

**U.S. DEPARTMENT OF ENERGY
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT**

**PRESENTATION TO
THE NUCLEAR WASTE TECHNICAL REVIEW BOARD**

**SUBJECT: IN SITU MECHANICAL
PROPERTIES TESTING**

PRESENTER: DR. LAURENCE S. COSTIN

**PRESENTER'S TITLE
AND ORGANIZATION: SUPERVISOR,
PERFORMANCE ASSESSMENT APPLICATIONS DIVISION
SANDIA NATIONAL LABORATORY
ALBUQUERQUE, NEW MEXICO**

**PRESENTER'S
TELEPHONE NUMBER: (505) 846-0488**

**REGISTRY HOTEL, DENVER, COLORADO
JUNE 25-27, 1991**

IN SITU MECHANICAL PROPERTIES STUDY

(STUDY PLAN 8.3.1.15.1.7)

PURPOSE:

OBTAIN IN SITU MEASUREMENTS OF MECHANICAL PROPERTIES OF THE ROCK MASS ON AN INTERMEDIATE SCALE

SCP APPROACH:

- PLATE LOADING TESTING**
- ROCK MASS RESPONSE EXPERIMENT**

IN SITU MECHANICAL PROPERTIES STUDY

(CONTINUED)

POST-SCP MODIFICATIONS

- **EXTEND TESTING TO CALICO HILLS**
 - **DESIGN INFORMATION FOR LONG-TERM SUPPORT OF OPENINGS**
 - **ADDITIONAL MODEL VALIDATION DATA**

- **TESTS IN UNITS ABOVE TSw2**
 - **UPPER DBR**
 - **OFF-BLOCK FAULTS**

- **ROCK MASS RESPONSE EXPERIMENTS**
 - **UNIAXIAL RESPONSE**
 - **AMBIENT BLOCK TESTS (BIAXIAL)**
 - **SLOT TESTS**

PLATE LOADING TESTS

OBJECTIVES

- **MEASURE DEFORMATION MODULI**
- **EVALUATE FRACTURING AROUND OPENING**
- **OBTAIN SEVERAL MEASUREMENTS**
 - **10 TO 20 TESTS**
 - **UPPER DBR, MAIN TEST LEVEL, AND CALICO HILLS**

PLATE LOADING TESTS

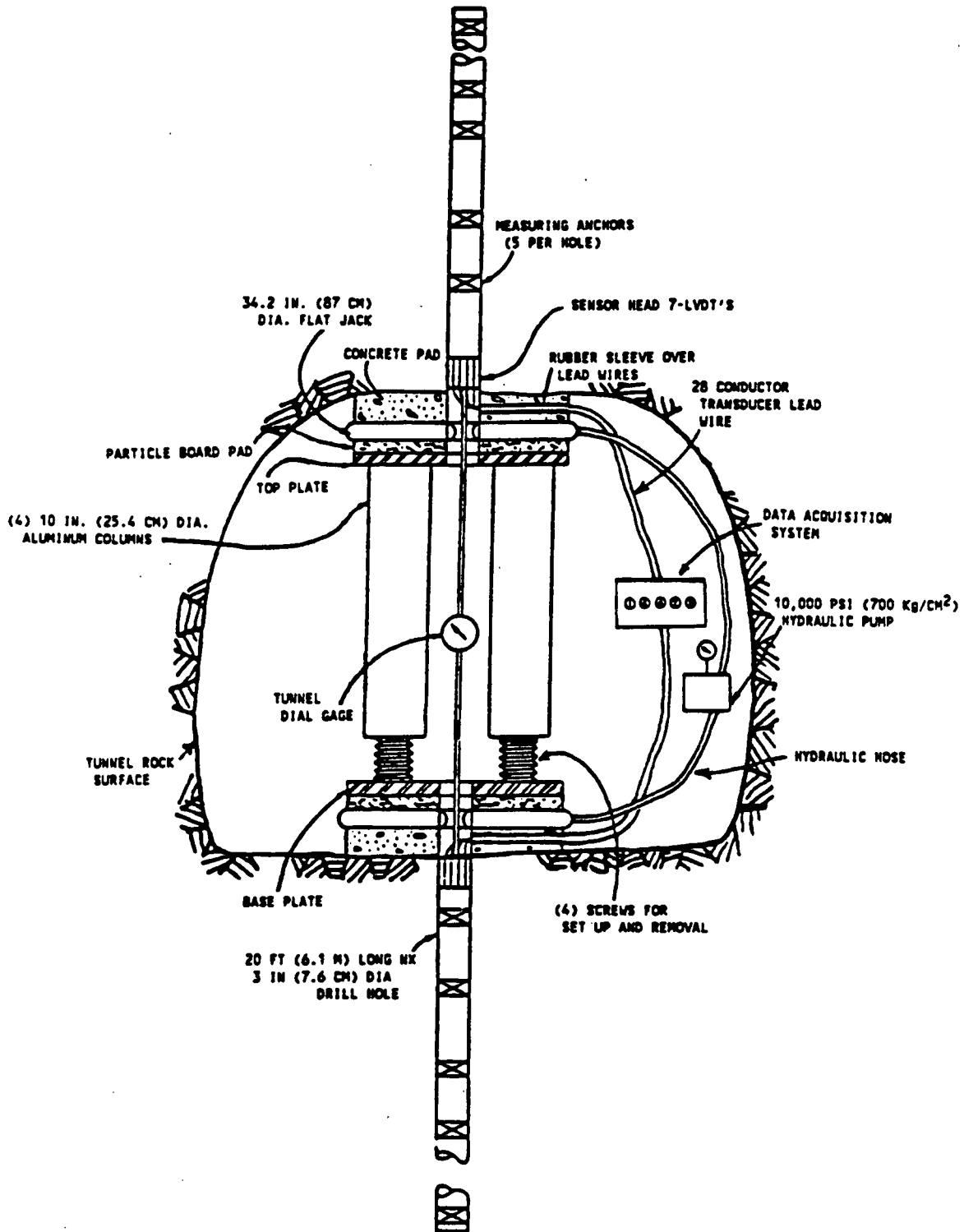
(CONTINUED)

DESCRIPTION OF TEST

- **ISRM AND USBR STANDARD TEST**
- **UNIAXIAL SURFICIAL LOADING WITH
FLAT JACKS**
- **DISPLACEMENTS WITH MPBX AND ROD
EXTENSOMETERS**

PLATE LOADING

DESCRIPTION OF TEST



PHOTOGRAPH OF MULTIPOINT BOREHOLE EXTENSOMETER (MPBX)

**PHOTOGRAPH OF
PLATE LOADING TEST**

PLATE LOADING TESTS

(CONTINUED)

DATA ANALYSIS AND USE

- FROM ELASTICITY THEORY

$$W_{z=0} = \frac{2(1 + \nu^2)}{E} q a$$

- W_z = DISPLACEMENT IN DIRECTION OF APPLIED PRESSURE
- ν = POISSON'S RATIO
- E = MODULUS OF ELASTICITY (DEFORMATION)
- q = PRESSURE
- a = RADIUS OF LOADED AREA

- CORRECTION FOR THE CENTRAL HOLE CAN BE MADE AND DEFORMATION MODULUS BETWEEN ANY TWO POINTS CAN BE OBTAINED

PLATE LOADING TESTS

(CONTINUED)

PREVIOUS EXPERIENCE

- **NO PROTOTYPE TESTS PLANNED**
- **TEST PARAMETERS IMPORTANT FOR ESF**
 - **GEOMETRY**
 - **LOAD CAPACITY**
 - **OBSTRUCTION AND TIME**

ROCK MASS RESPONSE EXPERIMENTS

OBJECTIVES

- **MEASURE ROCK MASS RESPONSE THROUGH INTERMEDIATE-SCALE FIELD EXPERIMENTS**
- **EVALUATE SCALE EFFECTS**
- **EFFECT OF JOINTS**
- **PROVIDE DATA FOR PRELIMINARY MODEL VALIDATION STUDIES**
- **MULTIPLE TESTS**
 - **MAIN TEST LEVEL AND CALICO HILLS**
- **DUPLICATION OF INFORMATION FROM DIFFERENT TESTS**

ROCK MASS RESPONSE EXPERIMENTS

(CONTINUED)

EXPERIMENTS INCLUDE:

- **COMPRESSION TESTS**
- **BLOCK TESTS**
- **SLOT TESTS**

TEST DESCRIPTION

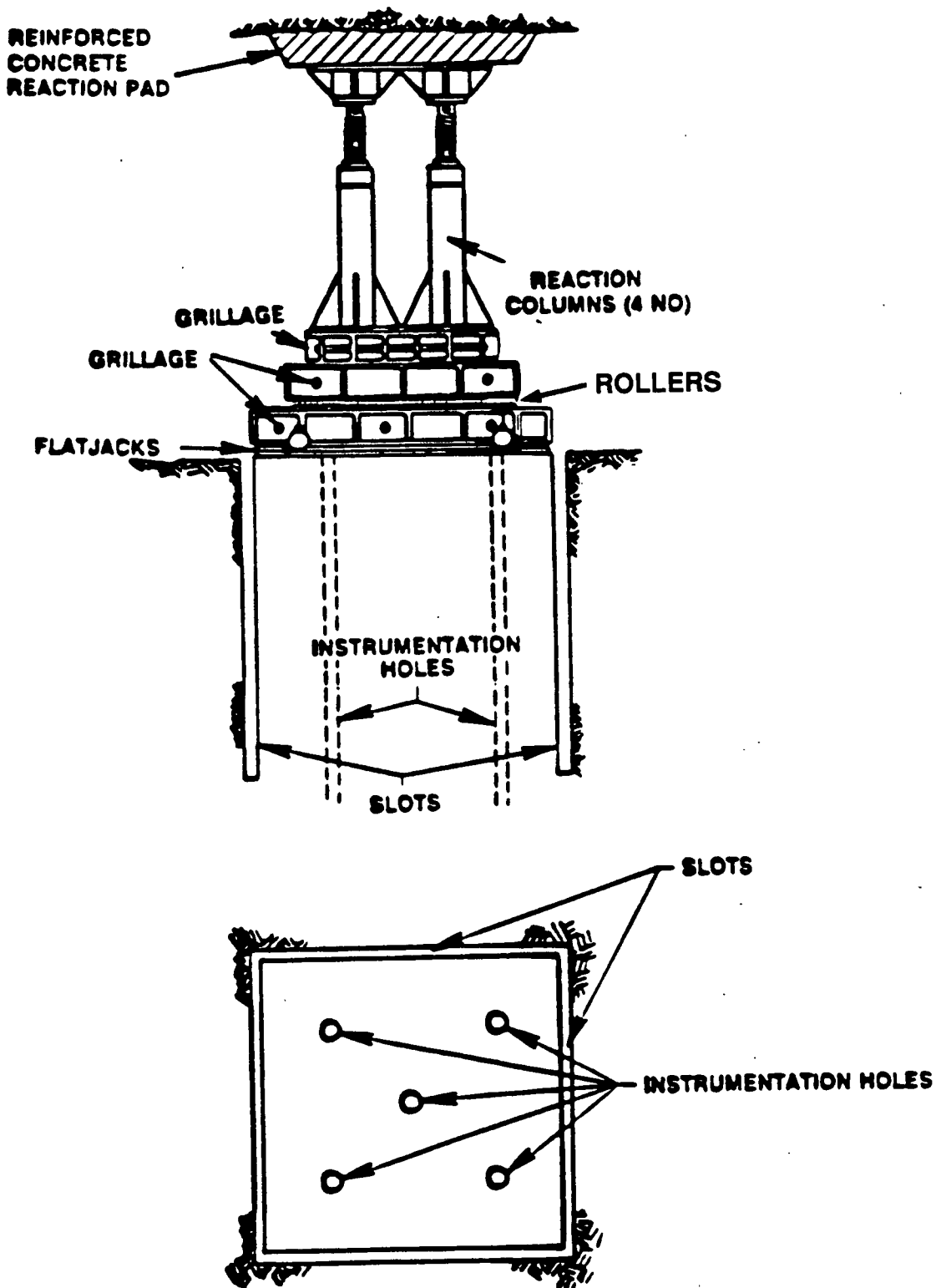
COMPRESSION TEST

- **SLOTS - ISOLATE 1.0 x 1.0 x 2.0 M BLOCK**

- **INSTRUMENTS**
 - **FIVE AXIAL BOF-EX MPBXs**
 - **ACOUSTIC EMISSION**
 - **DISPLACEMENT TRANSDUCERS AT RIGHT ANGLES TO THE BLOCK**

- **LOADING FRAME**
 - **LOAD APPLIED BY FLAT JACKS**
 - **MAY INCLUDE CONFINED TESTS AS SECOND STAGE**

UNIAXIAL ROCK MASS STRENGTH TEST



TEST DESCRIPTION

(CONTINUED)

BLOCK TEST

- **SLOTS - ISOLATE 1.0 x 1.0 x 2.0 M BLOCK**

- **INSTRUMENTS**
 - **SURFACE DISPLACEMENT GAGES**
 - **STRESS GAGES**
 - **ACOUSTIC EMISSION**

- **LOADING**
 - **FOUR FLAT JACKS, INDEPENDENTLY PRESSURIZED**
 - **MAY BE COMBINED WITH AXIAL LOADING**

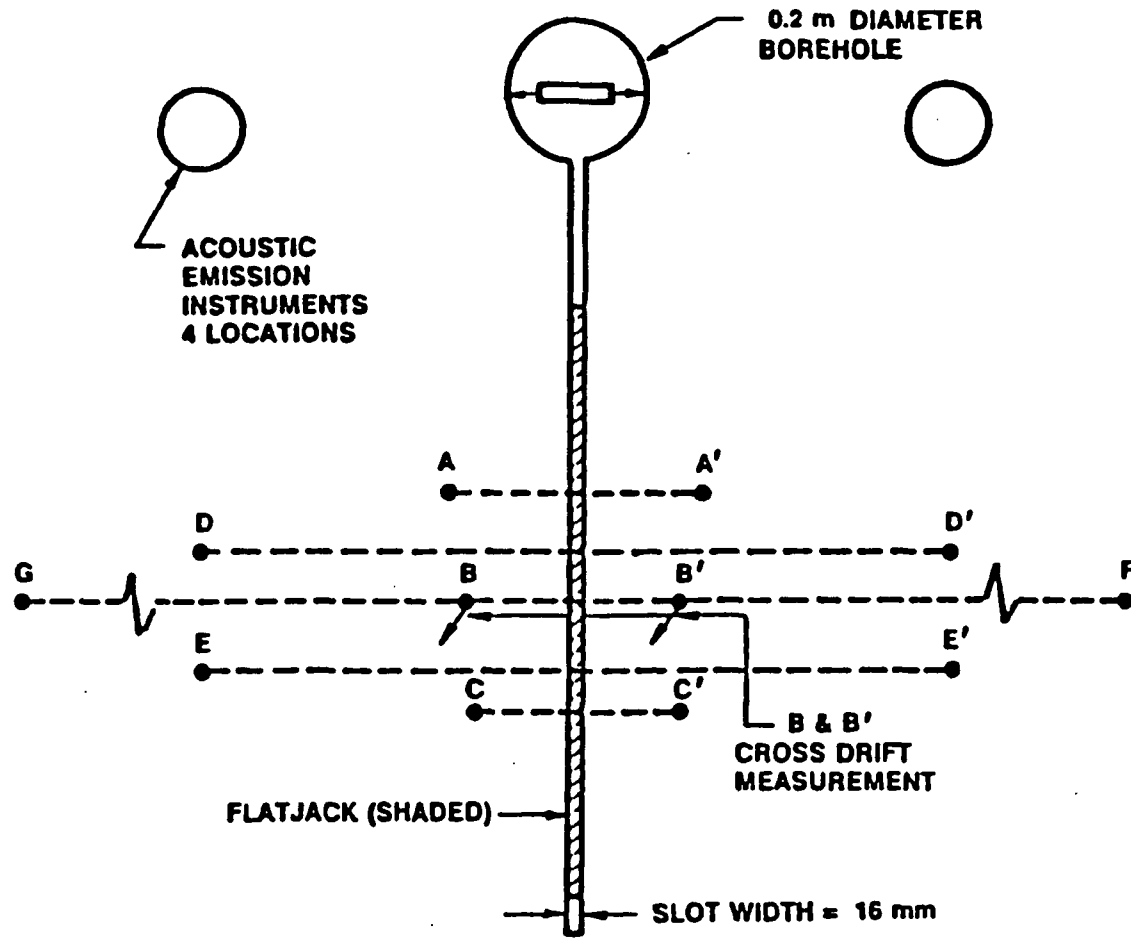
TEST DESCRIPTION

(CONTINUED)

SLOT TESTS

- **SINGLE SLOT 1 x 1 x 1**
- **INSTRUMENTS**
 - **SURFACE DISPLACEMENT GAGES**
 - **CROSS-DRIFT DISPLACEMENT GAGES**
 - **ACOUSTIC EMISSION**
- **SINGLE OR MULTIPLE (SANDWICH) FLAT JACKS**

G-TUNNEL SLOT TEST



ROCK MASS RESPONSE EXPERIMENTS

PREVIOUS EXPERIENCE

- **PROTOTYPE TESTS**

- **BLOCK TEST**
- **SLOT TESTS**

- **IMPORTANT TEST PARAMETERS**

- **GEOMETRY - ORIENTATION WITH RESPECT TO JOINT SETS**
- **LOAD CAPACITY**

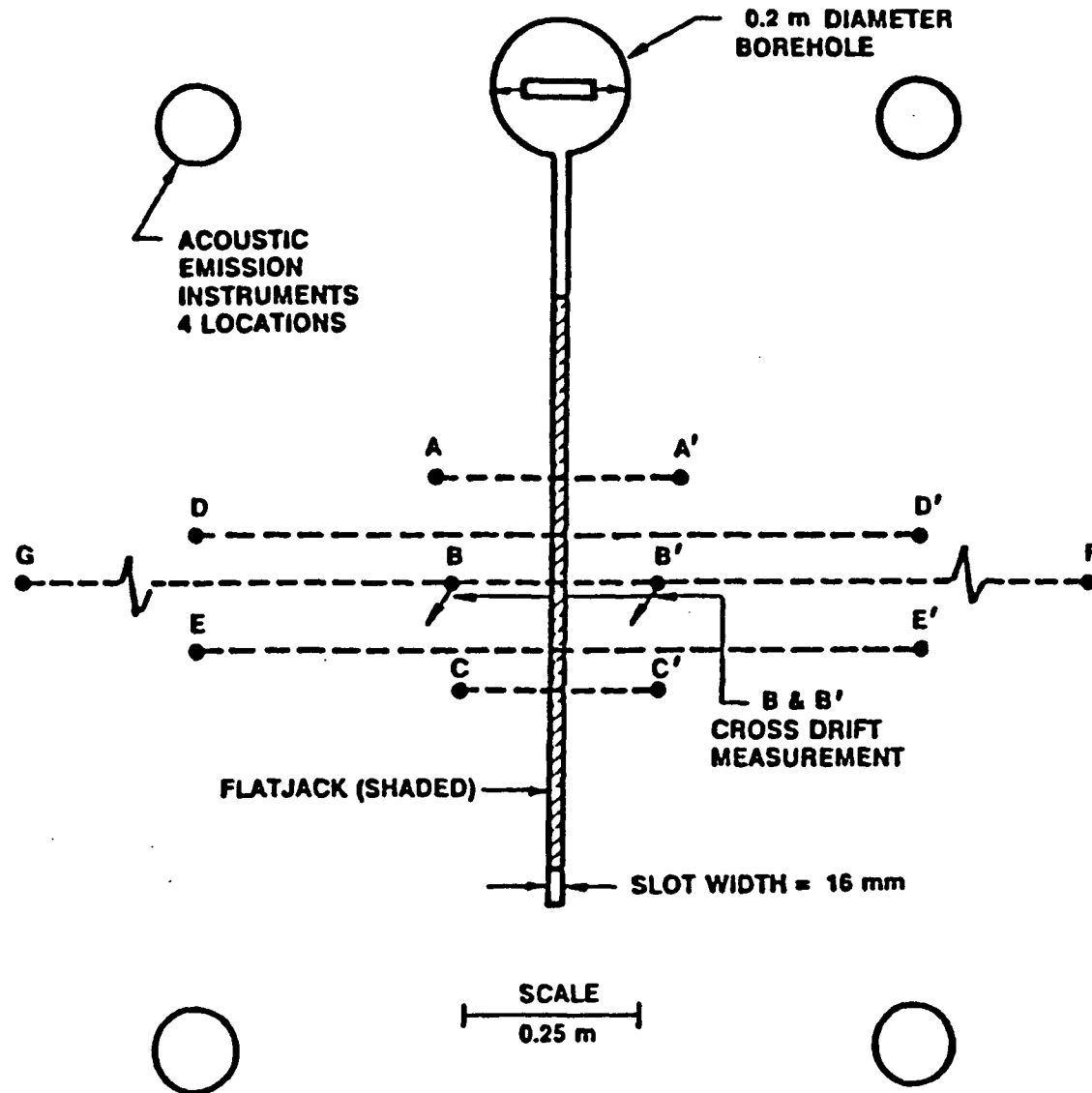
ROCK MASS RESPONSE EXPERIMENTS

(CONTINUED)

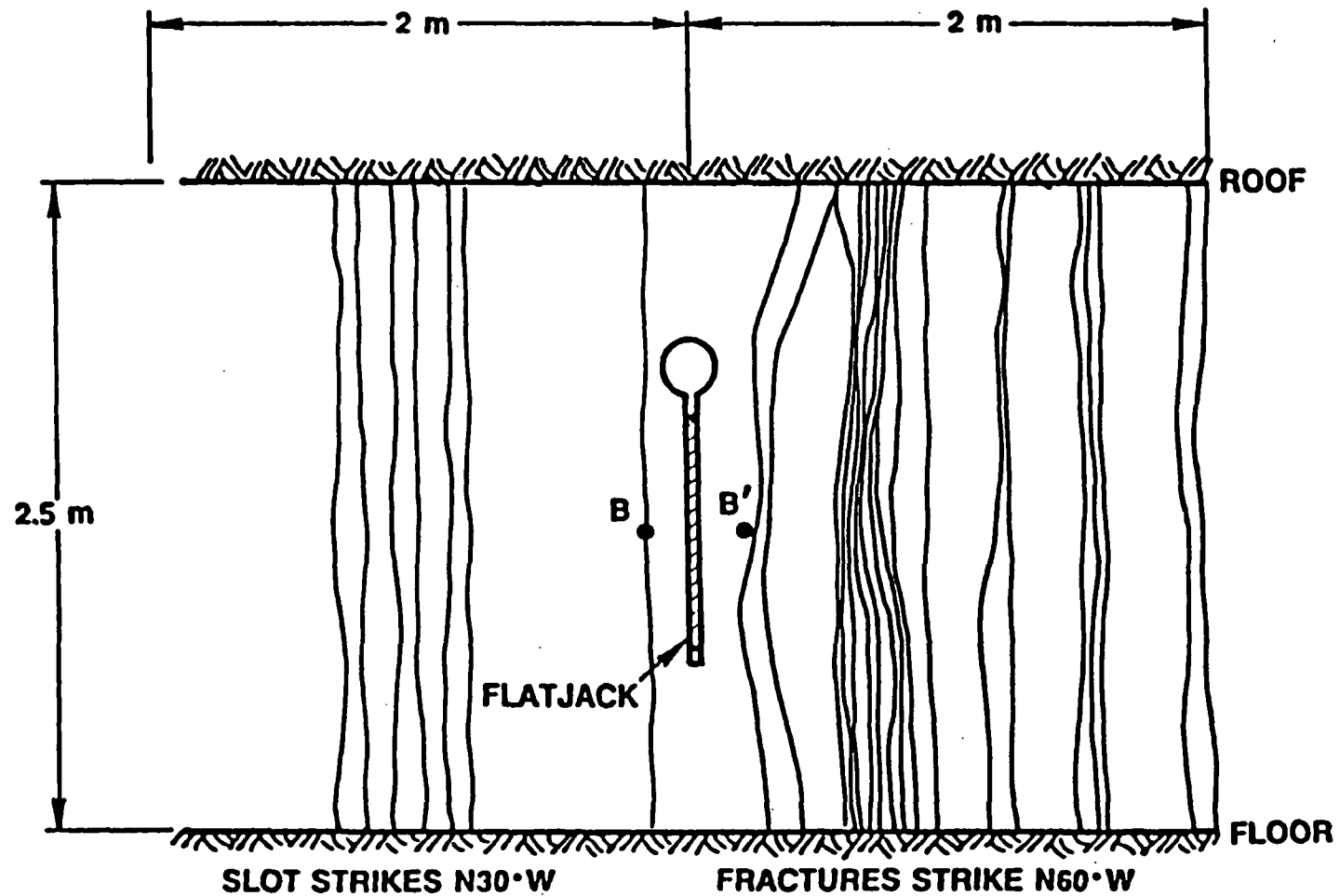
EXAMPLE - SLOT TEST

- **G-TUNNEL WELDED TUFF**
- **ORIENTATION - 30° TO PRINCIPAL JOINT STRIKE**
- **STARTER HOLE FOR CHAIN SAW**
- **30 MPA MAXIMUM FLAT JACK PRESSURE**
- **ANALYSES**
 - **2-D JOINTED ROCK MASS (CONTINUUM) MODEL**
 - **3-D DISCRETE JOINT MODEL**

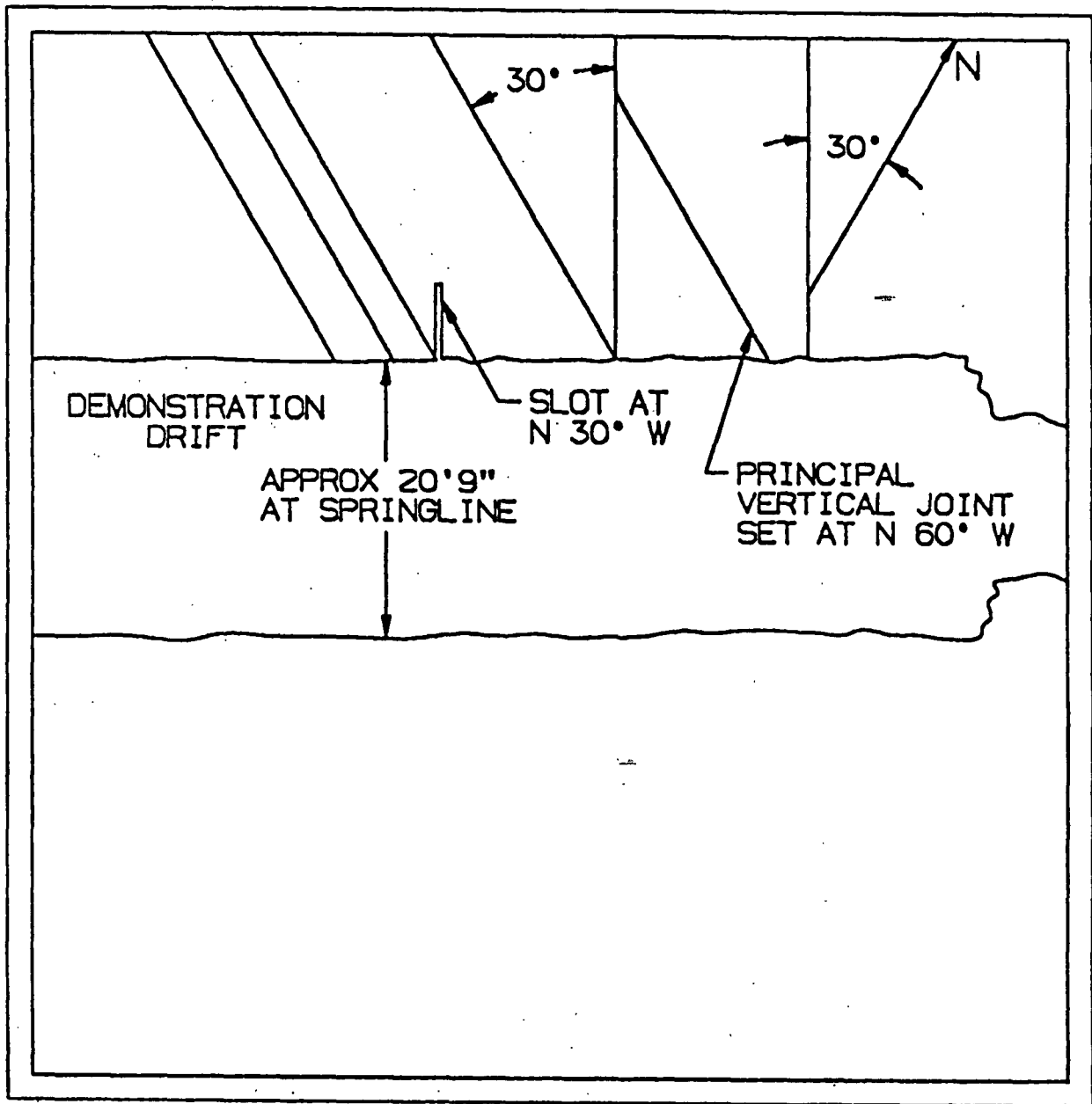
G-TUNNEL SLOT TEST



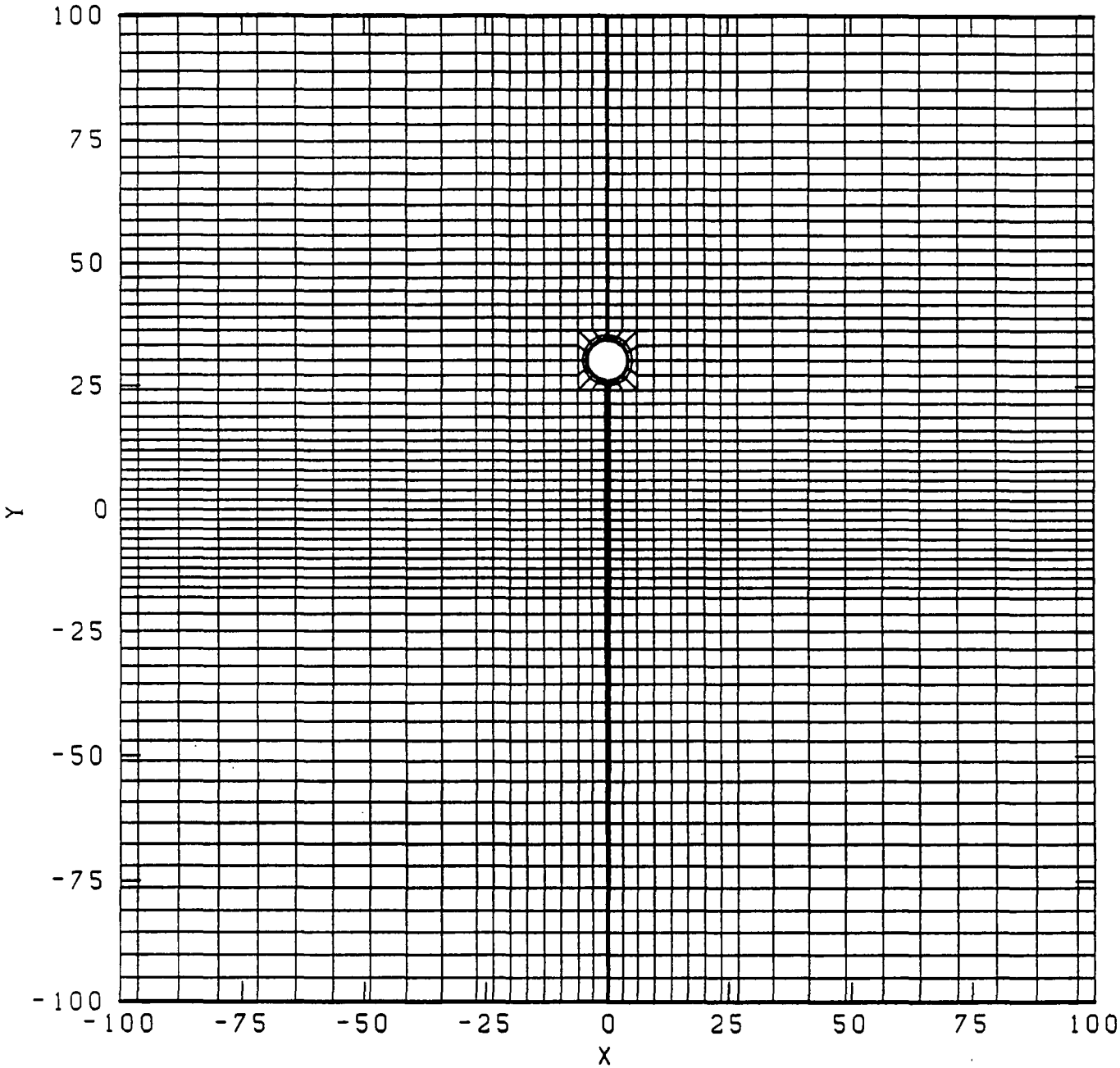
CROSS-SECTIONAL VIEW OF SLOT TEST



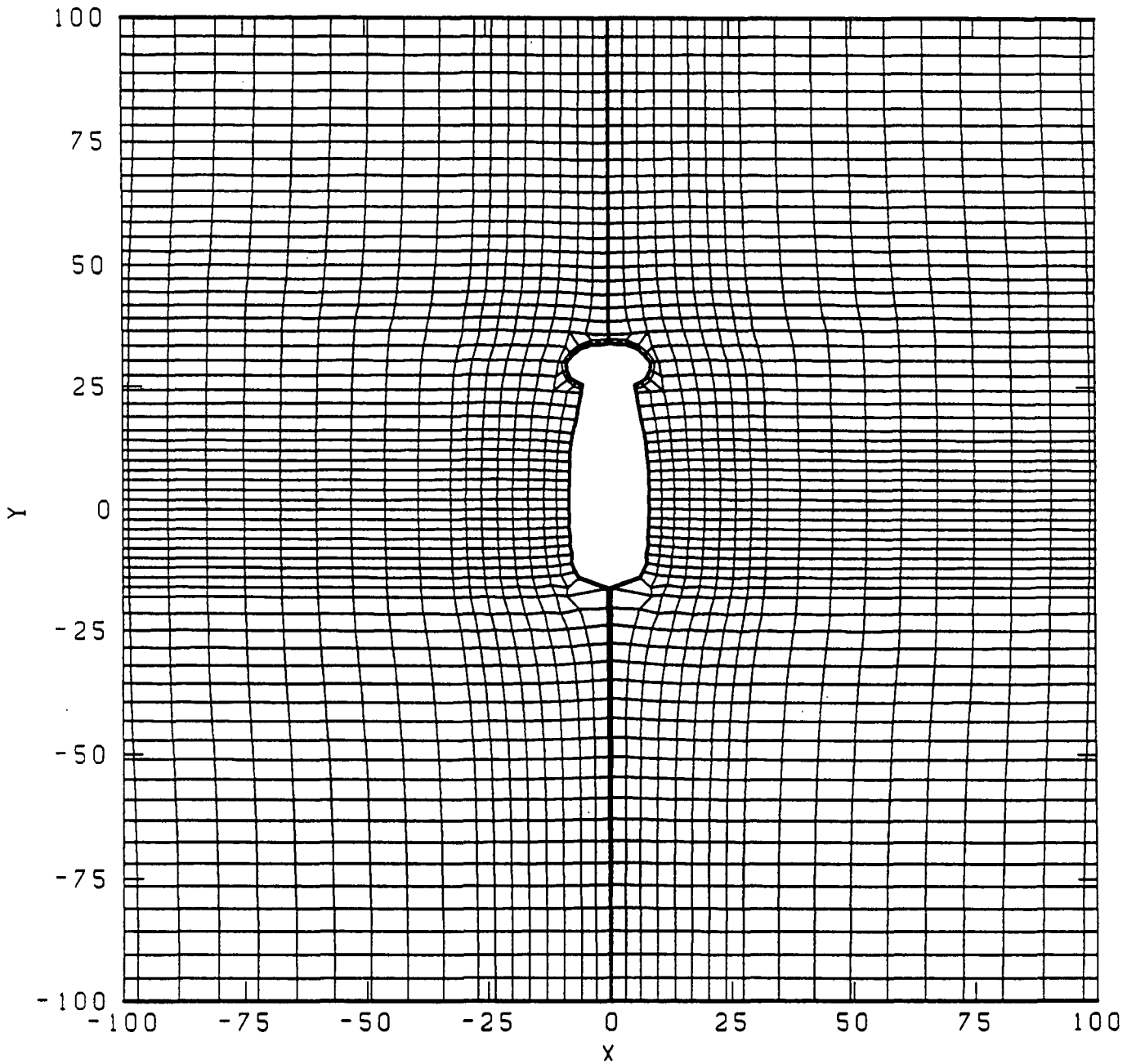
PLAN VIEW OF SLOT TEST



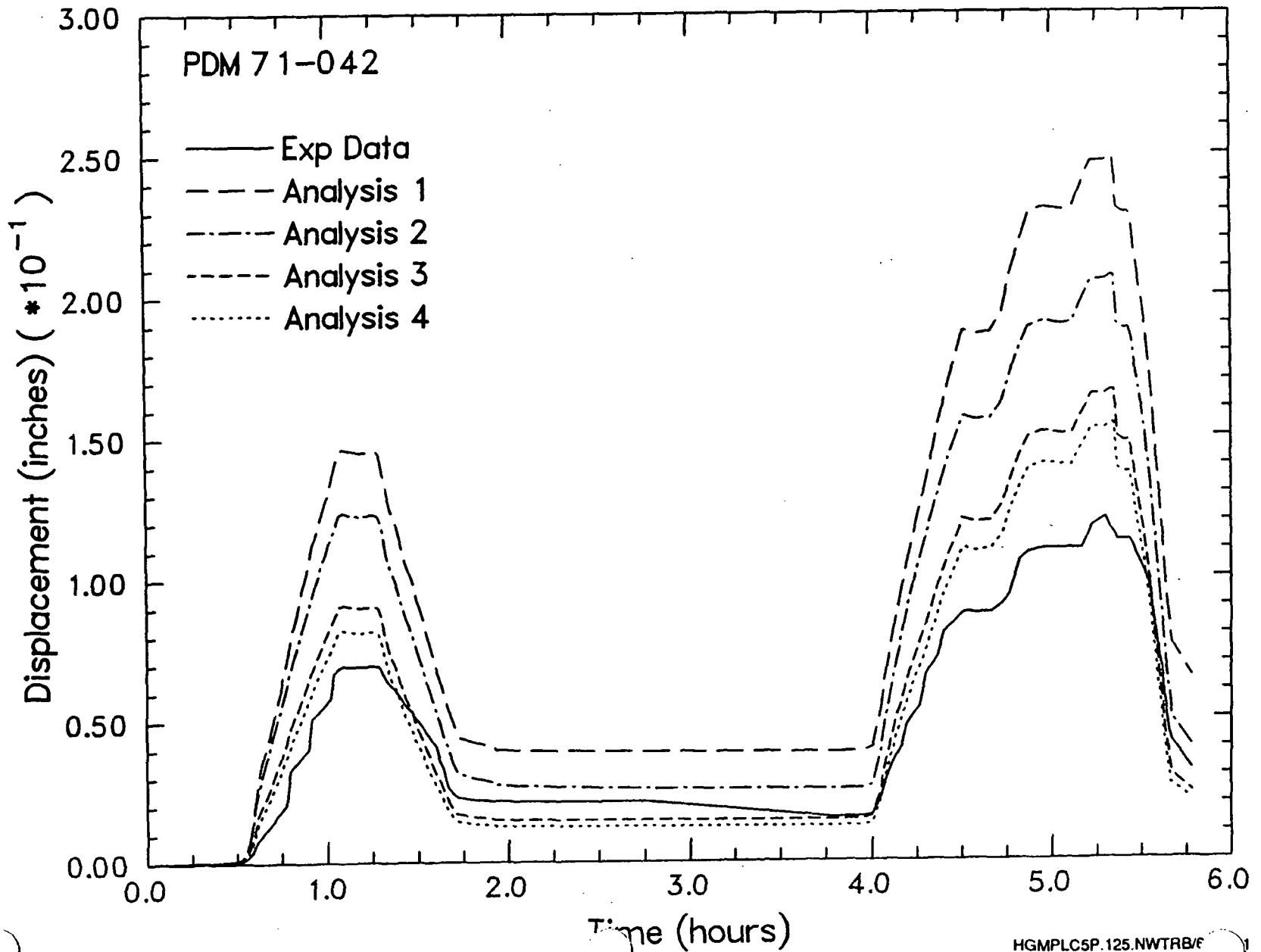
2-D ANALYSIS FINITE ELEMENT MESH



● RESULTS OF 2-D FINITE ELEMENT ANALYSIS

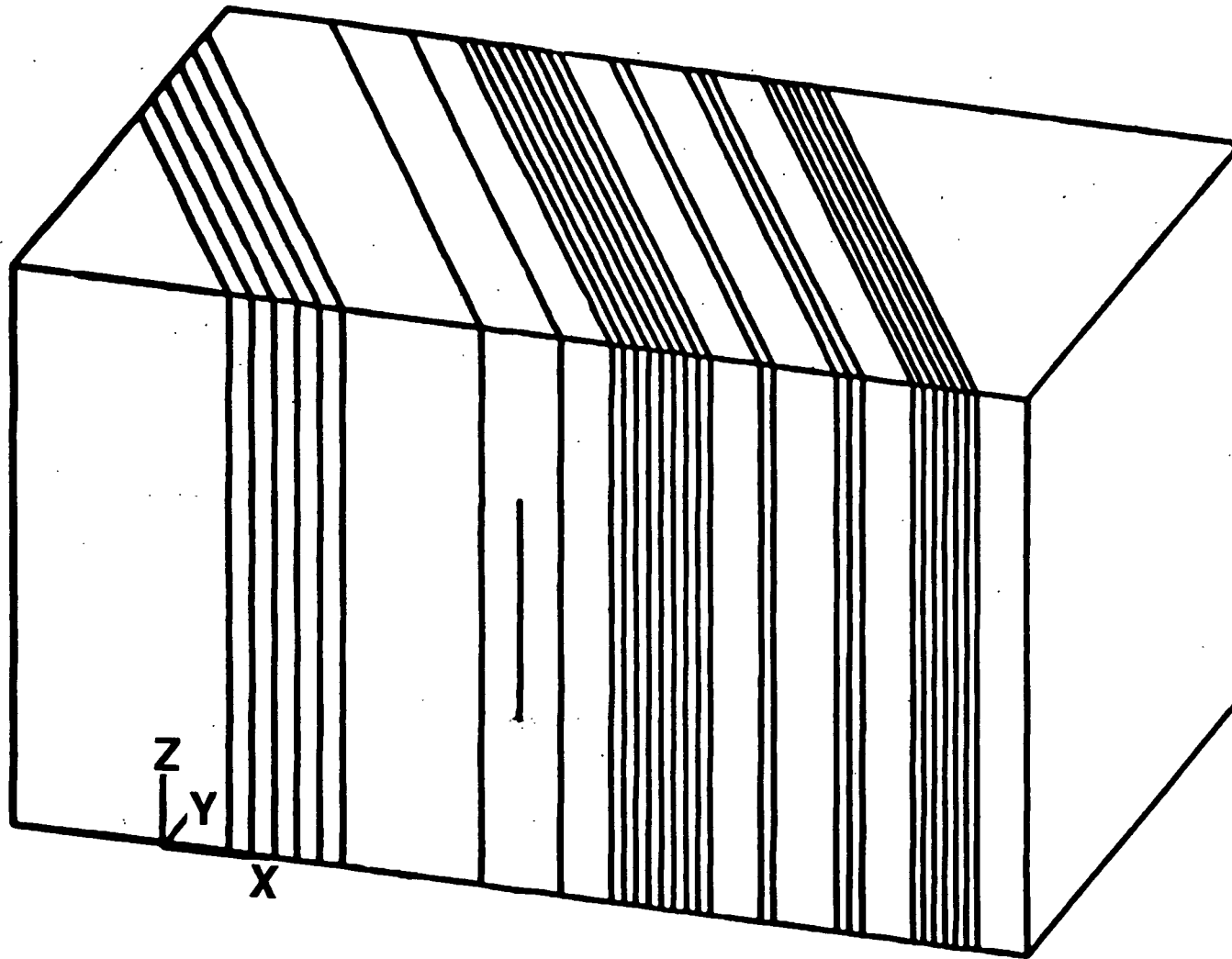


DISPLACEMENT AT GAGE LOCATION A - A'

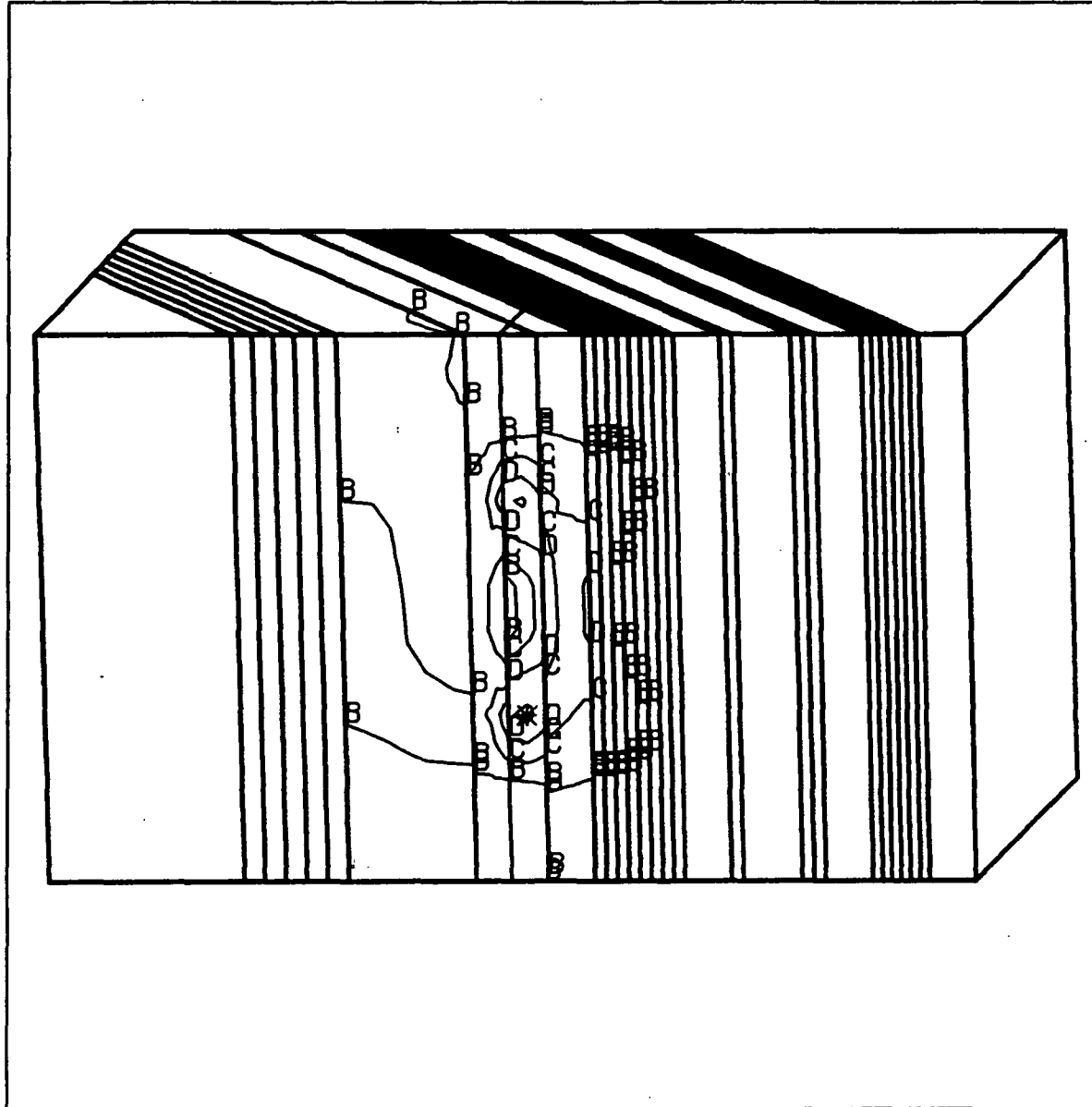


**PHOTOGRAPH OF
G-TUNNEL SLOT TEST**

3-D FINITE ELEMENT MODEL



3-D FINITE ELEMENT RESULTS



CREATED BY JAC3D 04
08/30/90 08:43:31
MODIFIED BY ALGEBRA
05/22/91 09:26:41
DRAWN BY BLOT
06/06/91 15:34:07

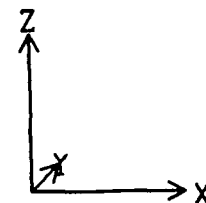
MAGNIFIED BY 1.000
ELEMENT BLOCKS ACTIVE:
34 OF 34

SMAX

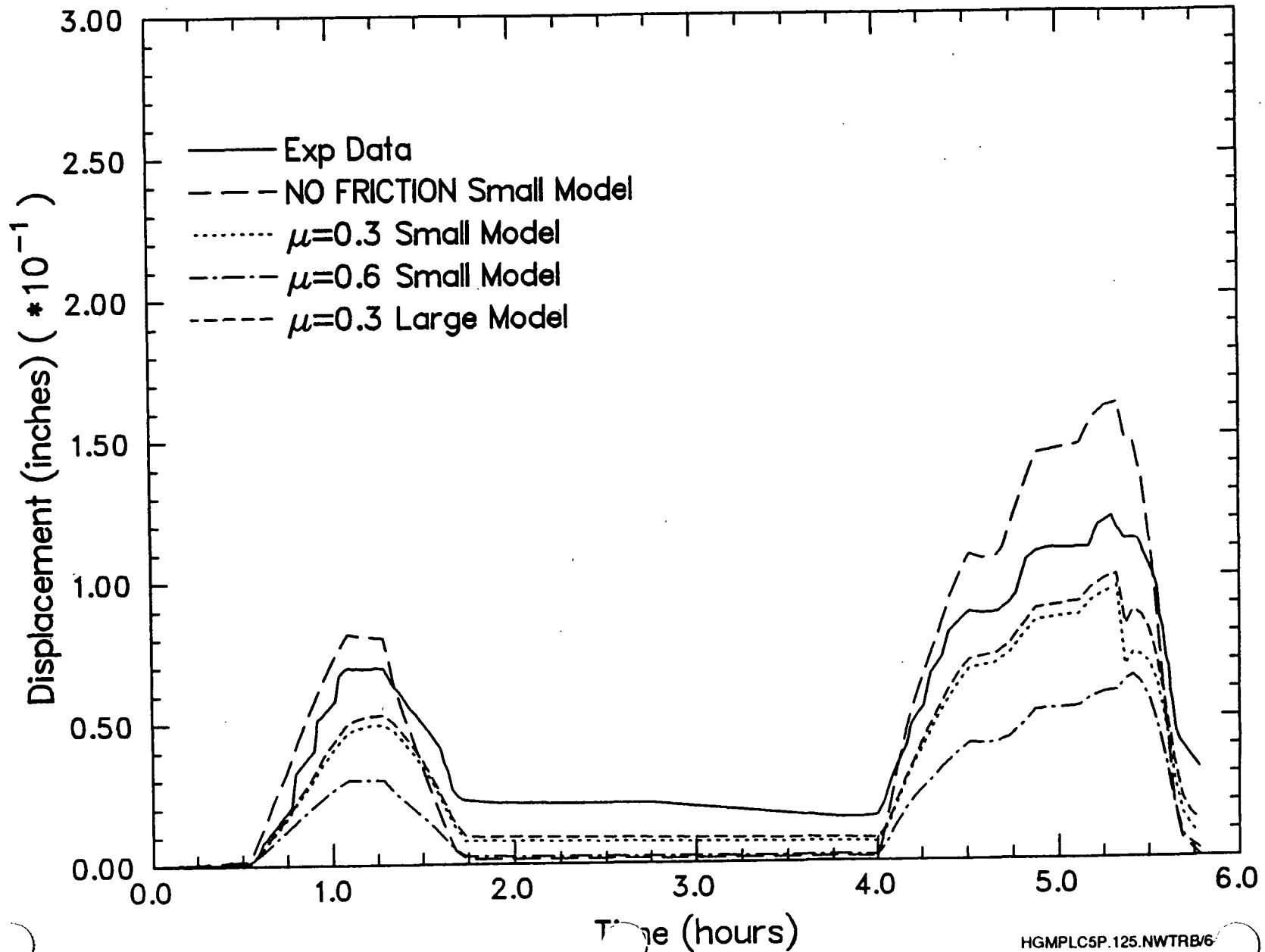
A = -0.500E+3
B = 0.500E+3
C = 1.500E+3
D = 2.500E+3
E = 3.500E+3
F = 4.500E+3

⊕ = -1.160E+3
* = 3.837E+3

TIME 5.328



DISPLACEMENT AT GAGE LOCATION A - A'



SITE CHARACTERIZATION - ROCK MECHANICS

PARAMETER VALUES

STATISTICAL CONFIDENCE

SPATIAL VARIABILITY

CODE VALIDATION

	LABORATORY	FIELD
	MANY	FEW
	X	
	X	MAYBE
	FEW	X

PLANNED LAB PROPERTIES TESTS

- **LABORATORY DETERMINATION OF MECHANICAL PROPERTIES OF INTACT ROCK**
 - **COMPRESSIVE MECHANICAL PROPERTIES AT BASELINE EXPERIMENT CONDITIONS**
 - **EFFECTS OF VARIABLE ENVIRONMENTAL CONDITIONS**

- **LABORATORY DETERMINATION OF MECHANICAL PROPERTIES OF FRACTURES**
 - **MECHANICAL PROPERTIES AT BASELINE EXPERIMENT CONDITIONS**
 - **EFFECTS OF VARIABLE ENVIRONMENTAL CONDITIONS**

- **LABORATORY THERMAL PROPERTIES**
 - **DENSITY AND POROSITY**
 - **VOLUMETRIC HEAT CAPACITY**
 - **THERMAL CONDUCTIVITY**

- **LABORATORY THERMAL EXPANSION TESTING**

SAMPLING FOR THERMAL AND MECHANICAL PROPERTIES

- **COORDINATED WITH OTHER SAMPLING/ DRILLING NEEDS**
- **DESIGNED TO PROVIDE STATISTICAL AND SPATIAL INFORMATION**
- **TAKE INTO ACCOUNT**
 - **EXISTING DATA (HIGH NATURAL VARIABILITY, UNITS, etc.)**
 - **DESIRED GOALS AND CONFIDENCE LEVELS OF DESIGNERS/ ANALYSTS**
 - **NEED FOR A REALISTIC INITIAL PROGRAM**

LABORATORY THERMAL PROPERTIES

● PARAMETERS MEASURED

- GRAIN DENSITY, POROSITY, THERMAL CONDUCTIVITY, HEAT CAPACITY

● MEASUREMENT LOCATIONS

- SIX CORE HOLES, TWO RAMP ACCESSSES AND DRIFTS (TBD) IN ESF, VICINITY OF *IN SITU* TESTS

● SITE CHARACTERIZATION CONTRIBUTIONS

- ROCK-MASS THERMAL CONDUCTIVITY FOR HEAT-TRANSFER CALCULATIONS, HEAT-FLOW ESTIMATES
- ROCK-MASS HEAT CAPACITY FOR HEAT-TRANSFER CALCULATIONS
- ROCK-MASS BULK DENSITY FOR HEAT-TRANSFER CALCULATIONS, ESTIMATION OF VERTICAL *IN SITU* STRESS, ESTIMATION OF RADIOLOGICAL SHIELDING PROPERTIES

LABORATORY THERMAL EXPANSION

- **PARAMETERS MEASURED**

- COEFFICIENT OF LINEAR THERMAL EXPANSION

- **MEASUREMENT LOCATIONS**

- SIX CORE HOLES, TWO RAMP ACCESSES AND DRIFTS (TBD) IN ESF, VICINITY OF *IN SITU* TESTS

- **SITE CHARACTERIZATION CONTRIBUTIONS**

- ROCK-MASS THERMAL-EXPANSION BEHAVIOR FOR ESTIMATION OF THERMALLY INDUCED STRESSES AND RELATED STABILITY ANALYSES

LAB MECHANICAL PROPERTIES OF INTACT ROCK

- **PARAMETERS MEASURED**

- **YOUNG'S MODULUS, POISSON'S RATIO, STRENGTH, COHESION, INTERNAL FRICTION ANGLE**

- **MEASUREMENT LOCATIONS**

- **SIX CORE HOLES, TWO RAMP ACCESSSES AND DRIFTS (TBD) IN ESF, VICINITY OF *IN SITU* TESTS**

- **SITE CHARACTERIZATION CONTRIBUTIONS**

- **INTACT-ROCK MECHANICAL PROPERTIES FOR ESTIMATION OF ROCK-MASS RESPONSE TO *IN SITU* AND THERMAL LOADS AND FOR STABILITY ANALYSES**

LAB MECHANICAL PROPERTIES OF FRACTURES

- **PARAMETERS MEASURED**

- **NORMAL STIFFNESS, SHEAR STIFFNESS, COHESION,
COEFFICIENT OF FRICTION, SURFACE ROUGHNESS**

- **MEASUREMENT LOCATIONS**

- **SIX CORE HOLES, TWO RAMP ACCESSSES AND DRIFTS
(TBD) IN ESF, VICINITY OF *IN SITU* TESTS**

- **SITE CHARACTERIZATION CONTRIBUTIONS**

- **FRACTURE MECHANICAL PROPERTIES FOR ESTIMATION OF
ROCK-MASS RESPONSE TO *IN SITU* AND THERMAL LOADS
AND FOR STABILITY ANALYSES**