Sandia National Laboratories
Albuquerque, New Mexico 87185

WM DOCKET CONTROL
CENTER

'84 FEB -1 P3:30

WM Record File A-1158
WM Project 10, 11, 16
Docket No.
PDR ✓
LPDR B, N, S
Distribution:
MN
(Return to WM, 623-SS) 15

January 31, 1984

Dr. Mysore S. Nataraja
Waste Management Engineering Branch
Division of Waste Management
U.S. Nuclear Regulatory Commission
7915 Eastern Avenue
Silver Spring, MD 20910

Dear Dr. Nataraja:

I recently (January 24-26, 1984) participated in a "Data Review Visit" to the Hanford Site at NRC's request. During our visit, we were given an opportunity to review the data from various tests performed at the Near Surface Test Facility (NSTF) and ask questions. Based on the answers provided by Ms. Chris Gregory and Mr. Randy Ames, both from BWIP, the Draft Rock Mechanics Data Review checklist was filled out for the Full Scale Heater Test #2 at the NSTF. A copy of the completed checklist is enclosed. Also enclosed are copies of the following:

- A fortran listing of an algorithm to calculate displacements from extensometer data
- Sample input data instructions for plots generated by the Data Aquisition System (DAS III)
- Plots of displacement and temperature at selected times and locations
- A list of documents requested
- A list of questions posed to BWIP for the thermo-mechanical models

The first three items were obtained at the time they were requested. The reference documents requested will presumably be mailed out at a later date through the BWIP Public Release System. Although many of the questions on thermomechanical models were answered, some were deferred for various reasons.

8403260353 840227
PDR WASTE
WM-10 PDR
W/LTR 8403260344 840227

If you have any questions, please call me at FTS 844-6268.

Sincerely,

Krishan K. Wahi

KKW:6431:jm

Copy to:
USNRC: Peter Ornstein
6430: N. R. Ortiz

ERROR ENCOUNTERED ON DATA RECOVERY FOR 01E21E03

IF YOU ARE RECOVERING CONVERTED OR RAW DATA, IT MAY BE THAT DATA IS NOT AVAILABLE FOR YOUR SPECIFIED DATE. YOU MAY WANT TO ABORT THE SCATTER GRAPHICS PROCESS, AND RECOVER DATA OVER A WIDE RANGE OF DATES USING THE SMOOTHED GRAPHICS PACKAGE TO DETERMINE AVAILABILITY OF DATA FOR THE DATES THAT INTEREST YOU.

IF YOU ARE ATTEMPTING TO RECOVER ANY OTHER TYPE OF DATA, IT SIMPLY DOES NOT EXIST FOR THIS CHANNEL.

YOUR CURRENT OPTIONS ARE TO EITHER DELETE THIS CHANNEL AND CONTINUE GATHERING DATA FOR THE OTHER CHANNELS, OR TO INTERRUPT THE DATA-GATHERING PROCESS.

WOULD YOU LIKE TO QUIT GATHERING DATA?

(18)

Documents Requested from the DOE Accession List (Jan. 26, 1984)

AVAILABLE BLOCK TEST DOCUMENTS

TEST PLANS

SD-BWI-TP-001 A-0, "Test Plan for Jointed Block Test #1"

SD-BWI-TI-042 0-2, "Operational Test Guidelines and Support Data for Jointed Block Test #1"

REPORTS

RSD-BWI-TI-059, "Pre-Test Analysis of Step 2 of the Jointed Block Test"

SD-BWI-TP-001, "Block Test Step 1 Report"

Cramer, M. L., Cunningham, J. P., Kim, K., "Rock Mass Deformation Properties from a Large-Scale Block Test," 24th U.S. Symposium on Rock Mechanics, Texas A&M University, College Station, Texas, June, 1983. Also to be published in the Bulletin of the Association of Engineering Geologists. (RHO-BW-SA-284P)

Cramer, M.L., Black, M. T., "The Design and Construction of a Block Test in Closely Jointed Rock," 24th Symposium on Rock Mechanics, Texas A&M University, College Station, Texas, June, 1983. Also to be published in the Bulletin of the Association of Engineering Geologists. (RHO-BW-SA-286P)

Gregory, E. C., Cramer, M. L., Ames, R. R., McHenry, J. M., "Applicability of Borehole Stress Measurement Instrumentation to Closely Jointed Rock," 24th U.S. Symposium on Rock Mechanics, Texas A&M University, College Station Texas, June 1983. Also to be published in the Bulletin of the Association of Engineering Geologists. (RHO-BW-SA-285P)

Cramer, M. L., Kim, K., "Rock Mass Deformation Properties of Closely Jointed Basalt," American Geophysical Union Fall Meeting, San Francisco, December 1982. (RHO-BW-SA-267P)

Gregory, E. C., Cramer, M. L., McCabe, W. M., Kim, K., "Summary of Near-Surface Test Facility Results and Their Application to Repository Design," 1982 NWTS Information Meeting, Las Vegas, December 1982. (RHO-BW-SA-256P)

Lanigan, D. C., Cramer, M. L., Kim, K., "Determination of Rock Mass Deformation Modulus in Closely Jointed Columbia River Basalt," 29th Pacific Northwest Meeting - American Geophysical Union, Fairbanks, September 1982. (RHO-BW-SA-229P)

Kim, K., Cramer, M. L., Jimenez, R. F., Christenson, J. E., "Thermo-mechanical Jointed Block Test in Basalt - Preliminary Results," 23rd U.S. Symposium on Rock Mechanics, Berkeley, August 1982. (RHO-BW-SA-230P)

OTHER DOCUMENTS

STP-M-991-00002 B-0, NSTF Operating Procedures - Block Test No. 1

SD-BWI-ATR-002, Acceptance Test Report for the Rock Instrumentation System for the Rock Instrumentation System Block Test #1, Step 2

SD-BWI-VP-002, Verification Plan for Equipment Installation, Block #1

HWS-10287, Specification for the Basalt Deformation Measurement System

RAW DATA REQUESTED FOR HYDROFRACTURING TEST REVIEW

From RHO/BWIP on January 26, 1984

1. Bore holes RRL-2, RRL-6, DC-4

   a. From RRL-2, Tests 1A, 2B, 3A, 3B
   b. From RRL-6, Tests 3, 8, 9
   c. From DC-4, Tests 1, 2, 3

2. Data Requested for Each Test

   a. Flow rate and pressure time histories
   b. Interpreted breakdown and shut-in pressures
   c. Computed algorithms
   d. Copy of televiewer data for the 10 ft interval containing the test
   e. Pre-and post-test packer data, as available
   f. Detail-scale geophysical logs for the 10 ft interval containing the test
   g. Detail-scale geologic logs for the 10 ft interval containing the test
   h. Calculations
   i. Equipment used, procedure, variations and deviations.

ENGINEERS INTERNATIONAL, INC.

TEST PLANS

SD-BWI-TP-018

"Test Plan For In Situ Stress Measurement by the Hydraulic Fracturing Method in Borehole RRL-2."

SD-BWI-TP-030

"Test Plan For In Situ Stress Measurement by the Hydraulic Fracturing Method in Boreholes RRL-6 and DC-4."

TEST REPORTS

SD-BWI-TD-006

"Summary of Borehole RRL-2 Hydraulic Fracturing Test Data and Data Analysis Methods."

RHO-BW-SA-257 P

"In Situ Stress Measurement at a Candidate Repository Horizon."

Craig, P. A., 1983, Tabulation of Young's Moduli and Poisson's Ratio Determinations from Uniaxial and Triaxial Compressive Strength Tests from Boreholes RRT-2, RRL-6, and RRL-14, SD-BWI-TI-132, Rev. 0-0, Rockwell Hanford Operations, Richland, Washington. Official Release Date September 29, 1983.

Hulstrom, L. C., and D. J. Hanson, 1982, Tabulation of Physical and Mechanical Property Data from Borehole RRL-2, SD-BWI-TD-002, Rev. 0-1, Rockwell Hanford Operations, Richland, Washington. Official Release Date November 2, 1982.

Hulstrom, L. C. and D. J. Hanson, 1983, Tabulation of Physical and Mechanical Property Data from Borehole RRL-6, SD-BWI-TD-003, Rev. 0-0, Rockwell Hanford Operations, Richland, Washington. Official Release Date January 31, 1983.

Hulstrom, L. C., and D. J. Hanson, 1983, Tabulation of Physical and Mechanical Property Data from Borehole RRL-14, SD-BWI-TD-004, Rev. 0-1, Rockwell Hanford Operations, Richland, Washington. Official Release Date March 9, 1983.

Landon, R. D., 1983, Geologic Thickness Data - Candidate Repository Horizons, SD-BWI-DP-011, Rev. A-0, Rockwell Hanford Operations, Richland, Washington. Official Release Date August 6, 1983.

Sublette, W. R., 1983, Rock Mechanics Data Package, SD-BWI-DP-041, Rev. 0-0, Rockwell Hanford Operations, Richland, Washington. Official Release Date Sept. 20, 1983.

List of Reports Requested

The reference documents with an asterisk in the left-hand margin have been requested from BWIP.

PARTIAL LIST OF REFERENCES

ROCK MECHANICS ACTIVITIES AT THE
NEAR-SURFACE TEST FACILITY

(January 24, 1984)

NEAR-SURFACE TEST FACILITY

BWIP Staff, 1980a, "Near-Surface Test Facility Test Program (Phase I and Phase II)", BWI-02-TP-0101, Rockwell Hanford Operations, Richland, Washington. (Replaced RHO-BWI-CD-15, Rev. 3)

BWIP Staff, 1980b, "Near-Surface Test Facility Test Procedure Guidelines," BWI-212-MD-01, Rockwell Hanford Operations, Richland, Washington.

Edwards, R. C., Gregory, E. C., Heneveld, W. H. and Thirumalai, K., 1981, "Results from the Near-Surface Test Facility — Heater Tests and Block Tests," Proceedings, 1981 National Waste Terminal Storage Information Meeting, U.S. Dept. of Energy, Columbus, Ohio.

Gregory, E. C., Cramer, M. L., McCabe, W. M. and Kim, K., 1982, "Summary of Near-Surface Test Facility Results and Their Application to Repositiory Design," Proceedings, 1982 National Waste Terminal Storage Information Meeting, Las Vegas, Nevada.

Hocking, G., 1980, "Near-Surface Test Facility Numerical Analysis of the Phase I Tests," RSD-BWI-ES-001, Rockwell Hanford Operations, Richland, Washington.

Moak, D. J. and Wintczak, T. M., 1980, "Near-Surface Test Facility, Phase I Geologic Site Characterization Report," RHO-BWI-ST-6, Rockwell Hanford Operations, Richland, Washington.

Reed, B. M., 1980, "Basalt Wire Nomenclature for Near-Surface Test Facility," HWS-10096, Rockwell Hanford Operations, Richland, Washington.

Reed, B. M., and Underwood, D. H., 1981, "Specification, Rock Instrumentation, System for Near-Surface Test Facility at Richland, Washington," HWS-10070, R009, Rockwell Hanford Operations, Richland, Washington.

Rock Mechanics and Mining Technology Staff, 1981, "Supporting Document: Applicability of the Near-Surface Test Facility Program to Repository Design," RSD-BWI-TI-024, Rev. A000, Rockwell Hanford Operations, Richland, Washington.

Starr, J. L., 1982, "Automated Data Acquisition and Analysis System Used in the Basalt Waste Isolation Project's Near-Surface Test Facility," RHO-BW-ST-33P, Rockwell Hanford Operations, Richland, Washington.

FULL-SCALE HEATER TESTS NOS. 1 AND 2

Aichele, W. T., 1980a, "Rock Instrumentation Full-Scale Test #1 Wire Run List by Borehole for Near-Surface Test Facility," HWS-10098, Rockwell Hanford Operations, Richland, Washington.

Aichele, W. T., 1980b, "Rock Instrumentation Full-Scale Test #2, Wire Run List by Borehole For Near-Surface Test Facility," HWS-10100, Rockwel Hanford Operations, Richland, Washington.

Aichele, W. T., 1980c, "Rock Instrumentation Full-Scale Test #1 Data Logger Inputs for Near-Surface Test Facility," HWS-10097, Rockwell Hanford Operations, Richland, Washington.

Aichele, W. T., 1980d, "Rock Instrumentation Full-Scale Test #2 Data Logger Inputs for Near-Surface Test Facility," HWS-10099, Rockwell Hanford Operations, Richland, Washington.

Baxter, J. T., Cunningham, J. P., Gregory, E. C. and Jimenez, R. F., 1982, "Status Report on the Full-Scale Electric Heater Tests at the Hanford Near-Surface Test Facility," 23rd U.S. Symposium on Rock Mechanics, University of California, Berkeley, California.

Boonlualohr, P., Mustoe, G. and Williams, J. R., 1980, "Program DAMSWEL Programming Manual Code Verification, Program Listing," RHO-BWI-C-74, Rockwell Hanford Operations, Richland, Washington.

BWIP Staff and Hardy, M. P., 1979, "Phase I Heater Test Plan for the Thermomechanical Response of Basalt," RHO-BWI-CD-15 Rev 2, Rockwell Hanford Operations, Richland, Washington.

BWIP Staff, 1980a, "Specification of Rock Instrumentation Location and Orientations for Full-Scale Heater Test #1," HWS-10092, Rev. 004, Rockwell Hanford Operations, Richland, Washington.

BWIP Staff, 1980b, "Specification of Rock Instrumentation Locations and Orientations for Full-Scale Heater Test #1," HWS-10093, Rev. 005, Rockwell Hanford Operations, Richland, Washington.

BWIP Staff, 1980c, "Operating Test Procedure Support Data Full-Scale Test # 1," BWI-72-STP-01, Rockwell Hanford Operations, Richland, Washington.

BWIP Staff, 1980d, "Operating Test Procedure Support Data Full-Scale Test #2," BWI-725-TP-02, Rockwell Hanford Operations, Richland, Washington.

BWIP Staff, 1981, "Supporting Document: Verification of Thermal Model for Full-Scale Heater Test," RSD-BWI-TI-060, Rockwell Hanford Operations, Richland, Washington.

BWIP Staff, 1983, "Test Instructions for Evaluation of the Anchorage System of the Multiple Position Borehole Extensometers Used at the Near-Surface Test Facility," SD-BWI-TN-002, Rockwell Hanford Operation, Richland, Washington.

Case, J. B., Krug, A. D. and Williams, J., 1980, "Full-Scale Heater Tests #1 and #2 at the Near-Surface Test Facility Prelimianry Results, RHO-BWI-LD-34, Rockwell Hanford Operations, Richland, Washington.

FSI Staff, 1979, "Conversion Algorithms for Rock Instrumentation System, Near-Surface Test Facility, No. A-001," Prepared by Foundation Sciences, Inc. for Rockwell Hanford Operations, Richland, Washington.

FSI Staff, 1980, "Final Report for the Rock Instrumentation System Full-Scale Heater Tests No. 1 & No. 2 at the Near-Surface Test Facility, Hanford Nuclear Reservation, Washington," Prepared by Foundation Sciences, Inc. for Rockwell Hanford Operations, Richland, Washington.

Foundations Sciences, Inc., 1980a, "Thermal/Mechanical Properties of Pomona Member Basalt -- Full-Scale Heater Test #1 (Area 1)," RHO-BWI-C-77, Rockwell Hanford Operations, Richland, Washington.

Foundation Sciences, Inc., 1980b, "Thermal/Mechanical Properties of Pomona Member Basalt -- Full-Scale Heater Test #2 (Area 2)," RHO-BWI-C-85, Rockwell Hanford Operations, Richland, Washington.

Foundation Sciences, Inc., 1980c, "Thermal/Mechanical Properties of Pomona and Umtanum Basalts -- Elevated Temperature Comperative Triaxial Test," RHO-BWI-C-91, Rockwell Hanford Operations, Richland, Washington.

Foundation Sciences, Inc., 1981, "Thermal/Mechanical Properties of Pomona Member Basalt -- Area 3 and Summary," RHO-BWI-C-100, Rockwell Hanford Operations, Richland, Washington.

Gregory, E. C. and Kim, K., 1981, "Preliminary Results From the Full-Scale Heater Tests at the Near-Surface Test Facility," Proceedings, 22nd U.S. Symposium on Rock Mechanics, Massachusetts Institute of Technology, Cambridge, Massachusetts.

Hocking, G., Williams, J. R., Boonlualohr, P., Mathews, I., and Mustoe, G., 1980, "Numerical Predication of Basalt Response for Near-Surface Test Facility Heater Test #1 and #2," RHO-BWI-C-86, Rockwell Hanford Operations, Richland, Washington.

Huyakorn, P., Williams, J. R., and Thomas, S., 1981, "Supporting Document -- Analysis of Thermal Properties of Basalt from Heater Test #2 Experiment," RSD-BWI-TI-023, Rockwell Hanford Operations, Richland, Washington.

Schmidt, B., Daly, W. F., Bradley, S. W., Squire, P. R. and Hulstrom, L. C., "Thermal and Mechanical Properties of Hanford Basalts: Compilation and Analyses," RHO-BWI-C-90, Rockwell Hanford Operations, Richland, Washington.

St. Laurent, 1980, "Data Verification Plan NSTF Full-Scale Heater Test No. 1 and 2," RSD-BWI-VP-001, Rockwell Hanford Operations, Richland, Washington.

Williams, J. R., Mustoe, G., Mathews, I., and Sharp, J., 1981, "Preliminary Results for Full-Scale Heater Tests #1 and #2 (Vol. I and II)," RSD-BWI-TI-061, Prepared by Dames and Moore for Rockwell Hanford Operations, Richland, Washington.

BOREHOLE JACKING

De la Cruz, R. V. and Karfakis, M., 1980, "Rock-Mass Measurements at the Near-Surface Test Facility, Hanford Site," RHO-BWI-C-95, Rockwell Hanford Opertions, Richland, Washington.

De la Cruz, R. V., Karfakis, M., and Kim, K., 1982, "Analysis of Displacement and Strain Data for the Determination of the In Situ Deformability of Rock Masses," RHO-BW-SA-197A, Presented at the Society of Mining Engineers of AIME, Dallas, Texas.

Shuri, F. S., Dodds, D. J., and Kim, K., 1980, "Measurement of Rock-Mass Deformation Properties by the Borehole Jacking Method at the Near-Surface Test Facility," RHO-BWI-C-87, Rockwell Hanford Operations, Richland, Washington.

Shuri, F. S., 1981, "Borehole Diameter as a Factor in Borehole Jack Results," Proceedings, 22nd U.S. Symposium on Rock Mechanics, Cambridge, Massachusetts.

Stephansson, O., 1982, "Supporting Document: Test Plan for In Situ Stress Measurement by Sleeve Fracturing," Prepared by the Colorado School of Mines for Rockwell Hanford Operations, Richland, Washington.

Stickney, R. G., Senseny, P. E., and Hansen, F. D., (in clearance), "Performance Testing of the Doorstopper Biaxial Strain Cell, SD-BWI-TRP-005, Prepared by RE/SPEC Inc. for Rockwell Hanford Operations, Richland, Washington.

HYDRAULIC FRACTURING

Haimson, B. C., 1978, "Report on Hydrofracturing Tests for In Situ Stress Measurement -- Near-Surface Test Facility, Hole DC-11, Hanford Reservation," Prepared for Lawrence Berkeley Laboratory, Berkeley, California.

Gregory, E. C., Rundle, T. A., McCabe, W. M., and Kim, K., 1982, "Test Plan for Suitability Assessment of Five Overcoring Stress Measurement Techniques," SD-BWI-TP-015 A-0, Rockwell Hanford Operations, Richand, Washington (the Test Plan includes hydraulic fracturing testing at the NSTF).

CROSSHOLE SEISMIC

Lanigan, D. C., 1983, "Test Plan for Crosshole Seismic Geophysical Testing," SD-BWI-TP-028, Rockwell Hanford Operations, Richland, Washington.

Lawrence Berkeley Laboratories, (in review), "Crosshole Seismic Tests at the Near-Surface Test Facility -- Final Report," Prepared under LBL Subcontract 3E for Rockwell Hanford Operations, Richland, Washington.

INSTRUMENTATION DEVELOPMENT

Ames, R. K., Gregory, E. C., Kim, K., and McCabe, W. M., 1983, "Rock Mechanics Instrumentation Modifications for Thermomechanical Field Tests in Basalt at the Near-Surface Test Facility," SD-BWI-TI-005, Rockwell Hanford Operations, Richland, Washington.

FSI Staff, 1980, "Calibration and Environmental Testing of the Rock Instrumentation System for Jointed Block Test No. 1 at the Near-Surface Test Facility, Hanford Nuclear Reservation, Washington," Prepared by Foundation Sciences, Inc. for Rockwell Hanford Operations, Richland, Washington.

SRI Staff, 1981e, "Instrument Document No. 3: Vibrating Wire Stressmeter -- Phase II Rock Instrumentation System, Near-Surface Test Facility," Prepared by Soil & Rock Instrumentation Division, Goldberg-Zoino & Ass., Inc., for Rockwell Hanford Operations, Richland, Washington.

SRI Staff, 1981f, "Instrument Document No. 4: Borehole Deformation Gage - Phase II Rock Instrumentation System, Near-Surface Test Facility," Prepared by Soil & Rock Instrumentation Division, Goldberg-Zoino & Ass., Inc., for Rockwell Hanford Operations, Richland, Washington.

SRI Staff, 1981g, "Multiposition Borehole Extensometer Baseline Conversion Algorithm, Near-Surface Test Facility," Prepared by Soil & Rock Instrumentation Division, Goldberg-Zoino & Ass., Inc., for Rockwell Hanford Operations, Richland, Washington.

SRI Staff, 1981h, "Vibrating Wire Stressmeter Conversion Algorithm, Near-Surface Test Facility," Prepared by Soil & Rock Instrumentation Division, Goldberg-Zoino & Ass., Inc., for Rockwell Hanford Operations, Richland, Washington.

SRI Staff, 1981i, "Borehole Deformation Gage Baseline Conversion Algorithm, Near-Surface Test Facility," Prepared by Soil & Rock Instrumentation Division, Goldberg-Zoino & Ass., Inc., for Rockwell Hanford Operations, Richland, Washington.

White, W. F., and Kim, K., 1980a, "Supporting Document - U.S. Bureau of Mines Borehole Deformation Gage Baseline Algorithm," RSD-BWI-TI-007, Rockwell Hanford Operations, Richland, Washington.

(Algorithm revised on DAS per letter, K. Kim to O. B. Richardson, February 23, 1983, 10410-KK/JTB-83-014, "USBM Borehole Deformation Gauge Algorithm and Initialization Values, Predictive Data Set Formats for USBM Borehole Deformation Gauges and Vibrating Wire Stress Gauges.")

White, W. F., and Kim, K., 1980b, "Supporting Document - IRAD Vibrating Wire Stressmeter Baseline Algorithm," RSD-BWI-TI-008, Rockwell Hanford Operations, Richland, Washington.

(Algorithm revised on DAS per the following - for Block Test Step 2 Instruments):

- Letter, K. Kim to O. B. Richardson, June 21, 1982, 10410-82-KK-013 "Algorithms for Block Test Step 2 Instruments."

Duvall, W. I., R. J. Miller, and F. D. Wang, 1978, Preliminary Report on Physical and Thermal Properties of Basalt, Drill Hole DC-10, Pomona Flow, Gable Mountain, RHO-BWI-C-11, Rockwell Hanford Operations, Richland, Washington.

Excavation Engineering and Earth Mechanics Institute, 1978, Final Report for Fiscal Year 1978 on the Physical and Thermal Properties of Basalt Cores, RHO-BWI-C-38, Rockwell Hanford Operations, Richland, Washington.

Martinez-Baez, L. F. and C. Hal Amick, 1978, Thermal Properties of Gable Mountain Basalt Cores, Hanford Nuclear Reservation, LBL-7038, Lawrence Berkeley Laboratory, Berkeley, California.

Excavation Engineering and Earth Mechanics Institute, 1979, Determination of Basalt Physical and Thermal Properties at Varying Temperatures, Pressures, and Moisture Contents, First Progress Report, Fiscal Year 1979, RHO-BWI-C-50, Rockwell Hanford Operations, Richland, Washington.

Excavation Engineering and Earth Mechanics Institute, 1979, Determination of Basalt Physical and Thermal Properties at Varying Temperatures, Pressures, and Moisture Contents, Second Progress Report, Fiscal year 1979, RHO-BWI-C-54, Rockwell Hanford Operations, Richland, Washington.

Excavation Engineering and Earth Mechanics Institute, 1979, Determination of Basalt Physical and Thermal Properties at Varying Temperatures, Pressures, and Moisture Contents, Third Progress Report, Fiscal Year 1979, RHO-BWI-C-55, Rockwell Hanford Operations Richland, Washington.

Foundation Sciences, Inc., 1980, Thermal/Mechanical Properties of Pomona Member Basalt - Full-Scale Heater Test #1 (Area 1), RHO-BWI-C-77, Rockwell Hanford Operations, Richland Washington.

Foundation Sciences, Inc., 1980, Thermal/Mechanical Properties of Pomona Member Basalt - Full-Scale Heater Test #2 (Area 2), RHO-BWI-C-85, Rockwell Hanford Operations, Richland, Washington.

Schmidt, R., W. F. Daly, S. W. Bradley, P. R. Squire, and L. C. Hulstrom, 1980, Thermal and Mechanical Properties of Hanford Basalts, Compilation and Analyses, RHO-BWI-C-90, Rockwell Hanford Operations, Richland, Washington.

Shuri, F. S., D. J. Dodds, and K. Kim, 1980, Measurement of Rock-Mass Deformation Properties by the Borehole Jacking Method at the Near-Surface Test Facility, RHO-BWI-C-89, Rockwell Hanford Operations, Richland, Washington.

Foundation Sciences, Inc., 1981, Thermal/Mechanical Properties of Pomona Member Basalt - Area 3 and Summary, RHO-BWI-C-100, Rockwell Hanford Operations, Richland, Washington.

Foundation Sciences, Inc., 1981, Thermal/Mechanical Properties of Umtanum Basalt -- Borehole DC-2, RHO-BWI-C-92, Rockwell Hanford Operations, Richland, Washington.

Erikson, R. L. and K. M. Krupka, undated, Thermal Property Measurements of Pomona Member Basalt from Core Holes DB-5 and DB-15, Hanford Site, Southeastern Washington, RHO-BWI-C-76, Rockwell Hanford Operations, Richland, Washington.

Myer, Larry, 1982, Results of Thermomechanical Tests on Specimens of Hanford Basalts, Letter Report, September 30, 1982, Lawrence Berkeley Laboratory, Berkeley, California.

Craig, P. A., 1983, Tabulation of Young's Moduli and Poisson's Ratio Determinations from Uniaxial and Triaxial Compressive Strength Tests from Boreholes RRI-2, RRL-6, and RRL-14, SD-BWI-TI-132, Rev. 0-0, Rockwell Hanford Operations, Richland, Washington. Official Release Date September 29, 1983.

Hulstrom, L. C., and D. J. Hanson, 1982, Tabulation of Physical and Mechanical Property Data from Borehole RRL-2, SD-BWI-TD-002, Rev. 0-1, Rockwell Hanford Operations, Richland, Washington. Official Release Date November 2, 1982.

Hulstrom, L. C. and D. J. Hanson, 1983, Tabulation of Physical and Mechanical Property Data from Borehole RRL-6, SD-BWI-TD-003, Rev. 0-0, Rockwell Hanford Operations, Richland, Washington. Official Release Date January 31, 1983.

Hulstrom, L. C., and D. J. Hanson, 1983, Tabulation of Physical and Mechanical Property Data from Borehole RRL-14, SD-BWI-TD-004, Rev. 0-1, Rockwell Hanford Operations, Richland, Washington. Official Release Date March 9, 1983.

Landon, R. D., 1983, Geologic Thickness Data - Candidate Repository Horizons, SD-BWI-DP-011, Rev. A-0, Rockwell Hanford Operations, Richland, Washington. Official Release Date August 6, 1983.

Sublette, W. R., 1983, Rock Mechanics Data Package, SD-BWI-DP-041, Rev. 0-0, Rockwell Hanford Operations, Richland, Washington. Official Release Date Sept. 20, 1983.

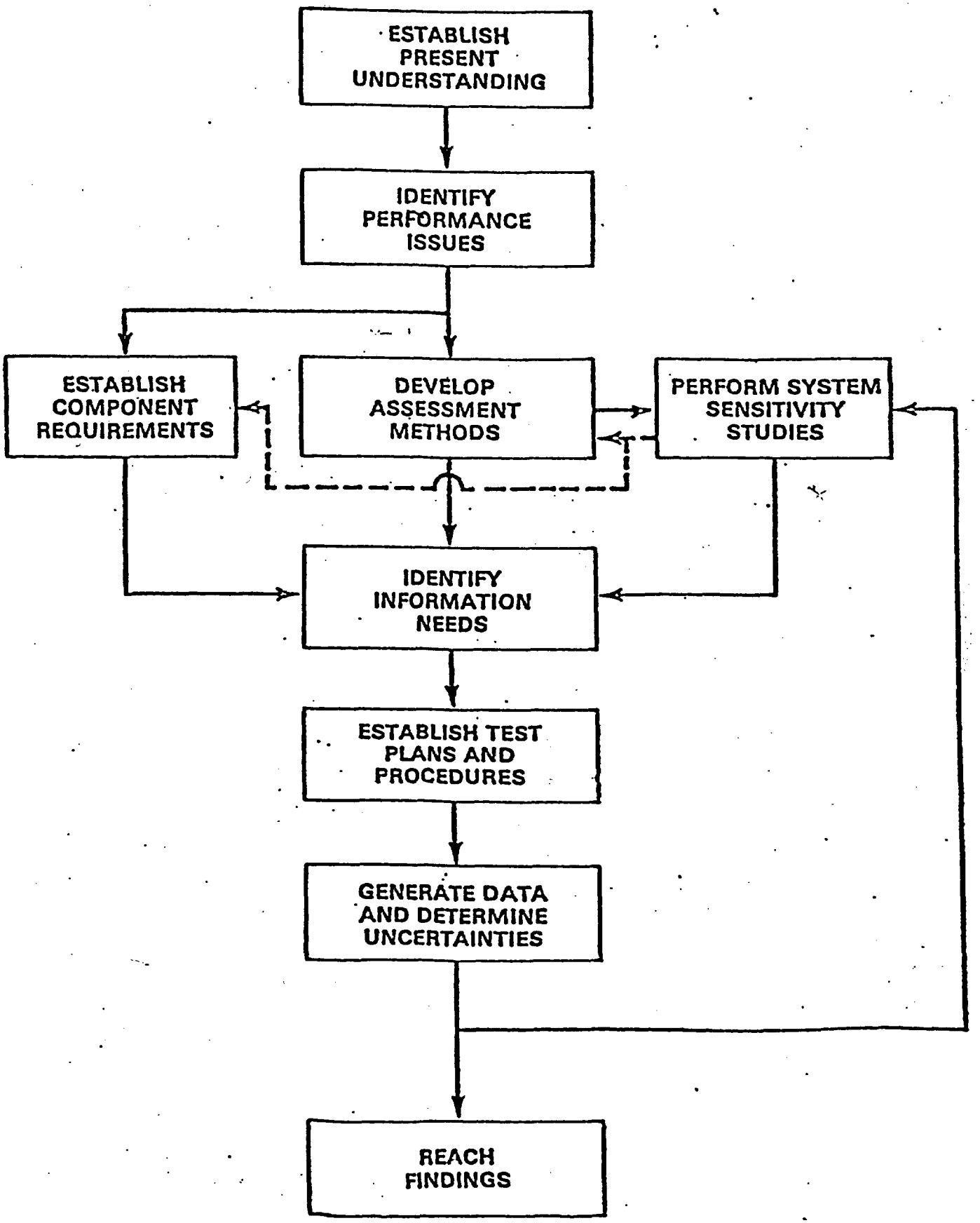
BASALT WASTE ISOLATION PROJECT

APPROACH TO DEFINING DATA NEEDS

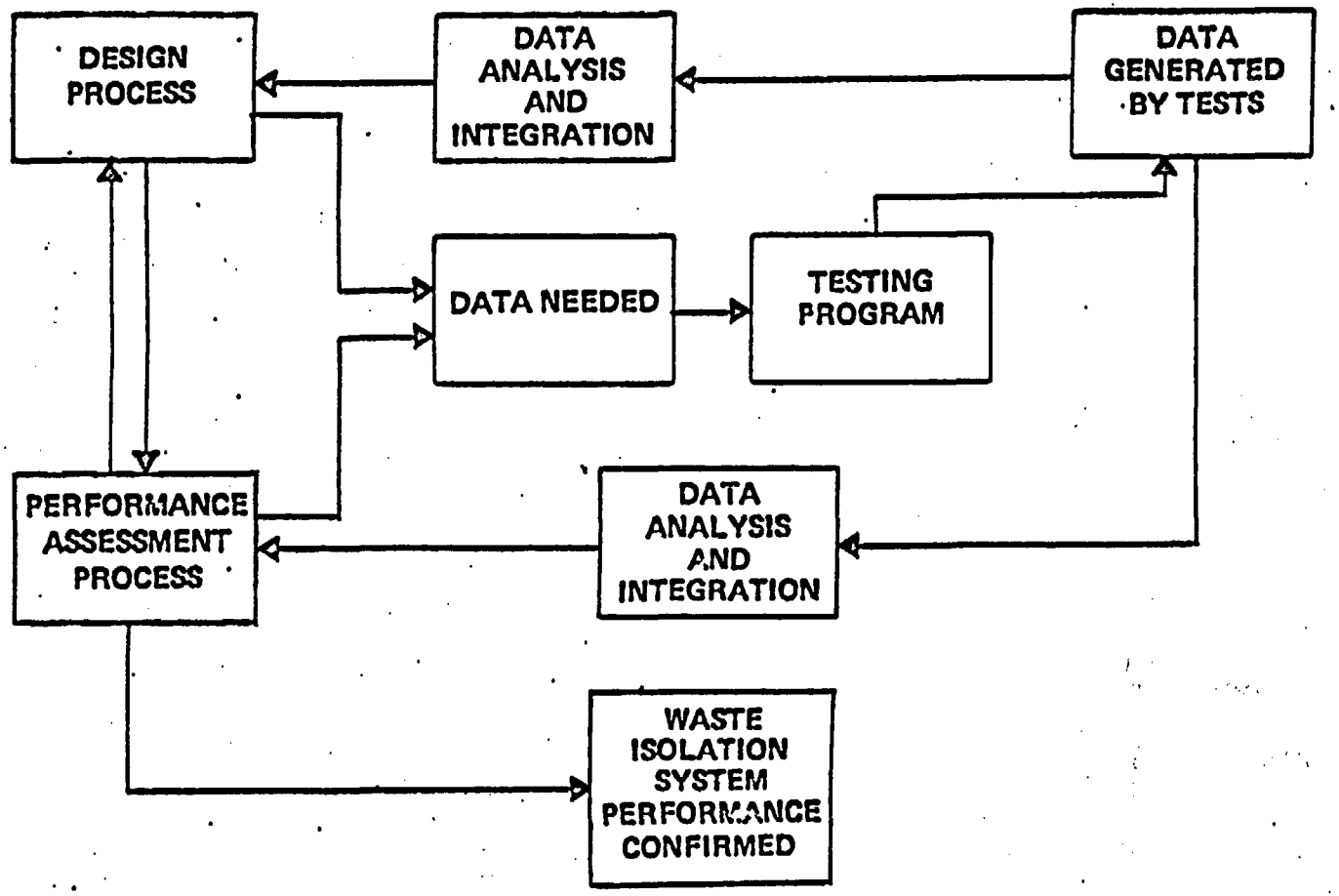
(9)

Dick Wilde

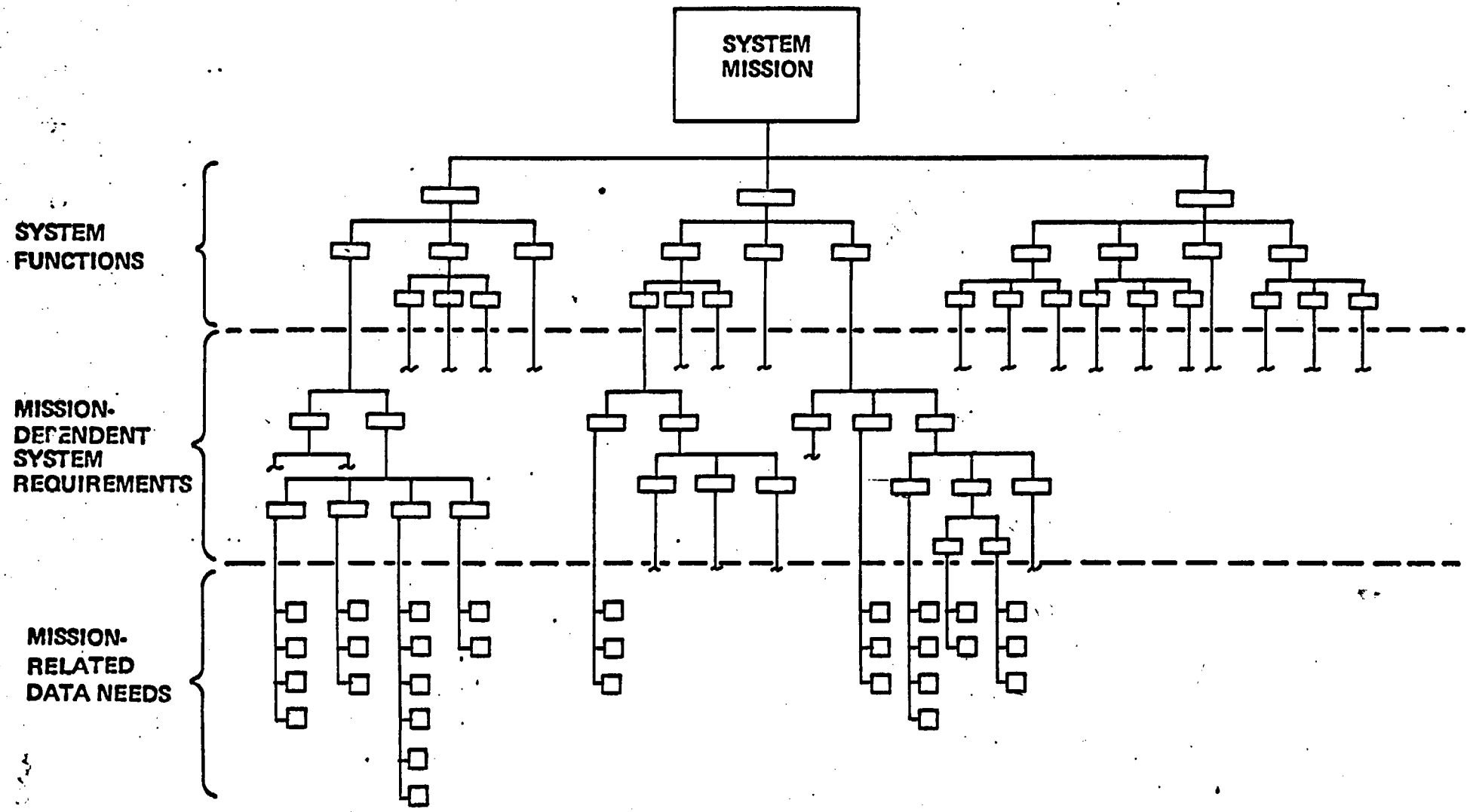
SITE CHARACTERIZATION PROGRAM LOGIC



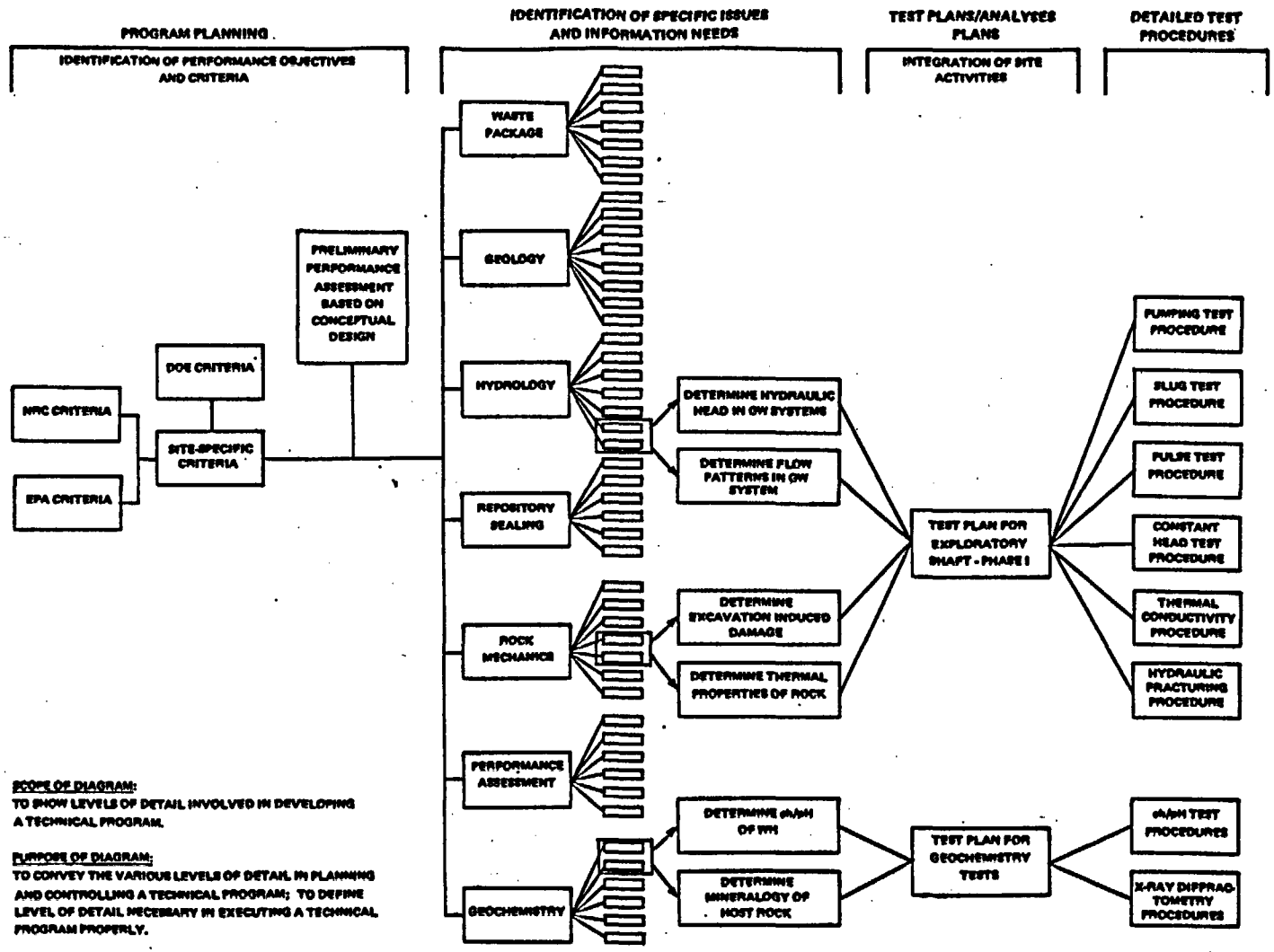
DESIGN, PERFORMANCE ASSESSMENT AND DATA ACQUISITION PROCESS RELATIONSHIPS



STRUCTURE OF REQUIREMENTS TREE



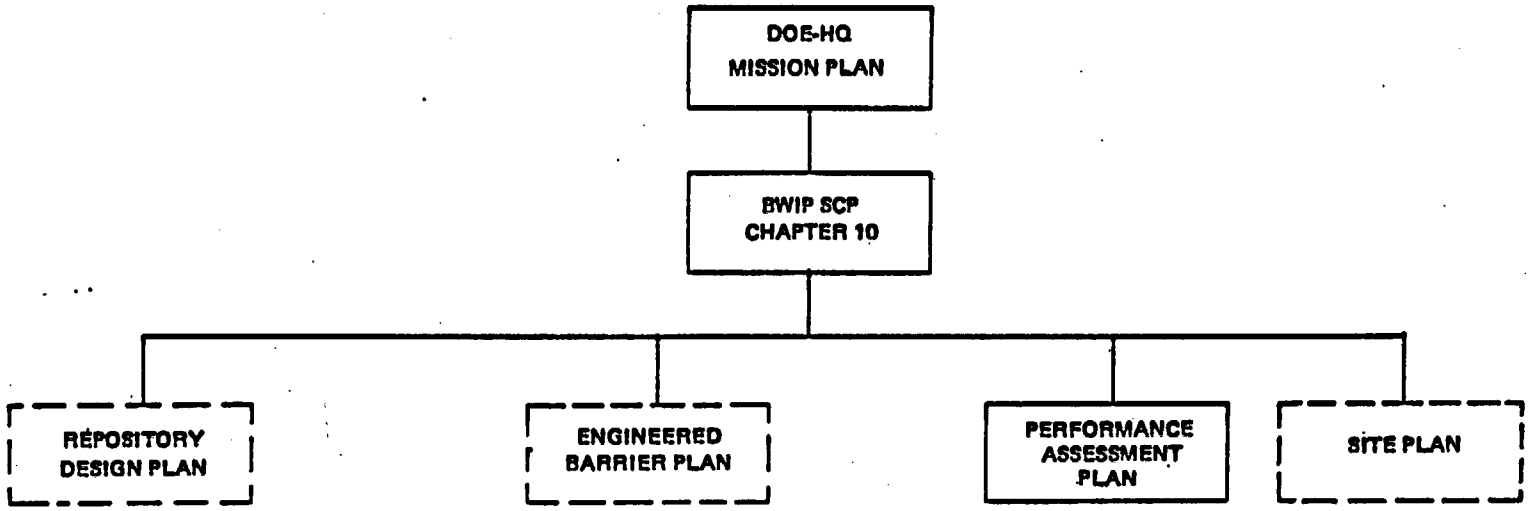
TEST PLANNING



SCOPE OF DIAGRAM:
TO SHOW LEVELS OF DETAIL INVOLVED IN DEVELOPING A TECHNICAL PROGRAM.

PURPOSE OF DIAGRAM:
TO CONVEY THE VARIOUS LEVELS OF DETAIL IN PLANNING AND CONTROLLING A TECHNICAL PROGRAM; TO DEFINE LEVEL OF DETAIL NECESSARY IN EXECUTING A TECHNICAL PROGRAM PROPERLY.

HIERARCHY OF TECHNICAL PLANNING DOCUMENTS



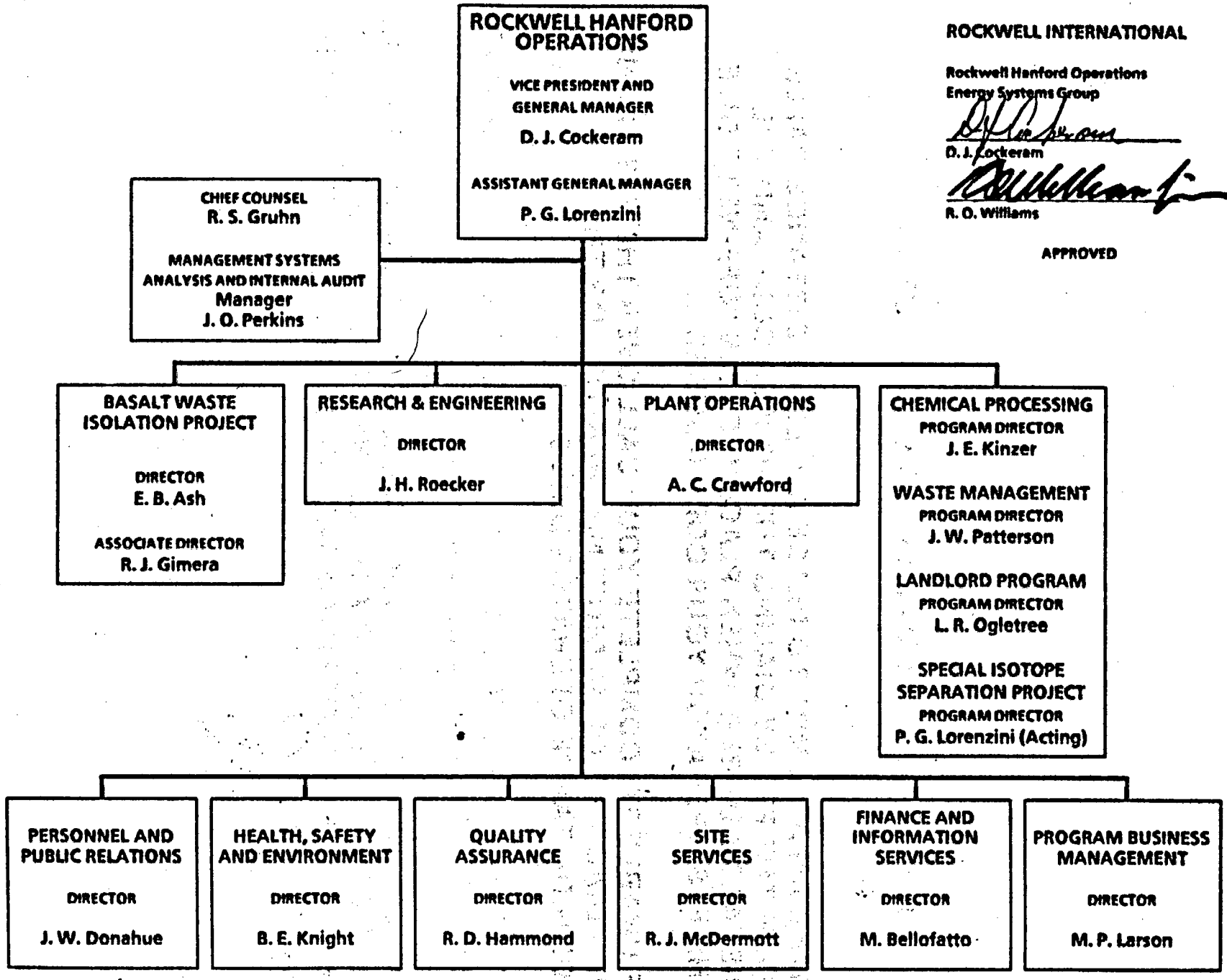
- FULL SCALE HEATER TESTS I & II TEST PLAN
- JOINTED BLOCK TEST PLAN
- (3) • IN SITU STRESS MEASUREMENT BY HYDRAULIC FRACTURING METHOD IN DC-12, RRL-2, RRL-6, DC-4
- OVERCORING STRESS MEASUREMENT TEST PLAN
- LARGE DIAMETER SHAFT LINER DEVELOPMENT TEST PLAN
- LARGE DIAMETER SHAFT BORING DEVELOPMENT TEST PLAN
- MINING EXCAVATION DEV. TEST PLAN
- GROUND SUPPORT DEV. TEST PLAN
- IN SITU INSTRUMENTATION DEV. TEST PLAN
- CROSSHOLE SEISMIC GEOPHYSICAL TEST PLAN
- CANISTER BOREHOLE DRILLING DEV. TEST PLAN
- CANISTER EMPLACEMENT/RETRIEVAL DEV. TEST PLAN

- BARRIER MATERIALS TEST PLAN
- REPOSITORY SEAL MATERIALS TEST PLAN
- REPOSITORY SEALS DEVELOPMENT TEST PLAN
- WASTE PACKAGE BACKFILLING PROCESS DEVELOPMENT TEST PLAN
- REPOSITORY SEALS IN SITU TEST PLAN
- WASTE PACKAGE IN SITU TEST PLAN
- WASTE PACKAGE PERFORMANCE ENGINEERING TEST PLAN

- MODEL TEST PLAN(S)

- BOREHOLE DRILL & TEST PLAN
- GROUNDWATER MONITORING TEST PLAN
- TECTONICS CHARACTERIZATION PLAN
- LITHOLOGIC CHARACTERIZATION PLAN
- HYDROCHEMISTRY

- EXPLORATORY SHAFT TEST PLAN



ROCKWELL INTERNATIONAL

Rockwell Hanford Operations
Energy Systems Group

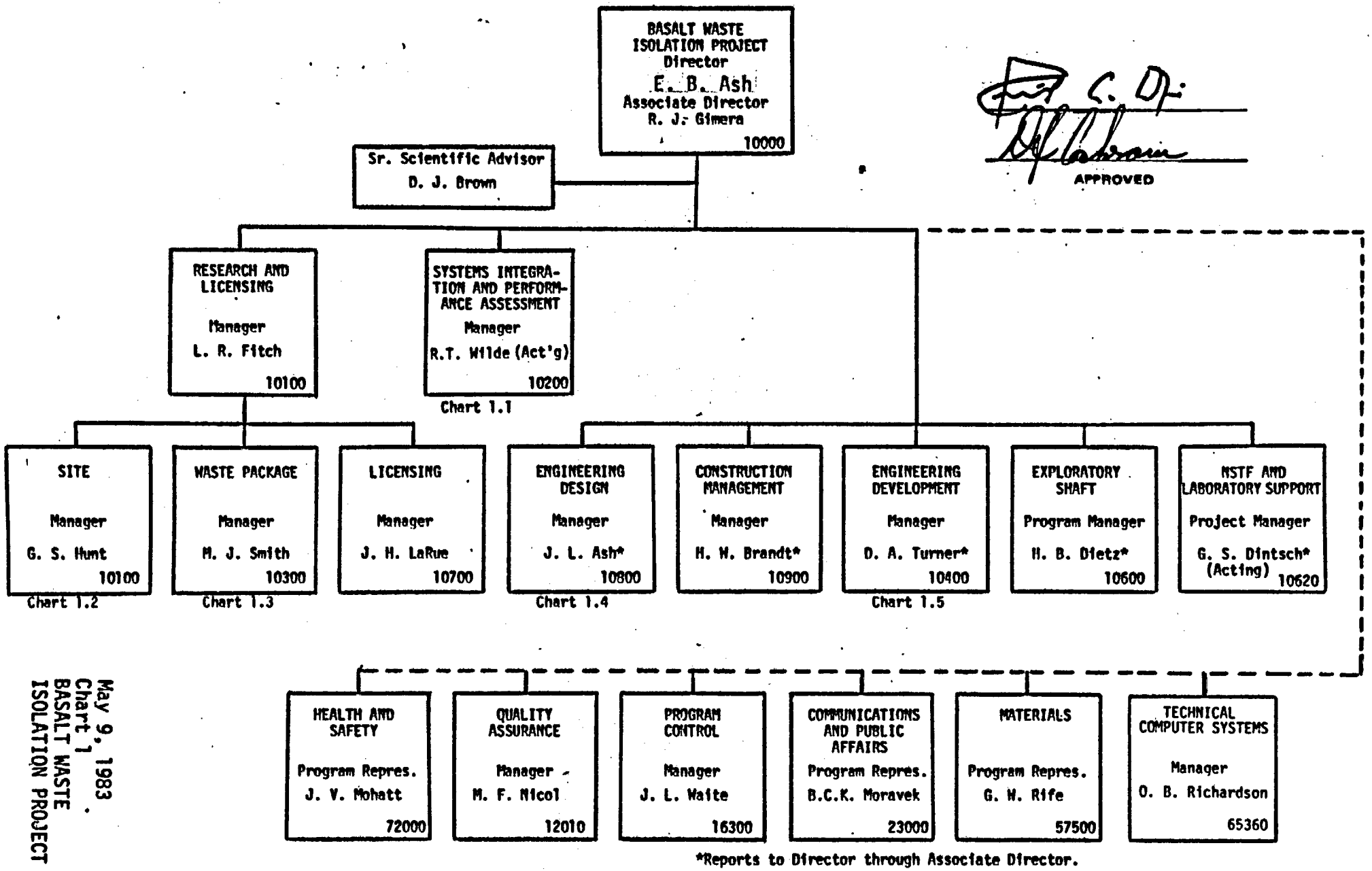
D. J. Cockeram

R. O. Williams

APPROVED

September 18, 1983

Rockwell International
Rockwell Hanford Operations
Energy Systems Group



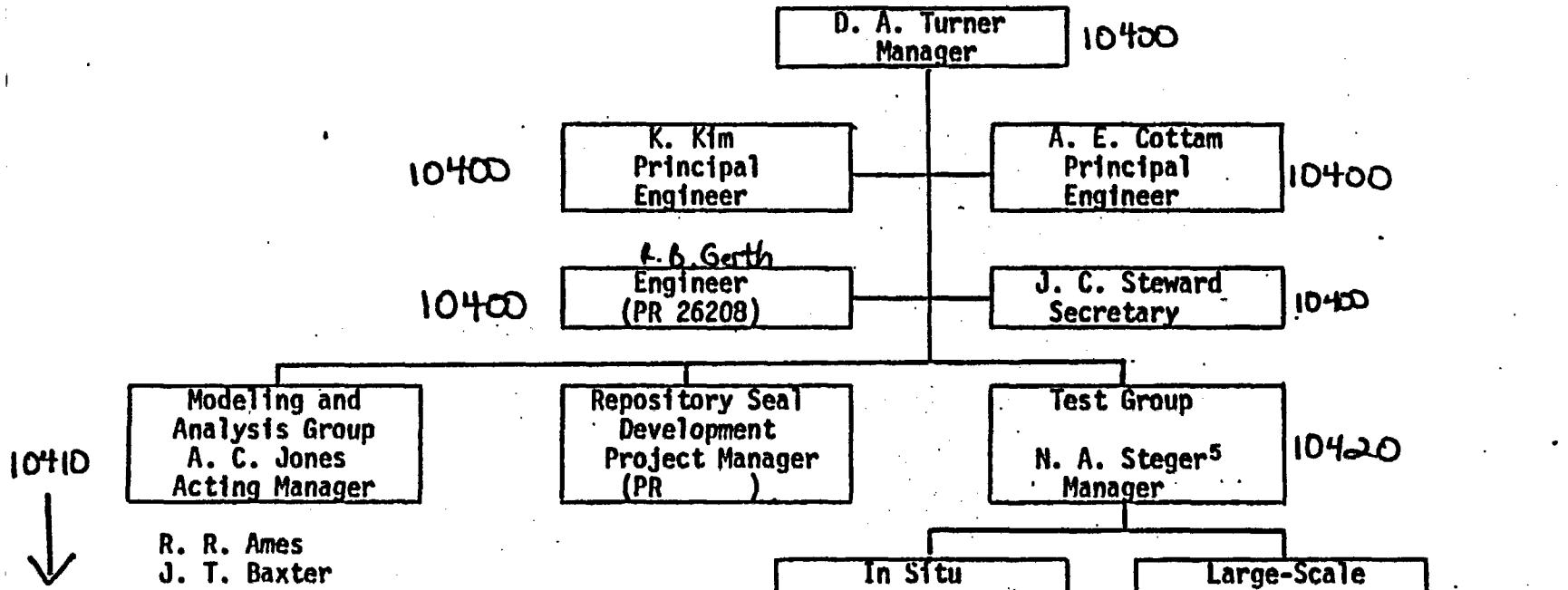
APPROVED

*Reports to Director through Associate Director.

May 9, 1983
Chart 1
BASALT WASTE ISOLATION PROJECT

11-11-83

ENGINEERING DEVELOPMENT DEPARTMENT



R. R. Ames
J. T. Baxter
D. R. Bonin
W. J. Karwoski
R. M. Moore (Clerk)
D. L. South
W. R. Sublette
Staff Engineer (PR 25123)
Staff Engineer (PR 25113)
Senior Engineer (PR 25116)

J. A. Curl[4]
M. L. Cramer
~~J. P. Cunningham[1]~~
S. A. Dischler[2]
E. C. Gregory
G. L. Kasza[4]
~~D. G. Lanigan[3]~~
W. M. McCabe
W. A. Skelly
T. A. Rundle
Staff Engineer (PR 20421)
Staff Engineer (PR 20421)
Senior Engineer (PR 11552)

J. M. McHenry
R. J. Morris[4]
J. G. Patricio

(1) Transfer to R&E effective 11/14/83.
(2) Temporary employee.
(3) Transfer to R&E effective 11/21/83.
(4) Morrison-Knudsen Company, Inc.
(5) Effective 11/14/83.

APPROVED: _____

R. J. Gimera, Associate Director
Basalt Waste Isolation Project

SUMMARY OF CODES FOR PERFORMANCE ASSESSMENT AND REPOSITORY DESIGN

Computer code	Approach		Stress/ Strain		Ground-water flow		Heat		Radionuclide transport			Computational method			
	CO	DC	LI	NL	IS	NI	AD	DS	S	MC	DE	FE	FD	AL	DI
Very Near-Field															
ADINA	X		X	X								X			3
ADINAT	X				X	X		X				X			3
BETA	X		X		X	X		X				X			2
DAMSWEL	X		X	X	X	X		X				X			2
ANSYS	X	X	X	X	X	X		X				X			3
HEATING5	X					X		X					X		3
MAGNUM	X	X			X	X	X	X				X			2
CHAINT	X	X							X	X	X	X			2
BARIER[a]	X					X			X				X		1
WAPPA[a]	X					X			X				X		1
EQI 3/6	X					X				X					1
Near-Field															
PORFLO	X				X	X	X	X	X				X		2
PATH[b]	X	X			X	X						X			2
WOOD/SALTER	X				X				X	X				X	1
NUTRAN	X								X	X				X	1
Far-Field															
MAGNUM 3D	X				X							X			3
PATH 3D[b]	X				X							X			3
FECTRA	X								X			X			3
SWIFT	X				X	X	X	X	X	X	X		X		3
FE3DGW	X				X							X			3
PABLM	X									X	X			X	1

LEGEND:

CO-Continuum	IS-Isothermal	S-Single Component	FD-Finite Difference
DC-Discontinuum	NI-Nonisothermal	MC-Multicomponent	AL-Analytical
LI-Linear Properties	AD- Advection	DE-Decay Chains	DI-Dimensionality
NL-Nonlinear Properties	DS-Diffusion	FE-Finite Element	

[a]Codes currently under development.

[b]Computes pathlines, streamlines, and travel times.

[c]Currently being considered

STATUS OF BASALT THERMAL CONDUCTIVITY DETERMINATIONS

DATA NEED	STATUS	CURRENT PLANNED ACTIVITIES
CONTINUA (INTACT BASALT)	• OBTAINED BY SUBCONTRACT TESTING OF CORES FROM HANFORD SITE SURFACE BOREHOLES • BASELINED IN SD-BWI-DP-041, "ROCK MECHANICS DATA PACKAGE"	• PROCURE IMPROVED EQUIPMENT INCLUDING TRACEABLE STANDARDS, SUBCONTRACT NO. SA-962 • EQUIPMENT OPERATIONAL 7/84 • NEW TESTING ON EXISTING CORE INVENTORIES TO BE INITIATED 9/84 • ES TEST PLANNING HAS BEEN INITIATED
DISCONTINUA (JOINTS, SHEAR ZONES, ETC.)	• NO WORK TO DATE • LABORATORY AND LARGE-SCALE FIELD TEST RESULTS FROM THE NSTF PHASE I PROGRAM WILL PROVIDE SOME INFORMATION ON SCALE EFFECT	• AN OVERALL PLAN FOR MECHANICAL AND HYDROLOGIC JOINT TESTING IS BEING DEVELOPED TO SUPPORT REPOSITORY DESIGN AND PERFORMANCE ASSESSMENT • SCHEDULE WILL BE ADJUSTED TO SUPPORT ES TEST PLANNING AND REPOSITORY DESIGN ACTIVITIES
LARGE-SCALE (ROCK-MASS SCALE)	• "ROCK MASS" THERMAL CONDUCTIVITY DETERMINATIONS WERE PART OF THE NSTF PHASE I TEST PROGRAM • PARAMETER ESTIMATION HAS BEEN APPLIED TO DATA REDUCTION OF BLOCK TEST STEP 1 AND FS NO. 2 THERMAL TEST DATA	• REPORT ON "DETERMINATIONS OF" ROCK MASS THERMAL PROPERTIES FROM THE NSTF PHASE I TESTS IS DUE 3/84, SUBCONTRACT NO. SA-1006 • ES TEST PLANNING HAS BEEN INITIATED

REPOSITORY MODEL DEVELOPMENT

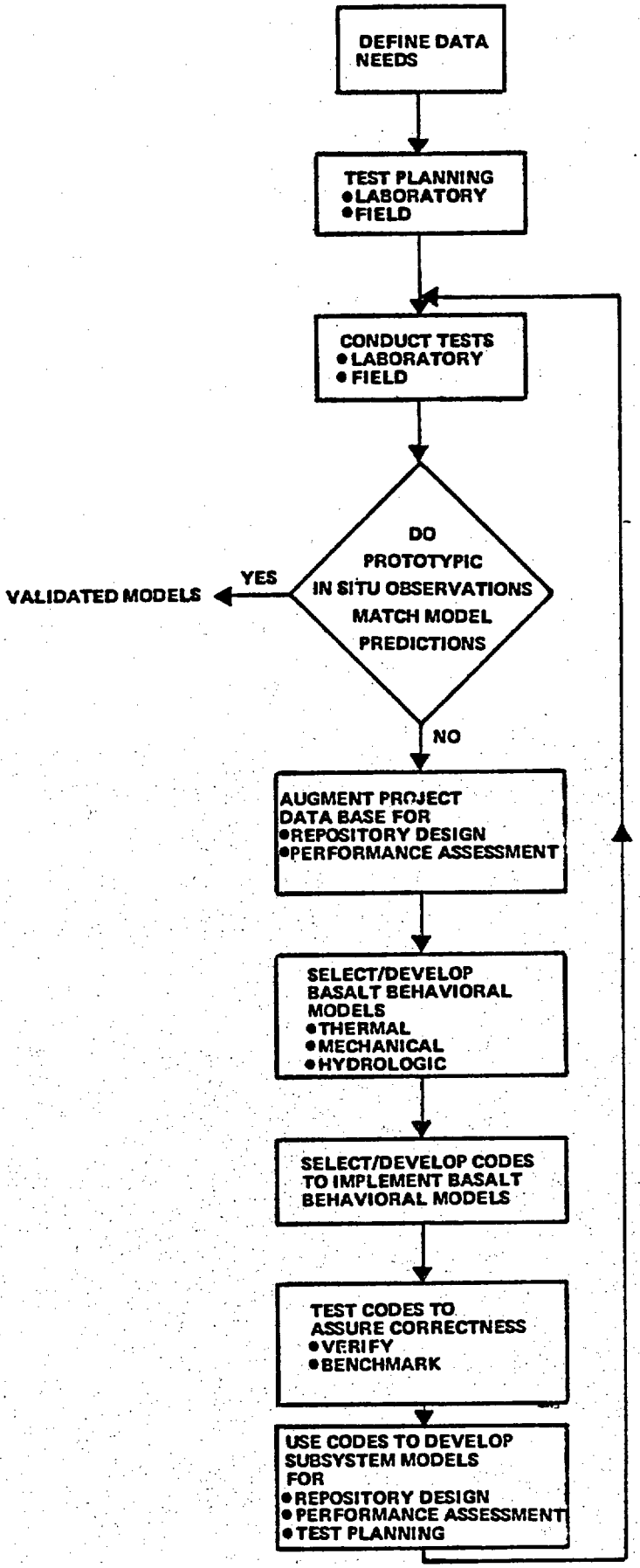
MODEL DEVELOPMENT IS DATA BASE DRIVEN

- LABORATORY AND FIELD TEST PROGRAMS ARE TIME PHASED TO SUPPORT MODEL DEVELOPMENT

- GEOMECHANICS MODEL DEVELOPMENT IS ORIENTED PRIMARILY TOWARD THERMAL, MECHANICAL, AND COUPLED THERMOMECHANICAL ANALYSIS

- SELECTION/DEVELOPMENT OF CODES FOR BOTH CONTINUUM AND DISCRETE ELEMENT MODELS IS CURRENTYLY PROCEEDING

DATA BASE DRIVEN MODEL DEVELOPMENT



JA840124-8

CONTINUUM CODES UNDER DEVELOPMENT

DAMSWEL

A FINITE ELEMENT COMPUTER PROGRAM FOR THERMAL STRESS ANALYSIS IN TWO DIMENSIONS. IT CONSISTS OF COUPLED THERMAL AND STRESS ANALYSIS SUBPROGRAMS COLDD AND MATLOC RESPECTIVELY. THE PRIMARY USE FIR THIS CODE IS MODELING OF THE NEAR SURFACE TEST FACILITY (NSTF) PHASE I TESTS AT GABLE MOUNTAIN ON THE HANFORD SITE. IT IS CURRENTLY BEING USED AS A DEVELOPMENT CODE FOR IMPLEMENTING BASALT MECHANICAL CONSTITUTIVE MODELS DERIVED FROM NSTF PRE-TEST CHARACTERIZATION AND PRELIMINARY BLOCK TEST AMBIENT TEMPERATURE RESULTS. DAMSWEL WILL BE REPLACED BY ADINA - ADINAT OVER THE NEXT TWO FISCAL YEARS.

CONTINUUM CODES UNDER DEVELOPMENT (CONTINUED)

ADINA

A GEOTECHNICALLY ORIENTED GENERAL PURPOSE FINITE ELEMENT CODE FOR LINEAR AND NON-LINEAR THERMAL, MECHANICAL, AND COUPLED THERMOMECHANICAL ANALYSES.

CAPABILITIES INCLUDE:

- COUPLED THERMOMECHANICAL ANALYSIS OF STEADY STATE AND TRANSIENT PROBLEMS
- FULL TWO AND THREE DIMENSIONAL CAPABILITY FOR BOTH THERMAL AND MECHANICAL PROBLEMS
- BOTH LINEAR AND NON-LINEAR THERMAL AND MECHANICAL CONTINUUM PROPERTIES CAN BE UTILIZED. THE EXISTING CURVE DESCRIPTION MODEL MAY BE USED TO MODEL NON-LINEAR BASALT MECHANICAL BEHAVIOR OR ALTERNATIVELY, THE CODE WILL BE MODIFIED
- ADDITIONAL MATERIAL MODELS ARE AVAILABLE FOR THERMOELASTIC-PLASTIC OR CREEP BEHAVIOR SHOULD FIELD OBSERVATIONS INDICATE THEIR APPROPRIATENESS

CONTINUUM CODES UNDER DEVELOPMENT (CONTINUED)

ANSYS

A GENERALIZED FINITE ELEMENT STRESS ANALYSIS CODE WIDELY USED IN THE NUCLEAR INDUSTRY. THIS PROPRIETARY CODE, DEVELOPED BY SWANSON ANALYSIS SYSTEMS, INC., HAS A BROAD CAPABILITY TO ANALYZE THE THERMOMECHANICAL RESPONSE OF BASALT ROCK.

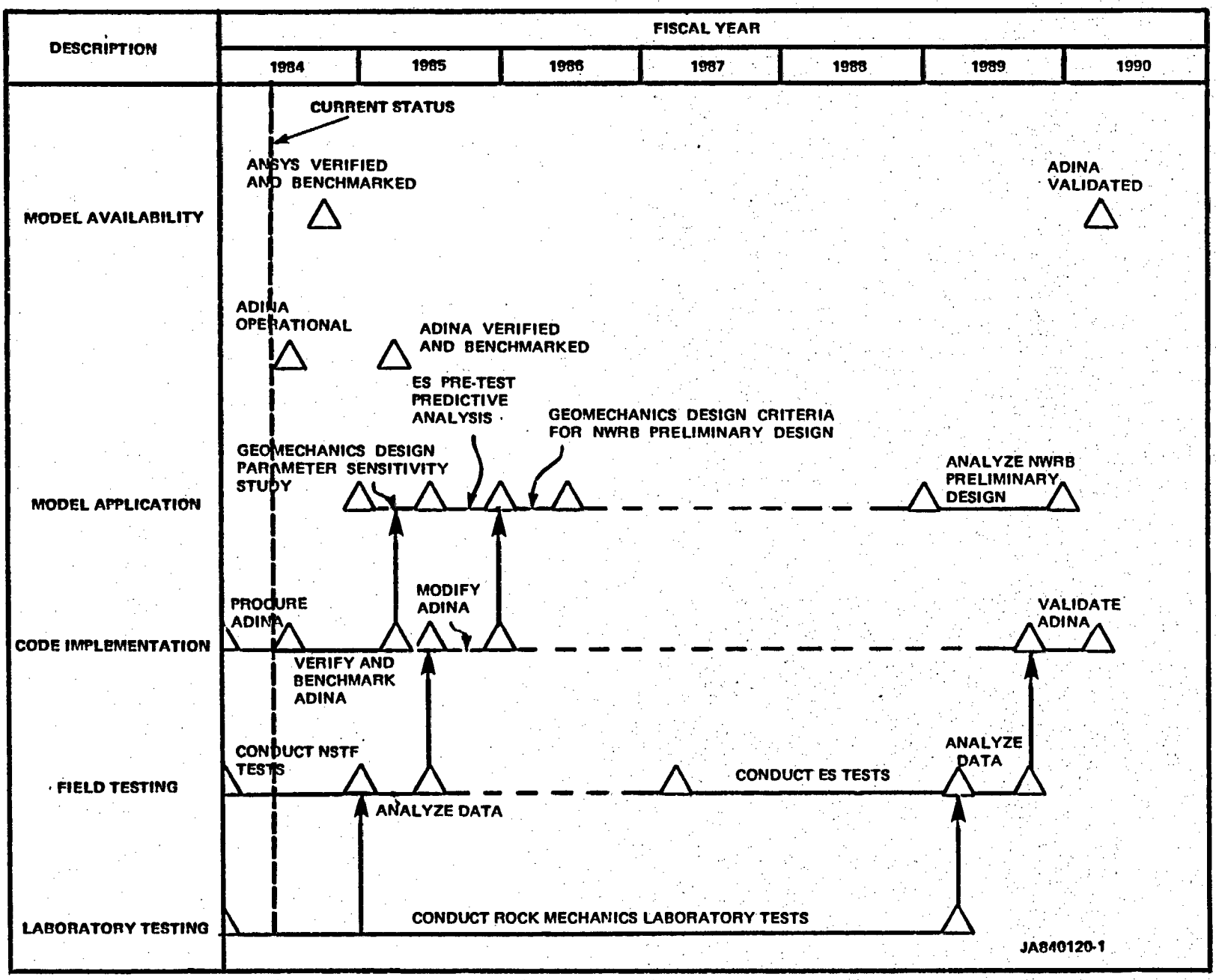
CAPABILITIES INCLUDE:

- COUPLED THERMOMECHANICAL ANALYSIS OF STEADY STATE AND TRANSIENT PROBLEMS
- FULL TWO AND THREE DIMENSIONAL CAPABILITY FOR BOTH THERMAL AND MECHANICAL PROBLEMS
- BOTH LINEAR AND NON-LINEAR THERMAL AND MECHANICAL CONTINUUM PROPERTIES CAN BE UTILIZED. NON-LINEAR MECHANICAL CAPABILITY IS NOT ORIENTED TOWARD GEOTECHNICAL MODELING
- GAP ELEMENTS ALLOW SIMPLE APPROXIMATIONS OF JOINT OR SLIP PLANE BEHAVIOR
- EXTENSIVE CAPABILITIES FOR DYNAMIC TRANSIENT ANALYSES OF SEISMIC EVENTS

CONTINUUM CODES UNDER DEVELOPMENT (CONTINUED)

CURRENT INTENT IS TO INCORPORATE THE DAMSWEL NON-LINEAR MECHANICAL MODEL IN ADINA FOR USE IN STATIC THERMAL, MECHANICAL, AND THERMOMECHANICAL ANALYSES. ANSYS PROVIDES CAPABILITY FOR VERIFICATION/BENCHMARK TESTING OF ADINA AND FURNISHES GENERAL CAPABILITIES FOR SEISMIC DESIGN ANALYSES INCLUDING MODELING OF GEOLOGIC DISCONTINUITIES WITH GAP ELEMENTS. WATER INFLOW CALCULATIONS CAN BE ACCOMPLISHED WITH EITHER CODE USING A CHANGE OF VARIABLE, HOWEVER, IT MAY BE PRUDENT TO USE PERFORMANCE ASSESSMENT CODES FOR THESE MODELS. NO SELECTION PROCESS HAS BEEN INITIATED FOR CODES TO SUPPORT REPOSITORY VENTILATION DESIGN.

CONTINUUM CODE AND MODEL DEVELOPMENT



DISCRETE ELEMENT MODELS

DATA BASE

- AN OVERALL PLAN FOR BASALT JOINT CHARACTERIZATION AND TESTING AT LABORATORY, BENCH, AND ROCK MASS SCALES IS BEING DEVELOPED IN FISCAL YEAR 1984/1985
- THE GOAL IS TO DEVELOP A DATA BASE ON JOINT STRENGTH, DEFORMATION AND HYDROLOGIC PROPERTIES TO BE USED FOR REPOSITORY DESIGN AND PERFORMANCE ASSESSMENT
- INFORMATION IN THE PROPOSED DATA BASE WILL BE USED WITH CONTINUUM MODELS FOR REPOSITORY DESIGN AND PERFORMANCE
- IN ADDITION, THIS DATA BASE MAY SUPPORT DEVELOPMENT OF DISCRETE ELEMENT MODELS FOR STUDIES ON BASALT "ROCK MASS" STRENGTH AND DEFORMATION BEHAVIOR AT STRESS LEVELS NOT ACHIEVEABLE IN LARGE-SCALE FIELD TESTS

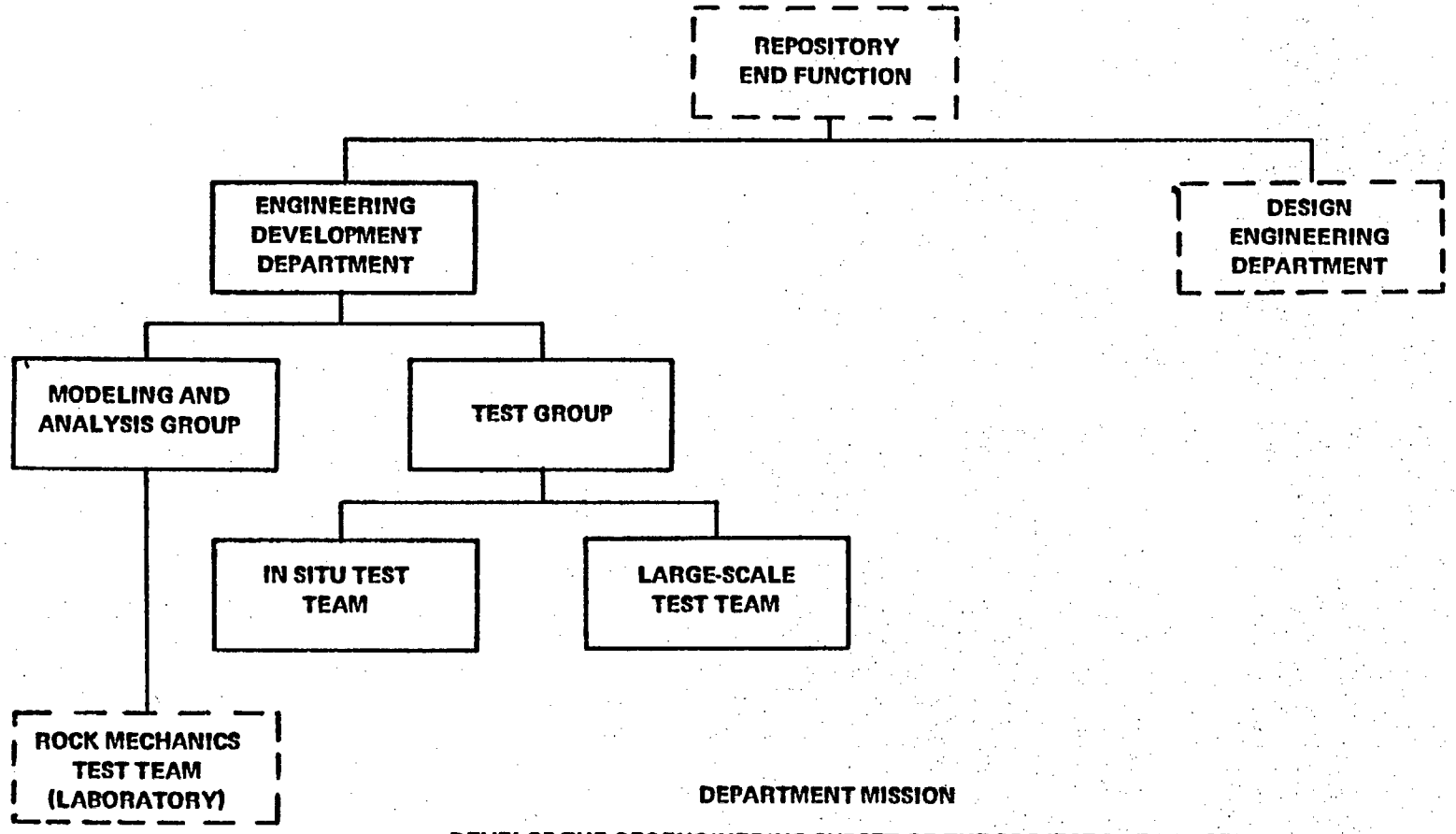
CODES

- THE PUBLIC DOMAIN UDEC TWO-DIMENSIONAL FINITE DIFFERENCE CODE IS BEING USED FOR BEHAVIORAL STUDIES OF THE JOINTED BLOCK TEST FOR COMPARISON TO AMBIENT TEMPERATURE OBSERVATIONS
- A SCREENING PROCESS FOR AVAILABLE CODES WILL BE INITIATED IN FISCAL YEAR 1984 TO ALLOW A DECISION ON SELECTION/DEVELOPMENT OF A PROJECT CODE IN FISCAL YEAR 1985

TESTING AND DOCUMENTATION
BWIP APPROACH TO COMPUTER CODE TESTING

- VERIFICATION - PROGRAM CHECKS COMPARISON WITH ACCEPTED ANALYTICAL AND/OR NUMERICAL SOLUTIONS
- BENCHMARKING - CODE TO CODE COMPARISONS, APPLICATION TO REPOSITORY TYPE PROBLEMS
- VALIDATION - COMPARISON OF NUMERICAL MODEL AS EMBODIED IN CODE WITH DATA (FIELD OR LABORATORY)

CAVEAT: VALIDATION DOES NOT NECESSARILY SATISFY ALL PERFORMANCE CONFIRMATION CONSIDERATIONS



DEPARTMENT MISSION

DEVELOP THE GEOENGINERING SUBSET OF THE PROJECT DATA BASE

DEVELOP SITE-SPECIFIC GEOENGINEERING DESIGN AND ANALYSIS METHODOLOGIES TO SUPPORT REPOSITORY DESIGN AND PERFORMANCE ASSESSMENT

CONDUCT SITE-SPECIFIC ENGINEERING DEVELOPMENT PROGRAMS TO SUPPORT REPOSITORY DESIGN

JA840124-5

DEVELOP MISSION-RELATED REQUIREMENTS TREE TO DEFINE

↓

DATA NEEDS

1. SITE-SPECIFIC DATA
2. NON-SITE SPECIFIC DATA

↓

PRIORITIZE DATA NEEDS BY ANALYSIS

1. USE EXISTING DATA BASE AND UNCERTAINTIES
2. SENSITIVITY STUDIES
3. PRELIMINARY DESIGN
4. PRELIMINARY PERFORMANCE ASSESSMENT

↓

ACQUIRE DATA TO MEET ACCURACY REQUIREMENTS BASED ON APPLICABLE PERFORMANCE CRITERIA

1. 10 CFR 60
2. 40 CFR 191

↓

COMMON INTERDISCIPLINARY PROJECT DATA BASE FOR

1. REPOSITORY DESIGN
2. WASTE PACKAGE DESIGN
3. PERFORMANCE ASSESSMENT

BWIP SITE CHARACTERIZATION PROCESS

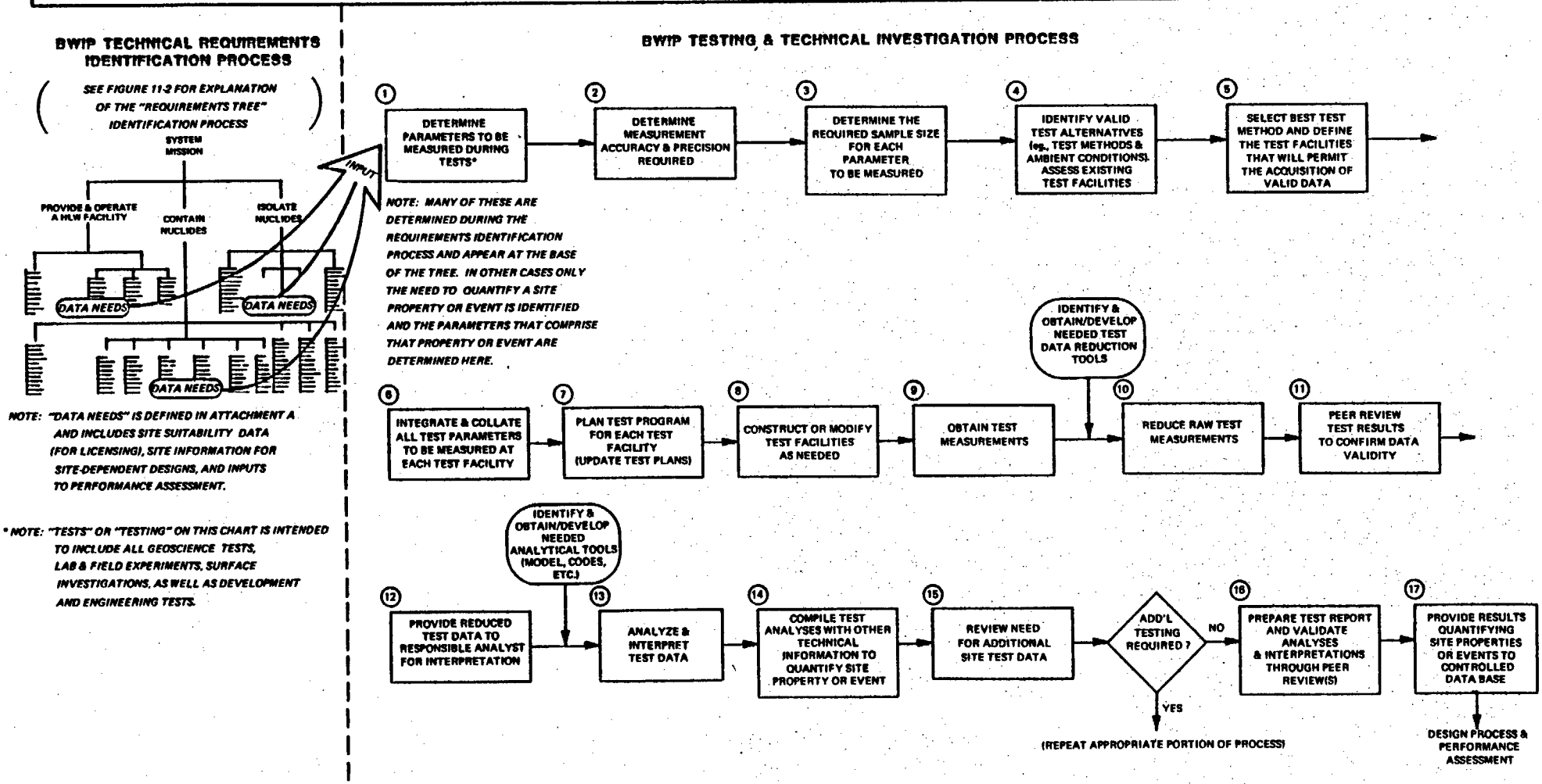


FIGURE 11-1. BWIP SITE CHARACTERIZATION PROCESS

GEOENGINEERING DATA BASE

RECOMMENDED FOR SITE CHARACTERIZATION

	CONTINUA (INTACT BASALT)	DISCONTINUA (JOINTS, SHEAR ZONES, ETC.)	LARGE-SCALE (ROCK MASS SCALE)
• MECHANICAL PROPERTIES [1,2]			
PHYSICAL	X	X	X
STRENGTH	X	X	X
DEFORMATION	X	X	X
• THERMAL PROPERTIES [1]			
CONDUCTIVITY	X	X	X
HEAT CAPACITY	X	X	X
COEFFICIENT OF THERMAL EXPANSION	X	X	X
FILM COEFFICIENT	X		
EMISSIVITY	X		

- GEOMECHANICS INTERPRETATION OF SITE GEOLOGIC DATA — To identify the source of the geomechanics test population within the site. Examples: geologic borehole logs correlated to core samples
- EXCAVATION CHARACTERISTICS
- IN SITU STRESS FIELD — And analysis correlating observations with geologic tectonic structural models

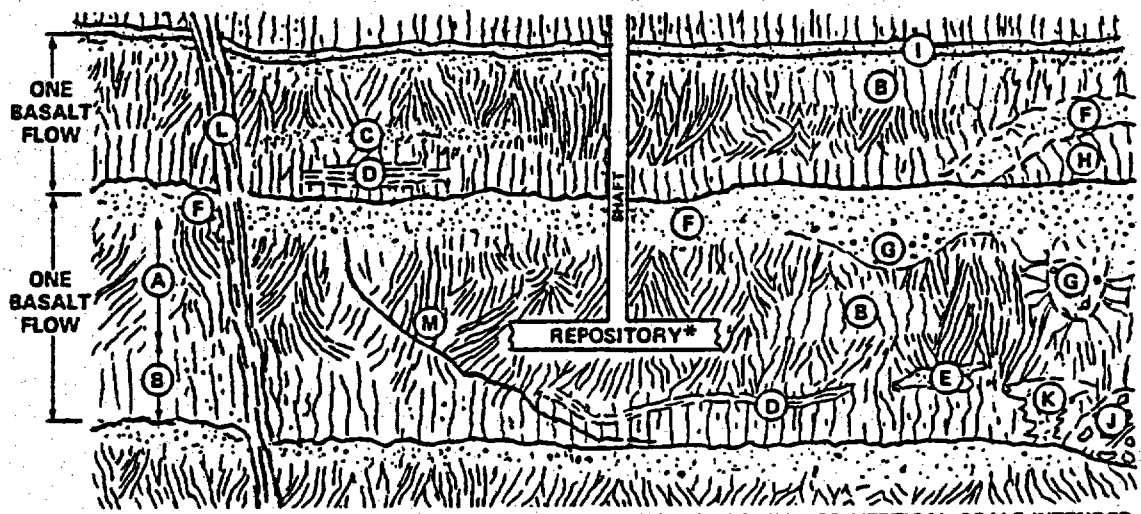
1. INCLUDING EFFECT OF SATURATION
2. INCLUDING EFFECT OF TEMPERATURE

JA840124-3

HYPOTHETICAL, COMPOSITE CROSS SECTION OF POSSIBLE GEOLOGIC FEATURES IN A LAYERED BASALT SEQUENCE (GEPHART ET AL., 1983)

WORKING DRAFT-DO NOT QUOTE OR CITE

CROSS SECTION OF POSSIBLE GEOLOGIC FEATURES IN BASALT



FLOW INTERIOR DISCONTINUITIES

- A ENTABLATURE JOINTS
- B COLONNADE JOINTS
- C VESICULAR ZONE
- D PLATY ZONE
- E ANOMALOUSLY FRACTURED ZONE

FLOW CONTACT

- F FLOW TOP
- G LOCAL THICKENING OF FLOW TOP BRECCIA
- H FLOW TERMINATION
- I SEDIMENTARY INTERBED
- J PILLOW BRECCIA
- K SPIRACLE OR SPIRACLE-LIKE FEATURE

BEDROCK STRUCTURAL DISCONTINUITIES

- L FAULT OR FRACTURE ZONE, HINGE OF FOLD, OR SHEAR ZONE
- M LOCALIZED TECTONIC FRACTURE

PS8310-60

EXAMPLE DATA NEED

PARAMETER: BASALT THERMAL CONDUCTIVITY

DATA USE:

REPOSITORY DESIGN

- SELECTION OF WASTE THERMAL LOADINGS
- REPOSITORY LAYOUTS TO MEET TEMPERATURE CRITERIA
- CALCULATION OF TEMPERATURES FOR INPUT INTO GEOMECHANICAL CODES TO EVALUATE THE EFFECTS OF THERMALLY INDUCED STRESSES

WASTE PACKAGE DESIGN

- SELECTION OF WASTE PACKAGE MATERIALS/GEOMETRY
- SELECTION OF ENGINEERED BACKFILL PROPERTIES TO MEET TEMPERATURE CRITERIA
- CALCULATION OF TEMPERATURES FOR INPUT TO GEOCHEMICAL CODES TO EVALUATE CHEMICAL REACTIONS WITHIN AND AROUND THE WASTE PACKAGE

EXAMPLE DATA NEED

PARAMETER: BASALT THERMAL CONDUCTIVITY (CONTINUED)

DATA USE:

PERFORMANCE ASSESSMENT

- CALCULATION OF TEMPERATURES FOR COUPLED NEAR-FIELD AND VERY-NEAR-FIELD THERMAL-HYDRAULIC MODELS

  (CALCULATIONS TO DATE INDICATE THAT CONDUCTION HEAT TRANSFER IN BASALT IS THE DOMINANT HEAT TRANSFER MECHANISM)

- CALCULATION OF TEMPERATURES FOR INPUT TO GEOMECHANICAL CODES TO EVALUATE THE EFFECT OF THERMALLY INDUCED STRESSES ON HYDRAULIC PERMEABILITY

(2d)

DATA SHEET

Thermal/Mechanical/Hydrological Models

1. **Type of Model:** ANSYS — — Mechanical, Thermal, finite element, linear & non-linear, steady state and transient. Heat transport by conduction, convection and radiation. Can perform static, buckling, modal dynamic and nonlinear transient analyses
2. **Dimension:** Fully three-dimensional; a total of 19 Thermal analysis elements are available. 45 of the 68 total element formulations are for structural analysis
3. **Documentation:** User's manual, theory manual, verification manual, and examples manual
4. **Validation/Verification:** The verification manual reports 126 problems solved using ANSYS and compared to theoretical results. BWIP plans to "validate" ~~them~~ ANSYS using the full scale heater tests
5. **Numerical ~~Criteria~~ Schemes:** Uses virtual work derivation for stress and conductivity matrix. The thermal solution uses a direct integration scheme. Automatic calculation of optimum time step. An iteration process with load increment for plastic analysis and a single load step for elastic analysis until convergence is achieved
6. **Computational Efficiency:** More efficient for complex, non-linear problems
7. **Author & Availability:** John Swanson; Swanson Analysis Systems, Inc
8. **Unique Features:** Three preprocessors for data input and 12 postprocessors for output data.
9. **Limitations:** Not originally intended for geomechanics application. Some material models and failure criteria may be difficult to implement. Iterative solution procedure not amenable to describe certain mechanical rock behavior
10. **Other Pertinent Facts:** Proprietary, available on a royalty basis from Swanson Analysis Systems.

DATA SHEET

Thermal/Mechanical/Hydrological Models

1. **Type of Model:** ADINA — mechanical or thermomechanical Finite element, linear or non-linear, static or dynamic, structural and geomechanical

2. **Dimension:** One-, two-, and three-dimensional Many different types of elements available

3. **Documentation:** ADINA Engineering, Inc. Report # AE 81-1, September 81

4. **Validation/Verification:** Sixteen verification problems with comparison to theoretical solutions. More than one solution procedure has been verified. Currently being validated against NSTF heater test. Sensitivity analyses have also been performed.

5. **Numerical ~~Criteria:~~ Schemes:** Several different solution procedures available: e.g., computed column reduction, multipoint criteria, Implicit Newmark etc. User specified accuracy criterion

6. **Computational Efficiency:** Not known

7. **Author & Availability:** K. J. Bathe; ADINA Engineering, Inc. Watertown, MA. May be leased or used through time-sharing services

8. **Unique Features:** Large strain & large displacement; Orthotropic material description; Restart capability; creep model.

9. **Limitations:** Not amenable for earthquake analyses, Proprietary

10. **Other Pertinent Facts:** A thorough review available in NUREG/CR-3450

DATA SHEET

Thermal/Mechanical/Hydrological Models

1. **Type of Model:** ADINAT :— Thermal
Finite element, linear and non-linear, steady state and transient heat transfer

2. **Dimension:** One-, two-, and three-dimensional
Can handle anisotropy of thermal conductivity

3. **Documentation:** It is documented as an ADINA Engineering, Inc. Report (AE 81-2), sept. 81.

4. **Validation/Verification:**
The user's manual gives verification of eight analytical problems. Sensitivity analyses with variable time steps, number of elements have been done. Plans exist to validate this model against the NSTF heater tests.

5. **Numerical ~~Criteria:~~ Schemes:**
A number of solution procedures are available:
Computed column reduction; explicit Euler forward, implicit trapezoidal or Euler backward
Equil. iteration in steady state and transient non-linear using Newton-Raphson
user defined accuracy criterion

6. **Computational Efficiency:**
Not known

7. **Author & Availability:**
K. J. Bathe; ADINA Engineering, Inc., Watertown, MA.
May be leased or used through time-sharing service

8. **Unique Features:**
Can be used as a thermal processor to ADINA (a mechanical response code). Convection and radiation in cavities (tunnels) can be handled. Allows restarts

9. **Limitations:**
Fixed format data input deck.
Probably expensive for non-linear analyses.
Proprietary

10. **Other Pertinent Facts:**
A thorough review available in NUREG/CR-3450

DATA SHEET

Thermal/Mechanical/Hydrological Models

1. **Type of Model:** DAMSWEL-CØLDD/MATLØC modules
CØLDD solves the thermal response } Finite element
MATLØC solves the mechanical " }
Steady state and transient, linear and non-linear thermal
Static linear and non-linear stress analysis

2. **Dimension:** Two-dimensional thermal/mechanical
CØLDD uses 8-noded isoparametric formulation
MATLØC uses 4-, 8-, or 12-noded isoparametric element formulations

3. **Documentation:** RHO-BWI-C-74 by Boonlualohr et al.
contains Programming manual, verification, and Program Listing.

4. **Validation/Verification:** Three analytical problems solved and compared using CØLDD. Has been used to predict the thermal response of the NSTF heater tests. Four analytical solutions were used to check the thermal or mechanical response. Comparison to the heater test deformation response in progress.

5. **Numerical ~~Criteria~~ Schemes:**
CØLDD uses the Galerkin method to formulate the solution; Lee's time-stepping algorithm is applied; a Gaussian elimination technique is used to solve the matrix eqns. for both modules. A Newton-Raphson incremental tangent stiffness approach is used in MATLØC.

6. **Computational Efficiency:**

7. **Author & Availability:**
Boonlualohr et al., Dames & Moore;
Developed for DOE for NSTF applications at the BWIP site.

8. **Unique Features:**
Specifically developed for BWIP applications. Transversely isotropic with bi-linear constitutive relationship.

9. **Limitations:** No internal radiation or convection transfer capability; No 3-D capability; User's manual not very detailed

10. **Other Pertinent Facts:**
A more thorough review available in NUREG/CR-3450

ROCK MECHANICS LABORATORY TOUR

1. Laboratory notebook system
2. Sample routing (see attached chart)
3. Sample characterization
4. Porosity measurement equipment
5. Direct-shear testing equipment
6. Wave velocity measuring equipment
7. Soil Test load frames
8. MTS machine and triaxial test demonstration

BASALT OPERATING PROCEDURE

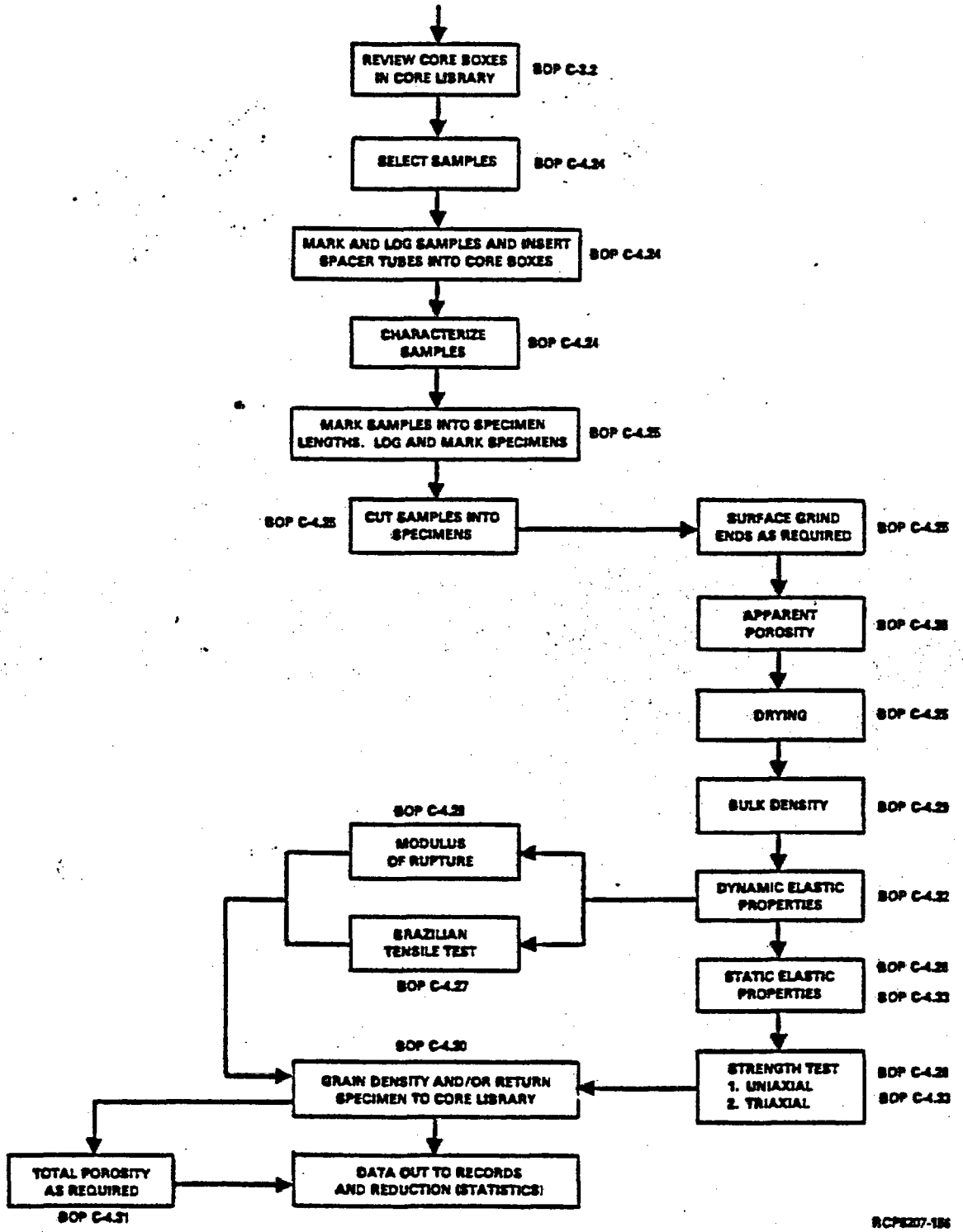


FIGURE 1. Specimen Flow Chart.

Date Issued	Supersedes Issue Dated	To Be Reviewed By	Page	No.
SEPT 1982	NEW	ANNUALLY	11 of 11	C-4.25