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

PRESENTATION TO THE NUCLEAR WASTE TECHNICAL REVIEW BOARD

SUBJECT: EXCAVATION INVESTIGATIONS

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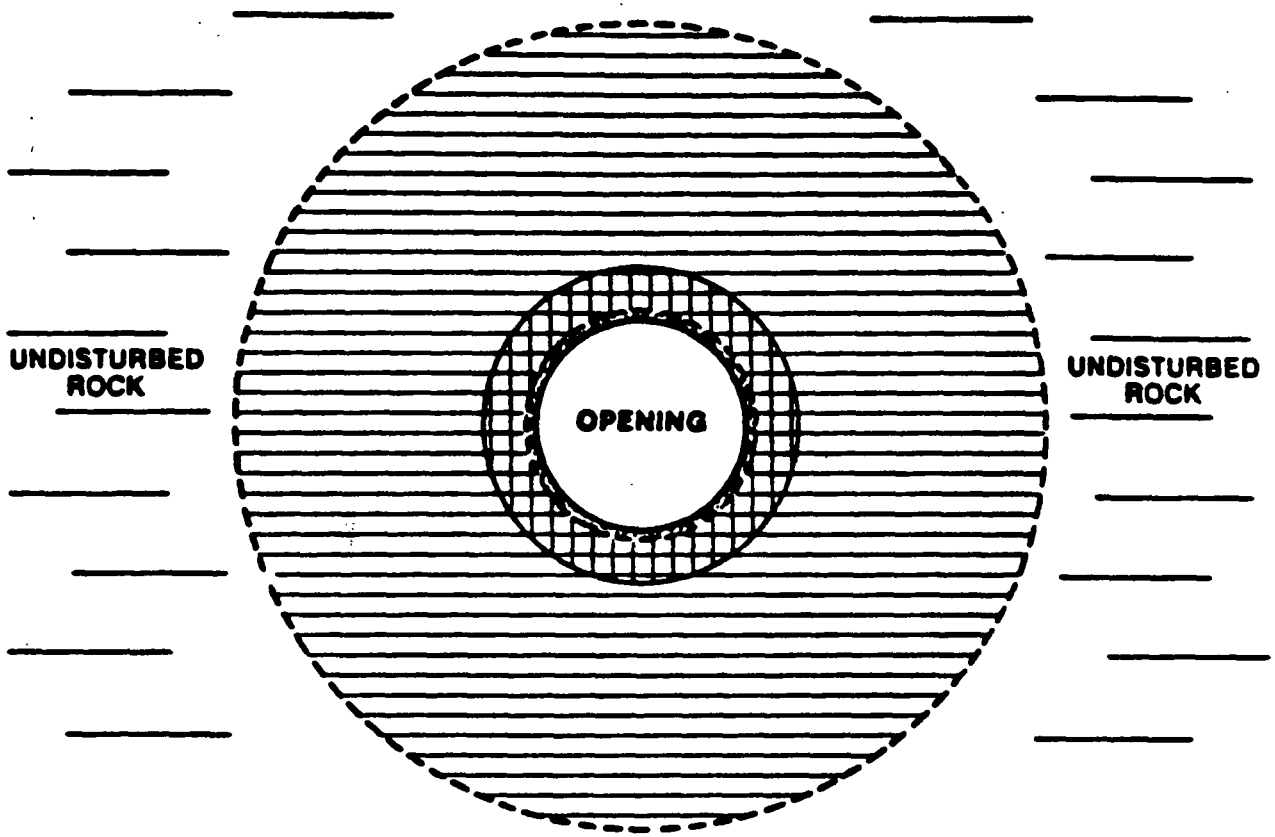
REGISTRY HOTEL, DENVER, COLORADO
JUNE 25-27, 1991

EXCAVATION INVESTIGATIONS STUDY

OBJECTIVES OF THE STUDY
(STUDY PLAN 8.3.1.15.1.5)

- **PROVIDE DATA TO HELP VALIDATE MODELS USED TO PREDICT ROCK MASS MECHANICAL BEHAVIOR**
  - **LARGEST SCALE**
  - **EXTENT OF STRESS-ALTERED REGION**
- **DEMONSTRATE CONSTRUCTABILITY OF THE REPOSITORY**

DISTURBED ZONE AROUND AN UNDERGROUND OPENING



EXCAVATION INVESTIGATIONS STUDY

(CONTINUED)

SCP APPROACH

- SHAFT CONVERGENCE EXPERIMENT
- DEMONSTRATION BREAKOUT ROOMS EXPERIMENT
- SEQUENTIAL DRIFT MINING EXPERIMENT

EXCAVATION INVESTIGATIONS STUDY

(CONTINUED)

POST-SCP MODIFICATIONS

- SHAFT CONVERGENCE - ACCESS CONVERGENCE
  - LESS EMPHASIS ON SHORT-TERM RESPONSE
  - MORE EMPHASIS ON EXTENT OF ALTERED REGIONS NEAR FAULTS AND IN UNITS ABOVE THE TSw2
  - RAMP TO CALICO HILLS
  - IN SITU STRESS MEASUREMENTS FROM ANGLED BOREHOLES
- DEMONSTRATION BREAKOUT ROOMS
  - LOWER ROOM MAY NOT BE NECESSARY EXCEPT TO PROVIDE SPACE FOR OTHER TESTS
  - MECHANICAL EXCAVATION DEMONSTRATION
- SEQUENTIAL DRIFT MINING
  - MECHANICAL EXCAVATION

ACCESS CONVERGENCE EXPERIMENT

OBJECTIVES

- MEASURE IN SITU STRESS AND STRESS CHANGES
- MEASURE DEFORMATION OF ROCK MASS SURROUNDING THE OPENING

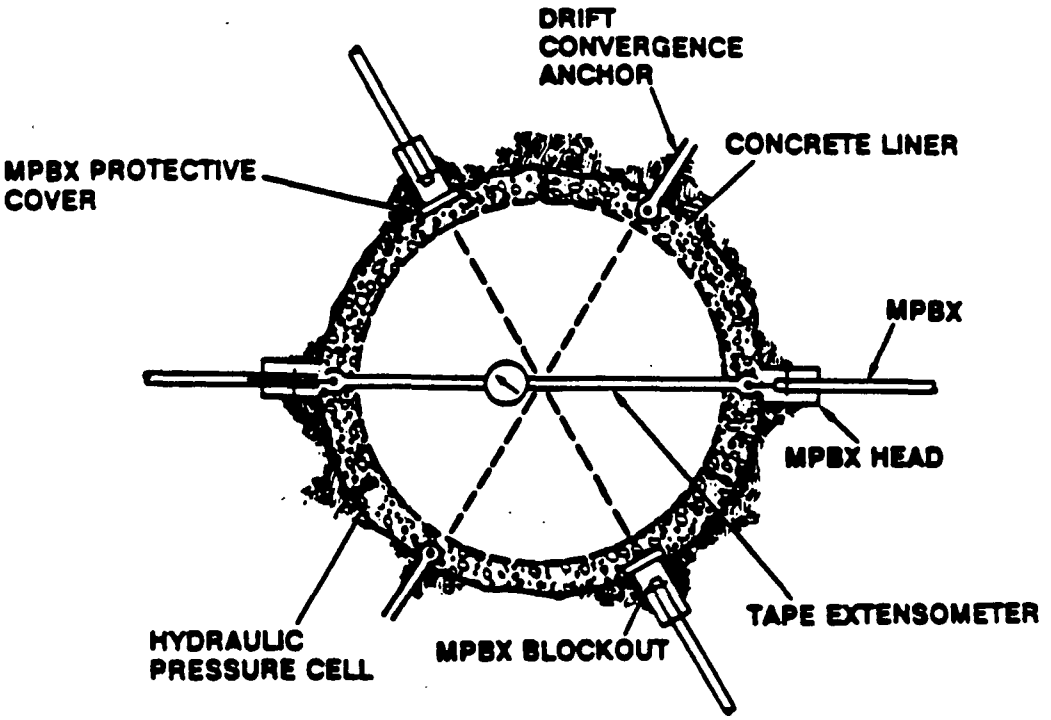
ACCESS CONVERGENCE EXPERIMENT

(CONTINUED)

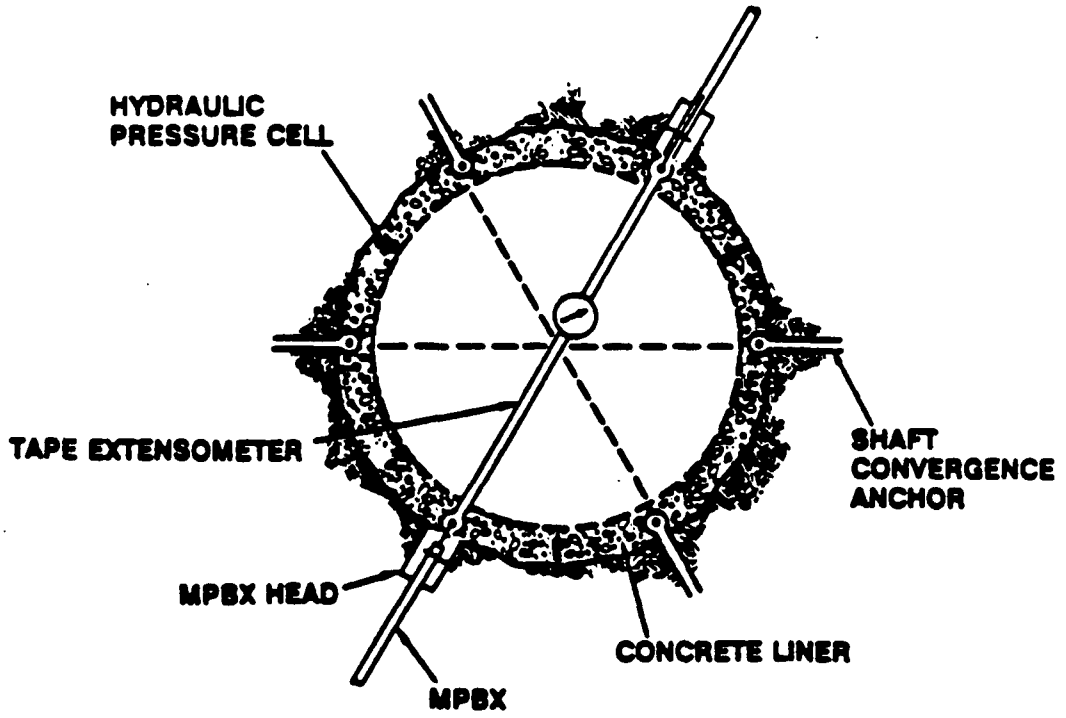
TEST DESCRIPTION

- MEASUREMENT STATIONS
  - EACH MAJOR UNIT
  - NEAR FAULTS
- EACH MEASUREMENT LEVEL INCLUDES THE SAME MEASUREMENTS
- IN SITU STRESS MEASUREMENTS USING OVERCOVERING TECHNIQUE AT EACH STATION
- 6-MPBXs, 12 TAPE EXTENSOMETER ANCHORS WILL BE USED AT EACH STATION

ACCESS CONVERGENCE MEASUREMENTS



UPPER MEASUREMENT LEVEL



LOWER MEASUREMENT LEVEL

SHAFT CONVERGENCE

PREVIOUS EXPERIENCE

PROTOTYPE

- NO FORMAL PROTOTYPE EXPERIMENT
- INSTRUMENTS HAVE BEEN EVALUATED IN:
  - G-TUNNEL
  - MPBX
  - TAPE EXTENSOMETER
  - HYDRAULIC PRESSURE CELLS

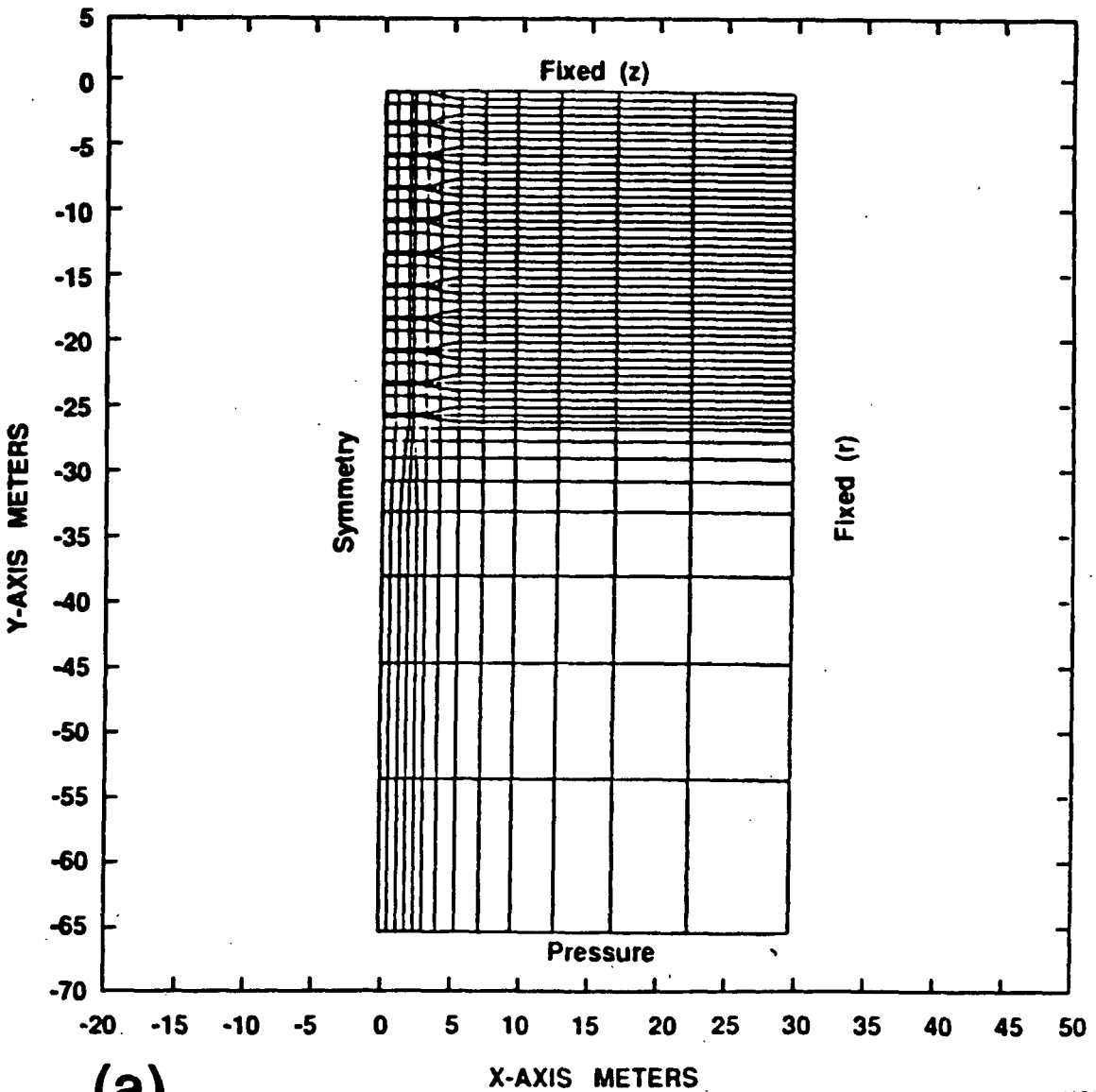
ANALYSES

- PRE-TEST ANALYSES FOR THE SHAFT WERE COMPLETED

REVISIONS

- RAMP ACCESS
- MACHINE BORING

FINITE ELEMENT MESH FOR SHAFT EXCAVATION ANALYSIS



(a)

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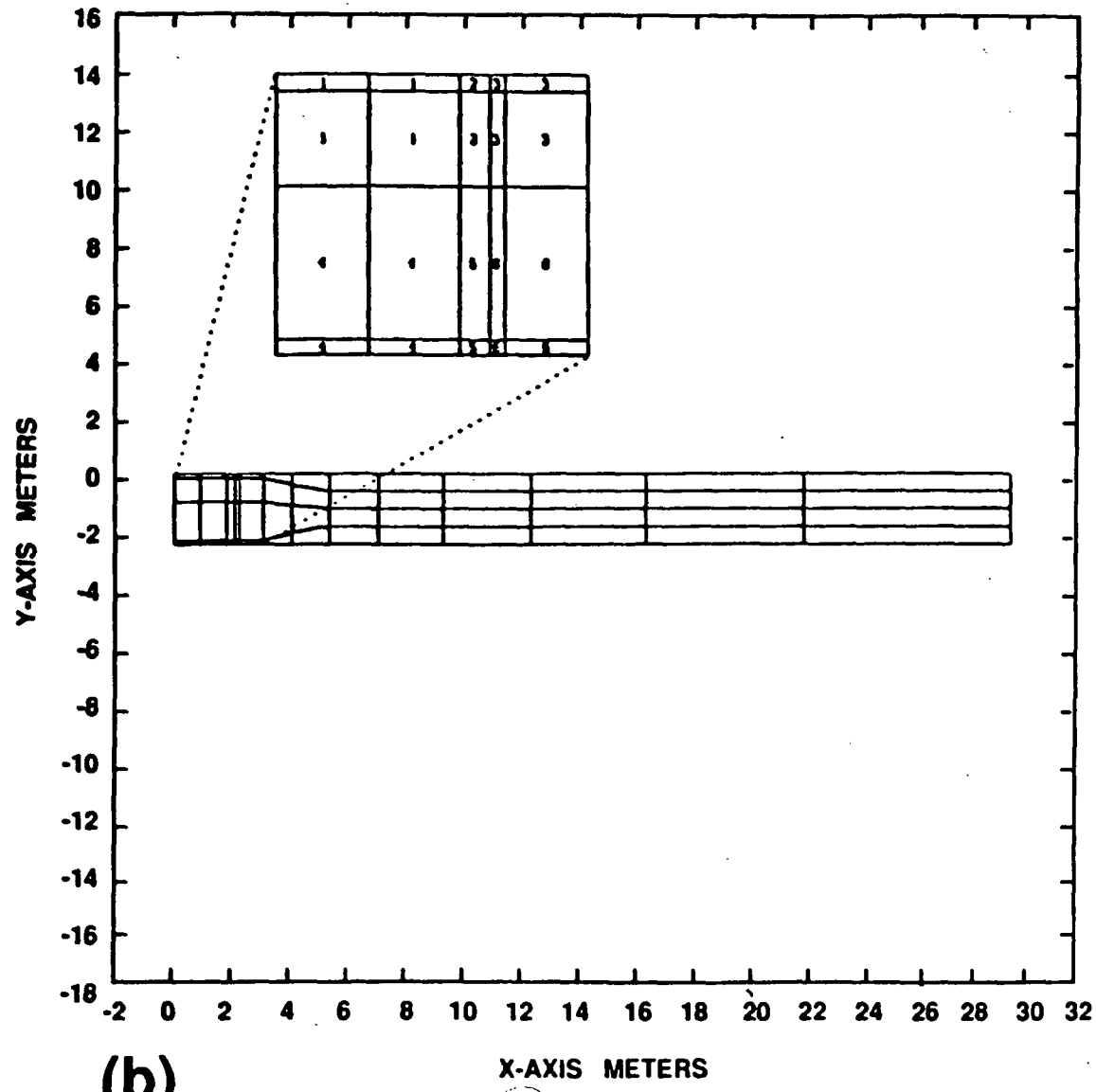
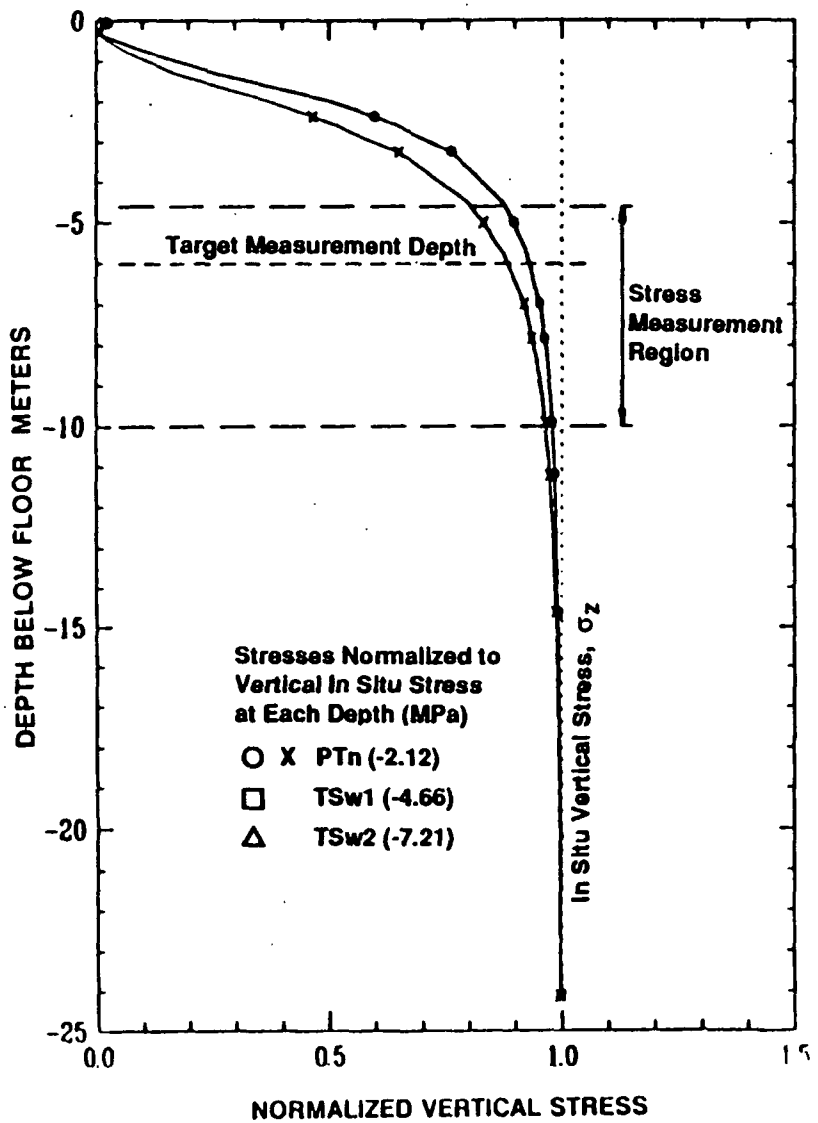
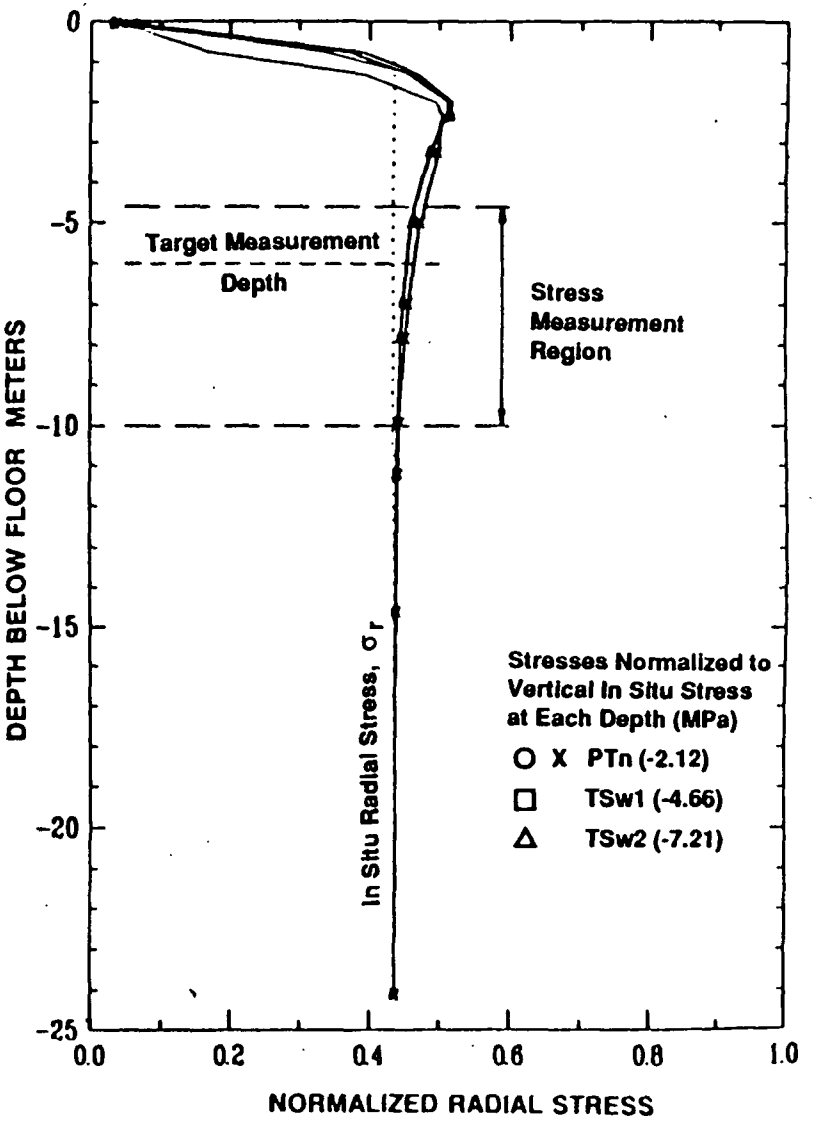
EXCAVATION SEQUENCE FOR THE SHAFT



(b)

EXCAVATION SEQUENCE ANALYSIS RESULTS





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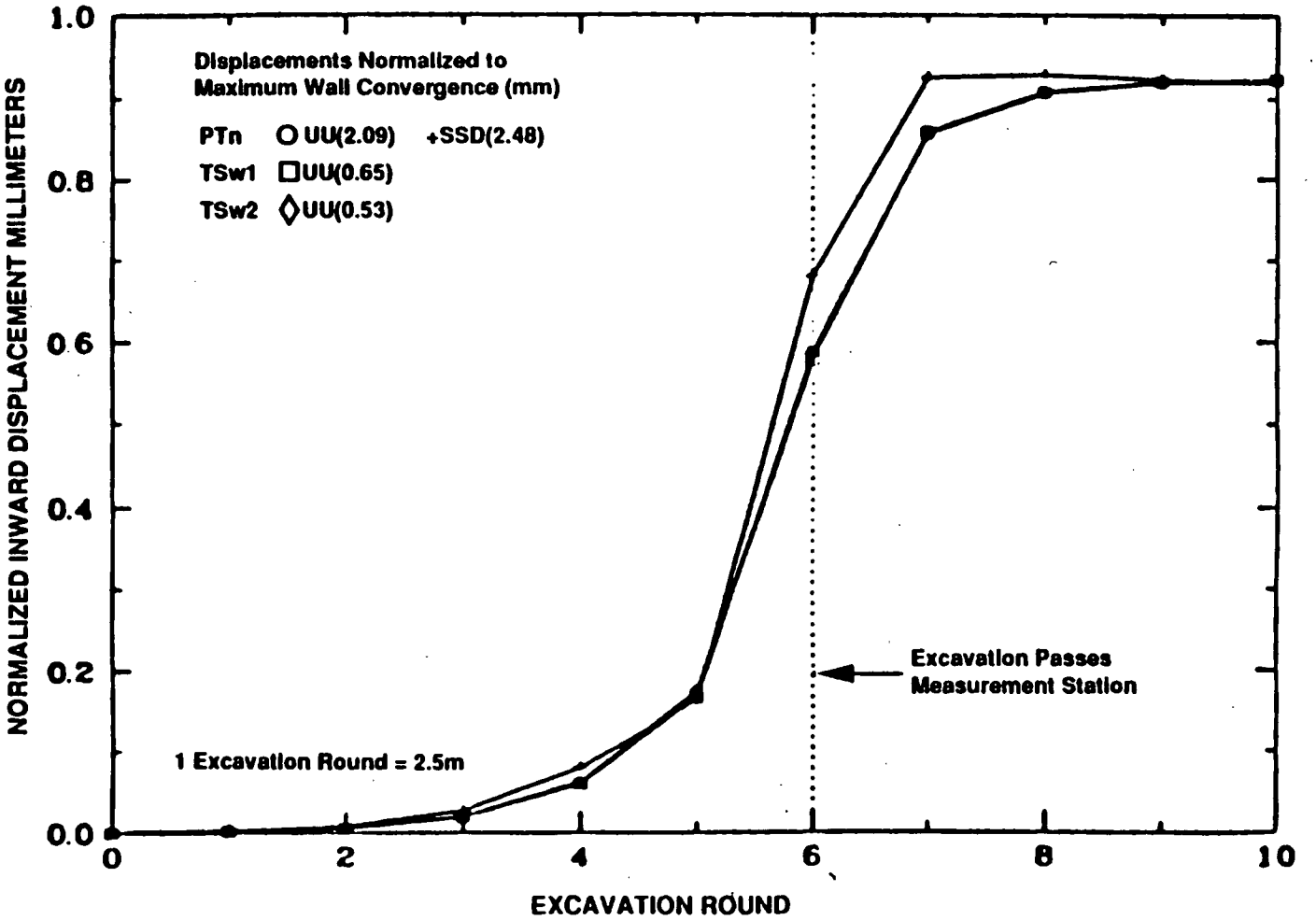
EXCAVATION SEQUENCE ANALYSIS RESULTS



EXCAVATION INVESTIGATIONS - DEMONSTRATION BREAKOUT ROOMS

OBJECTIVES

- PROVIDE EARLY DATA ON ROCK MASS RESPONSE TO EXCAVATION
- DEMONSTRATE CONSTRUCTABILITY OF REPOSITORY-SIZE OPENINGS IN THE HOST ROCK
  - HIGH AND LOW LITHOPHYSAE CONTENTS
  - EARLY FEEDBACK ON EFFECTIVE CONSTRUCTION TECHNIQUES
- PROVIDE SPACE TO CONDUCT OTHER TESTS

EXCAVATION INVESTIGATIONS - DEMONSTRATION BREAKOUT ROOMS

(CONTINUED)

TEST DESCRIPTION

- SELECT CRITICAL ORIENTATION BASED ON FRACTURE GEOMETRY AND IN SITU STRESSES
- EXCAVATE REPOSITORY-SIZED ROOMS BY BLASTING AND INSTALLING INSTRUMENTS IN SEQUENCE. MONITOR:
  - ROCK MASS MOVEMENT
  - ROCK BOLT LOADS OR STRAINS
  - EXCAVATION TECHNIQUES
- CONTINUE TO MONITOR DISPLACEMENTS AND LOADS UNTIL STEADY-STATE CONDITION IS REACHED

EXCAVATION INVESTIGATIONS - DEMONSTRATION BREAKOUT ROOMS

(CONTINUED)

CONDITIONS

- **LOCATIONS**
  - DENSELY WELDED TUFF, HIGH AND LOW LITHOPHYSAL CONTENT
- **ORIENTATION**
  - COINCIDENT WITH THE MOST CRITICAL OF THE TWO ORTHOGONAL ORIENTATIONS PLANNED FOR THE REPOSITORY DRIFTS
- **TIMING**
  - MINE BOTH DBRs PRIOR TO REMAINDER OF MAIN TEST LEVEL
- **DIMENSIONS**
  - CROSS SECTION: REPOSITORY SCALE
  - LENGTH: 6 X WIDTH
- **MINING**
  - MECHANICAL METHODS

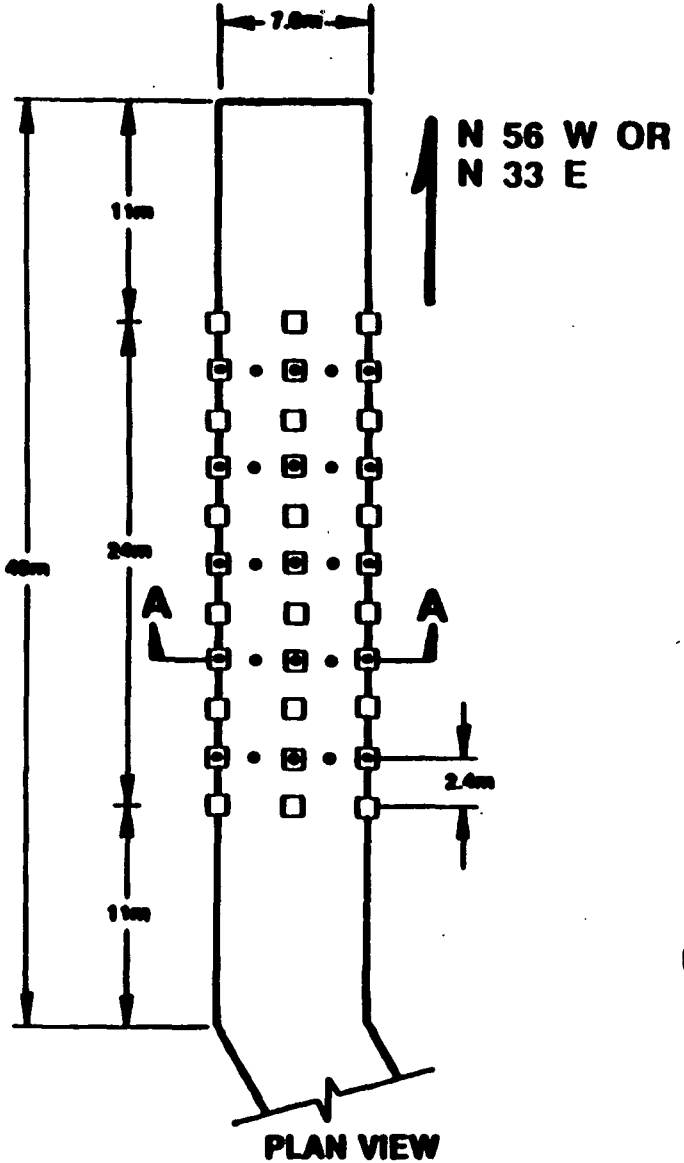
EXCAVATION INVESTIGATIONS - DEMONSTRATION BREAKOUT ROOMS

(CONTINUED)

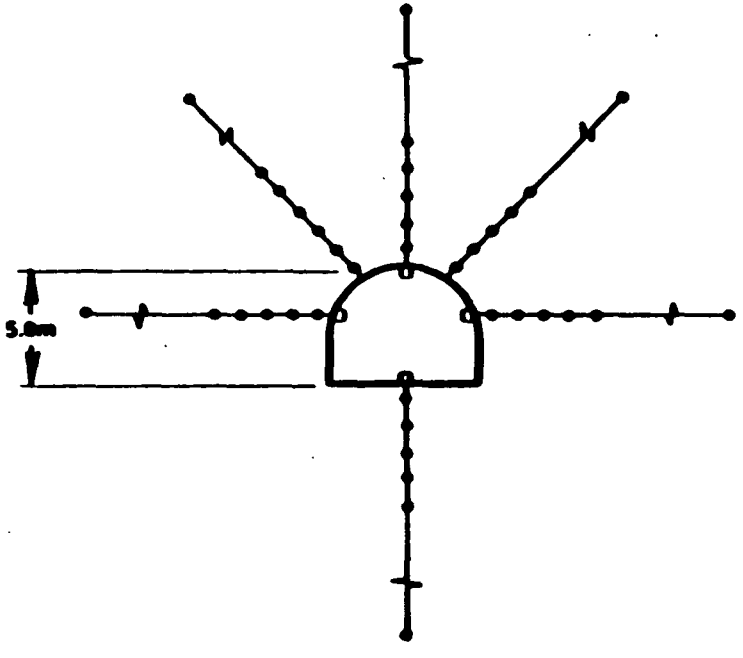
INSTRUMENTATION

PROPERTY	INSTRUMENT
- ROCK MASS MOVEMENT	- MULTIPLE-POINT BOREHOLE EXTENSOMETER (MPBX)
- CROSS-DRIFT CONVERGENCE	- TAPE EXTENSOMETER
- ROCK BOLT LOAD	- LOAD CELL, ULTRASONICS OR STRAIN GAUGES

DEMONSTRATION BREAKOUT ROOM



PLAN VIEW



SECTION A - A

□ CROSS-DRIFT CONVERGENCE PIN

• MULTIPLE-POINT BOREHOLE EXTENSOMETER (MPBX)

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EXCAVATION INVESTIGATIONS - DEMONSTRATION BREAKOUT ROOMS

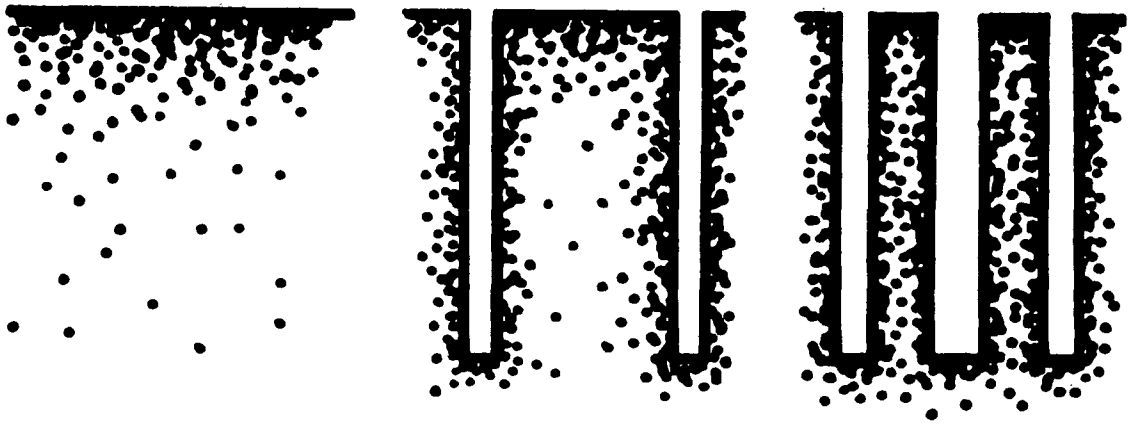
(CONTINUED)

PREVIOUS EXPERIENCE

- DEMONSTRATION DRIFT IN G-TUNNEL
  - MEASUREMENT OF RESPONSE TO EXCAVATION USING MPBXs, TAPE EXTENSOMETER, AND ROCK BOLT LOAD CELLS
  - INVESTIGATION OF TECHNIQUES FOR CONTROLLED BLASTING AND GROUND SUPPORT

EXCAVATION INVESTIGATIONS - SEQUENTIAL DRIFT MINING

SEQUENTIAL DRIFT MINING EXPERIMENT



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EXCAVATION INVESTIGATIONS - SEQUENTIAL DRIFT MINING

OBJECTIVES

- PROVIDE DETAILED INFORMATION ON EXCAVATION RESPONSE
  - SUPPORT MODEL VALIDATION
  - DELINEATE EXTENT OF EXCAVATION DAMAGE AND STRESS REDISTRIBUTION
- DEMONSTRATE CONSTRUCTABILITY OF REPOSITORY-SCALE OPENING
- PROVIDE SPACE AND BASELINE CONDITIONS FOR HEATED ROOM EXPERIMENT

EXCAVATION INVESTIGATIONS - SEQUENTIAL DRIFT MINING

(CONTINUED)

USE OF DATA

- VALIDATE MECHANICAL MODELS AT LARGEST SCALE
- DEFINE CHARACTERISTICS AND EXTENT OF BLAST-DAMAGED ZONE AND STRESS-ALTERED REGION
- VERIFY CONSTRUCTABILITY OF UNDERGROUND REPOSITORY AS DESIGNED
  - IMPACT OF LITHOPHYSAE
  - ORIENTATION
  - GEOMETRY
  - TECHNIQUES

EXCAVATION INVESTIGATIONS - SEQUENTIAL DRIFT MINING

(CONTINUED)

TEST DESCRIPTION

- MINE INSTRUMENTATION DRIFTS
- DRILL HOLES INTO CENTRAL AREA AND CHARACTERIZE ROCK MASS USING
  - CORE LOGGING AND BOREHOLE INSPECTION
  - BOREHOLE PERMEABILITY MEASUREMENTS
  - CROSS-BOREHOLE AND CROSS-DRIFT SEISMICS
- ESTABLISH BASE CONDITIONS USING
  - BOREHOLE EXTENSOMETERS
  - BOREHOLE STESSMETERS
  - BOREHOLE DEFLECTOMETERS

EXCAVATION INVESTIGATIONS - SEQUENTIAL DRIFT MINING

(CONTINUED)

TEST DESCRIPTION (CONTINUED)

- **EXCAVATE CENTER DRIFT**
  - MONITOR INSTRUMENTS CONCURRENTLY
  - INSTALL BOREHOLE EXTENSOMETERS, CROSS-DRIFT CONVERGENCE PINS, AND ROCK BOLT LOAD CELLS ALONG CENTER DRIFT
  - MONITOR MINING ACTIVITIES
- **REPEAT CHARACTERIZATION OF ROCK MASS AFTER EXCAVATION**

EXCAVATION INVESTIGATIONS - SEQUENTIAL DRIFT MINING

(CONTINUED)

CONDITIONS

- LOCATION
  - MAIN TEST LEVEL
- ORIENTATION
  - COINCIDENT WITH REPOSITORY
- DIMENSIONS OF CENTER DRIFT
  - CROSS SECTION: REPOSITORY SCALE
  - LENGTH: 6 X WIDTH
- MINING OF CENTER DRIFT
  - SAME METHOD AS REPOSITORY
- SUPPORTS
  - ROCK BOLTS, WIRE MESH

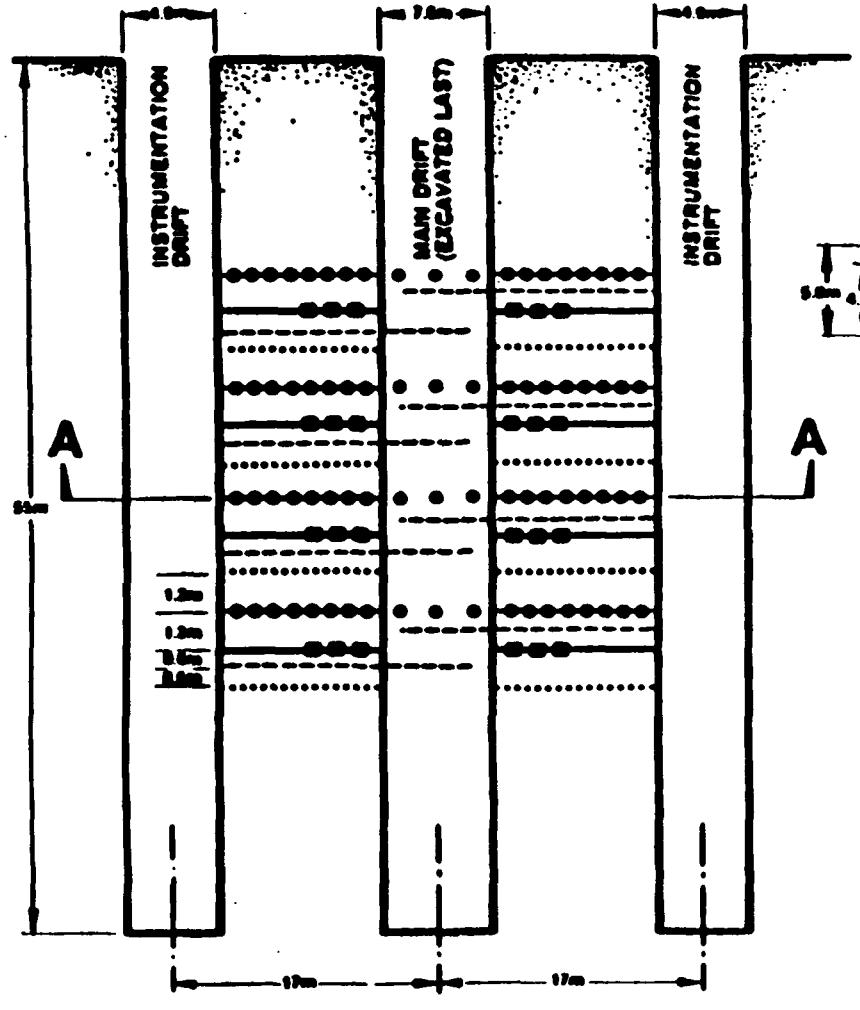
EXCAVATION INVESTIGATIONS - SEQUENTIAL DRIFT MINING

(CONTINUED)

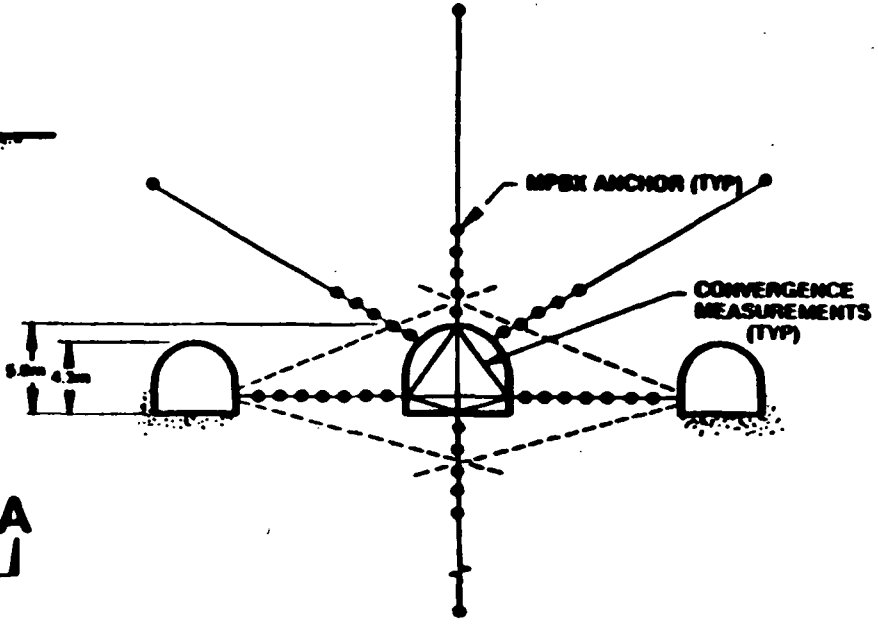
INSTRUMENTATION

PROPERTY	INSTRUMENT
- ROCK MASS MOVEMENT	- BOREHOLE EXTENSOMETER
- CROSS-DRIFT CONVERGENCE	- TAPE EXTENSOMETER
- ROCK BOLT LOAD OR STRAIN	- LOAD CELL, ULTRASONICS, OR STRAIN GAUGES
- BOREHOLE DEFLECTION	- DEFLECTOMETER
- PERMEABILITY	- STRADDLE PACKER/ INJECTION APPARATUS TO BE FABRICATED
- STRESS CHANGE	- UNDECIDED; PROTOTYPE EXPERIMENT USED RIGID INCLUSION BSMs

SEQUENTIAL DRIFT MINING EXPERIMENT



PLAN VIEW



SECTION A - A

MULTIPLE-POINT BOREHOLE EXTENSOMETER (MPBX)
BOREHOLE DEFLECTOMETER (BD)
BOREHOLE PERMEABILITY MEASUREMENTS (BP)
BOREHOLE STRESSMETER (BSM)

EXCAVATION INVESTIGATIONS - SEQUENTIAL DRIFT MINING

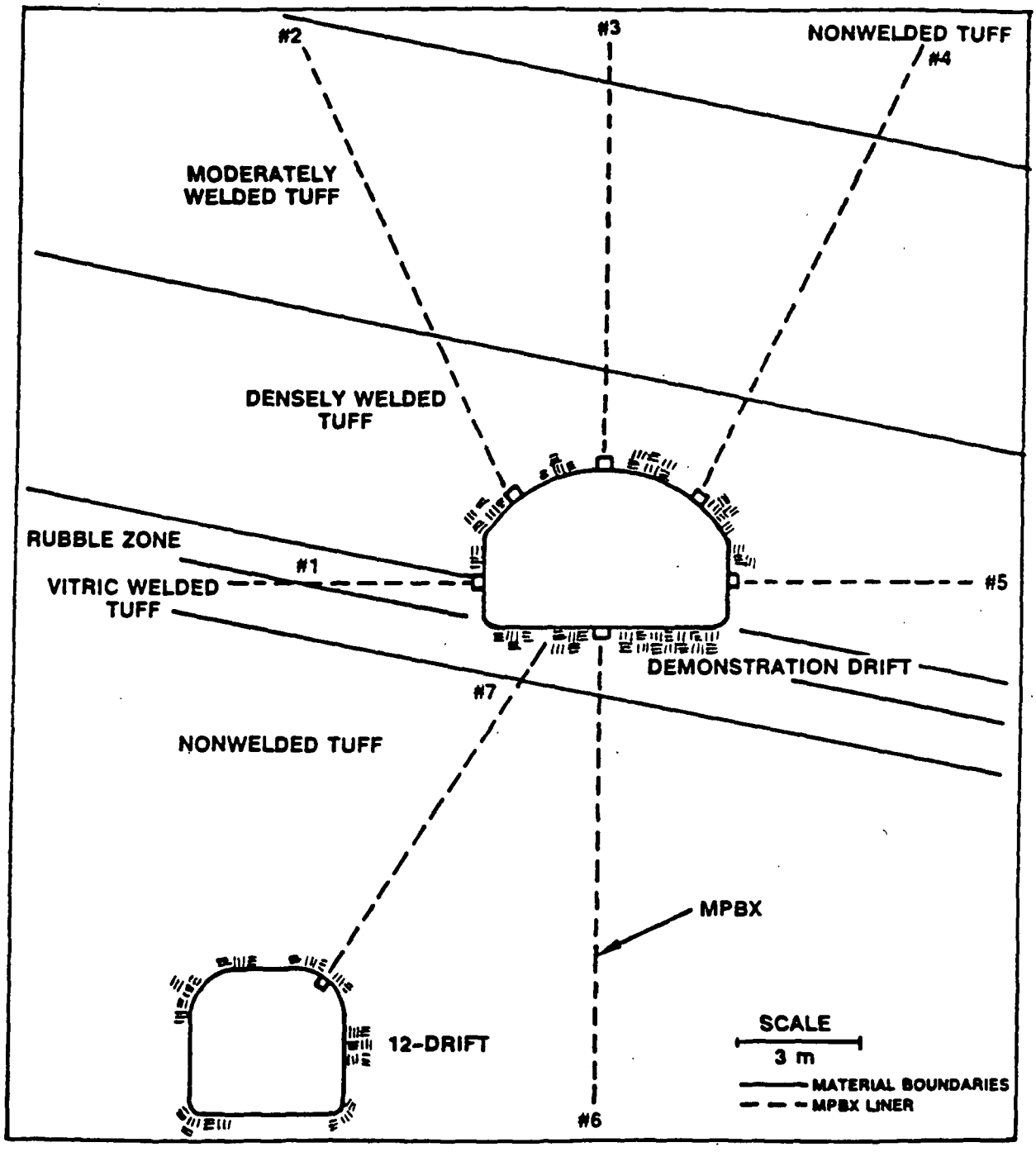
(CONTINUED)

PREVIOUS EXPERIENCE

PROTOTYPE TEST COMPLETED: DEMONSTRATION DRIFT IN G-TUNNEL

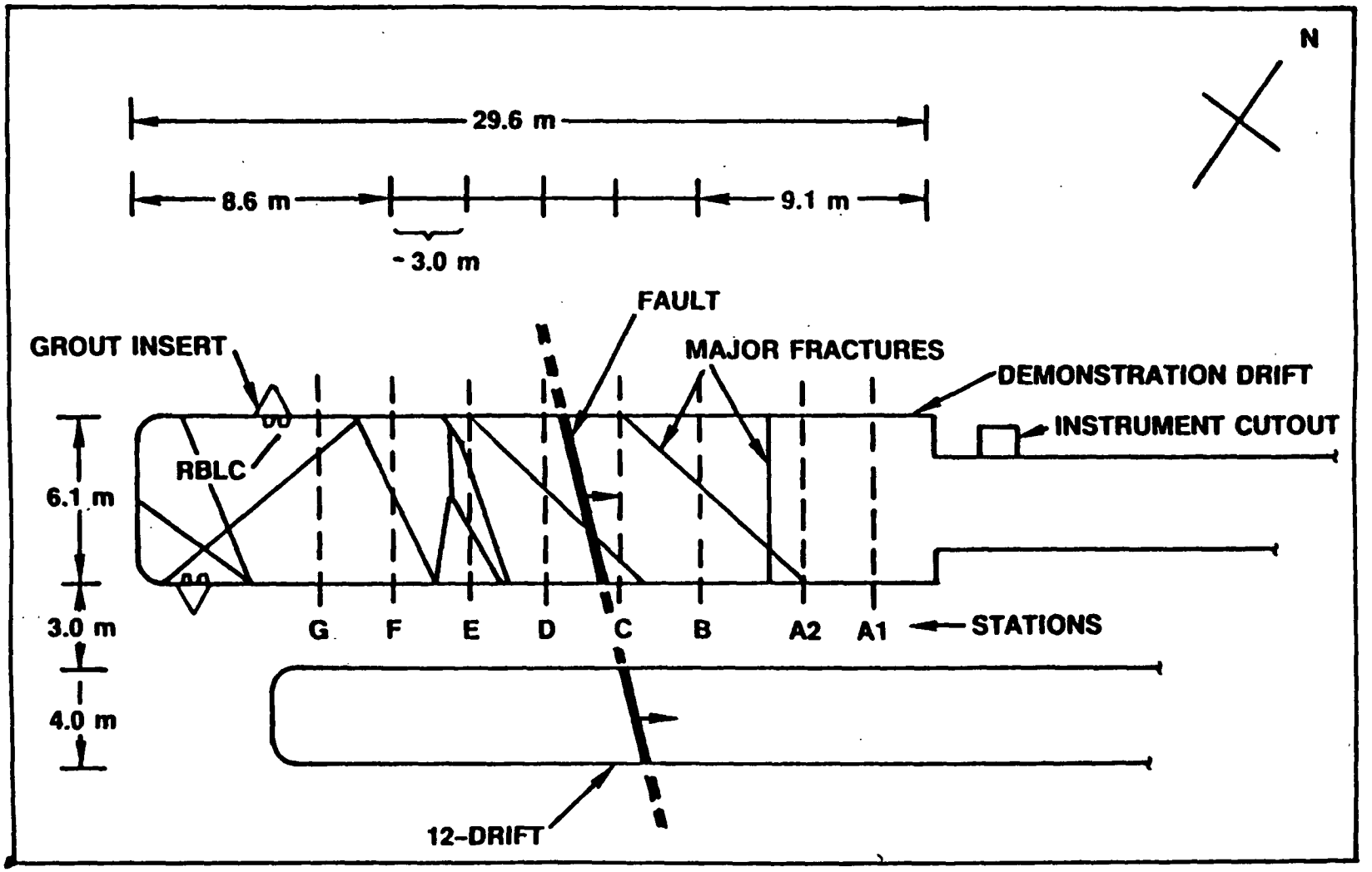
- SINGLE INSTRUMENTATION DRIFT
- MEASURED
  - ROCK MASS DISPLACEMENT
  - CROSS-DRIFT CONVERGENCE
  - ROCK BOLT LOADS
  - BOREHOLE DEFLECTION
  - PERMEABILITY CHANGES
  - STRESS CHANGES

DEMONSTRATION DRIFT



(b)

PLAN VIEW OF DEMONSTRATION DRIFT EQUIPMENT



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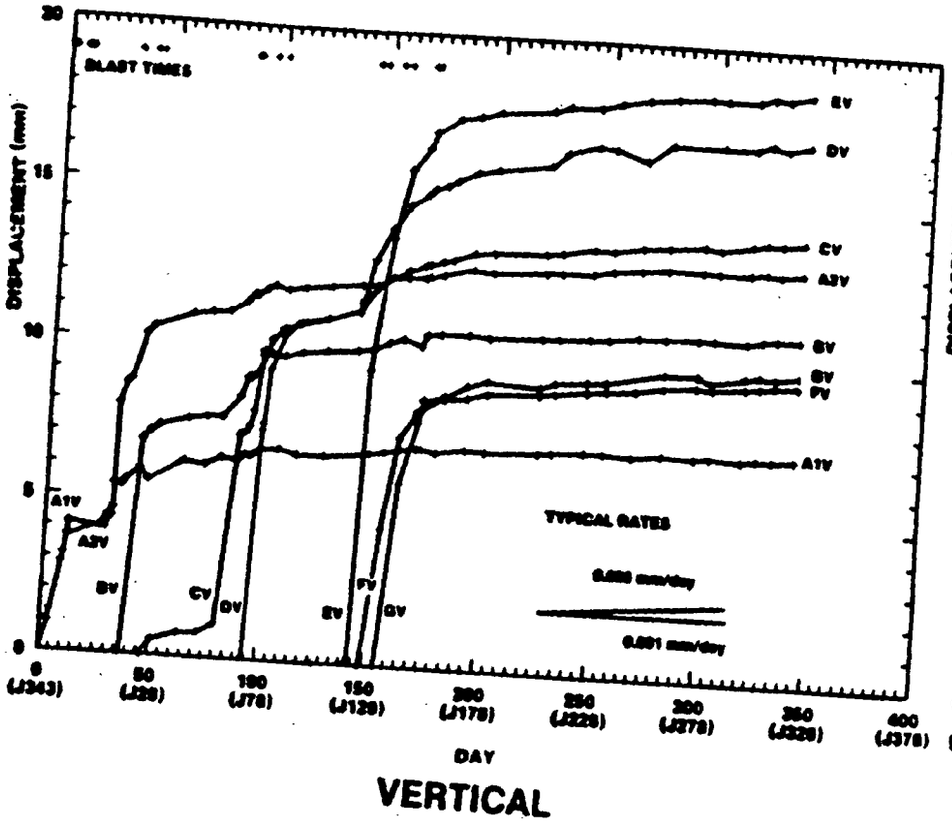
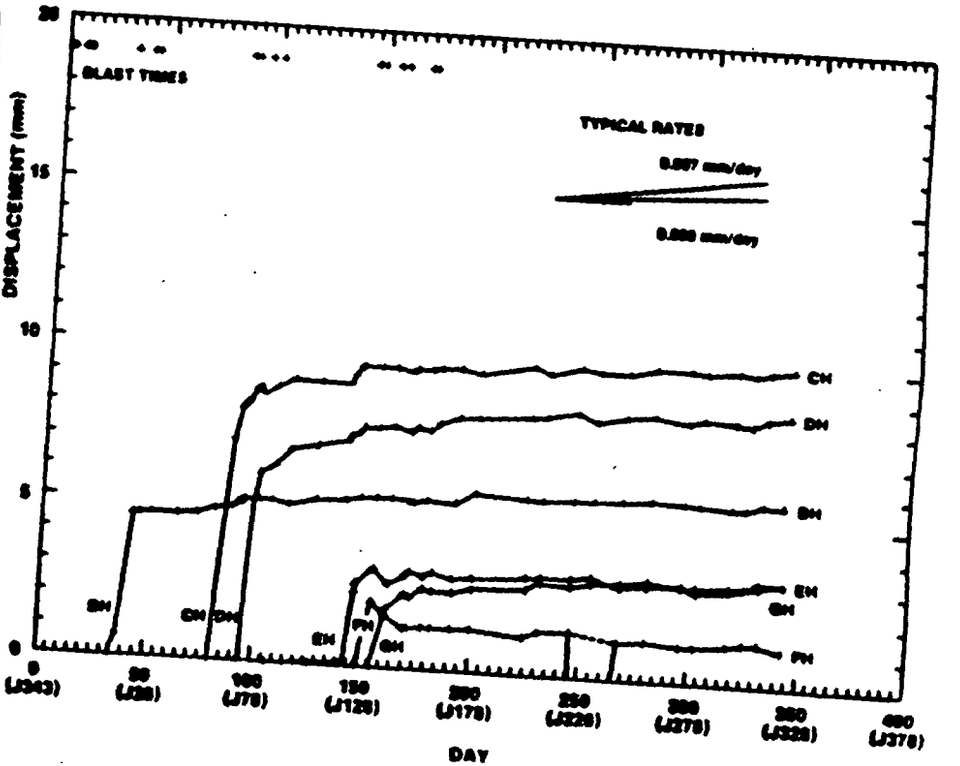
PHOTOGRAPH OF DEMONSTRATION DRIFT

TAPE EXTENSOMETER MEASUREMENTS
DEMONSTRATION DRIFT



VERTICAL



HORIZONTAL

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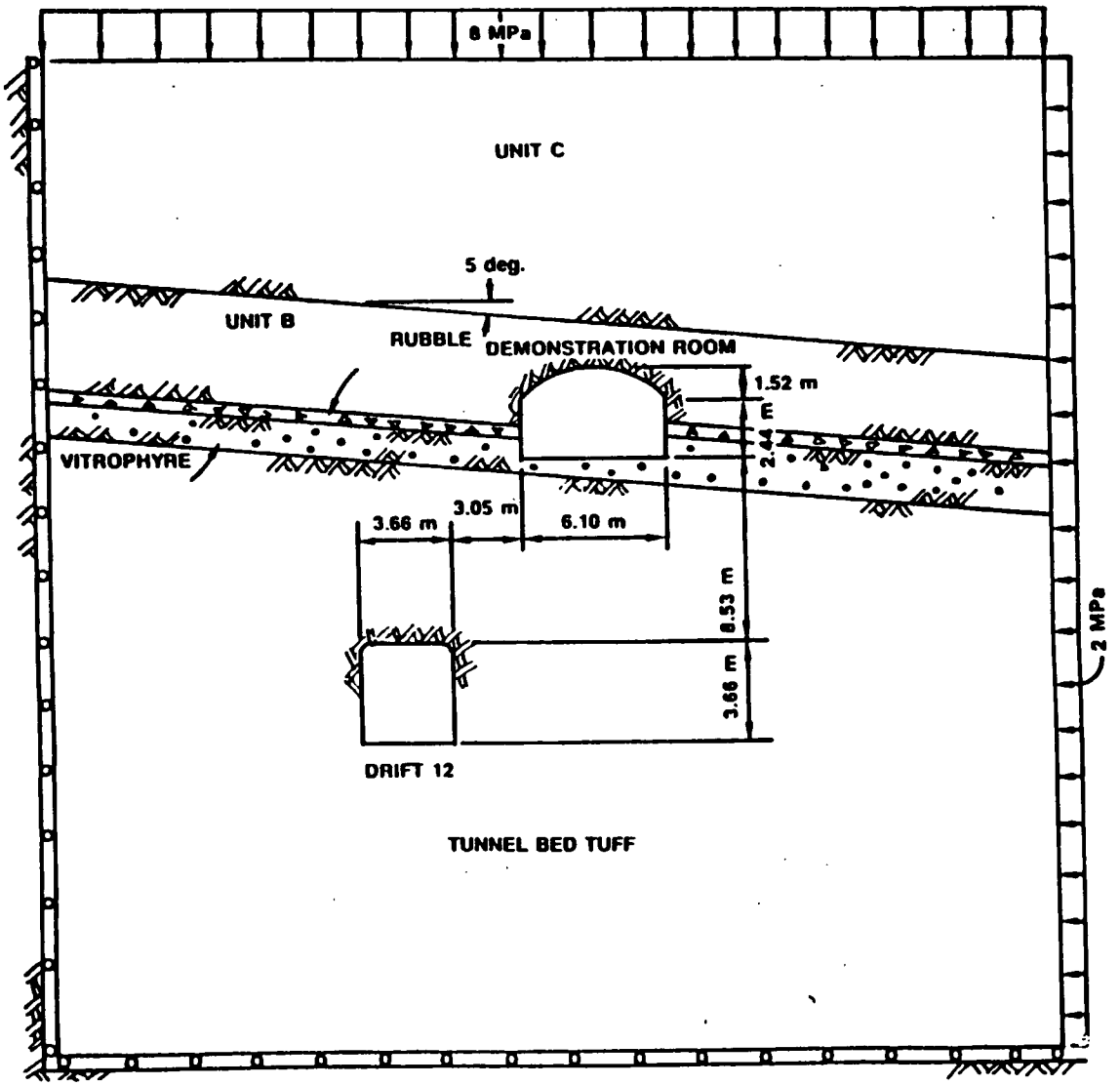
MODEL OF DEMONSTRATION DRIFT EXPERIMENT



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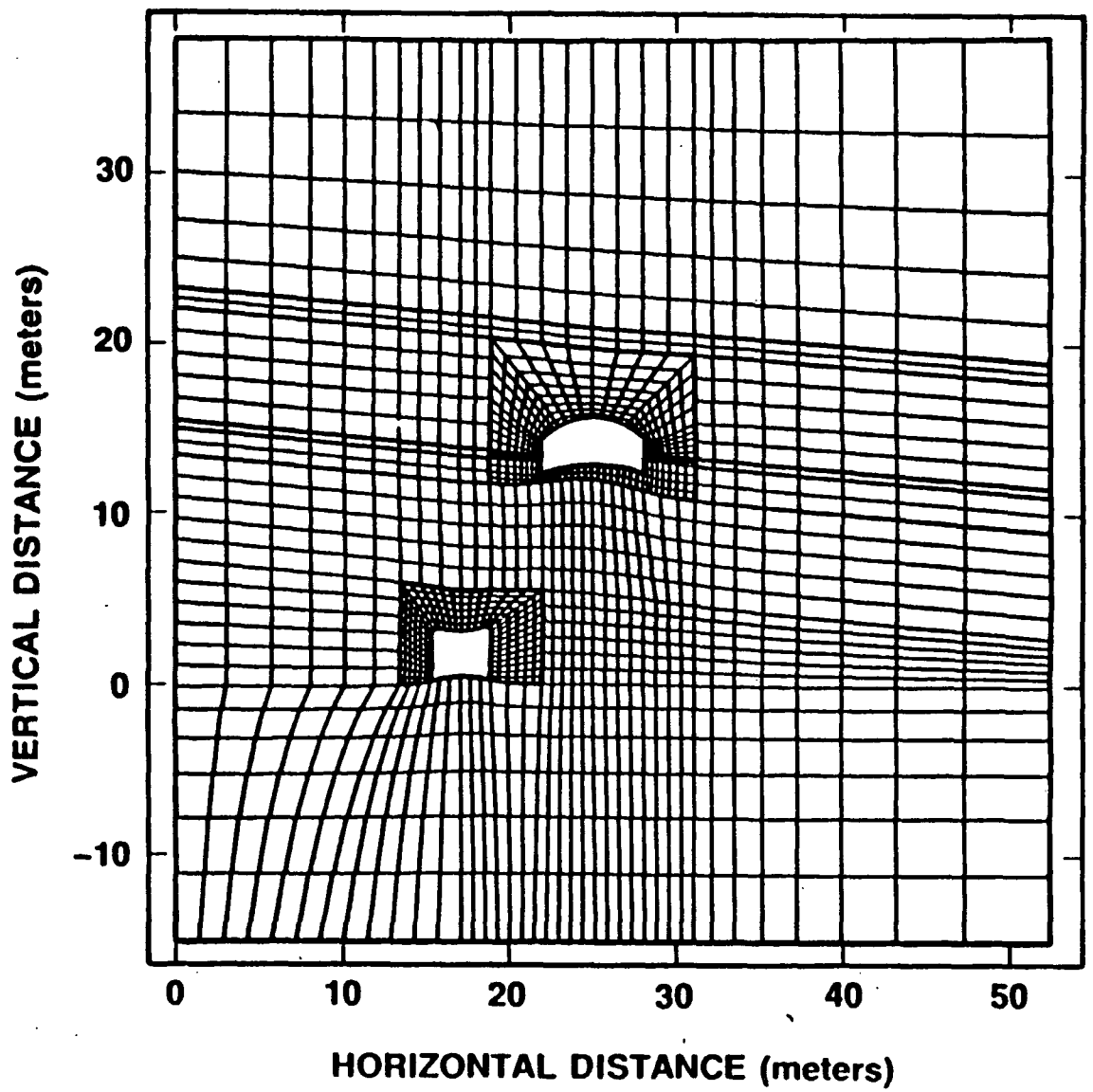
DEFORMED FINITE ELEMENT MESH



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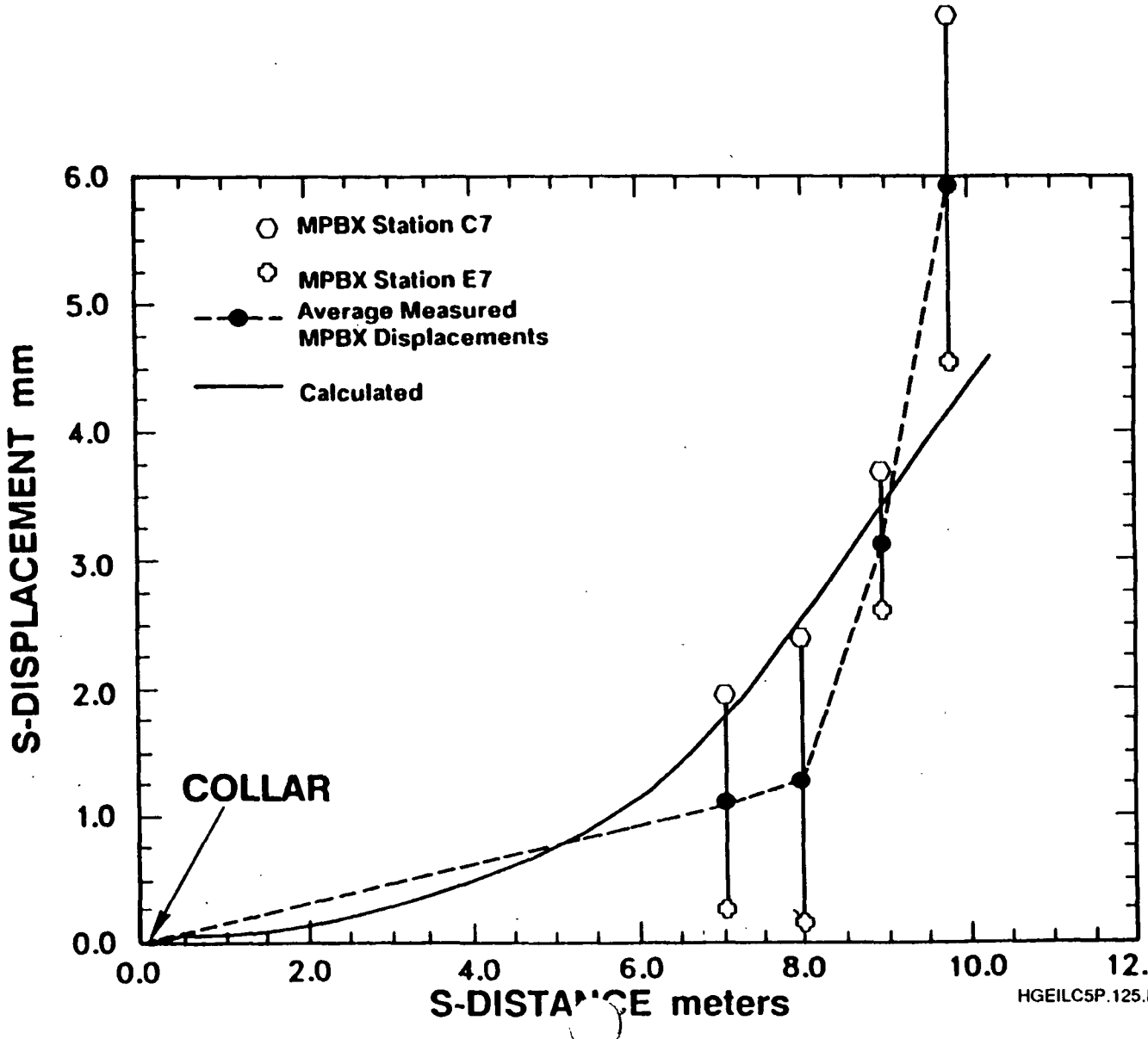
COMPARISON OF CALCULATED DISPLACEMENTS vs DATA



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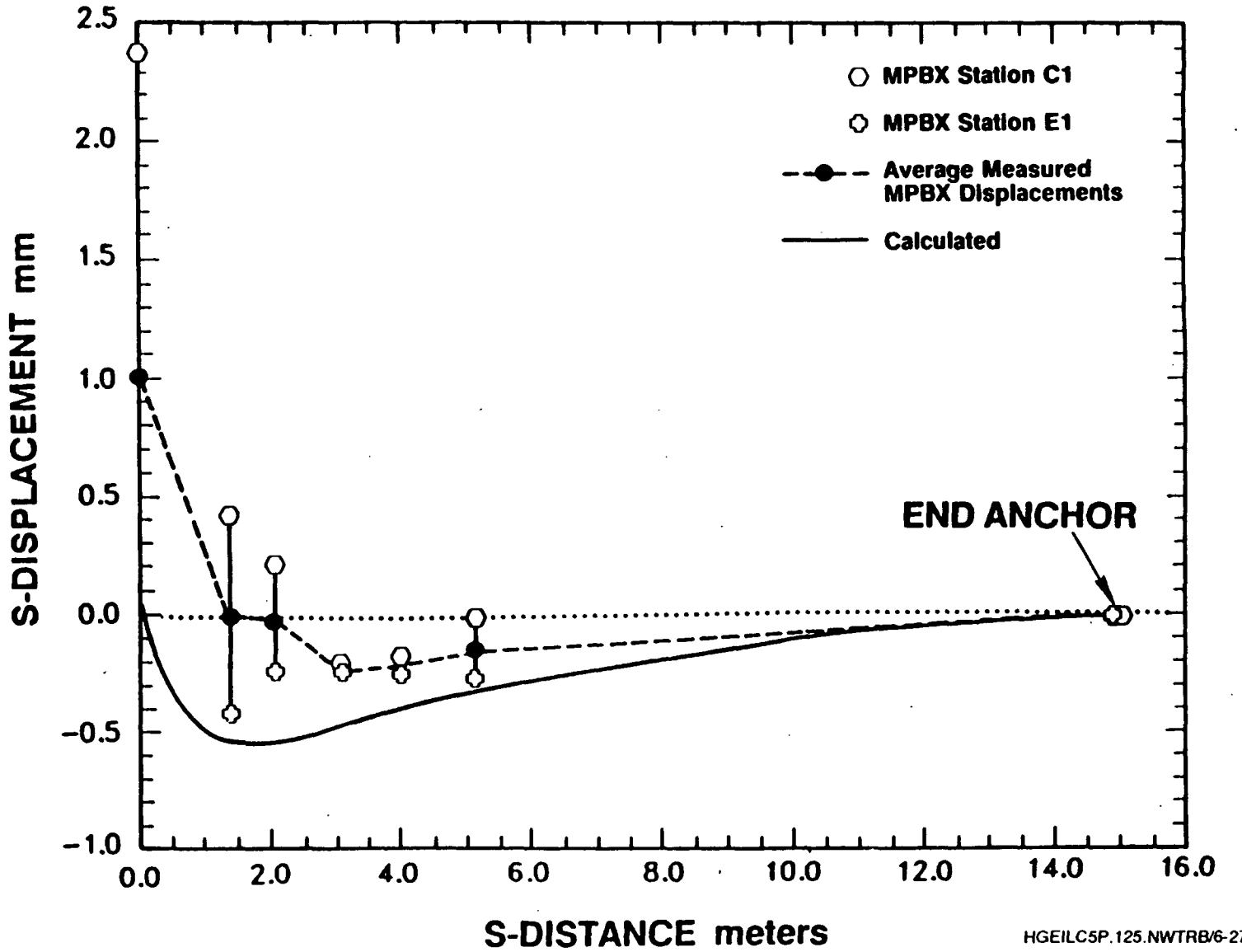

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