UNITED STATES
NUCLEAR REGULATORY COMMISSION
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MEMORANDUM FOR: John J. Surmeier, Chief
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Division of Low-Level Waste
Management and Decommissioning, NMSS

THRU: Michael Tokar, Section Leader
Engineering Section
Technical Branch
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Bernard Jagannath for M. Tokar

FROM: Everett Wick
Engineering Section
Technical Branch
Division of Low-Level Waste
Management and Decommissioning, NMSS

SUBJECT: SUMMARY OF AUGUST 23, 1990 MEETING BETWEEN NRC, BONDICO, AND SAIC

The subject meeting summary is enclosed. This summary highlights the NRC/SAIC concerns regarding the structural stability of the fiberglass-reinforced plastic material used on Bondico's proposed HIC-7 high integrity container for disposal of low-level radioactive waste (Docket Number WM-94).

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Attachment: Meeting Summary

cc: Attendees w/attachment

MEETING SUMMARY

DATE: August 23, 1990

TIME: 10:00 a.m. to 12:00 noon

PLACE: OWFN, Room 10B13

PURPOSE: TO DISCUSS NRC'S REVIEW OF THE STRUCTURAL STABILITY OF BONDICO'S HIC-7 FIBERGLASS-REINFORCED PLASTIC HIGH-INTEGRITY CONTAINER (DOCKET NUMBER WM-94)

PARTICIPANTS:

NRC
John Greeves NMSS/LLWM
Michael Tokar NMSS/LLTB
Banad Jagannath NMSS/LLTB
Robert Shewmaker NMSS/LLTB
Everett Wick NMSS/LLTB

BONDICO NUCLEAR
Homer Lowenberg

SAIC
Jim Hammelman
John Stokely
Joe Price

SUMMARY

1. SAIC presented a summary of its review of the structural stability of the fiberglass-reinforced plastic (FRP) HIC. This review concentrated on the durability of the physical properties of the FRP. A handout of the presentation is attached.

2. The conclusions of the review are that water absorption effects are potential FRP degradation mechanisms which should be evaluated for long-term applications. These potential degradation mechanisms are (a) hydroloysis of ester linkages of the polymer matrix and (b) debonding of the polymer matrix and reinforcing glass fiber.

3. In view of the above conclusions, the available data base does not support a finding that a FRP HIC will retain structural stability for 300 years.

4. Hydrolytic degradation of ester linkages has been observed experimentally. Thus, NRC asked Bondico during the review to (a) present evidence that this mechanism will not occur in the proposed FRP and (b) present evidence to support the projection of a 300-year service life.

5. Water diffusing through FRP would contribute to development of swelling stresses in the FRP and osmotic pressures in the vicinity of the glass fibers. During the review, Bondico was requested to demonstrate that any reduction in strength (caused by these phenomena during the 300-year service life) would not decrease material properties below values required in the design.

6. Bondico's responses to the NRC comments raised in items 4 and 5 are summarized below.

   a. The two questions (potential failure mechanisms) are judged to be interrelated and are addressed in a combined manner.

   b. Data on thermoplastic resins are not relevant to behavior of thermosetting plastics.

   c. Material properties, e.g., water uptake and tensile strength, are significantly different between the FRP material used in the hot-water tests and the FRP material to be used in the HICs.

   d. 30 years of data, under more stringent conditions, indicate that the FRP has little or no tendency to suffer from hydrolytic degradation; industrial experience (Owens-Corning) indicates no problems in this area.

   e. Immersion in laboratory water is irrelevant to exposure in the natural unsaturated zone environment; differences in water saturation, water chemistry, and temperature support this premise.

   f. Extrapolation of data (4 points) collected over an exposure period of 6 years to an exposure period of 300 years indicates acceptable strength retention.

7. NRC/SAIC's evaluation of Bondico's responses are summarized below.

   a. There is no direct evidence or analysis that the two degradation mechanisms do not occur in the HIC FRP over long time frames.

   b. Without a mechanistic basis, extrapolation of short-term data will not provide a supportable estimate of long-term properties.

   c. Modification of test conditions would not change the conclusions that the degradation mechanisms are credible and need to be evaluated.

8. SAIC agreed to perform the following actions and to document them in its draft summary report.

   a. Update the status of the research on water absorption that is being performed by Ford Motor Company. This would be done by telephoning the authors of the report, which has been referenced by NRC/SAIC and enclosed in NRC's formal comments to Bondico.

   b. Determine whether it is possible from the standpoint of thermodynamics for the potential failure mechanisms to occur at the soil temperature at the disposal site, i.e., 15°C.

c. Discuss whether it is more likely that the degradation observed in the polymer after immersion in 98°C water was caused by exposure to the higher temperature rather than exposure to the water. This would be done through discussions with a polymer chemist.

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Attachment: Handout of
presentation by SAIC (Dr. Joseph Price)

BACKGROUND

Project: Review Topical Report for a Fiberglass Reinforced Plastic High Integrity Container and evaluate HIC material behavior against regulatory performance requirements

REVIEW CRITERIA

General:

- 10 CFR 61
- Branch Technical Position on Waste Form

Specific:

- Maintain structural integrity for 300 years
- Corrosion tests to confirm material suitability to meet design lifetime goal
- Radiation stability; no significant changes in material properties to 100 million rads
- Test against biodeterioration

II. METHODOLOGY AND DATA REVIEW

MAJOR STEPS

- Characterize material
- Identify potential degradation mechanisms
- Identify available data
- Assess data and determine relevance of data to projection of HIC material properties over long time frames (i.e., 300 years)

II. METHODOLOGY AND DATA REVIEW

CHARACTERIZE MATERIAL

- Applicant information:

  Matrix material -

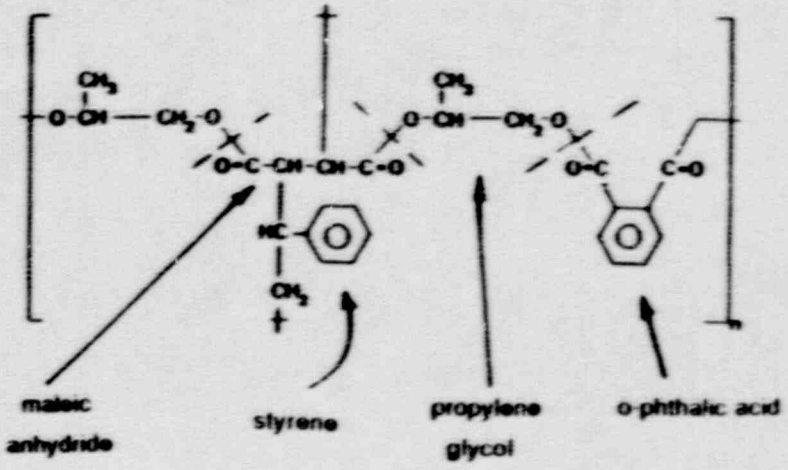
  Isophthalic resin produced by condensation reaction of maleic anhydride, isophthalic acid, diethylene glycol and propylene glycol, cross-linked with styrene

  Reinforcing fibers -

  E-glass

- Literature diagram:

  Matrix material -



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POTENTIAL DEGRADATION MECHANISMS

- Actinic degradation
- Biodeterioration
- Thermal oxidation
- Radiation degradation
- Water absorption effects
  - hydrolysis of ester linkages in polymer matrix
  - polymer / glass debonding due to osmotic effects

AVAILABLE DATA

Applicant Data (in-situ conditions)

- Water uptake; seven days exposure
- Flexural strength; seven days exposure, eight chemicals

Manufacturer Data (in-situ conditions)

- Flexural strength; unchanged after 30 years burial

AVAILABLE DATA (continued)

Literature Data (accelerated conditions)

- Polymer matrix hydrolysis
  - Related polyester (polyarylate), non-reinforced, not cross-linked

- Glass / polymer debonding
  - Similiar material, fabrication technique

- Unspecified
  - Fragmentary data on loss of flexural strength of isophthalic resin FRP following immersion in water at $72^{o}F$ and $210^{o}F$

II METHODOLOGY AND DATA REVIEW

ASSESS DATA : ACCELERATED TESTING ISSUES

- NEED TO PRESERVE THE MECHANISM
- USE REPRESENTATIVE CONDITIONS
  - SAME COMPOUNDS
  - SAME CHEMICAL POTENTIAL OF AMBIENT WATER
  - SAME CONCENTRATION OF SOLUTES IN WATER
- AVOID CONFOUNDING EFFECTS
  - MINIMIZE CHANGES IN RATE DETERMINING FACTORS OTHER THAN TEMPERATURE

ASSESS DATA: ESTER LINKAGE HYDROLYSIS

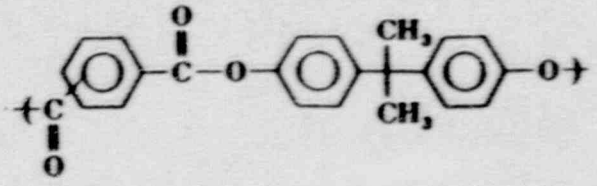
Reference: Golovoy & Cheung (Ford Motor Co.); J Appl Poly Sci (1988)

Experiment:

Immersion of polyester in water at varying temperatures (130 - 210^{o}F) and exposure intervals; determine tensile strength, average molecular weight

Material:

Amorphous aromatic polyester, no cross-linking or reinforcement



ASSESS DATA: ESTER LINKAGE HYDROLYSIS

Results:

- Tensile yield strength remained constant then made rapid transition to failure (yield strain and strain to break coincided)

- Limited extent of reaction, one scission per chain, rate limiting step is hydrolysis, concentration dependence could be represented as zero order with respect to polymer average molecular weight

- The logarithm of rate constant showed a linear dependence on reciprocal temperature (i.e., followed Arrhenius relation)

- Projected service life of polyarylate at 15^{o}C is 76 years

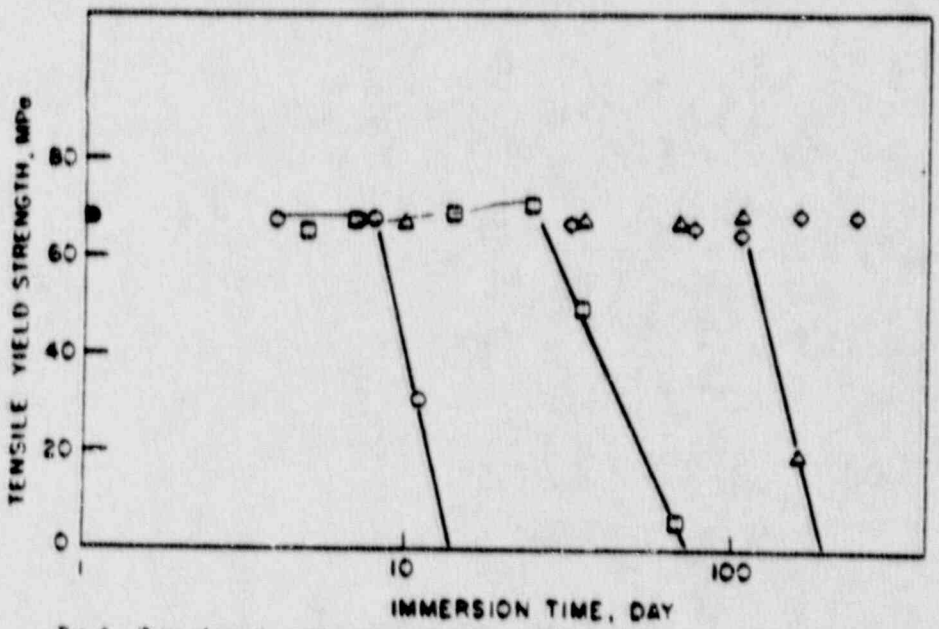


Fig 6. Plots of tensile yield strength vs. time. (○) 98°C, (□) 85°C, (△) 70°C, (◇) 55°C.

ASSESS DATA: GLASS / POLYMER DEBONDING

Reference: Phani and Bose; Comp Sci & Tech (1987)

Experiment:

Immersion of FRP in water at varying temperatures (120 - 212^{o}F) for varying time intervals; photomicrographs of material, flexural strength

Material:

Isophthalic polyester resin, cross-linked, glass reinforced

ASSESS DATA: GLASS / POLYMER DEBONDING

Results:

- Photomicrographs suggest interfacial debonding is main failure mechanism

- The logarithm of rate of loss of strength showed a linear dependence on reciprocal temperature; the magnitude of the activation energy indicated that water diffusion controlled the rate of the process

- Logarithm of fractional strength loss showed a linear dependence on time

CONCLUSIONS

- Hydrolysis of ester linkages and glass / polymer debonding are FRP degradation mechanisms which should be evaluated for long-term applications

- Given the above conclusion, the available data base does not support the finding that a FRP HIC will retain structural stability for 300 years.

IV SUMMARY OF QUESTIONS AND RESPONSES

NRC/SAIC QUESTIONS

1. HYDROLYTIC DEGRADATION OF ESTER LINKAGES HAS BEEN OBSERVED EXPERIMENTALLY. WHAT EVIDENCE CAN BE ADVANCED TO INDICATE THAT THIS MECHANISM WILL NOT OCCUR IN THE PROPOSED FRP ? WHAT EVIDENCE CAN BE ADVANCED TO SUPPORT THE PROJECTION OF 300 YEAR SERVICE LIFE ?

2. WATER DIFFUSING THROUGH FRP CONTRIBUTES TO DEVELOPMENT OF SWELLING STRESSES IN THE FRP AND OSMOTIC PRESSURES IN THE VICINITY OF GLASS FIBERS. DEMONSTRATE THAT ANY REDUCTION IN STRENGTH CAUSED BY THESE PHENOMENA DURING THE 300 YEAR SERVICE LIFE WOULD NOT DECREASE MATERIAL PROPERTIES BELOW VALUES REQUIRED IN THE DESIGN.

IV SUMMARY OF QUESTIONS AND RESPONSES

BONDICO RESPONSES

- THE TWO QUESTIONS ARE JUDGED TO BE INTERRELATED AND ARE ADDRESSED IN A COMBINED MANNER
- DATA ON THERMOPLASTIC RESINS ARE NOT RELEVANT TO BEHAVIOR OF THERMOSETTING PLASTICS
- MATERIAL PROPERTIES, E.G., WATER UPTAKE AND TENSILE STRENGTH, ARE SIGNIFICANTLY DIFFERENT BETWEEN THE TEST AND HIC MATERIAL
- 30 YEARS OF DATA, UNDER MORE STRINGENT CONDITIONS, INDICATE THAT THE FRP HAS LITTLE OR NO TENDENCY TO SUFFER FROM HYDROLYTIC DEGRADATION; INDUSTRIAL EXPERIENCE (O/C) INDICATES NO PROBLEMS IN THIS AREA
- IMMERSION IN LABORATORY WATER IS IRRELEVANT TO EXPOSURE IN THE NATURAL UNSATURATED ZONE ENVIRONMENT; DIFFERENCES IN WATER SATURATION, WATER CHEMISTRY AND TEMPERATURE SUPPORT THIS PREMISE
- EXTRAPOLATION OF DATA (4 POINTS) COLLECTED OVER 6 YEARS TO 300 YEARS EXPOSURE INDICATES ACCEPTABLE STRENGTH RETENTION

IV SUMMARY OF QUESTIONS AND RESPONSES

EVALUATION OF RESPONSES

- NO DIRECT EVIDENCE OR ANALYSIS THAT THE TWO DEGRADATION MECHANISMS DO NOT OCCUR IN THE HIC FRP OVER LONG TIME FRAMES
- WITHOUT A MECHANISTIC BASIS, EXTRAPLOATION OF SHORT-TERM DATA WILL NOT PROVIDE A SUPPORTABLE ESTIMATE OF LONG-TERM PROPERTIES
- MODIFICATION OF TEST CONDITIONS WOULD NOT CHANGE THE CONCLUSIONS THAT THE DEGRADATION MECHANISMS ARE CREDIBLE AND NEED TO BE EVALUATED