SPENT FUEL CASK CONTAINMENT

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NUCLEAR WASTE TECHNICAL REVIEW BOARD
TRANSPORTATION & SYSTEMS PANEL MEETING
SEPTEMBER 25, 1991
ARLINGTON, VA

- TRANSPORTATION REGULATIONS ADDRESS THREE BASIC SAFETY REQUIREMENTS IN TERMS OF PERFORMANCE STANDARDS FOR NORMAL AND ACCIDENT CONDITIONS OF TRANSPORT

  - **CONTAINMENT: THE SPENT FUEL TRANSPORT CASK MUST PROVIDE ADEQUATE CONTAINMENT OF RADIOACTIVE MATERIAL**

  - SUBCRITICALITY: THE SPENT FUEL TRANSPORT CASK MUST PROVIDE ASSURANCE OF NUCLEAR SUBCRITICALITY

  - SHIELDING: THE SPENT FUEL TRANSPORT CASK MUST PROVIDE ADEQUATE SHIELDING OF THE RADIATION EMITTED BY THE RADIOACTIVE CONTENTS

- THERE ARE SEVERAL BARRIERS TO THE RELEASE OF RADIOACTIVE MATERIALS FROM A SPENT FUEL CASK:

  - THE FUEL PELLET AND FUEL ROD CLADDING

  - THE PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE MATERIAL

  - DIFFUSIVE DEPOSITION AND GRAVITATIONAL SETTLING OF RADIOACTIVE MATERIALS DURING TRANSIT TO A LEAK SITE

  - SEALS

  - THE ACTUAL SIZE AND NATURE OF ANY LEAK PATH(S)

- TWO ELEMENTS OF CONTAINMENT WILL BE DISCUSSED

  - **THE RADIOACTIVE SOURCE TERM**

  - CASK CONTAINMENT SEALS

- THE RADIONUCLIDES IN A SPENT FUEL CASK ORIGINATE FROM THREE DISTINCT MEDIA

  - ACTIVATED CORROSION AND FREE FISSION PRODUCTS ADHERING TO THE SURFACE OF SPENT FUEL RODS (CRUD)

  - RESIDUAL CONTAMINATION THAT MAY BUILD UP IN THE CAVITY OF A CASK OVER TIME

  - THE LOADED SPENT FUEL

- ANSI N14.5 PROVIDES STANDARDIZED METHODS FOR DEMONSTRATING THAT SPENT FUEL PACKAGES COMPLY WITH THE REGULATORY CONTAINMENT REQUIREMENTS OF 10 CFR 71

  - TYPE B PACKAGE CONTAINMENT SYSTEMS MUST HAVE LEAKAGE OR RELEASE RATES LESS THAN, OR EQUAL TO, THE MAXIMUM PERMISSIBLE RATES DETERMINED FROM:

$$L_N = \frac{R_N}{C_N} \frac{1}{3600} \text{ CM}^3\text{/S, FOR NORMAL CONDITIONS}$$

$$L_A = \frac{R_A}{C_A} \; 1.65 \times 10^{-6} \text{ CM}^3\text{/S, FOR ACCIDENT CONDITIONS}$$

  - WHERE C_N AND C_A ARE THE ACTIVITIES PER UNIT VOLUME OF THE CASK MEDIUM THAT COULD ESCAPE FROM THE CONTAINMENT SYSTEM FOR NORMAL AND ACCIDENT CONDITIONS OF TRANSPORT, RESPECTIVELY

- A "SOURCE TERM" PROGRAM DETERMINES THE CONTRIBUTIONS FROM THE THREE SOURCES OF RELEASABLE MATERIAL

  - $L_I = R_I / C_{T,I}$ I = N (normal), A (accident)

  - $C_{T,I} = C_{CRUD,I} + C_{FUEL,I} + C_{RES,I}$

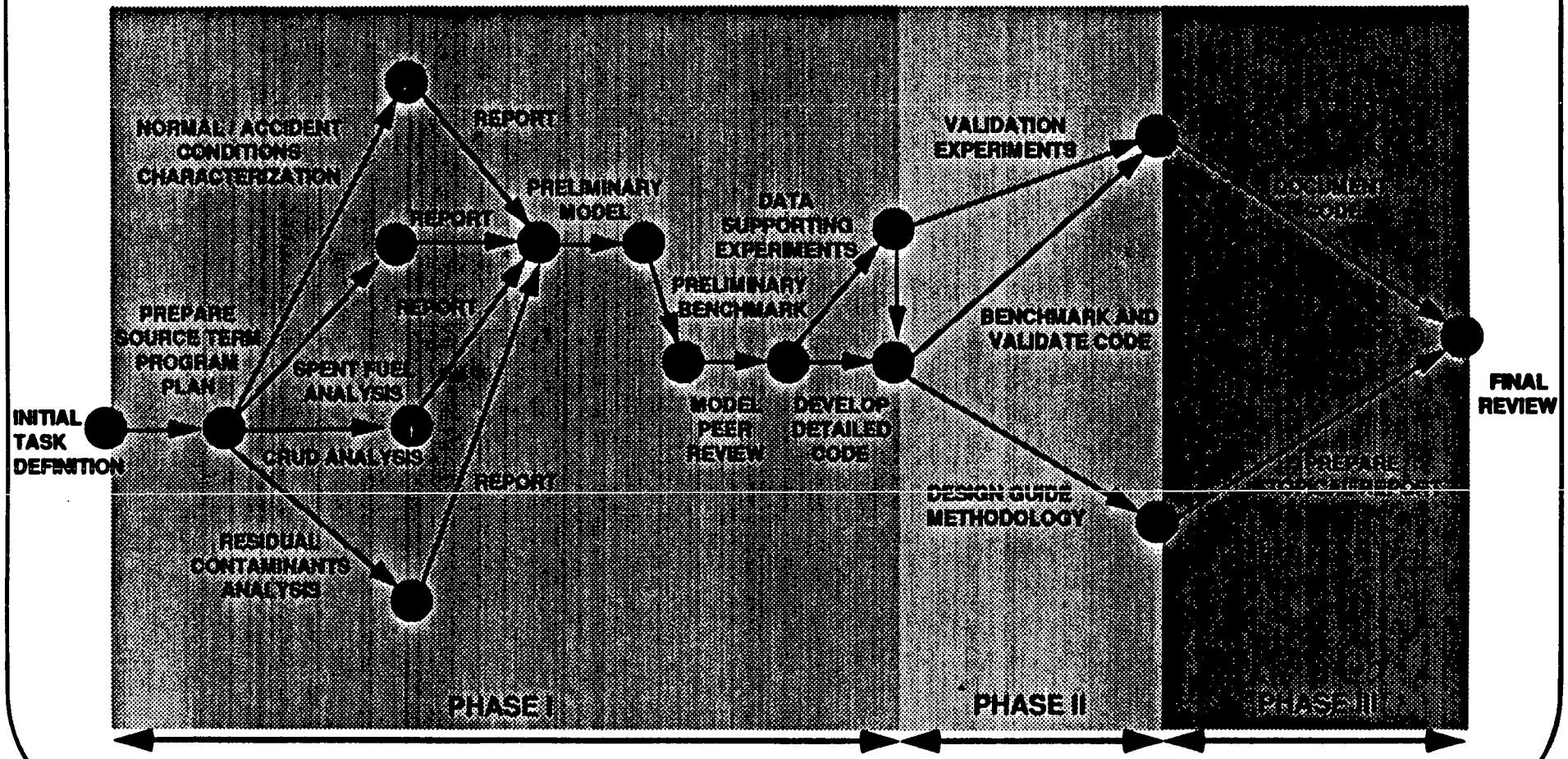
    $C_{CRUD,I}$ = THE SOURCE TERM FROM CRUD DEPOSITS AND CONDITION I

    $C_{FUEL,I}$ = THE SOURCE TERM ASSOCIATED WITH FUEL FISSION PRODUCTS, ACTINIDES, AND CONDITION I

    $C_{RES,I}$ = THE SOURCE TERM ASSOCIATED WITH INTERNAL CASK/BASKET RESIDUAL SURFACE CONTAMINANTS, AND CONDITION I

- $C_{T,I} = C_{T,I}$ (PARTICLE TRANSPORT, LEAK GEOMETRY, FAILURE MODES, PLUGGING)

Source Term Containment Evaluation Technical Approach



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- THE LITERATURE SURVEY AND FEASIBILITY ASSESSMENT TASKS HAVE PRODUCED FOUR REPORTS

  - "ESTIMATE OF CRUD CONTRIBUTION TO SHIPPING CASK CONTAINMENT REQUIREMENTS" - SAND 88 - 1358, JANUARY 1991

  - "A METHODOLOGY FOR ESTIMATING THE RESIDUAL CONTAMINATION CONTRIBUTION TO THE SOURCE-TERM IN A SPENT-FUEL TRANSPORT CASK" - SAND 90 - 2407 (TO BE PUBLISHED OCTOBER 1991)

  - "A METHOD FOR DETERMINING THE SPENT-FUEL CONTRIBUTION TO TRANSPORT CASK CONTAINMENT REQUIREMENTS" - SAND 90 - 2406

  - "A SOURCE-TERM METHOD FOR DETERMINING SPENT-FUEL TRANSPORT CASK CONTAINMENT REQUIREMENTS: EXECUTIVE SUMMARY" - SAND 90 - 2408

- SEVERAL CONCLUSIONS HAVE BEEN MADE FROM PRELIMINARY ANALYSES OF THE CRUD, RESIDUAL CONTAMINATION, AND SPENT FUEL CONTRIBUTIONS TO THE SOURCE TERM

  - THE MAXIMUM ALLOWABLE LEAK RATES DUE TO THE CRUD CONTRIBUTION FOR NORMAL CONDITIONS WERE SMALLER, AND THUS MORE LIMITING, THAN THOSE FOR ACCIDENT CONDITIONS BY SEVERAL ORDERS OF MAGNITUDE

  - THE RESIDUAL CONTAMINATION CONTRIBUTION TO THE RELEASABLE SOURCE TERM IS VERY SMALL IN COMPARISON TO THAT DUE TO CRUD AND THE SPENT FUEL

  - CALCULATED FAILURE FREQUENCIES ARE LESS THAN ONE ROD PER RAIL CASK ACCIDENT EVENT FOR THE EXAMPLE CASES THAT WERE EVALUATED. THEREFORE, THE ASSUMPTION OF MASSIVE FUEL ROD FAILURE FOR THE CONTAINMENT DESIGN OF SPENT FUEL TRANSPORT CASKS IS UNREALISTICALLY VERY CONSERVATIVE

- CONCLUSIONS. . .(CONT)

  - THE FUEL FINES, RATHER THAN THE GASEOUS OR VOLATILE SPECIES, DOMINATE THE POTENTIALLY RELEASABLE SOURCE TERM

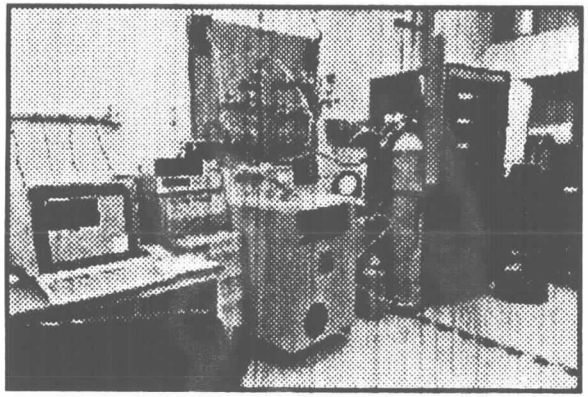
  - EXPERIMENTS WILL BE REQUIRED TO OBTAIN NECESSARY DATA AND TO VERIFY THE METHODS AND RESULTS

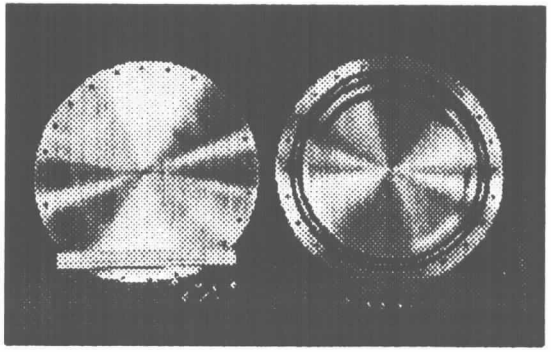
- TWO ELEMENTS OF CONTAINMENT WILL BE DISCUSSED

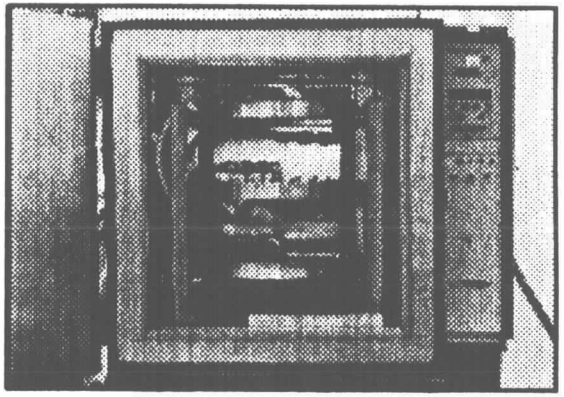
  - THE RADIOACTIVE SOURCE TERM

  - **CASK CONTAINMENT SEALS**

Sandia's seal technology task evaluates different seal materials and designs.







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- THE PRIMARY OBJECTIVE OF THE SEAL TECHNOLOGY PROGRAM IS TO ENLARGE AND IMPROVE THE AVAILABLE SELECTION OF SEAL MATERIALS FOR NUCLEAR WASTE TRANSPORTATION APPLICATIONS

  - CHARACTERIZE CURRENTLY USED SEAL MATERIALS

  - EXAMINE NEW MATERIALS AND TYPES OF SEALS

  - INVESTIGATE ALTERNATE TRACER GASES AND LEAK DETECTION METHODS

  - PROVIDE GUIDANCE TO CASK CONTRACTORS ON THE BEST CHOICE FOR THEIR SEAL MATERIAL

- 10 CFR 71 SPECIFIES THE ENVIRONMENTS THAT SEALS MUST BE ABLE TO SURVIVE:

  - RADIATION

  - VIBRATION

  - SHOCK

  - INTERNAL AND EXTERNAL PRESSURE

  - TEMPERATURE
    - - MINIMUM OF - 40°F
    - - MECHANICAL LOADING AT - 20°F
    - - MAXIMUM NORMAL OPERATION
    - - MAXIMUM HYPOTHETICAL ACCIDENT

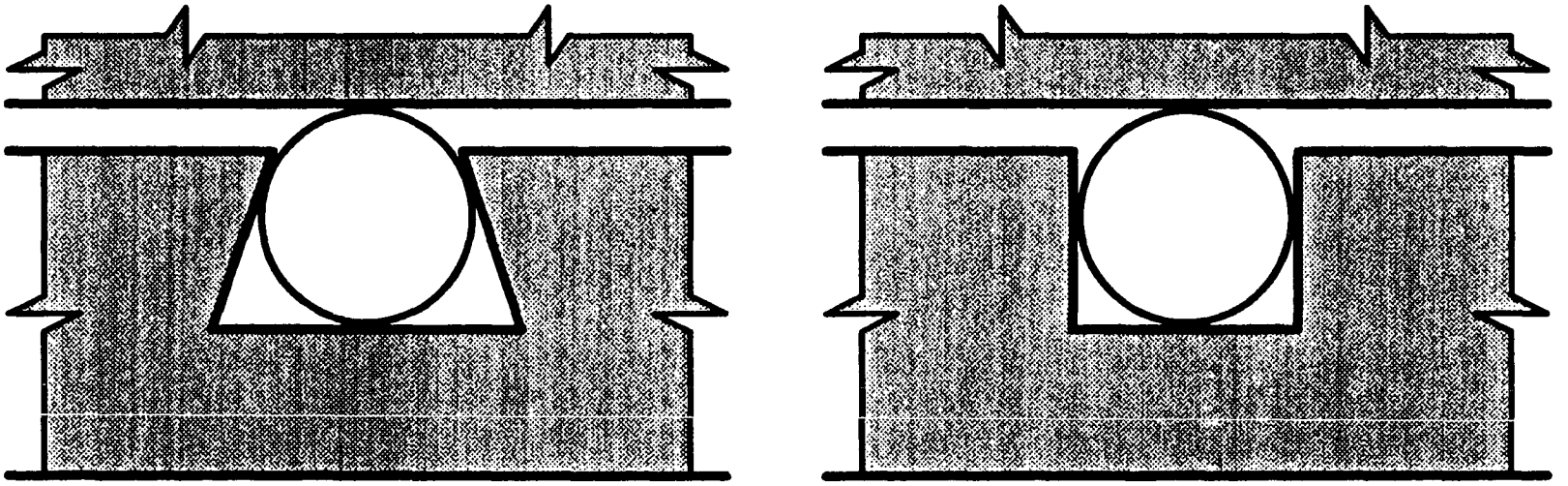
- GASKET MATERIALS ARE TYPICALLY EITHER ELASTOMER OR METAL

  - ELASTOMER
  - - BUTYL
  - - ETHYLENE PROPYLENE
  - - FLUOROSILICONE
  - - SILICONE
  - - FLUOROCARBON

  - METALS
  - - INCONEL
  - - STAINLESS STEEL
  - - COPPER

The O-ring groove is one type of closure design.

COMMON O-RING GROOVE SHAPES



Dovetail **Rectangular**

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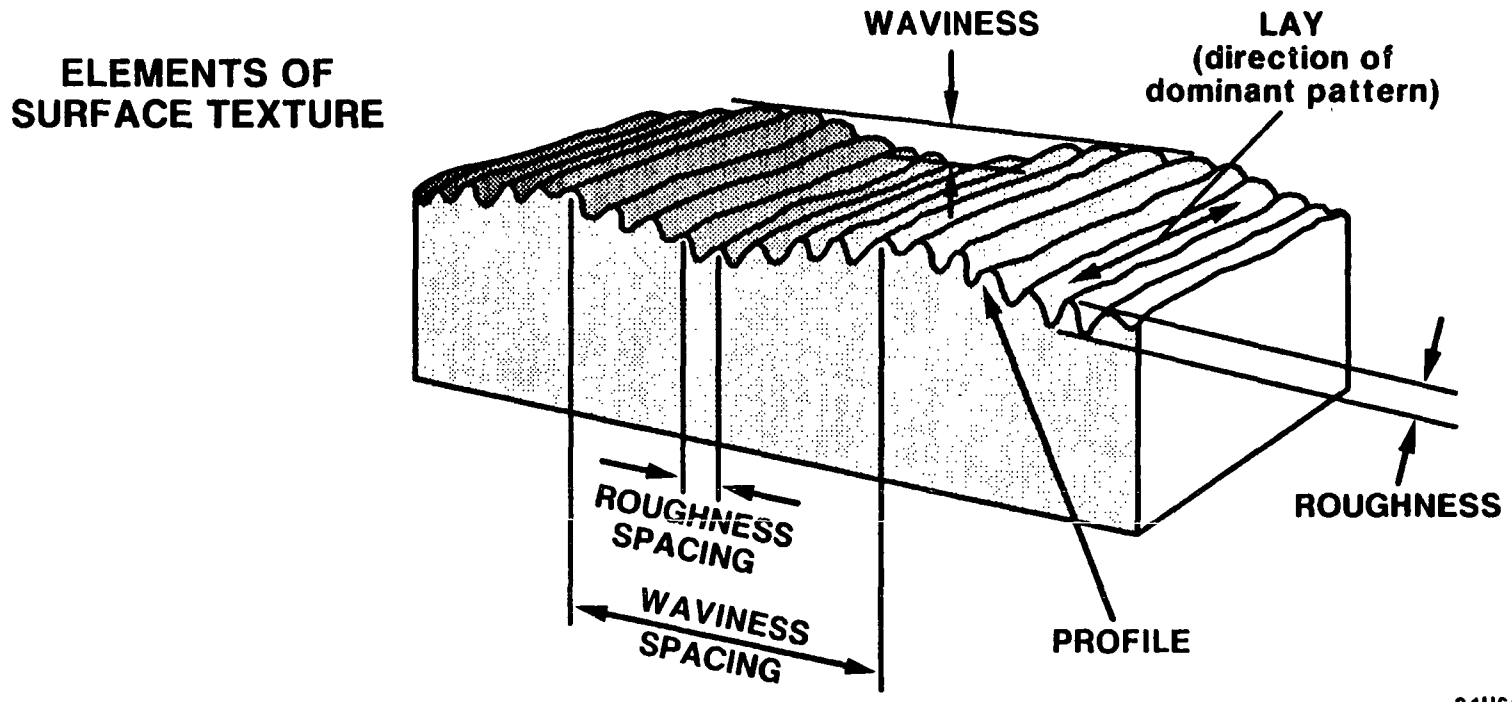
Sealing surfaces are affected by roughness, waviness, lays, and flaws.



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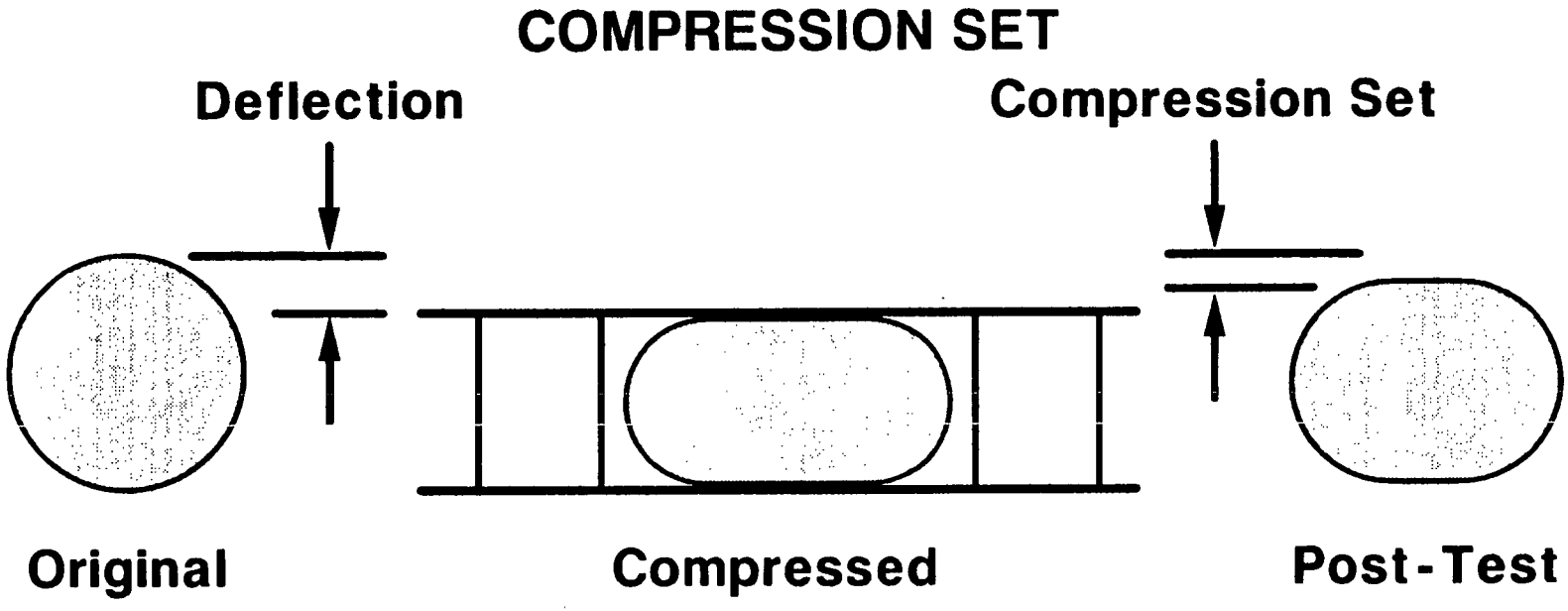
The radiation and elevated temperatures produced by the spent fuel cask contents can result in compression set and elastomer degradation



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- AN EXPERIMENTAL APPROACH HAS BEEN CHOSEN TO EVALUATE THE MANY TYPES OF SEALS

  - TEST UNDER DIFFERENT ENVIRONMENTAL CONDITIONS (HEAT, COLD, RADIATION, ETC.)

  - - PERMEATION RATE

  - - LEAK TIGHTNESS

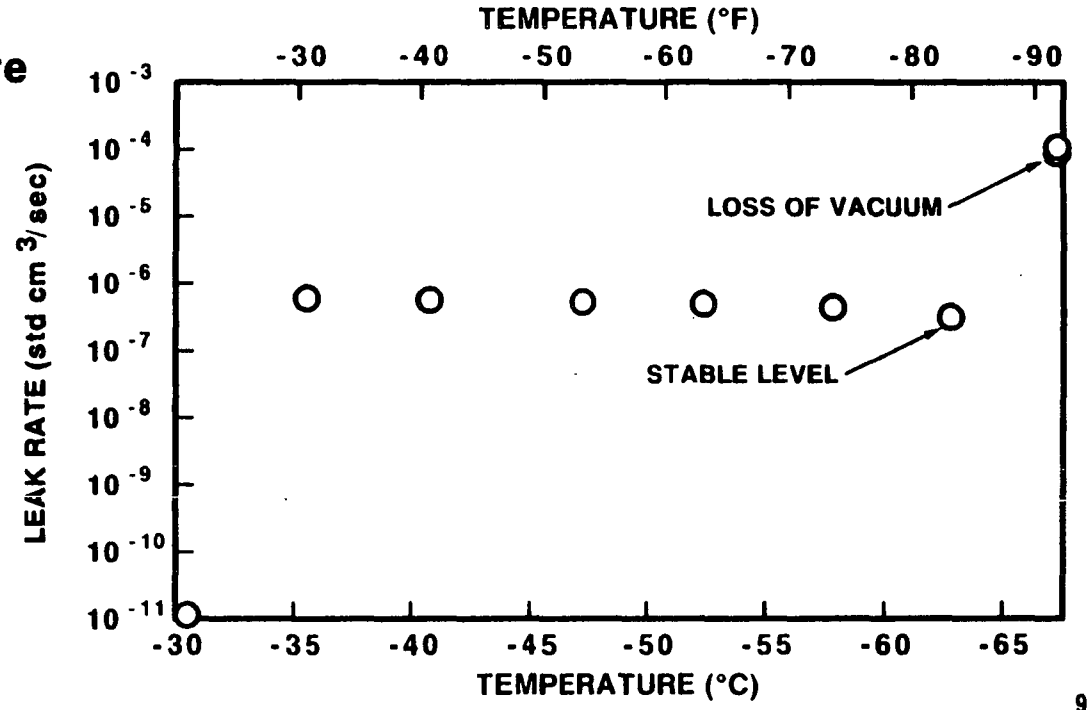
  - EXPERIMENT WITH DIFFERENT TRACER GASES AND LEAK DETECTORS

  - PERFORM MATERIALS/CHEMICAL EVALUATIONS ON VARIOUS MATERIALS

  - PROVIDE GUIDANCE TO THE CASK CONTRACTORS

Preliminary results indicate that elastomeric seal performance is sensitive to low temperatures.

Low Temperature Leak Test



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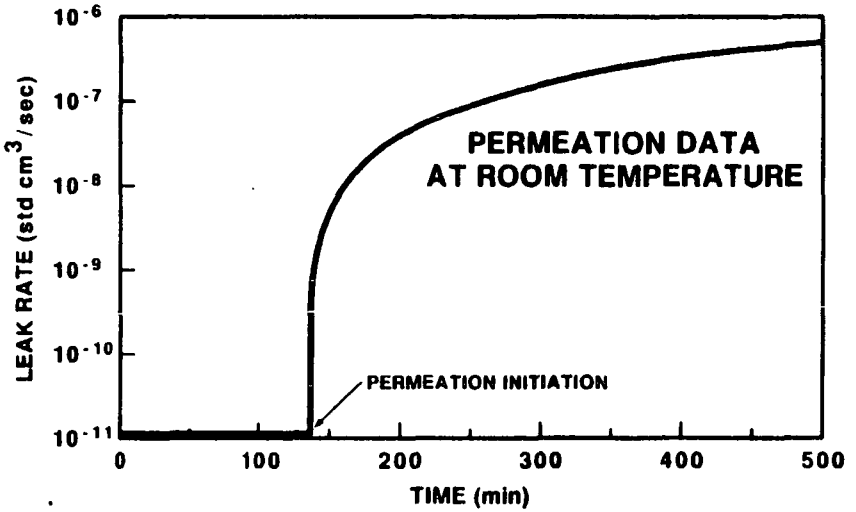
Results indicate that the helium leak test has some obvious limitations in evaluating elastomeric seal materials.

- The results of helium leak tests to measure seal performance are apparently different from manufacturer's specifications.
- Significant offgassing of the elastomer may occur at elevated temperatures leading to erroneous measurements.
- Helium permeates some elastomers quickly due to molecular diffusion -- this distorts the results since helium may be measured without an actual leak having occurred.



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- ALTERNATE TRACER GASES AND LEAK DETECTION METHODS ARE CURRENTLY BEING INVESTIGATED

  - ALTERNATE TRACER GASES:

    - - NEON

    - - KRYPTON

    - - ARGON

    - - HALOGENS (FLUORINE, CHLORINE, ETC.)

  - ALTERNATE LEAK DETECTION METHODS:

    - - DETECTORS TUNED TO TRACER GASES OTHER THAN HELIUM

    - - RESIDUAL GAS ANALYZERS

    - - HALOGEN LEAK DETECTORS

    - - PRESSURE RISE TESTS USING SENSITIVE PRESSURE GAUGES

- IN SUMMARY, THE SEAL TECHNOLOGY PROGRAM IS CURRENTLY WORKING TOWARDS SEVERAL OBJECTIVES:

  - EXPERIMENTS ON PERMEATION RATE AND LEAK TIGHTNESS TO CHARACTERIZE CURRENTLY USED SEAL MATERIALS

  - EXAMINATION OF NEW SEAL MATERIALS AND SEAL TYPES

  - INVESTIGATION OF ALTERNATE TRACER GASES AND LEAK DETECTION METHODS DUE TO LIMITATIONS WITH HELIUM LEAK TESTS