JUN 11 1990

CENTRAL FILES P-137

MEMORANDUM FOR: Ronald Ballard, Chief
Geosciences and Systems Performance
Branch, HLWM

FROM: Philip Justus, Section Leader
Geology-Geophysics Section
Geosciences and Systems Performance
Branch, HLWM

SUBJECT: TRIP REPORT, NUCLEAR WASTE TECHNICAL REVIEW BOARD/DOE TOUR OF G-TUNNEL AND N-TUNNEL, RANIER MESA, NEVADA TEST SITE, 6 APRIL 1990

Title: Nuclear Waste Technical Review Board/DOE Tour of G-Tunnel and N-Tunnel, Ranier Mesa, Nevada Test Site.

Date/Place: 6 April 1990, Mercury, Nevada.

Objective: Observe Drill and Blast and Tunnel Boring Machine excavations in unwelded tuff.

Agenda: See Enclosure 1.

Participants: Complete list not available. Other NRC attendees: Joseph Bunting and John Peshel, both of Division of High-Level Waste Management, Engineering Branch.

Scope: 1) Briefings of various prototype tests conducted in G-tunnel by principle investigators; 2) Guided tours of G- and N-Tunnels.

Results: The objective was fulfilled. Due to unforseen time constraints imposed by a delay in an underground nuclear explosion that was detonated earlier in the morning, each of us could observe only one of the tunnels. I chose N-tunnel. Messrs. Bunting and Peshel chose to observe G-tunnel.

Arch Girdley summarized all of the prototype testing under review or planned for G-tunnel (See Enclosure 2). The major objectives of prototype testing are to assure that planned Site Characterization testing can be carried out effectively at the actual Yucca Mountain site, both in the Exploratory Shaft Facility and from the surface, and to avoid potential major failures or delays that could result from the need to re-design testing concepts or equipment. He concluded that one of the best reasons for prototype testing was to practice. He felt that so many logistical and other problems were overcome and so many lessons were learned, that testing at Yucca will go much more efficiently.

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Prototype heater testing was summarized by A. Ramierez, LLNL. Of note to geological mapping program managers was his conclusion that fractures are profoundly important influences on the heat distribution and water flux. His work suggests that fractures must be identified and characterized in order to fully explain heater-test results. Influence of fractures was so great as to cause abandonment of the initial radial flow conceptual model. Also, borehole TV cameras did not detect decrepitation of minerals lining fractures; thin section microscopic examination is needed to supplement such photographic data. "Things" don't scale linearly. He concluded that large scale, but not full-scale, heater tests are needed. He reported an unusual event. Air-pumping of a drill-hole in one test area caused a dust-blow-out in a nearby test area. This suggested that fluids are channelized in the tuff.

Fred Hansen, SNL, described some of the large-block tests. One lesson learned: running too many experiments on one block results in interference and ambiguous results. He mentioned that a fault of several meters displacement was undetected by mapping smooth-wall-blasted surfaces. Of note to geologic mapping program managers was the identification of the cause of a failure of one flat-jack experiment. A large, about 5 by 8 inches, yellow-weathered lithic or vitric clast on the corner of a face collapsed before the rest of the rock reached its failure point; this caused the jack to buckle at that point.

Alan Flint, USGS, described some fracture and matrix permeability testing and ancillary hydraulic-property characterization of rocks. Of note to geologic mapping program managers was the observation that fractures in non-welded tuffs appear to be concentrated in silicified zones. Of note to flow and transport modelers is the observation that the pore structure in the matrix of the Grouse Canyon unit being tested in G-tunnel is different from that of the Topopah Springs unit, thus diminishing, somewhat, the utility of the G-tunnel results as an analog of the Topopah Springs. These observations were made at the microscopic level by a new staining technique.

The N-tunnel tour enabled me to observe drill and blasted non-welded tuff near the entrance, and machine-bored (TBM) tuff, further into the drift. The 1970's vintage TBM was abandoned in-place at the head of the drift. It produced an 18'-diameter circular opening; there was a zone of disturbed rock lining the opening. The disturbance seemed to be machine-induced. One type of disturbance was a rind that appeared to be powdered, compacted, crushed rock caused by the TBM's cutters. The rind produced smearing of stratigraphic contacts and fractures at their intersection with the drift wall. Another disturbance was slabbing of the drift walls. Slabs were up to about 10cm thick and .5 meters in the long dimension. Slabs dropped mainly from the lower two-thirds of the circular sections.

I observed a fault zone said to be about 1300' below the surface (at 15+00 on the strip map, see Enclosure 3), to have about 20" displacement and to have been discharging about 10gpm to a sump pump over at least the past two years. About 6000' into the drift the entire circumference of the drift was "sweating" and supporting an algal colony. This was pointed out to be evidence of local matrix saturation. However, most of the exposed matrix in the drift was dry. The principal mapping geologist, Tim, mapped satisfactorily in this rock unit regardless of the method of excavation. He observed no noticeable difference in personal safety hazard between the methods. I'd like to point out that the geologic units are continuous and apparently readily mappable and the gentle folds and planar faults are relatively simple structures to observe (see Enclosure 3).

/S/

Philip Justus, Section Leader
Geology-Geophysics Section
Geosciences and Systems Performance
Branch, HLWM

Enclosures: See Jacket ENCLOSURES 1+2 9006120368 900611
As stated

cc: J. Bunting
J. Peshel
M. Nataraja
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43 pgs

ENCLOSURE 1

UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
1111 18th Street, N.W., Suite 801
Washington, D.C. 20036
March 27, 1990

Received w/Ltr Dated 6/11/90
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ITINERARY FOR APRIL 6, 1990 NWTRB/DOE TOUR OF G-TUNNEL AND N-TUNNEL, RANIER MESA, NEVADA TEST SITE

6:00 a.m.	Depart Flamingo Hilton hotel (east side near tennis courts) by bus for Mercury
7:30 a.m.	Arrive Mercury Badging Office
8:00-10:00 a.m.	Briefings on G-Tunnel prototype testing and view mandatory safety film (Building 630, SNL Conference Room)
10:00-11:00 a.m.	Travel to Area 12
11:00 - 1:00 p.m.	Simultaneous tours of G-Tunnel and N-Tunnel*
	(Box lunches will be handed out in Mercury; no scheduled lunch break)
1:00-1:30 p.m.	Travel between tunnels
1:30-3:30 p.m.	Simultaneous tours of G-Tunnel and N-Tunnel*
4:00 p.m.	Depart for Las Vegas via Mercury
6:30 p.m.	Arrive Las Vegas

* The group will split into two groups of approximately 20 persons each. Group 1 will visit G-Tunnel while Group 2 tours N-Tunnel from 11 a.m. to 1 pm.; then the groups will change tunnels from 1:30 p.m. to 3:30 p.m.

Telephone: 202-254-4792 Fax: 202-254-4803

Rec'd w/LTR DTD
ENCLOSURE 2
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U.S. DEPARTMENT OF ENERGY

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YUCCA MOUNTAIN

YUCCA MOUNTAIN PROJECT

YUCCA MOUNTAIN PROJECT PROTOTYPE TESTING

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WASTE MANAGEMENT '90

TUCSON, ARIZONA
FEBRUARY 26-MARCH 2

UNITED STATES DEPARTMENT OF ENERGY
NEVADA OPERATIONS OFFICE/YUCCA MOUNTAIN PROJECT OFFICE

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

Yucca Mountain Project Prototype Testing

William T. Hughes and W. Arch Girdley
U.S. DOE Yucca Mountain Project Office

INTRODUCTION

The U.S. DOE is responsible for characterizing the Yucca Mountain site in Nevada to determine its suitability for development as a geologic repository to isolate high-level nuclear waste for at least 10,000 years. This unprecedented task relies in part on measurements made with relatively new methods or applications, such as dry coring and overcoring, for studies to be conducted from the land surface and in an underground facility. The Yucca Mountain Project has, since 1988, implemented a program of equipment development and methods development for a broad spectrum of hydrologic, geologic, rock mechanics, and thermomechanical tests planned for use in an Exploratory Shaft during site characterization at the Yucca Mountain site. A second major program was fielded beginning in April 1989 to develop and test methods and equipment for surface drilling to obtain core samples from depth using only air as a circulating medium. The third major area of prototype testing has been during the ongoing development of the Instrumentation/ Data Acquisition System (IDAS), designed to collect and monitor data from down-hole instrumentation in the unsaturated zone, and store and transmit the data to a central archiving computer. Future prototype work is planned for several programs, including the application of vertical seismic profiling methods and flume design to characterizing the geology at Yucca Mountain.

The major objectives of this prototype testing are to assure that planned Site Characterization testing can be carried out effectively at Yucca Mountain, both in the Exploratory Shaft Facility (ESF), and from the surface, and to avoid potential major failures or delays that could result from the need to re-design testing concepts or equipment.

This paper will describe the scope of the Yucca Mountain Project prototype testing programs and summarize results to date.

PROTOTYPE TESTING IN SUPPORT OF EXPLORATORY SHAFT TESTING

Site Characterization testing in the ESF is planned to investigate the conditions in the welded tuff at the proposed repository depth of approximately 1100 feet, as well as characterize the overlying welded and nonwelded tuffs and evaluate the effects of excavation that may influence the results of planned tests. Mapping and testing in the shafts will begin during the construction phase. Any delay or failure of tests could result in costly stand-by charges for construction resources and delays to the entire underground testing program. In addition, the durations and requirements for all the underground testing must be well defined and understood so that sequencing of operations and allocation of resources (i.e. drilling, ventilation air) can be managed efficiently. For these reasons the Prototype Testing Program was conducted in G-tunnel in Rainier Mesa on the Nevada Test Site in 1988 and 1989.

The objectives of the program were to test, evaluate and develop instrumentation, equipment, and methods for planned ESF tests. The test designs and procedures must not only provide confidence that they will result in data representative of the Yucca Mountain site, but that they are compatible with the stringent Quality Assurance controls that provide documentation in order that the test results are acceptable to support a license application to the Nuclear Regulatory Commission. In addition to technical confidence, the program also provided an opportunity to develop management practices to coordinate among the ten organizations and many investigators who will be responsible for conducting these same or similar operations at Yucca Mountain.

The G-tunnel facility, originally constructed for nuclear weapons testing in the 1960s, extends about a mile through nonwelded volcanic tuffs into Rainier Mesa, where it intersects a wedge of welded Grouse Canyon tuff, with an overburden of about 1430 feet (Fig. 1). This location is called the G-tunnel Underground Facility (G-TUF) (Fig. 2). These welded and nonwelded tuffs in the G-TUF were used by the Yucca Mountain Project for rock mechanics and heater tests starting in 1980. The similarity between the rock types and lithostatic load at the G-TUF and the proposed repository level makes G-tunnel well suited for feasibility testing. There are, however, differences that must be recognized when evaluating the results of G-TUF testing. The welded Grouse Canyon tuff exposed in G-tunnel is about 40 feet thick, highly fractured, and composed of alternating rubble beds and ash-flow tuffs, and so represents an environment less homogeneous and in general more fractured than the massive Topopah Springs tuff (1000 feet thick) at Yucca Mountain. The degree of zeolitic and argillic alteration in G-tunnel is greater than that at the proposed repository horizon, but is probably similar to that in the unsaturated zone underlying the proposed repository level. Lastly, there is more annual precipitation and hence greater infiltration at Rainier Mesa, which stands about 3000 feet higher than the crest of Yucca Mountain.

The Prototype Testing Program consisted of investigations spanning a range of disciplines, including geology, hydrology, geochemistry, rock mechanics, combined thermal and mechanical effects, and drilling and mining methods. These investigations are summarized below.

A significant number of tests planned for the ESF will depend on accurate geologic mapping of the shafts and drifts in considerable detail. Accurate mapping of fractures is of particular importance to hydrologic characterization of Yucca Mountain. Present plans call for a combination of full coverage stereoscopic mapping and conventional mapping. Testing of the stereoscopic equipment has been carried out by the U.S. Bureau of Reclamation in the G-TUF repository-scale Demonstration Drift. Testing involved various aspects of the proposed mapping procedure including wall-cleaning techniques using an air-water mist, stereoscopic photography, and laser surveying to provide extremely precise locations of features vital to generation of the final, highly detailed maps. In addition, methods of determining bearing geometrically, using a goniometer and hand-held gyrocompass, were tested. Data derived from prototype mapping in the G-TUF have been used to develop and test photogrammetric mapping procedures and evaluate results in the laboratory utilizing an analytical plotter.

During site characterization in the ESF, rock samples will be needed from which pore-water chemistry can be reliably determined. Consequently, part of the prototype effort by the USGS addresses sampling strategies and techniques.

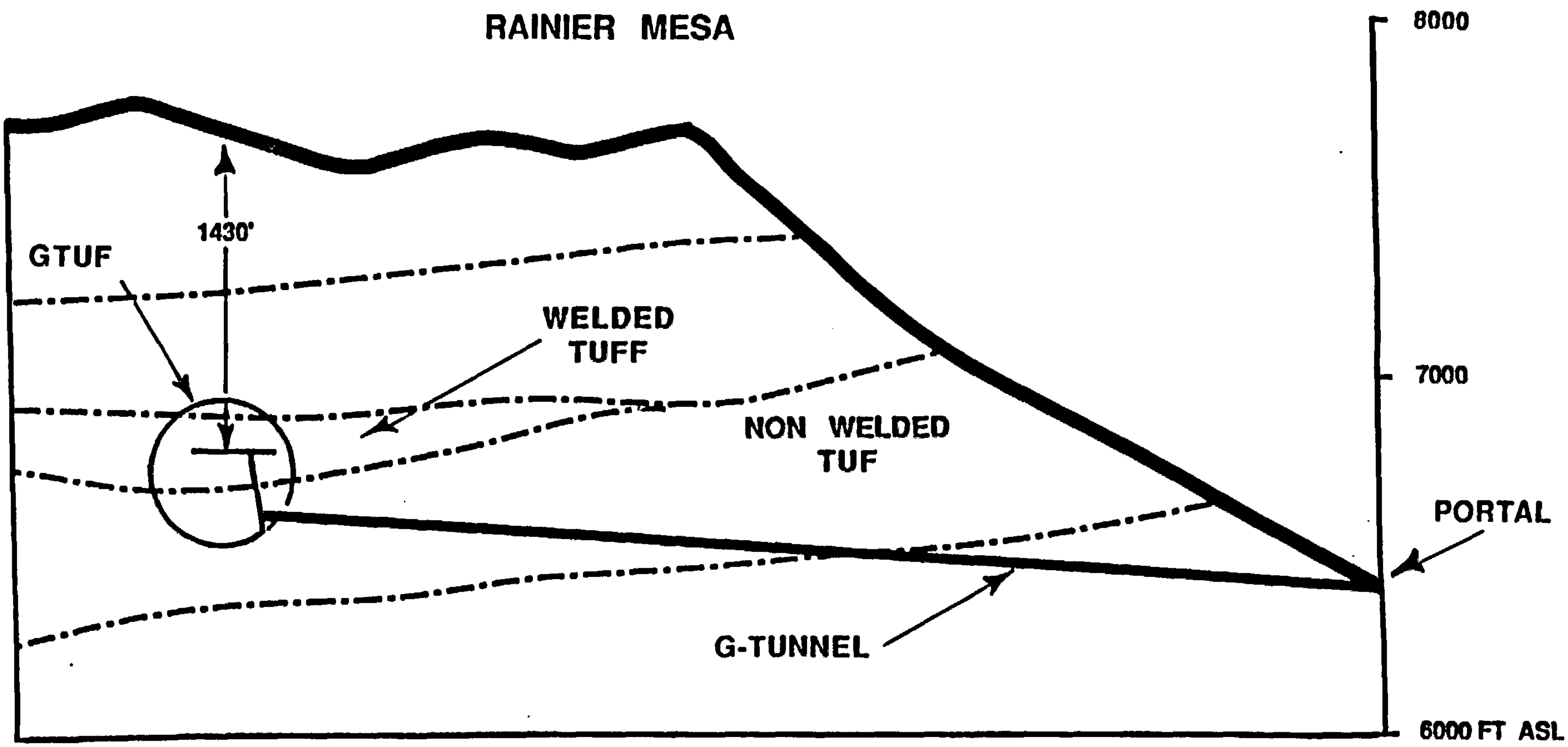


Figure 1. Generalized cross section through G-Tunnel.

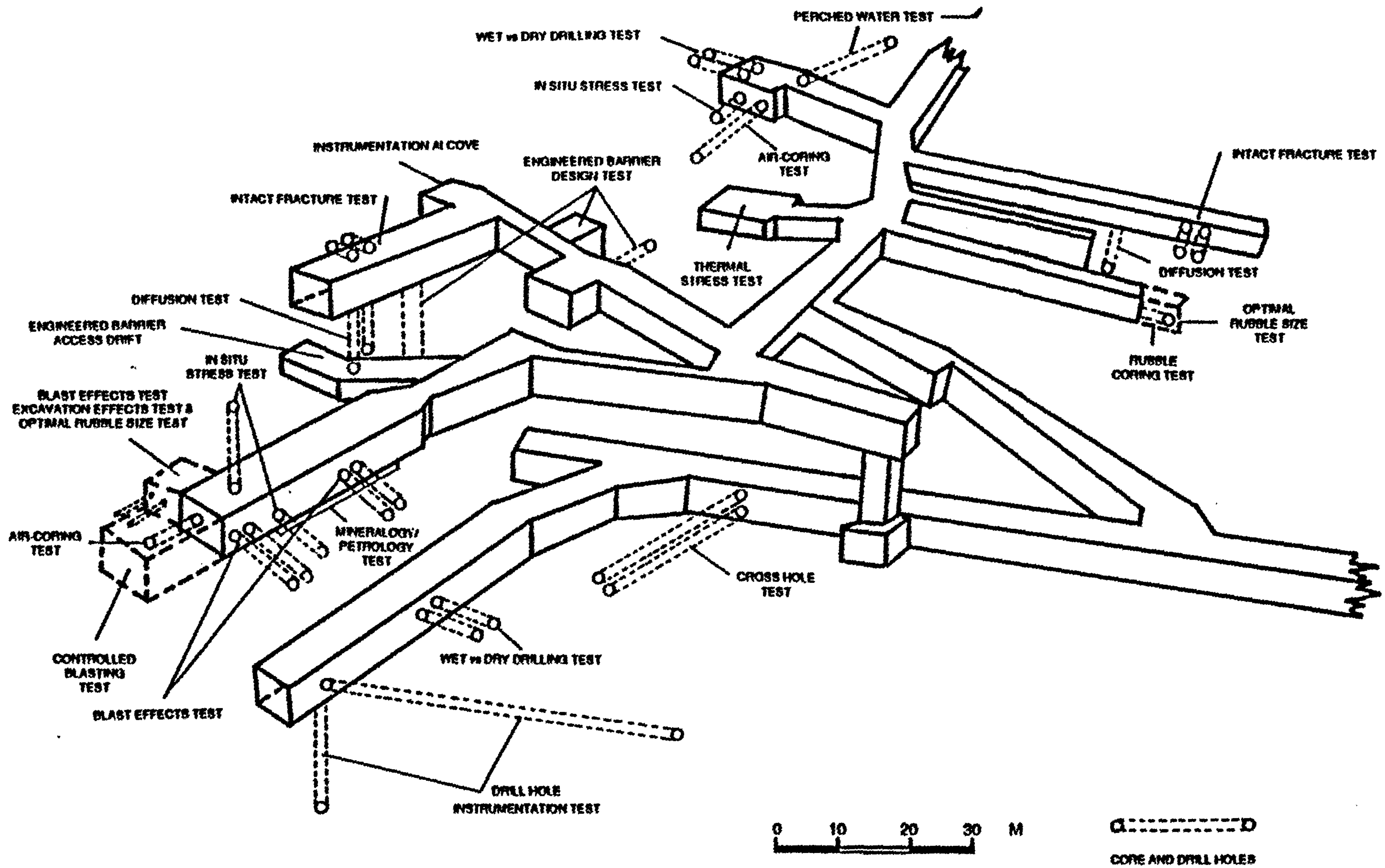


Figure 2. G-Tunnel Underground Facility showing locations of prototype tests

Because all or part of the ESF may be constructed using the drill-and-blast method, blast rubble of various sizes from mining operations in G-tunnel has been collected to determine the minimal size that can be successfully cored to produce a plug sample, uncontaminated by either gas or liquid blast chemicals and their by-products, to be used for hydrochemical and isotopic pore-water analysis. Evaluation will be based on comparison of pore water in plug samples from blast rubble with pore water extracted from cores obtained from intact wall rock. A second objective is to develop procedures to collect, log, seal, label, transport, and store rubble samples to prevent evaporation and to maintain structural and chemical integrity of the samples. A part of this effort focuses on perfecting an air coring technique that can acquire smooth, unbroken cores of appropriate sample size and that are not heated excessively during coring. To evaluate effectiveness of the technique, results are compared with analyses of chip or rubble samples from the same sample material.

Many tests planned for the ESF will utilize dry drilling in order to minimize contamination by drilling fluids that could affect the outcome of sample analyses. However, documented experience pertaining to air coring in hard, fractured rock in a mine environment is meager. As a consequence, several prototype tests conducted in the G-TUF included development and demonstration of dry drilling as a significant part of the overall test effort and, in some cases, this largely became the focal point of the test because of the problems encountered. An initial prototype drilling test was conducted by Los Alamos National Laboratory to develop air coring into a viable cost and time effective technique, to refine the technique for application to specific needs of the ESF testing program, to train personnel needed to perform the ESF drilling, and to establish health and safety practices for dry drilling. Two horizontal holes (150 feet and 50 feet) were air cored in densely welded, fractured tuff to simulate expected difficult drilling conditions at Yucca Mountain. This test evaluated standard drilling techniques, modified slightly for air circulation, to determine if they could meet ESF requirements. A standard core drill (Longyear 38) was used. Results demonstrate the viability and applicability of air coring to ESF requirements, although dry drilling has proven to be more difficult than wet drilling. A track-mounted drill rig with hydraulic outriggers and orientation control is now specified for future use to greatly improve the efficiency of underground drilling operations. General findings are that loss of air volume due to friction increases with hole depth and reduces flushing effectiveness, the volume of flushed air and cuttings that enter the dust collector must be regulated by the driller, and the RPM of the drill bit should be decreased with depth to facilitate smooth drilling.

A concern associated with air coring in the underground environment is the potential creation of a significant health hazard to investigators and support personnel because of the increased generation of airborne dust and fibers that would normally be mitigated by a drilling fluid such as water. In conjunction with the air coring test described above an assessment was made of the potential exposure of workers to airborne silica, zeolite fibers, and nuisance dust so that proper controls and physical protection devices can be incorporated into procedures involving air coring in the ESF. Also, an evaluation was made of the effectiveness of commercial dust control equipment when attached to the drilling apparatus during air coring.

The effects of drilling fluids on the in situ hydrologic conditions of the formation in the unsaturated zone at Yucca Mountain must be known before any boreholes are drilled in the ESF. Alteration of in situ hydrologic conditions of the rock matrix surrounding boreholes could have a significant impact on hydrologic experiments performed in or near boreholes, instrumentation installed in boreholes, and geophysical logging. To minimize the possibility of contaminating an area where an unsaturated zone hydrologic test is to be conducted in the ESF, the extent of drilling fluid penetration in the rock matrix and fractures must be accurately estimated. This can be accomplished in part by acquiring data to support appropriate unsaturated-zone hydrologic models. Field activities have been conducted by the U.S. Geological Survey in G-tunnel to compare results obtained from wet- and dry-drilled boreholes to determine how the drilling fluids affect the ambient hydrologic conditions of the formation. The G-tunnel activities consisted of coring two pairs of horizontal boreholes; one pair was drilled into fractured, welded tuff and the second pair was drilled into nonwelded tuff. Of each pair of boreholes, one was air cored and the other used water as the drilling fluid. Borehole geophysical and television camera logging was conducted prior to emplacing instrumentation to monitor the change with time of environmental conditions near each borehole and to establish ambient background moisture and temperature conditions appropriate to each tuff unit. Laboratory measurements of in-situ water saturation in core samples from each borehole were also made. Empirical data from the borehole measurements can subsequently be used to calibrate and validate hydrologic models being developed for Yucca Mountain.

Borehole packer and instrumentation systems to measure and monitor hydrologic conditions will be emplaced at several locations in the ESF. Installations during construction will need to be done efficiently to minimize delays in ESF construction and to ensure that monitoring is initiated prior to any significant changes related to excavation of underground openings. In this regard, systems originally tested by the USGS in simulated boreholes in the laboratory were field tested in horizontal and vertical boreholes in G-tunnel. The objectives of this test were to develop methods for efficiently installing instrumentation packages in boreholes in tuff surrounding the ESF so as to ensure both hydrologic continuity with the surrounding tuff and isolation of the instrumentation from portions of the borehole remote from the measuring location. Additionally, techniques are being developed for in-place calibration or verification of the accuracy of the instrumentation. Three isolated intervals in each of two boreholes were instrumented and were monitored over a 1-year period.

Fracture-flow characteristics are an important consideration for hydrologic characterization of the unsaturated zone at the Yucca Mountain site. As a consequence, prototype work in G-tunnel has been conducted by the USGS to develop and test methods to collect individual intact fracture core samples in a manner that will minimize any effects on the hydrologic properties of the fractures. Intact fracture samples will subsequently be used to develop methods and procedures for conducting laboratory tests related to characterizing hydrologic properties. G-tunnel testing has addressed the collection of fractures oriented radially and axially with respect to the sampling borehole. Radial fractures have been collected in satisfactory condition, but considerable trouble has been experienced in getting minimally disturbed axial fracture samples. It is hypothesized that binding by cuttings has caused the core to break off at unwanted places. Future plans call for using a different core-barrel configuration and/or a lexan liner.

In the event that perched water might be encountered during construction of the ESF at Yucca Mountain, work has been conducted to evaluate methodology and equipment for measuring rates of seepage from walls of an underground excavation, for measuring hydraulic head of a perched water body, for collecting representative samples, and for performing aquifer tests within the perched zone. Field work to date has consisted of coring four holes in perched water zones in the G-TUF and outfitting one hole with a packer and instrumentation system.

Tests to characterize in-situ stress are part of the activities to assess the geomechanical properties of rock at the Yucca Mountain site. Prototype work was initiated at G-tunnel by the USGS to test field procedures and instrumentation and to compare alternative methods of determining the in-situ stress in welded tuffs under conditions very similar to those expected at the ESF. The objective of the effort was to compare results of anelastic strain recovery and overcore stress test methods, but only the latter method has been addressed to date. Three locations in the G-TUF have been tested; two were drilled with air and one with water. Considerable difficulty was encountered in this effort, associated largely with dry drilling in fractured rock, and successful dry overcoring to retrieve borehole instrumentation was particularly difficult to achieve. Such difficulties resulted in much time allotted for testing to be consumed in addressing drilling problems. Although the original objectives for prototype stress measurements have not yet been met, lessons learned regarding methods for dry overcoring in fractured formations will be used to evaluate plans for further work.

Diffusion tests proposed for the ESF will measure the rate of solute diffusion into water-filled, or partly filled, pores of the tuffs in the unsaturated zone at Yucca Mountain. In-situ measurements of diffusion can be used to derive diffusion coefficients for use in performance assessment calculations, as solute diffusion is likely to be an important mechanism for retarding the water-borne transport of nonsorbing radioactive species. Prototype work by Los Alamos National Laboratory at G-tunnel involves pressurized injection of a tracer into the tuff at the end of a shallow, vertical borehole. After a predetermined period, the tuff surrounding the injection zone is overcored and the resulting core is sectioned and analyzed for tracer concentrations. The tracer distributions are used to calculate the in-situ diffusivities of solvents in the tuff. This test requires non-routine dry drilling and overcoring and has not been completed because of overcoring problems similar to ones experienced in other prototype tests.

Effects of heat generated by waste packages on the surrounding rock mass must be evaluated to understand and predict the response of the waste package and the natural environment during the period required for waste isolation at Yucca Mountain. Of particular interest are the relationships between the thermal load and the initial flow of fluid and gas away from the heat source and, then, the flow back toward the source as the waste cools. Prototype work in G-tunnel has been conducted by Lawrence Livermore National Laboratory that simulated a horizontal waste-emplacement configuration. A heater was emplaced horizontally in a small-diameter heater alcove. Boreholes, drilled at various orientations relative to the heater, contained instruments that monitored selected parameters, i.e., temperature, moisture content, air pressure, etc. This experiment was conducted in the Grouse Canyon welded tuff to simulate, as much as possible, expected conditions in the proposed repository host rock at Yucca Mountain. Plots of hydrologic parameters as a function of radial distance from the heater have provided results that confirm basic elements of the conceptual model of predicted environmental conditions. Prototype testing simulating vertical emplacement of a waste package is planned for a future date.

Many experiments planned for the ESF use equipment and instruments that require development and demonstration under conditions similar to those at the ESF before they are used under rigid Quality Assurance practices. An on-going effort in the G-TUF by Sandia National Laboratories has focused on evaluating and demonstrating reliability of such items as high pressure flatjacks, multiple-point borehole extensometers, remote convergence monitoring equipment, anelastic strain recovery equipment, and hydraulic chain saws designed for rock cutting. It is expected that other items may require evaluation in G-tunnel or another environment similar to the ESF prior to use at Yucca Mountain.

Not all of the prototype and developmental work planned to be executed in the G-TUF has been accomplished. Prototype activities in the G-TUF have been suspended because of budgetary constraints and a delay in the schedule for construction and testing in the ESF at Yucca Mountain. Planned prototype work either unfinished or not initiated include evaluations of controlled blasting techniques, effects of blasting on test instrumentation, effects of excavation on hydrologic properties, effects of thermal stress on rock properties, changes in rock characteristics associated with vertical emplacement of waste canisters, and further developmental work on dry drilling and coring methodology.

PROTOTYPE DRY DRILLING AND CORING FOR SURFACE-BASED APPLICATION

The Yucca Mountain Project is developing and testing dry dual-wall reverse circulation drilling and dry coring systems to be used for deep unsaturated zone boreholes to be drilled from the surface. Prototype testing of the initial concepts began in April 1989. The objectives of this prototype testing are to (1) provide core and drill cuttings in as uncontaminated condition as possible, (2) provide a borehole wall as clean and smooth as possible for future downhole testing, and (3) avoid contamination of the adjacent formation with conventional (liquid) drilling fluids. The ultimate objective of this prototype test is to ensure that the methods used will meet the requirements of the deep unsaturated zone site characterization program without undue adverse impact on the site's ability to isolate waste.

The concept is a new application of dual-wall drilling commonly used in the southwestern U.S. for gold exploration, combined with a wireline retrieval coring system. The dual-wall drill pipe assures air circulation and serves as temporary casing for the air coring (Fig. 3). The coring is done through an open centered bit on the dual-wall pipe, in advance of the dual-wall drilling.

The sequence used for dry coring is to core 20-40 feet in advance of the dual-wall system using air as the circulating fluid, pull the coring string out of the hole, and then advance the borehole with the dual-wall system system to the bottom of the cored zone. The wireline coring system is then lowered through the dual-wall pipe and open-centered roller-cone or cleanout bit, and the process continued.

Zones not requiring core will be drilled using a down-the-hole air hammer or an open-centered roller-cone bit. The air hammer drilling will generate fine to coarse cuttings while the open-centered roller-cone bit will generate large chunks of rock the size of the opening in the bit and as long as eight inches. These cuttings or larger samples are lifted by the circulating air, pass through a large-radius gooseneck pipe at the top of the drill string, and are recovered in the dust collection system. Finer cuttings remaining in the airstream are collected in a large double cyclone/ filter system.

To date, air-coring has been successful to 530 feet. Drilling was curtailed due to wetter conditions than expected at test drill sites in Utah. Plans are to drill to 1700 feet during the next development phase, limited by the capacity of the available drill rig. A larger drill rig is being fabricated, in preparation for the drilling at Yucca Mountain, which must penetrate unsaturated section as thick as 2600 feet.

Much has been learned about the size constraints on the design of open-centered roller cone bits and bearing life, about the sample handling and dust control systems, and benefits and limitations to several air-circulation systems (i.e. conventional versus reverse circulation, with and without vacuum assist, in dry and wet ground). Conventional circulation appears to be the most promising method for drilling with air through rock that contains sporadic inflow of water. This may be a factor should perched water be encountered during dry drilling at Yucca Mountain.

PROTOTYPE INSTRUMENTATION/DATA ACQUISITION SYSTEM

The Instrumentation/Data Acquisition System (IDAS) is designed by the USGS to support the collection of data from instruments emplaced in boreholes penetrating the unsaturated zone at Yucca Mountain. The IDAS consists of a network of shelters wired to down-hole instrumentation, linked telemetrically to a control archiving computer. Each shelter houses analog-to-digital converters, computers to archive data and to control the system functions, environmental control systems, security systems, and communication equipment.

To date, two prototype shelters have been constructed, a large portion of the controlling software has been developed, and the existing system has been field tested to measure system performance against design criteria for recording, transmitting, and storing sensor readings. Some modifications are still needed to incorporate 'field changes' into a final design for shelter production.

ADDITIONAL PLANNED PROTOTYPE TESTING

Several new methods or applications are currently planned for additional prototype testing. Two systems have been designed to apply vertical seismic profiling methods to the unsaturated zone at Yucca Mountain. Neither of these has been field tested at Yucca Mountain due to environmental permit constraints. Another study of surface run-off includes plans to construct at least one flume to evaluate the suitability of the current stage-sensing instrumentation systems, and to perform simulated run-off events to test and calibrate the instrumentation. One major unknown is how well the flume will be able to handle the bed-load moved during storm events.

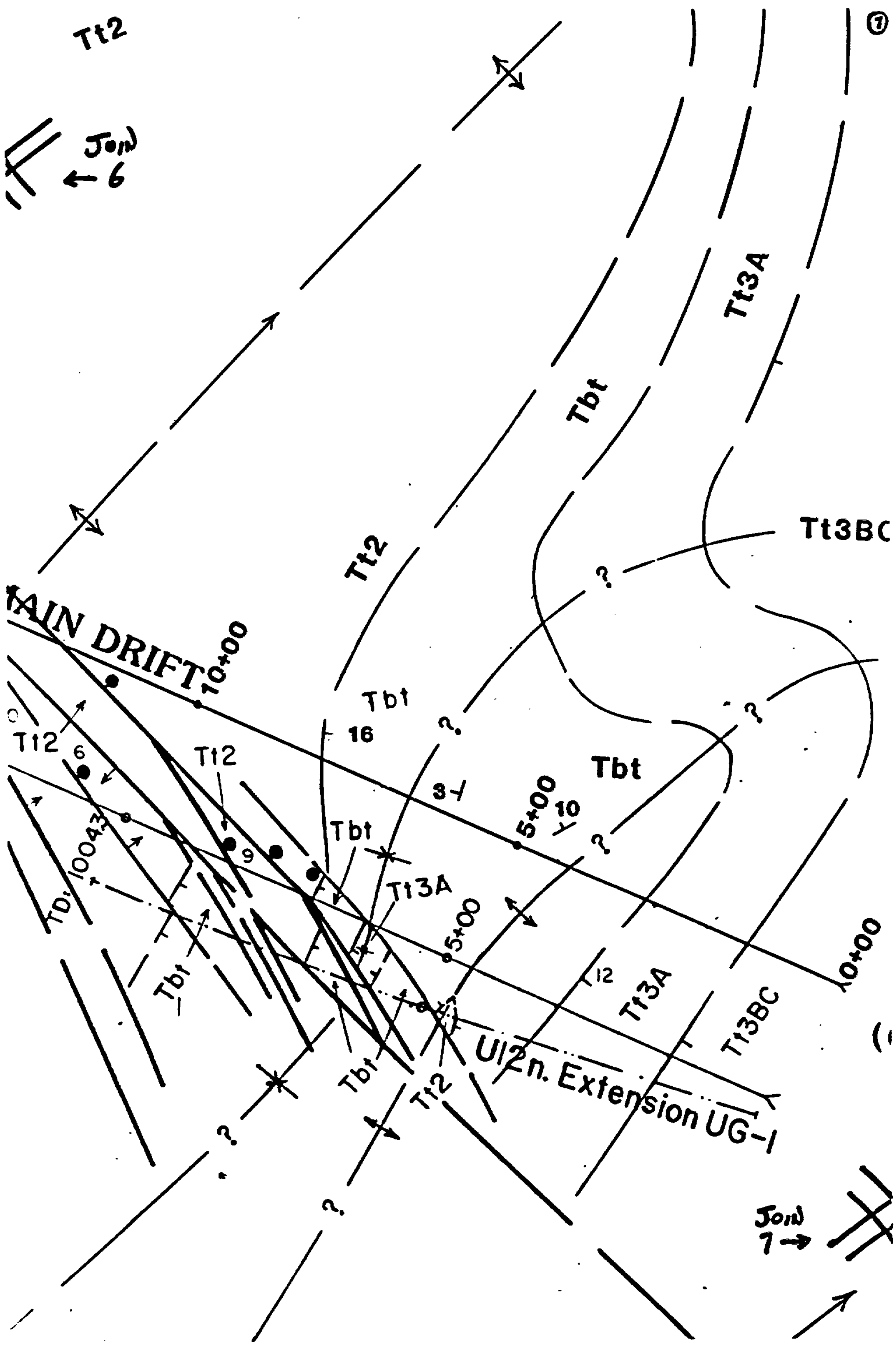
SUMMARY AND CONCLUSION

As surface-based and underground drilling technology and experience is developed, more complex combinations of tests and instruments will be tested in boreholes. Many of the techniques developed individually during the prototype testing described above will be combined or sequenced in planned site characterization boreholes. The prototype testing will at this point become feasibility testing leading to the use of proven concepts and techniques for site characterization testing.

The experience gained through the prototype field-testing program to date in G-tunnel and elsewhere has made great progress toward closing the gap between the conceptual planning of site characterization field activities and the development of detailed methods, instrumentation and other supporting equipment necessary to conduct the field program at Yucca Mountain.

ACKNOWLEDGMENT

Much of the information on prototype testing in G-tunnel was provided by Los Alamos National Laboratory, which coordinates ESF testing activities on behalf of the Yucca Mountain Project Office.



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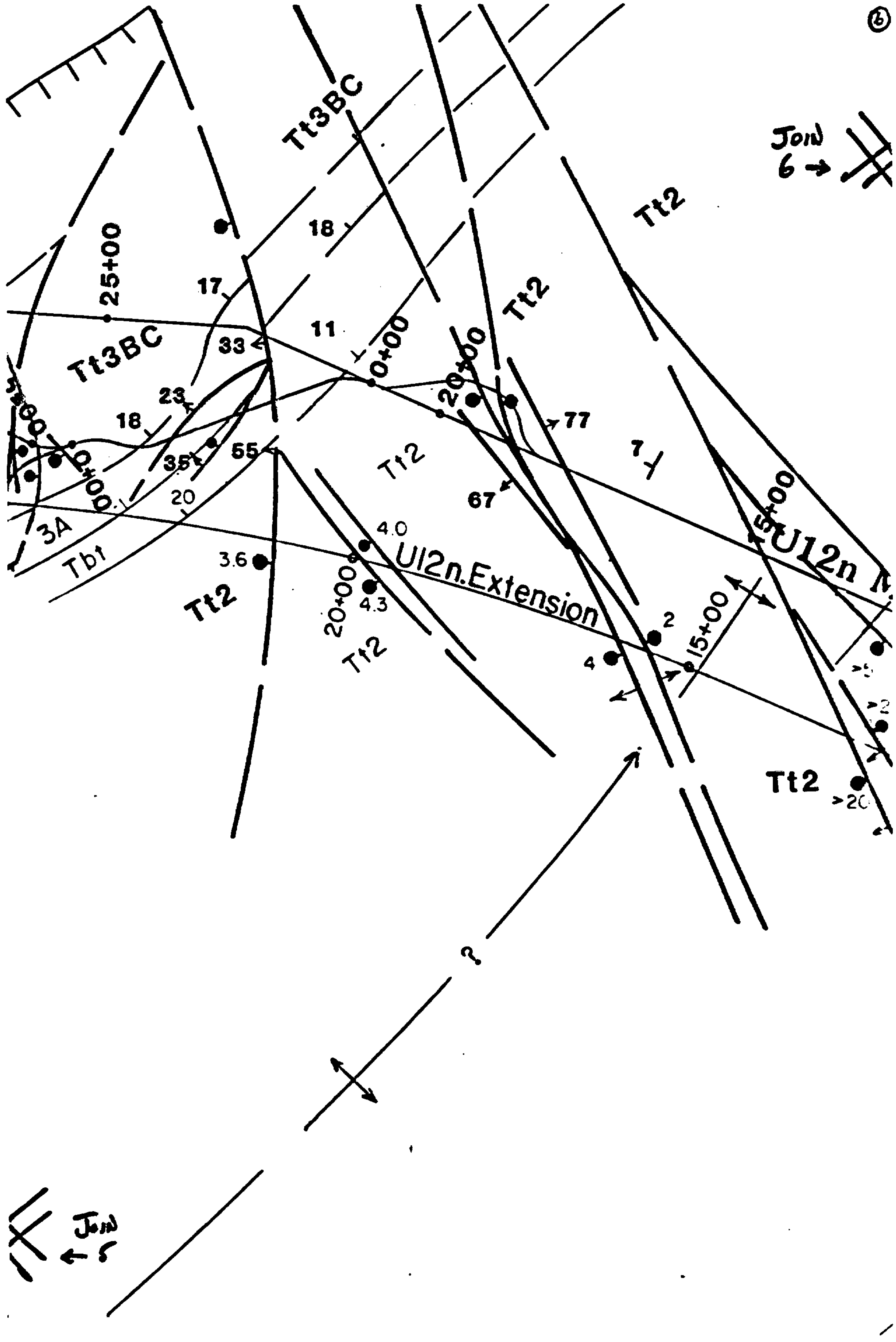
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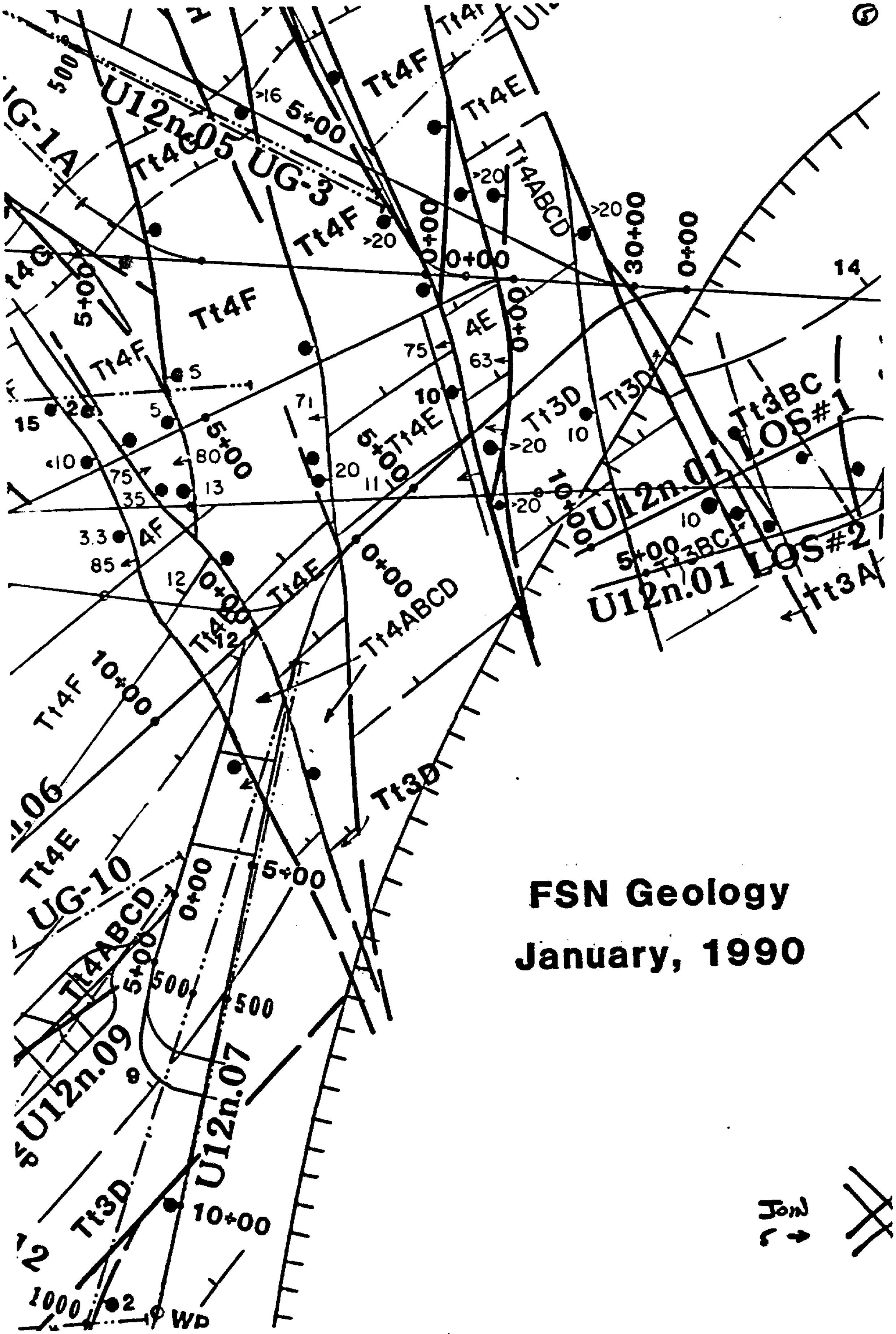

FSN Geology

January, 1990

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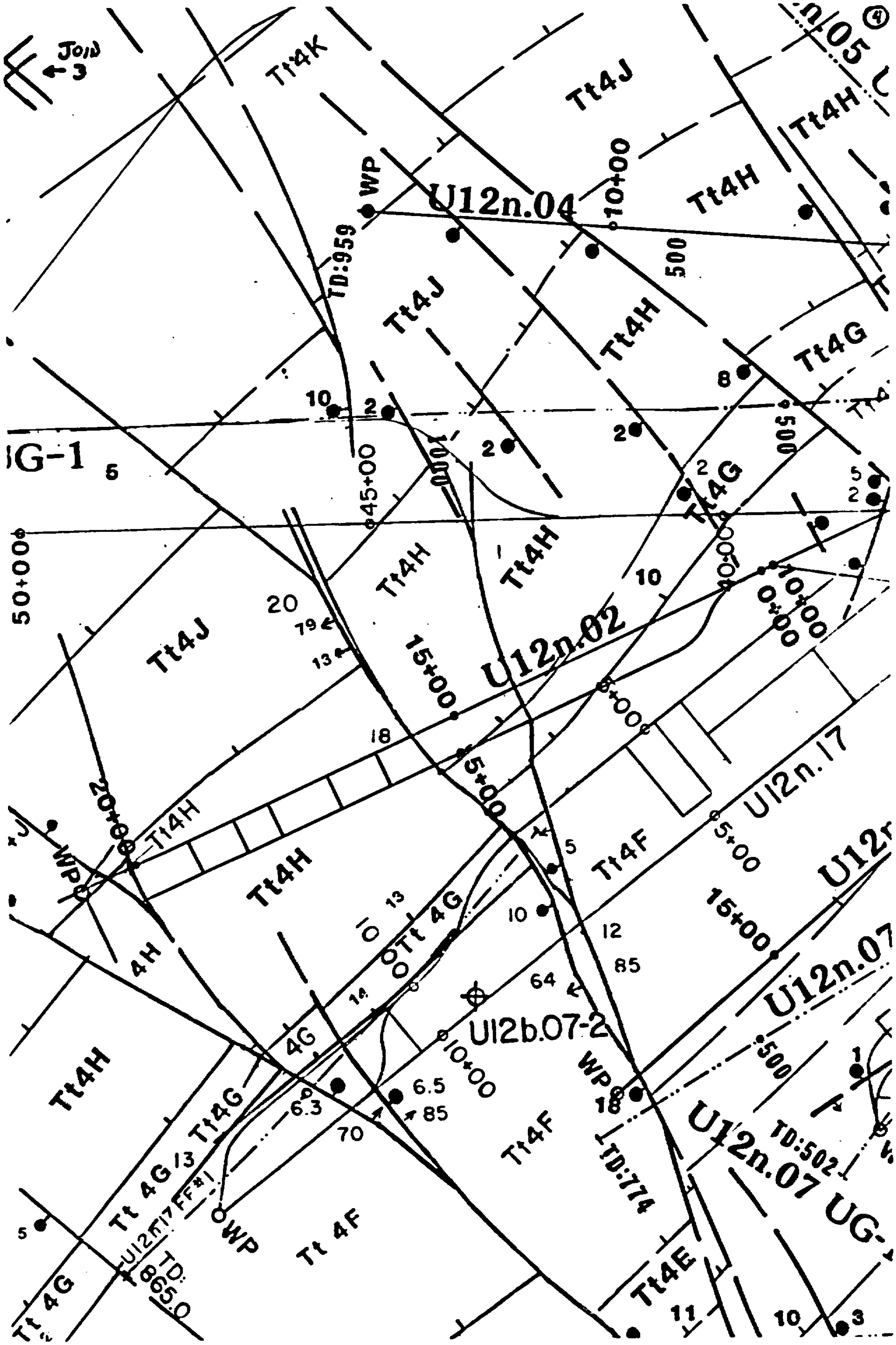

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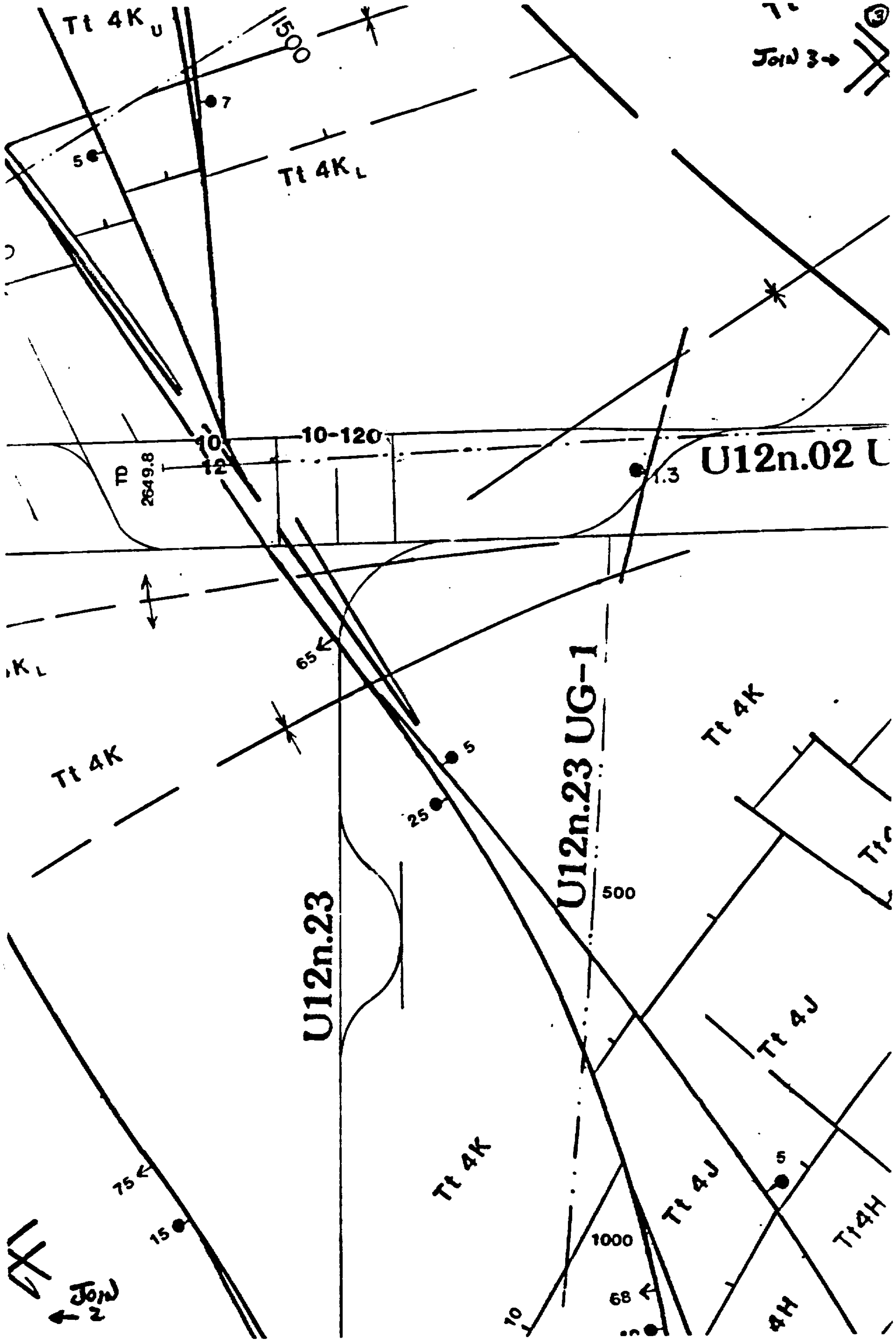

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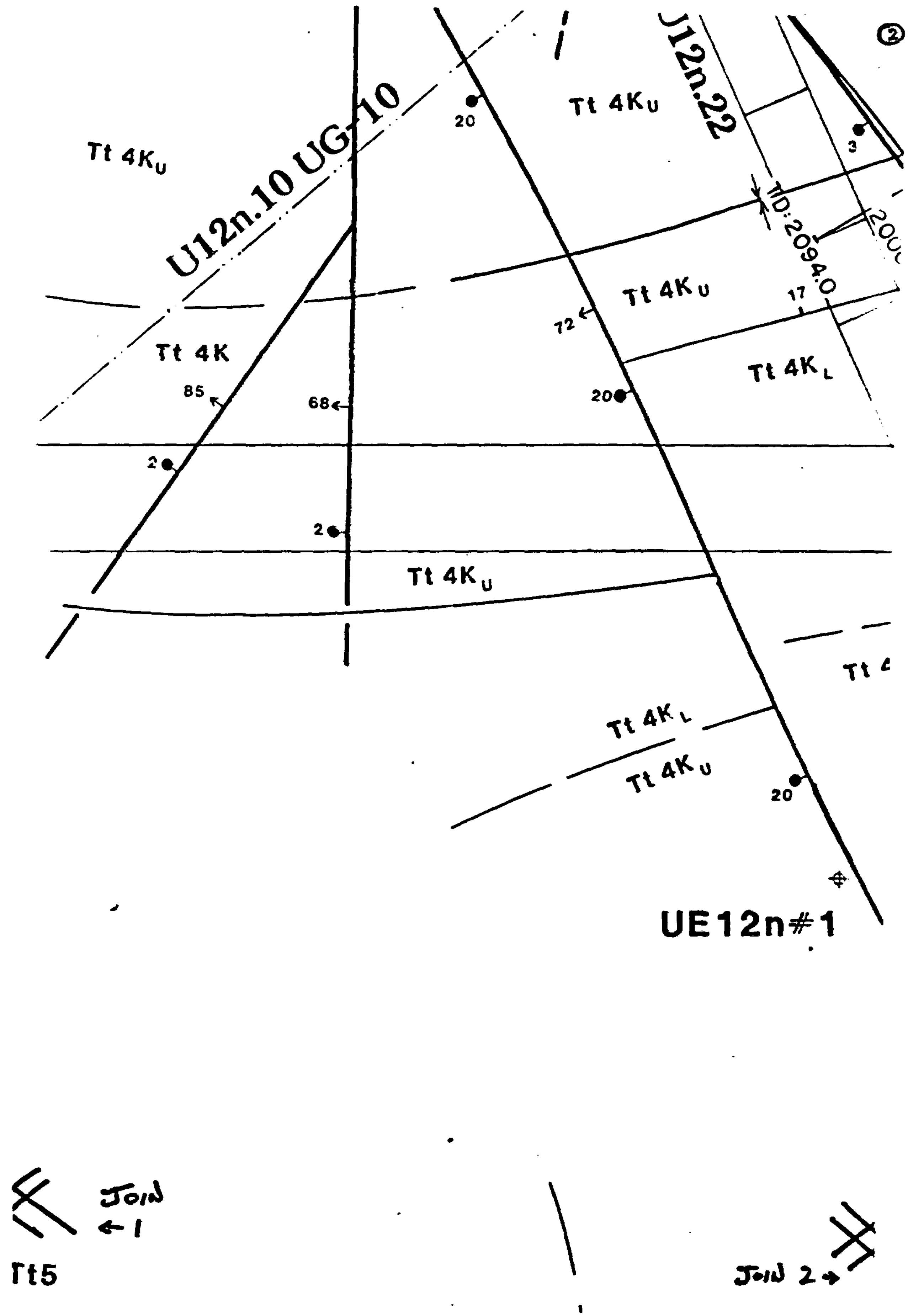

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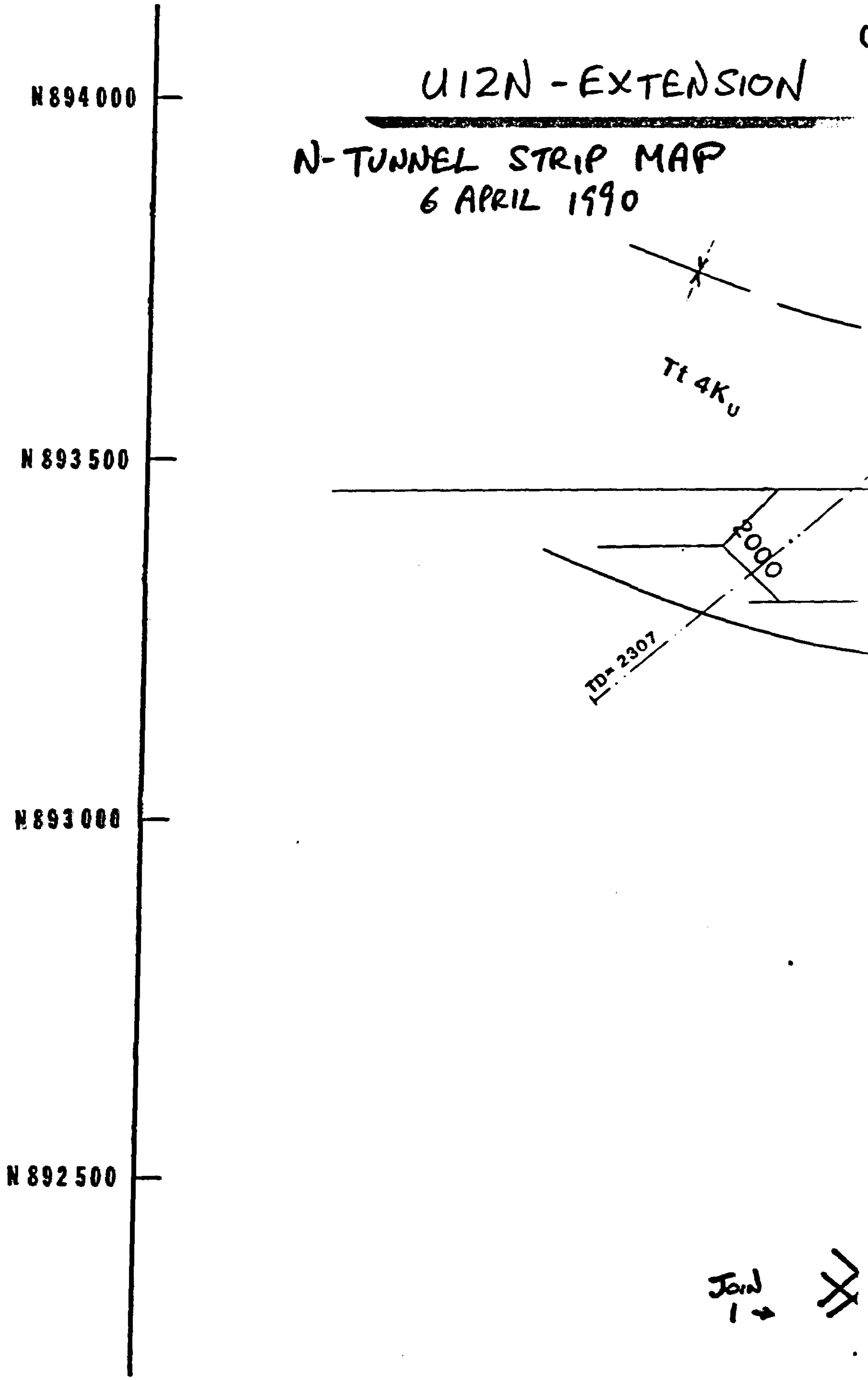
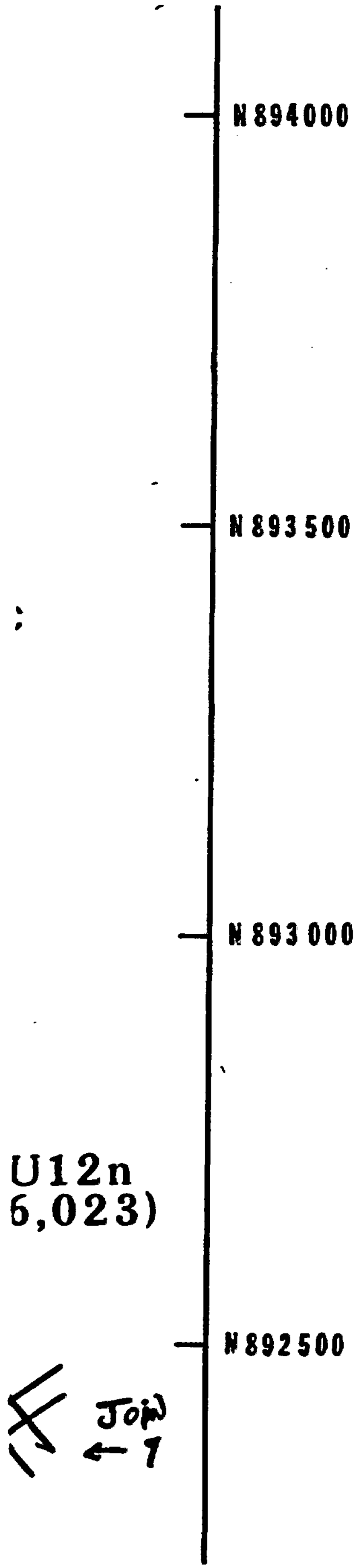
ENCLOSURE 3

(1)

U12N - EXTENSION

N-TUNNEL STRIP MAP
6 APRIL 1990

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Join
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U.S. DEPARTMENT OF ENERGY

OCRWM

YUCCA MOUNTAIN

YUCCA MOUNTAIN PROJECT

recvd from Mel Clawson
4/5/90 [signature]
Presented at TPO Meeting today.

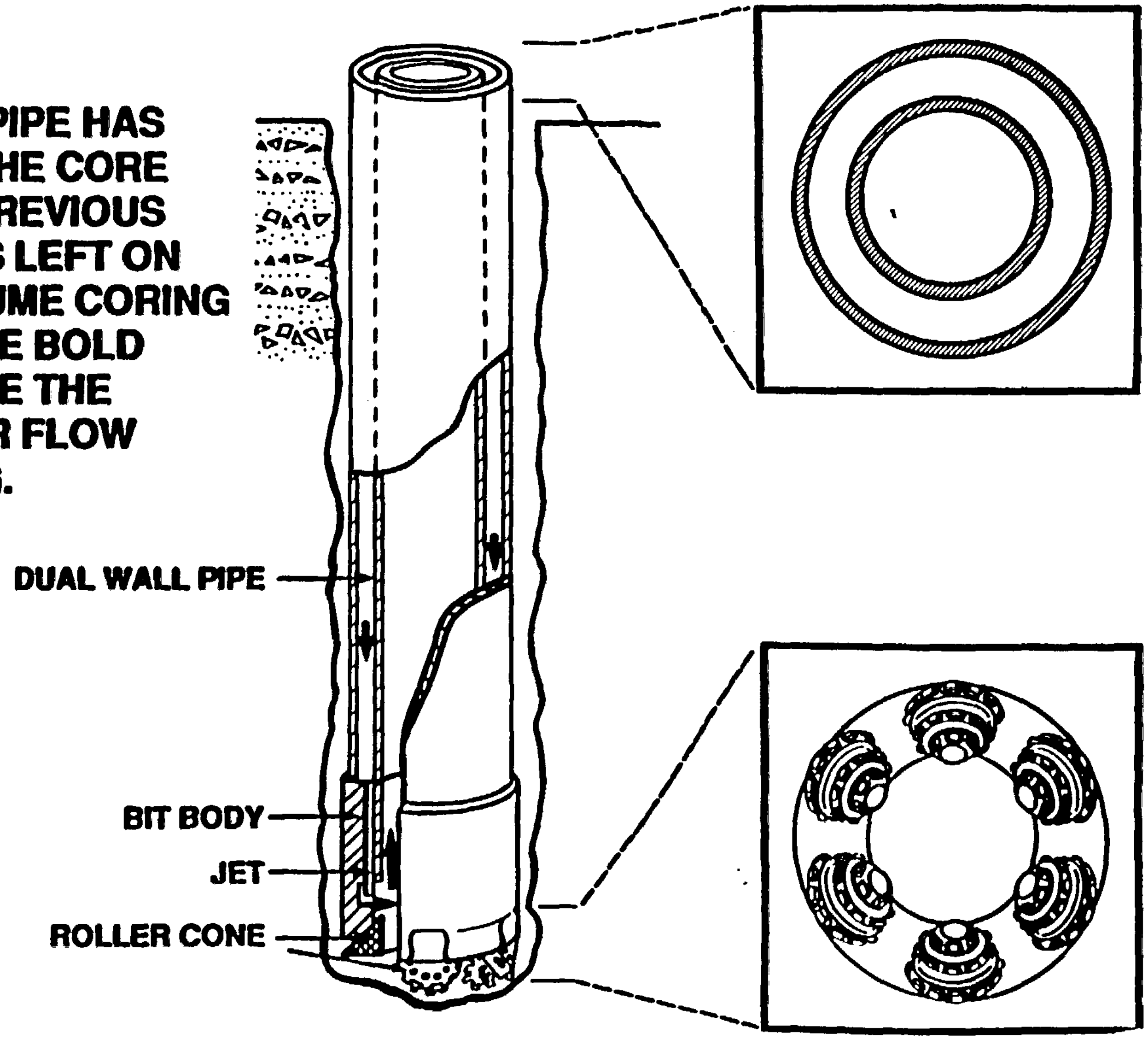
APACHE LEAP PROTOTYPE DRILLING

UNITED STATES DEPARTMENT OF ENERGY
NEVADA OPERATIONS OFFICE/YUCCA MOUNTAIN PROJECT OFFICE

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

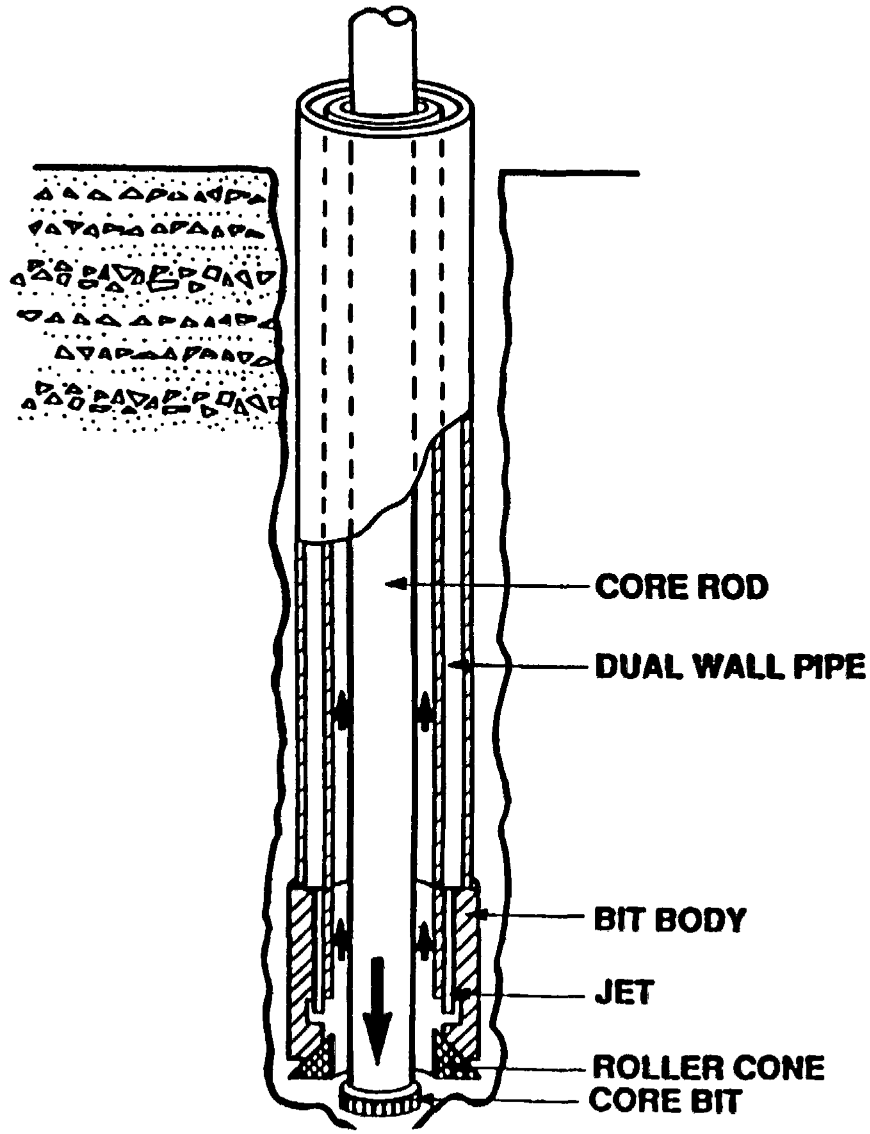
DUAL WALL DRILLING/CORING SYSTEM
DRAWING NO. 1

THE DUAL WALL PIPE HAS REAMED DOWN THE CORE TRACK FROM A PREVIOUS CORE RUN AND IS LEFT ON BOTTOM TO RESUME CORING OPERATIONS. THE BOLD ARROWS INDICATE THE DIRECTION OF AIR FLOW DURING REAMING.



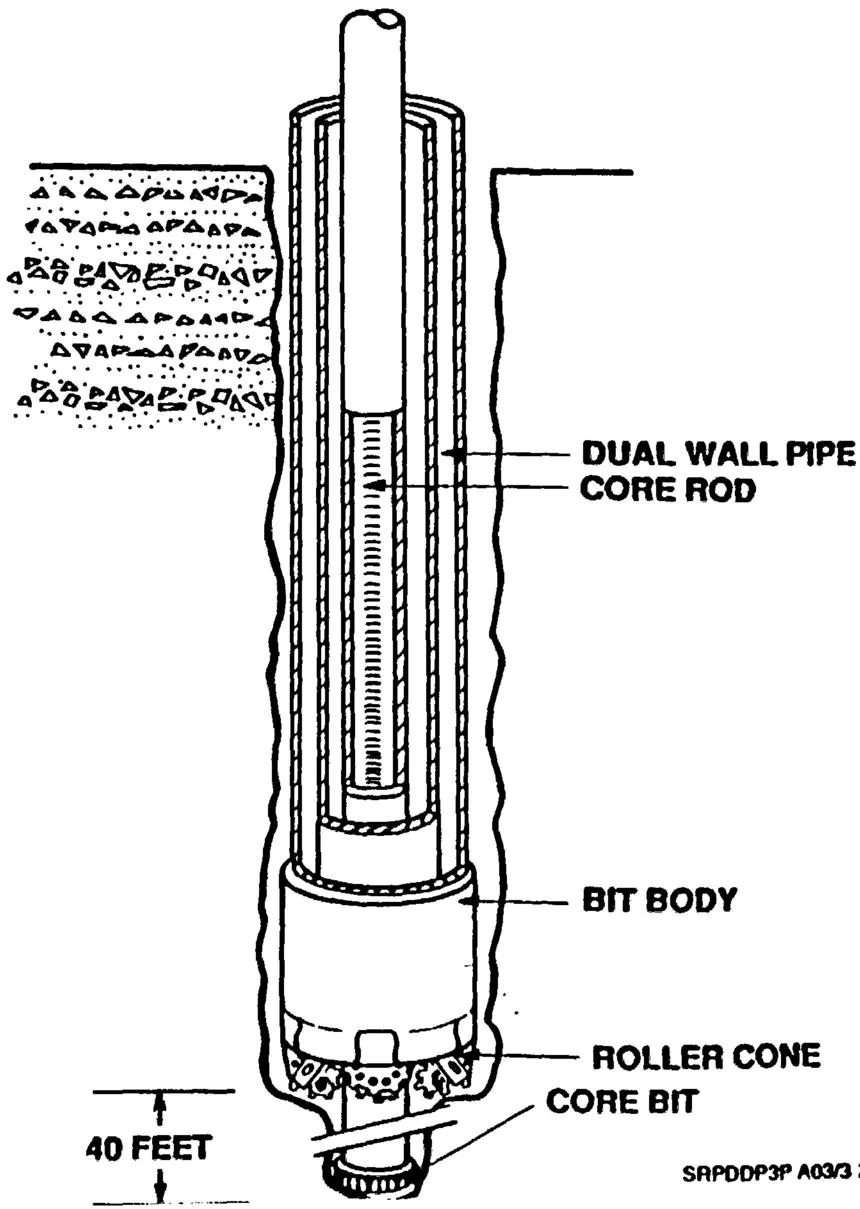
DUAL WALL DRILLING/CORING SYSTEM
DRAWING NO. 2

THE CORE ROD IS RUN IN THE HOLE INSIDE THE DUAL WALL PIPE. THE DRILLPIPE ACTS AS A PROTECTIVE CASING TO PROTECT THE CORE ROD FROM THE FORMATION AND TO PROTECT THE FORMATION FROM THE HIGH PRESSURE AIR AND CUTTINGS PRODUCED BY THE CORING OPERATION. ARROWS INSIDE AND ADJACENT TO CORING ASSEMBLY INDICATE DIRECTION OF AIR FLOW DURING CORING OPERATIONS.



DUAL WALL DRILLING/CORING SYSTEM
DRAWING NO. 3

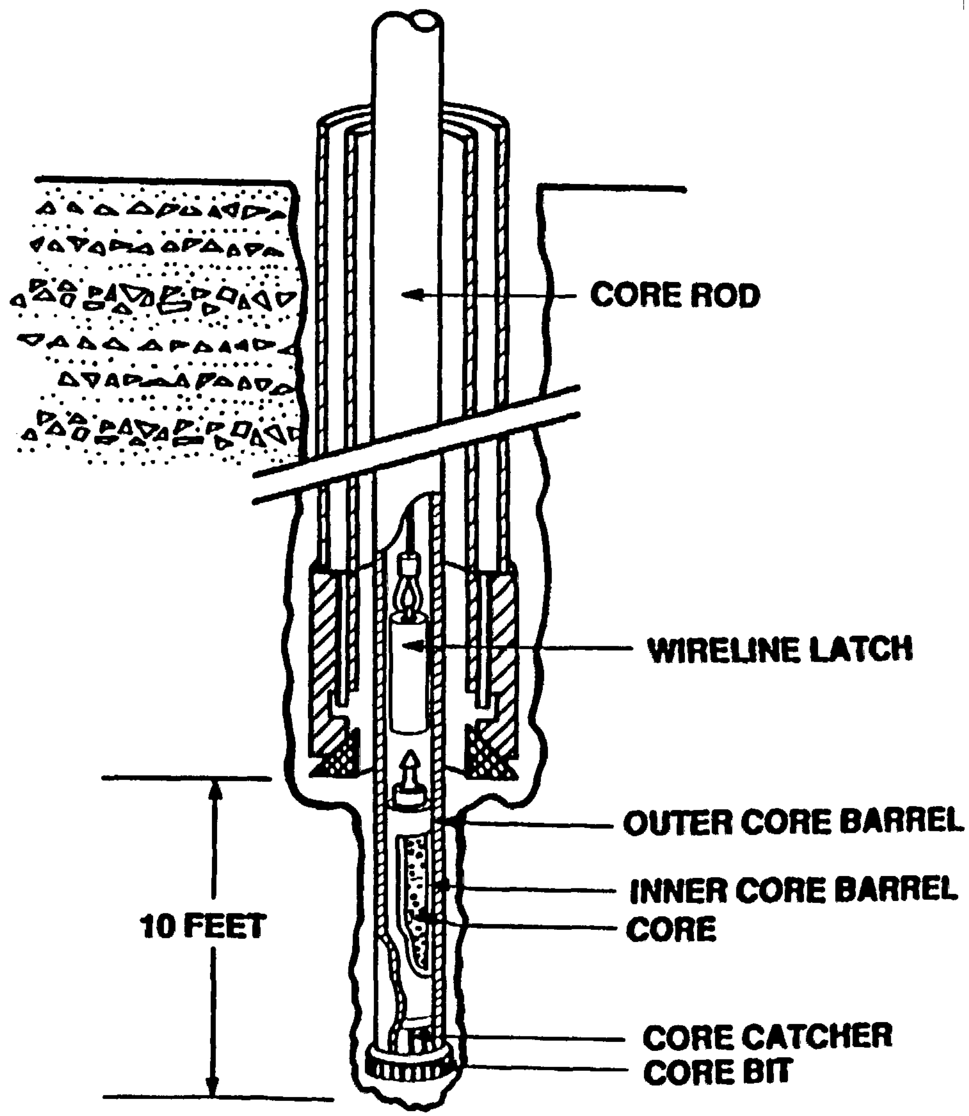
CORING OPERATIONS ARE COMMENCED AND THE CORE ROD IS ADVANCED 40 FEET AHEAD OF THE DUAL WALL PIPE IN 10 FOOT INCREMENTS (10 FOOT CORES). THE CORES ARE RETRIEVED BY CONVENTIONAL WIRELINE WHILE THE CORE ROD IS LEFT IN THE HOLE FOR THE DURATION OF THE 40 FOOT CORE RUN. THE 40 FOOT LIMIT IS USED TO PREVENT THE MORE FLEXIBLE CORE ROD FROM INITIATING A DEVIATION IN THE BOREHOLE AND CAUSING THE DRILLPIPE TO FOLLOW A DEVIATED PATH RESULTING IN BINDING OF THE DUAL WALL PIPE.



SRPDDP3P A03/3 26 90

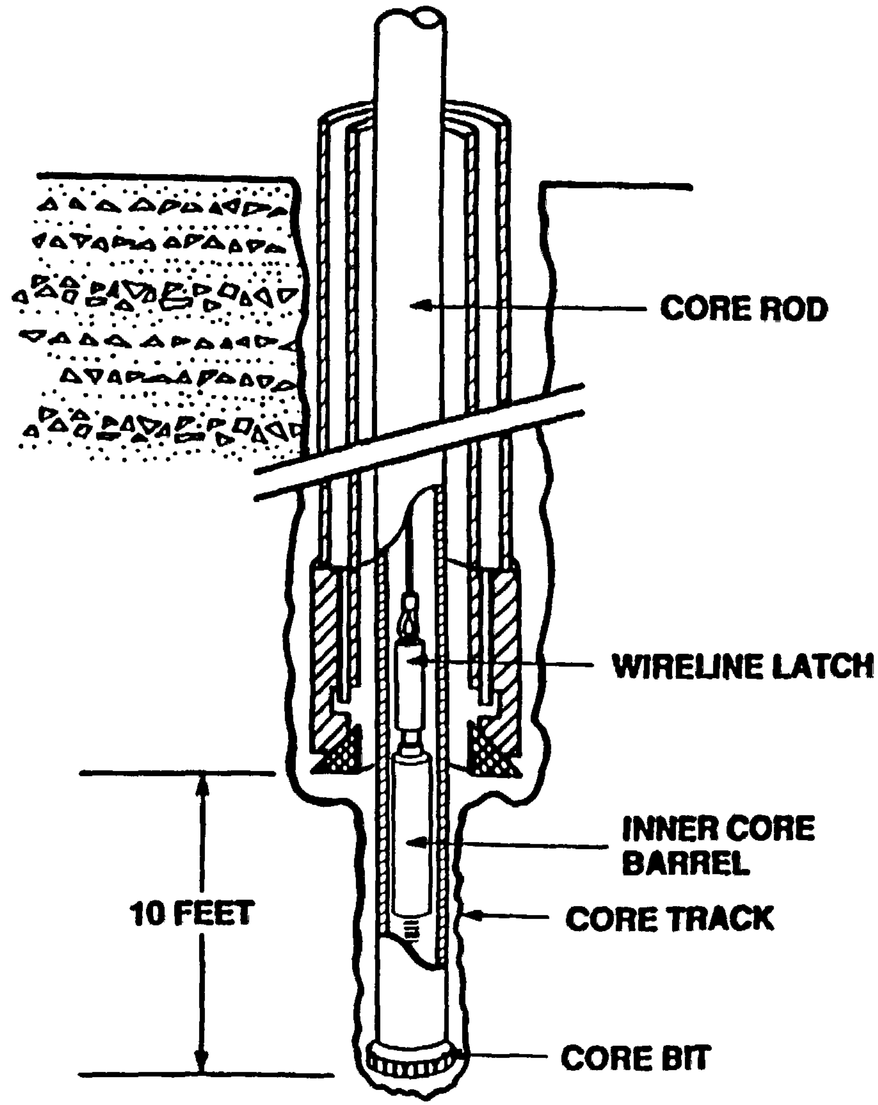
DUAL WALL DRILLING/CORING SYSTEM
DRAWING NO.4

AT THE END OF EACH 10 FOOT CORED INTERVAL THE CORE ROD IS PICKED UP SLIGHTLY AND THE CORE IS BROKEN BY THE CORE CATCHER JUST ABOVE THE CORE BIT. THE CATCHER IS A DEVICE WHICH ALLOWS THE CORE TO ENTER THE INNER BARREL BUT PREVENTS IT FROM BACKING OUT. A WIRELINE LATCH (OVERSHOT) IS THEN RUN INSIDE THE CORE ROD AND THE TOP OF THE INNER BARREL IS "CAUGHT" WITH THE WIRELINE.



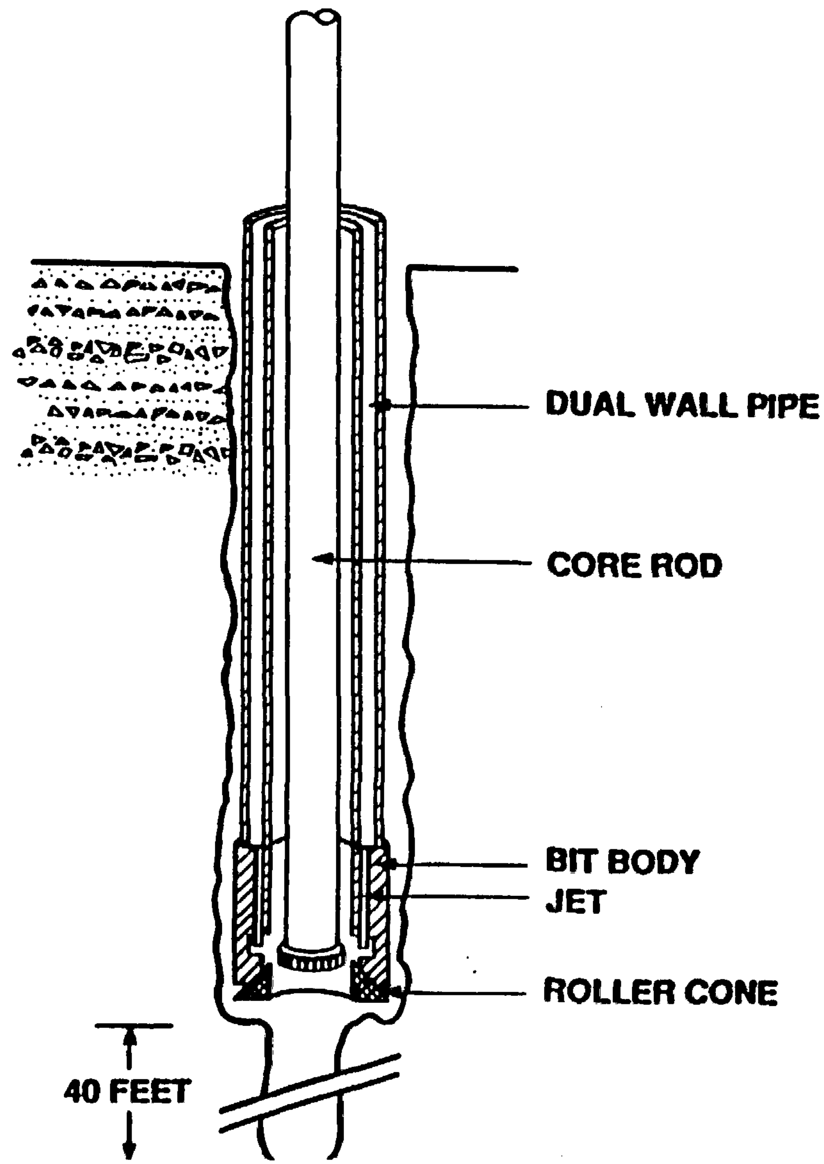
DUAL WALL DRILLING/CORING SYSTEM
DRAWING NO. 5

AFTER THE CORE IS BROKEN, THE INNER BARREL (WITH CORE HELD IN BY THE CORE CATCHER) IS PULLED OUT OF THE HOLE BY WIRELINE. A NEW (EMPTY) INNER BARREL IS THEN RUN IN HOLE, LATCHED INTO THE OUTER BARREL, AND THE WIRELINE IS REMOVED. THIS SEQUENCE IS REPEATED EACH TIME THE CORE TRACK IS ADVANCED 10 FEET.



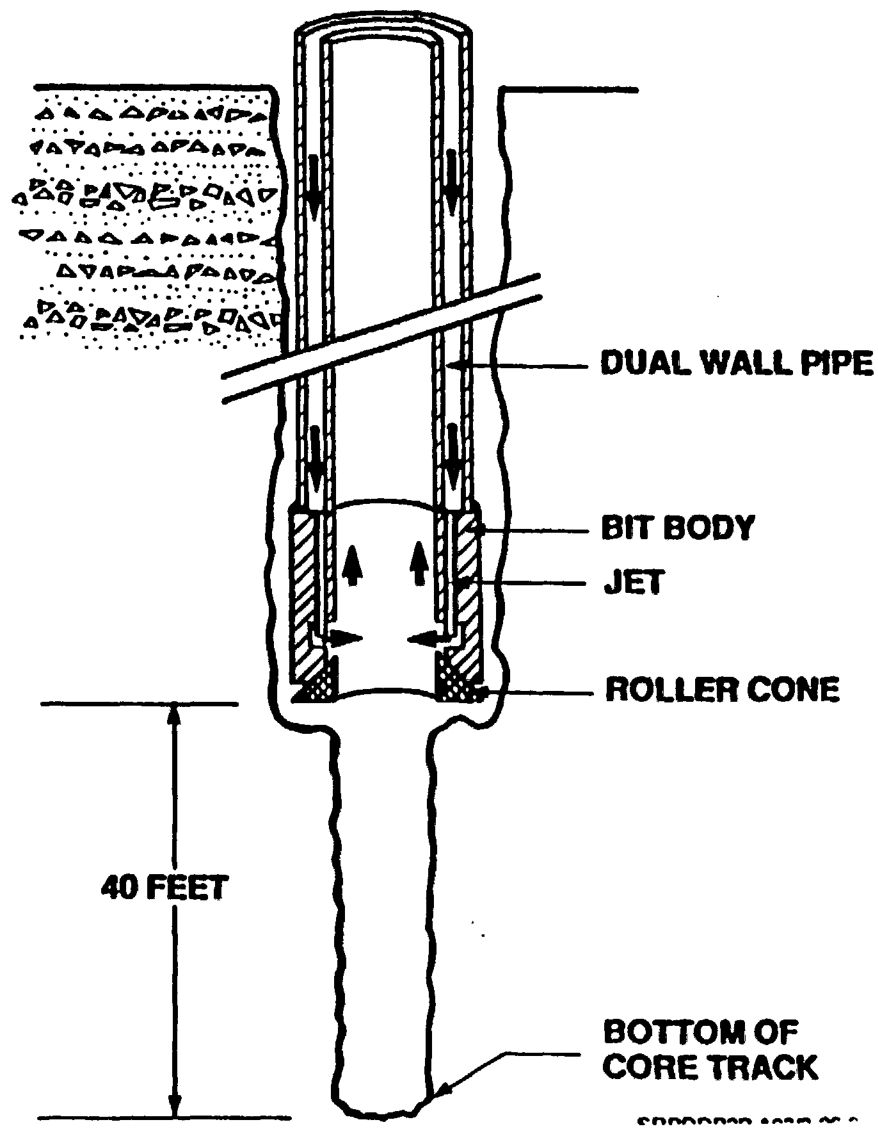
DUAL WALL DRILLING/CORING SYSTEM
DRAWING NO. 6

THE CORING STRING IS PULLED OUT OF THE HOLE AT THE END OF THE 40 FOOT CORE RUN IN PREPARATION FOR REAMING DOWN THE CORE TRACK WITH THE DUAL WALL PIPE.



DUAL WALL DRILLING/CORING SYSTEM
DRAWING NO. 7

ONCE THE CORING ASSEMBLY IS OUT OF THE BOREHOLE, IT IS DRILLED/REAMED WITH THE DUAL WALL DRILL STRING TO THE BOTTOM OF THE CORE TRACK. THE FORMATION IS PROTECTED FROM CONTAMINATION NORMALLY ASSOCIATED WITH DRILLING BY CIRCULATING THE CUTTINGS UP THE CENTER OF THE DUAL WALL PIPE. CONTAMINATED FORMATION CAUSED BY THE CORING OPERATION IS REMOVED WHEN THE CORE TRACK IS REAMED DOWN. THE BOLD ARROWS INDICATE THE DIRECTION OF AIR FLOW DURING REAMING.



DRILLING/CORING SEQUENCE

1. CORE 40' IN 10' INTERVALS USING WIRELINE CORE RETRIEVAL

2. REMOVE CORE ROD

3. REAM WITH 12 1/4" BIT THROUGH CORED INTERVAL (LEAVE 12 1/4" STRING IN HOLE)

4. RUN-IN HOLE WITH CORE ROD

   RETURN TO STEP 1

APACHE LEAP PROTOTYPE DRILLING

HOURLY BREAKDOWN BY CATEGORY:

CATEGORY	3 APRIL HOURS	2 APRIL HOURS	1 APRIL HOURS	31 MARCH HOURS	30 MARCH HOURS	29 MARCH HOURS
REAMING:	0.50	2.25	1.75	2.50	0.00	4.50
CORING:	2.25	6.00	3.25	0.40	9.50	2.25
CORE RECOVERY:	1.50	0.75	1.25	0.10	1.50	0.75
TRIP TIME FOR REAMING:	0.00	0.00	1.50	2.50	0.00	0.00
TRIP TIME FOR CORING:	4.00	1.00	1.00	1.00	0.00	1.25
RIGUP/RIGDOWN:	1.25	1.00	2.25	1.75	0.00	1.75
DOWNTIME:	1.50	0.00	0.00	2.75	0.00	0.50
STARTUP/SHUTDOWN:	1.00	1.00	1.00	1.00	1.00	1.00
TOTAL	12.00	12.00	12.00	12.00	12.00	12.00

LESSONS LEARNED
PHASE 1E PROTOTYPE DRILLING

- CORING PROBABLY LIMITED TO A MAXIMUM OF 40 FEET BEFORE REAMING
- ID OF THE REAMING BIT AND OD OF THE CORING BIT MUST BE WITHIN 1/8 INCH TO PREVENT PLUGGING
- THE VACUUM SEPARATOR/BOOSTER MAY BE REQUIRED FOR DRY DRILLING
- CUTTINGS DIVERTER TUBE/DISCHARGE PORT NEEDS TO BE REDESIGNED TO DECREASE RIGUP/RIGDOWN TIME
- SLIPS USED TO HOLD THE CORE ROD NEED TO BE MADE LARGER TO ALLOW PASSAGE OF CORE ROD STABILIZERS
- THE PRESENT CORE ROD STABILIZERS MAY OR MAY NOT WORK
- ROD/BIT CHATTER CAN BE MINIMIZED BY KEEPING RPM BELOW 50
- BIT LIFE ESTIMATES FOR THE 12 1/4 INCH OPEN CENTER BITS APPEAR TO BE VERY GOOD EVEN WITH PERIODS OF POOR CLEANING

LESSONS LEARNED
PHASE 1E PROTOTYPE DRILLING
(CONTINUED)

- DIAMOND IMPREGNATED BITS USED TO DATE APPEAR TO HAVE A BIT LIFE IN EXCESS OF 200 FEET
- THE VACUUM SYSTEM APPEARS TO BE AN EFFECTIVE METHOD FOR SURFACE DUST CONTAINMENT
- VERIFICATION AND DOCUMENTATION OF DEPTH CONTROL REQUIRES AN INTERFACE BETWEEN SAMPLE MANAGEMENT FACILITY STAFF AND THE DRILLING STAFF
- NOT ALL CORE ROD IS 19.68' (3 METERS) IN LENGTH. A CORE ROD AND DUAL WALL PIPE TALLY WILL BE REQUIRED
- SCRUBBERS MAY BE REQUIRED FOR OPERATING IN SOME WEATHER CONDITIONS
- KWIK-FIT AND THREADED HAMMER UNION CONNECTORS WILL BE REQUIRED TO REDUCE MAKE UP/BREAK OUT TIMES
- THE PRESENT PACKOFF HEAD DESIGN IS NOT ACCEPTABLE FOR LONG TERM OPERATIONS BECAUSE OF OIL CONTAMINATION

LESSONS LEARNED
PHASE 1E PROTOTYPE DRILLING

(CONTINUED)

- THE THREAD LUBRICANT (PIPE DOPE) POSES SOME PROBLEM OF CORE CONTAMINATION
- METERS MONITORING BOTH COMPRESSOR DISCHARGE AND DRILLING DISCHARGE ALLOW THE DETERMINATION/ CALCULATION OF OPTIMUM AIR FLOW/NUMBER OF COMPRESSORS
- DIFFICULTIES IN HANDLING PIPE DURING MAKE UP AND BREAK OUT ARE MORE APPARENT AND OF GREATER IMPACT WITH THE 9 5/8 INCH DRILL PIPE. AN ARTICULATED PIPE HANDLING SYSTEM WILL BE REQUIRED FOR THE DEEPER UZ DRILLING
- BASED ON USAGE/TESTING TO DATE, LEXAN DOES NOT APPEAR TO HAVE A CONSISTENT POTENTIAL FOR PROTECTING THE PQ DIAMETER CORE. THE HQ DIAMETER LEXAN WILL BE TESTED AGAIN BELOW 1100 FEET

LESSONS LEARNED
PHASE 1E PROTOTYPE DRILLING

(CONTINUED)

- A NEW SPLIT STAINLESS STEEL LINER INSIDE A SOLID INNER BARREL MAY BE WORKABLE COMPROMISE TO PROTECT THE CORE AND PROVIDE FOR CONSISTENT RECOVERY
- THE PRESENT SPECIAL PROCESSING OF CORE TO PRESERVE THE NATURAL STATE CONDITIONS IS CUMBERSOME, TIME CONSUMING, AND MAY COMPROMISE THE QUALITY OF THE SAMPLE RATHER THAN PROTECT IT
- THE PROTOTYPE PROGRAM HAS SHOWN THAT AN OPTIMIZED DRILLING/CORING PROGRAM IS A GRADUAL LEARNING PROCESS AND SHOULD BE CONTINUED AS TIME AND BUDGET WILL PERMIT

LESSONS LEARNED
PHASE 1E PROTOTYPE DRILLING
2 APRIL 90

1. The most recent experience indicates that improvements will be required over the previous attempt when coring ahead of the open-center reaming bit more than approximately 40'because of the tendency of the core bit to walk excessively. Trends thus far cannot be conclusive because the core barrel was not stabilized or centralized before attempting to core the 60' ahead when the core track became offset one full core width at 60'. Another attempt will likely be made utilizing the newly manufactured reaming bit for better centralization and with a stabilized coring string inside the dual wall pipe.

2. Reaming bits must be manufactured as a complement to the coring bit planned for use. The ID of the reaming bit should not be more that 1/8" larger than the OD of the coring bit in order to reduce the cuttings size to a minimum, and thus minimize plugging of the opencenter bit.

3. The vacuum separator appears to be effective (at this depth) during reaming when there is no obstruction in the throat of the reaming bit (effective cutting and cleaning on bottom during reaming). After running the reaming bit with reduced ID clearance, minimal indication of pressure was noted on the annulus of the 9-5/8" pipe (gage appeared to be moving due to vibration of the drillpipe against the surace casing packoff). The next test will be to remove the plug in the surface casing port to see if there is suction on the backside.

4. The tophead drive connector tube needs to be remachined to fit the newly designed tophead (same head that will be on the LM-300) in order for the diverter tube to seal off properly during coring. At present, the discharge hose has to be disconneced after reaming and the dischare port closed with a blind flange prior to coring. This refit should decrease rigup/rigdown time when changing between coring and reaming.

5. The slips used to hold the core rod during makeup of the next rod need to be larger in order to pass the stabilizers for the core rod. It may be necessary to purchase a different system rather than modifying the present slips.

6. The plastic stabilizers may or may not be of benefit to the coring operation and for decreasing wear on the inner tube. The one stabilizer run at a shallower depth actually seemed to increase rod chatter and has not been rerun since. Rod chatter, thus far, has been effectively countered by keeping rotation speed to 50 RPM or below.

7. Rod (bit body) chatter in the 9-5/8" pipe also appears to be minimized by keeping the rotation speed to 50 RPM or below. This is also the maximum recomended RPM for the 12-1/4" bit due to the nature of the manufacturing process (6-1/4" roller cones used for opencenter bits - 50 RPM max is based on increase of relative speed of cone on outer diameter of 12-1/4" track, approximately a factor of 2 increase in speed - 100 RPM max recommended speed for 6-1/4" journal bearing bit translates to 50 RPM when cone is used for 12-1/4" opencenter bit).

8. Bit life estimate of 12-1/4" bits continues to appear very good, even despite some situations of possible poor cuttings cleaning.

9. Core bits appear to be good for a minimum of 200'. Impregnated bits have been used exclusivley thus far. Some surface set bits will be run for comparison.

10. The vacuum system does appear to be a viable method to provide the following benefits: 1) A closed system for dust containment and minimization of any health threat caused by carcinogenic zeolites; 2) An air assist method to further help the reaming system to "unload" the hole and prevent air and cuttings dust from being injected into the formation; and 3) A means by which the discharge air can be metered and recorded to insure that the air volume injected for drilling/reaming equals the air discharged by the vacuum. A recent inspection of the drilling system by an industrial hygenist appeared favorable based on the fact that the closed system for dust containment resulted in more dust being generated by passing cars than by the drilling/sampling system perse. The system will need to be redesigned to reduce the size and amount of equipment required to drill on the drillsite.

11. Verification and documentation of depth control appears to be an absolute necessity for proper interface between the SMF and drilling personnel. A "depth control sheet" has been developed and is being used in order to facilitate this interface. The sheet shows the spaceout of all surface flanges, the rig floor, and the "stick-up" of core rod at the end of each coring run. This sheet, in addition to a tally of the core rod, is given to the SMF personnel after each core run. It is the responsibility of the SMF rep. to either resolve all conflicts with core depth during logging of the core or to "challenge" the record by requiring the rod to be remeasured and witnessed by an SMF representative. In this manner, a firm depth will be established for, at least, the next coring point so that operations can resume as soon as possible. All core between the present verified depth and some previously verified depth will be resolved by further analysis/requalification of the core from the interval in question. (Interesting note: need to verify rig floor distance from ground level was noted when the driller raised and lowered the floor to adjust the slips - this is not usual for the typical fixed base rig).

? 12. ~~In regard to depth~~ control, it was discovered that not all the core rod was 19.68' (3 meters) as previously assumed. The minor difference between assumed and actual will cause a cumulative error resulting in questionable % core recovery at depth. As a result, both core rod and dual-wall pipe tally's will be maintained as part of the depth control record. Good accuracy is anticipated on the tally because both core rod and dual-wall pipe are flush joint pipe and easily measured.

13. Scrubbers may have to be purchased for the compression system if the air must be dry during all weather conditions. When there is high humidity the cooling provided by the booster is not adequate to remove all water. As a result, a film of water is developed on the core durin coring. This film is noted to evaporate quickly on the dry core in the logging trailor because there is apparently not additional "moisture support" from within the core. This film may actually be beneficial to preserving moisture in the pore space of the core.

14. The present fine thread couplings require excessive makeup and breakout time. Kwik-fit couplings & coarse threaded hammer union type connections are a must to save time on makeup/breakout on all hoses & air/hydraulic couplings.

15. The sealing rubbers in the present packoff head will likely not be acceptable for long term operation due to the oil (or other lubricant) which must be kept on them to reduce the rotating friction of the pipe.

16. The present thread lubricant being used to prevent galding when the pipe is madeup and brokeout is standard "pipe dope", a grease-like lubricant. When the pipe is madeup some of the pipe dope extrudes both inside and outside the core rod. When air is injected down the core rod some of the pipe dope is picked up and carried down to the exposed core between the core bit and the core catcher (base of the inner barrel). The pipe dope residue is deposited on the surface of the core as it enters the core catcher where it is smeared by the teeth of the core catcher as the core enters the inner barrel. Most of the contamination appears to be on the surface of the core. If this is a problem with any PI's, some form of spray-on (thin-film) lubricant might be found which would provide adequate lubrication for the pipe without any contamination of the core. Time will be required to find an adequate product and it will likely be expensive. We need to know as soon as possible if there is a need to eliminate the core contamination by the pipe dope. Does anybody need to look at some of the core to evaluate the extent of contamination - some core runs were smeared pretty good?

17. A meter run has been installed on the compressor discharge line for this phase of prototype drilling. It has confirmed both the air coming from each compressor and the effect of atmospheric changes on equipment performance. Perhaps most important, it has allowed us to monitor the air and calculate minimum rates/compressors required for each operation. Metering the air has allowed the reduction of the coring air from two to one compressor. Further inspection/testing might also allow reduced air for reaming.

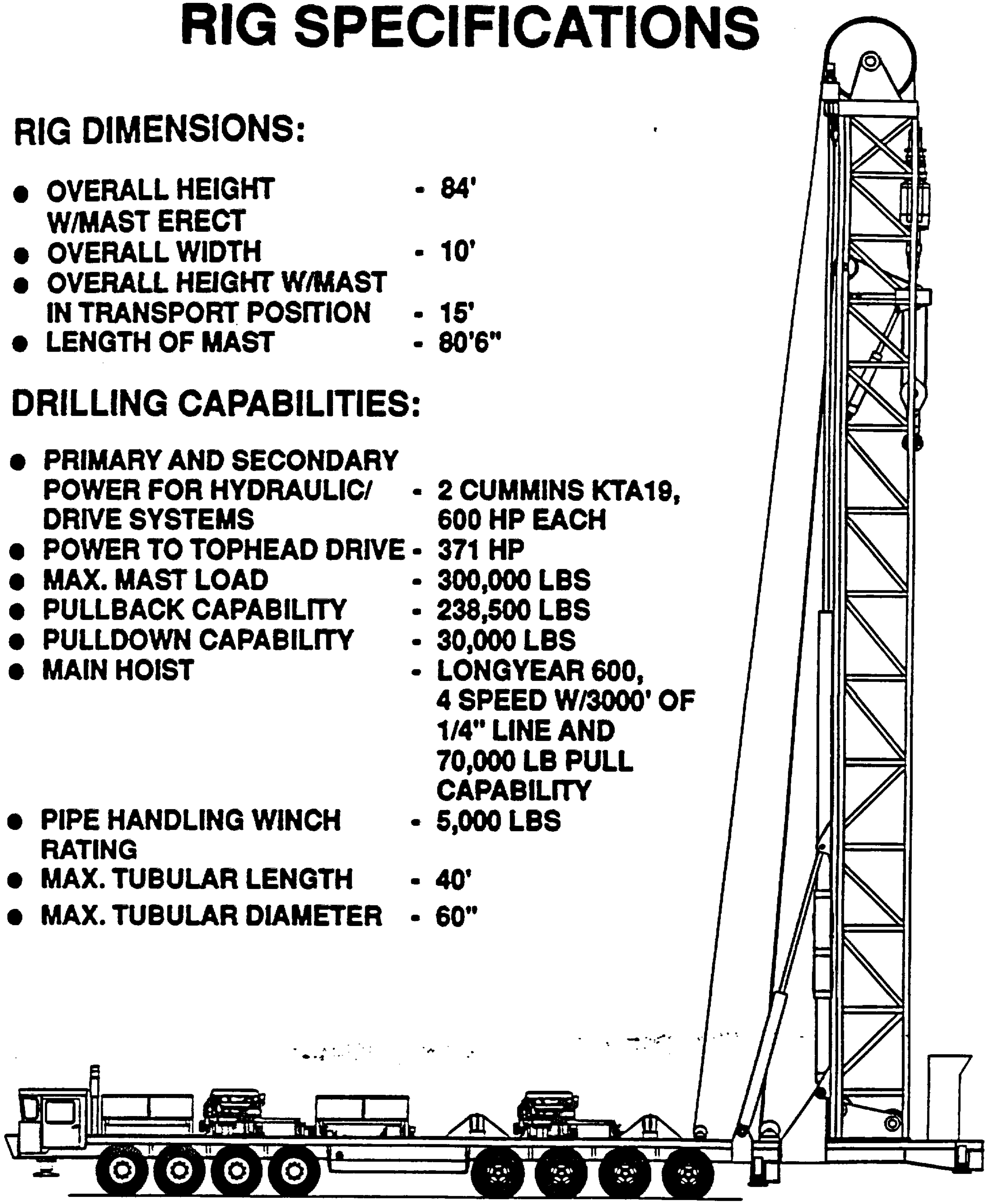
18. Difficulties in handling the pipe during makeup and breakout are more apparent with the large 9-5/8" drillpipe. The pipe rack provided by Lang Exploratory Drilling for this operation has proven to be an absolute necessity. The need for an articulated pipe handling system in combination with an efficient racking system appears essential for drilling deeper UZ boreholes.

19. The daily changes and re-evaluations of data emphasize that it is too early in the program to make too many decision making evaluations. The program has shown that optimized drilling/sampling will be a gradual learning process by all involved. What we have learned thus far, in effect, is that we need to continue development of equipment and procedures as long as time and budget will permit prior to initiating a QA-1 site investigation program.

20. Thus far, Lexan has been drilled, collapsed, chipped, crumpled and split with no sign of successful potential for protecting PQ core on anywhere near a consistent basis. A sample of HQ Lexan of the type successfully used in G-tunnel was inspected. The wall thickness was 0.056". By comparison, the better PQ Lexan which we have used has a maximum wall thickness of approximately 0.052" with a minimum of the weak Lexan being 0.028". The wall thickness to diameter ratio is critical to the rigidity of all tubulars With this as a basis of comparison, the wall thickness of the PQ Lexan should be increased 38% greater than that of the HQ barrel used in G-Tunnel. Thus, the PQ Lexan should have a minimum wall thickness of 0.077" in order to have the same chance of success as the HQ Lexan. The HQ lexan will be tested more extensively in the 9-1/2" hole below 1100'.

21. Perhaps a more important result is the fact that all the lexan tubes used to date (both PQ and HQ) have had holes drilled in the top to relieve pressure differentials across the lexan to keep it from collapsing. In addition, the core is not a tight fit in the lexan. The combination of loose fit in the lexan and holes at the top of the lexan allows air to be free to travel down the core thus wetting the surface of the core. The fit of the core in HQ lexan is better than that in the PQ. By comparison, however, a solid barrel with a stainless steel liner has recently been used with very good result from the standpoint of protecting the core. The split stainless steel liner is a tight fit around the core and the solid inner barrel protects the core from all pressure differentials and further wetting once the core is inside the inner tube, in addition to insuring that a jam does not result in a trip of the coring assembly. This split stainless steel liner appears to have good potential for being a compromise between lexan and a split inner barrel. The split liner can be retained after the core is removed from the solid inner barrel to protect it until it can be placed in a protected surrounding.

LM-300
RIG SPECIFICATIONS



RIG DIMENSIONS:

• OVERALL HEIGHT W/MAST ERECT	- 84'
• OVERALL WIDTH	- 10'
• OVERALL HEIGHT W/MAST IN TRANSPORT POSITION	- 15'
• LENGTH OF MAST	- 80'6"

DRILLING CAPABILITIES:

• PRIMARY AND SECONDARY POWER FOR HYDRAULIC/ DRIVE SYSTEMS	- 2 CUMMINS KTA19, 600 HP EACH
• POWER TO TOPHEAD DRIVE	- 371 HP
• MAX. MAST LOAD	- 300,000 LBS
• PULLBACK CAPABILITY	- 238,500 LBS
• PULLDOWN CAPABILITY	- 30,000 LBS
• MAIN HOIST	- LONGYEAR 600, 4 SPEED W/3000' OF 1/4" LINE AND 70,000 LB PULL CAPABILITY
• PIPE HANDLING WINCH RATING	- 5,000 LBS
• MAX. TUBULAR LENGTH	- 40'
• MAX. TUBULAR DIAMETER	- 60"

LANG EXPLORATORY DRILLING LM-300

PERCENT OF COMPLETION MARCH 29, 1990

ITEM	DESCRIPTION	MATERIAL	LABOR
1.	ENGINEERING	90	95%
2.	TRUCK FRAME	95	99%
3.	FRONT SUSPENSION, AXLES & STEERING	99	95%
4.	DRIVE AXLES & SUSPENSION	99	98%
5.	DRIVE SHAFTS	99	95%
6.	TIRES & WHEELS	100	99%
7.	CUMMINS ENGINES	100	90%
8.	TRANSMISSION	100	90%
9.	COTTA TRANSFER CASE	100	95%
10.	CAB FOR ROAD DRIVING	90	85%
11.	ELECTRICAL	95	30%
12.	AIR BRAKE SYSTEM	99	75%

LANG EXPLORATORY DRILLING LM-300

PERCENT OF COMPLETION MARCH 29, 1990

(CONTINUED)

ITEM	DESCRIPTION	MATERIAL	LABOR
13.	MAST	90	75%
14.	SHEAVES & BUSHINGS	95	75%
15.	RIG CONTROLS	95	60%
16.	LONGYEAR HOIST ASSEMBLY	99	60%
17.	SPINDLE ASSEMBLY	85	50%
18.	FEED CYLINDERS	---	---
19.	MAST RAISE CYLINDER	100	95%
20.	PIPE HANDLING WINCH	90	20%
21.	OUTRIGGERS & CYLINDERS	100	90%
22.	WIRELINE ASSEMBLY	100	60%
23.	HYDRAULIC PUMPS & MOTORS	100	75%
24.	HYDRAULIC HOSING	95	50%

LANG EXPLORATORY DRILLING LM-300

PERCENT OF COMPLETION MARCH 29, 1990

(CONTINUED)

ITEM	DESCRIPTION	MATERIAL	LABOR
25.	SHOP LABOR (FOR ASSEMBLY, TESTING & WARRANTY)	---	---
26.	PAINT & SANDBLAST	100	70%
27.	MISCELLANEOUS HYDRAULIC PARTS	100	60%
28.	PULL BACK CYLINDER CARRIER	80	20%
29.	RACKING PLATFORM	---	---
30.	DRILL TABLE LINER PLATES	95	80%
31.	WRENCHES	95	30%
32.	NOISE CONTROL	85	80%

PHASE 1e PROTOTYPE DRILLING WORK SCHEDULE

Commence drilling & coring operations

MARCH						
S	M	T	W	T	F	S
	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

APRIL						
S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

MAY						
S	M	T	W	T	F	S
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

JUNE						
S	M	T	W	T	F	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

PLANNED PROGRAM SCHEDULE

EXTENDED SCHEDULE