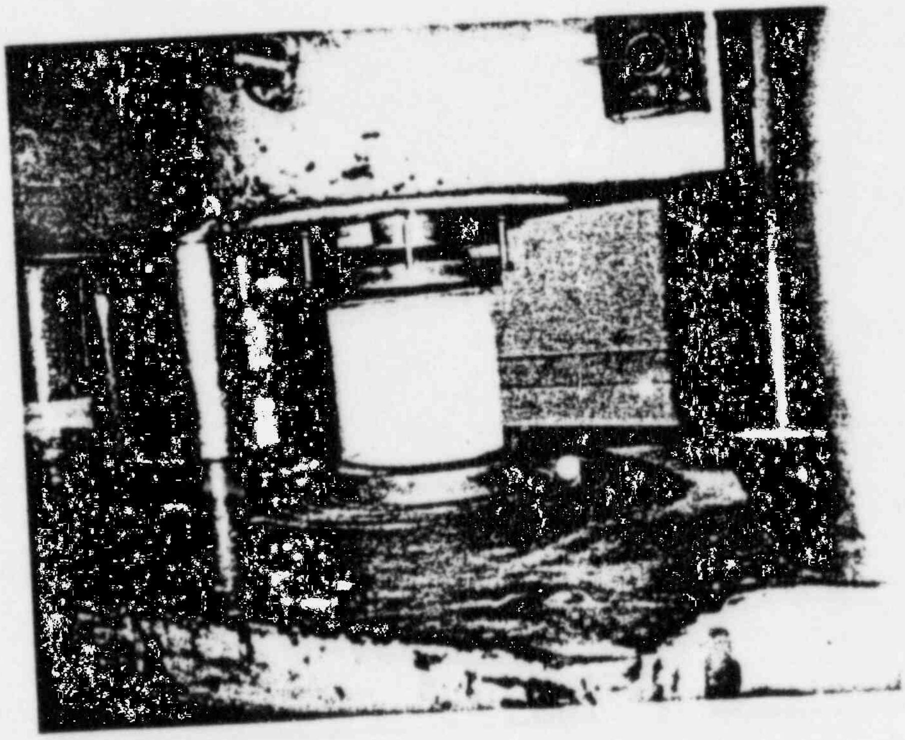

Figure B-14. Compression Test for Cement Matrix Containing Borated Material

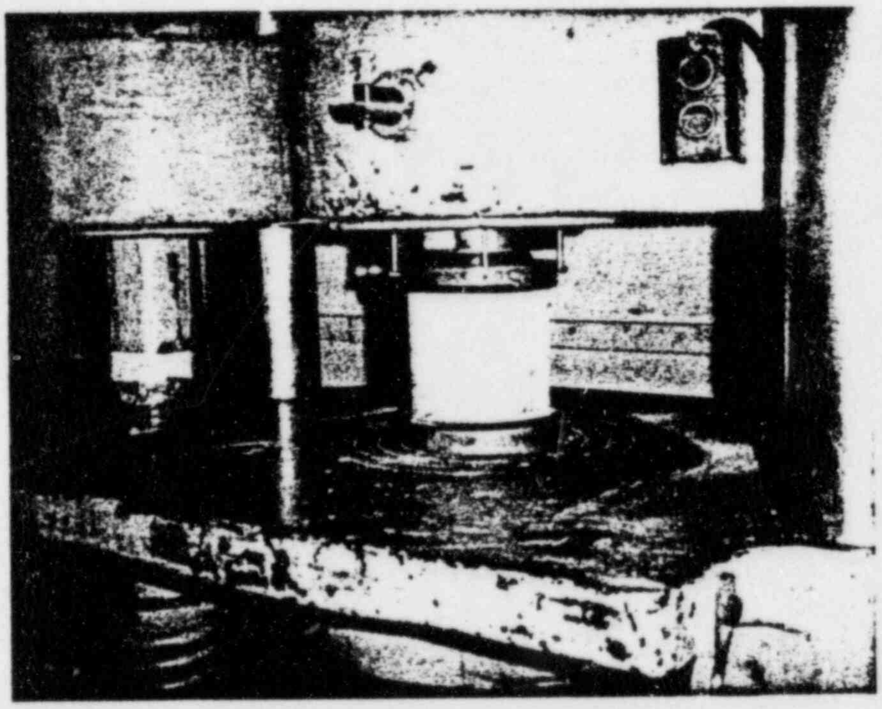

Figure B-15. Breaking Point of Specimen Containing Borated Material

APPENDIX IV

HEALTH PHYSICS

QUALITY ASSURANCE MANUAL

BARTLETT NUCLEAR INC.

PLYMOUTH INDUSTRIAL PARK, PLYMOUTH, MASSACHUSETTS 02360

TELEPHONE:

1-617-746-6464
1-800-225-0385

BARTLETT
NUCLEAR INC.

BARTLETT NUCLEAR INC.

Quality Assurance Program

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mouth: (617) 746-6464

BARTLETT
NUCLEAR INC.

1-800-225-0385

P.O. BOX 1800
MAIN OFFICE: 60 INDUSTRIAL PARK ROAD
PLYMOUTH INDUSTRIAL PARK
PLYMOUTH, MA 02360

II

Corporate Policy

It is the policy of Bartlett Nuclear, Inc. to provide high quality products and services to our customers.

To assure our customers of satisfactory service the following Quality Assurance program is set forth. The requirements of this program meet or exceed all regulations and guide lines of the Nuclear Regulatory Commission and any other pertinent Federal, State, Local or Plant specific requirements.

It is the responsibility of all Bartlett employees to strive for the highest standards of job performance as outlined in the Quality Assurance Manual. Overall responsibility for the Quality Assurance Program is vested in the Quality Assurance Manager who has the responsibility and authority to enforce full compliance with all pertinent regulations.

Bruce R. Bartlett

Bruce R. Bartlett
President

QUALITY ON-SITE DECONTAMINATION • ELECTROPOLISHING, LAUNDRY, AND SUPPORT SERVICES
HEALTH PHYSICS, CONSULTING, AND ENGINEERING

III

QUALITY ASSURANCE CONTROL

A. POLICY

As a service organization, Bartlett Nuclear, Inc. strives to maintain the highest standards for their equipment and personnel. A rigorous and thorough control system has been established to assure our customers of the highest quality equipment and personnel. These services are carefully scrutinized from contractual negotiation to job completion to maintain all NRC regulations and guides and all other pertinent Federal, State, Local and plant specific criteria.

B. MANAGEMENT

The Quality Assurance Manager has full responsibility and authority to implement the Quality Assurance Program. Each Department Manager, Sales Representative, Coordinator and Supervisor has Quality Assurance responsibilities assigned by the Quality Assurance Manager as outlined in the Quality Assurance Manual. Lines of responsibility and authority for Quality Assurance are separated from general company administrative functions as outlined on the appended Organizational Chart.

C. IMPLEMENTATION

1. Contract Negotiations

Company representatives are kept informed of equipment and personnel's reliability and availability when negotiating contracts with the customer.

2. Contracts

Proposed and/or issued contracts are carefully scrutinized by all affected department Quality Assurance respresentatives to assure the customer that all pertinent criteria are met.

3. Equipment

All equipment offered to the customer for lease or purchase is carefully inspected and evaluated prior to delivery to the customer. Records are maintained of equipment function and reliability.

4. Personnel

All employees are screened and categorized by the company. Qualifications of selected personnel are submitted to the customer for approval. Records of employee's qualifications are regularly updated.

5. Non-Compliance

If at any time services do not meet the appropriate Quality standards, the Quality Assurance Manager will be immediately notified. The Quality Assurance Manager and the affected manager will take

Non-Compliance cont.

immediate steps to rectify the non-compliance to the satisfaction of the customer.

6. Audits

Audits of the Quality Assurance Program will be conducted on a routine basis by the Quality Assurance Manager or his representative.
Customers are welcome and encouraged to audit our Quality Assurance Program. The Quality Assurance Manager will give prompt and courteous service to all customers.

IV

QUALITY ASSURANCE CONTROL

A. PURPOSE

This manual provides a coherent, systematic approach to insure quality and reliability of all services provided to the customer by Bartlett Nuclear, Inc.

B. SCOPE

The Quality Assurance Manual addresses quality assurance functions, responsibilities and forms of the company's management and employees.

C. RESPONSIBILITY

The Quality Assurance Manager is responsible for the Quality Assurance Manual and the administration of the program. Specific areas of responsibility are outlined in the manual.

D. APPLICABILITY

This manual applies to all Bartlett Nuclear, Inc. activities, which require conformance to the rules, regulations, guidelines of the NRC and any other applicable Federal, State, Local or customer specific requirements.

E. CONTROL

Control Copies are normally maintained at the Bartlett office. Each control copy of this manual has a control number affixed to the lower right hand cover. Each control copy issued is recorded by number, name of recipient and date of issue. Control copies are not issued to customers except upon request.

F. UPDATING

The Quality Assurance Manual will be updated on a routine annual basis and/or as needed. A confirmation of receipt will accompany all revisions and be entered in the master file in the corporation office.

G. APPROVALS

The Quality Assurance Manual and all revisions thereto shall have the expressed approval of the Quality Assurance Manager.

H. DISTRIBUTION

The Quality Assurance Manual of Bartlett Nuclear, Inc. shall be distributed to all company personnel who have a quality assurance function as designated by the quality assurance manager and to our customer's designated representatives, upon receipt of request.

I. ADMONITION

The Quality Assurance Manual and its contents are to be privileged information to Bartlett Nuclear, Inc. and customers.

Section 2

QUALITY ASSURANCE RESPONSIBILITIES

In order to assure continuing quality and reliability of equipment and services as outlined in Corporate Policy the following responsibilities and functions of control are designated.

a. QUALITY ASSURANCE MANAGER

Has the prime responsibility of all aspects of Quality Assurance. These responsibilities shall commence with contractual negotiations and bidding and shall continue throughout the duration of any specified contract, including, but not limited to, final critique with customer representative.

b. PERSONNEL DIRECTOR

Has the responsibility of maintaining up-to-date files on all personnel qualifications, clearances, and performance evaluations as directed by the Quality Assurance Manager.

c. HEALTH PHYSICS CONSULTANT

Has the responsibility to maintain current with changes in the state-of-the-art and inform the Quality Assurance Manager of all changes in techniques and formats, which effect Quality Assurance

d. SALES MANAGER

Must inform and coordinate with the Quality Assurance Manager all new contracts and/or changes in existing contracts which have quality specifications other than the NRC standards.

e. EQUIPMENT MANAGER

It is the responsibility of the Equipment Manager to inspect all equipment purchased by Bartlett Nuclear, Inc. All components must be tested and assembly tests of the complete unit must be documented before the units is offered to the customer. A file on each unit will be maintained in which running time, repairs, and frequency of repairs will be recorded. A master copy will be retained by the Equipment Manager and copy submitted to the Quality Assurance Manager. These copies will be kept current on a monthly basis. Any problem areas will be reported to the Quality Assurance Manager immediately and a joint effort of the Equipment Manager, Quality Assurance Manager, and the customer will be made to resolve the problem.

f. INSTRUMENT MANAGER

It is the responsibility of the Instrument Manager to inspect all instruments purchased by Bartlett Nuclear, Inc. All components must be tested and assembly tests of the complete unit must be documented before the units is offered to the customer. A file on each unit will be maintained in which running time, repairs, and frequency of repairs will be recorded. A master copy will be retained by the Instrument Manager and copy submitted to the Quality Assurance Manager. These copies will be kept current on a monthly basis. Any problem areas will be reported to the Quality Assurance Manager immediately and a joint effort of the Instrument Manager, Quality Assurance Manager, and the Customer will be made to resolve the problem.

g. SITE COORDINATOR

The site coordinator shall maintain a file on each Bartlett employee on site. This file shall include, but not limited to, a copy of the employee's resume, radiation dose record, and employee performance record.

The site coordinator shall maintain time sheets for all employees on site and submit a copy to the customer representative for review and approval. Time sheets shall be submitted on a weekly basis to the customer and Bartlett Nuclear, Inc.

Any irregularities in the aforementioned records shall be brought to the attention of the Quality Assurance Manager immediately for resolution and compliance to the appropriate standards and customer satisfaction.

QUALITY ASSURANCE MANAGER

The Quality Assurance Manager is responsible directly to the President for the Quality of all products and services of Bartlett Nuclear, Inc.

The Quality Assurance Manager has the responsibility and authority to formulate all Quality Assurance policies, records and manuals necessary in order to fulfill all of the standards and regulations set forth by the Nuclear Regulatory Commission, and all other applicable Federal, State, Local and specific customer requirements.

Section 3

PERSONNEL QUALIFICATIONS

1. Junior Technicians

    a. Must be 19 years of age or older;

    b. Must be a High School graduate;

    c. Must demonstrate a basic aptitude and ability in the science field by test or successfully completing applicable undergradate courses in the science field or have previous practical experience in Health Physics or related fields;

    d. Must successfully pass a test demonstrating emotional stability such as the MMPI test;

    e. Must be free of any criminal records other than minor offenses which would preclude security clearance;

    f. Must be able to pass a physical examination which verifies the technician to be in good health and able to perform the duties assigned to the technician. This physical must include appropriate tests or a registered physicians evaluation verifing the technician's ability to use respiratory equipment;

    g. Must sign release of information forms which will allow the company to contact past employers, educators, and law enforcement agencies to verify records.

2. Senior Technicians

    A. ANSI 18.1

    Must meet all of the requirements of Junior Technicians and:

        a. Must be 21 years of age or older;

        b. Must have a minimum of 2 years of practical Health Physics experience in a nuclear power plant or facility with problems similar to those of a nuclear power plant or;

I Have 5 years in practical applied Health Physics;
II Be a certified Health Physics Technician by NRRPT;
III Have an AA Degree in Health Physics and 1 year of practical experience or equivalent;
IV Have a BS Degree in a related science and 6 months practical experience.

B. ANSI 3.1-1978 and Reg. Guide 1980

a. Must have a minimum of 3 years of practical Health Physics experience in a nuclear power plant.

b. One year of experience should be in related technical training.

c. Must successfully complete a test for Senior Technicians;

d. Demonstrate to the company and the customer the ability to perform the duties required of a Senior Technician.

3. Health Physics Supervisor

Must meet all of the requirements of Senior Technicians and:

a. Must have a minimum of 5 years of Commercial Power Plant experience or:

I Be a certified technician by NRRPT or equivalent, and 2 years of commercial power plant experience;
II Have a BS Degree in the science field and 3 years commercial power plant experience;
III Have a MS Degree in Health Physics and 1 year of commercial power plant experience;
IV Have 7 years of applied Health Physics experience which includes 2 years of commercial power plant experience.

4. Site Coordinator

Must meet all of the requirement of Senior Technicians and:

a. Must have a thorough knowledge of the company's policies and procedures;

b. Must have the ability to write concise, accurate and legible reports and be familiar with standard administrative techniques;

c. Must be able to communicate effectively with the company and customer's representatives;

d. Must be able to communicate effectively with company employees and enforce the high quality standards set forth by company policy.

Section 4

PERSONNEL QUALIFICATIONS VERIFICATION

A. Education

Employment Questionnaire reveals education level and institution. Education above high school is verified by phone to appropriate registrar or company if not supported by a diploma or reproduction of diploma or certificate from a recognized educational institution or company.

B. Experience

Employment Questionnaire reveals job experience and is verified by contacting the last employer. Any irregularities are checked further by the next one or two previous employers.

C. Quality & Reliability

The quality of work and reliability of job performance are verified through previous employers, educators, and associates whichever is most practicable.

D. Security Clearance

A security check is made by Equifax, Pinkertons, independent investigative organizations, and/or company personnel in compliance with NRC regulations.

E. Stability

Verified by recognized Psychologist and/or testing by the MMPI or equivalent psychological test. These test results are evaluated by Dr. Al Petitpas, associated with the Psychology Department of Springfield College.

F. Testing

Theoretical
A test is administered to all new employees to evaluate their qualifications for job held. Practical - New employees are carefully monitored on the jobs to further evaluate their practical knowledge and applied health physics techniques.

Section 4

PERSONNEL QUALIFICATIONS VERIFICATION

A. Education

Employment Questionnaire reveals education level and institution. Education above high school is verified by phone to appropriate registrar or company if not supported by a diploma or reproduction of diploma or certificate from a recognized educational institution or company.

B. Experience

Employment Questionnaire reveals job experience and is verified by contacting the last employer. Any irregularities are checked further by the next one or two previous employers.

C. Quality & Reliability

The quality of work and reliability of job performance are verified through previous employers, educators, and associates whichever is most practicable.

D. Security Clearance

A security check is made by Equifax, Pinkertons, independent investigative organizations, and/or company personnel in compliance with NRC regulations.

E. Stability

Verified by recognized Psychologist and/or testing by the MMPI or equivalent psychological test. These test results are evaluated by Dr. Al Petitpas, associated with the Psychology Department of Springfield College.

F. Testing

Theoretical
A test is administered to all new employees to evaluate their qualifications for job held. Practical - New employees are carefully monitored on the jobs to further evaluate their practical knowledge and applied health physics techniques.

Appendix I

BARTLETT NUCLEAR INC.

PERSONAL PROFILE

NAME ____________________ H.P. TECHNICIAN TEST ____________

CLASSIFICATION ____________________ DATE ____________

DEGREES ☐ AA ☐ BA ☐ BS ☐ MS ☐ PHD

MAJOR SUBJECT,s ____________________

CERTIFICATES ____________________

____

YEARS OF APPLIED HEALTH PHYSICS EXPERIENCE ____________

YEARS OF COMMERCIAL POWER PLANT EXPERIENCE ____________

SPECIFIC JOB FUNCTION EXPERIENCE

FUNCTION	DATE	FUNCTION	DATE
Decontamination Area Equipment Personnel		Count Equip. Operator α Counter β Counter γ Counter $_0n^1$ Counter γ Spectrometer α Spectrometer Liquid Scintellator	
Smears & Surveys Alpha - HI (>50K dpm) LO (<50K dpm) Beta HI (>10 RAD) LO (<10 RAD) Gamma HI (>5 RAD) LO (<5 RAD) Neutron HI (>5 REM) LO (<5 REM)		Rad Waste Compaction Packaging Storage Shipping	
Air Samples HI Vol Lo Vol Lapel Cam		Respiratory Equipment Filter Air-Line SCBA Test Equipment	

SPECIFIC JOB FUNCTION EXPERIENCE (cont)

FUNCTION	DATE	FUNCTION	DATE
Dosimetry		Hazard Evaluation	
Self Reading		Air Sample Calc.	
Chemical		MPC Calc.	
TLD		Staytime Calc.	
Film Badge		Isotope Ident.	
Whole Body Count		Shielding Calc.	
Bio-Assay		Body Burden Calc.	

SPECIFIC JOB EXPERIENCE (Commercial Power)

PWR	DATE	BWR	DATE
Containment Power Entry		Refuel Floor	
Initial Shutdown Entry		Drywell/Vessel Head Rm.	
CRDM Removal		Drier/Moist. Seperator	
Upper Guide Structure		Refueling	
ICI Removal		Sparger Repair	
Head Removal		Jet Pump Repair	
Upper Internals Removal			
Refueling		Drywell	
In Vessel Work		Coolant Pumps	
Steam Generators		Relief Valves	
Tube Plugging		Pipe & Valve Repair	
Eddy Current		CRDM Remove	
Sludge Lancing		CRDM Repair	
Pipe Support Work		Torus	
Pressurizer		Valve Repair	
Relief Valve Repair		Support Mod.	
Inst. Repair & Mod.		Sand Blast	
Pipe & Support Work		Moisture Seperators	
Coolant Pumps		Pump Repair	
Seal Repair		Hx Repair	
Pump Repair/Replace		Condensor Repair	
Motor Repair/Replace		Water Box Repair	

SPECIFIC JOB EXPERIENCE (COMMERCIAL POWER) (cont.)

PWR	DATE	BWR	DATE
Heat Exchangers Regen. Non-Regen.		Turbine Floor Turbine Repair Control Valve Repair Hx. Repair Feed Pump Repair	

SPECIAL JOB EXPERIENCE

SPECIALTY	DATE	SPECIALTY	DATE
Training Inst. Employee Indoct. H.P. Jr. Tech. H.P. Sr. Tech. Reactor Oper. Emer. Response Basic Sciences		Consultant ALARA Applied Health Physics Reactor Chemistry Rad Waste Plant H.P. Inst. Respiratory Equipment Portable Inst. H.P. Procedures Waste Reduction Emergency Plans H.P. Training Spent Fuel Shipment Decon. Systems H.P. Outage Coord. Environ. Monitoring Computer System Program Accident Control	
Technical Writing Employee Tr. Manual H.P. Tech. Manual H.P. Procedures Air Sampling Techniques Respiratory Training Chemistry Procedures			
Decontamination Anti-C Laundry Tool Decon Resp. Decon Building Decon Land Area Decon Special Equipment Decon Personnel Decon			

Appendix IV

BARTLETT
NUCLEAR INC.

Personnel Evaluation and Performance Record

The following are guide lines to promote a more uniform method of personnel evaluations.

I. Gradients are based on a 4.0 being exceptional and the following general categories.

1. 0-1.0 Unacceptable performance
   1.1-2.0 Acceptable only with improvement
   2.1-3.0 Acceptable
   3.1-4.0 Most desirable

II Individual Categories general guide lines:

1. Reliability

   4.0 Employee is always on work station before the required time and never leaves job site without authorization before designated time.

   0-1.0 Employee is late more than once a week or employee leaves job site without proper authorization before designated time.

2. Dependability

   4.0 Employee is always at designated work station or immediately available if employee completes all designated tasks.

   0-1.0 Employee frequently missing from work station without authorization or unavailable for coverage. Employee does not complete assigned tasks or ignores them entirely.

3. Attitude

   4.0 Employee accepts all assigned tasks in a cheerful manner. Employee performs tasks to the best of his/her ability thoroughly, promptly, and correctly.

   0-1.0 Employee constantly complains that tasks assigned are beneath his/her ability or more difficult than other employee's tasks. Employee must be told repeatedly before he/she commences assigned task. Employee often fails to do task properly or task is incomplete or ignored entirely.

4. Aptitude

   4.0 Employee grasps new concepts readily. Employee often develops new techniques and is constantly aware of of ALARA and good Health Physics practices. Employees demonstrates excellent mechanical, mathematical, and practical abilities.

0-1.0 Employee cannot grasp new concepts, employee over/under reacts to ALARA concepts, employee cannot grasp Health Physics concepts, employee cannot put theoretical concepts to practical use.

5. Employee Relations (Colleagues)

4.0 Employee has excellent relationships with his co-workers and supervisors, employee has empathy for the problems and attitudes of his co-workers and supervisors both on and off the job.

0-1.0 Employee is a "loner" and does not associate with co-workers, employee feels he/she is better than his/her co-workers and is constantly deriding their abilities and job performance. Employee often lapses to vicious hositility and bitter arguments with co-workers.

6. Public Relations (Customers and General Public)

4.0 Employee has excellent rapport with customer's craftsmen, H.P.s and management, employee realizes he/she is responsible to aid and support the customer's policies and personnel.

0-1.0 Employee is argumentative and often is in conflict with customer personnel, employee resents customer personnel and authority and is constantly trying to tell them how to do their jobs, employee will perversely continue to perform a task "in his/her-own-way" regardless of customer's written and/or verbal procedures.

7. Professionalism

4.0 Employee always reports to work alert, neat, clean, and properly attired, employee communicates both written and verbal in clear concise English, employee is always courteous and respectful in dealing with subordinates, colleagues, and superiors, employee exhibits honesty and integrity in discharging his assignments to the company and the customer.

0-1.0 Employee reports to work dirty, unshaven, and improperly attired; employee reports to work under the influence of alcohol or drugs; employee appears illiterate and profane in his/her communications (rude and uncouth); employee is dishonest and without scruples in dealing with others.

8. Technical Competence

   4.0 Employee's technical ability far exceeds his job assignment; employee often studies new manuals and reports to increase his technical competence.

   0-1.0 Employee lacks the technical ability to perform his/her assigned tasks properly; employee makes no effort to improve his technical ability.

9. Progression

   4.0 Employee accepts criticism constructively and addresses problem areas aggresively; employee continues to improve his/her performance in all areas.

   0-1.0 Employee reacts to constructive criticism with open hostility and resentment; employee's job performance tends to continually degenerate with time.

10. Summary

    The final grade of the employee's evaluation and performance record is the average of the 9 listed items.

    Extenuating circumstances can vary the final score a maximum of 1 point at the discretion of the site coordinator and Quality Assurance Manager.

BARTLETT
NUCLEAR INC.

PERSONNEL EVALUATION AND PERFORMANCE RECORD

NAME ____________________ DATE __________ SUPERVISOR __________

ITEM	GR.	ITEM	GR.
Reliability		Public Relations	
Dependability		Professionalism	
Attitude		Technical Compentence	
Aptitude		Progression	
Employee Relations		Summary	

Comments: ____

BARTLETT
NUCLEAR INC.

June 10, 1982

To: Screening Staff Bartlett Nuclear, Inc.

Re: Procedures for ANSI N18.17-73

From: Bruce R. Bartlett, President

General Purpose:

ANSI N18.17-73 guidelines for screening individuals were instituted to determine that only trustworthy individuals are employed in the nuclear industry and that they are continually monitored for trustworthiness.

It is Bartlett Nuclear, Inc. goal to comply 100% with the "spirit" and "letter" of American National Standard N18.17-73.

A. Employee Screening

1. Background investigation will be conducted for a period of at least three years for all previous employers. This will be done by a letter similiar to Exhibit I. If the letter does not return in sufficient time a telephone investigation, Exhibit II, is permissable, providing item 7 of Bartlett Form S-1 is adhered to for dates, name, and title of person spoken to, and name of Bartlett employee who did background check. Personnel Form S-2 will be scrutinized to see the background is all inclusive for the three years.
   To aid in the background checks the following information is mandatory:

   1. Resume
   2. Employee Package- including authorization to do background check.
   3. Three personal references will be solicited similar to Exhibit III, and the results will be recorded on Personnel Form S-3.

   The following information is helpful but not mandatory:

   1. Birth certificate
   2. DD214
   3. Education verified (if not full time in previous 3 years).

Employee Screening (cont.)

B. An examination by a professionally trained person or our company mental health expert, Dr. Albert Petitpas to see that the person has no aberrant behavior or displays no indication of emotional instability.

Mandatory:

1. That the Minnesota Multiphasic Personality Inventory Test or a similar instrument be used to test aberrant behavior.

2. That a letter be received form Dr. Petitpas or similar mental health expert certifying that the test and or resulting followups revealed no indication of aberrant behavior. This information shall be recorded by date on Personnel Form S-1.

C. Continued Observation

The Bartlett Management shall continue to monitor for any "danger signs" that may help in early identification of troubled employees.

Mandatory:

1. That supervisors be trained in the techniques and procedures of the supervisor's letter, Exhibit IV.

2. That a form be filled out from the supervisors during the first weeks of July and February attesting to the continuing monitoring for aberrant behavior.

D. Audit Function

Steps A, B, and C will be audited by Paul M. McIsaac or a management person before any"good guy letters" are signed and items 11 and 12 of Personnel Form S-1 must be signed.

Mandatory:

Quarterly audits will be done the first weeks of July, October, January, and April, and the dates shall be so noted on Personnel Form S-1.

Very truly yours,

Bruce R. Bartlett

Bruce R. Bartlett
President

BRB/ss

Personnel Form S - 1

Name: ______________________

Date Hired: ______________________

ANSI N18.17 Requirements	Date	Verified by:
1. Authorization letter from employee		
2. Resume		
3. MMPI: Date of Results		
4. 3 year background check		
5. Dates on all letters		
6. Date and name of person that reviewed comments		
7. Telephone conversations - Date, name and title of person spoken to, and name of Bartlett employee who did background check. Sign full name.		
8. Birth Certificate Present		
9. DD214 Present (if applicable)		
10. Education verified		
11. Date of good guy letter		
12. Date of final audit by Paul McIsaac, Controller		

Continuous Employment (if not insert new audit sheet)	Yes	No	Quarterly Audits	

Personnel Form S - 2

NAME________________________

EMPLOYMENT BACKGROUND SUMMARY

Rating:
1-Excellent
2-Good
3-Fair
4-Poor

Dates From	to	Contractor	Plant	Type of Confirm V=Verbal W=Written	Rating

Personnel Form S - 3

NAME ______________________________

PERSONNAL REFERENCE SUMMARY

Reference check results

Name of reference	Excellent	Good	Fair	Poor	Type of Confirmation W=Written V=Verbal

Pl[illegible]uth: (617) 746-6464

BARTLETT
NUCLEAR INC.

1-800-225-0885

P.O. BOX 1800
MAIN OFFICE: 60 INDUSTRIAL PARK ROAD
PLYMOUTH INDUSTRIAL PARK
PLYMOUTH, MA 02360

Re: ______________________

Social Security # ______________

Att: Personnel

We would appreciate if you would supply us with the employment information on the above named individual. Please indicate if the individual did not perform in a satisfactory manner and meet your employment requirements.
Your prompt attention to this request will be greatly appreciated. An envelope is enclosed for your reply.

Very truly yours,

Personnel Administration

Dates of Employment:

From: ____________ to ____________ Location ______________________

From: ____________ to ____________ Location ______________________

Position/Job Title: ______________________

Reason for Termination of Employment (please check)

Involuntary _____ Voluntary _____

a. lack of work _______

b. other ______________________

____

Has individual exhibited aberrant behavior or untrustworthiness? Yes _____ No ___

Please explain (if yes) ______________________

____

Eligible for rehire? ______________________

Additional Comments:

Company Name ______________________

Signature ______________________

Title ______________________

Plymouth: (617) 746-6464

BARTLETT NUCLEAR INC.

1-800-225-0385

P.O. BOX 1800
MAIN OFFICE: 60 INDUSTRIAL PARK ROAD
PLYMOUTH INDUSTRIAL PARK
PLYMOUTH, MA 02360

You have been given as a reference by the below named person. We would appreciate it if you would supply us with any information regarding this person's character and standing in the community. Please indicate if the individual indicated any aberrant behavior or evidenced any untrustworthiness.

COMMENTS:

Your prompt attention to this matter will be greatly appreciated.

Very truly yours,

BARTLETT NUCLEAR INC.

Fay Viscariello
Personnel Secretary

QUALITY ON-SITE DECONTAMINATION • ELECTROPOLISHING, LAUNDRY, AND SUPPORT SERVICES
HEALTH PHYSICS, CONSULTING, AND ENGINEERING

Plymouth: (617) 746-6464

BARTLETT
NUCLEAR INC.

1-800-225-0385

P.O. BOX 1800
MAIN OFFICE: 60 INDUSTRIAL PARK ROAD
PLYMOUTH INDUSTRIAL PARK
PLYMOUTH, MA 02360

X Contractor Corp
1 Boston Place
Boston, MA

Personnel Manager
John Doe

Re: John Smith

Att: Personnel

Social Security # 000-00-0000

We would appreciate if you would supply us with the employment information on the above named individual. Please indicate if the individual did not perform in a satisfactory manner and meet your employment requirements.
Your prompt attention to this request will be greatly appreciated. An envelope is enclosed for your reply.

Very truly yours,

Personnel Administration

Dates of Employment:

From: May 6, 1981 to June 11, 1981 Location Y Nuclear Plant

From: ______ to ______ Location ______

Position/Job Title: Senior Health Physics Technician

Reason for Termination of Employment (please check)

Involuntary ______ Voluntary ______

a. lack of work ✓

b. other ______

Has individual exhibited aberrant behavior or untrustworthiness? Yes ______ No ✓

Please explain (if yes) ______

Eligible for rehire? yes

Additional Comments:

Per telephone conversation with John Doe

Company Name X Contractor Corp.

Signature John Doe

Title Personnel Manager

March 2, 1982

Judith Grossman
Personnel
Bartlett Nuclear

QUALITY ON-SITE DECONTAMINATION • ELECTROPOLISHING, LAUNDRY, AND SUPPORT SERVICES
HEALTH PHYSICS, CONSULTING, AND ENGINEERING

Pl[illegible]outh: (617) 746-6464

BARTLETT
NUCLEAR INC.

1-800-225-0385

P.O. BOX 1800
MAIN OFFICE: 60 INDUSTRIAL PARK ROAD
PLYMOUTH INDUSTRIAL PARK
PLYMOUTH, MA 02360

To: Bartlett Supervisors

From: Dr. Al Petitpas
Mental Health Consultant

Re: Continuous monitoring of on-site employees

As a follow up to our recent communication, I have attached a list of danger signs that may help you in the early identification of troubled employees.

QUALITY ON-SITE DECONTAMINATION • ELECTROPOLISHING, LAUNDRY, AND SUPPORT SERVICES
HEALTH PHYSICS, CONSULTING, AND ENGINEERING

BARTLETT
NUCLEAR INC.

A Guide for Early Recognition of Psychological Stress in Employees

As a field supervisor it is important for you to be aware of some of the possible danger signs of psychological stress. Early recognition of these warning signals may help to avoid situations in which an employee is experiencing a building of psychological stress which may negatively impact on job performance. The following is a brief list of these "danger signs". If you have serious concerns about the behavior of an employee, do not hesitate to seek professional consultation.

In addition to seeking help in the local area, you should also notify:

Bruce R. Bartlett, President
Paul M. McIsaac, Vice President or
Judy S. Gropman, Personnel Department or
Dr. Al Petitpas, Mental Health Consultant

1. Disturbances of Emotions

A. Anxiety is shown as uneasiness, apprehension, or fearfulness stemming from anticipated danger, the source of which is unidentifiable.

1) agitation is a state of restlessness and uneasiness often shown in physical manifestations.
2) tension is tautness, motor and emotional restlessness: dread.
3) panic is an acute anxiety attack of overwhelming severity; a loss of control

B. Depression is a feeling of sadness, loneliness, dejection, or hopelessness, typically found in major depressive disorders. It must be differentiated from grief, which is a state of sadness proportionate to a loss.

C. Euphoria is an exaggerated sense of well being not consistent with reality.

D. Apathy is the lack of feelings, emotion, interest, or concern; impassive or unfeelingness.

E. Inappropriateness is an emotion opposite to what would be expected.

F. Ambivalence is the coexistence of two opposing feelings toward the same individual or object.

G. Hostility is anger, antagonism, opposition, or resistance in thought or behavior. Unexpressed and internalized hostility may appear in physical symptoms.

H. Depersonalization is a pervasive feeling of unreality, strangeness, or altered identity.

2. Disturbances of Consciousness

    A. Confusion is disorientation in respect to time, place, or person and is accompanied by perplexity.

    B. Dream State is also known as twilight state. It is a transient clouding of consciousness of intrapsychic origin during which the person is unaware of reality and behaves violently or opposite to his or her usual pattern.

    C. Delirium is characterized by disturbance in affect, memory, and consciousness. There are obvious changes in mood, there are illusions, and there are hallucinations.

3. Disturbances of Orientation

    A. Disorientation is loss of awareness of one's relationship to time, surroundings, or other persons.

4. Disturbances of Perception

    A. Hallucinations are false sensory perceptions that are not caused by external stimuli.

        1) They may be auditory, visual, olfactory, gustatory, tactile (haptic), or kinesthetic (phantom limb is a kinesthetic hallucination).
        2) Hallucinations occur in substance-use disorder (caused by alcohol, cocaine, or hallucinogenic drugs such as LSD, peyote, or mescaline). May also be found in certain other psychotic conditions such as schizophrenic and manic disorders.

5. Disturbances of Thinking

    A. Fantasy, or phantasy, is fabricated series of mental pictures or sequences of events; daydreaming.

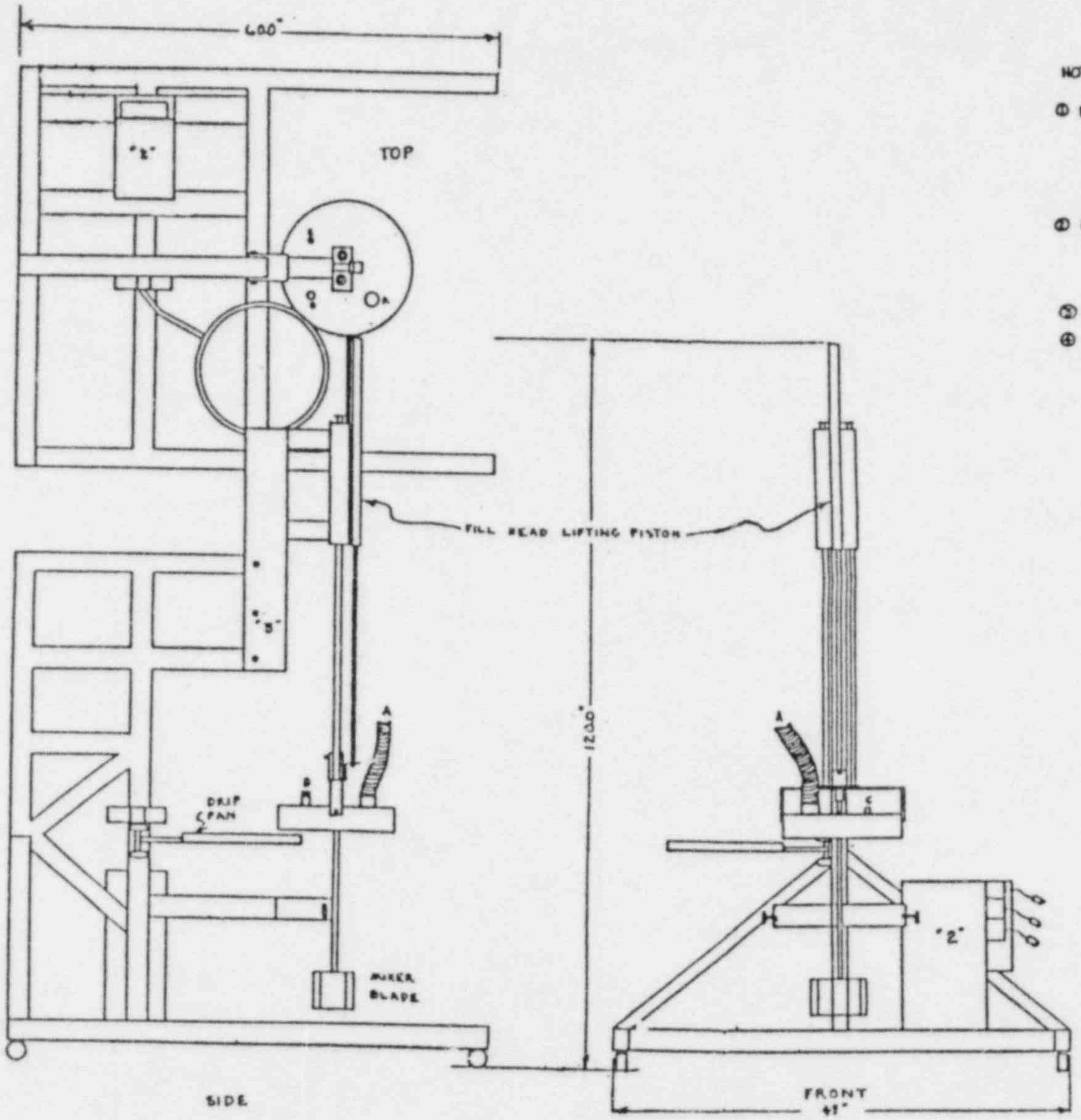
    B. Phobias are persistent, obsessive fears of specific objects, activities, or situations. Examples include fear of height, closed spaces, open spaces, strangers, animals, dirt or school. Certain fears, as of harmless bugs and snakes, are extremely common, and not considered pathological, but phobias are typically found in phobic disorders.

    C. Obsessions, also called ruminations, are persistent, recurring ideas or impulses that remain conscious despite their irrationality.

    D. Preoccupations are excessive concerns with one's own thoughts; engrossment.

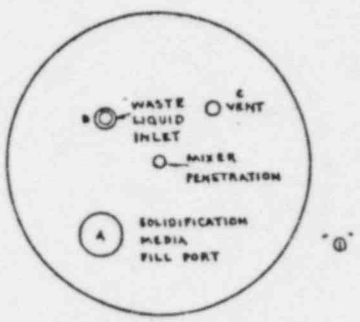
    E. Delusions are fixed, false beliefs that are not in keeping with the individual's cultural or intellectual level.

APPENDIX V



NOTES:

① FILL HEAD IS ALL 316 STAINLESS STEEL
A: SOLIDIFICATION MEDIA FILL PORT, 4" HOSE CONNECTION
B: WASTE INLET - 1½" CAMLOK CONNECTION
C: VENT - 1" CAMLOK CONNECTION
② HYDRAULIC POWER PACK (HOSES NOT SHOWN)
ELECTRICALLY OPERATED AND CONTROLLED REMOTEL
110 VAC 20 AMP
③ UNIT DISASSEMBLES FOR EASE OF SHIPMENT
④ UNIT BUILT OF MILD STEEL AND PAINTED



FILL-HEAD TOP

BARTLETT

SOLIDIFICATION MACHINE

SCALE: NONE
JOB: CRYSTAL R
DRAWN BY: DALE
CHECKED BY:
APPROVED BY:
SHEET 1