SANDIA REPORT
SAND87–2687 • UC–721
Unlimited Release
Printed December 1992

Multipass Mining Sequence Room Closures: In Situ Data Report

Waste Isolation Pilot Plant (WIPP) Thermal/Structural Interactions Program

Darrell E. Munson, Robert L. Jones, Christine L. Northrop-Salazar, Sally J. Woerner

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550
for the United States Department of Energy
under Contract DE-AC04-76DP00789

Issued by Sandia National Laboratories, operated for the United States Department of Energy by Sandia Corporation.

Printed in the United States of America. This report has been reproduced directly from the best available copy.

Available to DOE and DOE contractors from
Office of Scientific and Technical Information
PO Box 62
Oak Ridge, TN 37831

Prices available from (615) 576-8401, FTS 626-8401

Available to the public from
National Technical Information Service
US Department of Commerce
5285 Port Royal Rd
Springfield, VA 22161

NTIS price codes
Printed copy: A10
Microfiche copy: A01

Flyleaf. View of Multipass Mining of a Test Room

SAND87-2687
Unlimited Release
Printed December 1992

MULTIPASS MINING SEQUENCE ROOM CLOSURES: IN SITU DATA REPORT

WASTE ISOLATION PILOT PLANT (WIPP) THERMAL/STRUCTURAL INTERACTIONS PROGRAM

Darrell E. Munson
Repository Isolation Systems Department
Sandia National Laboratories
P.O. Box 5800, Albuquerque, NM 87185

Robert L. Jones, Christine L. Northrop-Salazar,
and Sally J. Woerner
Tech Reps, Inc.
5000 Marble Avenue NE, Albuquerque, NM 87110

ABSTRACT

During the construction of the Thermal/Structural In Situ Test Rooms at the Waste Isolation Pilot Plant (WIPP) facility, measurements of the salt displacements were obtained at very early times, essentially concurrent with the mining activity. This was accomplished by emplacing manually read closure gage stations directly at the mining face, actually between the face and the mining machine, immediately upon mining of the intended gage location. Typically, these mining sequence closure measurements were taken within one hour of mining of the location and within one meter of the mining face. Readings were taken at these gage stations as the multipass mining continued, with the gage station reestablished as each successive mining pass destroyed the earlier gage points. Data reduction yields the displacement history during the mining operation. These early mining sequence closure data, when combined with the later data of the permanently emplaced closure gages, gives the total time-dependent closure displacements of the test rooms. This complete closure history is an essential part of assuring that the in situ test databases will provide an adequate basis for validation of the predictive technology of salt creep behavior, as required by the WIPP technology development program for disposal of radioactive waste in bedded salt.

ACKNOWLEDGMENTS

There were a number of organizations and people that made significant contributions to the fielding and operation of the Thermal/Structural in situ tests. To the people who were involved we owe a great deal and wish to thank them for their dedication and hard work.

The WIPP (Waste Isolation Pilot Plant) Project Integration Office of the Department of Energy (DOE/WPIO) has overall responsibility for the WIPP Program. Site operations are under the WIPP Project Site Office (DOE/WPSO). As scientific advisor, Sandia National Laboratories (SNL) is responsible for technology development, a part of which involves the in situ tests. The mining sequence measurements are just one of many measurements made for the in situ tests fielded at the WIPP facility.

Continuous mining machines were used by Ohbayashi-Gumi (OBG) under contract to the DOE to mine the normal test rooms. The circular room was excavated by Westinghouse, the facility operation contractor to the DOE, using a tunnel boring machine (TBM). Westinghouse was also responsible for the drilling of the Intermediate Scale Borehole Test (ISBT). All site aspects of gage installation were the responsibility of RE/SPEC Inc., a contractor to SNL, utilizing additional contract support personnel or geotechnical crews. Geotechnical crews were initially formed under the auspices of International Technologies, and later under Westinghouse. The daily test operation and maintenance responsibility was with Westinghouse, with overall supervision by SNL.

We wish to thank all of the numerous SNL people who contributed to this program; with special thanks to R. Matalucci, J. McIlmoyle, and D. Blankenship (RE/SPEC). We also recognize the dedication of the geotechnical crews who obtained these data under difficult conditions.

CONTENTS

LIST OF FIGURES

LIST OF FIGURES (Cont.)

LIST OF FIGURES (Cont.)

LIST OF TABLES

1 INTRODUCTION

In 1981 the Waste Isolation Pilot Plant (WIPP) Project, under the direction of the U.S. Department of Energy (DOE), began construction of a facility in southeastern New Mexico to support the development of the technology for safe disposal of radioactive waste from the U.S. defense programs. This facility may eventually become a repository for defense Transuranic (TRU) wastes, provided the facility is demonstrated to be acceptable, which means compliance with relevant regulatory requirements. Although the complete facility includes both surface and underground construction, the Repository Isolation Systems Department under the auspices of the WIPP Project Management Department at Sandia National Laboratories (SNL) is primarily concerned with development of the underground portion of the facility; that portion of the facility is the focus of this report.

Underground construction is divided into three phases: (1) the Site and Preliminary Design Validation (SPDV), requiring the construction of two shafts and shaft stations, a limited entry system, the Transuranic Test Panel, and an exploratory drift (South Drift) to the southern extremity of the facility, (2) the Experimental Area, requiring the construction and fielding of several large research and development (R&D) Technology Development Program test rooms and the expansion of the shaft system, and (3) the TRU Waste Storage Area, requiring limited construction of a demonstration waste disposal panel to permit additional tests using real waste, and to demonstrate waste handling, storage, and facility operation. If the demonstration is successful and all of the necessary regulatory requirements are met, the facility could become operational and proceed to dispose of radioactive contact-handled (CH) and remote-handled

(RH) waste. The first two construction phases are complete; data are currently being acquired for technology development. The construction of the third phase has been completed in preparation for initial receipt of experimental quantities of TRU waste. Although some of the experiments have been completed and decommissioned, the Experimental Area remains fully operational, and the technology development activities continue. The research currently in progress and the research planned for the future within the Experimental Area are providing and will continue to provide in situ data of exceptional quantity and quality.

The experimental activities conducted in the underground facility are the responsibility of SNL. These in situ activities consist of several very large-scale tests and many small-scale experiments to directly address important technology issues through the Repository Isolation Systems, Disposal Room Systems, and Fluid Flow and Transport Programs. The technology development program addresses directly those issues concerning disposal of TRU CH and RH wastes generated from current and past defense programs, as relevant to the proposed disposal of these TRU wastes at the WIPP. The details of these tests, as initially published in a planning document [1], were carried forward through the individual test plans defining the implementation and fielding activities for each test.

This report is specific to the Thermal/Structural Interactions (TSI) in situ tests of the Experimental Area. Within the TSI tests are six major tests that involve four rooms or room complexes: (1) the 18 W/m^2 Mockup for Defense High-Level Waste (DHLW) in Rooms A1, A2, and A3; (2) the Overtest for Simulated Defense High-Level Waste (DHLW) in Room B; (3) the Geomechanical Evaluation Test in Room G; (4) the Heated Axisymmetric Pillar Test in Room H; (5) the In Situ Stress Field (Hydrofrac) Test in

Room G; and (6) the Clay Seam Shear Test. The Clay Seam Shear Test is not yet fielded. Additional in situ TSI data were also obtained from the Mining Development Test in Room D, an early excavation to provide facility ventilation; the Intermediate Scale Borehole Test (ISBT) fielded in the pillar between Rooms C1 and C2; and the Brine Inflow Test in the cylindrical excavation of Room Q. Several previous documents have discussed the planning, implementation, and fielding of the TSI in situ tests [2-4], and the reader is referred to these original documents for more detailed information.

This data report is one of a series intended to document the data obtained from the original TSI in situ tests and subsequent related tests and to make these data available to potential users. Other published data reports include those for the Mining Development Test (Room D) [5], the Geomechanical Evaluation Test (Room G) [6], the Heated Axisymmetric Pillar Test (Room H) [7], the Overtest for Simulated Defense High-Level Waste (DHLW) (Room B) [8], and the 18 W/m^2 Mockup for Defense High-Level Waste (DHLW) (Rooms A) [9,10]. The plan is to issue data reports for all of the TSI tests, including those for the ISBT and Room Q, as time and data reduction permits.

This report focuses on the data acquired from the temporary, manually read closure gages established concurrently with the mining of the test rooms. These special gages were denoted as "mining sequence" closure gages. They were emplaced directly at the mining face, immediately after the mining machine had excavated the intended gage location. Closure gage points were monitored thereafter throughout the excavation operation, with mined-out points replaced as necessary during the multipass mining. The mining sequence closure measurements were intended to provide very early closure data only until the permanent manual and remote closure stations were installed and operational. In general, the intent here is to report data from the time interval before the remote gages were taking data reliably, which was always less than 100 days for a typical test room. However, in a number of test rooms, the mining sequence closure gages continued to be read as a check and back-up on the remote closure gages for a much longer time; these data are reported here also. It should be noted that the mining sequence data are absolutely essential to the proper reconstruction of the total closure displacement taking place in any test room. The proper method for adding closure data from the permanent manual and remote gages to those mining sequence closure data to obtain the complete displacement history are, however, straightforward [11]. The data contained in this report are self standing and complete. As a result, no data update in the future is thought to be necessary.

2 EXPERIMENT DESCRIPTION

The individual test plans, as developed some two years in advance of fielding the in situ tests, did not include provision for obtaining the very early time displacement measurements. In part, this was a result of both a perception that interference with the mining operation was not advisable from the contractual standpoint and that any unmeasured displacements during the delay prior to the installation of permanent closure points would be too small to be of significance. As underground experience accumulated during the development of the SPDV area, it became apparent that displacements in the first few hours after excavation were significant. Indeed, it was then believed that the lost displacements would impair our ability to make meaningful validation comparisons. On this basis, construction contract modifications were made to permit the mining operation to accommodate the early closure measurements. An attempt was also made to obtain early closure measurements in the South Drift of the SPDV excavations; however, this was only partially successful because the poorly defined procedure for establishing protected gage points in the drift floor and the unrecognized problems caused by multipass mining still caused delays in establishing a gage station. Reliable operating procedures and methods for emplacement of the mining sequence gages were established in time for use in the mining of Room D, a ventilation room, which was the first room of the second phase of underground excavation.

As a consequence of the late recognition of the need for the mining sequence gages, the installation of these gages was organized within the general excavation contract. Thus, the mining sequence gages were considered as "add-ons" to the overall construction activity, rather than a part of the individual tests. The gage numbers, locations, and readings were defined for the entire Experimental Area at one time. The historical events of the development has caused the mining sequence data to be considered and treated as a separate database throughout the data acquisition and reduction system. Eventually, however, these data will be incorporated into the results of each of the individual in situ tests, as appropriate. Until such time as the mining sequence and the individual test room databases are combined, the analyst must be aware of both databases, and how both must be used in conjunction with each other.

The room configurations and construction sequence are almost as requested in the comprehensive planning document [1] and the individual test plans; however, exact descriptions and special features of the room introduced during and after construction will appear in separate documents on construction and instrumentation. Also, further relevant information is contained in separate documents on the data acquisition system [12] and on the overall WIPP In Situ Data Acquisition, Analysis, and Management (WISDAAM) System [13]. Some limited information from these documents is extracted for our purposes here.

2.1 Test Room Locations

The mining sequence gages were emplaced in all of the TSI test rooms, as well as in Room D, Rooms C (ISBT), and Room Q. All except Room Q are located in the Experimental Area in the north side of the underground facility (Figure 2.1.1). Room D, Room B, Room A2, Room A1, Room A3 and the ISBT are located in the eastern portion of the Experimental Area, and were excavated in the order listed. The ISBT was the last or most recent test fielded. Room G and Room H are located in the western portion of the Experimental Area, and were excavated in the order listed; however, the

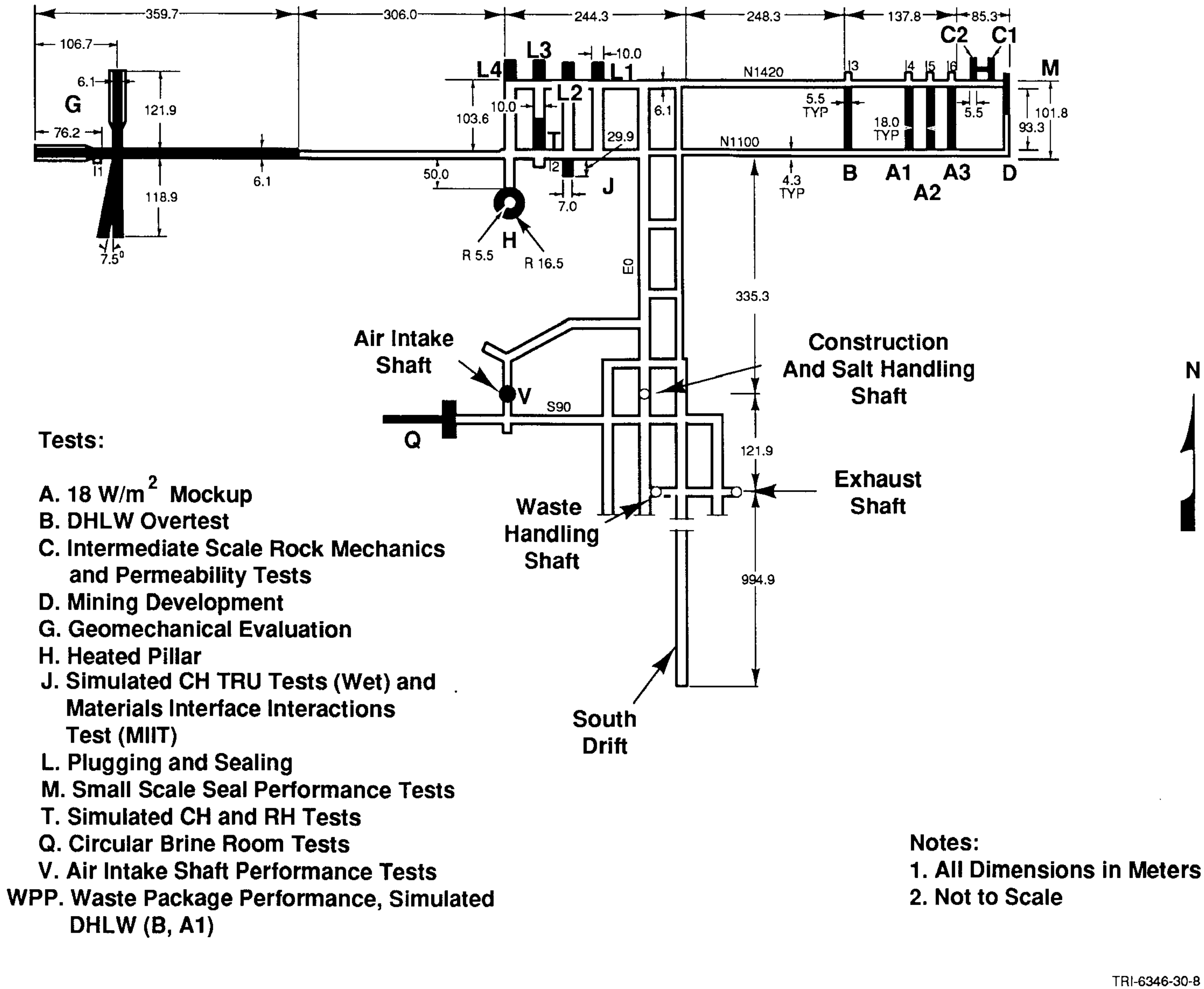


Figure 2.1.1. Plan View of the WIPP Underground Excavations

Room H entry was actually excavated before any of the test rooms to permit early instrumentation in the pillar salt. Room Q is located in the SPDV portion of the facility, and was constructed considerably after the TSI test rooms.

2.2 Construction

For this report, the construction activities will be summarized in an abbreviated form. Only those activities that are relevant to the mining sequence manual gages will be included. Details of permanent and remote gage installation and measurement procedures will not be discussed. The construction activities are divided into sections on geology and mining, and mining sequence gage installation.

2.2.1 Geology and Mining

Because the mining sequence measurements were taken throughout the Experimental Area of the underground, we must discuss the complete mining operation. The stratigraphy of the Salado formation is composed of relatively thick layers of salt, anhydrite, and polyhalite separated by distinct interbeds and partings formed by thin clay seams and anhydrite. In the bedded stratigraphy, a number of these distinct layers and interbeds are found in the vicinity of the underground excavations. This stratigraphy has been mapped in detail, particularly over the local interval within approximately ± 53 m (173 ft) of the WIPP excavations. The local stratigraphy is referenced to a coordinate system with the vertical zero fixed at a clay/anhydrite parting, denoted as either anhydrite "b" or Clay G. A detailed stratigraphy of the immediate region surrounding the test rooms was given initially as the '84 Reference Stratigraphy [14], but this has been updated recently [15] to that illustrated in Figure 2.2.1. This figure also shows all of the standard

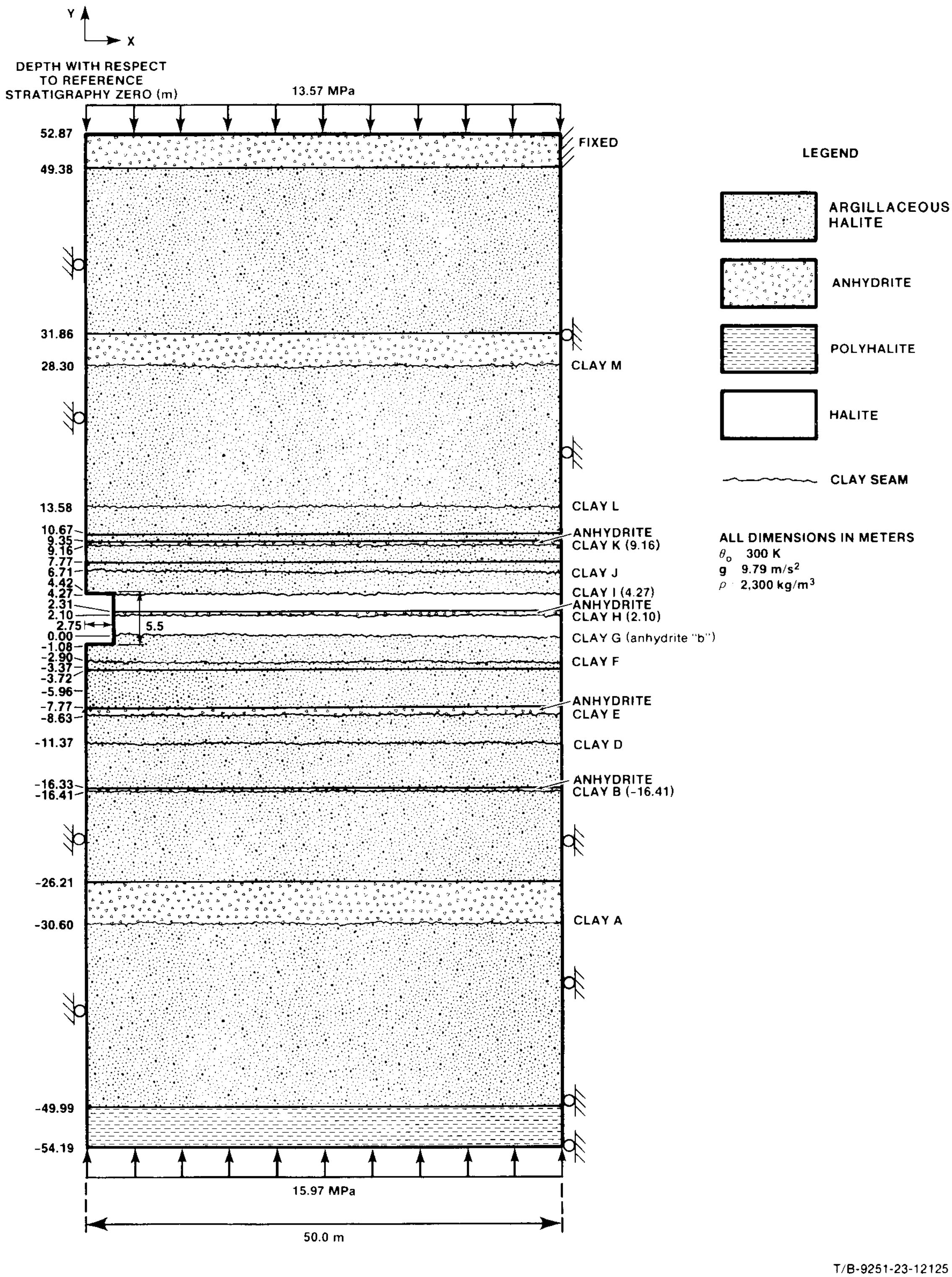


Figure 2.2.1. Local WIPP Horizon Stratigraphy

clay seam and anhydrite layer designations. Detailed mapping of the exposed stratigraphy in the rooms and specific details of the stratigraphy adjacent to the room can be found in the construction report [11].

Anhydrite "b" (Clay G) is nominally 648.6 m (2128.2 ft) below ground surface at the Construction and Salt Handling (C&SH) shaft. The floor of the C&SH shaft station, and what is commonly taken as the reference depth of the repository horizon, is at 655.3 m (2150.0 ft). The actual repository horizon depth below ground surface changes with location in the underground due to both topographic changes of the ground surface and elevation changes underground caused by the dipping of the beds. A very slight dip in the stratigraphy to the south causes the test rooms in the north to be relatively higher in elevation. The maximum elevation change of anhydrite "b" over the entire north-south extent of the facility is approximately 6.4 m (21 ft). In terms of the increase, or decrease, in overburden thickness, this amounts to less than 1% over the extent of the underground excavations, as measured at the "b" anhydrite. Also, the stratigraphic bedding has an east-west undulation with a period of about 100 m (328 ft) and an amplitude of as much as 5.0 m (16.4 ft). In terms of analysis, both the general north-south dip and east-west undulations are essentially insignificant. The individual rooms, and perhaps the facility as a whole, can be treated as having an orthogonal, flat-lying, horizontal coordinate system.

In planning the locations of the excavations, it was necessary to assure that no partings which could cause roof instabilities remained in the immediate roof of the drifts and rooms. As a result, the mining followed the stratigraphy. Thus, in all excavations, the roof (back) was the control on vertical location, and the floor elevation became the adjustable parameter of the excavation. The Experimental Area involved two different stratigraphic horizons: (1) the main WIPP repository horizon and (2) the heated DHLW test rooms horizon about 5.5 m (18 ft) above the main WIPP horizon. These are shown schematically in Figure 2.2.2 for a typical DHLW 5.5 m (18.0 ft) high by 5.5 m (18.0 ft) wide test room and a typical TRU Test Panel (repository) 3.96 m (13 ft) high by 10.06 m (33 ft) wide room. For the lower horizon rooms, the excavation removes Clay F to form the room roof; and, for the upper horizon rooms, the excavation just removes Clay I. The roof of the lower level excavations, the WIPP repository horizon, is at an elevation of - 2.00 m (- 6.6 ft) in the local stratigraphy. The roof of the test rooms in the upper level horizon is at an elevation of + 4.30 m (+ 14.1 ft) in the local stratigraphy.

The test room locations within the bedded salt formation can be related to the local stratigraphy given in Figure 2.2.1, which indicates the location of a heated, 5.5 m (18.0 ft) wide by 5.5 m (18.0 ft) high, DHLW test room. It should be noted that the local stratigraphy, including the boundary conditions shown in Figure 2.2.1, are used for numerical calculations simulating the WIPP structural response.

Except for Room Q and the ISBT, which are special cases, all mining excavation was performed under a fixed price contract by Ohbayashi-Gumi, a mining contractor. Excavation of the room entries and rooms was by a Mitsui-Miike continuous mining machines. The contractor, used two of these mining machines, operating concurrently, to maintain a very tight time schedule. The schedule was dictated by the need to have critical excavations available for prompt assembly of the data acquisition sheds and equipment and to permit the proper sequencing of certain test rooms. The actual schedule, independent of the specific locations of the two

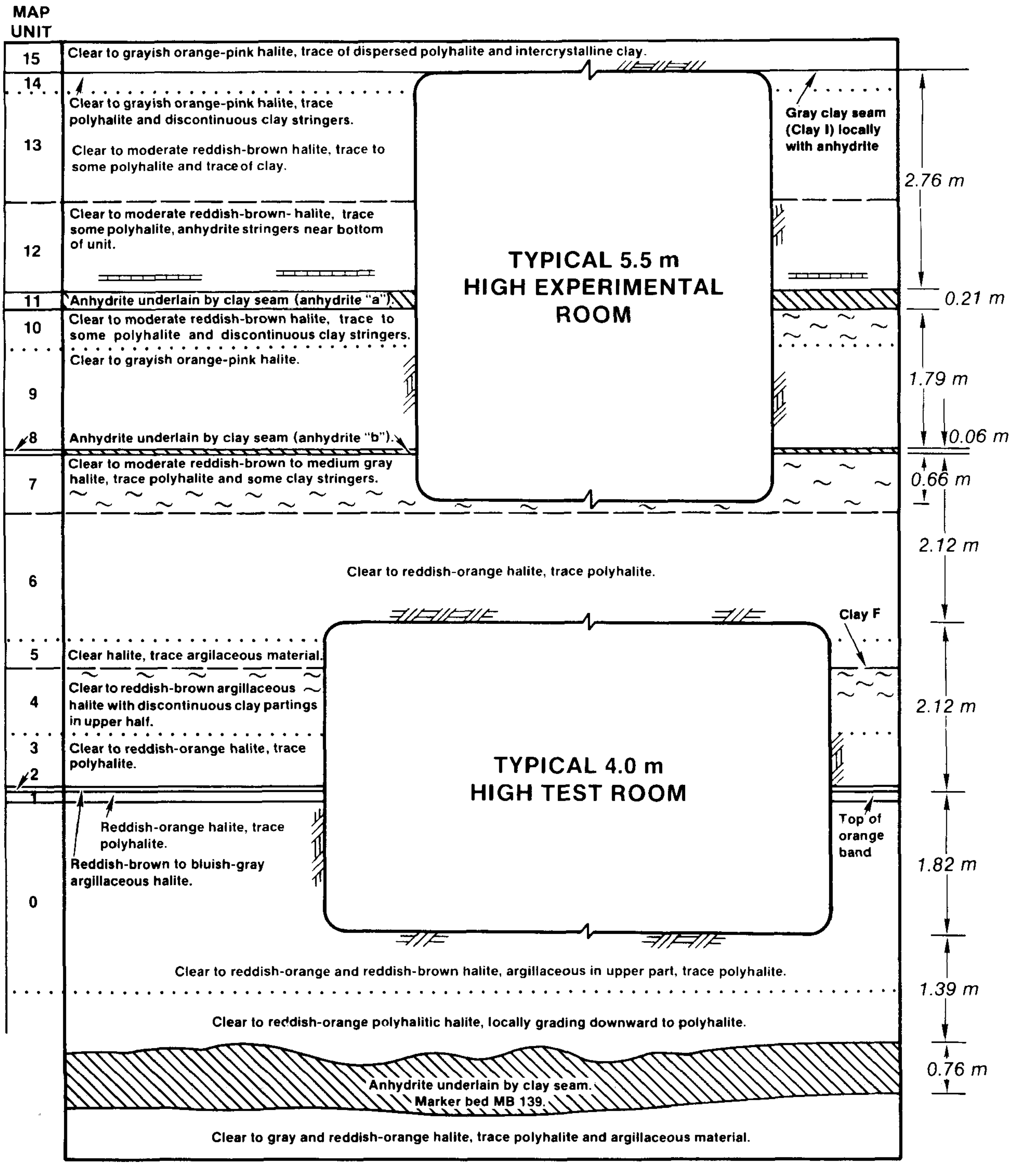


Figure 2.2.2. Test Room Elevations with Respect to Stratigraphy

mining machines, is given in Figure 2.2.3.

The excavation sequence for the construction of the TSI tests was according to the following: (1) the two long entry drifts, N1420 and N1100, into the Room D location, (2) Room D, which is a ventilation drift and was a practice area for the mining contractor, a qualification area for the drilling contractor, and a training area for geotechnical and instrumentation crews, (3) the instrument shed alcoves in eastern N1420 and western N1100, (4) the entry to Room H, which permitted installation of gages into what would eventually become the salt pillar, (5) the entry to Room G, which was also a mine-back portion of an earlier TSI hydrofrac test to measure in situ stresses, (6) Room B, which is a heated overtest, (7) Room A2, which is a heated mock-up configuration of a reference high-level defense waste (DHLW) repository, and which was fully instrumented and operational as a mine-by experiment before the two adjacent rooms of the A complex were mined, (8) Room A1, which is a thermally correct mock-up of the reference DHLW repository configuration, (9) Room A3, which is essentially identical to A1, (10) the first phase of Room G, which is a very long, unheated test room, and (11) Room H, which is a room formed as an annulus around a heated pillar. Additional phases of Room G initially planned to establish the north-south cross drift and wedge failure pillar have not been constructed.

The continuous mining machines were operated in the road header configuration with a nominal mining face "foot print" of 3.84 m (12.6 ft) high by 4.88 m (16.0 ft) wide, which was smaller than most of the drifts and rooms at the WIPP. As a result, most of the drifts and all of the test rooms required multipass mining. As will become quite evident, multipass mining makes measurement of the early excavation displacements

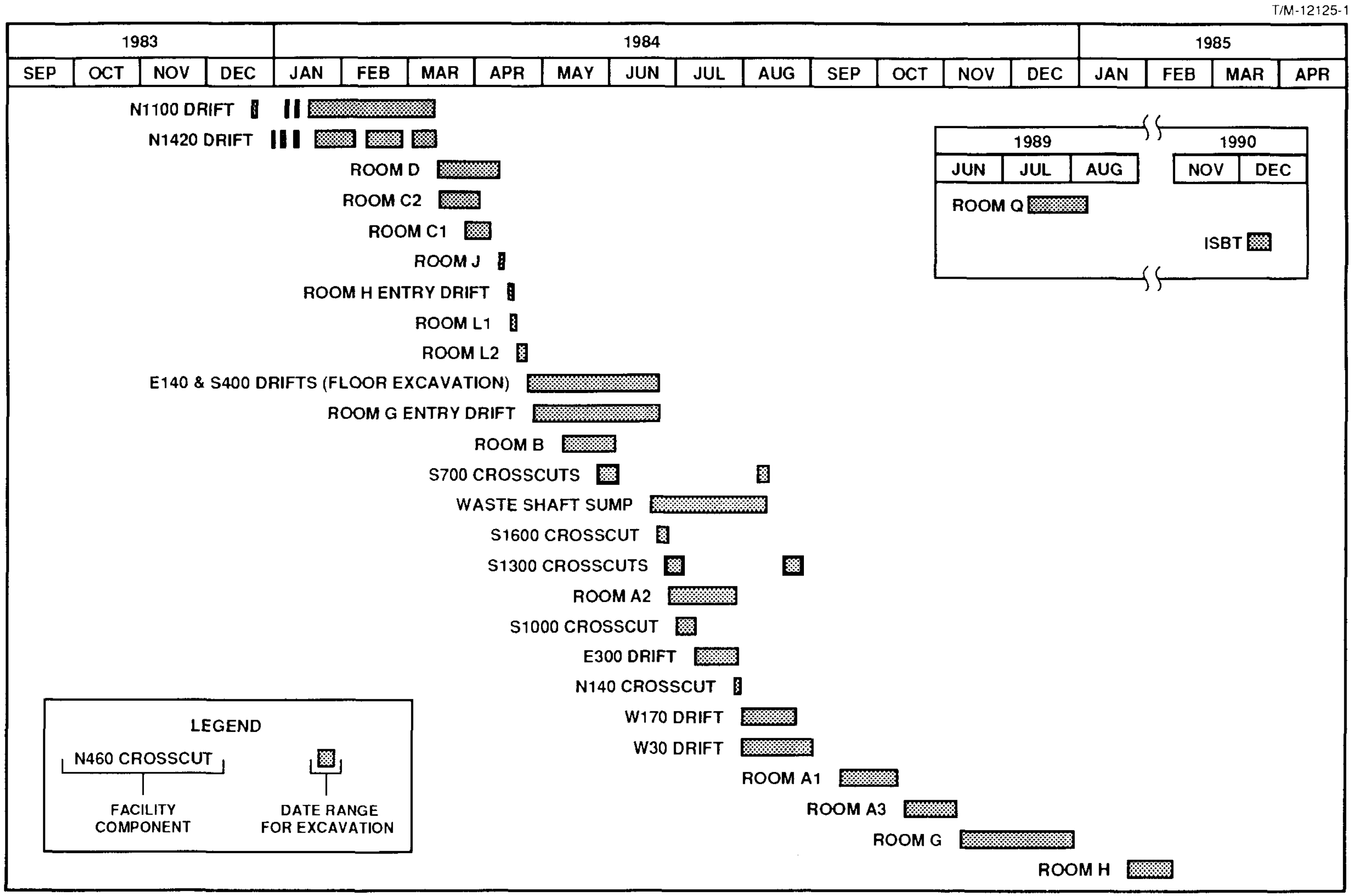


Figure 2.2.3. Excavation Schedule

complicated. In fact, this complication was the basis for the development of the mining sequence measurements and gages.

The extensive records maintained on the mining progress in each of the TSI test rooms permit us to reconstruct details of the multipass mining. In most cases, the passes were continuous in the sense that the pass began at one end of the test room and progressed essentially uninterrupted to the other end. However, in some test rooms, because of insufficient control over the mining contractor or because of practical concerns, the individual passes were discontinuous and room excavation advanced by stages. Typically, the stages involved distances convenient for carrying forward the utilities of power, ventilation, and cooling water for the mining machine. Within a stage, each pass was continuous from the beginning to the end of the distance spanned by that stage. Where stages were used in the mining, the span of each stage was sufficient that the mining would appear to be truly multipass mining at any gage station centrally located within that stage.

Practical requirements, typically those of "turning in" and ramping, necessitated by mining machine size and operation, often caused complex mining conditions at room entries. The room entries, however, are sufficiently removed from the central room test section that their effects are inconsequential during the time of interest.

In preparation for construction of the test rooms in the northeastern portion of the Experimental Area, the excavation of the N1420 and N1100 entries and the instrument shed alcoves used both mining machines. The approximately 518 m (1700 ft) long N1420 entry was mined in a single pass by one machine to a cross section of about 3.7 m (12.0 ft) high by 4.3 m (14.0 ft) wide during the time between 1/10/84 and 3/16/84. Concurrently, the comparable length N1100 entry was mined in a single pass by another machine to a cross section of about 2.6 m (8.5 ft) high and 4.3 m (14.0 ft) wide between 1/9/84 and 3/13/84. The N1420 machine mined Room C1 and Room C2, two incidental rooms, and the four instrument shed alcoves to the north of the N1420 entry. This machine was then released for excavations in other parts of the facility while the N1100 machine remained and began the multipass excavation of the TSI test rooms in the northeastern area.

We present the multipass mining results in alphanumerical order, according to the room designation. (Not according to mining order).

Room A1 was mined to the final 5.5 m (18.0 ft) high by 5.5 m (18.0 ft) wide cross section in four major continuous passes from south to north, followed by two minor floor trim passes. As shown in Figure 2.2.4, mining of the first pass started on 9/14/84 and the last trim pass was finished on 10/10/84. The first pass, 4.0 m (13.1 ft) wide and 3.4 m (11.2 ft) high, was something less than square in cross section, as shown in the inset of Figure 2.2.4. The two initial passes left a bench which was removed by two subsequent main passes, each 1.8 m (5.9 ft) high, and the two floor trims, each 0.3 m (1.0 ft) high. The face advance with time, as determined from the shift records, for all mining passes is plotted in Figure 2.2.5. Advance rates within a given pass are quite uniform. The excavation rate for a given pass was related to the size of the face being advanced, with smaller face size passes having the highest advance rates.

Room A1 is separated from Room B on the west by a 79.8 m (261.8 ft) thick barrier pillar and from Room A2 on the east by a 18.0 m (59.0 ft) thick pillar.

Room A2 was mined to the final 5.5 m (18.0 ft) high 5.5 m (18.0 ft) wide cross section in four major continuous [text continues on page 19]

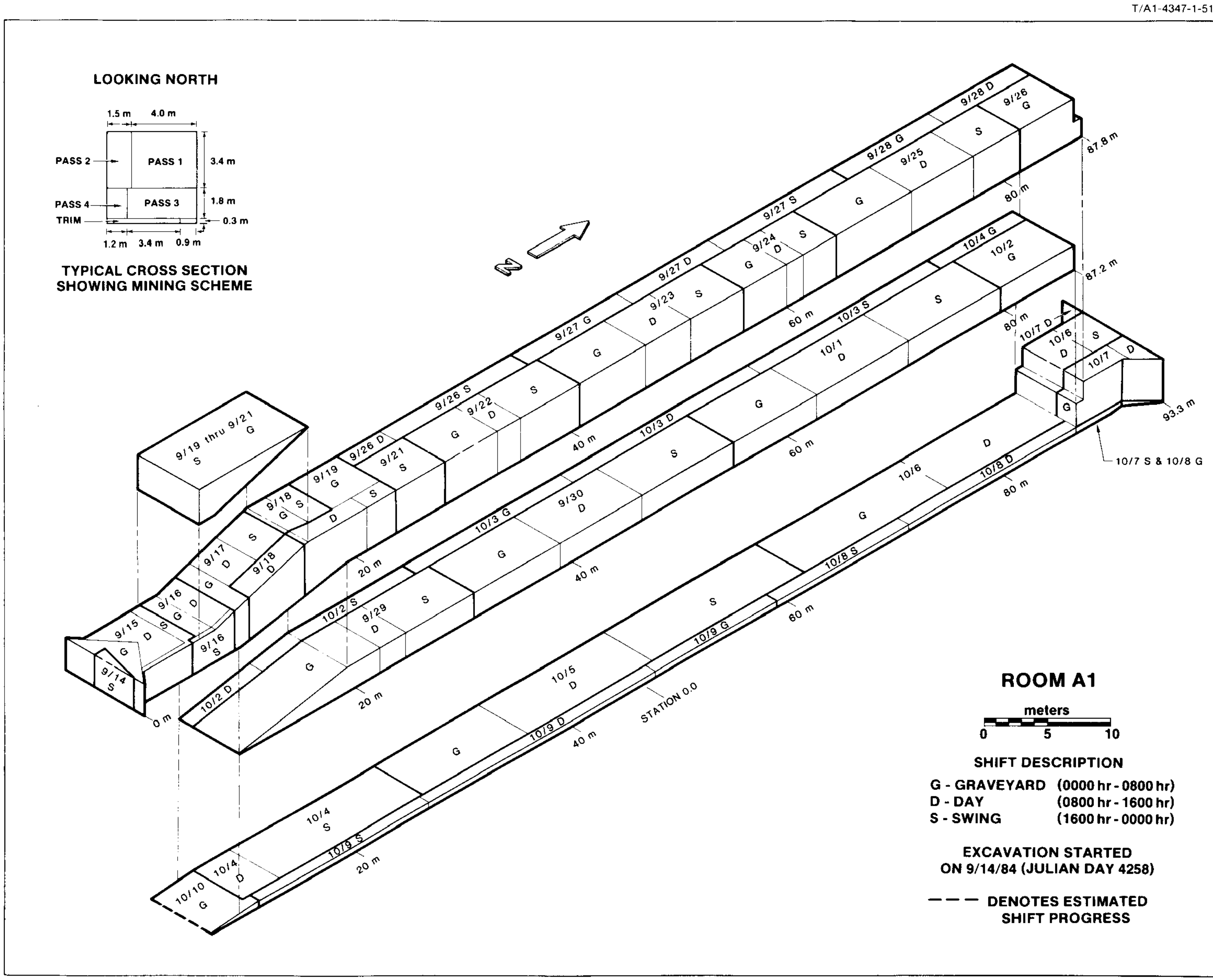


Figure 2.2.4. Isometric of Multipass Mining of Room A1

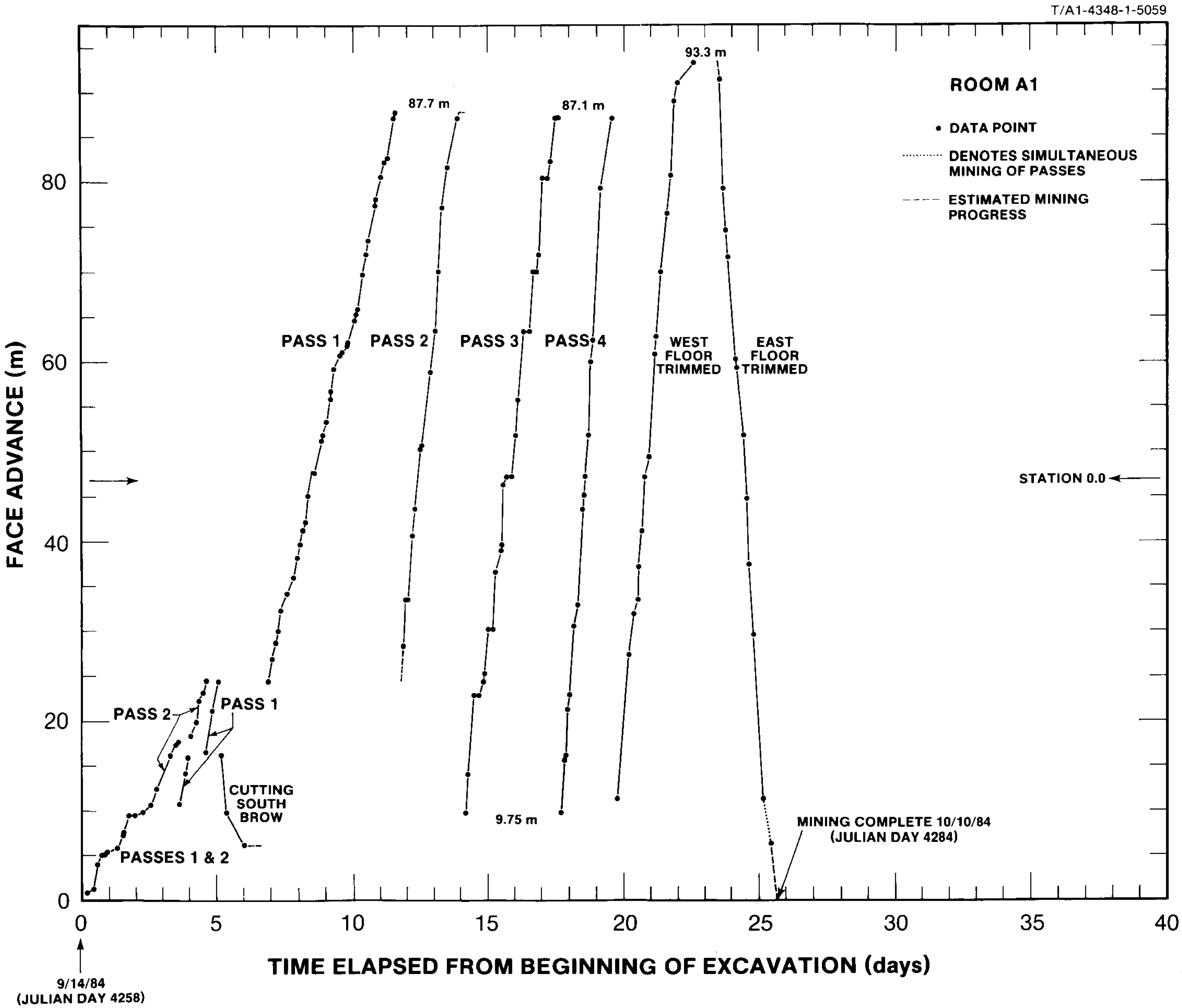


Figure 2.2.5. Mining Face Advance Rates for Room A1

passes from south to north, without significant subsequent trim passes. As shown in Figure 2.2.6, mining of the first pass started on 6/29/84 and the last pass was completed on 7/24/84. The first pass, 4.0 m (13.1 ft) wide by 3.7 m (12.1 ft) high, was very nearly of a square cross section, as shown in the inset of Figure 2.2.6. The two initial passes left a 1.8 m (5.9 ft) high bench which was removed by the final two passes. The face advance with time for each pass is plotted in Figure 2.2.7 and is quite uniform for a given pass.

Room A2 is the central room of the three room complex, separated from both Room A1 and A3 by 18.0 m (59.0 ft) thick pillars.

Room A3 was mined to the final 5.5 m (18.0 ft) high by 5.5 m (18.0 ft) wide cross section in four major continuous passes from south to north, followed by two minor floor trim passes, as was the case for Room A1. As shown in Figure 2.2.8, mining of the first pass started on 10/13/84 and the last trim pass was finished 11/6/84. As for Room A1, the first pass, 4.0 m (13.1 ft) high by 3.4 m (11.2 ft) was something less than square in cross section. The two initial passes left a bench which was subsequently removed by two main passes, each 1.8 m (5.9 ft) high, and two floor trims, each 0.3 m (1.0 ft) high. The face advance with time for each pass is plotted in Figure 2.2.9 and is quite uniform for a given pass.

Room A3 is separated from Room A2 on the west by a 18.0 m (59.0 ft) thick pillar and from Room D on the east by a 79.8 m (261.8 ft) thick barrier pillar.

Room B was cut from south to north in three principal passes, in which the third pass removed the bench in a series of stages. The final floor elevation was obtained with two small rib trimming passes on the lower part of the room. The first and largest [text continues on page 24]

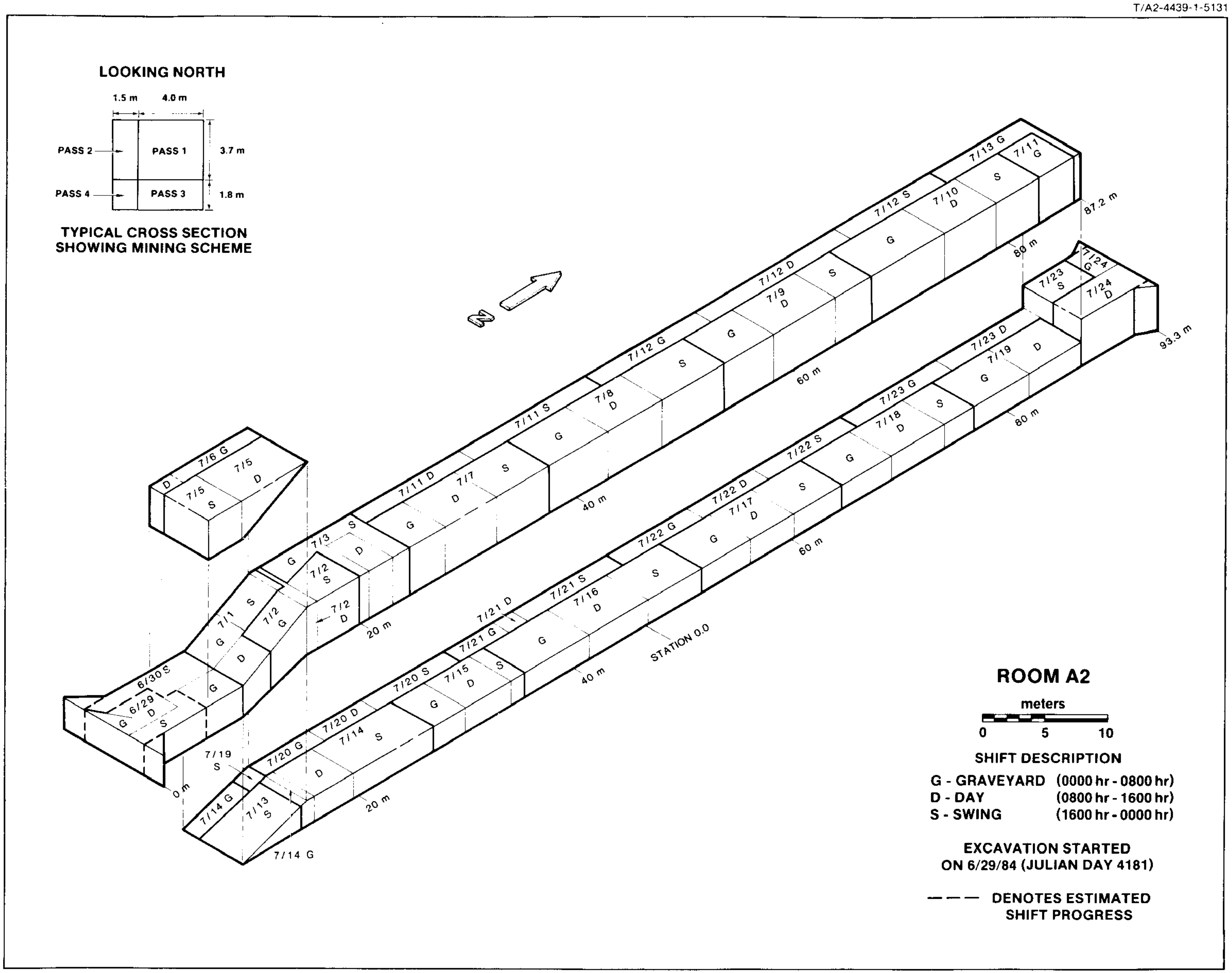


Figure 2.2.6. Isometric of Multipass Mining of Room A2

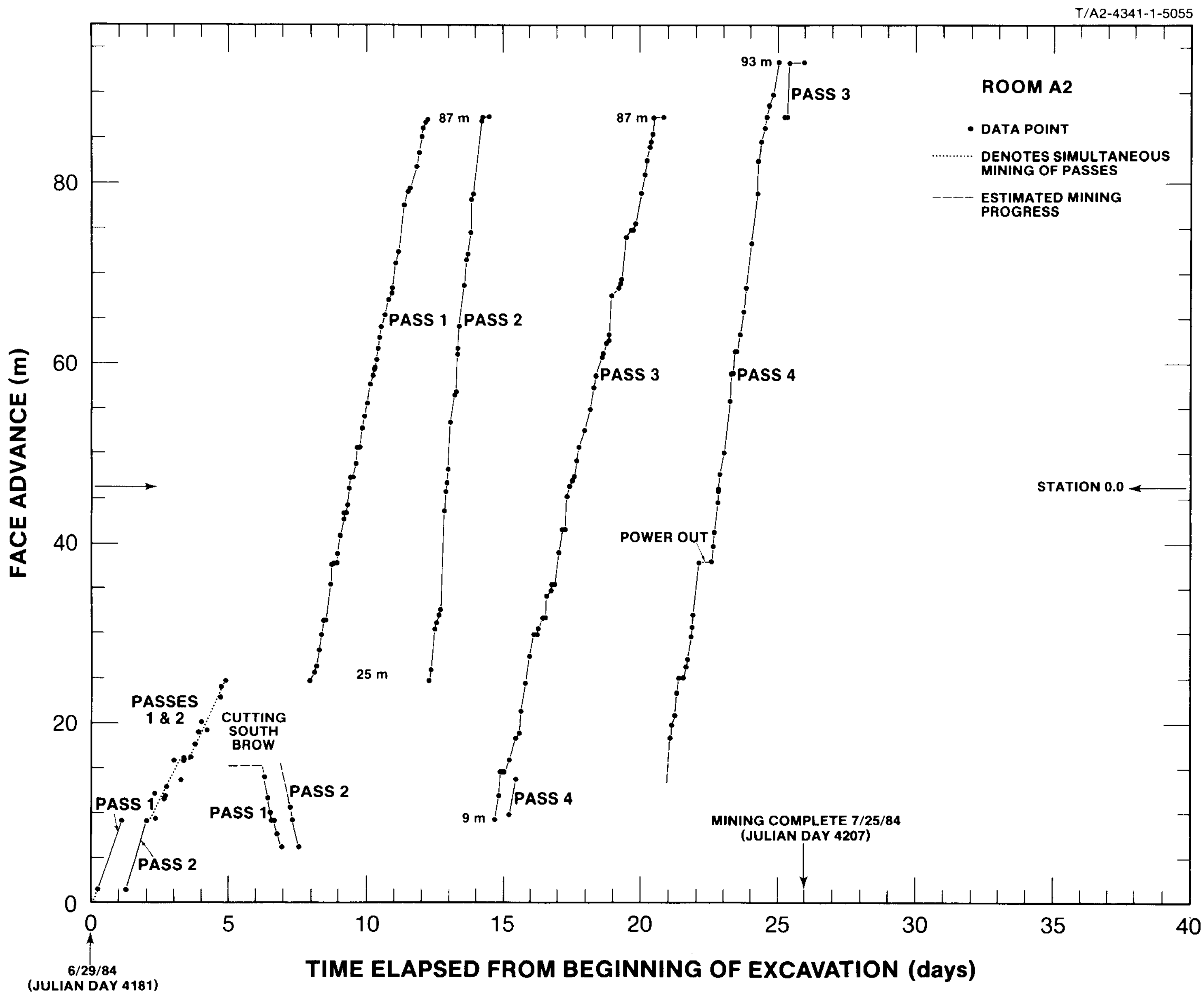


Figure 2.2.7. Mining Face Advance Rates for Room A2

T/A3-5120-1

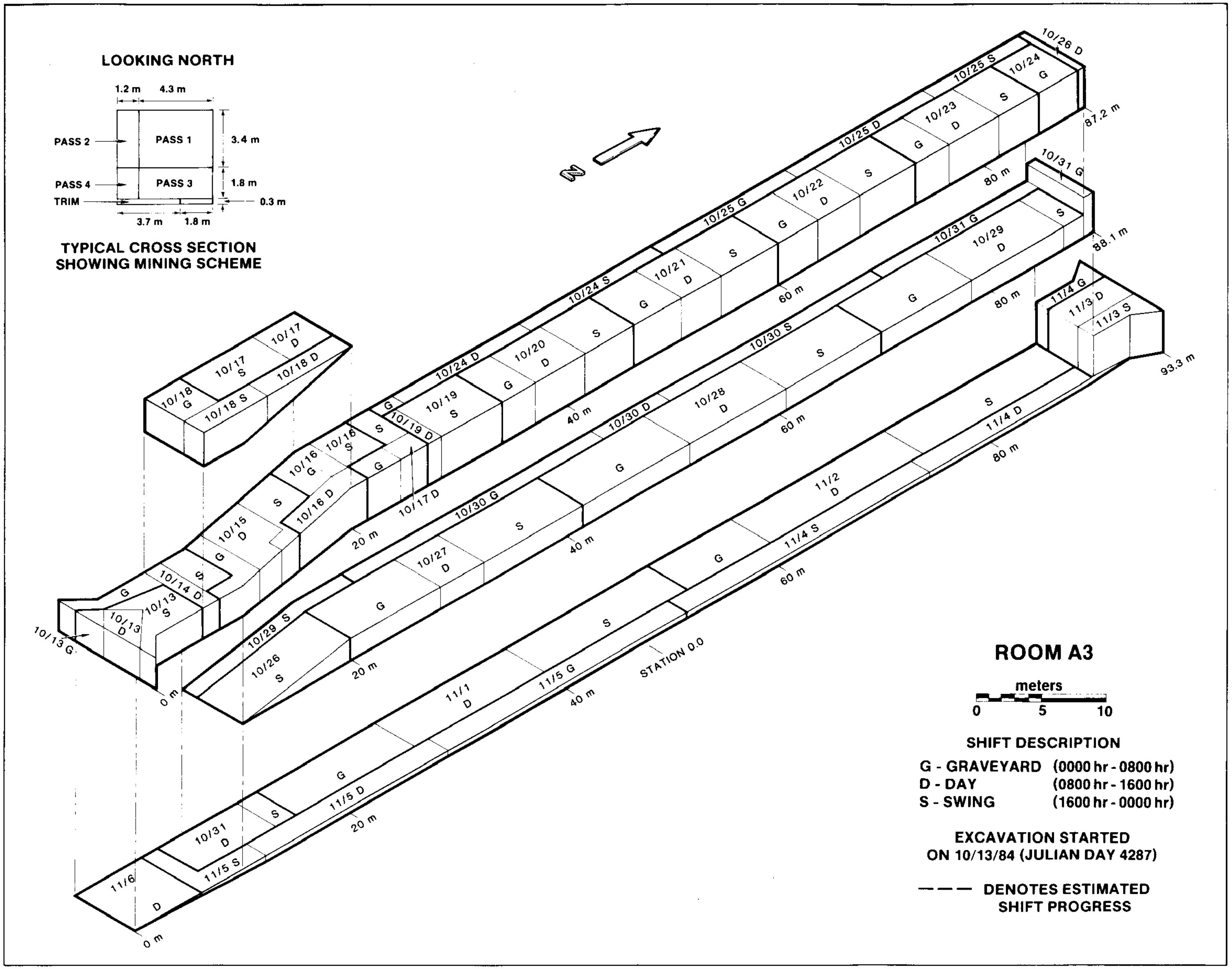


Figure 2.2.8. Isometric of Multipass Mining of Room A3

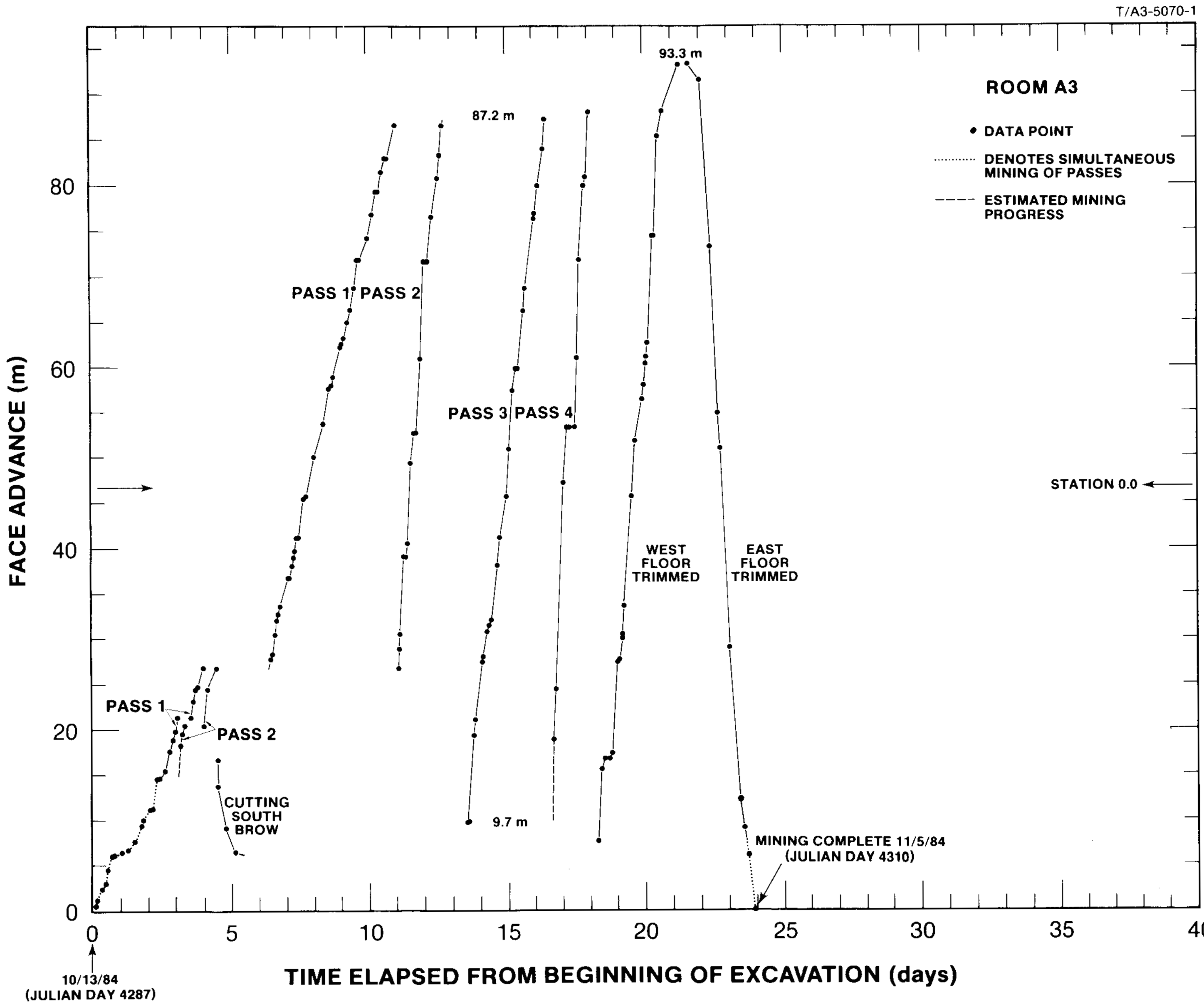


Figure 2.2.9. Mining Face Advance Rates for Room A3

pass, 4.3 m (14.1 ft) wide by 3.7 m (12.1 ft) high, was accompanied by the second pass to obtain the final 5.5 m (18.0 ft) room width, as shown in Figure 2.2.10. As is evident, the first pass was rectangular in cross section. These first two passes were staged in the southern third of the room and continuous in the northern two thirds of the room. The third pass was staged with two concurrent trim passes. The third main pass removed the central 4.6 m (15.1 ft) part of the bench to establish the final room height of 5.5 m (18.0 ft), while the two minor trim passes of the ribs, one 0.3 m (1.0 ft) and the other 0.6 m (2.0 ft) thick completed the removal of the bench. Mining of the first pass began on 5/4/84 and the final trim pass was completed on 6/3/84, after a total of 88 shifts. The mining face advance is shown in Figure 2.2.11. Effects of the staged third pass and trims for removal of the bench caused an erratic advance rate. Note also that two power outages resulted in about five days of downtime during the mining of the second pass.

Room B is separated from the E140 entry drift on the west by a 248.3 m (814.6 ft) thick barrier pillar and from Room A1 on the east by a 79.8 m (261.8 ft) thick barrier pillar.

The Rooms C, although not a part of the TSI test series, were excavated at the time of the mining of the N1420 entry as part of the operational demonstration for large canister emplacement equipment. The details of these excavations are of little importance except for the eventual use of the pillar between these rooms as the location of the ISBT test. The mining machine turned into Room C2 on 3/17/84 and mined a portion of the upper bench, but was soon moved and turned into Room C1 on 3/28/84 while the machine was in the short conveyor belt configuration. After the turn-in operation was completed for [text continues on page 27]

T/B-4338-1-5130

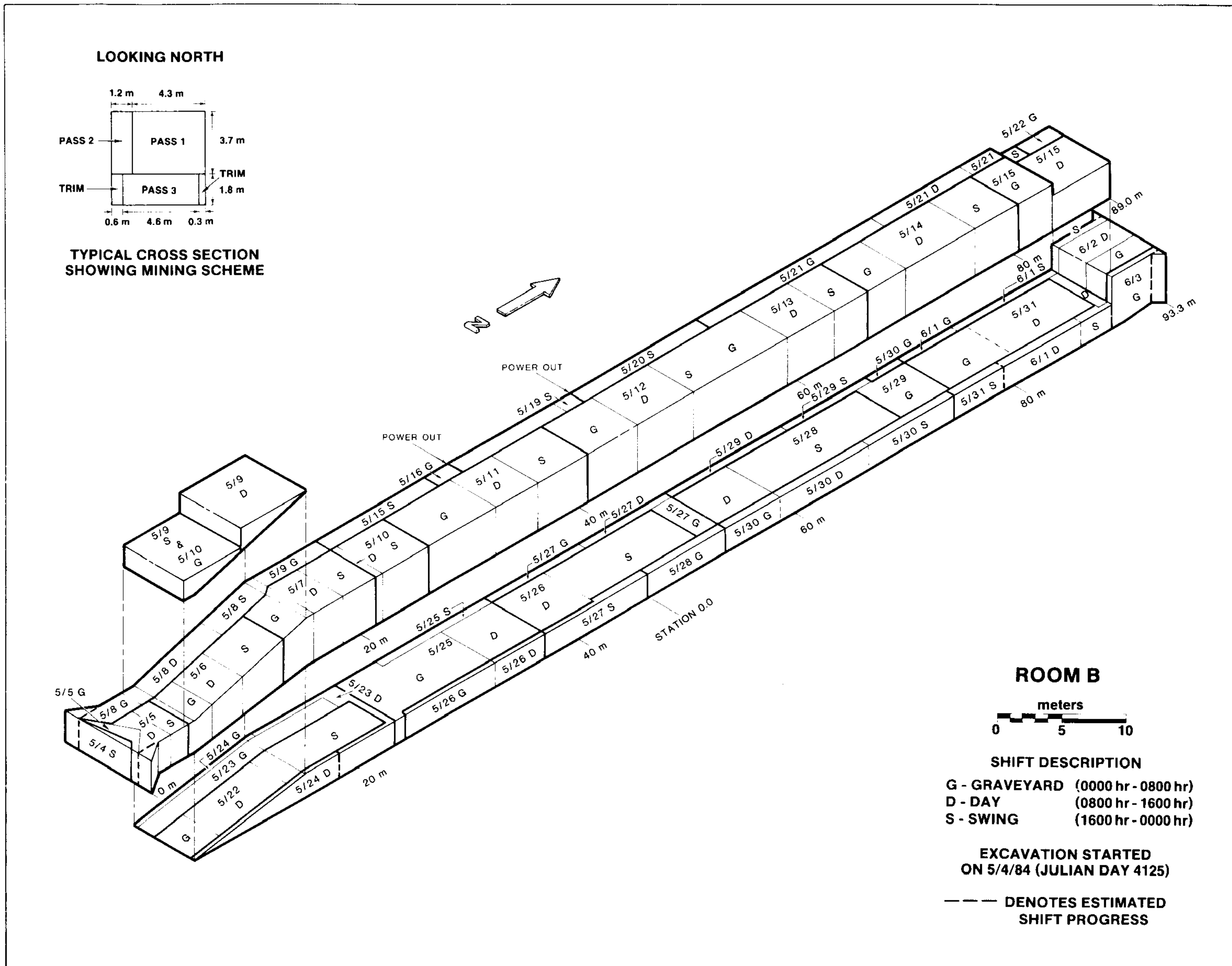


Figure 2.2.10. Isometric of Multipass Mining of Room B

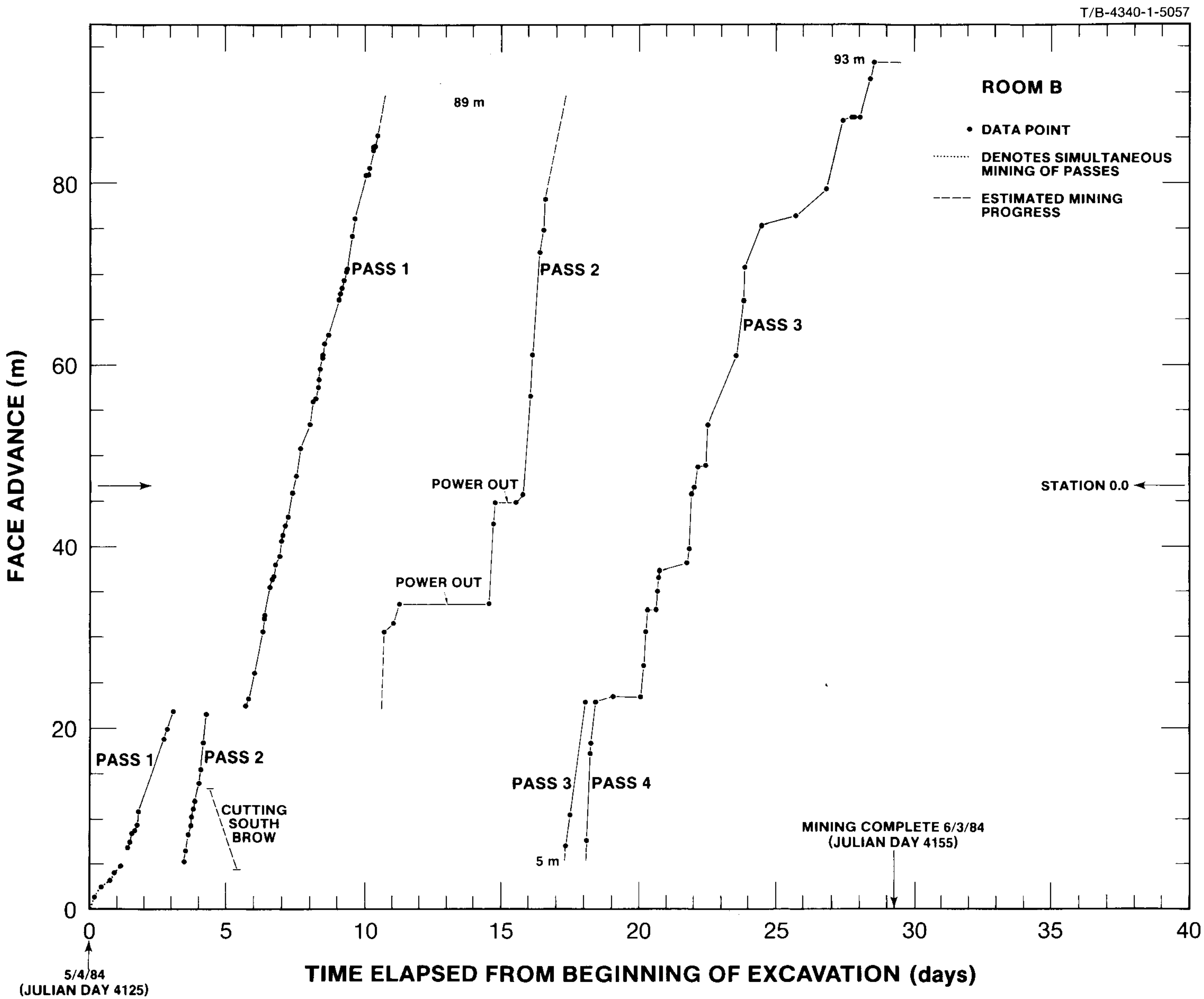


Figure 2.2.11. Mining Face Advance Rates for Room B

both rooms, the machine, then in the long conveyor belt configuration, mined the complete upper bench and the brows in Room C1 and then returned to Room C2 to mine in one full width pass the upper bench of this room and then the brows. Then the full width pass of the lower bench of Room C2 was mined, followed by a similar operation in Room C1, to complete the two rooms. Both rooms were completed by 4/9/84. These rooms both have 5.5 m (18.0 ft) square cross sections and are 29.9 m (98.1 ft) and 31.1 m (102.0 ft) deep, respectively. They are separated by an 18.0 m (59.0 ft) thick pillar.

Essentially there are no other major excavations to the west, north, or east of the rooms.

Room D, as shown in Figure 2.2.12, was excavated from south to north in four major passes, essentially with each continuous pass completed the entire length of the room before the next pass was started. The first pass, 4.3 m (14.1 ft) wide by 3.7 m (12.1 ft) high, was excavated on the east side of the room. Then, the second mining pass of about 1.2 m (3.9 ft) wide by 3.7 m (12.1 ft) high was excavated. This left a resulting bench of about 1.8 m (5.9 ft) in height within the room. At this point, the third and fourth passes were taken in sequence to remove the bench. The third pass on the east side of the room was about 3.7 m (12.1 ft) wide and the fourth, and final, pass on the west side of the room removed the remainder of the bench, or about a width of 1.8 m (5.9 ft). Room D excavation began on 3/14/84 and ended on 4/14/84. During each pass there were minor trimming operations on the ribs to bring the room within the dimensional tolerances specified. However, since the special mining tolerance specifications given for the actual TSI test rooms did not apply to Room D, the contractor did not make a costly final trim pass on the

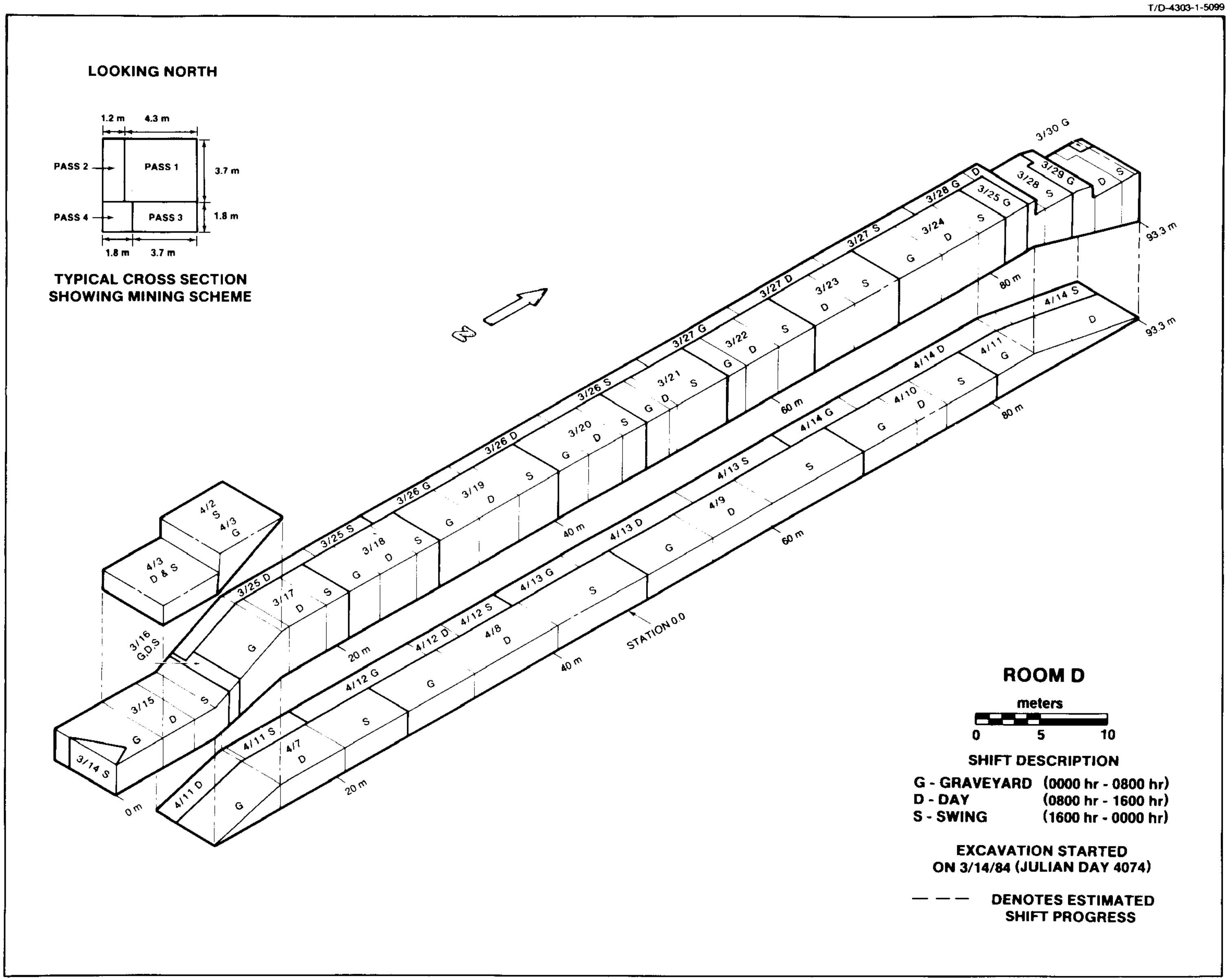


Figure 2.2.12. Isometric of Multipass Mining of Room D

room floor. Consequently, floor roughness in Room D exceeded specified tolerances for the actual test rooms. The floor roughness in some places exceeded 0.3 m (1.0 ft); however, this rather localized occurrence does not significantly alter measured room closures. Nominal dimensions of the final room were 5.5 m (18.0 ft) wide by 5.5 m (18.0 ft) high. Room excavation rates are presented in Figure 2.2.13. These rates are quite constant for any given pass.

Room D is separated from Room A3 on the west by a 79.8 m (261.8 ft) thick barrier pillar. To the east of Room D is an essentially infinite mass of undisturbed salt.

In preparation for mining of the test rooms in the northwestern part of the Experimental Area, the N1100 and N1420 entries were developed for the SPDV excavations of the four room TRU Test Panel. These SPDV entry excavations were further developed to include entries to the two TSI tests and the necessary instrument shed alcoves. As indicated by the schedule sequence, the mining machine released from the northeastern part of the facility excavated the Room H and Room G entries before leaving the Experimental Area for mining activities in the southern part of the facility. While the second machine finished the rooms of the northeastern part of the Experimental Area, the Room H entry was instrumented and the Room G instrument shed preassembled near the Room G entry. Upon the completion of the northeastern excavations, the second machine returned to the northwestern part of the Experimental Area to mine first Room G and then Room H.

Room G was excavated in a series of discontinuous steps, with each step some 15 m to 30 m (49 ft to 98 ft) long. Within a step the passes and trims were continuous. Each step required about three days of mining

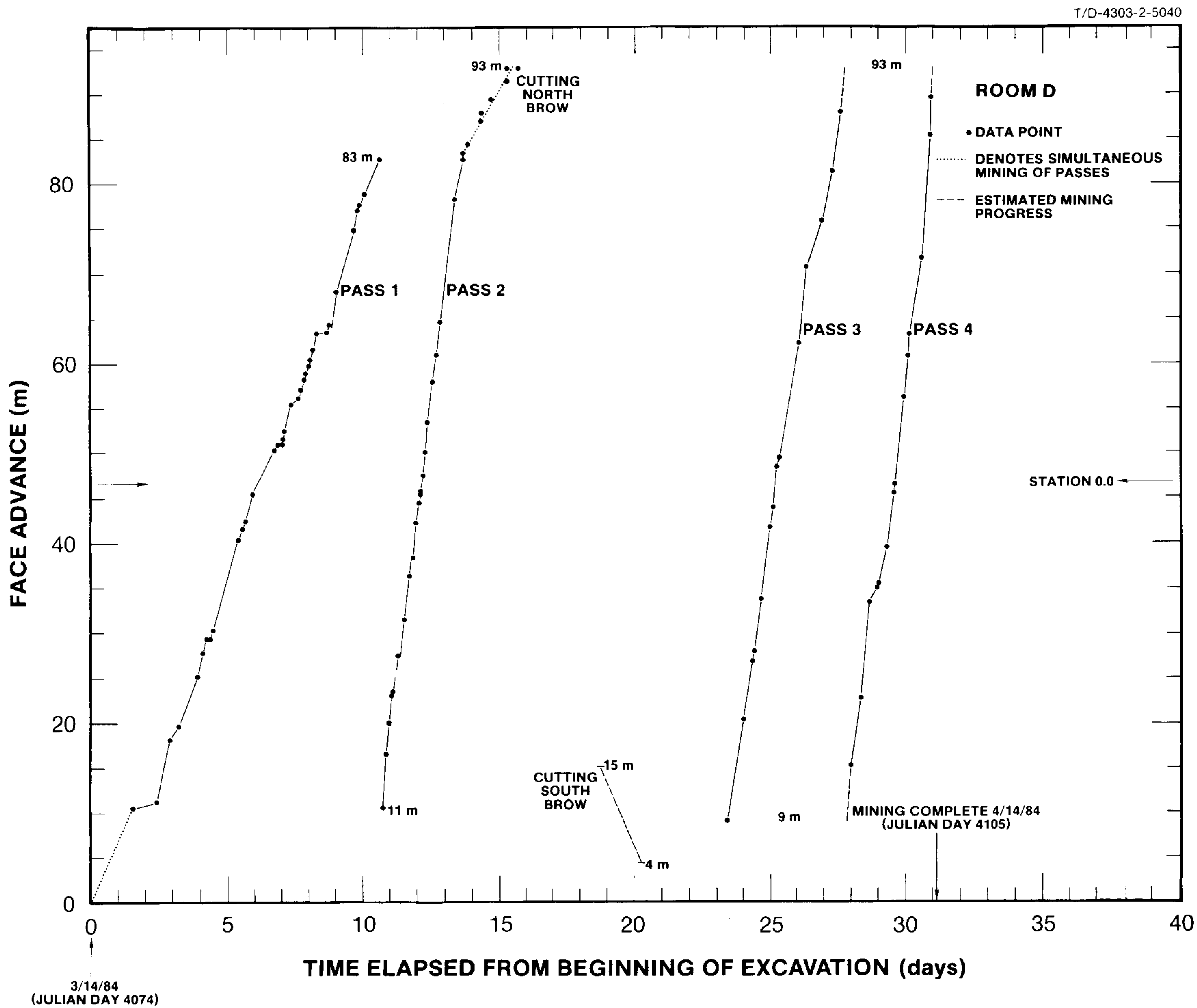


Figure 2.2.13. Mining Face Advance Rates for Room D

to complete. The excavation involved two main passes, with the first pass on the south side of the room being 2.7 m (8.9 ft) high by 4.3 m (14.1 ft) wide and the second pass on the north being of the same height and wide enough to complete the room to the final width of 6.1 m (20.0 ft). The floor was trimmed in two 0.3 m (1.0 ft) thick passes of the same widths as the main passes. The specific details are shown by Figures 2.2.14 through 2.2.16. Room excavation rates are plotted in Figure 2.2.17 and reflect the step-wise excavation sequence. Actually the effective rate of excavation of Room G is quite uniform if the time delay to mine the Room G alcove is ignored.

Room G is intentionally placed so as to isolate it from the other WIPP underground excavations. The test room begins at the western end of a 306.0 m (1003.9 ft) long access drift of somewhat smaller cross section than the test section. The access drift was later enlarged to the same cross section dimensions as the Room G test section; however, none of the excavation details of the entry influence the test section.

To the west, north, and the south of Room G are essentially infinite extents of undisturbed salt.

Room H is rather unusual because it is an annulus around an isolated, cylindrical pillar. The Room H entry was mined south from the N1100 entry in a single pass 3.0 m (9.8 ft) high by 3.7 m (12.1 ft) wide, starting on 4/16/84 and ending on 4/21/84 at what would eventually be the pillar surface. Mining sequence gages were placed in the entry and a collection of geomechanical gages were placed into the salt mass of what would become the pillar. Mining was interrupted for 277 days to obtain baseline data from these early gages. Excavation of the annular room began on 1/24/85 and ended on 2/13/85. The room was cut in [text continues on page 36]

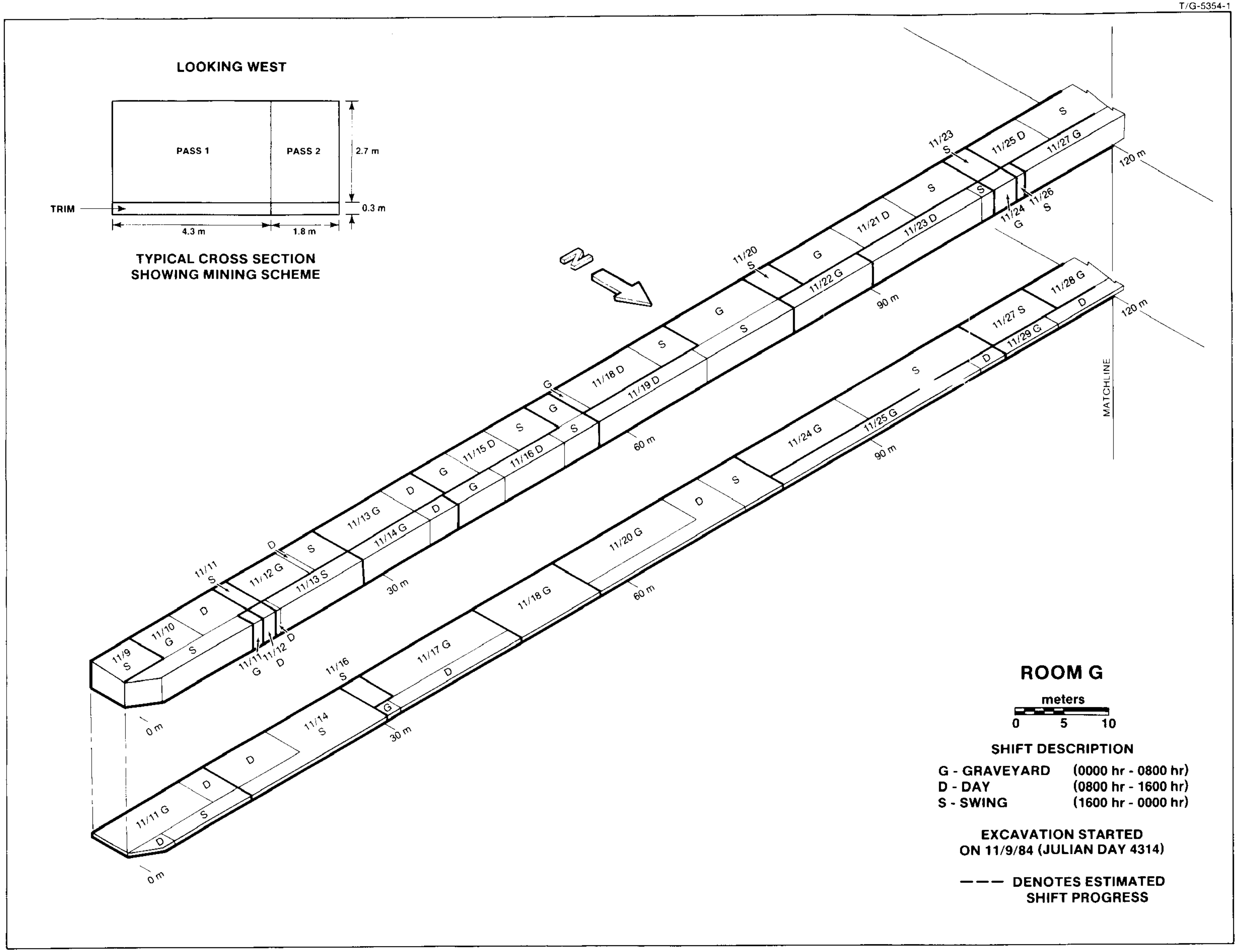


Figure 2.2.14. Isometric of Multipass Mining of Eastern Portion of Room G

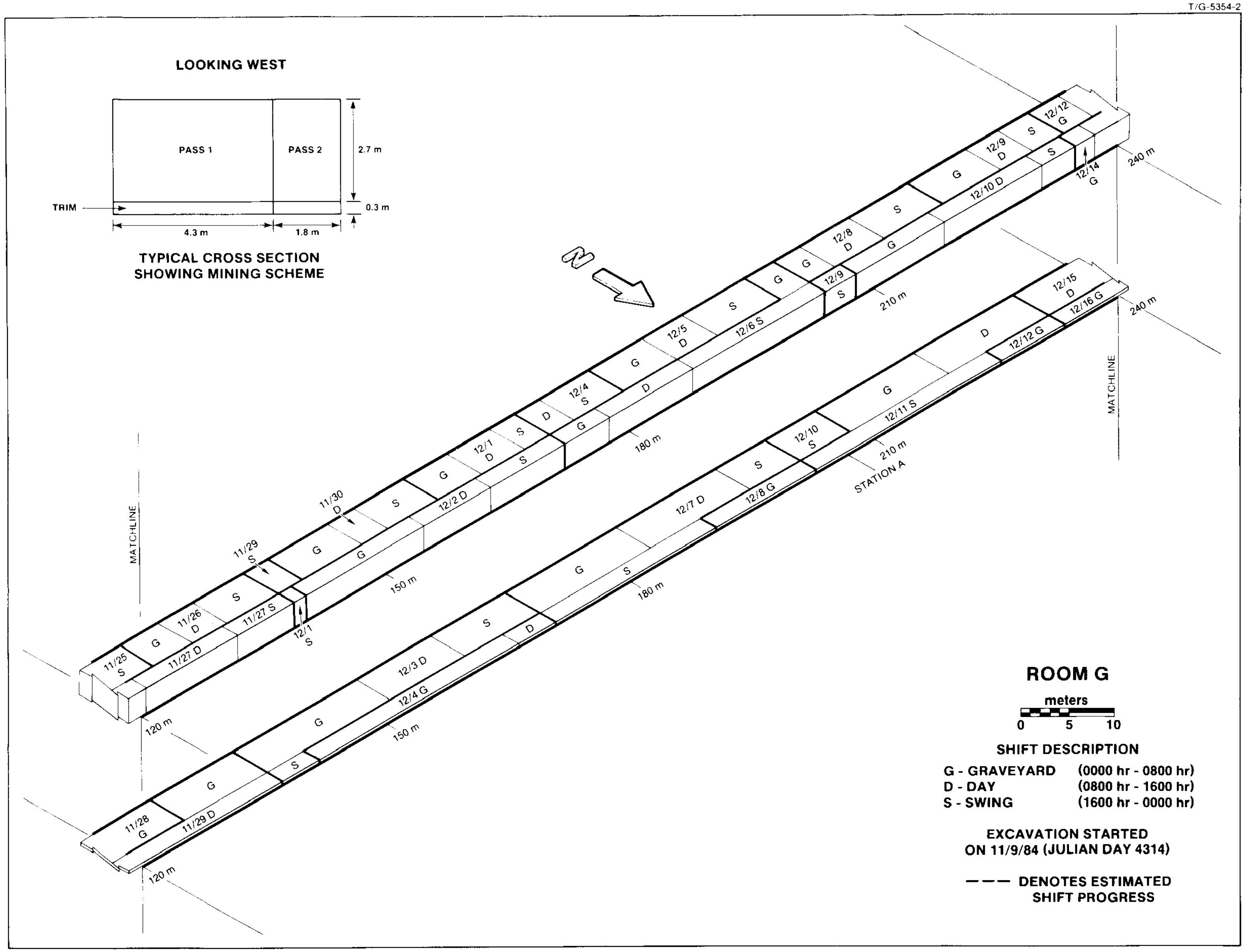


Figure 2.2.15. Isometric of Multipass Mining of Central Part of Room G

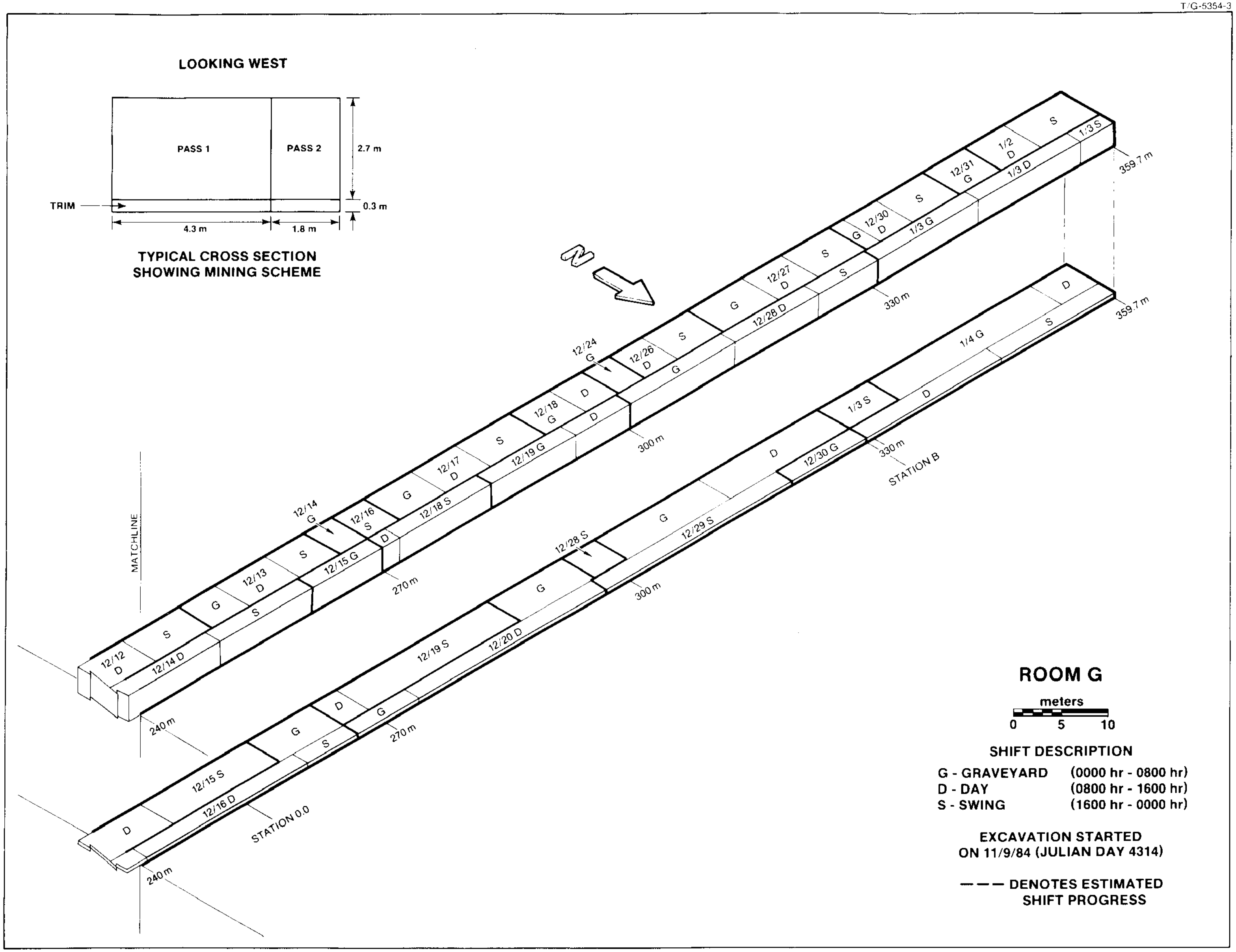


Figure 2.2.16. Isometric of Multipass Mining of Western Part of Room G

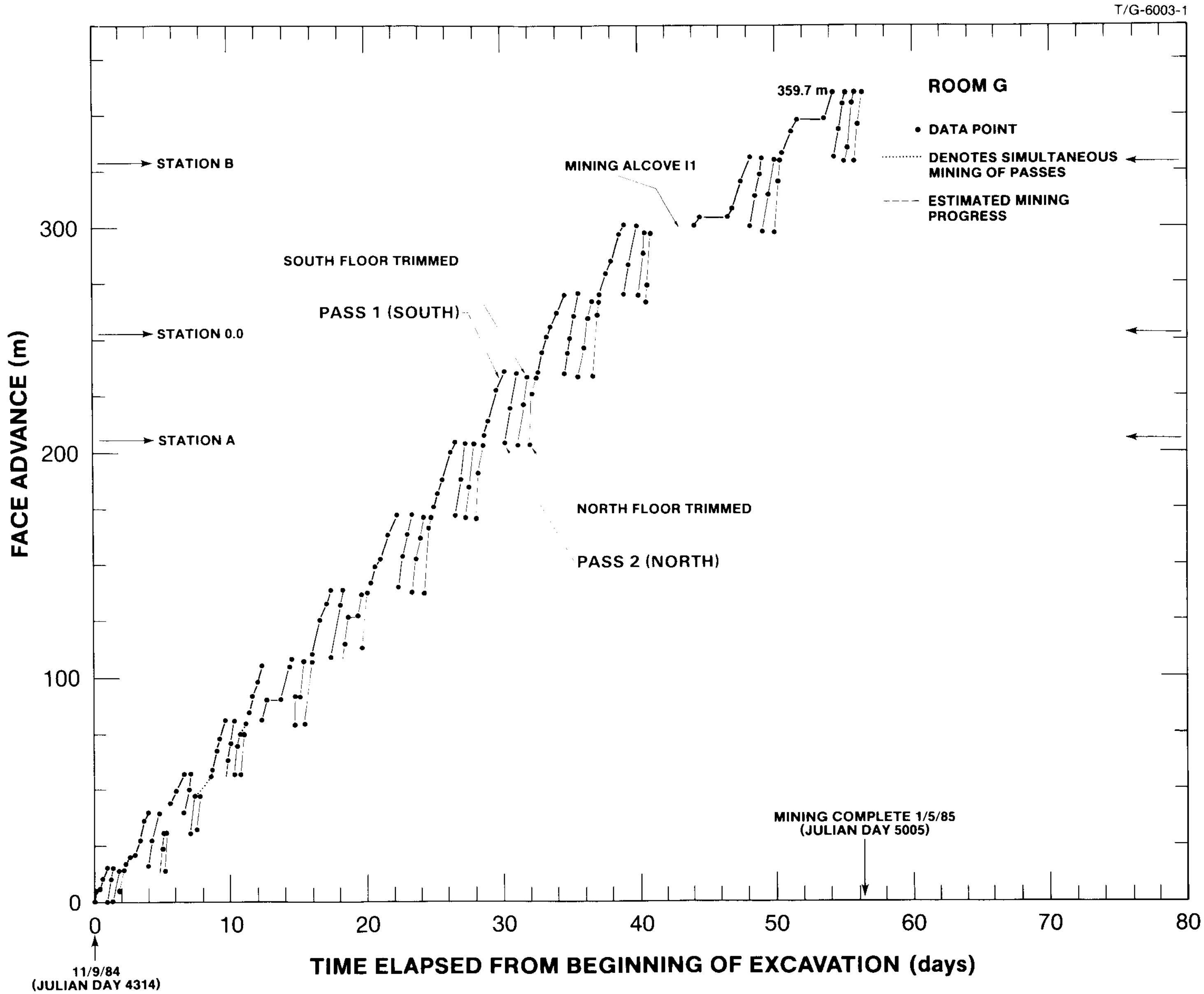


Figure 2.2.17. Mining Face Advance Rates for Room G

three major passes, with trim passes on both the pillar and rib and three trim passes of the floor, as shown in Figure 2.2.18. The first main pass was mined 2.7 m high (8.9 ft) by approximately 4.3 m (14.1 ft) wide in a series of chords of the room centerline, going counterclockwise. The mining machine was turned around to excavate the 2.7 m (8.9 ft) high by about 3.0 m (9.8 ft) wide second major pass, going clockwise, to form the rib surface. This major rib pass was followed by a 2.7 m (8.9 ft) high by 0.3 m (1.0 ft) thick pass, clockwise, to trim the rib. The mining machine was again turned around to excavate the 2.7 m (8.9 ft) by roughly 3.0 m (9.8 ft) wide third major pass, going counterclockwise, to form the pillar surface. This major pillar pass was followed by a 2.7 m (8.9 ft) high by 0.3 m (1.0 ft) thick pass, counterclockwise, to trim the pillar. Next, three floor trim passes, each 0.3 m (1.0 ft) thick, were made in the foot prints of the three main passes but with a difference in order, which was first a counterclockwise central pass, next a counterclockwise pillar pass, and then a clockwise rib pass. These passes brought the annular room to the required 3.05 m (10.0 ft) high by 11.0 m (36.0 ft) wide dimensions and the pillar to its required 5.5 m (18.0 ft) radius. The rather complicated mining history of Room H is reflected in the mining face advance plot in Figure 2.2.19.

The rib of Room H is separated on the north from the N1100 entry drift by a 50.0 m (164.0 ft) thickness of salt. The N1100 entry is the closest excavation to the room, with the end of Room J some 57.8 m (189.6 ft) to the east and the E0 entry some 171.7 m (561.5 ft) to the east. To the south some 207.0 m (679.0 ft) is the excavation for the entry to the Air Intake shaft. Although Room G is located to the west, it is essentially quite remote.

T/H-6002-1

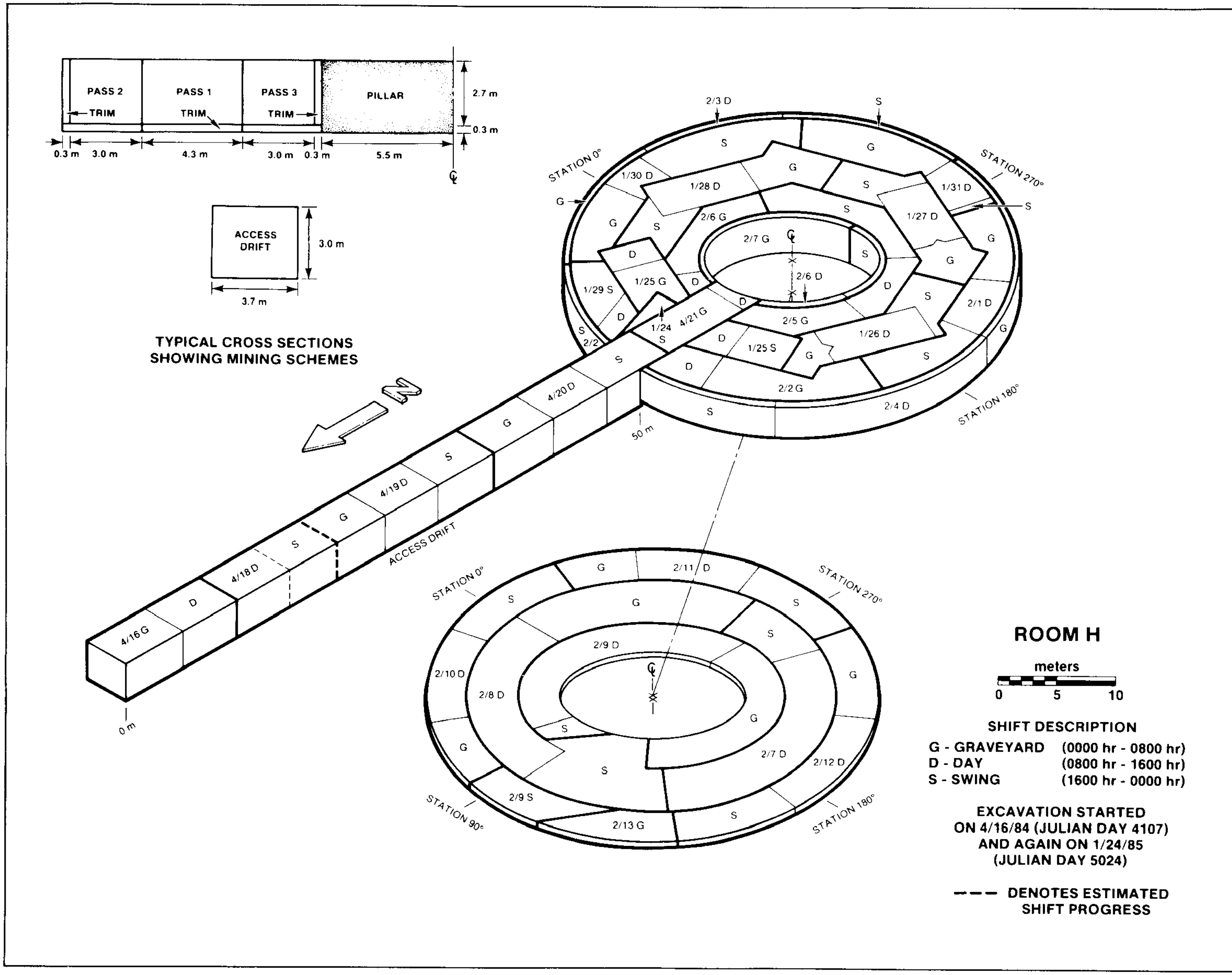


Figure 2.2.18. Isometric of Multipass Mining of Room H

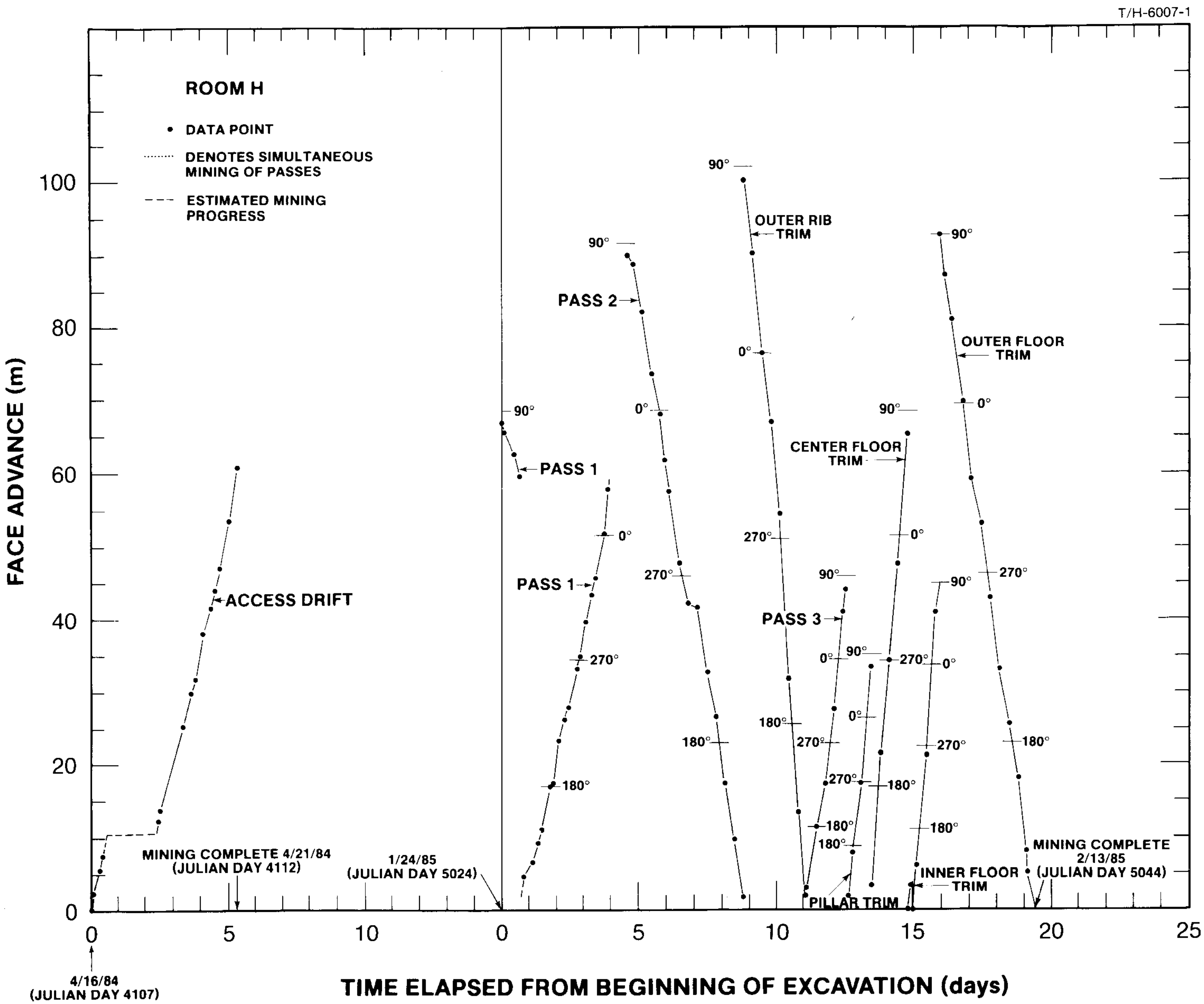


Figure 2.2.19. Mining Face Advance Rates for Room H

The ISBT was the last test to be fielded in the Experimental Area. This test was not planned in the original TSI tests, but was proposed later by the National Academy of Sciences' WIPP Panel. The test was to determine possible scale effects in salt deformation, with the intent of potentially resolving an early discrepancy between calculated and measured room closure. The excavation consists of a 0.91 m (3.0 ft) diameter hole drilled from Room C2 through the pillar into Room C1. The drill hole center line is located approximately at midlength of the somewhat unequal length rooms, parallel to and 15.2 m (50.0 ft) from the 3.7 m (12.0 ft) high by 4.3 m (14.0 ft) wide N1420 entry, as shown in Figure 2.2.20. The vertical center of the drill hole is in the middle of the clear salt layer found in the lower half of the room (see Figure 2.2.2) some 1.62 m (5.30 ft) above the room floor. To assure the drill hole remains centered in the salt layer, the center line dips slightly as it goes from Room C2 to Room C1 to accommodate the dip in the stratigraphy. Rooms C cross sections are each 5.5 m (18.0 ft) high by 5.5 m (18.0 ft) wide and the pillar is 18.0 m (59.0 ft) thick.

The ISBT drill hole was excavated using a Longyear ESH-38 drilling machine and a specially fabricated core bit with a centralizer stem that could core to a depth of about 1.02 m (1.35 ft). The core drill was guided by a 22.2 mm (0.875 in.) diameter pilot hole along previously drilled along the ISBT hole center line. Drilling was in stages to accommodate the finite length of core that could be taken by core bit. At each stage, the drilling progressed to the length of the core bit, then the bit was withdrawn from the hole leaving the core still attached at the base of the drill cut. The core length was broken loose and removed from the drill hole. This operation continued until the hole was completed.

T/C-12212-1

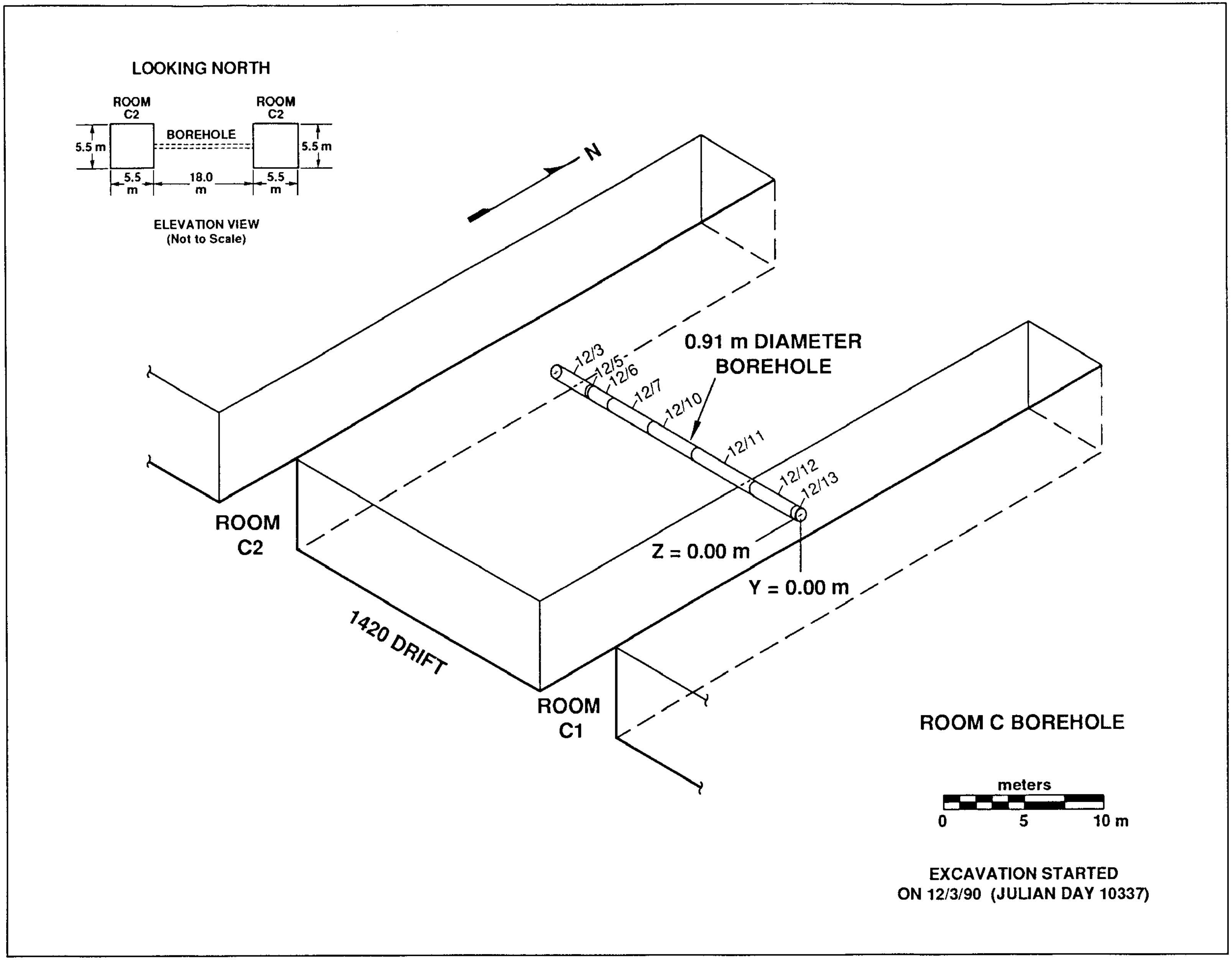


Figure 2.2.20. Isometric of the ISBT

Details of the daily drilling operation are shown in the isometric of Figure 2.2.20. The excavation rate, as given in Figure 2.2.21, was quite uniform, except at the beginning of the drilling where maintaining directional control required special attention and later when drilling was stopped over a weekend. Mining sequence gage measurements were made in the borehole while it was being drilled in essentially the same manner as the mining sequence measurements in a test room.

As noted in the previous discussion of Rooms C, excavation of these rooms started on 3/17/84 and finished on 4/9/84. Some 6.7 years later, drilling of the ISBT began on 12/03/90 and was completed on 12/13/90.

Considerably after the completion of the TSI test rooms, an important test was fielded outside of the Experimental Area in what was initially the SPDV portion of the facility. This test was the Brine Inflow test in Room Q. Although the purpose of this test was not to determine structural response, it was possible to make geomechanical measurements during the excavation of this unique room which would augment the mining sequence results from the TSI tests.

Room Q is a very long cylindrical room excavated by full-face boring using a Robbins Tunnel Boring Machine. The work was accomplished under a fixed price contract by Boretec, Inc. In preparation for the boring operation, the 3.66 m (12 ft) high by 6.10 m (20.0 ft) wide S90 drift was extended westward 82.3 m (270 ft) from the W620 entry by continuous miner to a region well removed from the influence of earlier excavations. At the western end of the drift extension, a large instrument alcove was excavated, with dimensions of 9.1 m (30.0 ft) deep by 24.4 m (80.0 ft) wide and 4.75 m (15.6 ft) high. Room Q was bored westward from this instrument alcove in a single pass beginning on 7/12/89 and finishing on

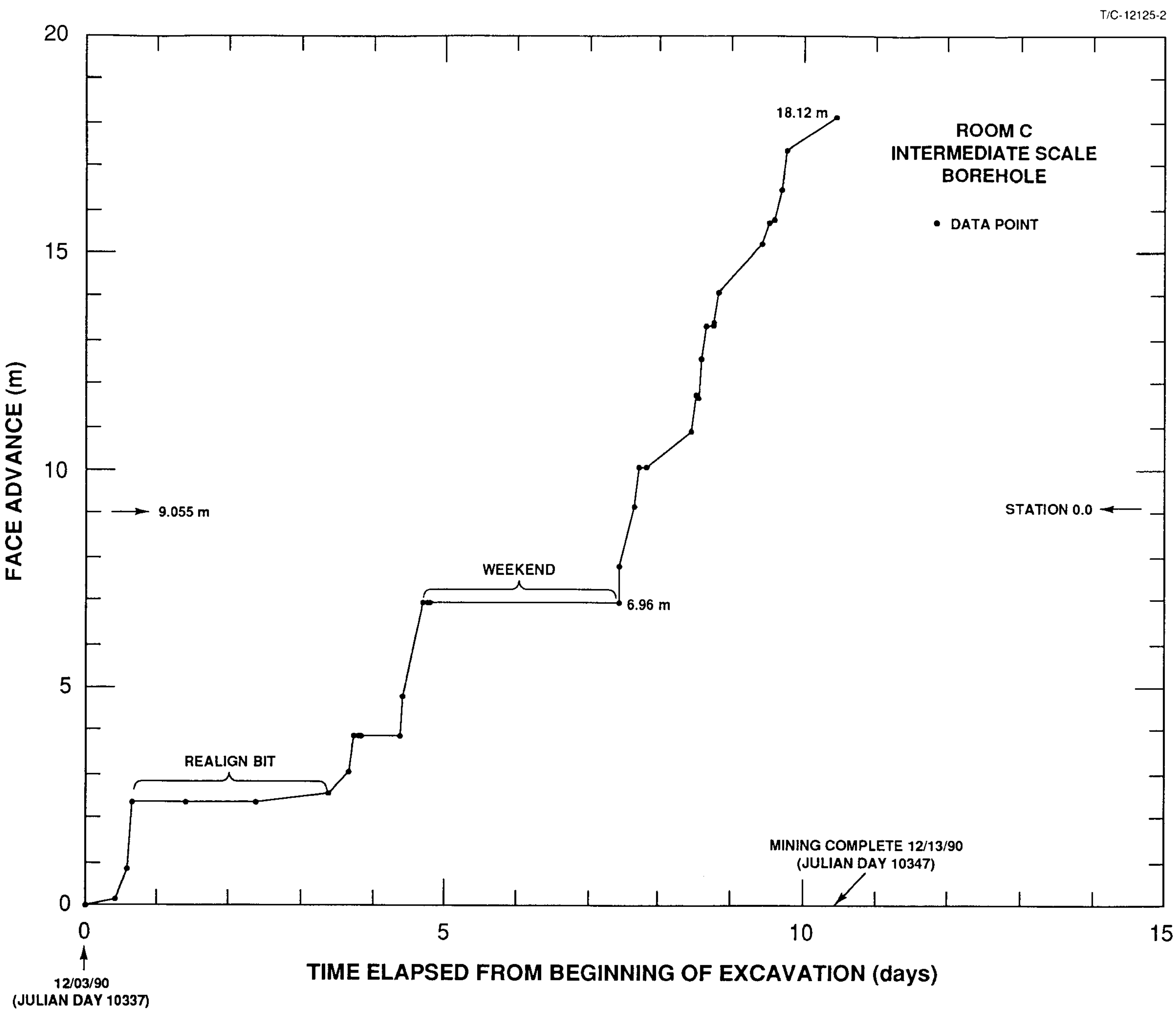


Figure 2.2.21. Drilling Advance Rates for the ISBT

8/8/89, as shown in the isometric of Figure 2.2.22. The room was 2.90 m (9.5 ft) in diameter and nominally 106.7 m (350.0 ft) long, with a conical face about 1.7 m (5.5 ft) deep at the room end. The cylindrical axis of the room was 0.69 m (2.25 ft) above an orange marker bed that is a geological feature often used to control the elevation of the excavation process. This placed the roof invert line (the top of the cylindrical excavation) at the same elevation as the roof of the planned storage rooms and the four SPDV test panel rooms, as shown in Figure 2.2.2. The center of the room is taken as midway along the longitudinal axis or 53.3 m (175.0 ft) from the alcove. A plot of the face advance rate, as given in Figure 2.2.23, shows considerable variation, primarily because of the initially slow excavation process as the boring machine was being "sunk" into the salt mass.

Room Q is separated from the W620 entry drift by an 82.30 m (270.0 ft) long access drift and 6.10 m (20.0 ft) wide instrument alcoves. The nearest excavation to the north of Room Q is Room G, some 361 m (1184 ft) away. To the west and south of Room Q is essentially an infinite extent of undisturbed salt.

2.2.2 Mining Sequence Gages

The mining sequence gages were special manual closure points developed specifically for rapid installation in very restricted spaces and under severe time restraints, by a crew operating without normal utilities. As shown schematically in Figure 2.2.24, a gage point installation consists of a 12.7 mm (0.5 in.) drill hole, nominally 25.4 mm (1.0 in.) deep, made with a hand-held electric drill. Into this hole is placed a threaded male Ramset bolt onto which is attached a 9.43 mm (0.375 in.) female eyebolt. Because the eyebolt is below the surface of [text continues on page 47]

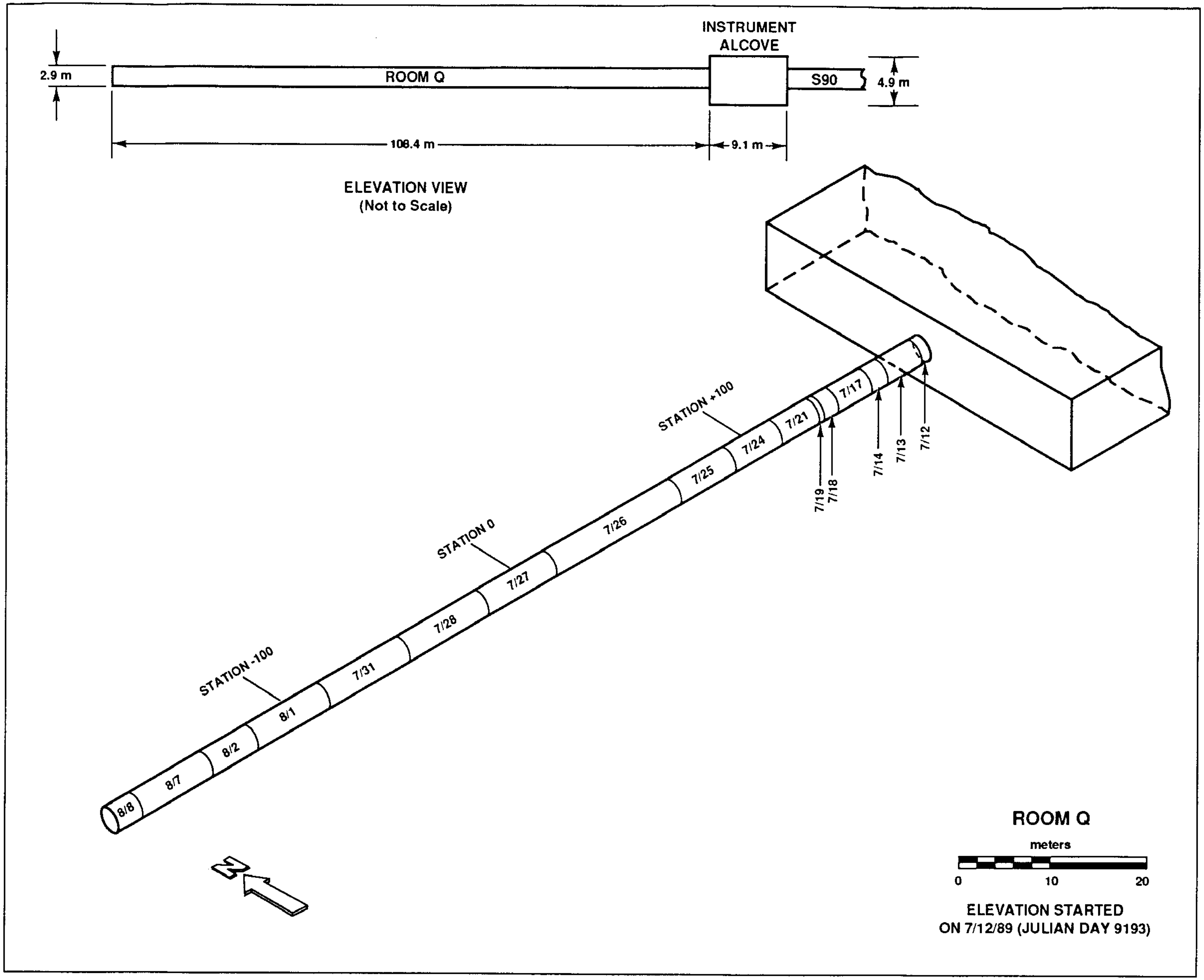


Figure 2.2.22. Isometric of the Mining of Room Q

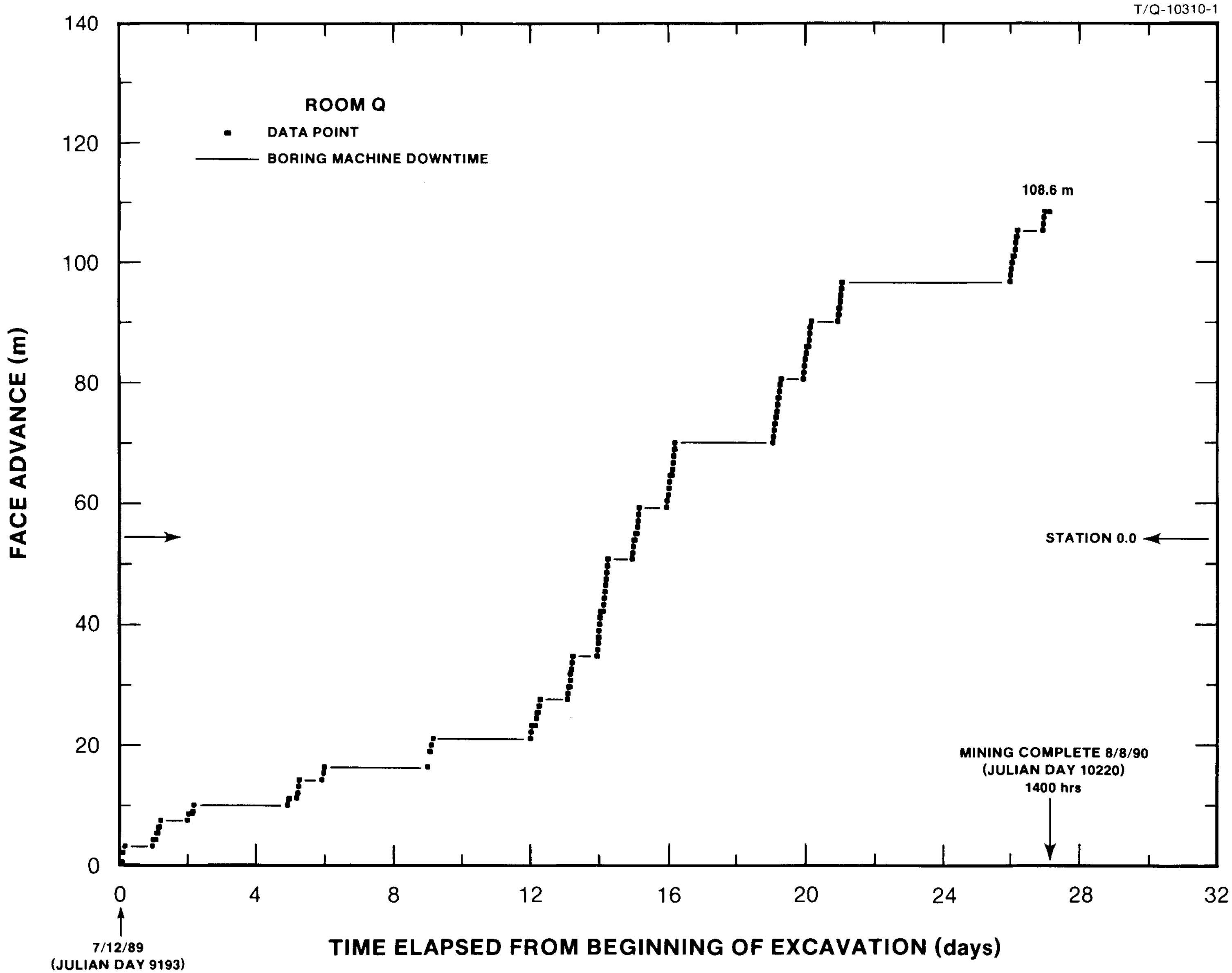


Figure 2.2.23. Mining Face Advance Rates for Room Q

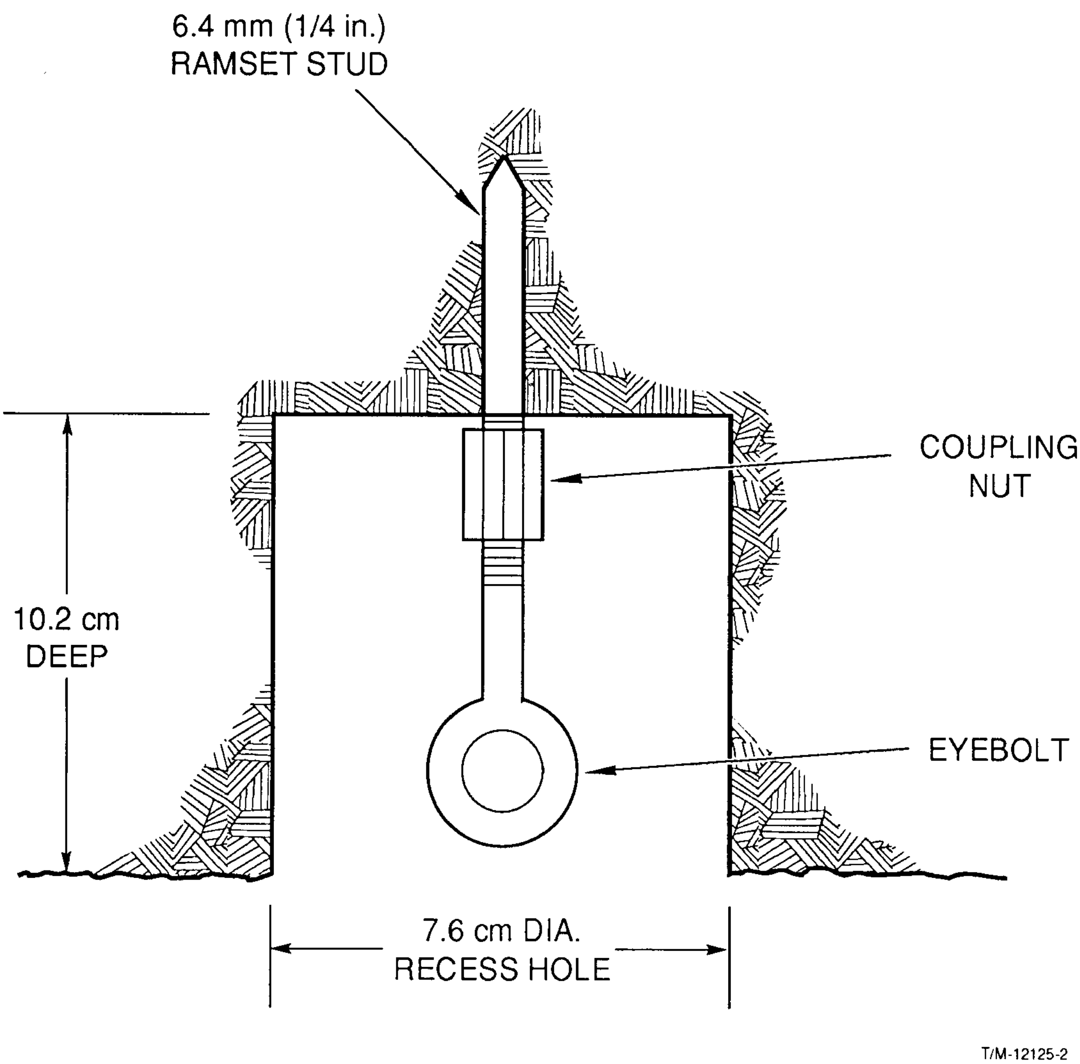


Figure 2.2.24. Schematic of a Mining Sequence Gage Point

the excavation, it is protected from further normal activities of the miners and mining machinery. There was no attempt to cover the installation which meant that muck could and did fill in around the emplacement as the excavation process continued. It was found that these installations were quite durable even though floor installations had to endure severe heavy machine traffic.

Each mining sequence gage has a distinguishing code. These gage designations (numbers) were configured to convey important information about the gage. The gage designation code is a set of seven alphanumeric characters (for example, A1M01-1 that contains several useful pieces of information. The first character is a letter representing the specific test room (in this example, the "A" test). The next character field indicates a subtest within the room (in this case the Room "1" subtest of the A test). The gage type is given by the next three characters. For gages that were part of the initial test plan, the first character is a number whose value represents a specific gage type. Special gages, such as the mining sequence gages, added after completion of the test plan, have a gage type with an initial alphabetic character keyed to the type of special gage. For example, the mining sequence gages in Room A1 are designated A1Mxx, where "xx" is a unique number representing an individual unit. The sixth alphanumeric character is the subunit. In the mining sequence gages we encounter only one type of subunit indicated with a "-" which tells us that the gages of the subunit are all contained in the same borehole. Since there are no actual boreholes for the mining sequence gage, this is a figurative designation indicating that all of the gages of a unit are along the same line through the cross section. Finally the last numerical character is the specific gage of the unit. Gages of a unit or subunit may range from 0 to 9. Normally, some units, such as the permanent closure gage types, have only 1 gage. However, in the case of the mining sequence gages, a sequence of gage numbers was associated with the replacement of mined-out gage points. Thus, the gages installed in the first pass were all designated as gage "1". If a subsequent pass mined out gage 1, its reinstallation, which is actually a new gage length, is designated as a gage corresponding to the number of the pass. In some rooms the multipass mining sequence resulted in the designation of up to gage "3". In cases where a trim pass was required that removed little salt, the gage point was replaced but retained the same gage number, which is consistent with the idea that it is not a new gage because the gage length did not change.

The location of each gage is specified, within the tolerance limits of installation, in terms of the room rectangular (X,Y,Z) or cylindrical (R,T,Z) coordinate system. Ideally, the geometric center of the room is X=0, Y=0, and Z=0 where "X" is positive in the east direction, "Y" is positive in the north direction, and "Z" is positive in the vertical (upward) direction. The cylindrical coordinate system is used for Room H only, with the origin of R=0, Z=0 in the center of the pillar. "Z" is positive in the vertical (upward) direction, "T" is a positive angle taken in the counterclockwise direction from a zero line to the east, and "R" is a radius which has only positive values. The gage location requires pairs of coordinates which specify the two end locations of the closure gage.

Because of the peculiarities of excavation of the test rooms in a slightly dipping geology, two pairs of "Z" values are given. One pair of values is the location in terms of the test room coordinate system; the other pair of values is in terms of the local midheight origin of the gage station. The locations in both coordinate systems are presented for each gage.

2.2.3 Gage Stations

A simple complete mining sequence closure station consisted of two pairs of gage points, one pair to measure vertical displacements and one pair to measure horizontal displacements.

Gage point surveying of a station required only a plumb bob and string level. For a simple station, the plumb line was dropped from the roof of the excavation, at about midspan. At midheight of the plumb line string, a horizontal string line, using a string level, was stretched between ribs. The plumb line was adjusted to the midpoint of the horizontal string line. Rough perpendicularity to the room axis was assured by obtaining the minimum possible string length between the two ribs. Gage points were installed at the locations at which the plumb line and the horizontal string lines touched the excavation surfaces. Location accuracy depended upon the roughness of the excavation surfaces, which according to the permitted construction tolerances was ± 76 mm (± 3.0 in.)

The simple closure station procedure became more complex for multipass mining situations which involved other than midspan or midheight gage locations. However, the same basic installation method applied.

The procedure developed for establishing a gage station was compatible with the mining activity. The requested station locations as determined by the Principal Investigator (PI) were only target locations. Actual station locations, although close to the requested station locations, were determined by the normal pauses in the excavation activities. This was necessary to minimize the delay to the mining contractor caused by gage installation. Typically, station locations were within ± 1.5 m (± 5.0 ft) of the requested location. When the mining machine had excavated about 0.9 m (3.0 ft) beyond the intended station, mining was stopped and the machine backed sufficiently away from the mining face to permit the geotechnical crew to work in front of the mining machine. A similar procedure was used in Room Q, where the boring machine was withdrawn from the excavation face and the geotechnical crew removed a segment of the machine shield to gain access to the space in front of the boring machine. In the ISBT, the geotechnical crew crawled into the borehole as soon as the drill bit and core segment were removed from the location of the station to be installed.

Once the station location was made available by the mining contractor, the geotechnical crew removed the muck from the floor to clear the spot intended for the gage and installed the gages. The geotechnical crew could install a complete simple mining sequence station within about 30 minutes, including the initial gage reading. Even in those cases where unusual circumstances made installation more difficult, the maximum installation time never exceeded one hour.

As soon as the station was installed, initial tape extensometer readings taken, and the mining machine or drill was again advanced to the mining face to continue the excavation process.

Although the exact installation depends upon the details of the mining passes, the final room size, and the station configuration, the principles governing the station installation are illustrated by an example for the DHLW test rooms. In this example, typically, for the first pass, gage points are installed at the midspan and midheight of the pass dimensions, and also at the midspan and midheight of the final room dimensions. As shown in Figure 2.2.25 for this typical four pass excavation, the gage

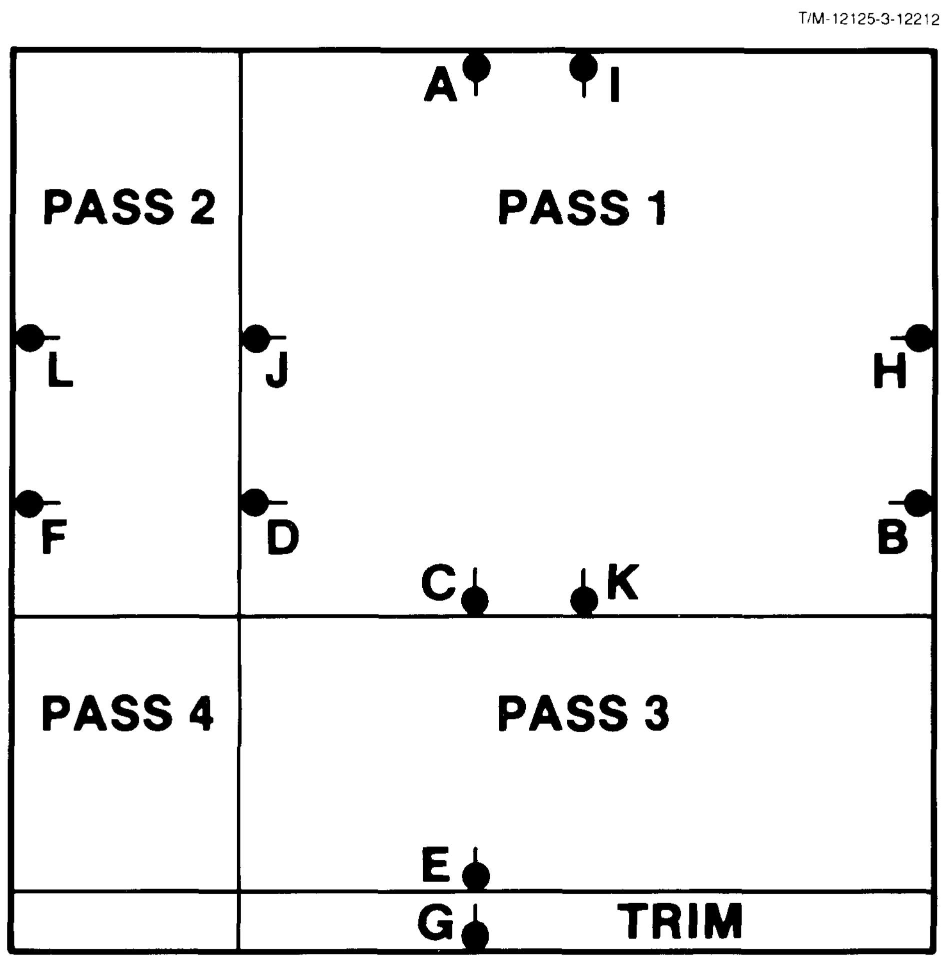


Figure 2.2.25. Schematic of Mining Sequence Gage Station

points installed in the first pass are I-K and H-J for the first pass dimensions and A-C and B-D for the final room dimensions. The second pass mined out some of the gage points installed in the first pass which required the installation of new gage points, L and F in Figure 2.2.25. In a similar manner, the third mining pass also removed previous gage points, which in the example of Figure 2.2.25 are reinstalled as a single midspan gage point for the final room dimension. The fourth pass did not remove any existing gage points. As indicated, any gage point removed by trimming of the room surfaces was replaced at the same location. All reinstalled and replaced gage points were emplaced in front of the mining machine under the same conditions of time and excavation face separation as the original points.

2.2.4 Data Acquisition Procedure

Initial readings using a manually read tape extensometer were obtained immediately upon the installation of the gage station and, just as in the case of the original gage installation, initial readings were taken for any reinstallation or replacement of a gage point. In a typical example, as the gage station was excavated on the first pass and the mining machine was backed away from the mining excavation face, the gage points were installed and initial readings obtained. These gages were again read as soon as the mining had advanced enough that the mining machine had cleared the points (the length of the mining machine and conveyer system was about 12.2 m (40 ft)). Gage readings continued as the mining machine moved away from the station to complete the first pass and the machine was moved back into position for the beginning of the second pass. Readings of the station established on the first pass continued as the excavation face of the second pass approached the station and, if the second pass destroyed any of the first pass gage points, these were reinstalled and new initial readings taken. Again, gage readings continued as soon as the mining machine cleared the station, and moved away in the completion of the second pass. The same procedure was used in any subsequent pass, as well as for any trim pass.

The mining sequence gage measurements were all made using a manual tape extensometer, calibrated periodically against a known length of a transfer standard. The transfer standard was itself calibrated against a primary standard.

2.2.5 Gage Locations

There were a total of 24 mining sequence stations installed in the TSI tests. In addition there were seven mining sequence stations installed in the ISBT and four mining sequence stations installed in the Room Q test. At these stations, there were an initial total of 104 mining sequence gages installed.

The permanent gages of any test room were concentrated at various stations or cross sections, which were designated "principal" (as explained in detail in Section 2.3.1) stations along the room length. These concentrations make it possible to specify accurately the gage installation locations and analysis procedures. Because of the requirements of mining, the mining sequence gage stations do not always correspond to a principal station of the permanent gages of the test room; however, they are typically close enough to each other to assure little, if any, error in transferring the mining sequence gage measurements to the permanent gages of the principal station. This is certainly the case for the central mining sequence station and the associated central principal station.

Gage locations for the mining sequence gages are shown in the schematic plan views given for each of the Rooms A1, A2, A3, B, and D in Figure 2.2.26. Gage station cross sections are given for Room A1 in Figure 2.2.27, Room A2 in Figure 2.2.28, Room A3 in Figure 2.2.29, Room B in Figure 2.2.30, and Room D in Figure 2.2.31. All of these rooms have identical room dimensions and were excavated in a similar manner. In Table 2.2.1, the actual dimensions of the final room and each mining pass are summarized for the similar rooms, together with the ratios of gage location to span or height. As is evident, the relative gage location with respect to the span or height changes abruptly with each mining pass. Although not required for our purposes here, Munson et al. [16] have shown how the closure curves at a nearly constant span ratio can be constructed from the multipass data.

The remaining tests, three large rooms and one drill hole, are quite dissimilar; some are just single pass excavations, whereas others are not. Also, the geometries encompass two rooms with rectangular cross sections and two tests with circular sections. The station locations for Room G are given in Figure 2.2.32, with cross sections in Figure 2.2.33; for Room H in Figure 2.2.34 and Figures 2.2.35 and 2.2.36; for the ISBT in Figure 2.2.37 and Figure 2.2.38; and for Room Q in Figure 2.2.39 and Figure 2.2.40. Table 2.2.2 summarizes the initial final room and mining pass dimensions for the non-similar rooms, together with the span and height ratios for the gage locations.

2.2.6 Operation

Although the official date at which the various test rooms were considered to be operational depended on various test details, we consider the mining sequence gages to have been [text continues on page 61]

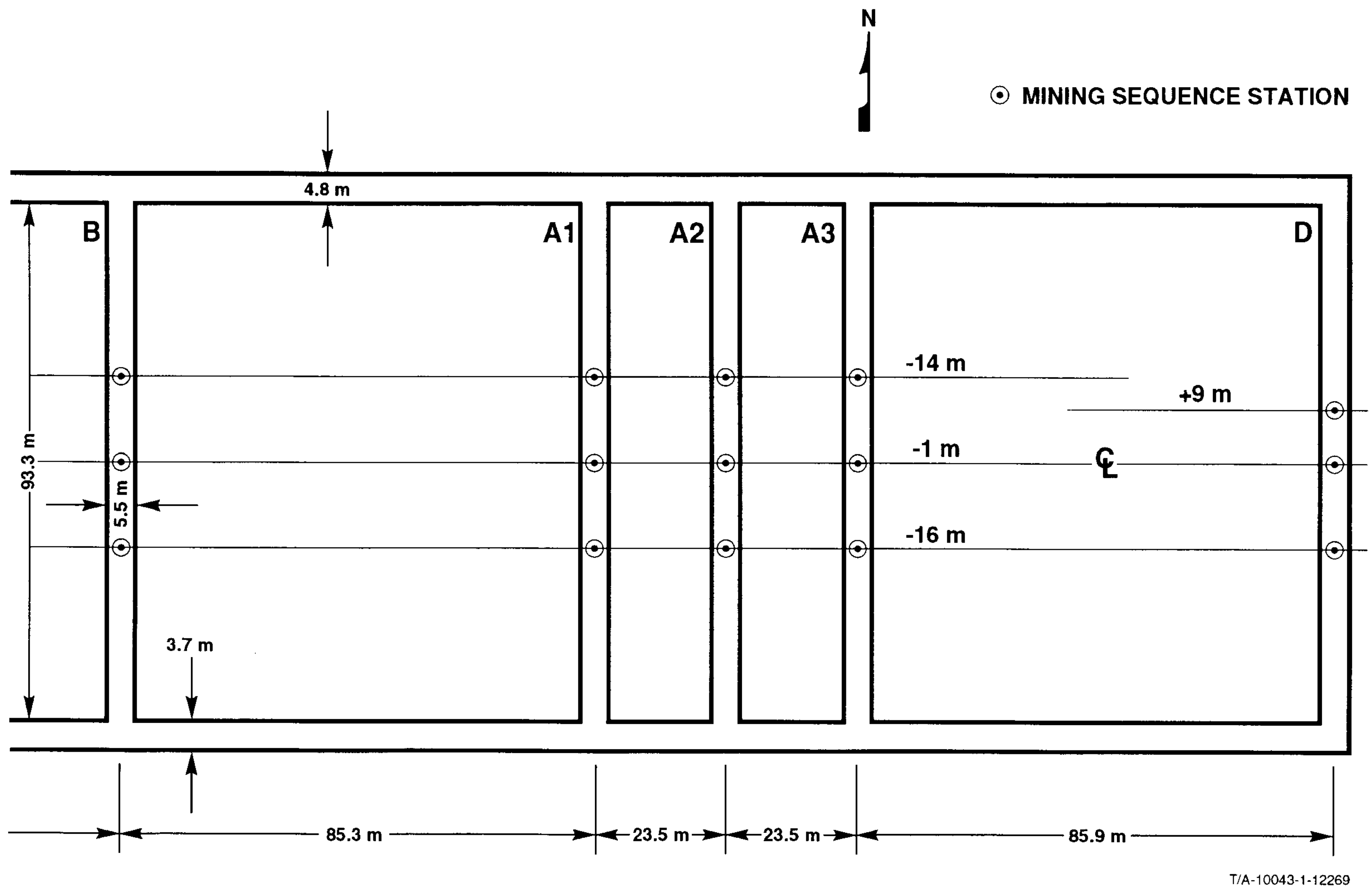


Figure 2.2.26. Plan View of the A1, A2, A3, B, and D Gage Stations

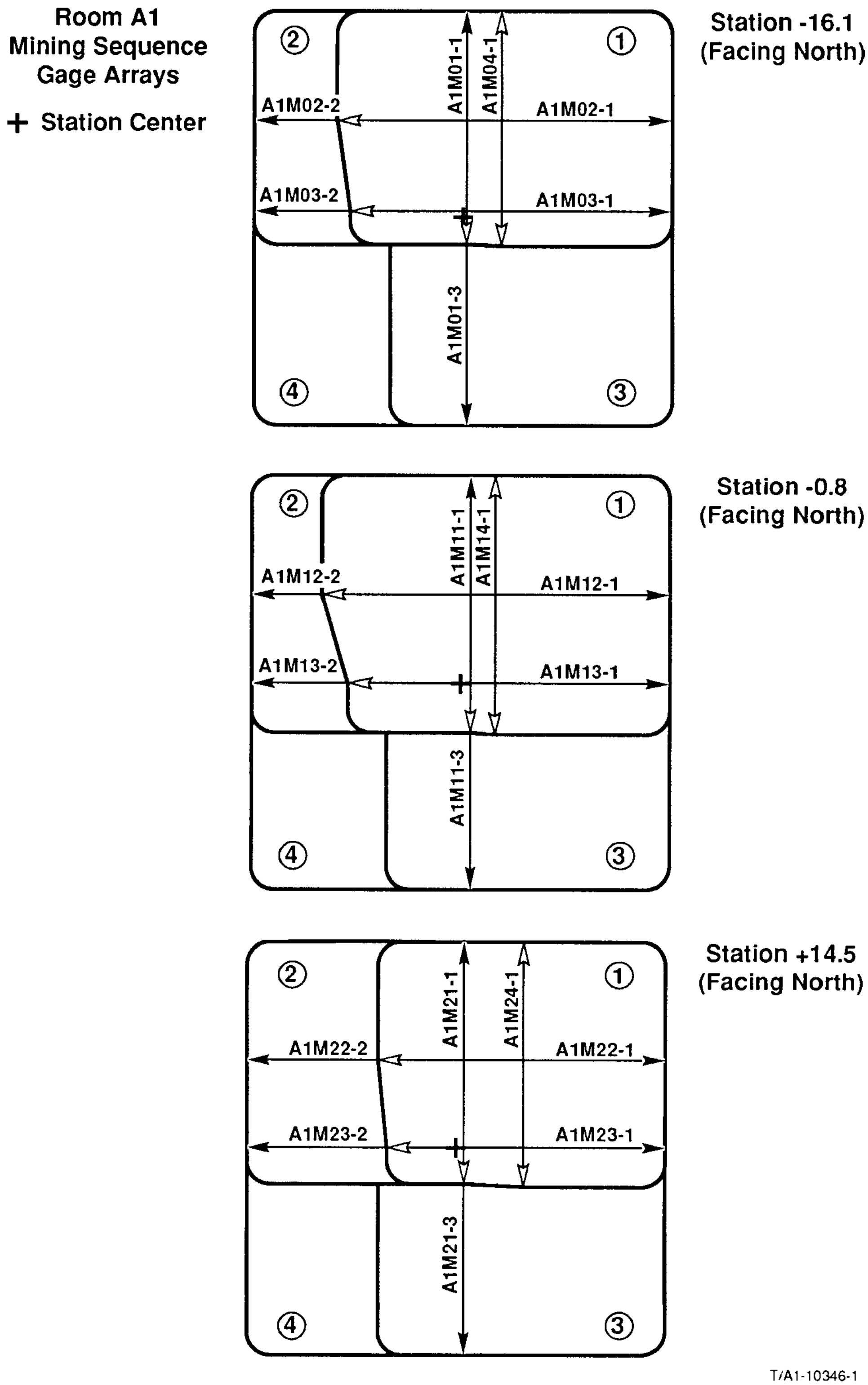


Figure 2.2.27. Mining Sequence Gage Station Cross Sections in Room A1

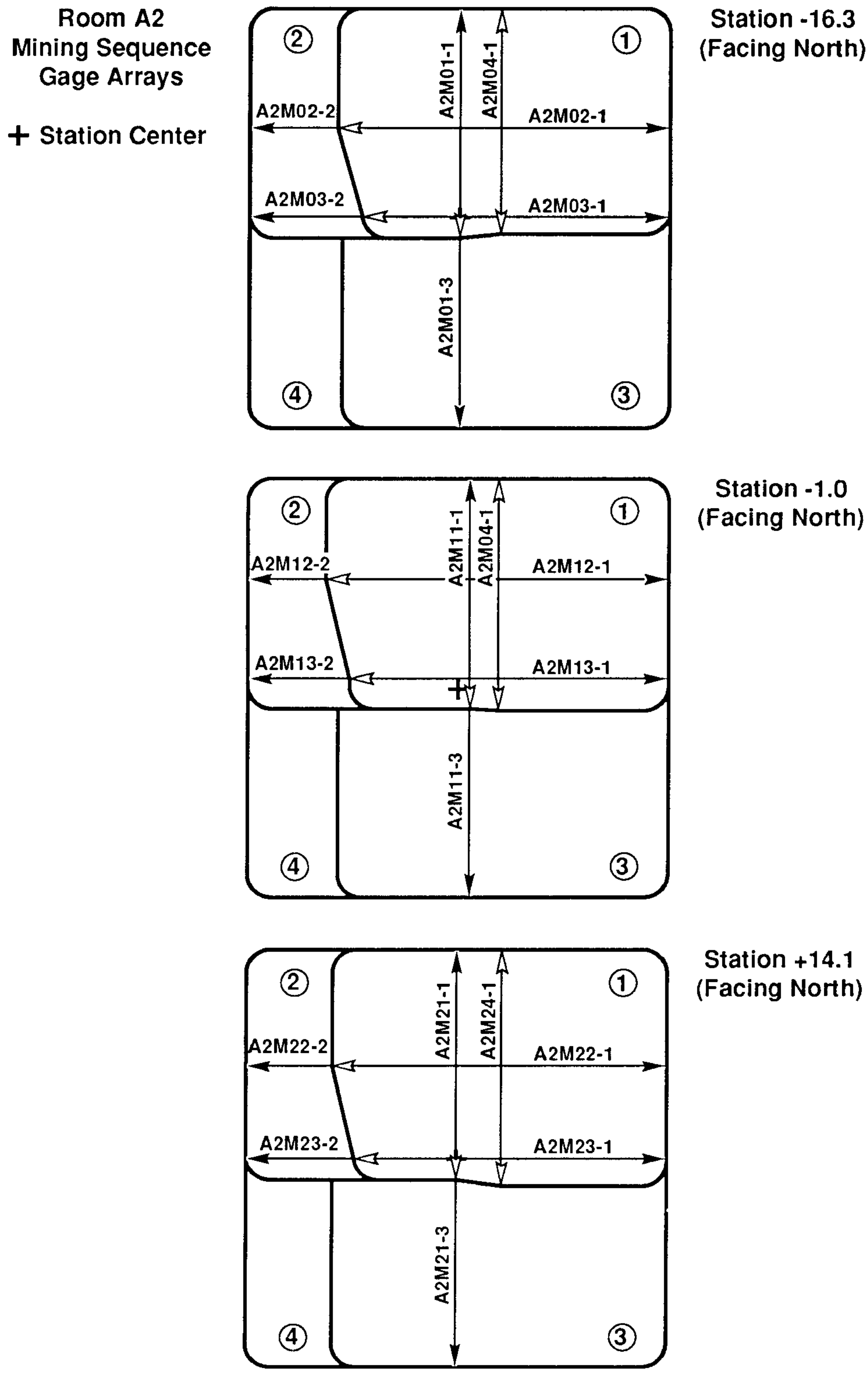


Figure 2.2.28. Mining Sequence Gage Station Cross Sections in Room A2

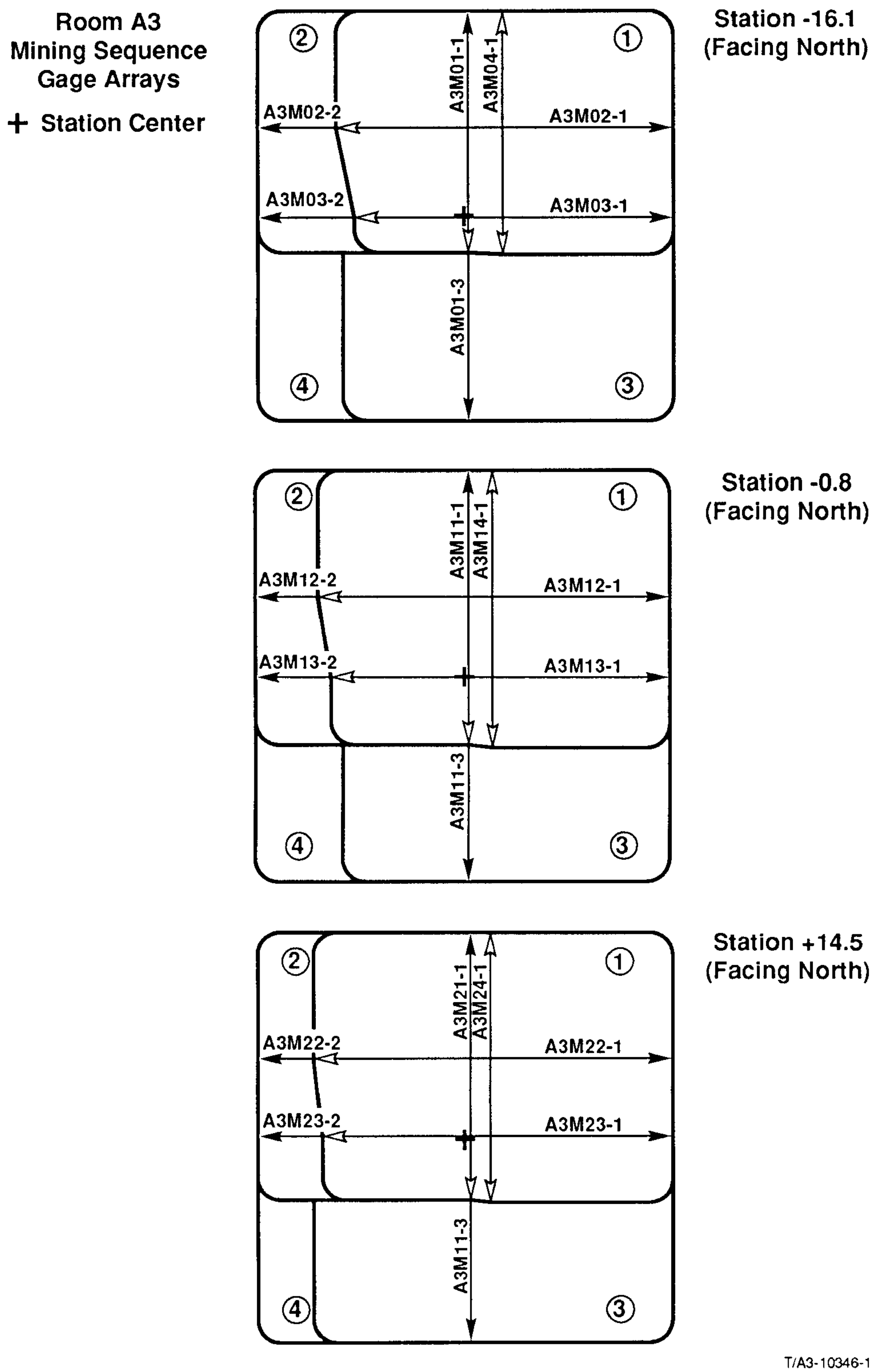


Figure 2.2.29. Mining Sequence Gage Station Cross Sections in Room A3

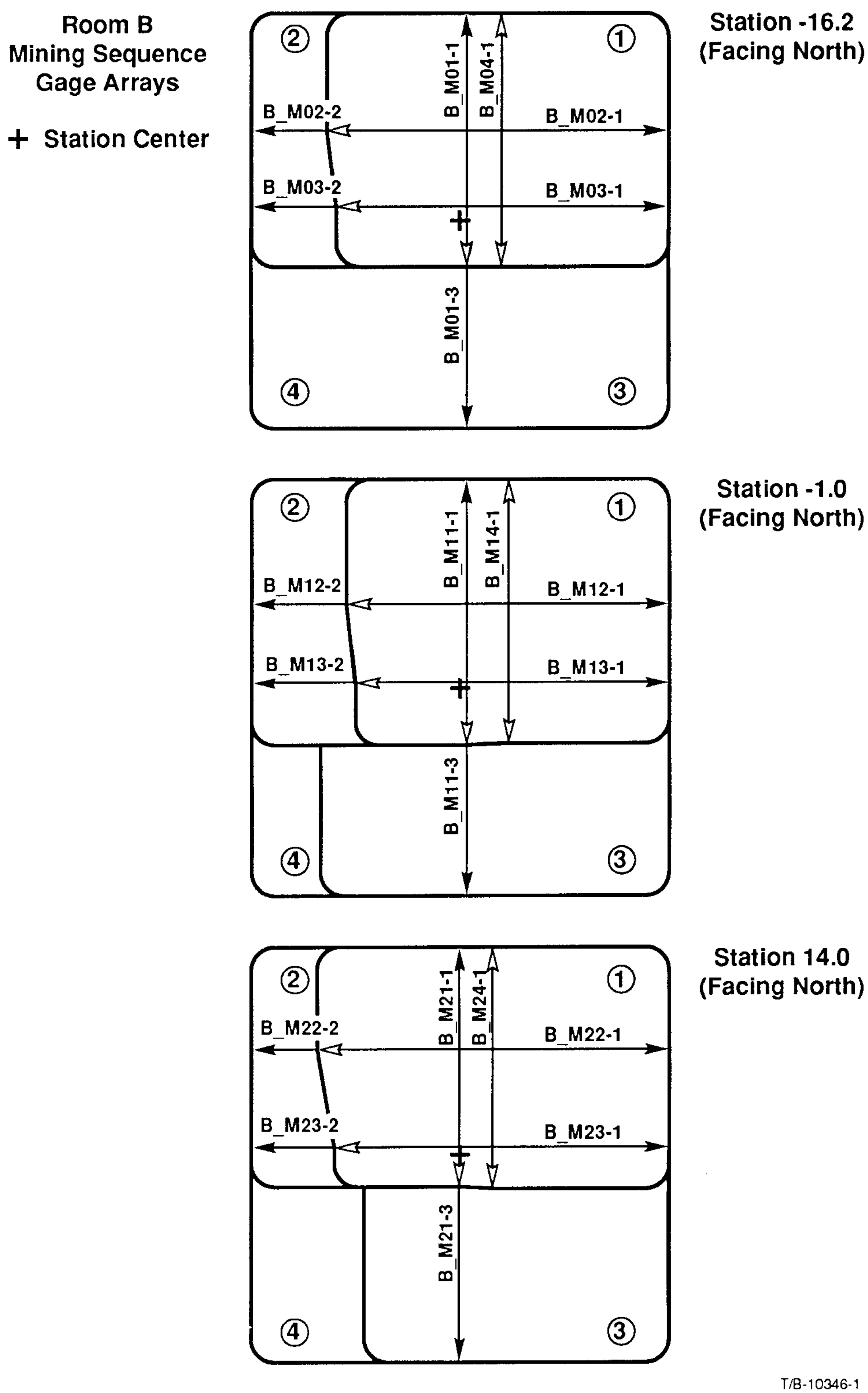


Figure 2.2.30. Mining Sequence Gage Station Cross Sections in Room B

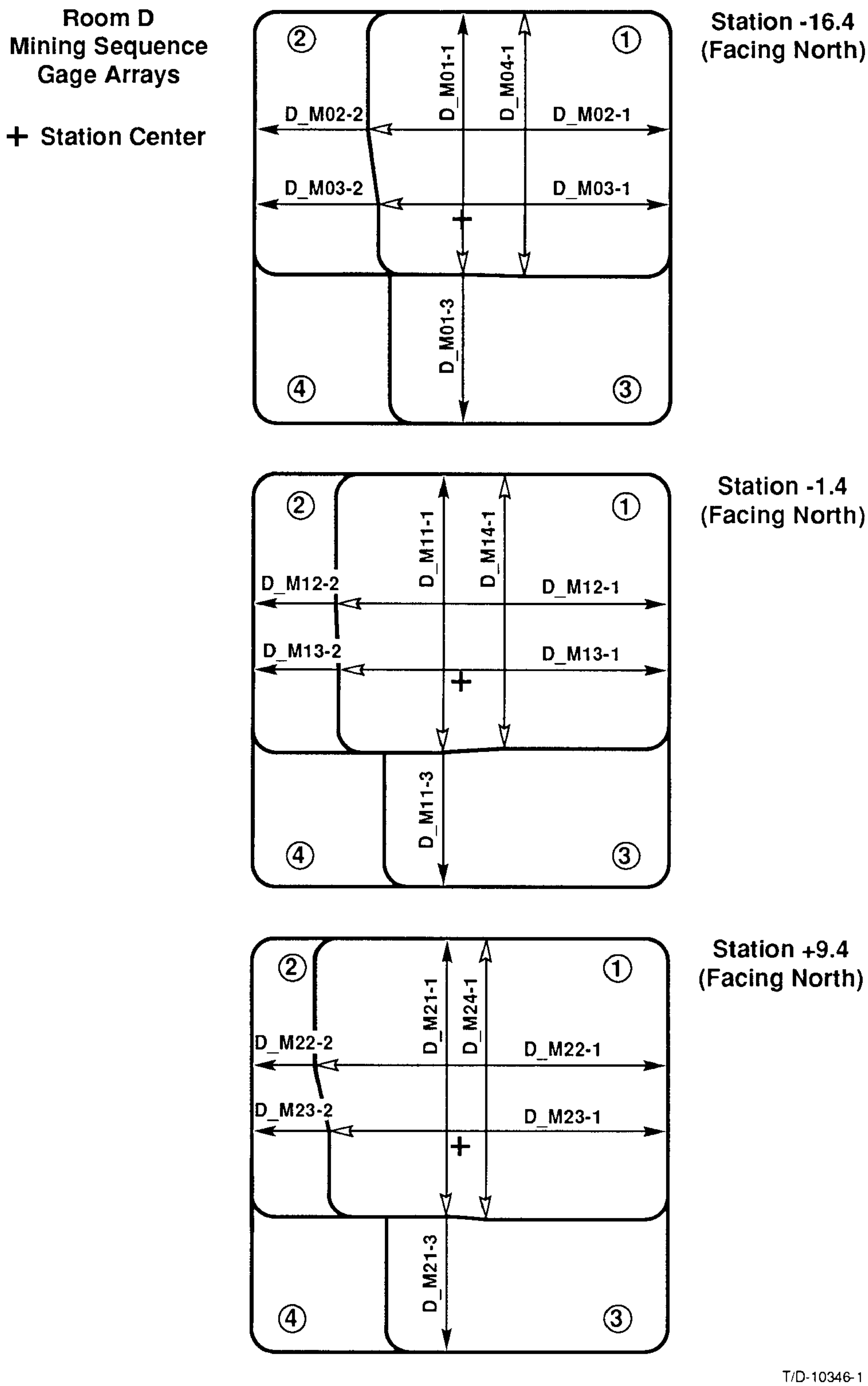


Figure 2.2.31. Mining Sequence Gage Station Cross Sections in Room D

Table 2.2.1. Final and Multipass Dimensions for Similar Rooms

Unit	Dir	Pass 1			Pass 2			Pass 3			Pass 4 + Trim -Final-		
		Gage	Len. (m)	Span/ Hght* (%)	Gage	Len. (m)	Span/ Hght (%)	Gage	Len. (m)	Span/ Hght (%)	Gage	Len. (m)	Span/ Hght (%)
A1M01	V	-1	3.11	(61)			(48)	-3	5.18	--	-3	5.45	(48)
A1M03	H	-1	4.19	(87)	-2	5.41	--			(49)	-2	5.61	(49)
A1M04	v	-1	3.12	(50)			(40)		xx			xx	(40)
A1M02	h	-1	4.41	(47)	-2	5.59	--			(27)	-2	5.59	(27)
A1M11	V	-1	3.39	(57)			(46)	-3	5.09	--	-3	5.54	(46)
A1M13	H	-1	4.22	(79)	-2	5.41	--			(50)	-2	5.63	(50)
A1M14	v	-1	3.38	(49)			(40)		xx			xx	(40)
A1M12	h	-1	4.56	(47)	-2	5.63	--			(29)	-2	5.63	(29)
A1M21	V	-1	3.16	(70)			(48)	-3	5.13	--	-3	5.47	(48)
A1M23	H	-1	3.69	(85)	-2	5.46	--			(49)	-2	5.59	(49)
A1M24	v	-1	3.19	(49)			(34)		xx			xx	(34)
A1M22	h	-1	3.83	(48)	-2	5.61	--			(28)	-2	5.61	(28)
A2M01	V	-1	3.01	(64)			(50)	-3	5.68	--	-3	5.68	(50)
A2M03	H	-1	4.03	(91)	-2	5.30	--			(50)	-2	5.60	(50)
A2M04	v	-1	2.95	(51)			(34)		xx			xx	(34)
A2M02	h	-1	4.33	(52)	-2	5.65	--			(29)	-2	5.65	(29)
A2M11	V	-1	3.05	(58)			(47)	-3	5.52	--	-3	5.52	(47)
A2M13	H	-1	4.18	(87)	-2	5.49	--			(49)	-2	5.57	(49)
A2M14	v	-1	3.05	(49)			(40)		xx			xx	(40)
A2M12	h	-1	4.49	(45)	-2	5.76	--			(25)	-2	5.76	(25)
A2M21	V	-1	3.07	(62)			(50)	-3	5.65	--	-3	5.67	(50)
A2M23	H	-1	4.12	(89)	-2	5.35	--			(50)	-2	5.64	(50)
A2M24	v	-1	3.10	(49)			(38)		xx			xx	(38)
A2M22	h	-1	4.41	(49)	-2	5.71	--			(28)	-2	5.71	(28)
A3M01	V	-1	3.21	(61)			(48)	-3	5.01	--	-3	5.49	(48)
A3M03	H	-1	4.14	(86)	-2	5.43	--			(50)	-2	5.65	(50)
A3M04	v	-1	3.20	(51)			(40)		xx			xx	(40)
A3M02	h	-1	4.39	(48)	-2	5.66	--			(28)		5.66	(28)
A3M11	V	-1	3.54	(58)			(49)	-3	5.07	--	-3	5.43	(49)
A3M13	H	-1	4.46	(76)	-2	5.51	--			(49)	-2	5.60	(49)
A3M14	v	-1	3.55	(50)			(43)		xx			xx	(43)
A3M12	h	-1	4.65	(46)	-2	5.61	--			(30)	-2	5.61	(30)

Table 2.2.1. Final and Multipass Dimensions for Similar Rooms (Cont.)

Unit	Dir	Pass 1			Pass 2			Pass 3			Pass 4 + Trim -Final-		
		Gage	Len. (m)	Span/ Hght (%)	Gage	Len. (m)	Span/ Hght (%)	Gage	Len. (m)	Span/ Hght (%)	Gage	Len. (m)	Span/ Hght (%)
A3M21	V	-1	3.50	(57)			(49)	-3	5.07	--	-3	5.47	(49)
A3M23	H	-1	4.64	(76)	-2	5.54	--			(49)	-2	5.59	(49)
A3M24	v	-1	3.53	(50)			(44)		xx			xx	(44)
A3M22	h	-1	4.82	(47)	-2	5.64	--			(30)	-2	5.64	(30)
B M01	V	-1	3.35	(60)			(48)	-3	5.24	--	-3	5.49	(48)
B M03	H	-1	4.36	(76)	-2	5.55	--			(47)	-2	5.64	(47)
B M04	v	-1	3.35	(50)			(40)		xx			xx	(40)
B M02	h	-1	4.55	(46)	-2	5.74	--			(28)	-2	5.74	(28)
B M11	V	-1	3.39	(62)			(48)	-3	5.19	--	-3	5.53	(48)
B M13	H	-1	4.18	(78)	-2	5.58	--			(48)	-2	5.63	(48)
B M14	v	-1	3.38	(49)			(39)		xx			xx	(39)
B M12	h	-1	4.27	(48)	-2	5.69	--			(29)	-2	5.69	(29)
B M21	V	-1	3.17	(60)			(50)	-3	5.29	--	-3	5.53	(50)
B M23	H	-1	4.36	(83)	-2	5.49	--			(48)	-2	5.57	(48)
B M24	v	-1	3.18	(50)			(42)		xx			xx	(42)
B M22	h	-1	4.58	(43)	-2	5.68	--			(25)	-2	5.68	(25)
D M01	V	-1	3.45	(69)			(51)	-3	5.56	--	-3	5.56	(51)
D M03	H	-1	3.74	(73)	-2	5.42	--			(46)	-2	5.42	(46)
D M04	v	-1	3.46	(48)			(36)		xx			xx	(36)
D M02	h	-1	3.95	(45)	-2	5.53	--			(28)	-2	5.53	(28)
D M11	V	-1	3.74	(66)			(53)	-3	5.69	--	-3	5.69	(53)
D M13	H	-1	4.31	(70)	-2	5.53	--			(47)	-2	5.53	(47)
D M14	v	-1	3.72	(48)			(38)		xx			xx	(38)
D M12	h	-1	4.40	(46)	-2	5.57	--			(31)	-2	5.57	(31)
D M21	V	-1	3.73	(62)			(52)	-3	5.64	--	-3	5.64	(52)
D M23	H	-1	4.41	(68)	-2	5.55	--			(47)	-2	5.55	(47)
D M24	v	-1	3.77	(51)			(43)		xx			xx	(43)
D M22	h	-1	4.63	(44)	-2	5.65	--			(31)	-3	5.65	(31)

* Note: Span or height percentages are calculated from the right rib or the back (roof) of the room. The -- notation mean the value has not changed from the previously given value. The xx notation means that the gage was discontinued or not reinstalled after being mined out.

[text continues on page 72]

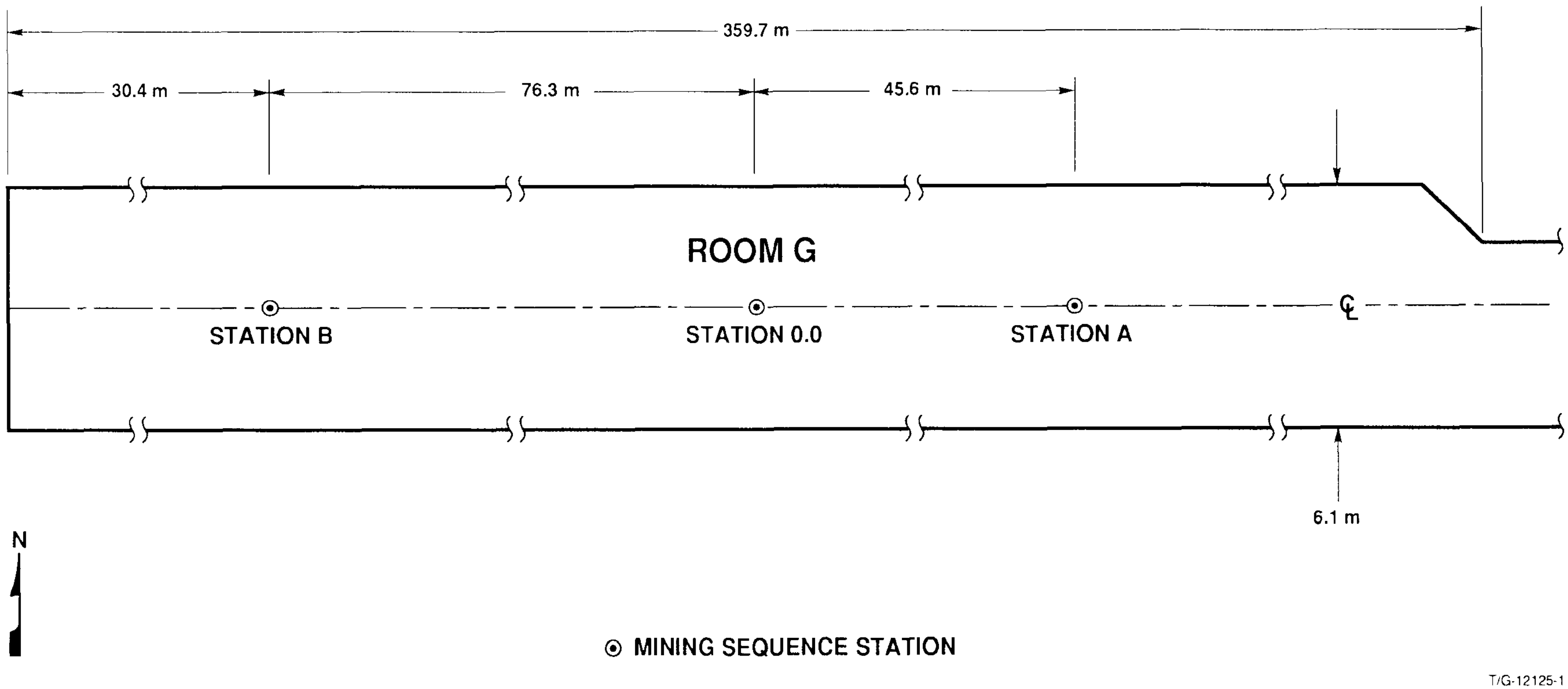


Figure 2.2.32. Plan View of Room G Gage Stations

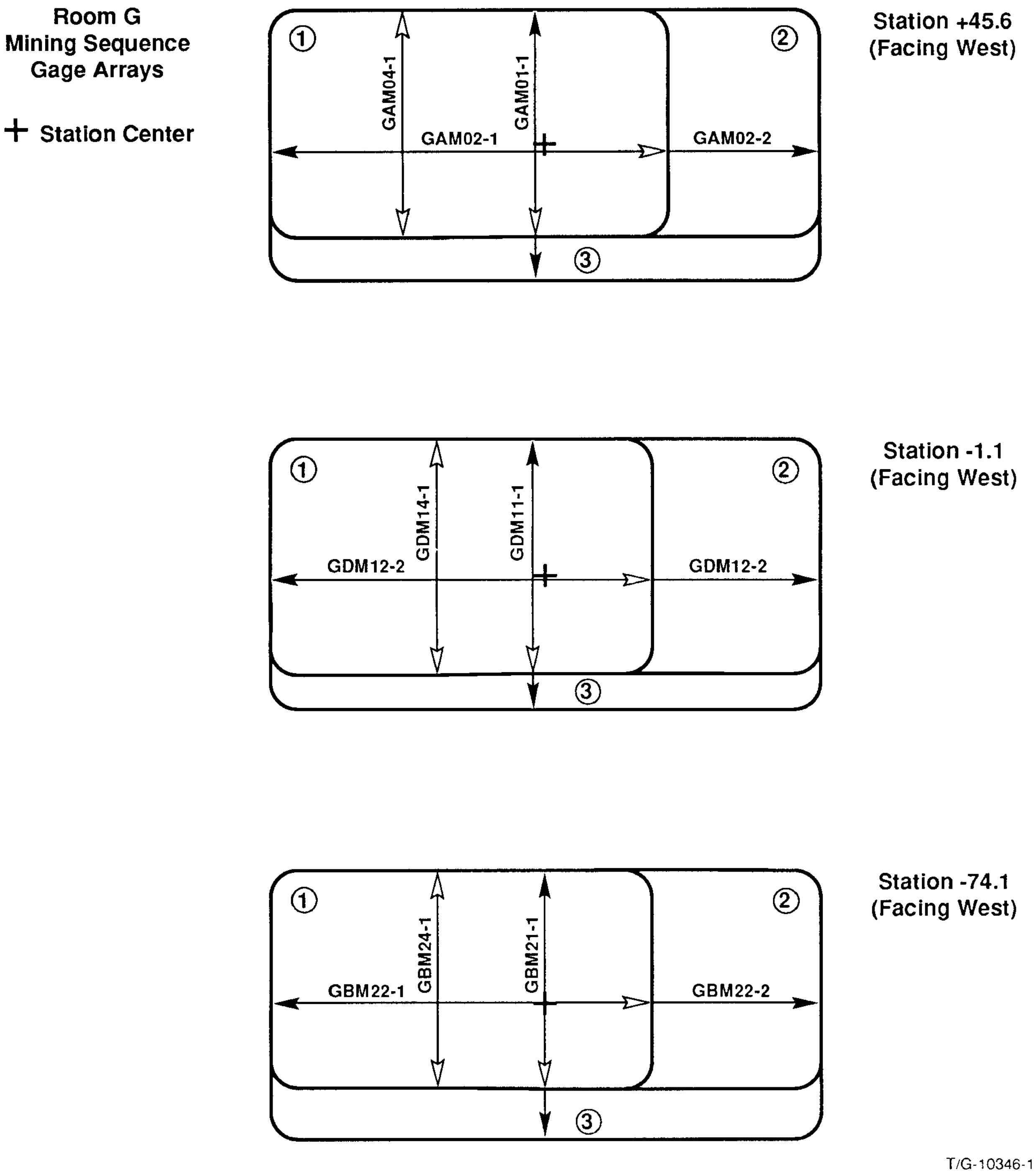


Figure 2.2.33. Mining Sequence Gage Station Cross Sections in Room G

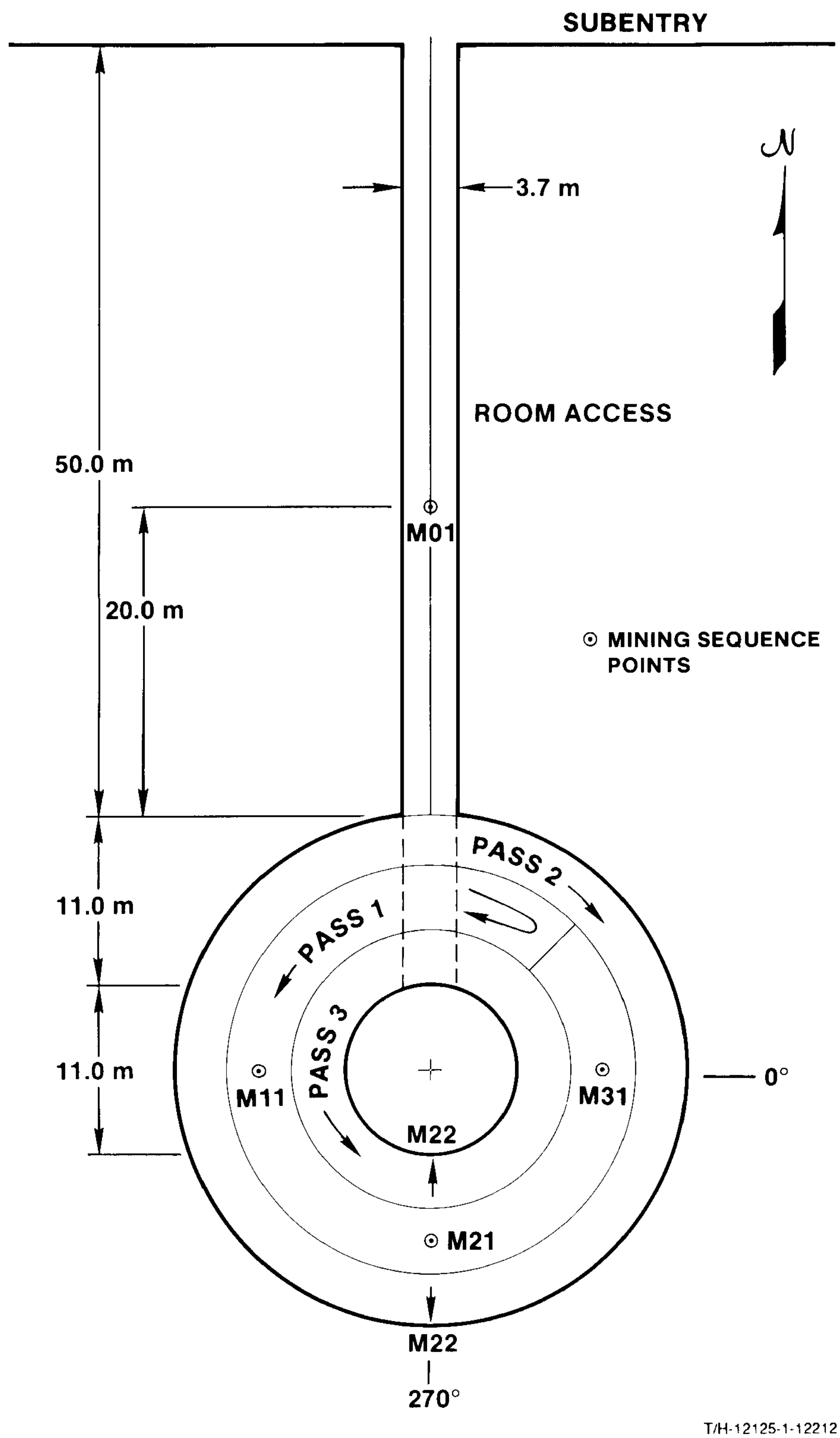
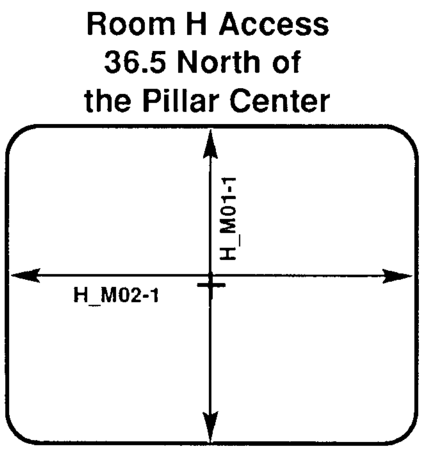


Figure 2.2.34. Plan View of Room H Gage Stations



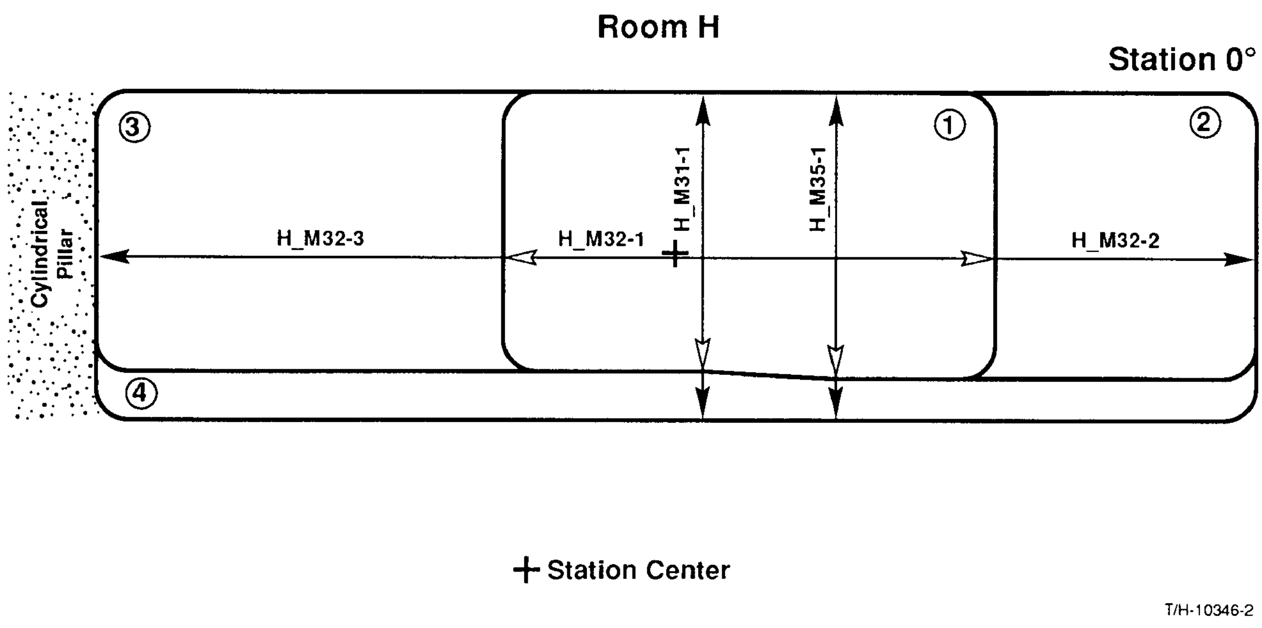


Figure 2.2.35. Mining Sequence Gage Cross Sections, Room H and Entry

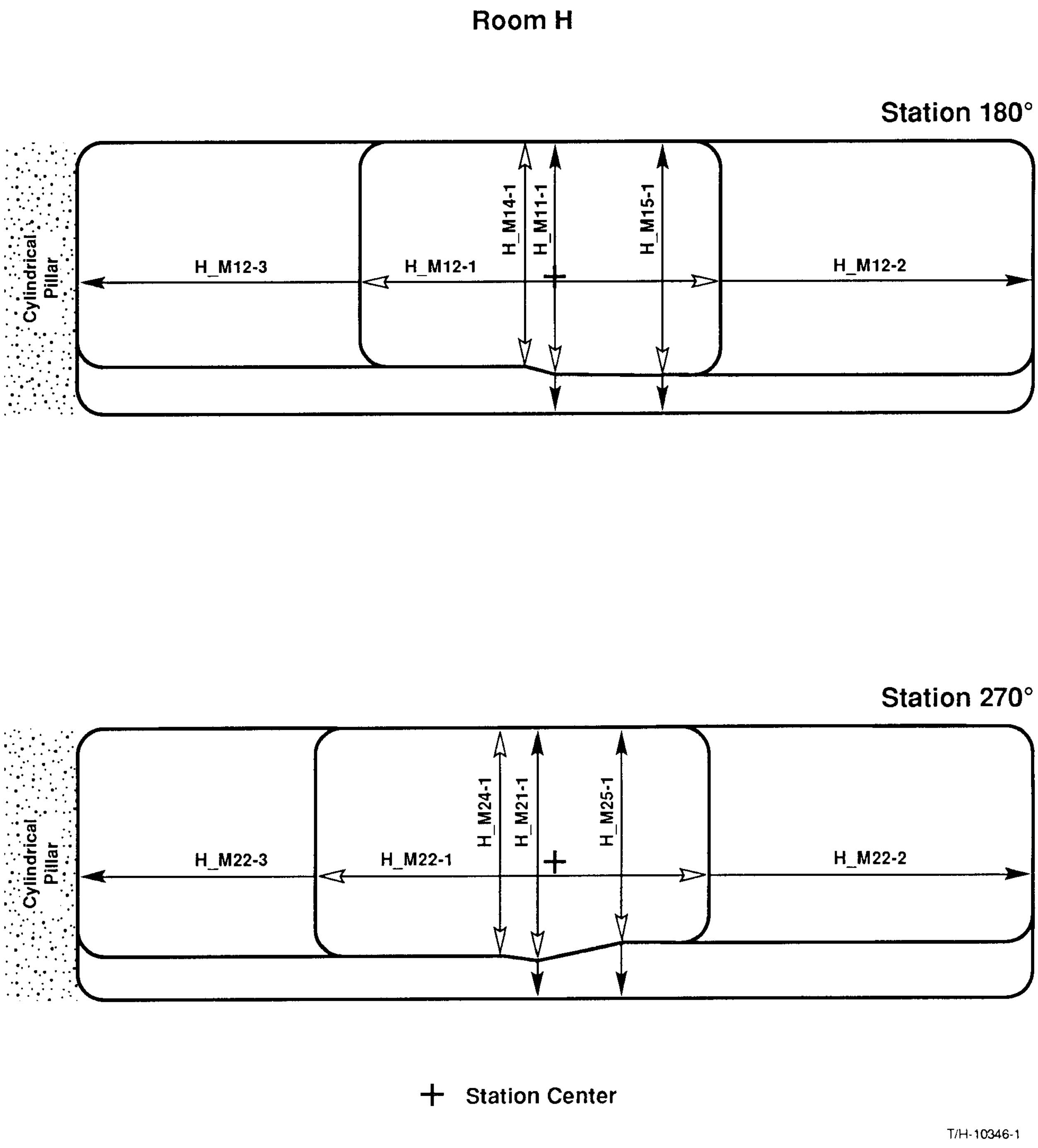


Figure 2.2.36. Mining Sequence Gage Station Cross Sections in Room H

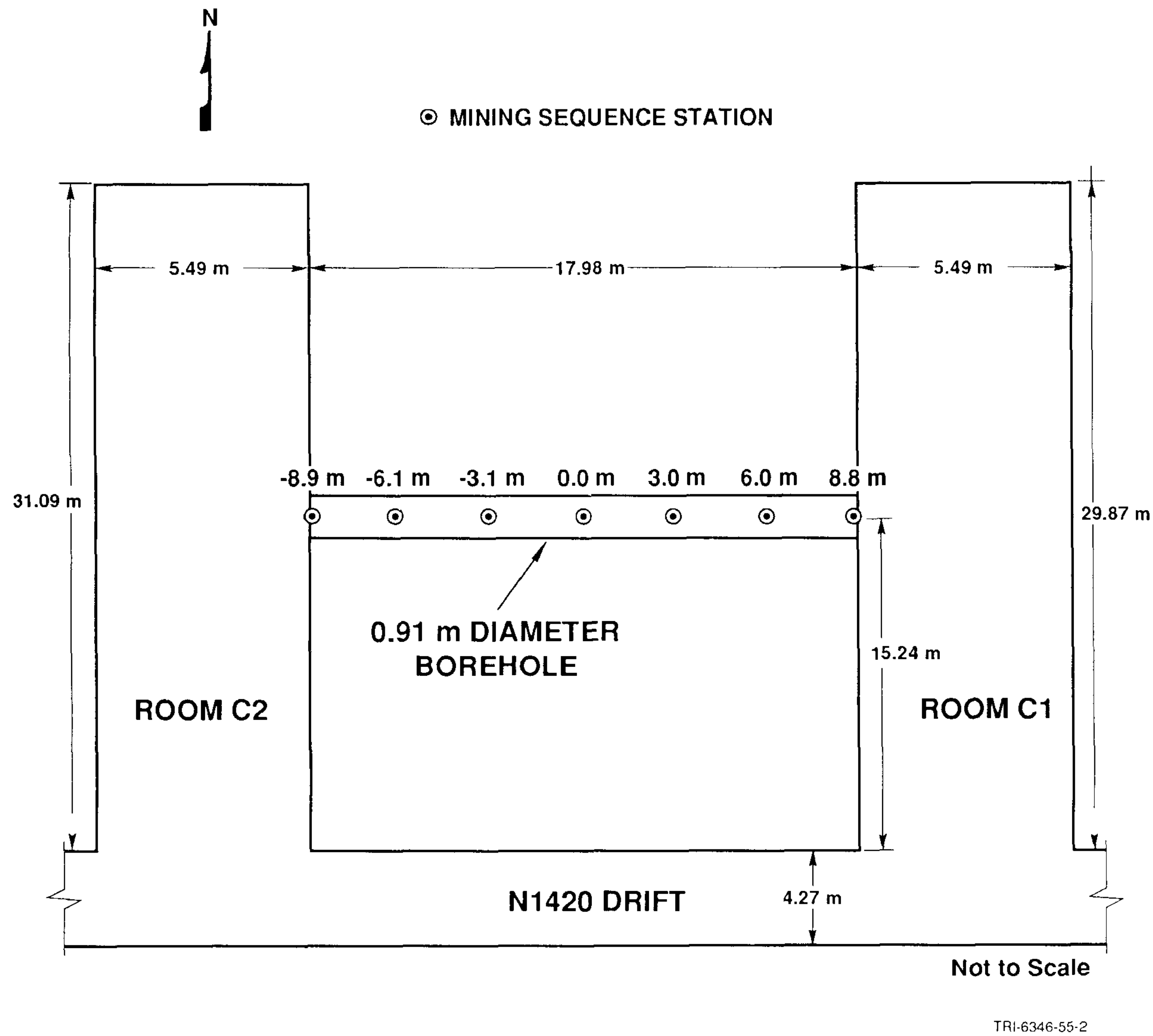


Figure 2.2.27. Plan View of the ISBT Gage Stations

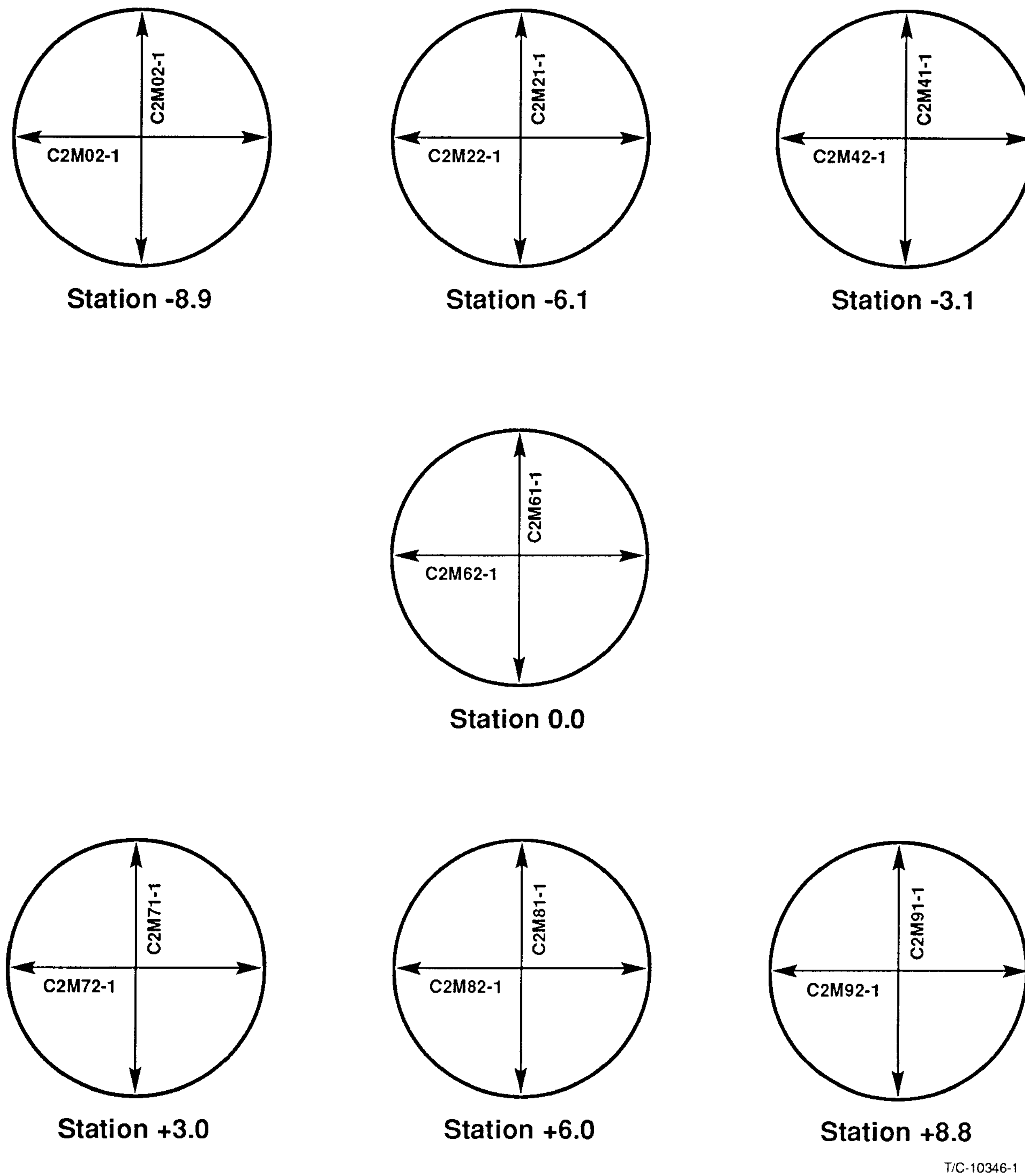


Figure 2.2.38. Mining Sequence Gage Station Cross Sections in the ISBT

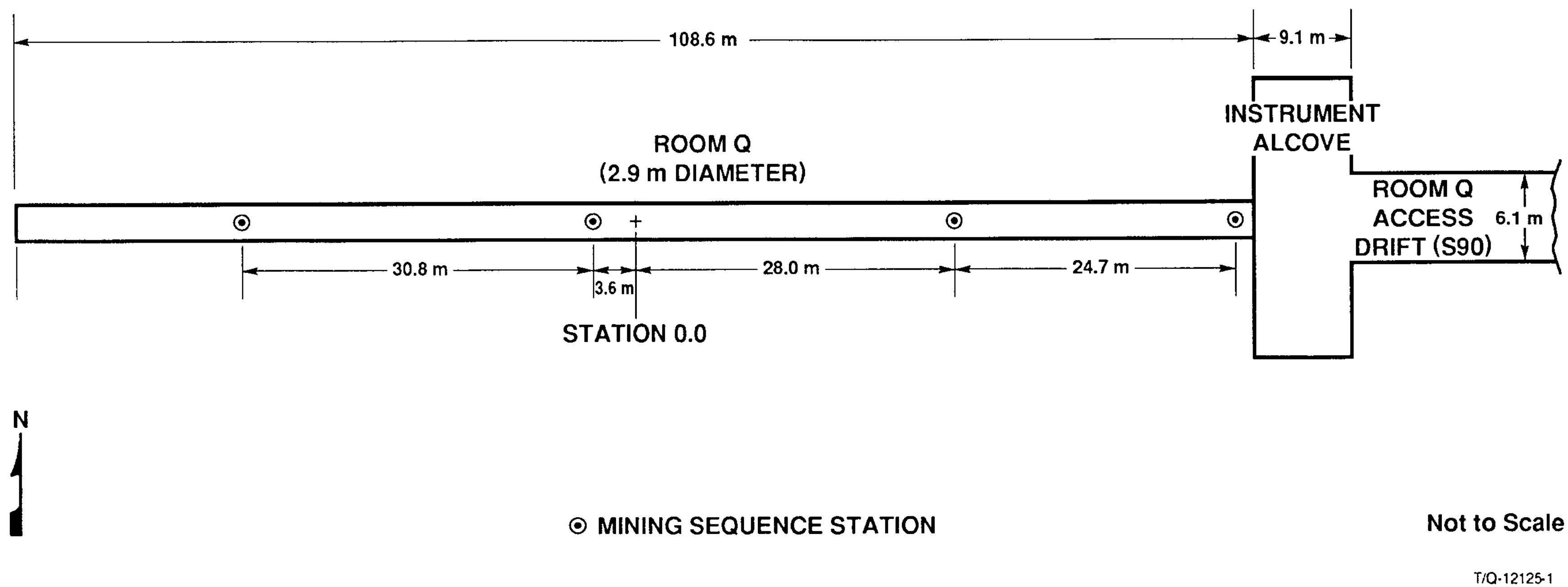


Figure 2.2.39. Plan View of Room Q Gage Stations

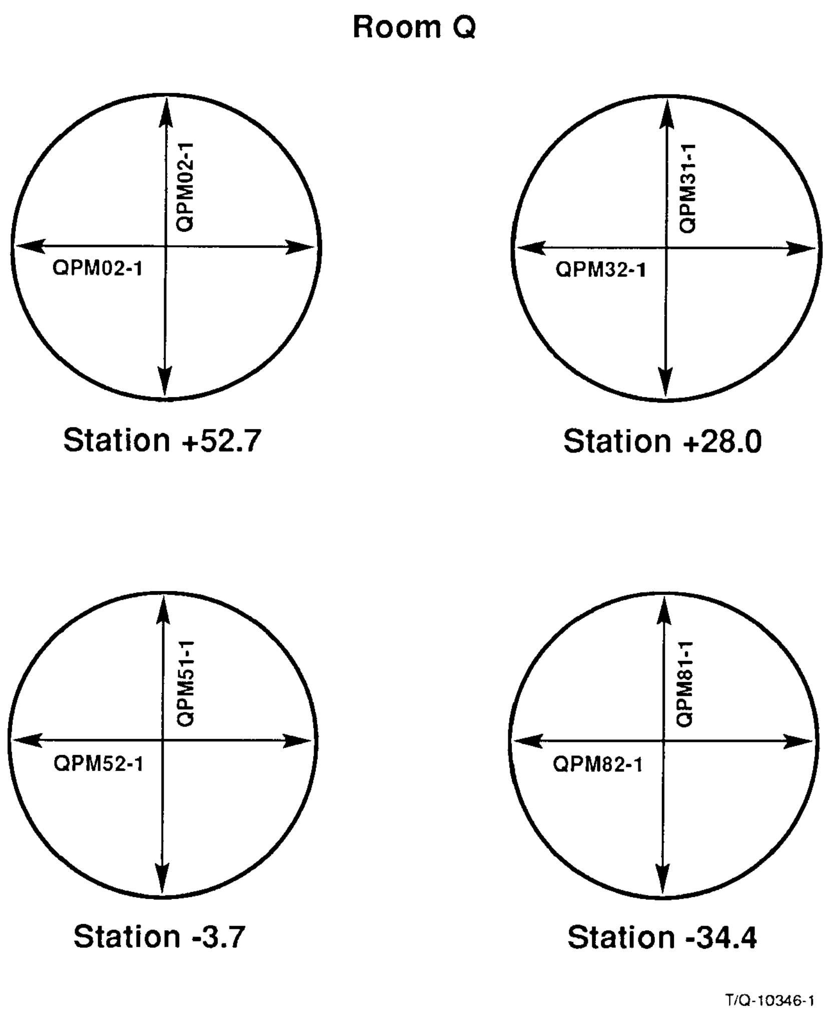


Figure 2.2.40. Mining Sequence Gage Station Cross Sections in Room Q

Table 2.2.2. Final and Multipass Dimensions for Non-Similar Rooms

Unit	Dir	Pass 1 Gage	Pass 1 Len. (m)	Pass 1 Span/Hght* (%)	Pass 2 Gage	Pass 2 Len. (m)	Pass 2 Span/Hght (%)	Pass 3 Gage	Pass 3 Len. (m)	Pass 3 Span/Hght (%)	Pass 4 + Trim -Final- Gage	Pass 4 + Trim -Final- Len. (m)	Pass 4 + Trim -Final- Span/Hght (%)
GAM01	V	-1	2.58	(66)			(48)		None		-1	3.09	(48)
GAM02	H	-1	3.37	(61)	-2	6.16	--		None		-2	6.16	(52)
GAM04	v	-1	2.58	(32)			(24)		None			xx	(24)
GBM21	V	-1	2.74	(84)			(50)		None		-1	3.06	(50)
GBM22	H	-1	4.36	(54)	-2	6.18	--		None		-2	6.18	(50)
GBM24	v	-1	2.73	(44)			(30)					xx	(30)
GDM11	V	-1	2.52	(69)			(47)		None		-1	3.06	(47)
GDM12	H	-1	4.23	(55)	-2	6.18	--		None		-2	6.18	(52)
GDM14	v	-1	2.52	(43)			(30)		None			xx	(30)
H M01	V	-1	3.20	(50)		None			None		-1	3.20	(50)
H M02	H	-1	3.81	(47)		None			None		-1	3.81	(47)
H M11	V	-1	2.59	(46)						(50)	-1	3.05	(50)
H M12	H	-1	4.10	(61)	-2	7.70	--	-3	10.92	--	-3	10.93	(53)
H M14	v	-1	2.59	(54)						(54)		xx	(54)
H M15	v	-1	2.60	(16)						(37)	-1	3.01	(37)
H M21	V	-1	2.65	(44)						(51)	-1	3.16	(51)
H M22	H	-1	4.51	(70)	-2	8.20	--	-3	10.62	--	-3	10.95	(53)
H M24	v	-1	2.61	(54)						(56)		xx	(56)
H M25	v	-1	2.43	(24)						(43)	-1	3.14	(43)
H M31	V	-1	2.65	(59)						(47)	-1	3.02	(47)
H M32	H	-1	4.61	(58)	-2	7.04	--	-3	10.69	--	-3	11.05	(50)
H M35	v	-1	2.68	(32)						(36)	-1	3.09	(36)
C2M01	V	-1	0.95	(50)		None			None		-1	0.95	(50)
C2M02	H	-1	0.97	(50)		None			None		-1	0.97	(50)
C2M21	V	-1	0.95	(50)		None			None		-1	0.95	(50)
C2M22	H	-1	0.96	(50)		None			None		-1	0.96	(50)
C2M41	V	-1	0.95	(50)		None			None		-1	0.95	(50)
C2M42	H	-1	0.95	(50)		None			None		-1	0.95	(50)
C2M61	V	-1	0.96	(50)		None			None		-1	0.96	(50)
C2M62	H	-1	0.96	(50)		None			None		-1	0.96	(50)
C2M71	V	-1	0.96	(50)		None			None		-1	0.96	(50)
C2M72	H	-1	0.97	(50)		None			None		-1	0.97	(50)

Table 2.2.2. Final and Multipass Dimensions for Non-Similar Rooms (Cont.)

Unit	Dir	Pass 1			Pass 2			Pass 3			Pass 4 + Trim -Final-		
		Gage	Len. (m)	Span/ Hght (%)	Gage	Len. (m)	Span/ Hght (%)	Gage	Len. (m)	Span/ Hght (%)	Gage	Len. (m)	Span/ Hght (%)
C2M81	V	-1	0.96	(50)		None			None		-1	0.96	(50)
C2M82	H	-1	0.97	(50)		None			None		-1	0.97	(50)
C2M91	V	-1	0.96	(50)		None			None		-1	0.96	(50)
C2M92	H	-1	0.96	(50)		None			None		-1	0.96	(50)
QPM01	V	-1	2.91	(50)		None			None		-1	2.91	(50)
QPM02	H	-1	2.91	(50)		None			None		-1	2.91	(50)
QPM31	V	-1	2.95	(50)		None			None		-1	2.95	(50)
QPM32	H	-1	2.92	(50)		None			None		-1	2.92	(50)
QPM51	V	-1	2.91	(50)		None			None		-1	2.91	(50)
QPM52	H	-1	2.93	(50)		None			None		-1	2.93	(50)
QPM81	V	-1	2.91	(50)		None			None		-1	2.91	(50)
QPM82	H	-1	2.92	(50)		None			None		-1	2.92	(50)

* Note: Span or height percentages are calculated from the right rib or the back (roof) of the room. The -- notation means the value has not changed from the previously given value. The xx notations mean that the gage was discontinued or not reinstalled after being mined out.

operational immediately upon installation. The intent, and the need, was to obtain as much of the early closure displacements as physically possible. The manual readings of the mining sequence closure gages continued throughout excavation and construction of the test rooms and for some time thereafter. In fact, a number of these gages still remain active, although gage readings have become infrequent. It was necessary for the purposes of this report to limit the amount of data to some reasonable quantity. Consequently, sufficient data were taken to assure an adequate overlap (at least of two months) in the data of the mining sequence closure gages and the permanent closure gages. This permits a reconstruction of the complete closure history of the test rooms with considerable accuracy. Mining sequence gage data after the remote data became available merely duplicates and makes possible a redundancy check on the more extensive remote data.

2.3 Special Features

Certain special features of the fielding of the in situ tests relate directly to the analysis of the data presented here and in other data reports. For TSI tests in general, except for some gages fielded as special groups, most gages were installed in groupings at "principal stations," and many of the displacement gages were "linked" together, both physically and in time. As a further refinement of the tests, gages at principal stations, and even special collections of gages, are often related to each other by symmetry; and therefore, a system of checks on gage performance of the regular TSI manual and remote reading gages is readily established for the tests through redundancy. However, it should be remembered that the mining sequence gages and gage stations in the completed test room may appear to be related by symmetry; but, because the excavation process is fundamentally three-dimensional (3-D), that is non-symmetrical, the data obtained for any given gage will not be a duplicate of any other gage. Only at late times, after the effects of the mining excavation sequence diminish, can the displacements again be expected to reflect the symmetry of the room.

For the purposes of this report, we will consider all of the mining sequence gages as a special gage group. However, the mining sequence gages are grouped at a station in close proximity to a principal station of permanent displacement gages. This allows reconstruction of the principal station displacement by the addition of mining sequence, temporary, and permanent gage data to give a complete closure history.

2.3.1 Principal Stations

Even though the mining sequence gage stations are a special case of the principal station concept, it is important to understand the reason for the principal station concept. All of the tests were designed assuming an ideal, flat-lying, bedded-salt stratigraphy, which is also an assumption required for analyses using two-dimensional (2-D), plane strain, numerical models. It was necessary to adapt the ideal two-dimensional conditions appropriately to the actual field conditions of slightly dipping beds. As noted earlier, the field conditions required following the beds because of a parting in the roof. Actually, following the beds conforms to two-dimensionality because it preserves the fixed location of the opening with respect to the layered stratigraphy. However, location and installation of the gages over the total length of the room presented a problem. To minimize the problem, collections of gages were located relative to a local reference, called a principal station. Thus, it is possible to create a local reference at the principal station that is a flat-lying coordinate system with the origin centered vertically at the principal station. The local coordinate system is an orthogonal system in X (positive to the east), Y (positive to the north), and Z (positive up) directions or a cylindrical system in R (positive radially), T (positive in the counterclockwise direction, and Z (positive up). Z moves up and down according to the dip of the stratigraphy. Gages within about 1.0 m (3.3 ft) of the principal station are assigned to the station. As a consequence of the principal station concept, gages are given two sets of Z coordinates; one set is relative to the principal station zero (local coordinate system), and the other set is relative to the test room coordinate zero (room coordinate system). Use of principal stations not only simplifies fielding the gages but also aids considerably in analyzing the data. The small amount of dip that occurs in the actual room setting is automatically removed if the two-dimensional (2-D) analysis utilizes principal station (local) coordinates.

Table 2.3.1 organizes the gages according to their principal station, for easy reference. The table also gives the principal station directory name as contained in the WISDAAM System data base management system [13].

2.3.2 Gage Linking

All TSI tests were designed to provide a complete data history. To do this, we linked the gages in both time sequence and physical sequence. The following example shows primarily the time linking of the closure gages. For this example, a mining sequence closure gage station was placed in proximity to the location of the future temporary closure gage station. The temporary closure station was in turn located within about 0.3 m (1.0 ft) of the permanent closure station. As a result of this location procedure, the data of the very early closures obtained manually from the mining sequence station can be linked to the later closures obtained manually at the temporary closure station, and these can be linked in turn to the even later closures obtained remotely from the permanent gage station. The distances between these different gage stations were intentionally minimized so as to introduce as little error as possible into the displacements when the data were linked, and to give the complete time history of salt displacements at a given station. Time linking of closure data is discussed and demonstrated in at least four

Table 2.3.1. Mining Sequence Gages Grouped by Principal Station

Principal Station (Constant Y or T)	Type	Units (Gages)
Room A1		
A1ST-16	MS Closure(M)	A1M01, A1M02, A1M03, A1M04
A1ST-01	MS Closure(M)	A1M11, A1M12, A1M13, A1M14
A1ST014	MS Closure(M)	A1M21, A1M22, A1M23, A1M24
Room A2		
A2ST-16	MS Closure(M)	A2M01, A2M02, A2M03, A2M04
A2ST-01	MS Closure(M)	A2M11, A2M12, A2M13, A2M14
A2ST014	MS Closure(M)	A2M21, A2M22, A2M23, A2M24
A3ST-17	MS Closure(M)	A3M01, A3M02, A3M03, A3M04
A3ST-01	MS Closure(M)	A3M11, A3M12, A3M13, A3M14
A3ST014	MS Closure(M)	A3M21, A3M22, A3M23, A3M24
Room B		
B ST-16	MS Closure(M)	B M01, B M02, B M03, B M04
B ST-01	MS Closure(M)	B M11, B M12, B M13, B M14
B ST014	MS Closure(M)	B M21, B M22, B M23, B M24
Room D		
D ST-16	MS Closure(M)	D M01, D M02, D M03, D M04
D ST-01	MS Closure(M)	D M11, D M12, D M13, D M14
D ST009	MS Closure(M)	D M21, D M22, D M23, D M24
Room G		
GAST-45	MS Closure(M)	GAM01, GAM02
GDST-01	MS Closure(M)	GDM11, GDM12
GBST074	MS Closure(M)	GBM21, GBM22
Room H & Entry		
H ST091	MS Closure(M)	H M01, H M02
H ST178	MS Closure(M)	H M11, H M12, H M13, H M14
H ST268	MS Closure(M)	H M21, H M22, H M23, H M24
H ST360	MS Closure(M)	H M31, H M32, H M33, H M34

Table 2.3.1. Mining Sequence Gages Grouped by Principal Station (Cont.)

Principal Station (Constant Y or X)	Type	Units (Gages)
ISBT		
C2ST-09	MS Closure(M)	C2M01, C2M02
C2ST-06	MS Closure(M)	C2M21, C2M22
C2ST-03	MS Closure(M)	C2M41, C2M42
C2ST 00	MS Closure(M)	C2M61, C2M62
C2ST 03	MS Closure(M)	C2M71, C2M72
C2ST 06	MS Closure(M)	C2M81, C2M82
C2ST 09	MS Closure(M)	C2M91, C2M92
Room Q		
QPST 52	MS Closure(M)	QPM01, QPM02
QPST 28	MS Closure(M)	QPM31, QPM32
QPST-04	MS Closure(M)	QPM51, QPM52
QPST-34	MS Closure(M)	QPM81, QPM82

earlier analysis papers [11, 17-19].

Actually, physical linking of the gages pertains only to the permanent displacement gages associated with a given principal station. Physical linking originates in the details of gage installation in collared holes. All of the permanent gages were installed on 0.53 m (21 in.) flanged pipe collars grouted 0.46 m (18 in.) into the salt. The outer flange surface of the collars served as the reference surface from which all distances were measured for installation, as-built surveys, and displacements. In the case of the multipoint extensometers and the remote permanent closure gages, the gage or unit was attached to or measured at the collar reference flange surface. The sharing of a common reference surface means that the displacements measured by the appropriate linked gages at a principal station are in a continuous system and are exactly related to each other. As a consequence, well-defined displacement balances are possible. A displacement balance is just the room closure minus the sum of the salt displacements as measured for the deepest anchors of opposing extensometers. If the extensometer measurements contain all of the salt displacements, then the balance will be zero.

A note of caution is given here. Although the displacement gages were physically linked while fielding the gages, it was not possible to field the gages simultaneously. Therefore, the time distribution of the fielding of the gages causes the origin of a given gage data to be shifted by some amount in both time and displacement with respect to the other physically linked gages. The procedure for correctly reconstructing the displacements to correct for the lost displacements caused by the time shifts is not discussed in this report; only the reduced data are presented here. Reconstruction to account correctly for all installation time shifts are more properly an analysis activity, because it requires knowledge of the constitutive model of salt behavior and appropriate numerical calculations. Also, the time correction for the linking of displacements will involve not only the physically linked gages but also the earlier displacements of the mining sequence and temporary gages.

2.3.3 Special Gage Groups

The mining sequence gages, in the sense of being fielded globally and being initially treated as a group covering all of the TSI tests, are a special group of gages. However, this is a peculiarity of the history of this group of gages. After data reduction of the individual gages, the data were put into the WISDAAM System such that the mining sequence gage stations were associated with the nearest appropriate principal station of the proper test room. As a result, the mining sequence gages have finally become principal station gages rather than a special gage group.

3 DATA REDUCTION PROCESS

Even though all of the data presented in this report are entirely from manually read gages, these data are part of a larger system of data collection, reduction, and storage for the TSI tests. It is important that the overall system be described so that the mining sequence data can be put into proper context. The use of the mining sequence data will be through the overall system, and more specifically, through the individual databases for each test room.

The critical nature of data used in any development or process involving repositories for the disposal of radioactive waste requires that all data collection, reduction, and analysis must be formally documented. This documentation formalism is certainly necessary even for the R&D activities of the Technology Development Program, of which the TSI in situ tests are a part. Data reduction forms a special part of a larger data collection, analysis, management, and documentation system developed for the in situ tests. This larger system is denoted as the WIPP In Situ Data Acquisition, Analysis, and Management (WISDAAM) System [13]. The important parts of the system for this data report are the manual data reduction and Quality Assurance (QA) procedures.

3.1 WISDAAM System Functions

Input to the raw data base is either manual (paper forms) or remote (electronic computer). Both types have large associated data bases. Incorporating them into a single, quality-controlled, reduced data base requires care and some effort. Although the mining sequence data were all taken manually, these data normally will be used in conjunction with other manual and remote data. As a result, all aspects of the data system will be relevant to the user.

3.1.1 Manual Data

Manual data, handwritten records concerning nearly all aspects of the in situ tests, include far more than just the actual gage data. For this report, only the manually taken gage data concern us. These data are collected on special forms and placed into the WISDAAM, QA-controlled, Notebook System as raw data [13]. This Notebook System, as a special appendix to the TSI in situ test plans, is maintained in the WIPP Central Files of the Waste Management Technology Library at SNL. From the raw data base, the data are entered into a computer-based management system using dBase III and reduced at individual work stations on IBM-AT computers. The result of the data reduction process is QA Certified Data. It is the responsibility of the Principal Investigator (PI) for the test to determine when the data become certified. These certified data are transferred to the overall data base management system installed on the central WISDAAM System data base management MicroVAX II computer. Detailed explanations of the reduction process and the exact procedures for manual data are available [20].

3.1.2 Remote Data

The remotely collected data come from the automated data acquisition system (DAS) at the WIPP site [12]. Analog voltage data from individual gages are periodically interrogated by digital voltmeters located in underground instrument sheds adjacent to the in situ test. The digital data are transmitted by wire from the underground shed to a ModComp Classic 7840 computer at ground surface. These data constitute the raw remote data base. From raw voltages, gage calibrations, and conversion factors, raw engineering values are calculated and stored as part of the raw data base. Periodically, the data are transferred to magnetic tape and transported to the central WISDAAM System data management MicroVAX II computer. These tapes are considered part of the WISDAAM, QA-controlled, Notebook System [13] and are also retained in the Sandia WIPP Central Files. When the tapes are entered into the MicroVAX II computer system, the raw data are compressed by the removal of redundant data, and then reduced. The resulting reduced data are certified by the PI and stored in the MicroVAX II computer as Certified Data. Descriptions of the computer software components, the data reduction system, and procedures for reduction of remote data are available [21].

3.2 Quality Assurance (QA) Requirements

Extensive QA procedures have been practiced before, during, and after fielding the in situ tests. These QA procedures begin with the Sandia Quality Assurance Program Plan for the Waste Isolation Pilot Plant (WIPP) [22] and the specific QA requirements of the individual test plans. Although the overall QA has many implications for the data, we are concerned here only with the specific practices that relate to the data reduction process. The reduction process is compatible with overall QA requirements and includes QA features peculiar to a working data reduction system and the WISDAAM System. As a necessary requirement of the QA practice, all the raw and reduced data bases are periodically archived on long-lived (about 25 years), maintenance-free, optical disks.

3.2.1 Reduction Levels

Because of the massive amount of raw data, the high level of overall QA, and the need to document the reduction process, the TSI program has defined several well-controlled levels of data reduction that can be associated with a set of very specific repetitive activities and routine treatment of data:

Level 0 ---- Raw data in the form of magnetic tape or paper records. Remote raw data are stored in the MicroVAX II computer; manual raw data in the Notebook System.

Level 1 ---- Remote data compressed by removal of nondata zeros, system flags, and redundant (values identical within the least significant figure) data; and manual data entered into the MicroVAX II computer data base.

Level 2 ---- All documented, known-cause corrections to the manual and remote data are made to the data and noted.

Level 3 ---- All undocumented, known-cause corrections to the manual and remote data are made and noted.

Certified -- Level 3 data, PI approved as Certified Data, published in a data report, and available for use in analysis.

Level 1 data reduction is fairly straightforward. Because raw remote data are collected on a very frequent schedule, many of the readings change only in the places beyond the least significant figure. Thus, readings that are identical to the place of the least significant figure are redundant, and only one value needs to be retained. At Level 1, the raw manual data simply are transferred under close QA checks to a computer data base.

Level 2 data reduction for both remote and manual data are the corrections taken when a planned or inadvertent human activity involving the gage or data acquisition system alters the gage reading(s). Examples are power failure, gage maintenance, gage replacement, and intentional or accidental disconnection of a gage. Because of the nature of the human activity, and because of the QA requirement to document that activity, the exact time and the exact activity are known. Correction procedures for these activities can be employed properly in the data reduction.

Level 3 data reduction activities are basically routine and involve a known problem of the gage response that is not the result of a planned or accidental human action. These problems are the result of gage peculiarities or uncontrolled events. Examples are gage hysteresis, an unpredictable event controlled by the gage; low-resistance shorts to ground because of collection of moisture; an undetected reading error; or a necessary routine reconstruction of zeros because of destruction of a gage point. When these events occur, it is apparent from a characteristic signature of the gage response; thus, corrective data reduction actions can be determined and applied routinely.

In developing the data reduction procedures, we were extremely careful to assure that no activity was in the realm of analysis. In other words, no modifications or corrections were made during data reduction that required the application of abstract concepts, scientific judgments, or fundamental interpretations to the data. These reduction levels were applied rigorously. All data reduction was documented by level for each gage, and these records form an important part of the data base.

3.2.2 Certified Data

After data reduction has been applied to a given gage and the data have progressed to Level 3, the Principal Investigator (PI) checks to determine that (1) all reduction activities are proper, (2) all relevant data for the gage are included in the records, and (3) all QA requirements have been fulfilled. At this point, the PI is responsible for application of the QA Stamp to the data, which then becomes Certified Data. Certified or QA Stamped Data are releasable to analysts for their use.

All the data in this report are Certified.

4 REDUCED DATA PRESENTATION

Presentation of the mining sequence closure data from the TSI tests, including the ISBT, and Room Q Test, in exactly the manner matched to the needs of any specific analyst, is quite difficult. We can, however, present the data in a reasonable form and provide several keys that permit the analyst to readily find the desired collection of data. The first key is found in Table 2.3.1. All gages of the principal station are shown in the table, which gives the analyst a comprehensive overview of the instruments in the test. Analysis might logically center on a principal station. As noted previously, the gage number (designation) contains specific gage information that indicates the test room, gage type, unit number, and gage number. Thus, it is possible to determine the gage type directly from the gage number. In the case of this report, all of the gages carry the designation of "xxMxx" indicating that they are mining sequence gages. All the data are presented in sections (Chapter 5) according to individual test room, beginning with Room A1 and progressing in alphabetical order. All data in each section are presented by gage number in ascending order. At the beginning of each of the sections is a location guide (table) showing the schematic location of each of the gages at the principal stations. Use of the guide permits identification of gages peculiar to the needs of the analyst. From the guide, for example, all the gage numbers for the vertical closure gages can be readily identified. Gage numbering generally follows a systematic pattern to aid in identifying direction or location.

In each section, individual gage data are presented for that room. This includes a table for each gage (in most cases a unit consisting of several gages) that contains <u>first</u> the <u>PI Comments</u> on the quality and the important aspects of the data reduction and, second, the Information and Location lists specifying location and other relevant information concerning the unit (gages). The location of the gage is given in both room and principal station coordinates. The third and final information on the page is a table of the Gage Length on Installation that gives the initial reading of each gage according to the mining passes. On the following page, the closure data for the gage(s) are then shown in one or two graphs.

In this report we are concerned only with manual gages; the consideration of the remote gages can be found in data reports which include remote data. Several items in the PI Comments on the mining sequence manual gages themselves require some explanation. First, the comments indicate the date of the evaluation, the initials of the person(s) responsible for the data reduction, and a percentage of retained data. The retained data relates almost automatically to the collection quality of the data, but not to the correctness of the data. In other words, the data could have very little meaning in terms of analysis and physical correctness and still have a high retention. Thus, the retention is actually more of a measure of the type and number of reduction actions taken during the reduction process and the severity of the actions. Also, we need to note that manual data are treated differently than remote data in Level 1. There never are redundant manual data, and so the compression ratio of 1:1 always applies.

The Location information gives the Y (or T) coordinate of the principal station designation and the actual station for the unit or gages. Then tabular entries present the gage number, type, gage direction (vertical, horizontal, or diagonal), initial gage status (permanent or temporary), recording method (remote or manual), gage manufacturer, initial installation date, and item number. The table continues with the X,Y,Z (R,T,Z) coordinate pairs for both ends of the gage (with sets of Z in both Principal (Local) Station and Room coordinates).

The Gage Length on Installation is given in a final table. These are the measured initial lengths measured at the time the gage was installed. Because a given gage point installed on one pass could be mined out on any subsequent pass, a given unit may have several initial lengths, each specified as a different gage. Because the final trim could change the gage length, the initial length of the fourth pass includes the trim. These lengths are the measured lengths.

Facing the PI Comments page are graphs of the data for the station. The unique nature of the mining sequence gage station causes the data of several units to be placed on the same graph. This presentation gives a complete history of the displacement at that station through all of the multipass mining. Typically, there are two graphs of the same station. One graph covers just the period of the excavation, usually the first 50 days, in which the detail of the multiple pass mining is evident. The other graph covers the complete period over which the mining sequence gages were monitored. In some cases this period extends to the cut off date of this report, even though the gages may still be active. The total times for the second graph range from 350 to 2800 days after installation of the station. Several items are included to aid the viewer. The room, the principal station, and the gage (or unit) number with a symbol legend that distinguishes each gage within a unit are shown in the upper left corner. In most cases, a cartoon cross section showing the physical location of the gage(s) is given in the upper or lower right corner. The cartoon gives the relative location and designation of the gages in the station cross section. The graph origin is linked to the calendar and Julian day (Jday) on which the gage was first recorded. An abbreviated form of Julian day is used in which the first number is the last digit of the calendar year (two numbers are used beginning with 1990) and the remaining numbers are the total days of the year to that day. It is possible, consequently, to arithmetically manipulate Julian days in modulo 365 (leap year 366). Like graphs can be compared by overlaying them because the engineering values of the ordinate and the time values of the abscissa axes are normally plotted to identical scales.

5 REDUCED DATA

The mining sequence closure gages measure the surface displacements of the underground excavations or openings concurrently with the excavation process, be it either single or multipass mining. These measurements are crucial because they give the integrated effect of the creep displacements in the salt around the excavation. Moreover, because the mining sequence closure gages were installed concurrently with the excavation, their data assures that as much of the salt displacement is captured as is physically possible.

Before we discuss the data of each test room, please note a very significant appraisal of data quality: the data about to be presented are of high quality. This is noteworthy because they were obtained from large-scale underground field tests under sometimes harsh and congested environmental conditions and under occasionally difficult operational constraints. They would be judged of superior quality even against typical laboratory data obtained under ideal conditions. The geotechnical crews showed considerable dedication to their task to obtain such high quality data.

The data return from the mining sequence gages during the construction of the test rooms was also remarkable, by any measure. The principal causes for loss of manual mining sequence gage data were lack of access to the gage because of mining activity and gross reading errors. Both causes resulted in minor loss of data. There was about a 98% total return of manual data from the 104 mining sequence units (158 gages), during the period the tests were in operation or the period covered by this report.

Failure of gages was essentially zero. Here we consider failure to mean a nonmaintainable condition leading to obviously incorrect data and, possibly, discontinuation of the measurement. As of the date covered by this report, all the mining sequence gages in active test rooms continue to be maintained and can be read, although the reading of most of these manual gages is very infrequent. By the stated standard, none of the mining sequence gages can be considered failed during a test.

In addition to the comments on data quality, there are a number of comments required because of the peculiar nature of the mining sequence gages and the resulting data. These very important comments follow.

Replacement of a gage point of any destroyed or lost permanent closure gage in an existing room, which does not involve an excavation of salt prior to the replacement, is treated in the Level 3 data reduction by a simple shift in the measured displacements after the replacement to account for the rezeroing of the data at the time of gage point replacement. Such a simple procedure is not normally possible for lost mining sequence gage points destroyed during multipass mining. Because the multipass mining operation may not only remove gage points but also substantial amounts of salt, the mining sequence data require a data reduction step that differs from those normally permitted in Level 3 data reduction. For mining sequence gage data, this reduction step requires an interpolation to adjust those data obtained prior to the removal of the gage point to those obtained after the removal of the gage point.

The reason this adjustment is more difficult for mining sequence data than for the permanent closure data is the result of three-dimensional effects at the mining face and the significant change in the gage length between the mined out gage and the reinstalled gage. These factors result in a pronounced difference in the displacement rates before and after the excavation face passes the affected mining sequence gage station. The transition between the displacement conditions of the former excavation dimensions resulting from earlier passes and the new excavation dimensions being produced by the current pass forms a continuous displacement curve. Theoretically, the displacement must accelerate as the mining face of a given pass approaches the affected station and decelerate as the mining face moves away from the affected station. The form of this transition curve is poorly defined by the mining sequence measurements because equipment operation constraints and installation delays do not permit the reading frequency necessary to adequately resolve the transients during the critical time period that the station is being excavated. In addition, the form of the transition displacement curve is non-symmetric because the excavation of a given pass increases the gage length at the station.

An interpretation method developed for this reduction process attempts to minimize the uncertainty in establishing the transition curve and in determining the proper displacement shift for the measured data. The procedure uses the face advance rate to obtain the apparent time of station excavation (gage point removal). Then, the "before excavation" displacement of the old gage length is obtained by forward extrapolation, based on the most recent available (accelerating) closure rate, to the time of station excavation. This forward extrapolation establishes the displacement at the time and location of the mined out point. After the point was reinstalled and an initial reading taken, sufficient data were taken to establish the change (deceleration) in displacement rate of the new gage length. Because the initial reading is delayed in time, it does not account for the amount of displacement occurring between the time of station excavation and the initial reading. As a consequence, a back extrapolation of the "after excavation" displacement rate is used to obtain a correction to the initial reading. Thus, the interpretation permits the displacement before and after station excavation to be established at the time of station excavation. A shift of the "after" excavation data by the displacement amount of the "before" excavation closures establishes the curves presented in this report.

In all of the following graphs of the data, the legend of symbols for individual curves are all open symbols; however, on the curves of data some points are filled. These filled data points are those obtained by the procedure just described for the reconstruction of the transition displacements for that unit (gage).

For minor trim passes or simple replacement of a destroyed gage point not involving excavation, the transition curve reduces to an extrapolation at nearly constant slope across the interval of time that the data are missing, and the simple reduction procedure for reestablishing the gage displacement is applied.

The transition associated with face advance through a station is not unique to multipass mining but occurs even on a single mining pass. For the first pass excavation, the salt behind the mining face experiences creep displacements as the mining face approaches the location of the, as yet, uninstalled mining sequence gage station. Although, the transition in displacement, with the same characteristic changes in displacement rates, applies to a single pass or the first pass of multipass mining, it differs because there is no prior displacement history upon which to base the forward extrapolation. Consequently, it is possible to only partially correct, within the limits of the correction procedure, the measured displacement for the delay time between the mining of the gage station and gage installation. For the first pass data presented here, the measured "after excavation" transition rate is simply back extrapolated to the time of the station excavation. Displacements that occur prior to the time of station excavation could not used to estimate the first pass "before excavation" transition rates, because these rates cannot be determined experimentally, except under some very special circumstances. The only manner that these displacements can be estimated is through numerical calculation [23] and are normally small compared to the measured displacements obtained at the mining face from the mining sequence gages.

It is also appropriate to make a few general comments which apply to all of the mining sequence data independent of test room. It is apparent that the measured response at any station within a room is very similar to any other station, except for the obvious differences in the time interval between passes as a result of excavation history. The differences in the interval between passes cause the associated displacements between passes to also differ. However. the excavation history effects diminish rather quickly. and within 40-60 days from the initial pass excavation, the total measured displacements are nearly identical, as demonstrated by Munson et al. [16]. This observation has some important consequences because it demonstrates that the exact excavation method and history does not have a lasting affect on the displacement of the finished excavation. This conclusion may have been anticipated, because the stress and strain perturbations induced by the mining sequence are near to the excavation surface and will exhibit rather high creep rates, which means the time required to obtain a uniform redistribution of stress and strain fields around the final opening is short, on the order of the time to complete the multipass mining. An example of this uniformity of the displacements of the finished room can be seen in the data of the three mining sequence gage stations of Room D. Superposition of these data show that the accumulated displacements at 60 days are essentially identical.

Also, as one would expect, the measured displacements from those rooms with the same final dimensions, although the details of the multipass mining differ, have very nearly the same measured displacements within a short time of completion of mining. This can be seen in the results of the central stations in Room D, Room B, and Room A2 (for early times, before the deformation is affected by the mining of the adjacent rooms, A1 and A3).

One of the interesting aspects of the mining sequence measurements was found by Munson et al. [16] through a process of non-dimensionalization of the displacements. This process divides the measured displacements by the initial dimension of the excavation to produce a measure of the effective strain in the salt around the excavation. Although this closure is not a true strain, this non-dimensionalized displacement has been designated as a "pseudostrain". Pseudostrain has the advantage of permitting comparison of not only dimensionally identical single or multipass excavations but also comparison of geometrically similar single or multipass excavations.

We are now ready to present the mining sequence data. This is done in alphabetical order according to the test designation.

5.1 Rooms A1, A2, and A3 Mining Sequence Closure Data

The 18-W/m^2 Mockup of Defense High-Level Waste (DHLW) is the test fielded in Rooms A1, A2, and A3. The test used electrical heaters to simulate the heat output of high level waste in a waste canister and room configuration thought to be representative of a potential high level waste repository. Although the actual repository would consist of a number of disposal rooms, the test configuration was limited to three rooms because of economic constraints. This was felt to be a reasonable compromise that would produce nearly the correct stress on the central room and pillars and that could simulate the thermal fields correctly, at least for the expected three year duration of the test. The three room configuration also permitted a "mine-by" experiment to be performed in which the central room was excavated and instrumented before the two outside rooms were excavated. The mechanical behavior of the Rooms A complex, including the mining sequence closure, has been analyzed by Munson et al. [24].

Excavation of Room A2 started on the graveyard shift of 6/29/84 and ended on the day shift of 7/24/84. This room was instrumented with the geomechanical gages within 45 days. Excavation of Room A1 started on the swing shift of 9/14/84 and ended on the graveyard shift of 10/10/84. The excavation of the final room of the complex, Room A3, started on the graveyard shift of 10/13/84 and ended on the day shift of 11/6/84. The heaters in all rooms of the complex were activated on 10/2/85.

A fall of the roof in Room A2 on 6/19/90 resulted in termination of the experiment. Although many of the gages in the Room A2 and the unaffected adjacent rooms remained in operation and continued to be monitored, heating of the rooms stopped, which made the experimental boundary conditions uncontrolled from the analysis standpoint.

Table 5.1.1. Room A1 Mining Sequence Closure Units (Gages) Location Guide

Station	Direction		west rib		center	pass 1	east rib
A1ST-16	Vertical	roof			A1M01	A1M04	
	Horizontal	pass 1	-2	-1			A1M02
	Horizontal	mid	-2	-1			A1M03
					-1	-1	
	Vertical	floor			-3		
A1ST-01	Vertical	roof			A1M11	A1M14	
	Horizontal	pass 1	-2	-1			A1M12
	Horizontal	mid	-2	-1			A1M13
					-1	-1	
	Vertical	floor			-3		
A1ST014	Vertical	roof			A1M21	A1M24	
	Horizontal	pass 1	-2	-1			A1M22
	Horizontal	mid	-2	-1			A1M23
					-1	-1	
	Vertical	floor			-3		

The location guide for the gages in Room A1 is given in Table 5.1.1, for Room A2 in Table 5.1.2, and for Room A3 in Table 5.1.3. Each table schematically presents the relative gage positions at the principal stations of the room. In general, the gage numbers of logical collections of gages are in sequence. Thus, gages A1M01, A2M01, and A3M01 are all vertical gages, located at the midspans of the final room dimension at the first (most southern) stations mined in rooms A1, A2, and A3. Similar patterns of gage numbers apply to the horizontal gages or to the vertical

Table 5.1.2. Room A2 Mining Sequence Closure Units (Gages) Location Guide

Station	Direction		Relative Location: west rib		center	pass 1	east rib
A2ST-16	Vertical	roof			A2M01	A2M04	
	Horizontal	pass 1	-2	-1			A2M02
	Horizontal	mid	-2	-1			A2M03
					-1	-1	
	Vertical	floor			-3		
A2ST-01	Vertical	roof			A2M11	A2M14	
	Horizontal	pass 1	-2	-1			A2M12
	Horizontal	mid	-2	-1			A2M13
					-1	-1	
	Vertical	floor			-3		
A2ST014	Vertical	roof			A2M21	A2M24	
	Horizontal	pass 1	-2	-1			A2M22
	Horizontal	mid	-2	-1			A2M23
					-1	-1	
	Vertical	floor			-3		

gages of a given station.

Mining sequence closure data are given in Tables 5.1.4a-c and Figures 5.1.1a-c for Room A1, in Tables 5.1.5a-c and Figures 5.1.2a-c for Room A2, and in Tables 5.1.6a-c and Figures 5.1.3a-c for Room A3.

Although the data in this report are presented in the order of the test room number, it must be remembered that the order of mining of the rooms was <u>first Room A2</u>, then <u>second Room A1</u>, and finally <u>third Room A3</u>. The influence of nearby mining could be measured in the already mined and

Table 5.1.3. Room A3 Mining Sequence Closure Units (Gages) Location Guide

Station	Direction		Relative Location: west rib		center	pass 1	east rib
A3ST-17	Vertical	roof			A3M01	A3M04	
	Horizontal	pass 1	-2	-1			A3M02
	Horizontal	mid	-2	-1			A3M03
					-1	-1	
	Vertical	floor			-3		
A3ST-01	Vertical	roof			A3M11	A3M14	
	Horizontal	pass 1	-2	-1			A3M12
	Horizontal	mid	-2	-1			A3M13
					-1	-1	
	Vertical	floor			-3		
A3ST014	Vertical	roof			A3M21	A3M24	
	Horizontal	pass 1	-2	-1			A3M22
	Horizontal	mid	-2	-1			A3M23
					-1	-1	
	Vertical	floor			-3		

instrumented adjacent rooms. The result is that an abrupt, but small, increase in closure rate caused by excavation of Rooms A1 and A3 can be seen in the mining sequence data of the adjacent Room A2, and the effects of mining of Room A3 also can be seen in Room A1, just as the mining face passes adjacent to the gage stations. These times are denoted by the arrows in the plots for Rooms A2 and A1.

The most significant result of the multiple room test is that the close proximity of the three rooms causes an increase in closure rate compared to an isolated single room, such as Room D. Also, the affect of mining in a near-by adjacent room is observed instantaneously. This instantaneous response of the nearby rooms to the mining of a new room is caused by the change in stress field, which initially occurs at the speed of an elastic stress wave in the salt. Furthermore, it is apparent from the results that the measured displacements are the largest for Room A2, and diminish in the mining of Room A1 and A3, progressively. This is caused by the fact that the deformation around Room A2 has the effect of strain hardening the ground into which the subsequent rooms are mined. Strain hardening, in terms of the creep response of salt, diminishes the subsequent creep rate and, as a result, lowers the observed closure rate and magnitude of the room mined into the strain hardened ground. Since the strain hardening is time dependent, A3, the last room to be mined, shows the greatest decrease in measured closure displacement. These effects are clearly interpreted through numerical calculations [24].

The effect of heating appears as an abrupt increase in closure rate when the heaters were turned on about 364 days after the completion of excavation of the room complex.

The mining sequence data are in substantial agreement with the remotely collected mechanical data for the Rooms A, as published in a separate report [9]. The remotely collected thermal data have also been published separately [10].

[text continues on page 118]

Table 5.1.4a. Mining Sequence Gages A1M0x-x, Room A1, Station -16 m

A1M01 - A1M04 PI Comments

02/12/92 RLJ [91%] This set of Mining Sequence Closure Gages (2 vertical and 2horizontal) was installed in the south half of Room A1. They were measured initially only 4 hours after the first mining machine pass. Early results (top graph) showed a smaller difference between vertical and horizontal closure when compared to similar data from other stations. Excavation effects can be clearly seen as bump like features that correspond to the mining of each pass. Gage disruption due to mining required a total of 8 reinstallations. Long term data (bottom graph) show a significant rise in closure at about a year (374 days) when the heaters were activated. (DEM)

Gage Information

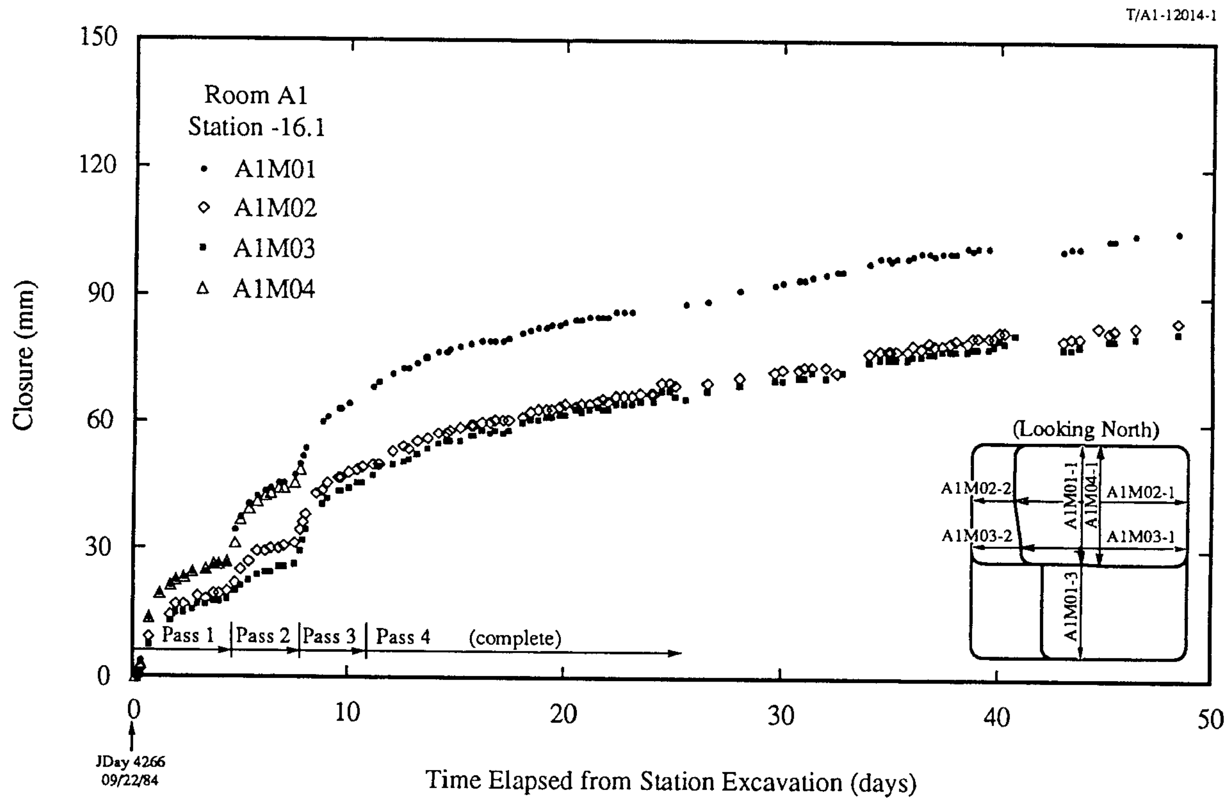
Gage Number	Gage Type	Gage Orient.	—— Record ——		Gage Manf.	Installation Date	Drawing Number
A1M01-1	CONV	V	T	MAN	SNL	9/22/84	T91025-000A
A1M01-3	CONV	V	T	MAN	SNL	9/29/84	T91025-000A
A1M02-1	CONV	H	T	MAN	SNL	9/22/84	T91025-000A
A1M02-2	CONV	H	T	MAN	SNL	9/26/84	T91025-000A
A1M03-1	CONV	H	T	MAN	SNL	9/22/84	T91025-000A
A1M03-2	CONV	H	T	MAN	SNL	9/26/84	T91025-000A
A1M04-1	CONV	V	T	MAN	SNL	9/22/84	T91025-000A

Gage Location

	Gage Coordinates							
					—— Local ——		—— Room ——	
Gage Number	X1 (m)	X2 (m)	Y1 (m)	Y2 (m)	Z1 (m)	Z2 (m)	Z1 (m)	Z2 (m)
A1M01-1	0.07	0.07	-16.08	-16.08	-0.41	2.70	-0.48	2.62
A1M01-3	0.06	0.07	-16.02	-16.08	-2.70	2.70	-2.77	2.62
A1M02-1	-1.47	2.72	-15.97	-15.97	1.28	1.28	1.21	1.21
A1M02-2	-2.72	2.72	-16.06	-15.97	1.24	1.28	1.61	1.21
A1M03-1	-1.70	2.71	-16.00	-16.00	0.05	0.05	-0.02	-0.02
A1M03-2	-2.76	2.71	-16.00	-16.00	0.05	0.05	-0.02	-0.02
A1M04-1	0.50	0.50	-16.08	-16.08	-0.42	2.70	-0.50	2.62

Gage Length Upon Installation

		Pass 1		Pass 2		Pass 3		Pass 4 + Trim -Final-	
Gage Number	Dir	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)
A1M01	V	-1	3.11		--	-3	5.18	-3	5.45
A1M03	H	-1	4.19	-2	5.41		--	-2	5.61
A1M04	v	-1	3.12		--		xx		xx
A1M02	h	-1	4.41	-2	5.59		--	-2	5.59



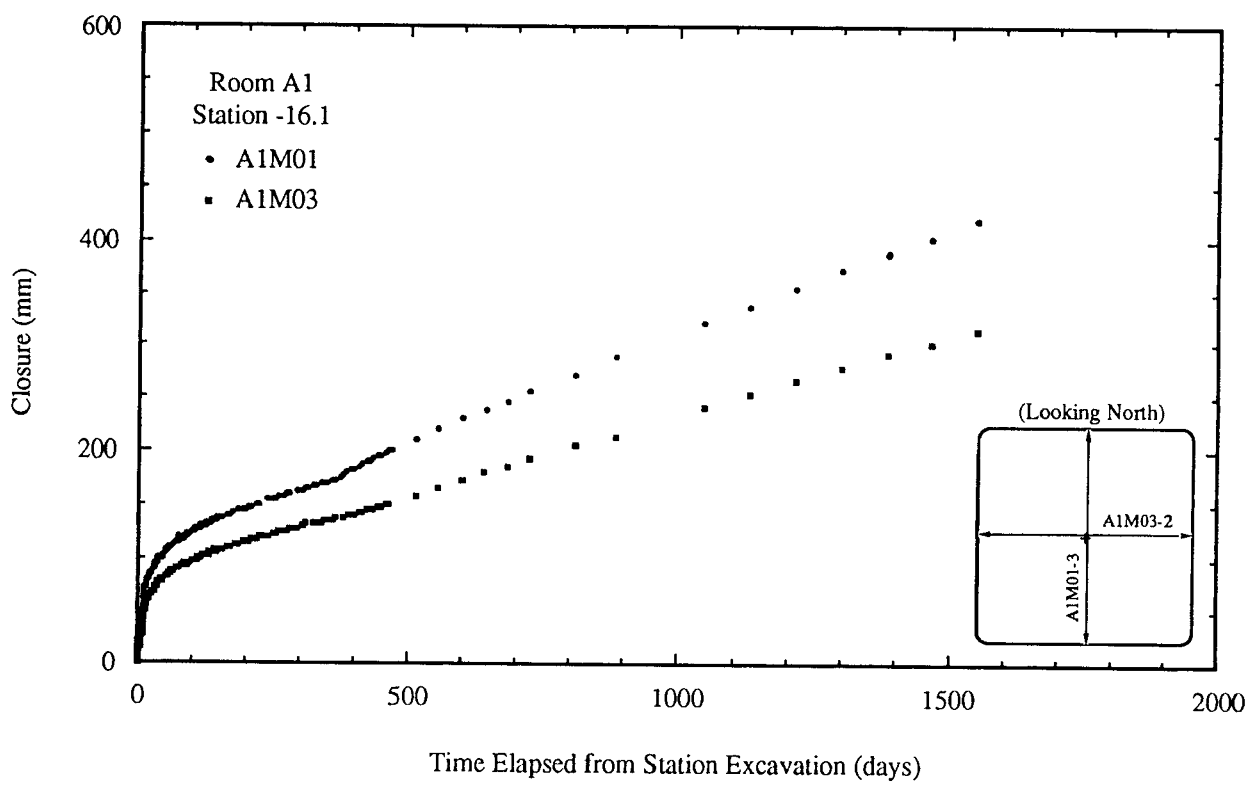


Figure 5.1.1a. Mining Sequence Gages A1M0x-x, Room A1, Station -16 m

Table 5.1.4b. Mining Sequence Gages A1M1x-x, Room A1, Station -01 m

A1M11 - A1M14 PI Comments

02/12/92 RLJ [90%] This set of Mining Sequence Closure Gages (2 vertical and 2 horizontal) was installed in the center of Room A1. They were initially measured about 3 hours after the first mining machine pass. Early results (top graph) are typical for early data from other closure stations of similar geometry. Excavation effects can be clearly seen as bump like features that correspond to the mining of each pass. Gage disruption due to mining required a total of 6 reinstallations. Long term data (bottom graph) are remarkably uniform. The marked change in slope seen on day 373 is the result of heater activation. (DEM)

Gage Information

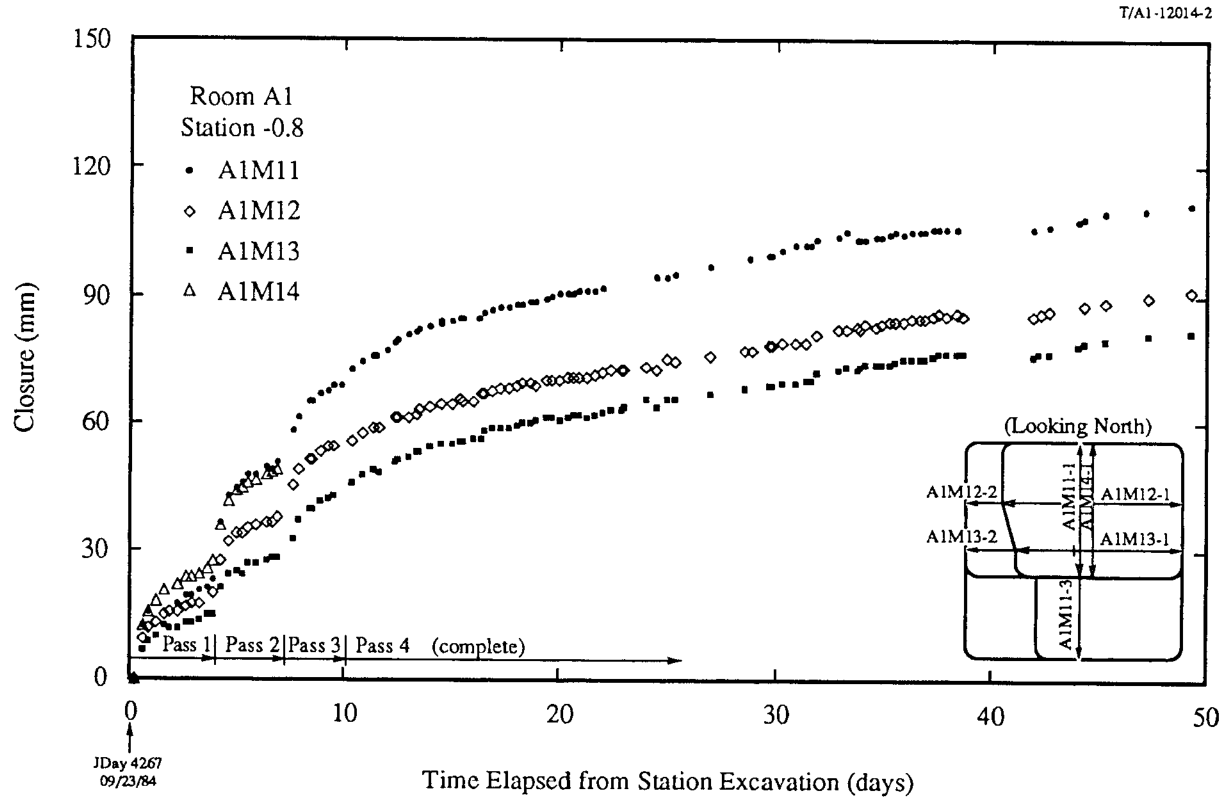
Gage Number	Gage Type	Gage Orient.	Record		Gage Manf.	Installation Date	Drawing Number
A1M11-1	CONV	V	T	MAN	SNL	29486.00	T91025-000A
A1M11-3	CONV	V	T	MAN	SNL	29493.00	T91025-000A
A1M12-1	CONV	H	T	MAN	SNL	29486.00	T91025-000A
A1M12-2	CONV	H	T	MAN	SNL	29490.00	T91025-000A
A1M13-1	CONV	H	T	MAN	SNL	29486.00	T91025-000A
A1M13-2	CONV	H	T	MAN	SNL	29490.00	T91025-000A
A1M14-1	CONV	V	T	MAN	SNL	29486.00	T91025-000A

Gage Location

	Gage Coordinates							
					Local		Room	
Gage Number	X1 (m)	X2 (m)	Y1 (m)	Y2 (m)	Z1 (m)	Z2 (m)	Z1 (m)	Z2 (m)
A1M11-1	0.11	0.11	-0.77	-0.77	-0.75	2.65	-0.75	2.65
A1M11-3	0.03	0.11	-0.68	-0.77	-2.83	2.65	-2.83	2.65
A1M12-1	-1.82	2.75	-0.68	-0.68	1.16	1.16	1.16	1.16
A1M12-2	-2.76	2.75	-0.74	-0.68	1.05	1.16	1.05	1.16
A1M13-1	-1.46	2.76	-0.70	-0.70	0.08	-0.14	0.08	-0.14
A1M13-2	-2.77	2.76	-0.73	-0.70	-0.02	0.08	-0.02	0.08
A1M14-1	0.46	0.46	-0.77	-0.77	-0.73	2.65	-0.73	2.65

Gage Length Upon Installation

		Pass 1		Pass 2		Pass 3		Pass 4 + Trim -Final-	
Gage Number	Dir	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)
A1M11	V	-1	3.39		--	-3	5.09	-3	5.54
A1M13	H	-1	4.22	-2	5.41		--	-2	5.63
A1M14	v	-1	3.38		--		xx		xx
A1M12	h	-1	4.56	-2	5.63		--	-2	5.63



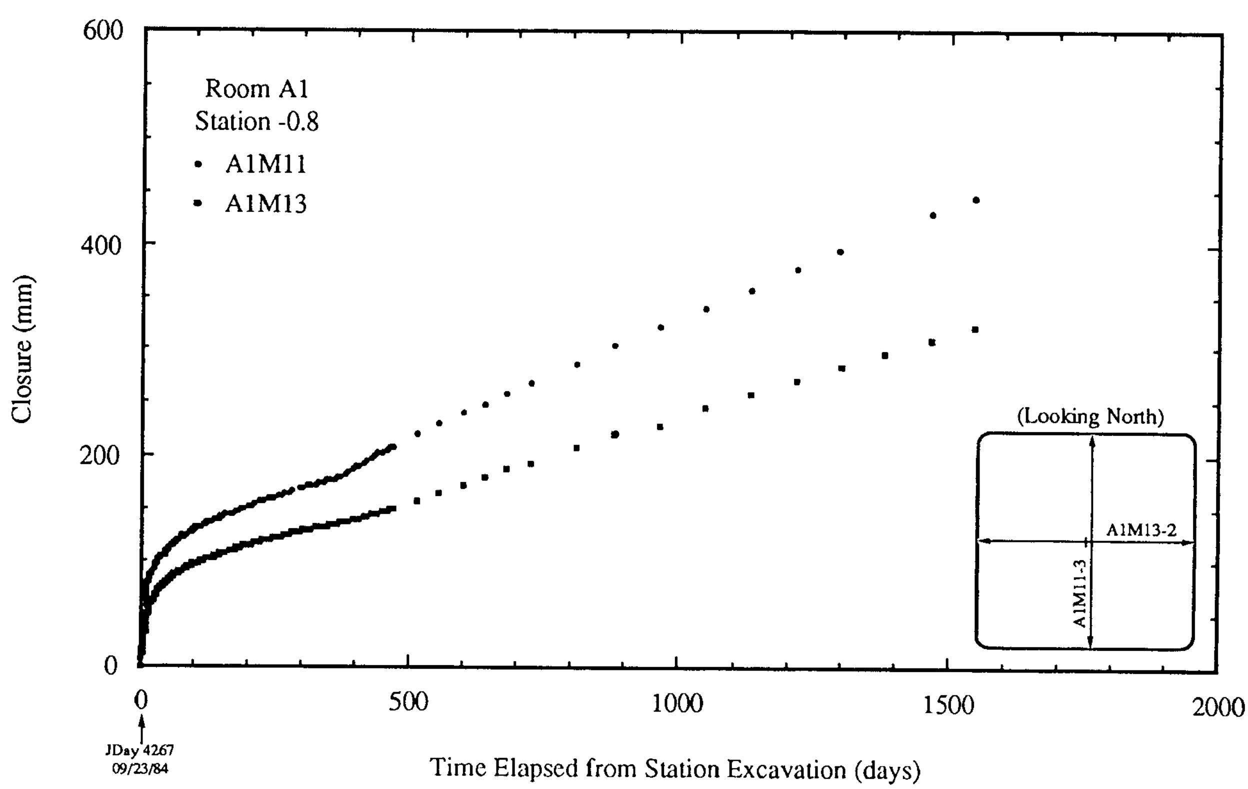


Figure 5.1.1b. Mining Sequence Gages A1M1x-x, Room A1, Station -01 m

Table 5.1.4c. Mining Sequence Gages A1M2x-x, Room A1, Station +14 m

A1M21 - A1M24 PI Comments

02/12/92 RLJ [90%] This set of Mining Sequence Closure Gages (2 vertical and 2 horizontal) was installed in the north half of Room A1. They were initially measured less than 3 hours after the first mining machine pass. Early results (top graph) are typical for early data from other closure stations of similar geometry. Excavation effects can be clearly seen as bump like features that correspond to the mining of each pass. Gage disruption due to mining required a total of only 5 reinstallations. Long term data (bottom graph) are remarkably uniform. The marked change in slope seen on day 373 is due to heater activation. (DEM)

Gage Information

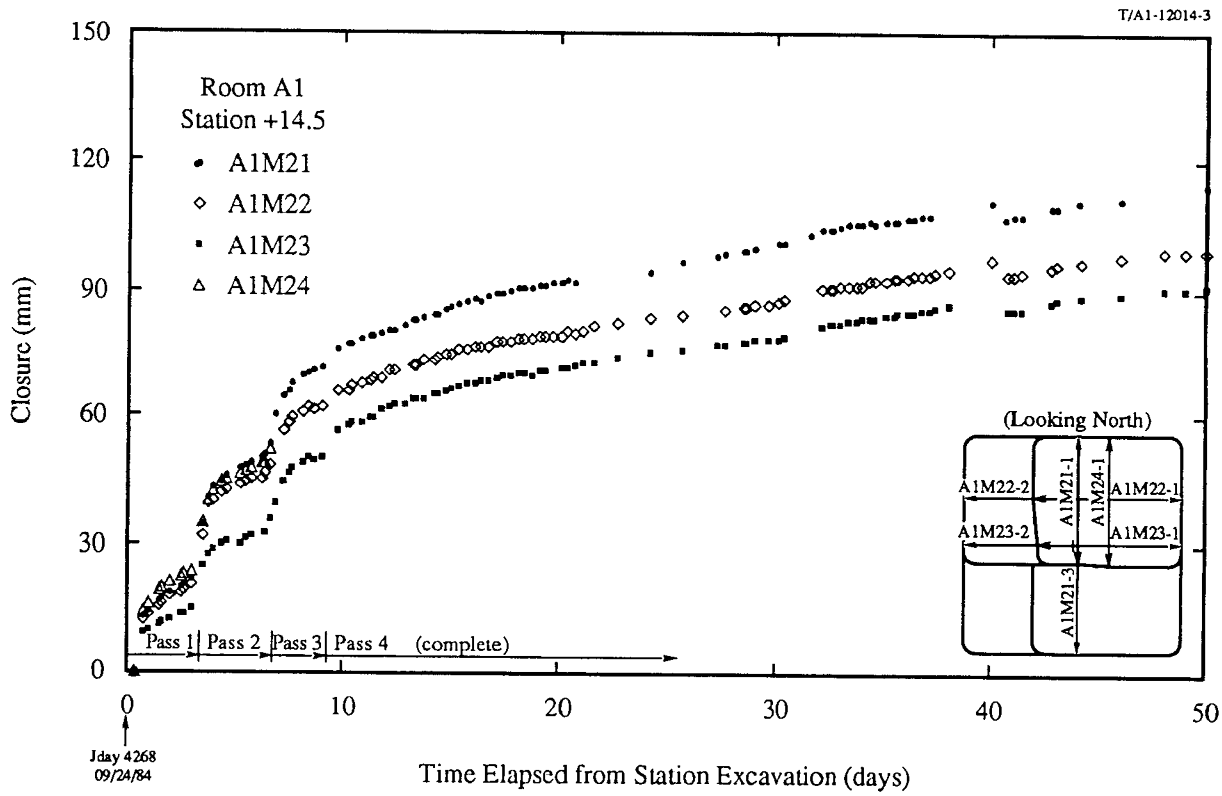
Gage Number	Gage Type	Gage Orient.	Record		Gage Manf.	Installation Date	Drawing Number
A1M21-1	CONV	V	T	MAN	SNL	9/24/84	T91025-000A
A1M21-3	CONV	V	T	MAN	SNL	10/1/84	T91025-000A
A1M22-1	CONV	H	T	MAN	SNL	9/24/84	T91025-000A
A1M22-2	CONV	H	T	MAN	SNL	9/27/84	T91025-000A
A1M23-1	CONV	H	T	MAN	SNL	9/24/84	T91025-000A
A1M23-2	CONV	H	T	MAN	SNL	9/27/84	T91025-000A
A1M24-1	CONV	V	T	MAN	SNL	9/24/84	T91025-000A

Gage Location

	Gage Coordinates							
					Local		Room	
Gage Number	X1 (m)	X2 (m)	Y1 (m)	Y2 (m)	Z1 (m)	Z2 (m)	Z1 (m)	Z2 (m)
A1M21-1	0.09	0.09	14.43	14.43	-0.47	2.69	-0.31	2.85
A1M21-3	0.10	0.09	14.48	14.43	-2.69	2.69	-2.54	2.85
A1M22-1	-1.04	2.79	14.49	14.49	1.16	1.16	1.31	1.31
A1M22-2	-2.72	2.79	14.53	14.49	1.14	1.16	1.30	1.31
A1M23-1	-0.88	2.81	14.58	14.58	0.00	0.00	0.16	0.16
A1M23-2	-2.72	2.81	14.58	14.58	0.00	0.00	0.16	0.16
A1M24-1	0.87	0.87	14.43	14.43	-0.50	2.69	-0.34	2.85

Gage Length Upon Installation

		Pass 1		Pass 2		Pass 3		Pass 4 + Trim -Final-	
Gage Number	Dir	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)
A1M21	V	-1	3.16		--	-3	5.13	-3	5.47
A1M23	H	-1	3.69	-2	5.46		--	-2	5.59
A1M24	v	-1	3.19		--		xx		xx
A1M22	h	-1	3.83	-2	5.61		--	-2	5.13



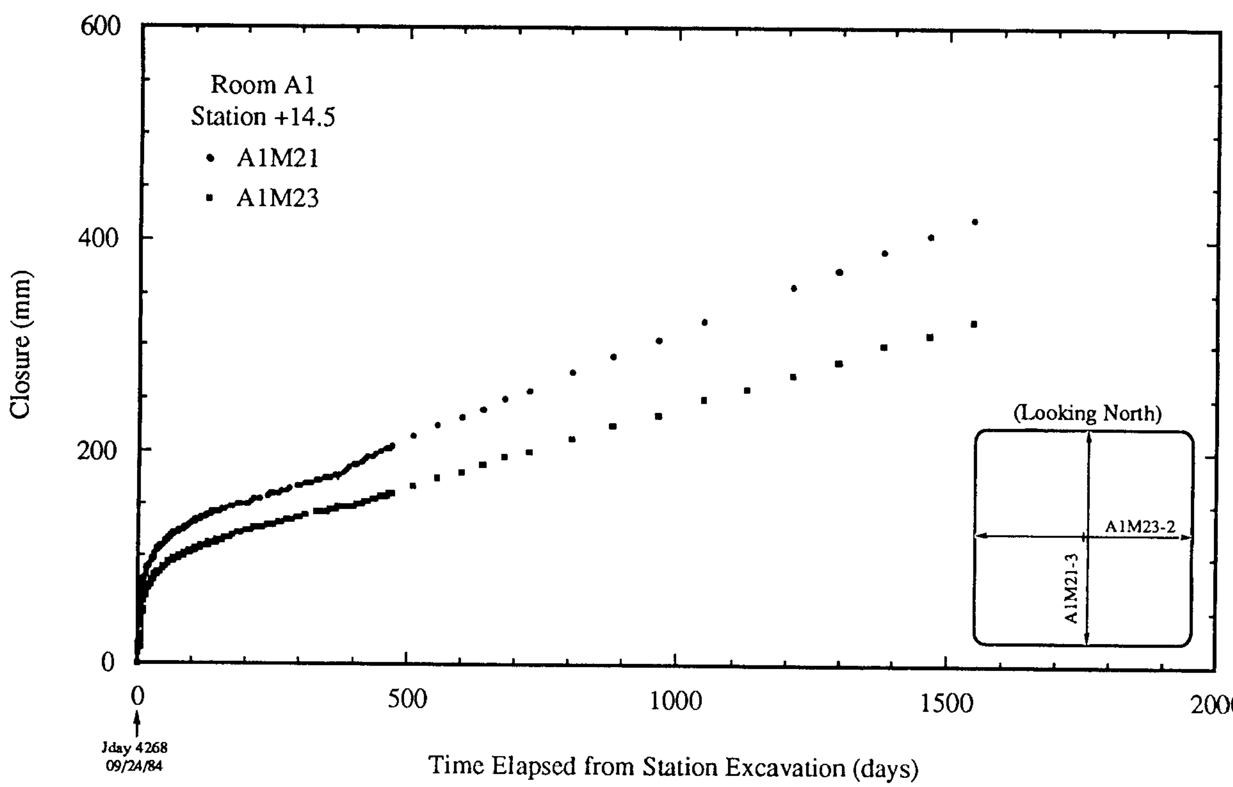


Figure 5.1.1c. Mining Sequence Gages A1M2x-x, Room A1, Station +14 m

Table 5.1.5a. Mining Sequence Gages A2M0x-x, Room A2, Station -16 m

A2M01 - A2M04 PI Comments

02/12/92 RLJ [92%] This set of Mining Sequence Closure Gages (2 vertical and 2 horizontal) was installed in the south half of Room A2. They were initially measured less than 2 hours after the first mining machine pass. Early results (top graph) are typical for early data from other closure stations of similar geometry. Excavation effects can be clearly seen as bump like features that correspond to the mining of each pass. Gage disruption due to mining required a total of only 5 reinstallations. Long term data (bottom graph) clearly show the excavation effect of the two adjacent rooms (A1 & A3) as an increase in closure occurring from about day 75 through day 125. Another change in slope is seen subsequent to day 550 due to heater activation. (DEM)

Gage Information

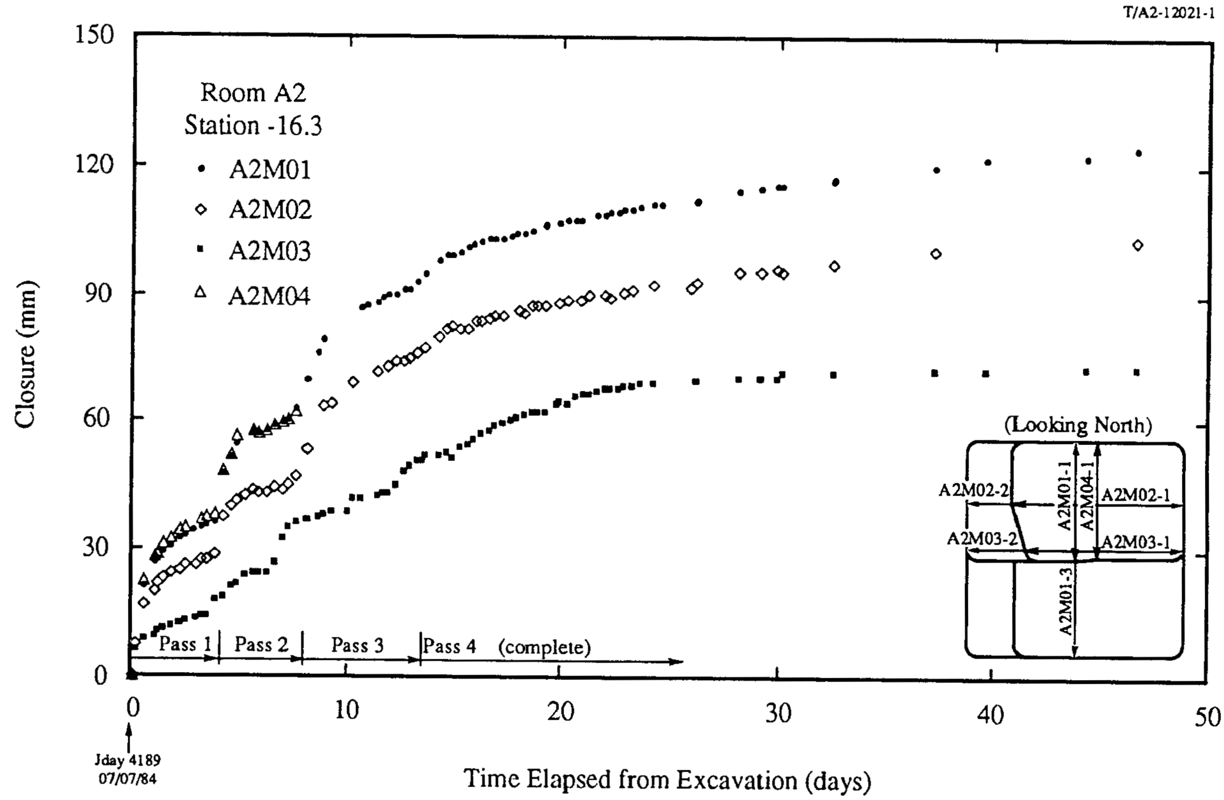
Gage Number	Gage Type	Gage Orient.	Record		Gage Manf.	Installation Date	Drawing Number
A2M01-1	CONV	V	T	MAN	SNL	7/7/84	T91025-000A
A2M01-3	CONV	V	T	MAN	SNL	7/15/84	T91025-000A
A2M02-1	CONV	H	T	MAN	SNL	7/7/84	T91025-000A
A2M02-2	CONV	H	T	MAN	SNL	7/11/84	T91025-000A
A2M03-1	CONV	H	T	MAN	SNL	7/7/84	T91025-000A
A2M03-2	CONV	H	T	MAN	SNL	7/11/84	T91025-000A
A2M04-1	CONV	V	T	MAN	SNL	7/7/84	T91025-000A

Gage Location

	Gage Coordinates							
					Local		Room	
Gage Number	X1 (m)	X2 (m)	Y1 (m)	Y2 (m)	Z1 (m)	Z2 (m)	Z1 (m)	Z2 (m)
A2M01-1	-0.02	-0.02	-16.32	-16.32	-0.23	2.78	-0.66	2.36
A2M01-3	-0.02	-0.02	-16.32	-16.32	-2.78	2.78	-3.20	2.36
A2M02-1	-1.60	2.72	-16.29	-16.29	1.60	1.60	1.17	1.17
A2M02-2	-2.73	2.72	-16.32	-16.29	1.60	1.60	1.17	1.17
A2M03-1	-1.30	2.72	-16.29	-16.29	0.00	0.00	-0.42	-0.42
A2M03-2	-2.80	2.72	-16.29	-16.29	0.00	0.00	-0.42	-0.42
A2M04-1	0.56	0.56	-16.32	-16.32	-0.18	2.78	-0.60	2.36

Gage Length Upon Installation

		Pass 1		Pass 2		Pass 3		Pass 4 + Trim -Final-	
Gage Number	Dir	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)
A2M01	V	-1	3.01		--	-3	5.68	-3	5.68
A2M03	H	-1	4.03	-2	5.30		--	-2	5.60
A2M04	v	-1	2.95		--		xx		xx
A2M02	h	-1	4.33	-2	5.65		--	-2	5.65



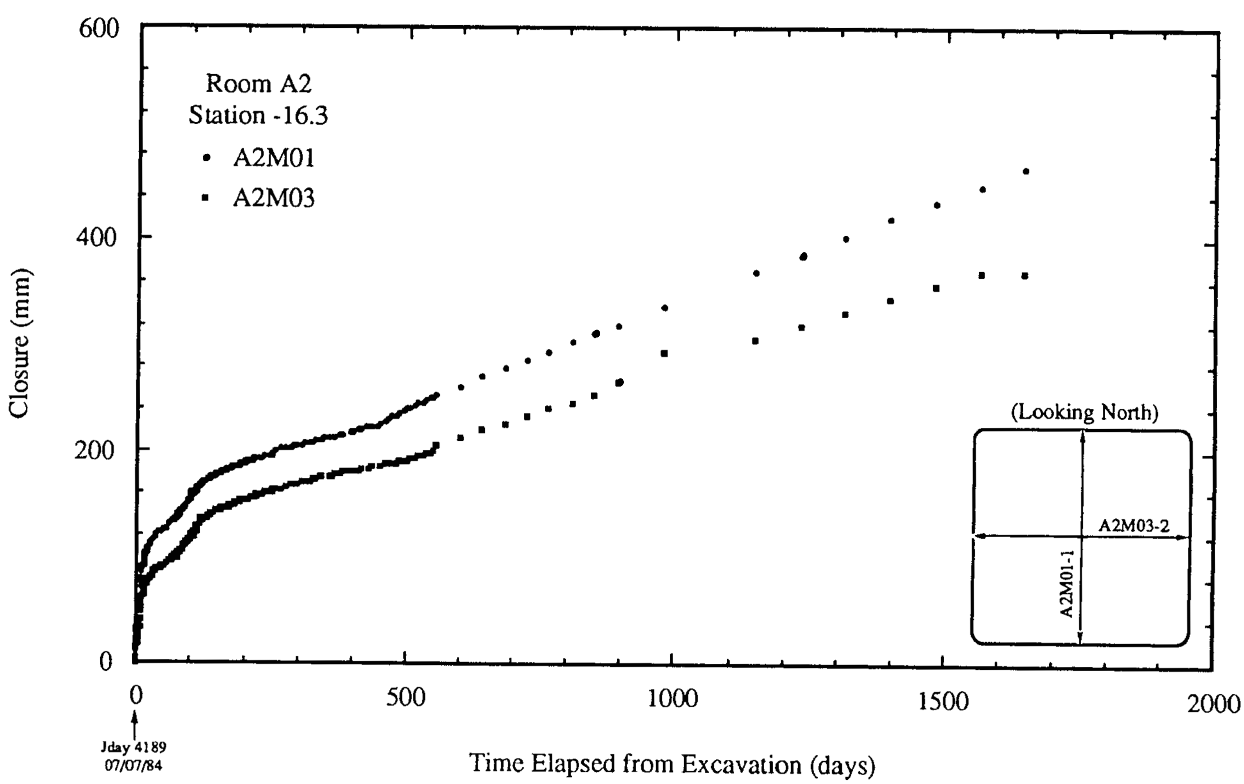


Figure 5.1.2a. Mining Sequence Gages A2M0x-x, Room A2, Station -16 m

Table 5.1.5b. Mining Sequence Gages A2M1x-x, Room A2, Station -01 m

A2M11 - A2M14 PI Comments

02/13/92 RLJ [89%] This set of Mining Sequence Closure Gages (2 vertical and 2 horizontal) was installed in the center of Room A2. They were initially measured less than 2 hours after the first mining machine pass. Early results (top graph) are typical for early data from other closure stations of similar geometry. Excavation effects can be clearly seen as bump like features that correspond to the mining of each pass. Gage disruption due to mining required a total of 7 reinstallations. Long term data (bottom graph) clearly show the excavation effect of the two adjacent rooms (A1 & A3) as an increase in closure occurring from about day 75 through day 125. Another change in slope is seen subsequent to day 549 due to heater activation. Some of the early data (day 19 through day 75) for gage A2M13 is missing because gage access was blocked by drilling equipment. (DEM)

Gage Information

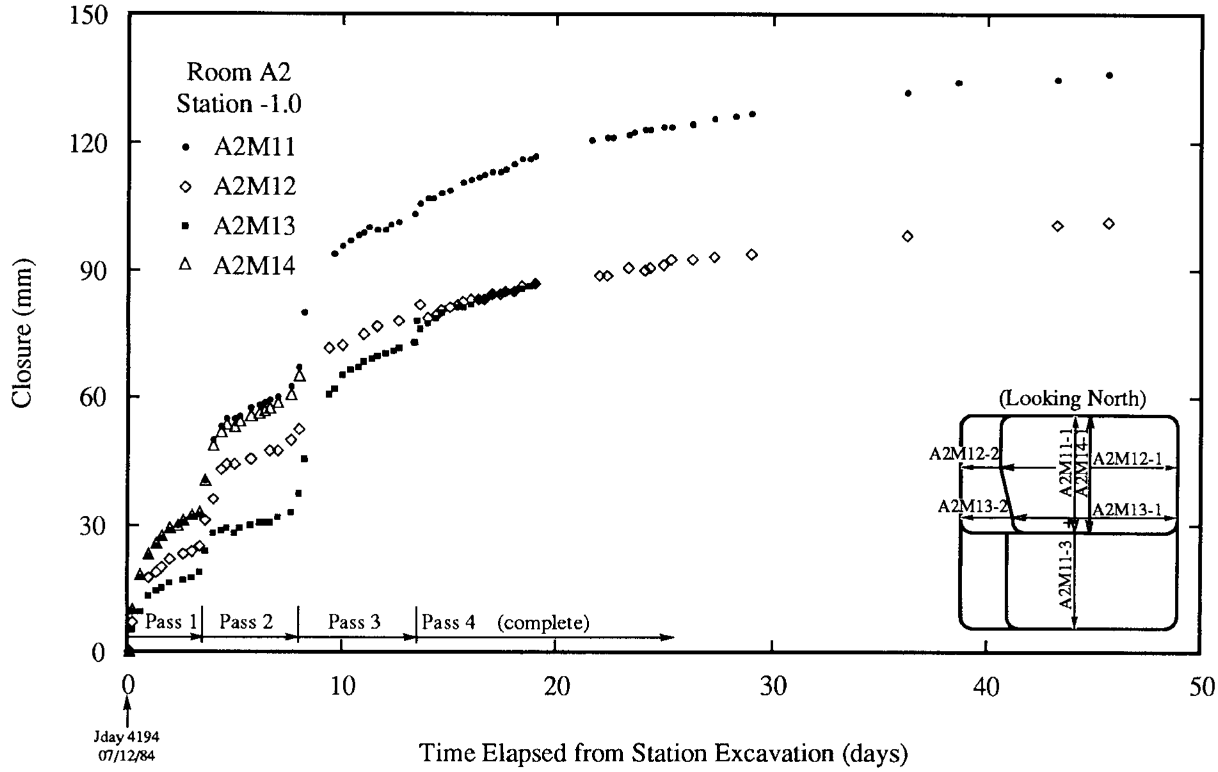
Gage Number	Gage Type	Gage Orient.	Record		Gage Manf.	Installation Date	Drawing Number
A2M11-1	CONV	V	T	MAN	SNL	7/8/84	T91025-000A
A2M11-3	CONV	V	T	MAN	SNL	7/16/84	T91025-000A
A2M12-1	CONV	H	T	MAN	SNL	7/8/84	T91025-000A
A2M12-2	CONV	H	T	MAN	SNL	7/12/84	T91025-000A
A2M13-1	CONV	H	T	MAN	SNL	7/8/84	T91025-000A
A2M13-2	CONV	H	T	MAN	SNL	7/12/84	T91025-000A
A2M14-1	CONV	V	T	MAN	SNL	7/8/84	T91O25-000A

Gage Location

	Gage Coordinates							
					Local		Room	
Gage Number	X1 (m)	X2 (m)	Y1 (m)	Y2 (m)	Z1 (m)	Z2 (m)	Z1 (m)	Z2 (m)
A2M11-1	0.15	0.15	-1.05	-1.05	-0.55	2.50	-0.55	2.50
A2M11-3	0.18	0.15	-1.04	-1.05	-2.82	2.50	-2.82	2.50
A2M12-1	-1.73	2.77	-1.01	-1.01	1.11	1.11	1.11	1.11
A2M12-2	-2.74	2.77	-1.20	-1.01	1.16	1.11	1.16	1.11
A2M13-1	-1.41	2.77	-1.01	-1.01	-0.17	-0.17	-0.17	-0.17
A2M13-2	-2.79	2.77	-1.01	-1.01	-0.17	-0.17	-0.17	-0.17
A2M14-1	0.52	0.52	-1.05	-1.05	-0.55	2.50	-0.55	2.50

Gage Length Upon Installation

		Pass 1		Pass 2		Pass 3		Pass 4 + Trim -Final-	
Gage Number	Dir	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)
A2M11	V	-1	3.05		--	-3	5.52	-3	5.52
A2M13	H	-1	4.18	-2	5.49		--	-2	5.57
A2M14	v	-1	3.05		--		xx		xx
A2M12	h	-1	4.49	-2	5.76		--	-2	5.76



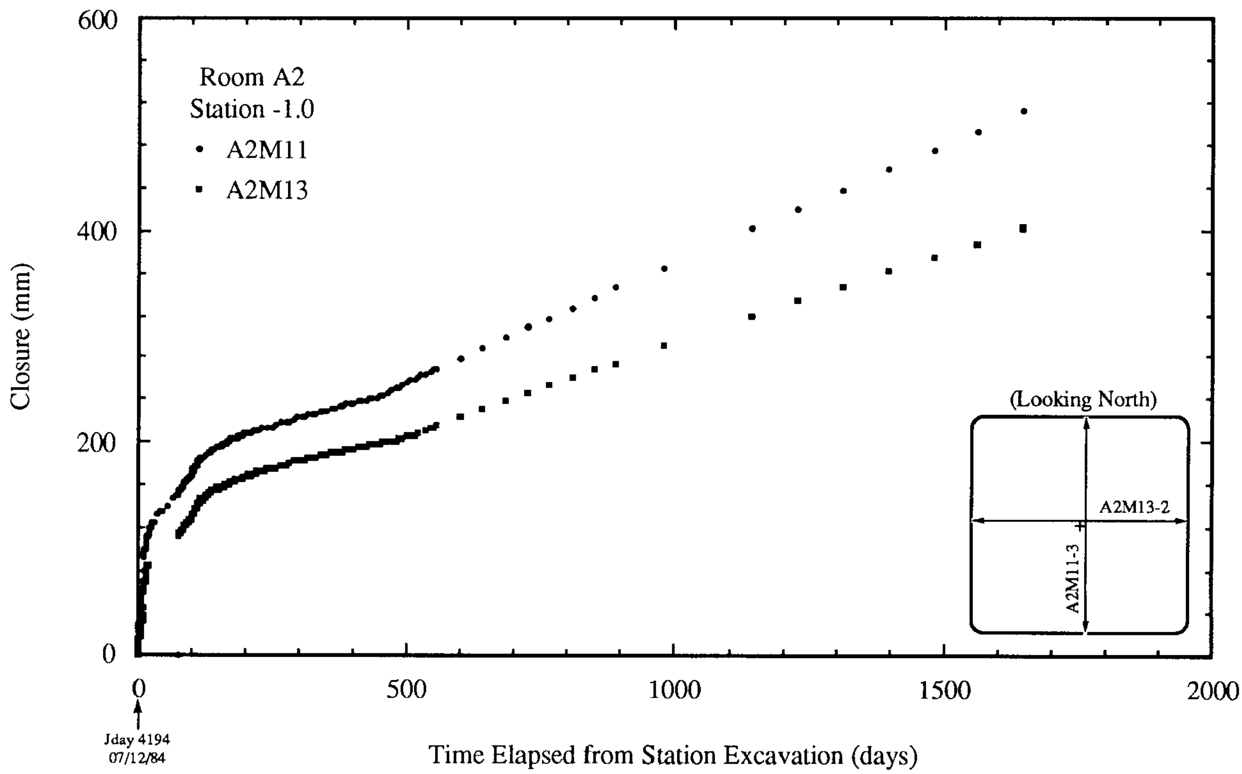


Figure 5.1.2b. Mining Sequence Gages A2M1x-x, Room A2, Station -01 m

Table 5.1.5c. Mining Sequence Gages A2M2x-x, Room A2, Station +14 m

A2M21 - A2M24 PI Comments

02/13/92 RLJ [93%] This set of Mining Sequence Closure Gages (2 vertical and 2 horizontal) was installed in the north half of Room A2. They were initially measured about 1 hour after the first mining machine pass. Early results (top graph) are typical for early data from other closure stations of similar geometry. Excavation effects can be clearly seen as bump like features that correspond to the mining of each pass. Gage disruption due to mining required a total of 6 reinstallations. Long term data (bottom graph) clearly show the excavation effect of the two adjacent rooms (A1 & A3) as an increase in closure occurring from about day 75 through day 125. Another change in slope is seen subsequent to day 548 due to heater activation. (DEM)

Gage Information

Gage Number	Gage Type	Gage Orient.	Record		Gage Manf.	Installation Date	Drawing Number
A2M21-1	CONV	V	T	MAN	R.I.	7/9/84	T91997-000A
A2M21-3	CONV	V	T	MAN	R.I.	7/17/84	T91997-000A
A2M22-1	CONV	H	T	MAN	R.I.	7/9/84	T91997-000A
A2M22-2	CONV	H	T	MAN	R.I.	7/12/84	T91997-000A
A2M23-1	CONV	H	T	MAN	R.I.	7/9/84	T91997-000A
A2M23-2	CONV	H	T	MAN	R.I.	7/12/84	T91997-000A
A2M24-1	CONV	V	T	MAN	R.I.	7/9/84	T91997-000A

Gage Location

	Gage Coordinates							
					Local		Room	
Gage Number	X1 (m)	X2 (m)	Y1 (m)	Y2 (m)	Z1 (m)	Z2 (m)	Z1 (m)	Z2 (m)
A2M21-1	0.01	0.01	14.08	14.08	-0.29	2.78	-0.30	2.77
A2M21-3	0.01	0.01	14.08	14.08	-2.78	2.78	-2.79	2.77
A2M22-1	-1.64	2.77	14.08	14.08	1.23	1.23	1.22	1.22
A2M22-2	-2.71	2.77	14.14	14.08	1.13	1.23	1.12	1.22
A2M23-1	-1.35	2.77	14.08	14.08	0.00	0.00	-0.01	-0.01
A2M23-2	-2.76	2.77	14.08	14.08	0.00	0.00	-0.01	-0.01
A2M24-1	0.57	0.57	14.08	14.08	-0.32	2.78	-0.33	2.77

Gage Length Upon Installation

		Pass 1		Pass 2		Pass 3		Pass 4 + Trim -Final-	
Gage Number	Dir	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)
A2M21	V	-1	3.07		--	-3	5.65	-3	5.67
A2M23	H	-1	4.12	-2	5.35		--	-2	5.64
A2M24	v	-1	3.10		--		xx		xx
A2M22	h	-1	4.41	-2	5.71		--	-2	5.71

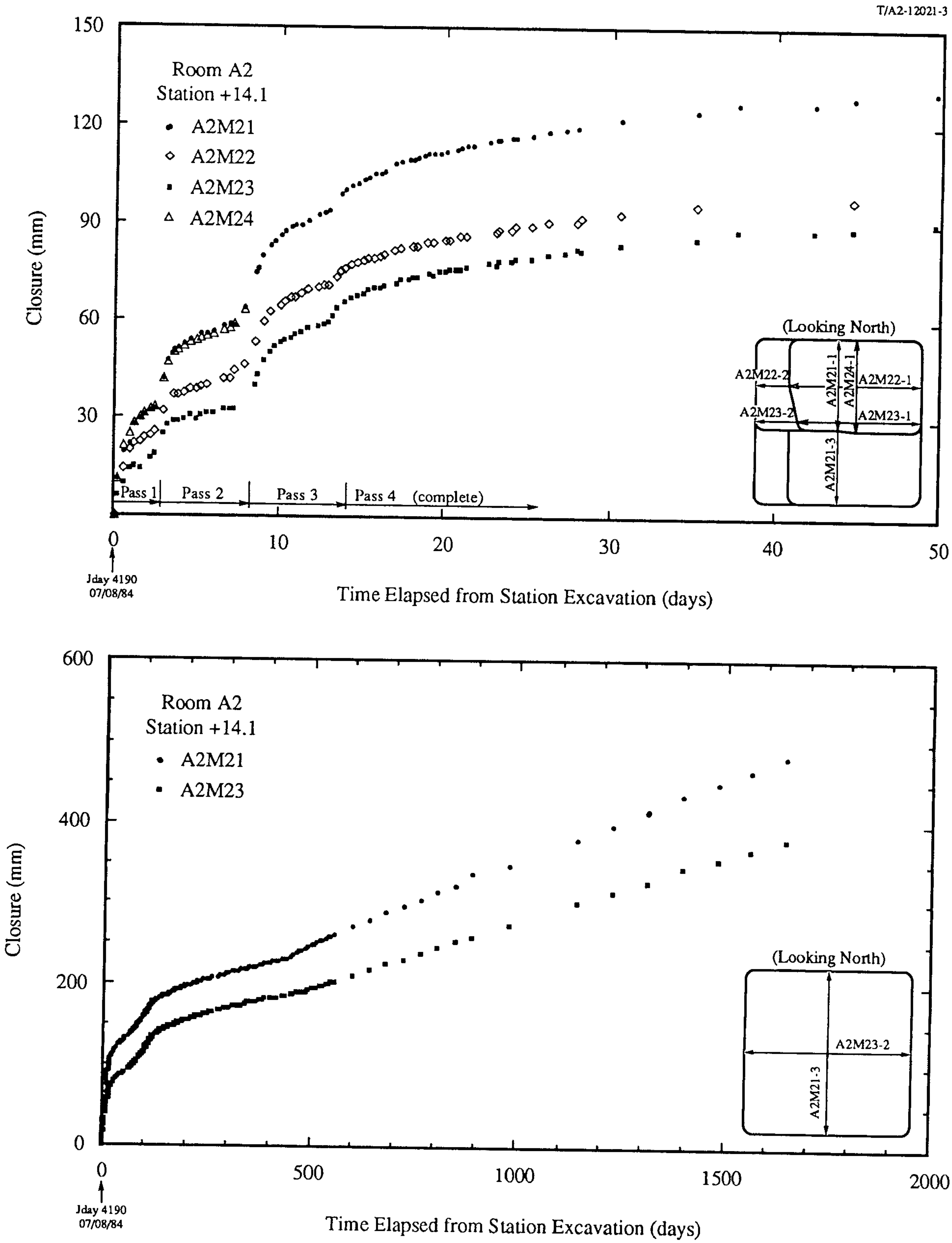


Figure 5.1.2c. Mining Sequence Gages A2M2x-x, Room A2, Station +14 m

Table 5.1.6a. Mining Sequence Gages A3M0x-x, Room A3, Station -17 m

A3M01 - A3M04 PI Comments

02/13/92 RLJ [92%] This set of Mining Sequence Closure Gages (2 vertical and 2 horizontal) was installed in the south half of Room A3. They were first measured less than 2 hours after the initial mining machine pass. Early results (top graph) are typical for early data from other closure stations of similar geometry. Excavation effects can be clearly seen as bump like features that correspond to the mining of each pass. There appeared to be an error in the initial reading of Gage A3M04 which was corrected to make these data consistent with the more normal response of similar gages at other stations. Gage disruption due to mining required a total of 6 reinstallations. Long term data (bottom graph) clearly show an increase in closure subsequent to day 346 due to heater activation. (DEM)

Gage Information

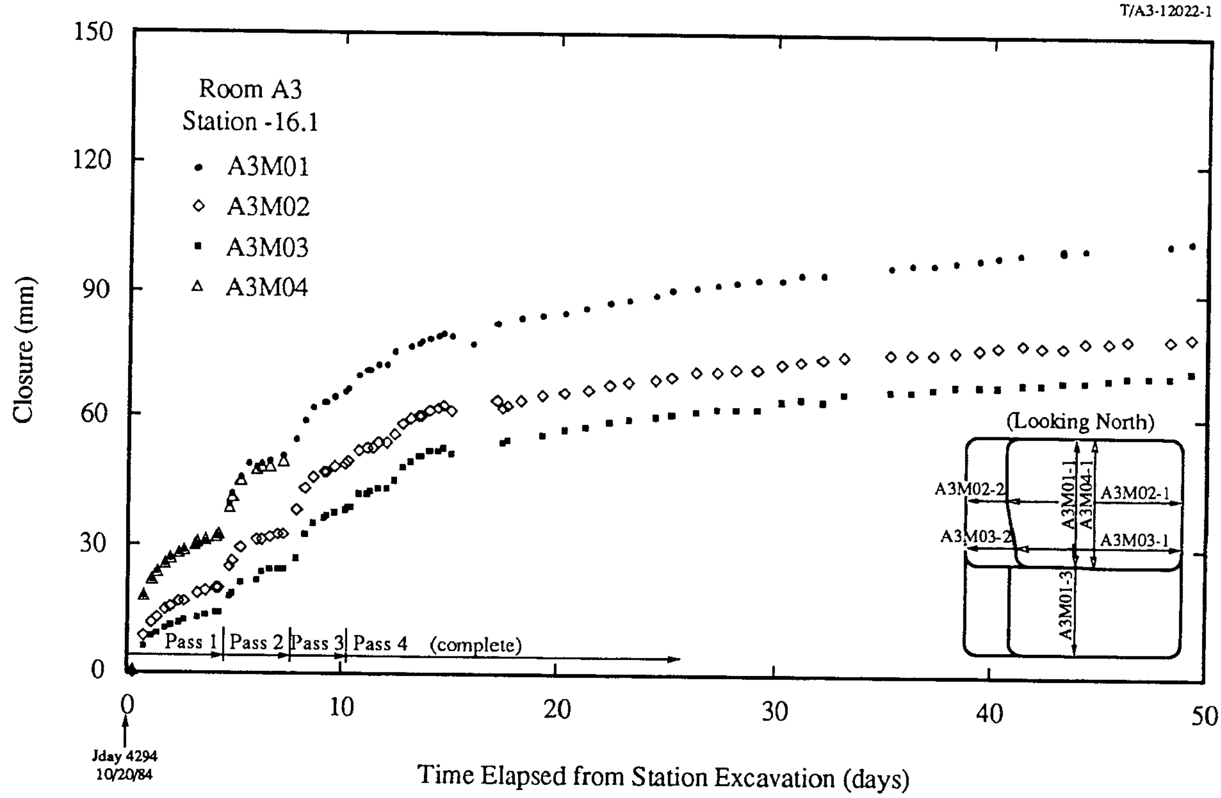
Gage Number	Gage Type	Gage Orient.	Record		Gage Manf.	Installation Date	Drawing Number
A3M01-1	CONV	V	T	MAN	SNL	10/20/84	T91025-000A
A3M01-3	CONV	V	T	MAN	SNL	10/27/84	T91025-000A
A3M02-1	CONV	H	T	MAN	SNL	10/20/84	T91025-000A
A3M02-2	CONV	H	T	MAN	SNL	10/24/84	T91025-000A
A3M03-1	CONV	H	T	MAN	SNL	10/20/84	T91025-000A
A3M03-2	CONV	H	T	MAN	SNL	10/24/84	T91025-000A
A3M04-1	CONV	V	T	MAN	SNL	10/20/84	T91025-000A

Gage Location

	Gage Coordinates							
					Local		Room	
Gage Number	X1 (m)	X2 (m)	Y1 (m)	Y2 (m)	Z1 (m)	Z2 (m)	Z1 (m)	Z2 (m)
A3M01-1	0.06	0.06	-16.09	-16.09	-0.51	2.69	-0.69	2.51
A3M01-3	0.03	0.06	-16.07	-16.09	-2.69	2.69	-2.88	2.51
A3M02-1	-1.68	2.71	-15.95	-15.95	1.17	1.17	0.98	0.98
A3M02-2	-2.76	2.71	-16.09	-15.95	0.93	1.17	0.74	0.98
A3M03-1	-1.43	2.71	-15.95	-15.95	-0.02	-0.02	-0.20	-0.20
A3M03-2	-2.84	2.71	-15.95	-15.95	-0.02	-0.02	-0.20	-0.20
A3M04-1	0.52	0.52	-16.09	-16.09	-0.69	2.51	-0.69	2.51

Gage Length Upon Installation

		Pass 1		Pass 2		Pass 3		Pass 4 + Trim -Final-	
Gage Number	Dir	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)
A3M01	V	-1	3.21		--	-3	5.01	-3	5.49
A3M03	H	-1	4.14	-2	5.43		--	-2	5.65
A3M04	v	-1	3.20		--		xx		xx
A3M02	h	-1	4.39	-2	5.66		--	-2	5.66



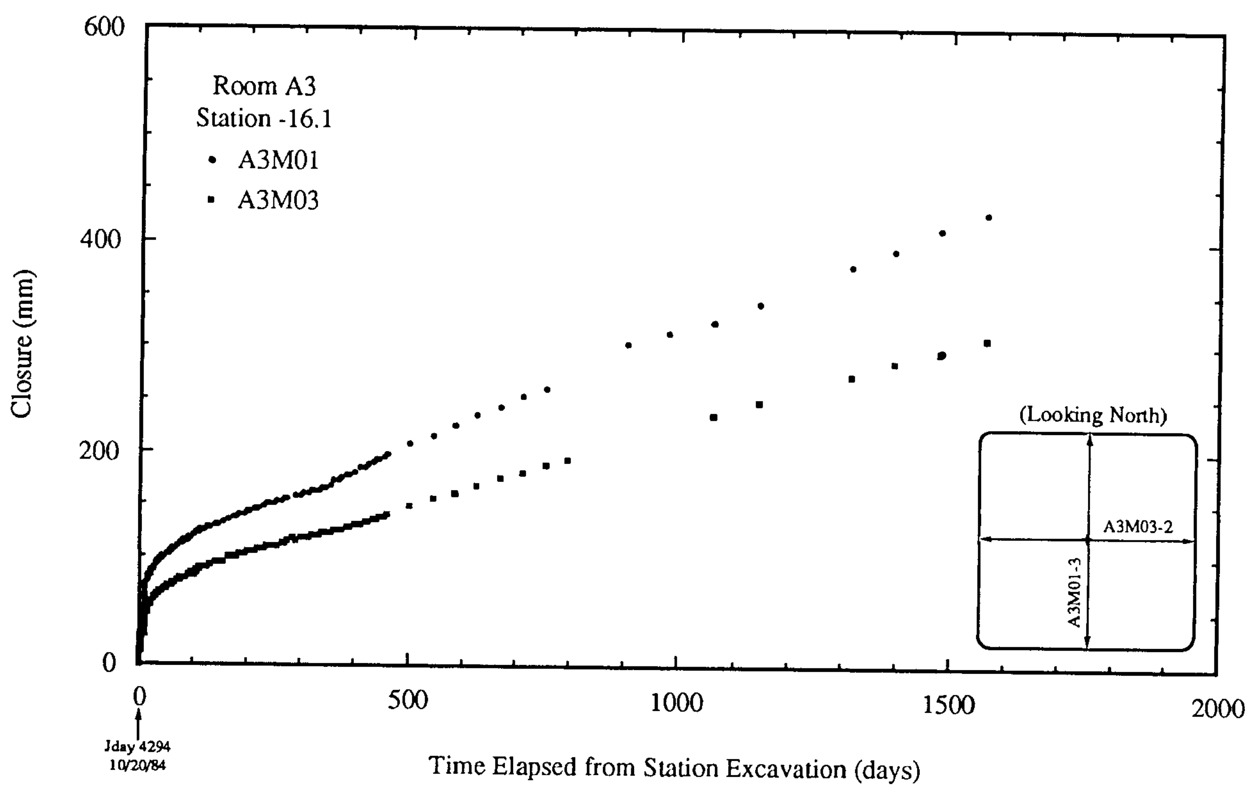


Figure 5.1.3a. Mining Sequence Gages A3M0x-x, Room A3, Station -17 m

Table 5.1.6b. Mining Sequence Gages A3M1x-x, Room A3, Station -01 m

A3M11 - A3M14 PI Comments

02/18/92 RLJ [93%] This set of Mining Sequence Closure Gages (2 vertical and 2 horizontal) was installed in the center of Room A3. They were initially measured about 1 hour after the first mining machine pass. Early results (top graph) are typical for early data from other closure stations of similar geometry. Excavation effects can be clearly seen as bump like features that correspond to the mining of each pass. Gage disruption due to mining required a total of 5 reinstallations. Long term data (bottom graph) clearly show an increase in closure subsequent to day 345 due to heater activation. (DEM)

Gage Information

Gage Number	Gage Type	Gage Orient.	—— Record ——		Gage Manf.	Installation Date	Drawing Number
A3M11-1	CONV	V	T	MAN	SNL	10/21/84	T91025-000A
A3M11-3	CONV	V	T	MAN	SNL	10/28/84	T91025-000A
A3M12-1	CONV	H	T	MAN	SNL	10/21/84	T91025-000A
A3M12-2	CONV	H	T	MAN	SNL	10/24/84	T91025-000A
A3M13-1	CONV	H	T	MAN	SNL	10/21/84	T91025-000A
A3M13-2	CONV	H	T	MAN	SNL	10/24/84	T91025-000A
A3M14-1	CONV	V	T	MAN	SNL	10/21/84	T91025-000A

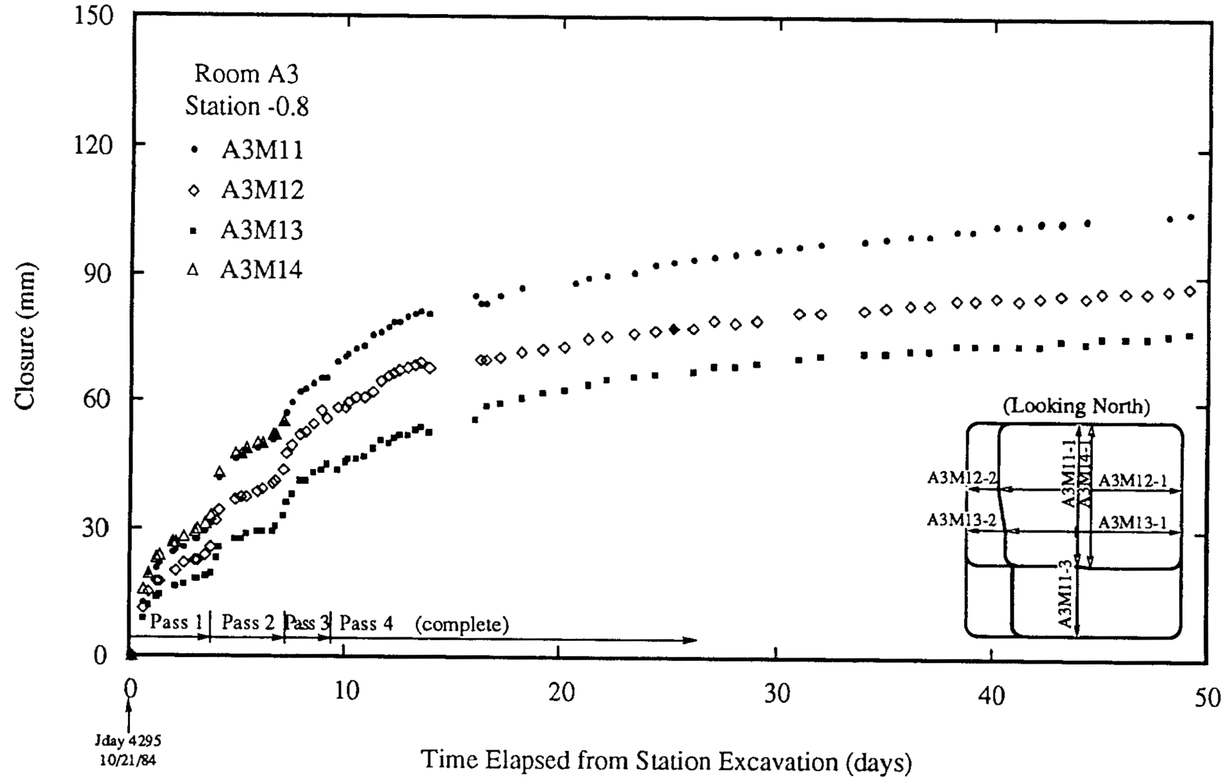
Gage Location

	Gage Coordinates				—— Local ——		—— Room ——	
Gage Number	X1 (m)	X2 (m)	Y1 (m)	Y2 (m)	Z1 (m)	Z2 (m)	Z1 (m)	Z2 (m)
A3M11-1	0.02	0.02	-0.77	-0.77	-0.94	2.60	-0.94	2.60
A3M11-3	-0.01	0.02	-0.77	-0.77	-2.78	2.60	-2.78	2.60
A3M12-1	-1.92	2.73	-0.70	-0.70	1.03	1.03	1.03	1.03
A3M12-2	-2.76	2.73	-0.70	-0.70	1.03	1.03	1.03	1.03
A3M13-1	-1.73	2.74	-0.70	-0.70	-0.02	-0.02	-0.02	-0.02
A3M13-2	-2.76	2.74	-0.70	-0.70	-0.02	-0.02	-0.02	-0.02
A3M14-1	0.40	0.40	-0.77	-0.77	-0.95	2.60	-0.95	2.60

Gage Length Upon Installation

		Pass 1		Pass 2		Pass 3		Pass 4 + Trim -Final-	
Gage Number	Dir	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)
A3M11	V	-1	3.54		--	-3	5.07	-3	5.43
A3M13	H	-1	4.46	-2	5.51		--	-2	5.60
A3M14	v	-1	3.55		--		xx		xx
A3M12	h	-1	4.65	-2	5.61		--	-2	5.61

T/A3-12022-2



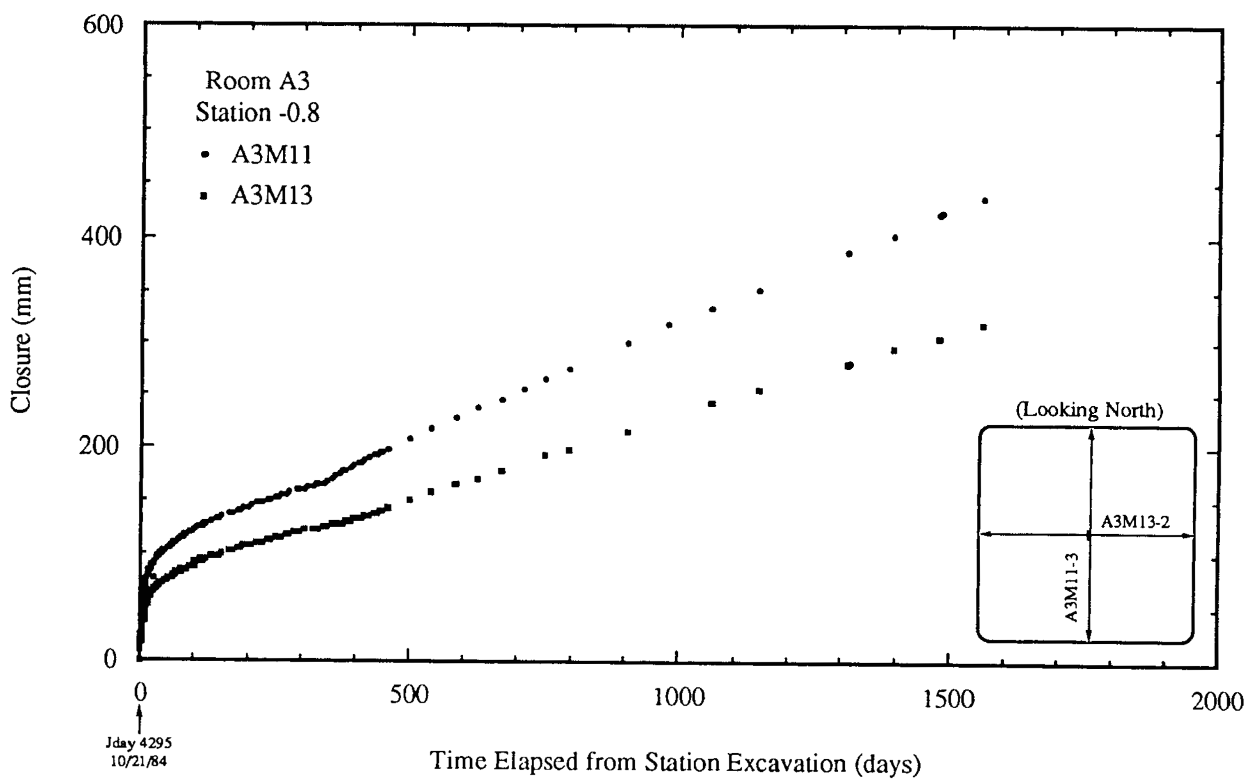


Figure 5.1.3b. Mining Sequence Gages A3M1x-x, Room A3, Station -01 m

Table 5.1.6c. Mining Sequence Gages A3M2x-x, Room A3, Station +14 m

A3M21 - A3M24 PI Comments

02/18/92 RLJ [93%] This set of Mining Sequence Closure Gages (2 vertical and 2 horizontal) was installed in the north half of Room A3. They were initially measured about 1 hour after the first mining machine pass. Early results (top graph) are typical for early data from other closure stations of similar geometry. Excavation effects can be clearly seen as bump like features that correspond to the mining of each pass. Gage disruption due to mining required a total of 5 reinstallations. Long term data (bottom graph) clearly show an increase in closure subsequent to day 344 due to heater activation. (DEM)

Gage Information

Gage Number	Gage Type	Gage Orient.	Record		Gage Manf.	Installation Date	Drawing Number
A3M21-1	CONV	V	T	MAN	SNL	10/22/84	T91025-000A
A3M21-3	CONV	V	T	MAN	R.I.	10/28/84	T91997-000A
A3M22-1	CONV	H	T	MAN	R.I.	10/22/84	T91997-000A
A3M22-2	CONV	H	T	MAN	R.I.	10/25/84	T91997-000A
A3M23-1	CONV	H	T	MAN	R.I.	10/22/84	T91997-000A
A3M23-2	CONV	H	T	MAN	R.I.	10/25/84	T91997-000A
A3M24-1	CONV	V	T	MAN	R.I.	10/22/84	T91997-000A

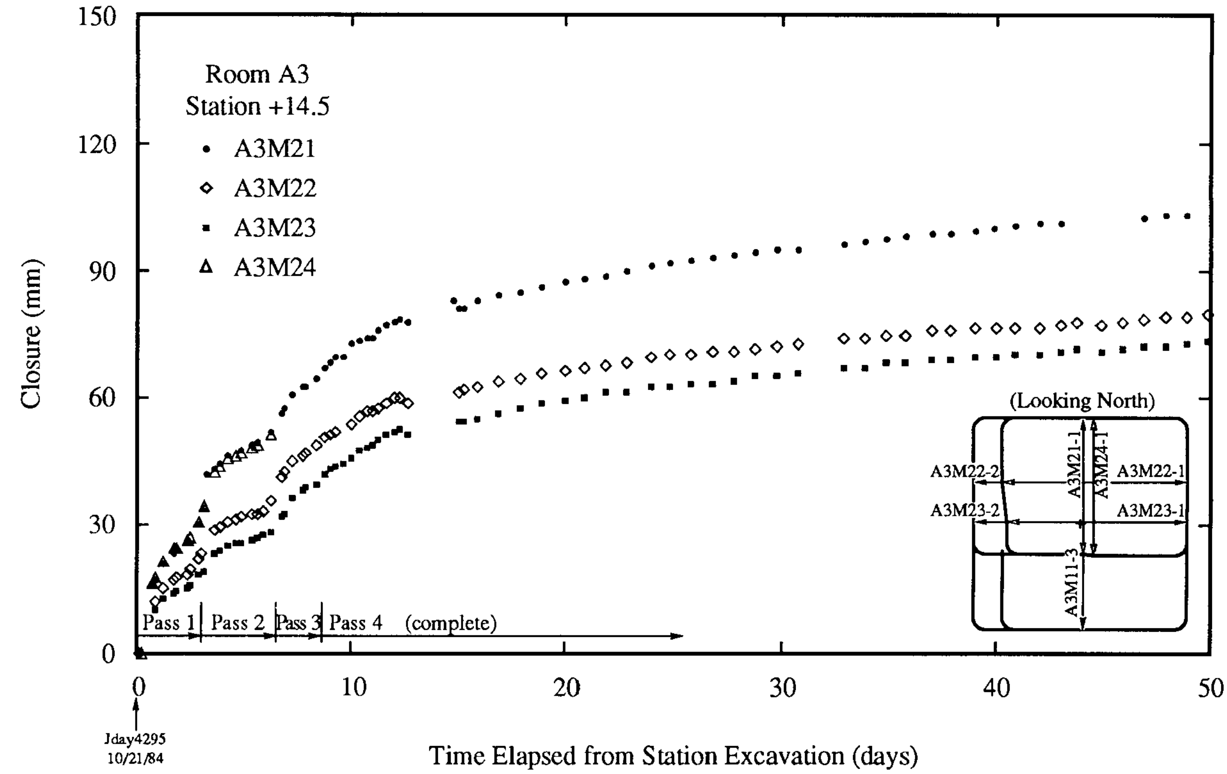
Gage Location

					Gage Coordinates			
					Local		Room	
Gage Number	X1 (m)	X2 (m)	Y1 (m)	Y2 (m)	Z1 (m)	Z2 (m)	Z1 (m)	Z2 (m)
A3M21-1	0.05	0.05	14.48	14.48	-0.78	2.72	-0.83	2.67
A3M21-3	0.07	0.05	14.56	14.48	-2.72	2.72	-2.77	2.67
A3M22-1	-2.08	2.74	14.53	14.53	1.05	1.05	1.00	1.00
A3M22-2	-2.83	2.74	14.53	14.53	1.05	1.05	1.00	1.00
A3M23-1	-1.90	2.74	14.53	14.53	0.02	0.02	-0.03	-0.03
A3M23-2	-2.75	2.74	14.53	14.53	0.02	0.02	-0.03	-0.03
A3M24-1	0.33	0.33	14.56	14.56	-0.80	2.72	-0.85	2.67

Gage Length Upon Installation

		Pass 1		Pass 2		Pass 3		Pass 4 + Trim -Final-	
Gage Number	Dir	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)
A3M21	V	-1	3.50		--	-3	5.07	-3	5.47
A3M23	H	-1	4.64	-2	5.54		--	-2	5.59
A3M24	v	-1	3.53		--		xx		xx
A3M22	h	-1	4.82	-2	5.64		--	-2	5.64

T/A3-12022-3



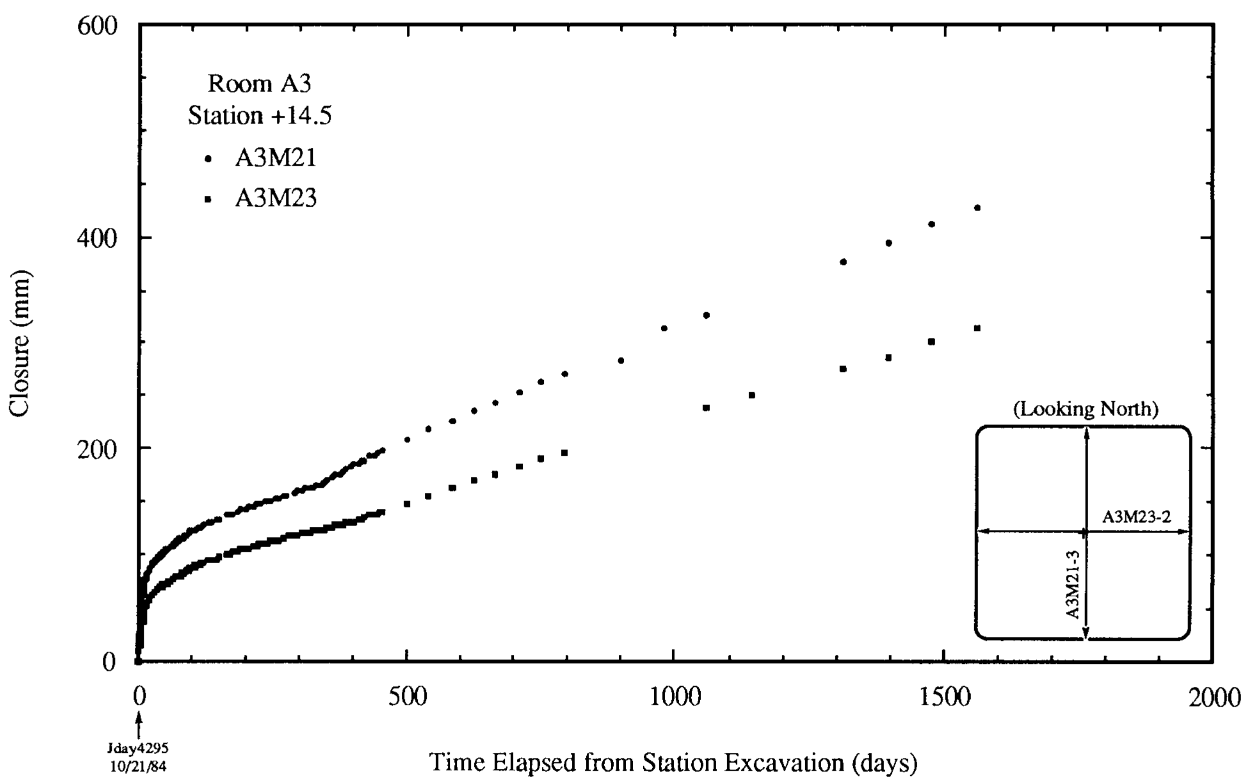


Figure 5.1.3c. Mining Sequence Gages A3M2x-x, Room A3, Station +14 m

5.2 Room B Mining Sequence Closure Data

The Overtest for Simulated Defense High-Level Waste (DHLW) is the test fielded in Room B. This test used electrical heaters to exaggerate the output of simulated defense high level waste by a factor of about four. The heaters were configured to produce uniform heating, with compensation for end effects, over the central portion of the test room during the expected three year duration of the test. In practice, uniform conditions over the central test section were maintained for the 3.74 years duration of the controlled test. The test room also contained a number of Waste Package Performance (WPP) heaters fielded by the Disposal Systems Group. While these heaters aided in extending the length the heated test section, they were not an integral part of the TSI test. A rather detailed and complete analysis of the mechanical and thermal response. including the mining sequence closure, of Room B has been given by Munson et al. [19].

Excavation of the test room began on the swing shift of 5/4/84 and was completed on the graveyard shift of 6/3/84. The heaters were activated on 4/23/85. Deterioration of the roof prevented room access for reading of the manual mining sequence gages after about 1000 days of operation. At about 1200 days of operation, the decision was made to recover the WPP heaters for analysis. Roof support was provided for the safe recovery of the heaters. The test was subsequently terminated on 7/2/88 after the room was ventilated to permit recovery of the WPP heaters. In the process of room ventilation and recovery of these heaters, thermal control was lost over the room conditions, which compromised the ability to further analyze the room response, even though most gages remained operable for some time after that. Eventually, however, all of the remaining room heaters were deactivated and the test was formally terminated.

The location guide for the mining sequence gages in Room B is given in Table 5.2.1. The table presents schematically the relative gage positions at the three principal stations of the room. Thus, the gages of a given station will all be of the form B_Mxx, where the numerical value of the first number, as in "0x" indicates the first principal station, and so on, in order. The numerical value of the second number of the gage is an indication of whether the gage is vertical or horizontal. Similar keys to other gages groups are apparent.

Mining sequence closure data for Room B are given in Tables 5.2.2a-c and in Figures 5.2.1a-c.

Room B is a single, isolated room of the same dimensions as Rooms A1, A2, A3, and D. Until the onset of heating, room closure is essentially identical to that for Rooms D and A2 (until mining of the adjacent rooms, A1 and A3, altered the stress and displacement fields of Room A2), except for those differences in the early closure that depend upon the details of the mining passes.

Although the displacement history of the specific station varies considerably depending upon the details of the multipass mining, the accumulation of displacement for any station within a month of completion of mining appears to be essentially the same. Thus, the influence of the details of the mining operation on the measured closure diminish with time. Measured closures during this period when all of these three rooms were identical has been compared through a pseudostrain analysis [16]. The validity of the experimental observation was demonstrated in a full three-dimensional calculation for Room D [23], with progressive removal of meshes to simulate the mining sequence. Room D is geometrically and mechanically identical to Room B during the mining operation.

Table 5.2.1. Room B Mining Sequence Closure Units (Gages) Location Guide

Station	Direction		west rib		center	pass 1	east rib
B ST-16	Vertical	roof			B_M01	B_M04	
	Horizontal	pass 1	-2	-1			B_M02
	Horizontal	mid	-2	-1			B_M03
					-1	-1	
	Vertical	floor			-3		
B ST-01	Vertical	roof			B_M11	B_M14	
	Horizontal	pass 1	-2	-1			B_M12
	Horizontal	mid	-2	-1			B_M13
					-1	-1	
	Vertical	floor			-3		
B ST014	Vertical	roof			B_M21	B_M24	
	Horizontal	pass 1	-2	-1			B_M22
	Horizontal	mid	-2	-1			B_M23
					-1	-1	
	Vertical	floor			-3		

Heating of the room started 354 days after beginning the mining, as is quite evident in the closure plots as an abrupt increase in closure rate at a time. Although difficult to discern in these data, at late times the vertical closure continues to diverge from the horizontal closure. This is thought to be the result of the development of separations in the immediate roof [19]. With time, further acceleration of vertical closure indicates the onset of roof slabbing. Thermal acceleration of the room closure rates probably contributed to the early deterioration of the roof.

The remotely collected mechanical and thermal data for Room B are reported elsewhere [8]. These extensive results, in conjunction with the mining sequence data reported here, give a complete history of the test.

[text continues on page 128]

Table 5.2.2a. Mining Sequence Gages B_M0x-x,. Room B, Station -16 m

B_M01 - B_M04 PI Comments

02/20/92 RLJ [96%] This set of Mining Sequence Closure Gages (2 vertical and 2 horizontal) was installed in the south half of Room B. They were initially measured less than 2 hours after the first mining machine pass. Early results (top graph) are typical for early data from other closure stations of similar geometry. Excavation effects can be clearly seen as bump like features that correspond to the mining of each pass. The Room B mining plan called for only three passes as opposed to the four pass plan in each "A" room. Gage disruption due to mining required a total of 7 reinstallations. Early data acquisition was interupted for 3 days because of a power outage. Long term data (bottom graph) clearly show a dramatic increase in closure subsequent to day 346 due to the heating of the room starting on that day. (DEM)

Gage Information

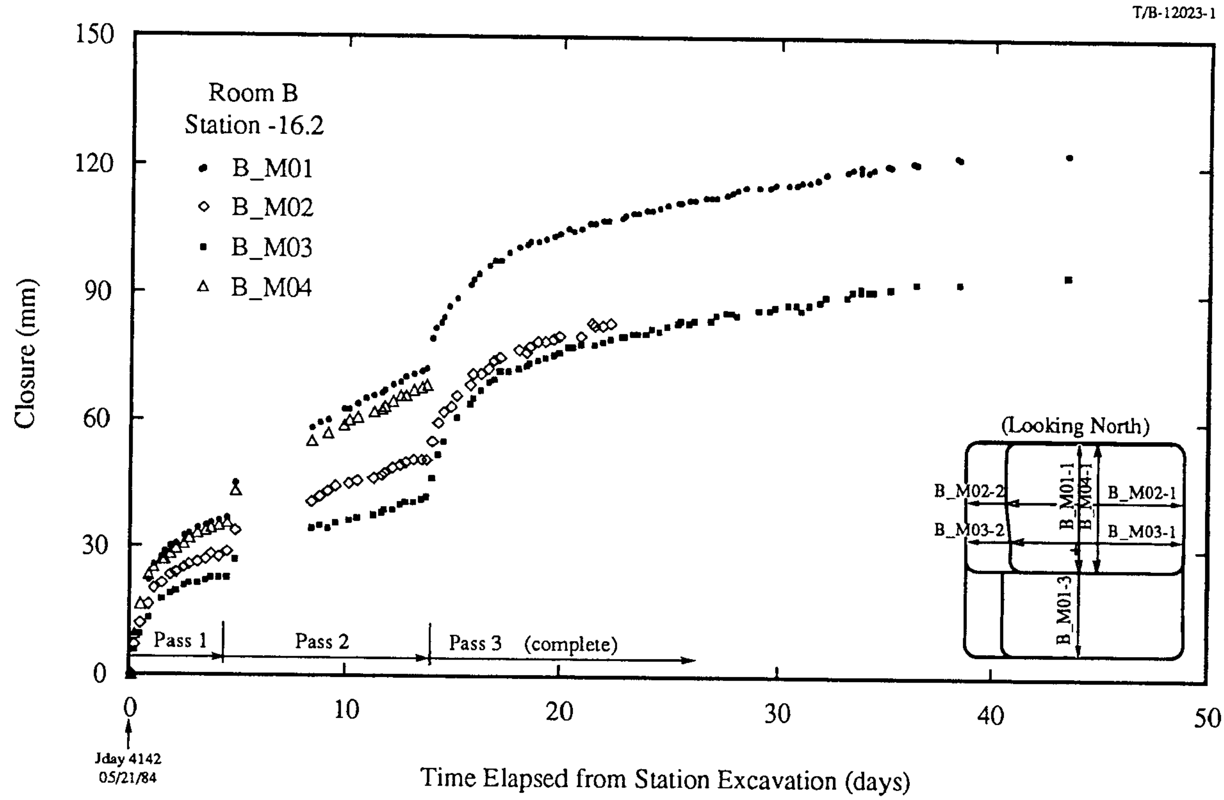
Gage Number	Gage Type	Gage Orient.	Record		Gage Manf.	Installation Date	Drawing Number
B_M01-1	CONV	V	T	MAN	SNL	5/11/84	T91025-000A
B_M01-3	CONV	V	T	MAN	SNL	5/25/84	T91025-000A
B_M02-1	CONV	H	T	MAN	SNL	5/11/84	T91025-000A
B_M02-2	CONV	H	T	MAN	SNL	5/16/84	T91025-000A
B_M03-1	CONV	H	T	MAN	SNL	5/11/84	T91025-000A
B_M03-2	CONV	H	T	MAN	SNL	5/16/84	T91025-000A
B_M04-1	CONV	V	T	MAN	SNL	5/11/84	T91025-000A

Gage Location

	Gage Coordinates							
					Local		Room	
Gage Number	X1 (m)	X2 (m)	Y1 (m)	Y2 (m)	Z1 (m)	Z2 (m)	Z1 (m)	Z2 (m)
B_M01-1	0.09	0.09	-16.22	-16.22	-0.61	2.75	-0.66	2.69
B_M01-3	0.10	0.09	-16.20	-16.22	-2.74	2.75	-2.80	2.69
B_M02-1	-1.77	2.78	-16.29	-16.29	1.20	1.19	1.15	1.14
B_M02-2	-2.82	2.78	-16.24	-16.29	1.17	1.19	1.12	1.14
B_M03-1	-1.61	2.76	-16.32	-16.32	0.19	0.19	0.13	0.13
B_M03-2	-2.78	2.76	-16.29	-16.32	0.16	0.19	0.11	0.13
B_M04-1	0.51	0.51	-16.22	-16.22	-0.61	2.75	-0.66	2.69

Gage Length Upon Installation

		Pass 1		Pass 2		Pass 3		Pass 4 + Trim -Final-	
Gage Number	Dir	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)
B M01	V	-1	3.35		--	-3	5.24	-3	5.49
B M03	H	-1	4.36	-2	5.55		--	-2	5.64
B M04	v	-1	3.35		--		xx		xx
B M02	h	-1	4.55	-2	5.74		--	-2	5.74



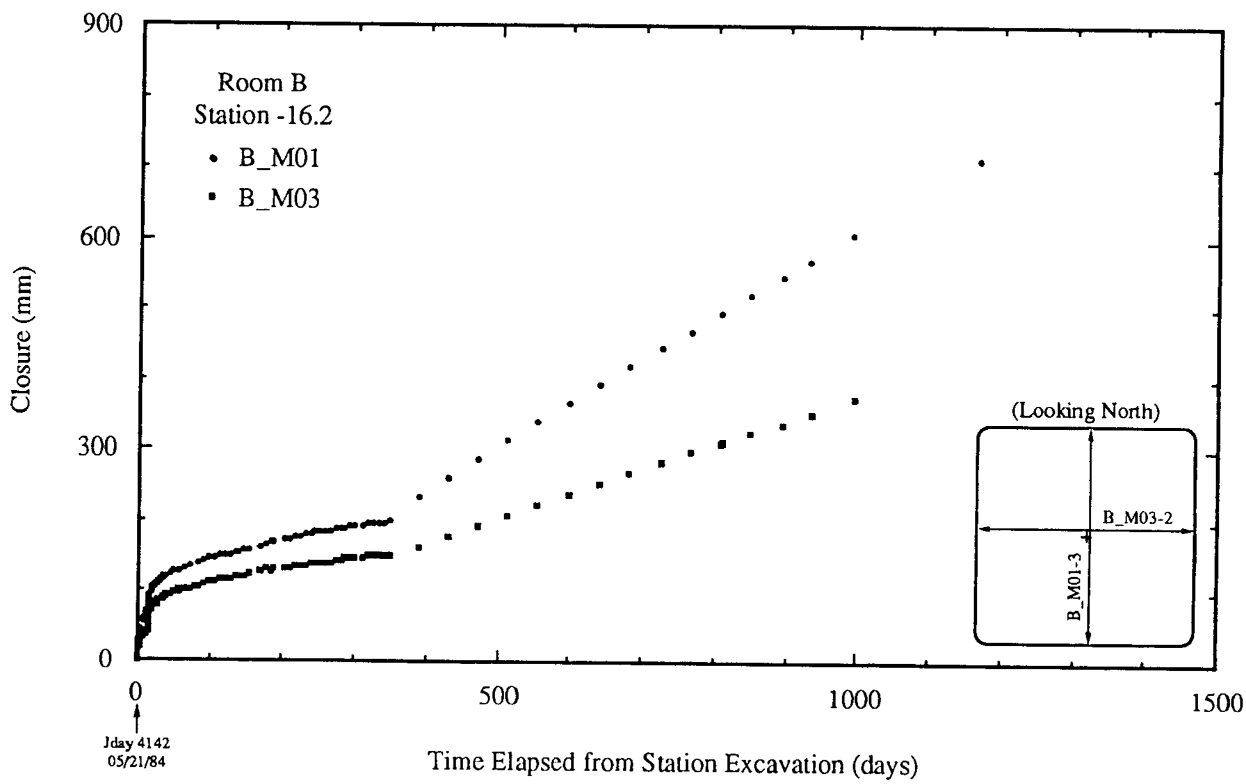


Figure 5.2.1a. Mining Sequence Gages B_M0x-x,. Room B, Station -16 m

Table 5.2.2b. Mining Sequence Gages B_M1x-x,. Room B, Station -01 m

B_M11 - B_M14 PI Comments

02/20/92 RLJ [96%] This set of Mining Sequence Closure Gages (2 vertical and 2 horizontal) was installed in the center of Room B. They were initially measured about 1 hour after the first mining machine pass. Early results (top graph) are typical for early data from other closure stations of similar geometry. Excavation effects can be clearly seen as bump like features that correspond to the mining of each pass. The Room B mining plan called for only three passes as opposed to the four pass plan in each "A" room. Gage disruption due to mining required a total of 7 reinstallations. Early data acquisition was interupted for 3 days because of a power outage. Long term data (bottom graph) clearly show a dramatic increase in closure subsequent to day 345 due to the start of room heating on that day. (DEM)

Gage Information

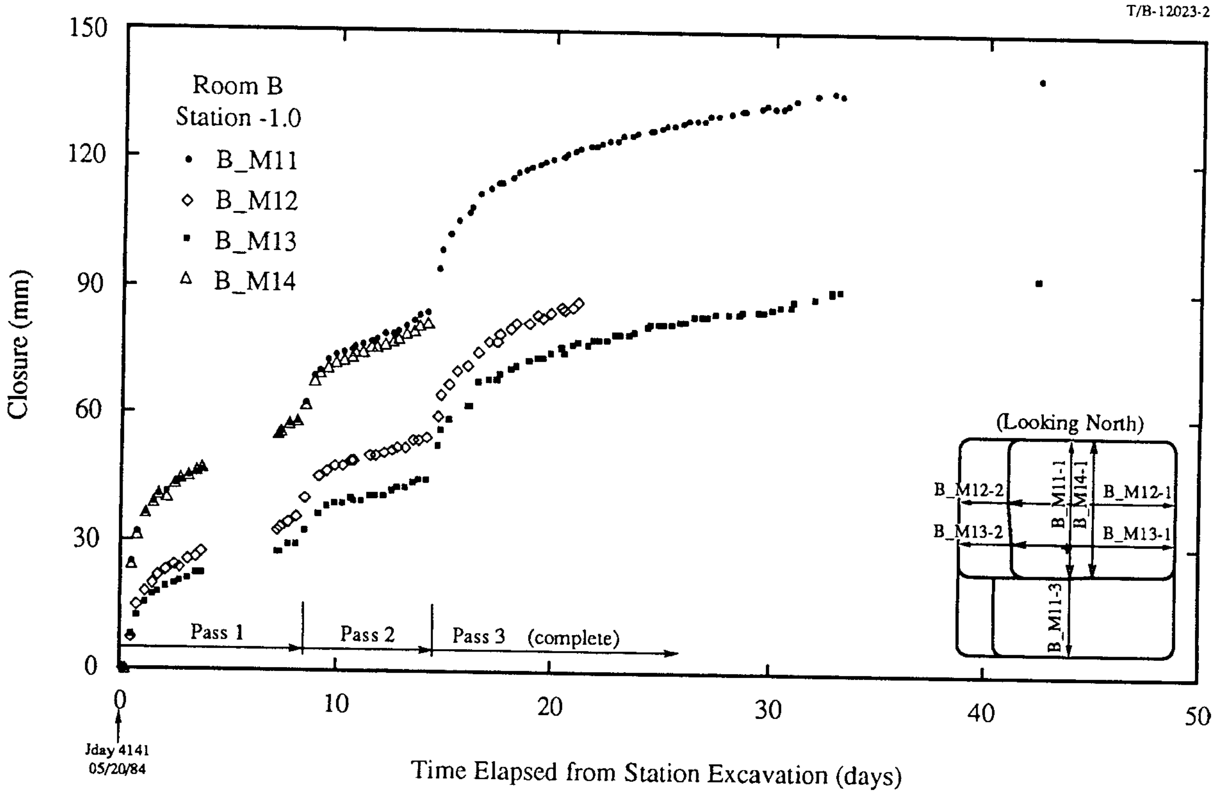
Gage Number	Gage Type	Gage Orient.	Record		Gage Manf.	Installation Date	Drawing Number
B_M11-1	CONV	V	T	MAN	SNL	5/12/84	T91025-000A
B_M11-3	CONV	V	T	MAN	SNL	5/26/84	T91025-000A
B_M12-1	CONV	H	T	MAN	SNL	5/12/84	T91025-000A
B_M12-2	CONV	H	T	MAN	SNL	5/20/84	T91025-000A
B_M13-1	CONV	H	T	MAN	SNL	5/12/84	T91025-000A
B_M13-2	CONV	H	T	MAN	SNL	5/20/84	T91025-000A
B_M14-1	CONV	V	T	MAN	SNL	5/12/84	T91025-000A

Gage Location

	Gage Coordinates							
					Local		Room	
Gage Number	X1 (m)	X2 (m)	Y1 (m)	Y2 (m)	Z1 (m)	Z2 (m)	Z1 (m)	Z2 (m)
B_M11-1	0.10	0.10	-1.03	-1.11	-0.75	2.64	-0.75	2.64
B_M11-3	0.10	0.10	-1.03	-1.11	-2.80	2.64	-2.80	2.64
B_M12-1	-1.50	2.77	-1.16	-1.16	1.08	1.08	1.08	1.08
B_M12-2	-2.78	2.77	-1.19	-1.16	1.07	1.08	1.07	1.08
B_M13-1	-1.41	2.76	-1.25	-1.25	0.05	0.05	0.05	0.05
B_M13-2	-2.73	2.76	-1.39	-1.25	0.02	0.05	0.02	0.05
B_M14-1	0.63	0.63	-1.11	-1.11	-0.74	2.64	-0.74	2.64

Gage Length Upon Installation

		Pass 1		Pass 2		Pass 3		Pass 4 + Trim -Final-	
Gage Number	Dir	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)
B M11	V	-1	3.39		--	-3	5.19	-3	5.53
B M13	H	-1	4.18	-2	5.58		--	-2	5.63
B M14	v	-1	3.38		--		xx		xx
B M12	h	-1	4.27	-2	5.69		--	-2	5.69



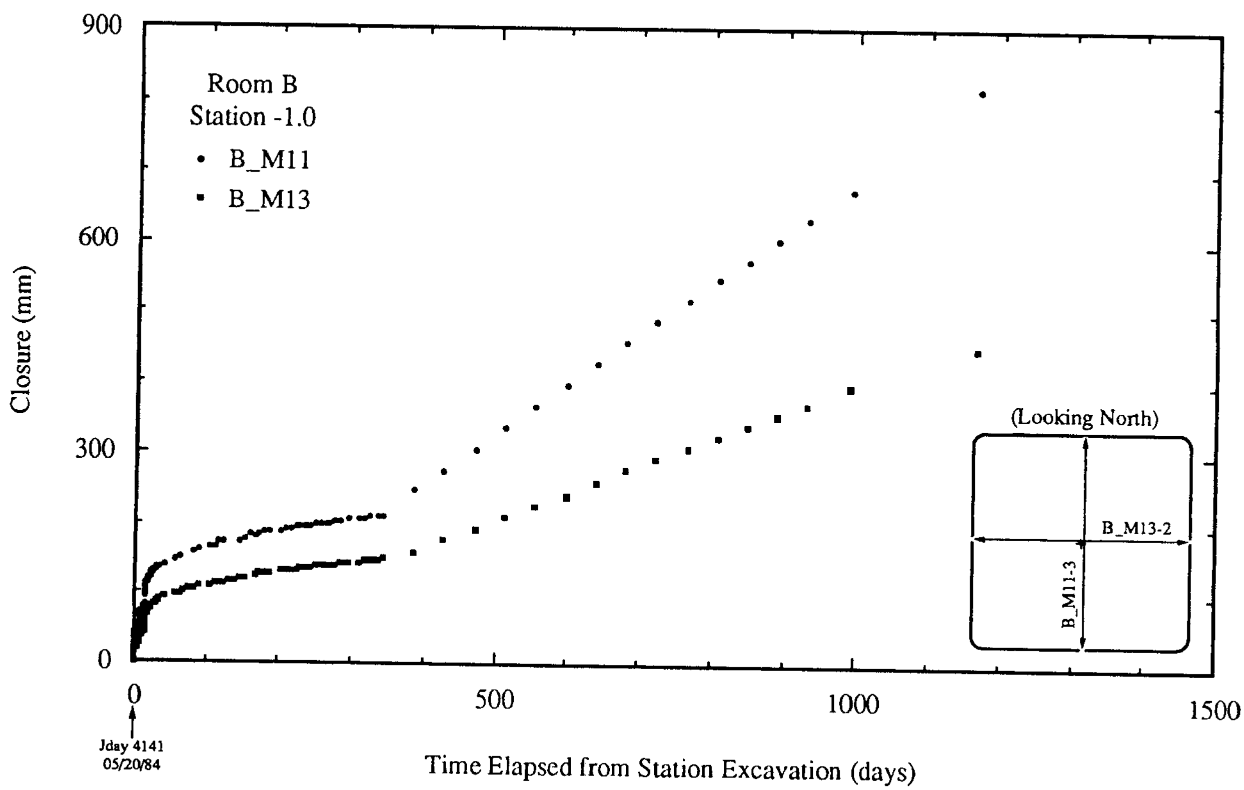


Figure 5.2.1b. Mining Sequence Gages B_M1x-x,. Room B, Station -01 m

Table 5.2.2c. Mining Sequence Gages B_M2x-x,. Room B, Station +14 m

B_M21 - B_M24 PI Comments

02/21/92 RLJ [96%] This set of Mining Sequence Closure Gages (2 vertical and 2 horizontal) was installed in the center of Room B. They were initially measured about 3 hours after the first mining machine pass. Early results (top graph) are typical for early data from other closure stations of similar geometry. Excavation effects can be clearly seen as bump like features that correspond to the mining of each pass. The Room B mining plan called for only three passes as opposed to the four pass plan in each "A" room. Gage disruption due to mining required a total of 7 reinstallations. Early data acquisition was interupted for 3 days because of a power outage. Long term data (bottom graph) clearly show a dramatic increase in closure subsequent to day 344 due to initiation of heating on that day. (DEM)

Gage Information

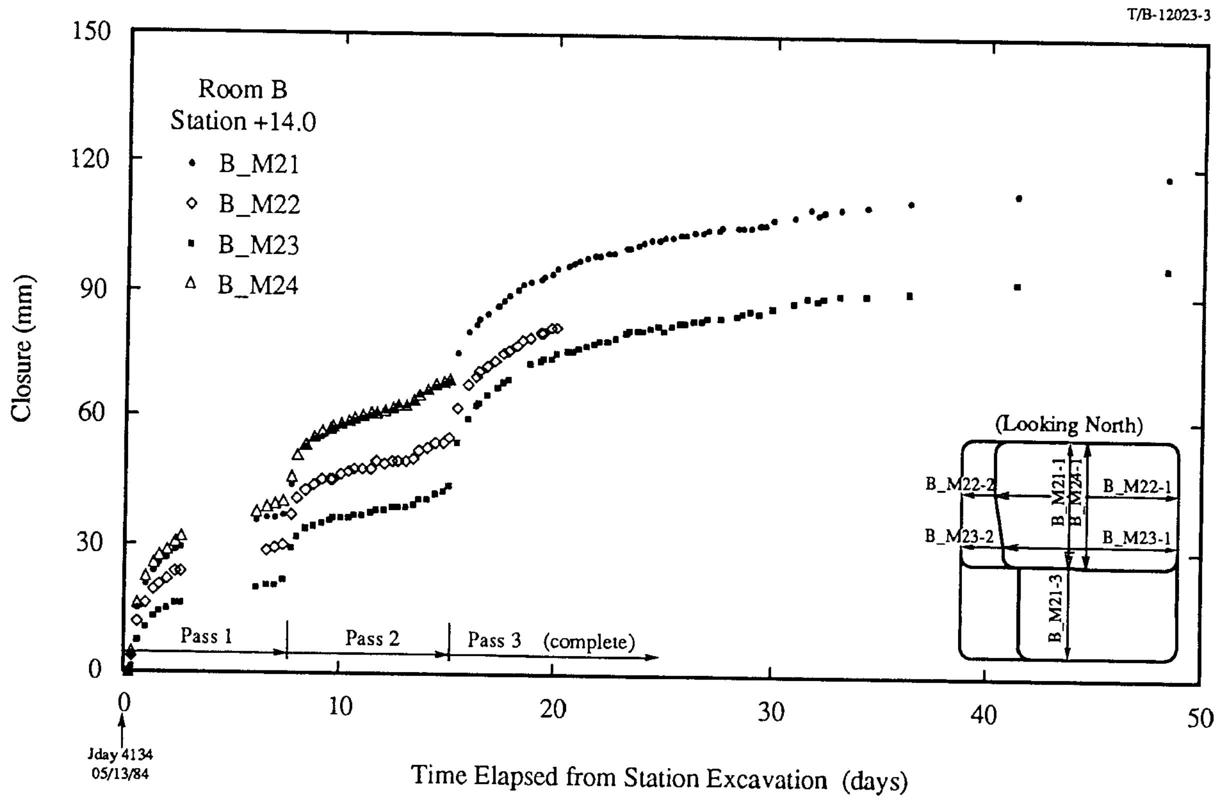
Gage Number	Gage Type	Gage Orient.	Record		Gage Manf.	Installation Date	Drawing Number
B_M21-1	CONV	V	T	MAN	SNL	5/13/84	T91025-000A
B_M21-3	CONV	V	T	MAN	SNL	5/28/84	T91025-000A
B_M22-1	CONV	H	T	MAN	SNL	5/13/84	T91025-000A
B_M22-2	CONV	H	T	MAN	SNL	5/21/84	T91025-000A
B_M23-1	CONV	H	T	MAN	SNL	5/13/84	T91025-000A
B_M23-2	CONV	H	T	MAN	SNL	5/21/84	T91025-000A
B_M24-1	CONV	V	T	MAN	SNL	5/13/84	T91025-000A

Gage Location

	Gage Coordinates							
					Local		Room	
Gage Number	X1 (m)	X2 (m)	Y1 (m)	Y2 (m)	Z1 (m)	Z2 (m)	Z1 (m)	Z2 (m)
B_M21-1	0.01	0.01	13.98	13.98	-0.42	2.74	-0.37	2.79
B_M21-3	-0.02	0.01	14.03	13.98	-2.75	2.74	-2.71	2.79
B_M22-1	-1.85	2.73	14.05	14.05	1.37	1.37	1.41	1.41
B_M22-2	-2.77	2.73	14.02	14.05	1.28	1.37	1.33	1.41
B_M23-1	-1.63	2.74	14.11	14.11	0.09	0.09	0.13	0.13
B_M23-2	-2.72	2.74	13.85	14.11	0.08	0.09	0.12	0.13
B_M24-1	0.44	0.44	13.98	13.98	-0.43	2.74	-0.38	2.79

Gage Length Upon Installation

		Pass 1		Pass 2		Pass 3		Pass 4 + Trim -Final-	
Gage Number	Dir	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)
B M21	V	-1	3.17		--	-3	5.29	-3	5.53
B M23	H	-1	4.36	-2	5.49		--	-2	5.57
B M24	v	-1	3.18		--		xx		xx
B M22	h	-1	4.58	-2	5.68		--	-2	5.68



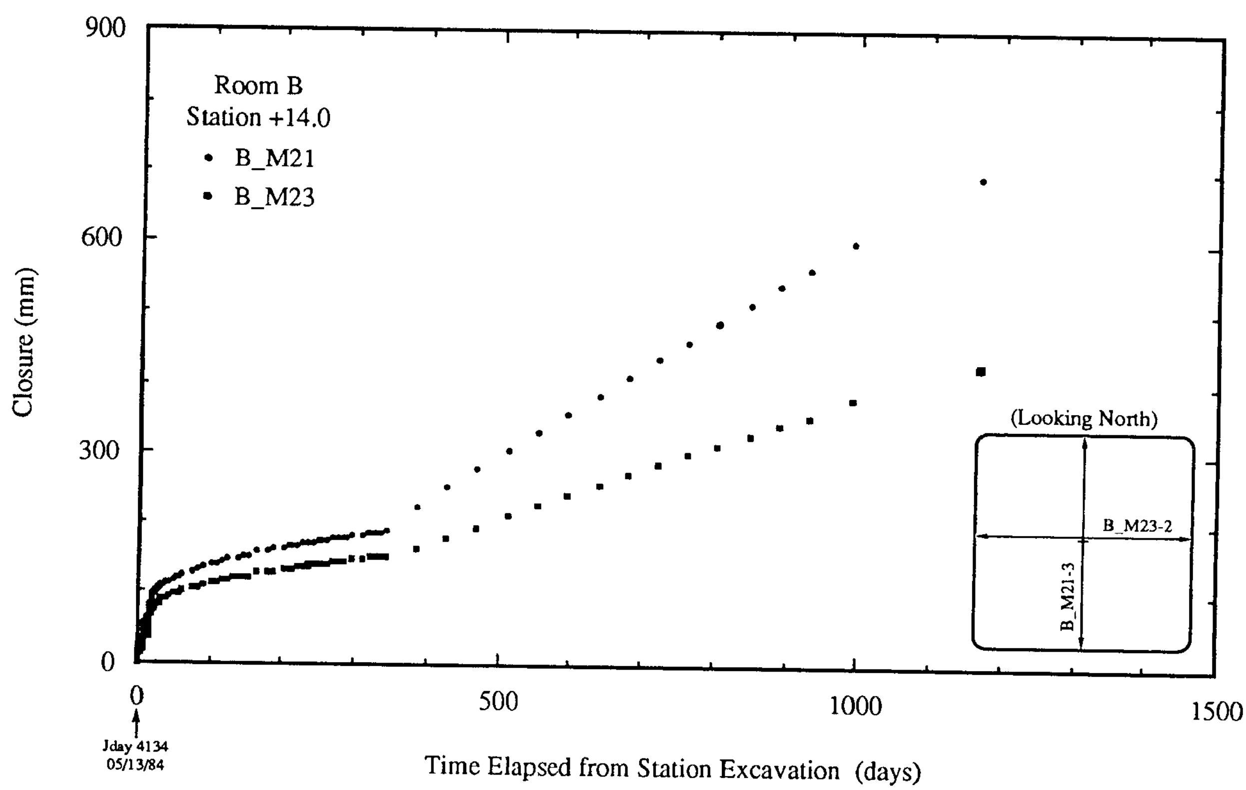


Figure 5.2.1c. Mining Sequence Gages B_M2x-x,. Room B, Station +14 m

5.3 Room D Mining Sequence Closure Data

The Mining Development Test which eventually developed in Room D was not a planned test, rather the room was planned only as a ventilation passage. However, it was soon realized the room offered potential for perfecting mining methods, contractor qualification exercises, and geotechnical crew training. In fact, the mining sequence gages that were installed during excavation of Room D as training for the geotechnical crews have become a significant source of data for the TSI program. Room D excavation started on the swing shift of 3/14/84 and was completed on the swing shift of 4/14/84. Room D is an unheated room. The room remains as an active test at the date of this report and will continue as long as the room can be maintained.

The location guide for the Room D mining sequence gages is given in Table 5.3.1. The table represents schematically the relative location of the gages at each principal station. The numerical designation of the gage can be used as a key to the station and orientation of the gage.

Mining sequence closure data are given in Tables 5.3.2a-c and plotted in Figures 5.3.1a-c.

A very detailed analysis of the mechanical response, including the complete details of the mining sequence closure, has been made by Munson et al. [18]. This Room D analysis provided the constitutive model and numerical methodology for all subsequent numerical analyses for the WIPP program. Room D has served as the baseline test room for comparison and evaluation of the heated Room B results [19] and heated multiple Rooms A results [24]. Variations in the accumulation of displacement between the different stations is to be expected. But, as previously noted in the case of the other similar rooms, the closure becomes essentially identical

Table 5.3.1. Room D Mining Sequence Closure Units (Gages) Location Guide

Station	Direction		Relative Location: west rib		center	pass 1	east rib
D ST-16	Vertical	roof			D_M01	D_M04	
	Horizontal	pass 1	-2	-1			D_M02
	Horizontal	mid	-2	-1			D_M03
					-1	-1	
	Vertical	floor			-3		
D ST-01	Vertical	roof			D_M11	D_M14	
	Horizontal	pass 1	-2	-1			D_M12
	Horizontal	mid	-2	-1			D_M13
					-1	-1	
	Vertical	floor			-3		
D ST009	Vertical	roof			D_M21	D_M24	
	Horizontal	pass 1	-2	-1			D_M22
	Horizontal	mid	-2	-1			D_M23
					-1	-1	
	Vertical	floor			-3		

for all the stations within a month of the completion of mining [16,23].

Because Room D is unheated, the long term closure history consists of a smooth curve of decreasing slope. Also, the close similarity of closure of Rooms A2, B, and D, which have identical cross sections, are seen to be completely uniform. This uniformity of behavior suggests that the layered salt response is well defined over the rather large distances separating these test rooms, or essentially location independent.

[text continues on page 136]

Table 5.3.2a. Mining Sequence Gages D_M0x-x, Room D, Station -16 m

D_M01 - D_M04 PI Comments

02/21/92 RLJ [96%] Installation of this set of Mining Sequence Closure Gages (2 vertical and 2 horizontal) resulted in the first early closure measurements made at WIPP. They were installed in the south half of Room D. The gages were initially measured within 3 hours after the first mining machine pass. Early results (top graph) are typical for early data from other closure stations of similar geometry. Excavation effects can be seen as bump like features that correspond to the mining of each pass. The data collected in Room D clearly show a "crossover" or tendancy for the midspan vertical gage to close more than a vertical gage located off center. D_M01 became the centermost gage with Pass 2 widening, therefore data from D_M01 reflects greater closure than data from D_M04. Gage disruption due to mining required a total of 5
0 reinstallations. Long term data (bottom graph) are quite smooth for this unheated room and appear unaffected by extensive roof bolting that occurred in September of 1987 (~ day 1250 - 1300). (DEM)

Gage Information

Gage Number	Gage Type	Gage Orient.	—— Record ——		Gage Manf.	Installation Date	Drawing Number
D_M01-1	CONV	V	T	MAN	SNL	3/19/84	T91025-000A
D_M01-3	CONV	V	T	MAN	SNL	4/8/84	T91025-000A
D_M02-1	CONV	H	T	MAN	SNL	3/19/84	T91025-000A
D_M02-2	CONV	H	T	MAN	SNL	3/26/84	T91025-000A
D_M03-1	CONV	H	T	MAN	SNL	3/19/84	T91025-000A
D_M03-2	CONV	H	T	MAN	SNL	3/26/84	T91025-000A
D_M04-1	CONV	V	T	MAN	SNL	3/19/84	T91025-000A

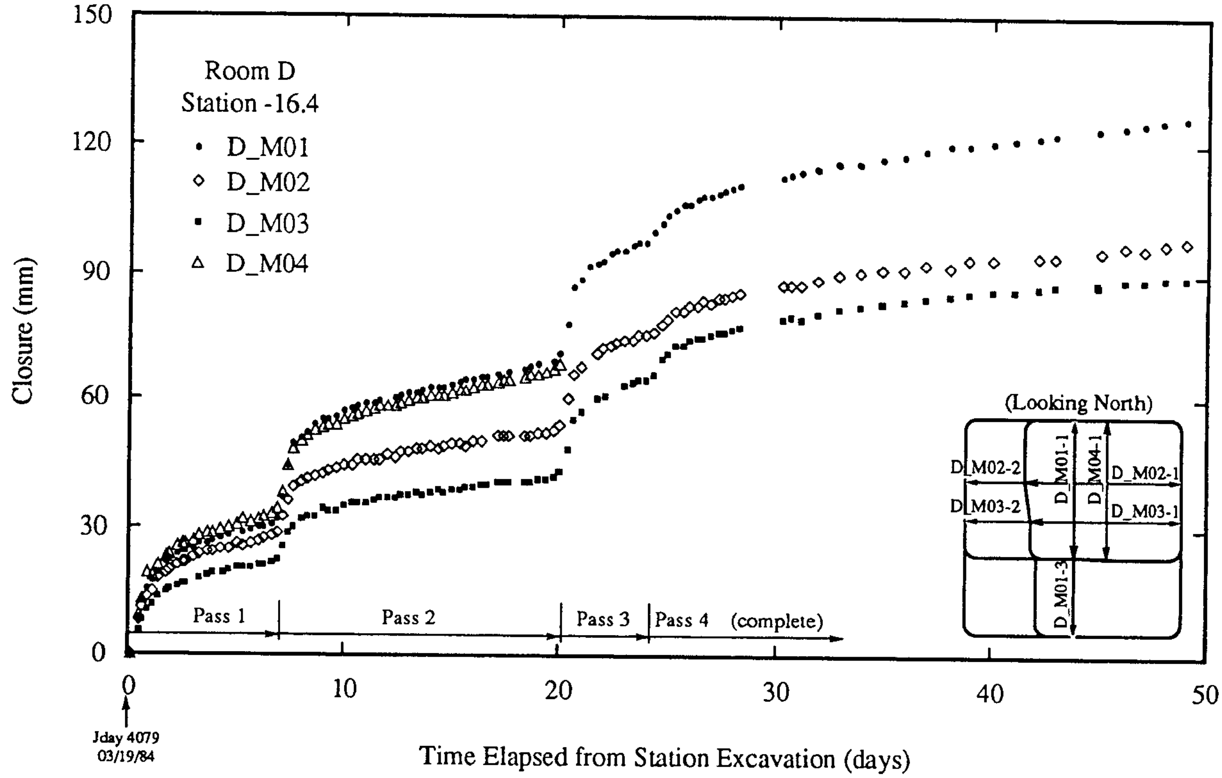
Gage Location

	Gage Coordinates							
					—— Local ——		—— Room ——	
Gage Number	X1 (m)	X2 (m)	Y1 (m)	Y2 (m)	Z1 (m)	Z2 (m)	Z1 (m)	Z2 (m)
D_M01-1	-0.03	-0.03	-16.47	-16.47	-0.77	2.68	-0.71	2.74
D_M01-3	0.00	-0.03	-16.60	-16.47	-2.68	2.68	-2.62	2.74
D_M02-1	-1.27	2.68	-16.57	-16.57	1.16	1.16	1.22	1.22
D_M02-2	-2.68	2.68	-16.32	-16.57	1.10	1.16	1.16	1.22
D_M03-1	-1.12	2.62	-16.60	-16.60	0.18	0.18	0.24	0.24
D_M03-2	-2.71	2.62	-16.29	-16.60	0.09	0.18	0.15	0.24
D_M04-1	0.79	0.79	-16.47	-16.47	-0.74	2.71	0.68	2.77

Gage Length Upon Installation

		Pass 1		Pass 2		Pass 3		Pass 4 + Trim -Final-	
Gage Number	Dir	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)
D M01	V	-1	3.45		--	-3	5.56	-3	5.56
D M03	H	-1	3.74	-2	5.42		--	-2	5.42
D M04	v	-1	3.46		--		xx		xx
D M02	h	-1	3.95	-2	5.53		--	-2	5.53

T/D-12024-1



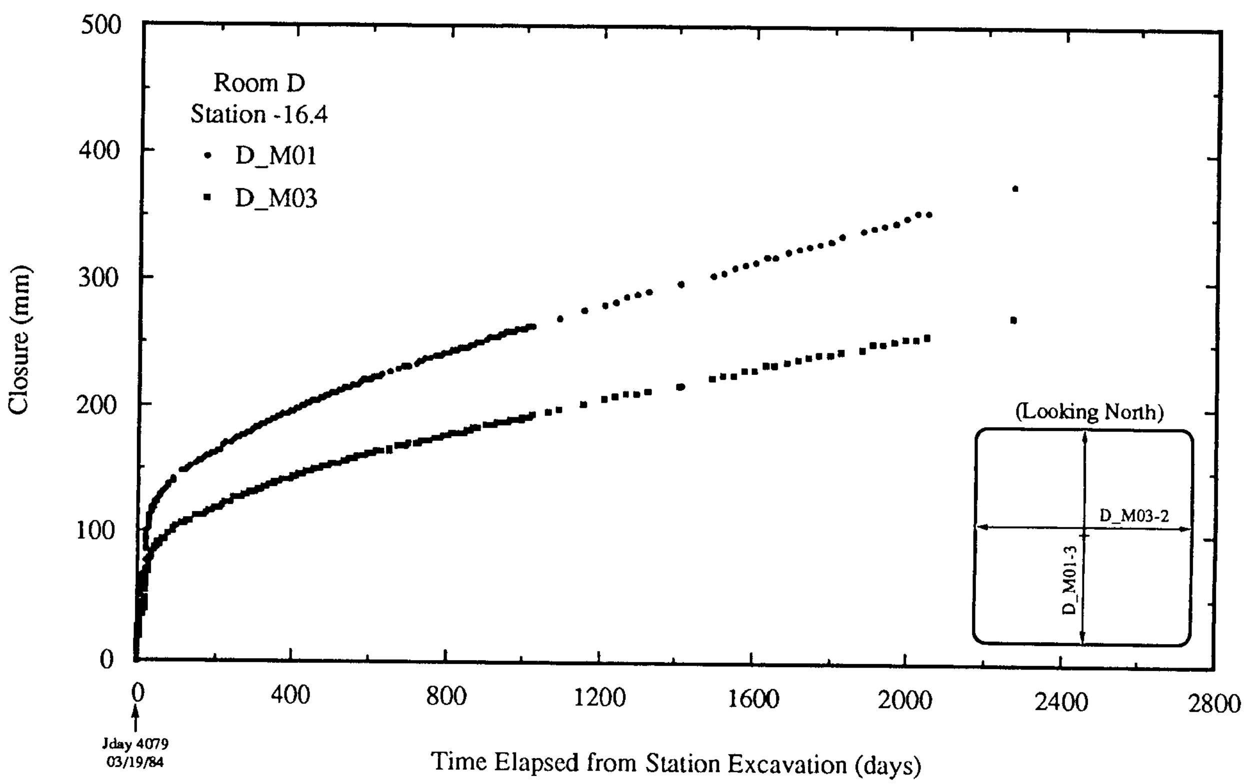


Figure 5.3.1a. Mining Sequence Gages D_M0x-x, Room D, Station -16 m

Table 5.3.2b. Mining Sequence Gages D_M1x-x, Room D, Station -01 m

D_M11 - D_M14 PI Comments

02/24/92 RLJ [96%] Installation of this set of Mining Sequence Closure Gages (2 vertical and 2 horizontal) resulted in the first early closure measurements made at WIPP. They were installed in the center of Room D. The gages were measured within 4 hours after the firat mining machine pass. Early results (top graph) are typical for early data from other closure stations of similar geometry. Excavation effects can be seen as bump like features that correspond to the mining of each pass. The data collected in Room D clearly show a "crossover" or tendancy for the midspan vertical gage to close more than a vertical gage located off center. D_M11 became the centermost gage with Pass 2 widening, therefore data from D_M11 reflects greater closure than data from D_M14. Gage disruption due to mining required a total of 5 reinstallations. Long term data (bottom graph) are quite smooth for this unheated room and appear unaffected by the extensive roof bolting that occurred in September of 1987 (~ day 1250 - 1300). (DEM)

Gage Information

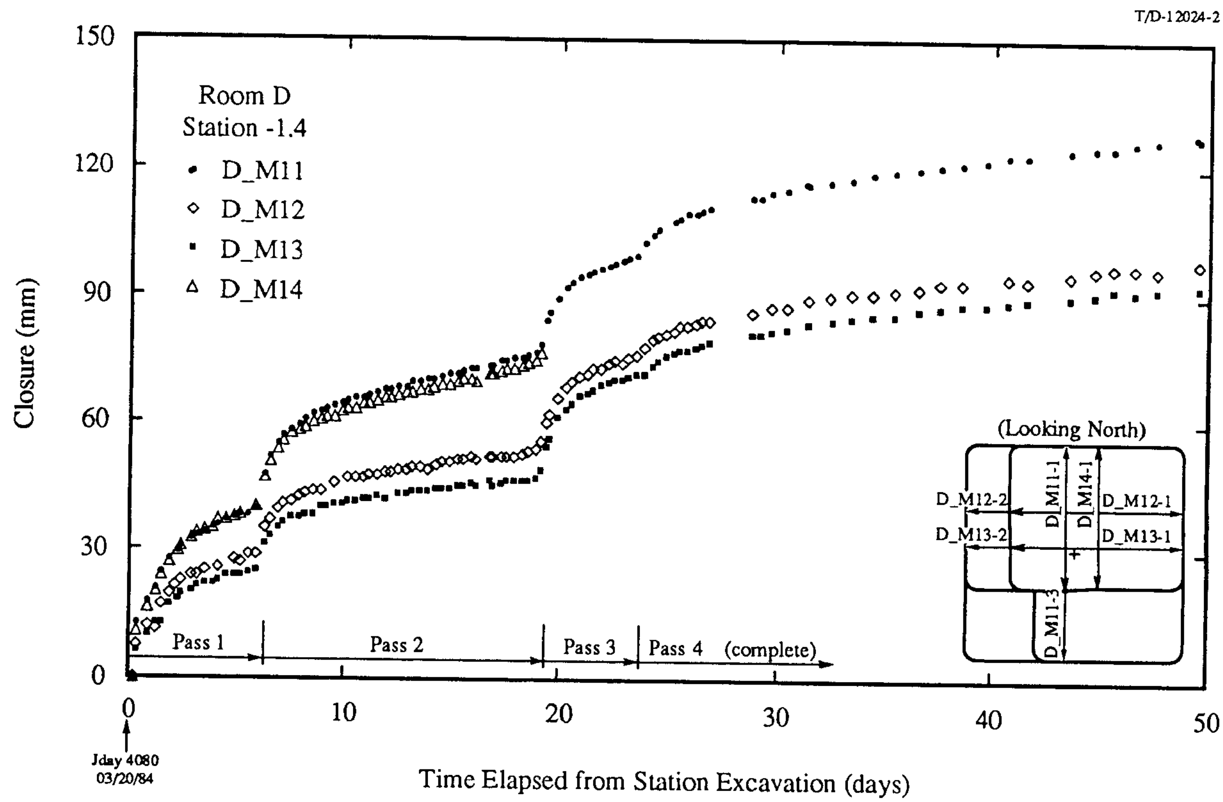
Gage Number	Gage Type	Gage Orient.	—— Record ——		Gage Manf.	Installation Date	Drawing Number
D_M11-1	CONV	V	T	MAN	SNL	3/20/84	T91025-000A
D_M11-3	CONV	V	T	MAN	SNL	4/8/84	T91025-000A
D_M12-1	CONV	H	T	MAN	SNL	3/20/84	T91025-000A
D_M12-2	CONV	H	T	MAN	SNL	3/26/84	T91025-000A
D_M13-1	CONV	H	T	MAN	SNL	3/20/84	T91025-000A
D_M13-2	CONV	H	T	MAN	SNL	3/26/84	T91025-000A
D_M14-1	CONV	V	T	MAN	SNL	3/20/84	T91025-000A

Gage Location

	Gage Coordinates							
					—— Local ——		—— Room ——	
Gage Number	X1 (m)	X2 (m)	Y1 (m)	Y2 (m)	Z1 (m)	Z2 (m)	Z1 (m)	Z2 (m)
D_M11-1	-0.21	-0.21	-1.39	-1.39	-0.97	2.77	-0.97	2.77
D_M11-3	-0.18	-0.21	-1.48	-1.39	-2.80	2.77	-2.80	2.77
D_M12-1	-1.66	2.74	-1.11	-1.11	1.04	1.04	1.04	1.04
D_M12-2	-2.68	2.74	-1.54	-1.11	1.01	1.04	1.01	1.04
D_M13-1	-1.62	2.68	-1.14	-1.14	0.12	0.12	0.12	0.12
D_M13-2	-2.68	2.68	-1.54	-1.14	0.12	0.12	0.12	0.12
D_M14-1	0.58	0.58	-1.39	-1.39	-0.92	2.80	-0.92	2.80

Gage Length Upon Installation

		Pass 1		Pass 2		Pass 3		Pass 4 + Trim -Final-	
Gage Number	Dir	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)
D M11	V	-1	3.74		--	-3	5.69	-3	5.69
D M13	H	-1	4.31	-2	5.53		--	-2	5.53
D M14	v	-1	3.72		--		xx		xx
D M12	h	-1	4.40	-2	5.57		--	-2	5.57



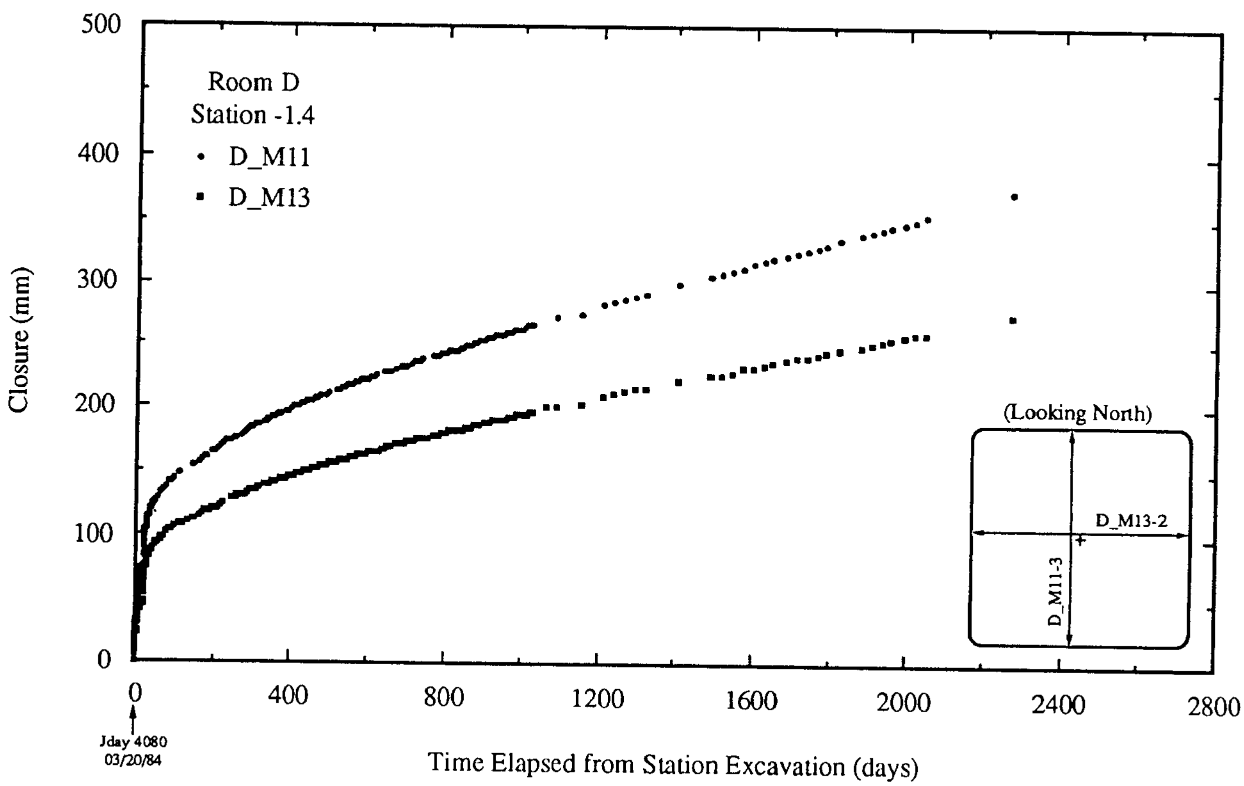


Figure 5.3.1b. Mining Sequence Gages D_M1x-x, Room D, Station -01 m

Table 5.3.2c. Mining Sequence Gages D_M2x-x, Room D, Station +09 m

D_M21 - D_M24 PI Comments

02/24/92 RLJ [97%] Installation of this set of Mining Sequence Closure Gages (2 vertical and 2 horizontal) resulted in the first early closure measurements made at WIPP. They were installed in the north half of Room D. The gages were measured within 3 hours after the first mining machine pass. Early results (top graph) are typical for early data from other closure stations of similar geometry. Excavation effects can be seen as bump like features that correspond to the mining of each pass. The data collected in Room D clearly show a "crossover" or tendancy for the midspan vertical gage to close more than a vertical gage located off center. D_M21 became the centermost gage with Pass 2 widening, therefore data from D_M21 reflects greater closure than data from D_M24. Gage disruption due to mining required a total of 9 reinstallations. Long term data (bottom graph) are quite smooth for this unheated room and appear unaffected by the extensive roof bolting that occurred in September of 1987 (~ day 1250 - 1300). (DEM)

Gage Information

Gage Number	Gage Type	Gage Orient.	Record		Gage Manf.	Installation Date	Drawing Number
D_M21-1	CONV	V	T	MAN	SNL	3/22/84	T91025-000A
D_M21-3	CONV	V	T	MAN	SNL	4/9/84	T91025-000A
D_M22-1	CONV	H	T	MAN	SNL	3/22/84	T91025-000A
D_M22-2	CONV	H	T	MAN	SNL	3/27/84	T91025-000A
D_M23-1	CONV	H	T	MAN	SNL	3/22/84	T91025-000A
D_M23-2	CONV	H	T	MAN	SNL	3/27/84	T91025-000A
D_M24-1	CONV	V	T	MAN	SNL	3/22/84	T91025-000A

Gage Location

	Gage Coordinates							
					Local		Room	
Gage Number	X1 (m)	X2 (m)	Y1 (m)	Y2 (m)	Z1 (m)	Z2 (m)	Z1 (m)	Z2 (m)
D_M21-1	-0.15	-0.15	9.37	9.37	-0.97	2.76	-1.08	2.65
D_M21-3	-0.12	-0.15	9.34	9.37	-2.76	2.76	-2.87	2.65
D_M22-1	-1.92	2.71	9.31	9.31	1.05	1.05	0.94	0.94
D_M22-2	-2.74	2.71	9.28	9.31	0.78	1.05	0.67	0.94
D_M23-1	-1.70	2.71	9.28	9.28	0.17	0.17	0.06	0.06
D_M23-2	-2.74	2.71	9.34	9.28	0.08	0.17	-0.03	0.06
D_M24-1	0.37	0.37	9.37	9.37	-1.01	2.76	-1.12	2.65

Gage Length Upon Installation

		Pass 1		Pass 2		Pass 3		Pass 4 + Trim -Final-	
Gage Number	Dir	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)
D M21	V	-1	3.73		--	-3	5.64	-3	5.64
D M23	H	-1	4.41	-2	5.55		--	-2	5.55
D M24	v	-1	3.77		--		xx		xx
D M22	h	-1	4.63	-2	5.65		--	-2	5.65

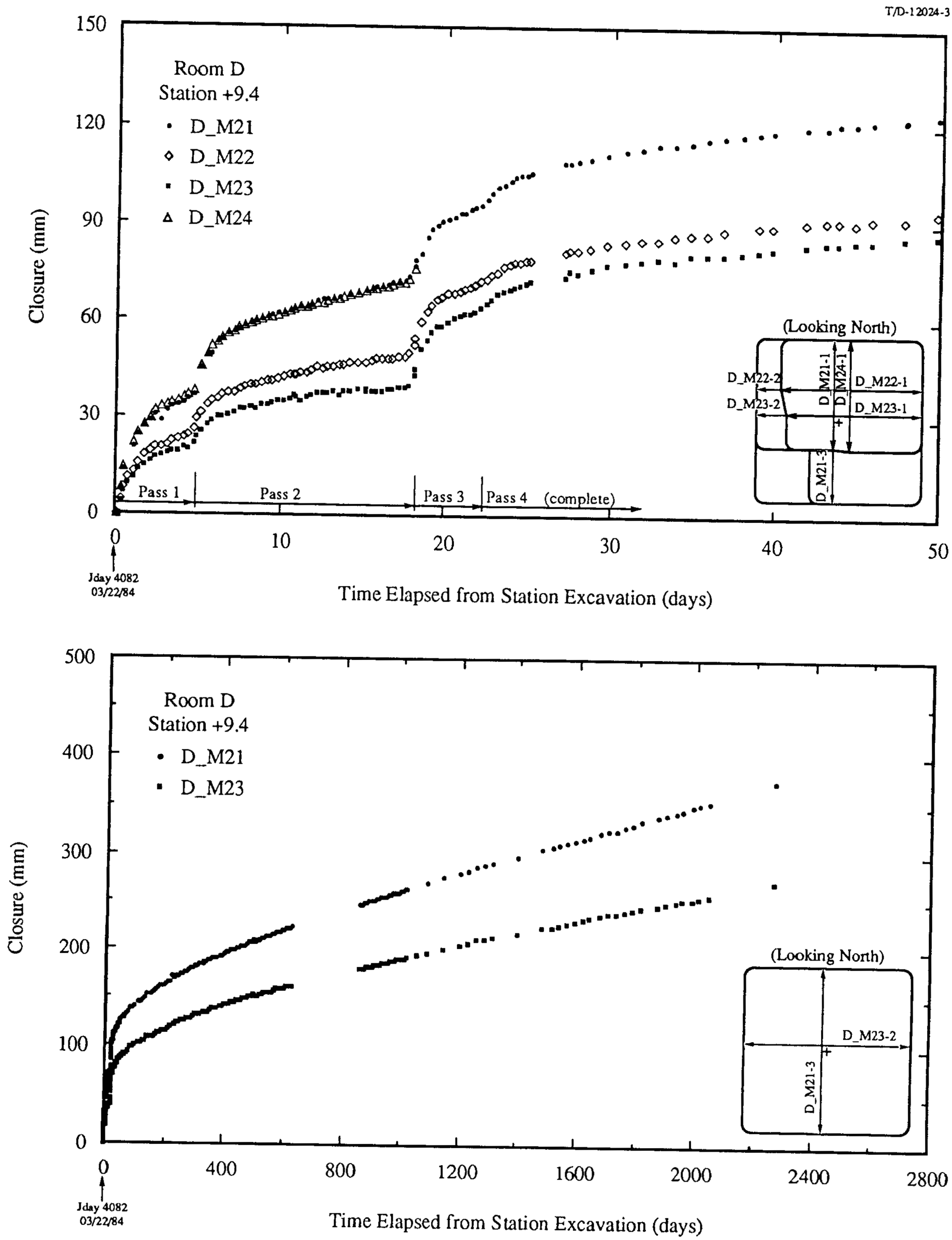


Figure 5.3.1c. Mining Sequence Gages D_M2x-x, Room D, Station +09 m

5.4 Room G Mining Sequence Closure Data

The Geomechanical Evaluation Test is the test fielded in Room G. As initially planned, this was to be a multiphase test involving a long, isolated drift (test room), a long cross-drift with a yield pillar, and subsequent widening of some drifts. All of these were to be unheated. Only the first phase, the excavation of the long test room was completed. At this point in time, there is no plan to field the other phases of the test. The intent of the long test room is to provide a test that conforms closely to a two-dimensional test configuration so that no simplifying assumptions are required to simulate the test numerically in our common two-dimensional structural codes. The excavation of Room G started on the swing shift of 11/9/84 and was completed on the swing shift of 1/4/85. The room remains as an active test as of the date of this report, and will continue as long as the room can be maintained.

The location guide for the gages in Room G is given in Table 5.4.1. The table presents schematically the relative gage positions in the test room. The numerical designation of the gage can be used as a key to the location and orientation of the gage.

Mining sequence closure gage information is given in Tables 5.4.2a-c and gage data are plotted in Figures 5.4.1a-c.

Because of the simplicity of the room excavation, the mining sequence data are straightforward. The closure response of the three stations are essentially identical, except for the minor differences because of the slight differences in pass dimensions and timing of the mining sequence from one station to another.

Although Room G has not been specifically analyzed, preliminary calculational results have been presented as part of more general

Table 5.4.1. Room G Mining Sequence Closure Units (Gages) Location Guide

Station	Direction		so.rib	pass 1	center	no.rib
			Relative Location			
GAST+46	Vertical	roof		GAM04	GAM01	
	Horizontal	mid	GAM02			-1
	Vertical	floor		-1	-1	
GDST-01	Vertical	roof		GDM14	GDM11	
	Horizontal	mid	GDM12			-1
	Vertical	floor		-1	-1	
GBST-74	Vertical	roof		GBM24	GBM21	
	Horizontal	mid	GBM22			-1
	Vertical	floor		-1	-1	

discussions of predictive technology validation [25]. Because the floor of this test room is just above a massive anhydrite bed (MB139) which is, as yet, not well characterized mechanically, additional analysis work remains to be done for Room G.

The Room G remotely collected mechanical data are presented in a separate report [6]. Use of the mining sequence data in conjunction with the remotely collected data give a complete closure history.

[text continues on page 144]

Table 5.4.2a. Mining Sequence Gages GAM0x-x, Room G, Station +46 m

GAM01 - GAM04 PI Comments

02/28/92 RLJ [97%] This set of Mining Sequence Closure Gages (2 vertical and 1 horizontal) was installed in the east portion of Room G. They were initially measured about 3 hours after the first mining machine pass. Early results (top graph) differ in closure magnitude and slope from data recorded in the 5.5 x 5.5 m rooms. The difference between horizontal and vertical closure is not nearly as pronounced in Room G probably because of a width to height ratio of 2:1. Excavation effects are barely discernable because pass 2 followed pass 1 by only 2.3 days and because of the simple 2 pass mining scheme. Gage disruption due to mining required only 3 reinstallations. Long term data (bottom graph) acquisition was suspended for nearly a year because of restrictions in room access to permit roof bolting and other ground control measures. This suspension is seen as a gap in the plot starting at day 1967. (DEM)

Gage Information

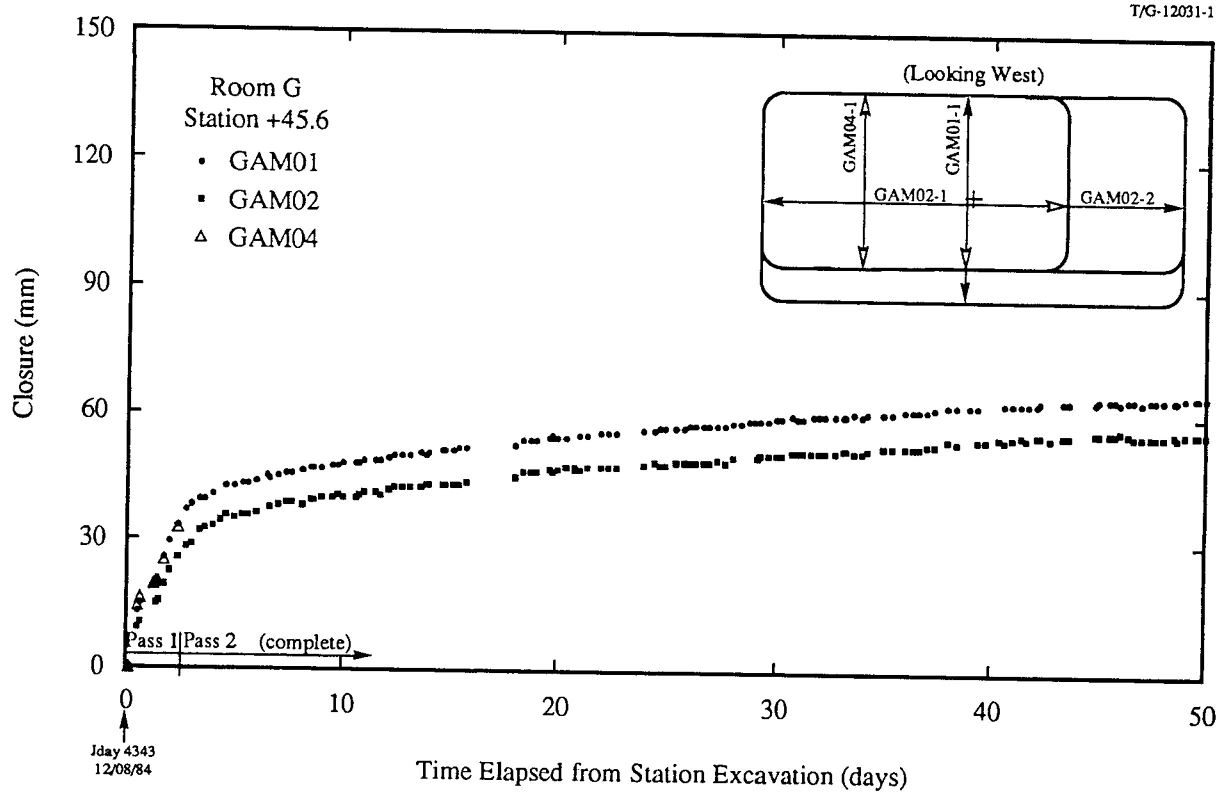
Gage Number	Gage Type	Gage Orient.	Record		Gage Manf.	Installation Date	Drawing Number
GAM01-1	CONV	V	T	MAN	SNL	12/8/84	T91025-000A
GAM02-1	CONV	H	T	MAN	SNL	12/8/84	T91025-000A
GAM02-2	CONV	H	T	MAN	SNL	12/10/84	T91025-000A
GAM04-1	CONV	V	T	MAN	SNL	12/8/84	T91025-000A

Gage Location

	Gage Coordinates							
					Local		Room	
Gage Number	X1 (m)	X2 (m)	Y1 (m)	Y2 (m)	Z1 (m)	Z2 (m)	Z1 (m)	Z2 (m)
GAM01-1	45.55	45.55	-0.08	-0.08	-1.56	1.46	-1.11	1.91
GAM02-1	45.60	45.60	-2.97	1.39	-0.10	-0.10	0.35	0.35
GAM02-2	45.60	45.60	-2.97	2.97	-0.10	-0.04	0.35	0.41
GAM04-1	45.58	45.58	-1.58	-1.58	-1.05	1.53	-0.61	1.98

Gage Length Upon Installation

		Pass 1		Pass 2		Pass 3		Pass 4 + Trim -Final-	
Gage Number	Dir	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)
GAM01	V	-1	2.58		--		None	-1	3.09
GAM03	H	-1	3.37	-2	6.16		None	-2	6.16
GAM04	v	-1	2.58		--		None		xx



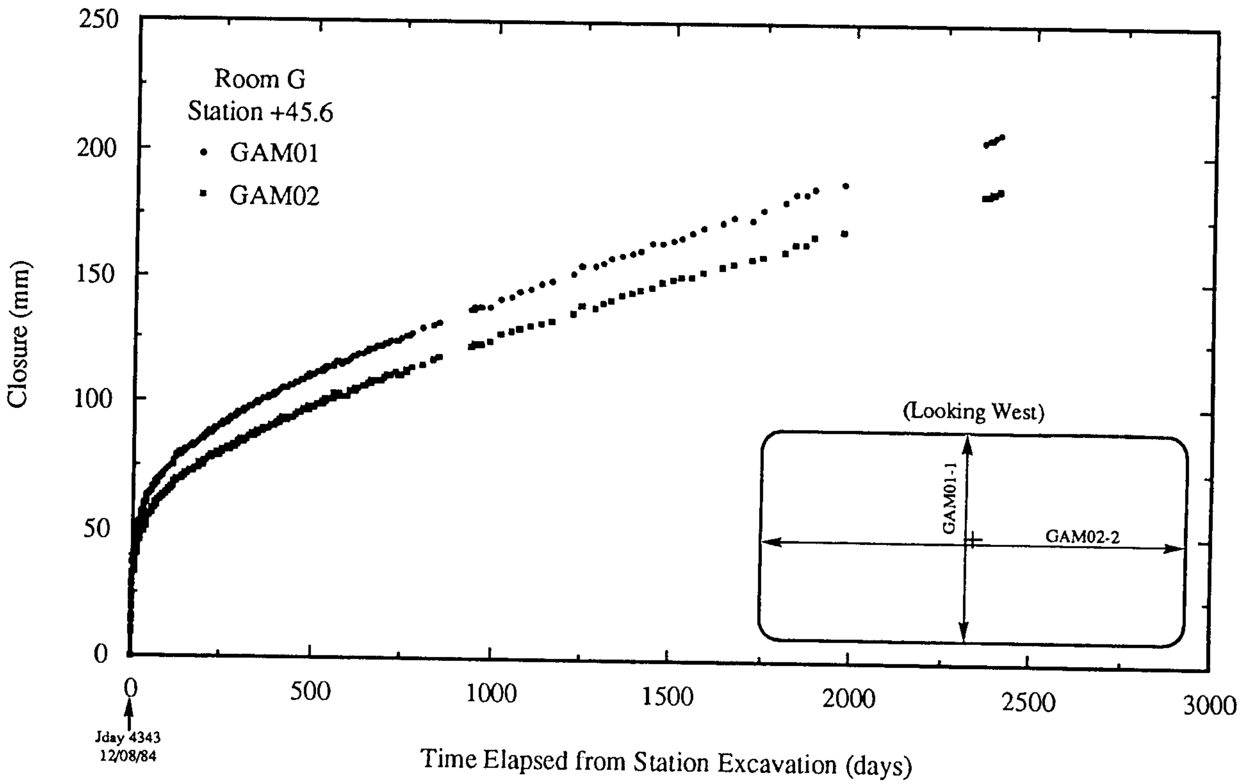


Figure 5.4.1a. Mining Sequence Gages GAM0x-x, Room G, Station +46 m

Table 5.4.2b. Mining Sequence Gages GDM1x-x, Room G, Station -01 m

GDM11 - GDM14 PI Comments

02/28/92 RLJ [98%] This set of Mining Sequence Closure Gages (2 vertical and 1 horizontal) was installed in the center portion of Room G. They were initially measured less than 1 hour after the first mining machine pass. Early results (top graph) differ in closure magnitude and slope from data recorded in the 5.5 x 5.5 m rooms. The difference between horizontal and vertical closure is not nearly as pronounced in Room G probably because of a width to height ratio of 2:1. Gage disruption due to mining required 4 reinstallations. Long term data (bottom graph) acquisition was suspended for nearly a year because of limitations to room access to permit roof bolting and other ground control measures. This suspension is seen as a gap in the plot starting at day 1963. (DEM)

Gage Information

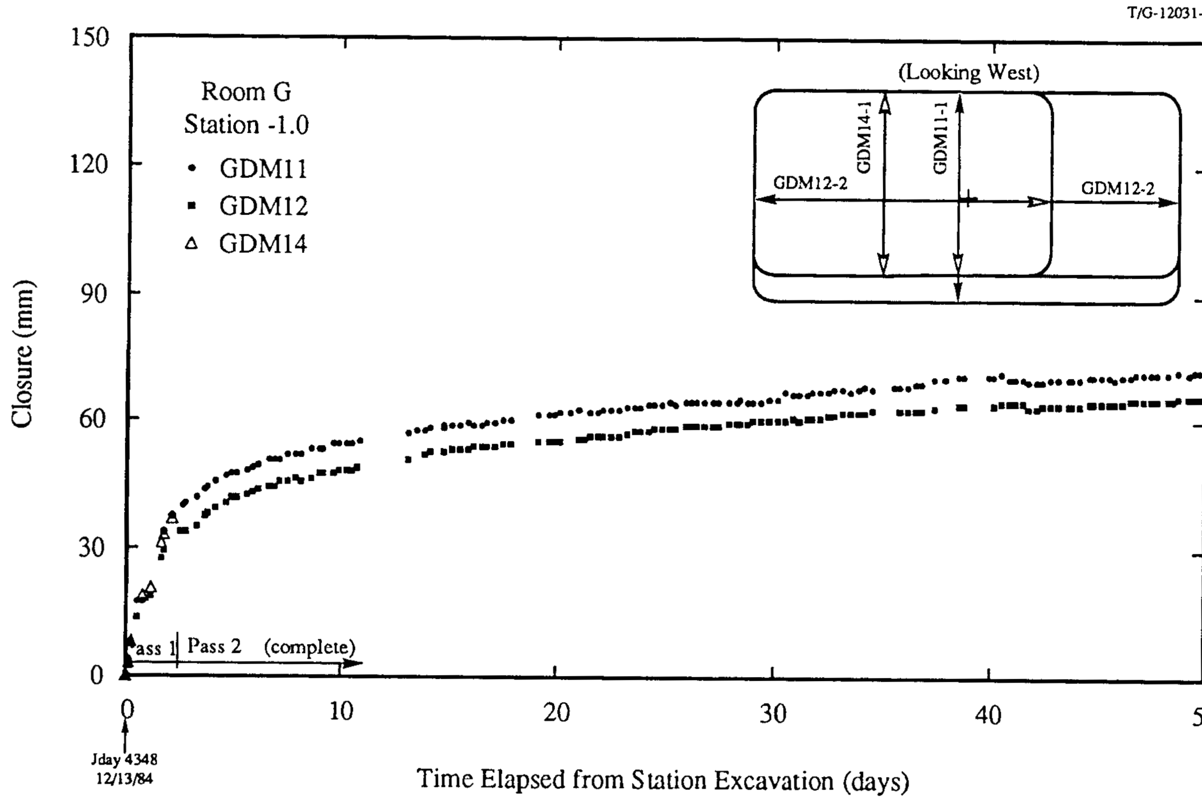
Gage Number	Gage Type	Gage Orient.	Record		Gage Manf.	Installation Date	Drawing Number
GDM11-1	CONV	V	T	MAN	SNL	12/13/84	T91025-000A
GDM12-1	CONV	H	T	MAN	SNL	12/13/84	T91025-000A
GDM12-2	CONV	H	T	MAN	SNL	12/14/84	T91025-000A
GDM14-1	CONV	V	T	MAN	SNL	12/13/84	T91025-000A

Gage Location

	Gage Coordinates				Local		Room	
Gage Number	X1 (m)	X2 (m)	Y1 (m)	Y2 (m)	Z1 (m)	Z2 (m)	Z1 (m)	Z2 (m)
GDM11-1	-1.06	-1.03	-0.11	-0.11	-1.48	1.53	-1.51	1.51
GDM12-1	-1.00	-1.00	-3.03	1.19	-0.05	-0.05	-0.08	-0.08
GDM12-2	-1.00	-1.09	-3.03	2.97	-0.05	-0.05	-0.08	-0.08
GDM14-1	-1.06	-1.06	-1.23	-1.23	-1.16	1.57	-1.19	1.55

Gage Length Upon Installation

		Pass 1		Pass 2		Pass 3		Pass 4 + Trim -Final-	
Gage Number	Dir	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)
GDM11	V	-1	2.52		--		None	-1	3.06
GDM13	H	-1	4.23	-2	6.18		None	-2	6.18
GDM14	v	-1	2.52		--		None		xx



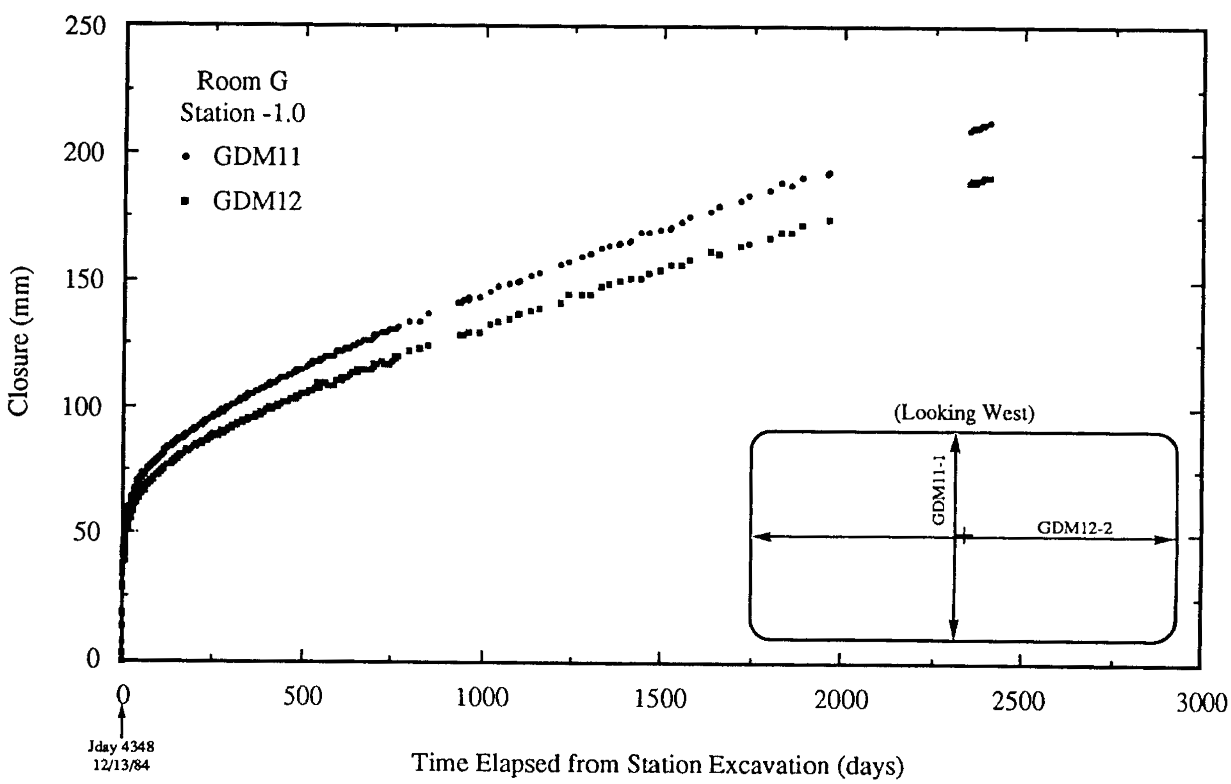


Figure 5.4.1b. Mining Sequence Gages GDM1x-x, Room G, Station -01 m

Table 5.4.2c. Mining Sequence Gages GBM2x-x, Room G, Station -74 m

GBM21 - GBM24 PI Comments

02/28/92 RLJ [96%] This set of Mining Sequence Closure Gages (2 vertical and 1 horizontal) was installed in the west portion of Room G. They were initially measured about 4 hours after the first mining machine pass. Early results (top graph) differ in closure magnitude and slope from data recorded in the 5.5 x 5.5 m rooms. The difference between horizontal and vertical closure is not nearly as pronounced in Room G probably because of a width to height ratio of 2:1. Gage disruption due to mining required 6 reinstallations. Long term data (bottom graph) acquisition was suspended for nearly a year because of restrictions in room access to permit roof bolting and other ground control measures. This suspension is seen as a gap in the plot starting at day 1948. (DEM)

Gage Information

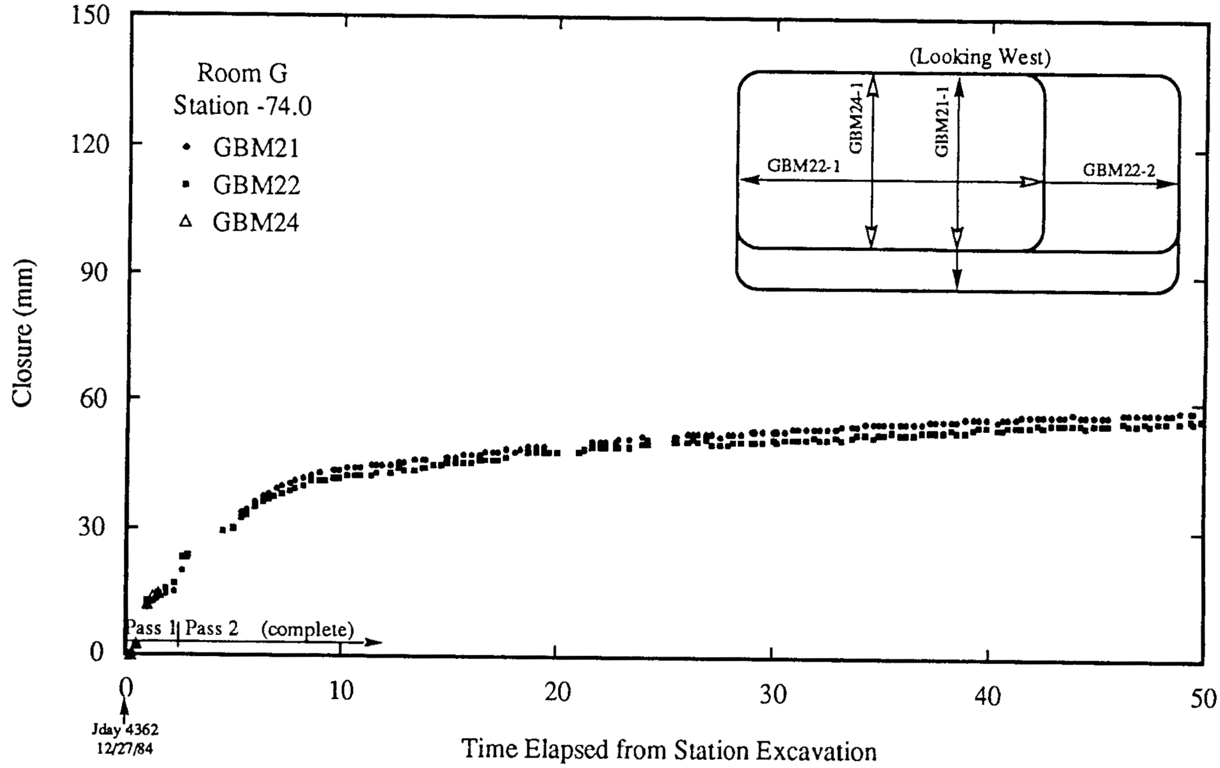
Gage Number	Gage Type	Gage Orient.	Record		Gage Manf.	Installation Date	Drawing Number
GBM21-1	CONV	V	T	MAN	SNL	12/28/84	T91025-000A
GBM22-1	CONV	H	T	MAN	SNL	12/28/84	T91025-000A
GBM22-2	CONV	H	T	MAN	SNL	12/28/84	T91025-000A
GBM24-1	CONV	V	T	MAN	SNL	12/28/84	T91025-000A

Gage Location

	Gage Coordinates							
					Local		Room	
Gage Number	X1 (m)	X2 (m)	Y1 (m)	Y2 (m)	Z1 (m)	Z2 (m)	Z1 (m)	Z2 (m)
GBM21-1	-74.24	-74.21	0.02	-0.02	-1.48	1.57	-1.33	1.72
GBM22-1	-74.00	-74.00	-3.03	1.19	0.04	0.04	0.20	0.20
GBM22-2	-74.00	-74.15	-3.03	2.94	0.04	-0.05	0.20	0.11
GBM24-1	-74.24	-74.24	-1.23	-1.23	-0.96	1.57	-0.80	1.72

Gage Length Upon Installation

		Pass 1		Pass 2		Pass 3		Pass 4 + Trim -Final-	
Gage Number	Dir	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)
GBM21	V	-1	2.74		--		None	-1	3.06
GBM23	H	-1	4.36	-2	6.18		None	-2	6.18
GBM24	v	-1	2.73		--		None		xx



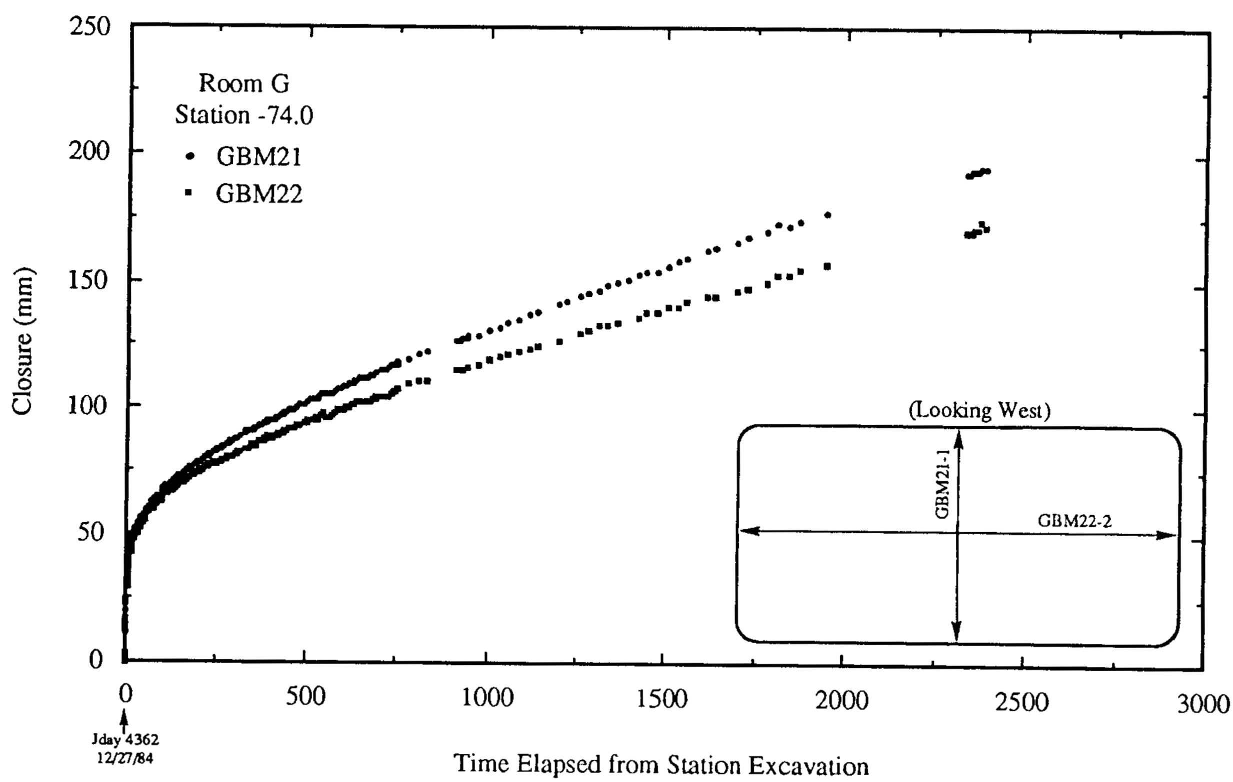


Figure 5.4.1c. Mining Sequence Gages GBM2x-x, Room G, Station -74 m

5.5 Room H Mining Sequence Closure Data

The Heated Axisymmetric Pillar Test (Room H) is a unique configuration which conforms to the two-dimensional constraints of the most commonly used numerical codes. Thus, the test could be modeled exactly in the codes. The test room was excavated in two stages: First, the single pass mining of the room access drift started on the swing shift of 4/16/84 and ended on the day shift of 4/21/84. Second, the test room was excavated as an annulus around the central pillar in three passes and two major rib or pillar trims and three major floor trims, beginning on the swing shift of 1/24/85 and ending on the graveyard shift of 2/13/85. The room remains active at the time of this report and will continue as long as possible.

The location guides for the mining sequence gages in Room H and for the temporary closure gages in the Room H access drift are given in Table 5.5.1. This table presents schematically the relative gage positions in the test room and access drift. The numerical designation of the gage can be used as an indication of the location and orientation of the gage.

Mining sequence closure gage information for Room H entry is given in Table 5.5.2 and Figure 5.5.1 and for Room H proper in Tables 5.5.3a-c and in Figures 5.5.2a-c.

Heating of the pillar began on 2/13/86, some 364 days after completion of room excavation and 662 days after completion of the access drift excavations. Heating caused a marked increase in the closure rates, as is evident in the data. A preliminary analysis of Room H mining sequence data has been published [17], which indicates the influence of the close proximity of mining around the pillar on the measured response. The remotely read mechanical and thermal gage data for Room H have been reported [7].

Table 5.5.1. Room H Mining Sequence Closure Units (Gages) Location Guide

Access Drift

Station	Direction		pillar		N1100
H ST091	Vertical	roof		H_M01	
				H_M02	
	Vertical	floor		-1	

Room

Station	Direction		pillar	pass 3	center pass 1	pass 2	rib
H ST178	Vertical	roof		H_M14	H_M11	H_M15	
	Horizontal	mid	-3	H_M12			-2
				-1			
	Vertical	floor			-1	-1	
H ST268	Vertical	roof		H_M24	H_M21	H_M25	
	Horizontal	mid	-3	H_M22			-2
				-1			
	Vertical	floor			-1	-1	
H ST360	Vertical	roof			H_M31	H_M35	
	Horizontal	mid	-3	H_M32			-2
	Vertical	floor			-1	-1	

[text continues on page 154]

Table 5.5.2. Mining Sequence Gages H_M0x-x, Room H Entry, Station 90°

H_M01 - H_M02 PI Comments

03/03/92 RLJ [97%] This set of Mining Sequence Closure Gages (1 vertical and 1 horizontal) was installed in the access drift to room H. They were initially measured less than 3 hours after the mining machine pass. Early results (top graph) differ in closure magnitude and slope from data recorded in the 5.5 x 5.5 m rooms. There is practically no difference between horizontal and vertical closure for these gages, although horizontal closure is very slightly greater. Gage disruption due to mining required no reinstallations (the access drift was mined with a single pass). Long term data (bottom graph) clearly show the effect of subsequent mining in Room H as an acceleration in closure occurring about day 280. This feature is noteworthy because both H_M01 & H_M02 were 20 m away from the main room excavation. (DEM)

Gage Information

Gage Number	Gage Type	Gage Orient.	Record		Gage Manf.	Installation Date	Drawing Number
H_M01-1	CONV	V	T	MAN	SNL	4/19/84	T91025-000A
H_M02-1	CONV	H	T	MAN	SNL	4/19/84	T91025-000A

Gage Location

					Gage Coordinates			
					Local		Room	
Gage Number	R1 (m)	R2 (M)	T1 (deg)	T2 (deg)	Z1 (m)	Z2 (m)	Z1 (m)	Z2 (m)
H_M01-1	36.48	36.51	90.00	89.90	-1.54	1.54	-0.86	2.22
H_M02-1	36.55	36.49	92.70	87.10	0.08	0.08	0.75	0.75

Gage Length Upon Installation

		Pass 1		Pass 2		Pass 3		Pass 4 + Trim -Final-	
Gage Number	Dir	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)
H M01	V	-1	3.20		None		None	-1	3.20
H M02	H	-1	3.81		None		None	-1	3.81

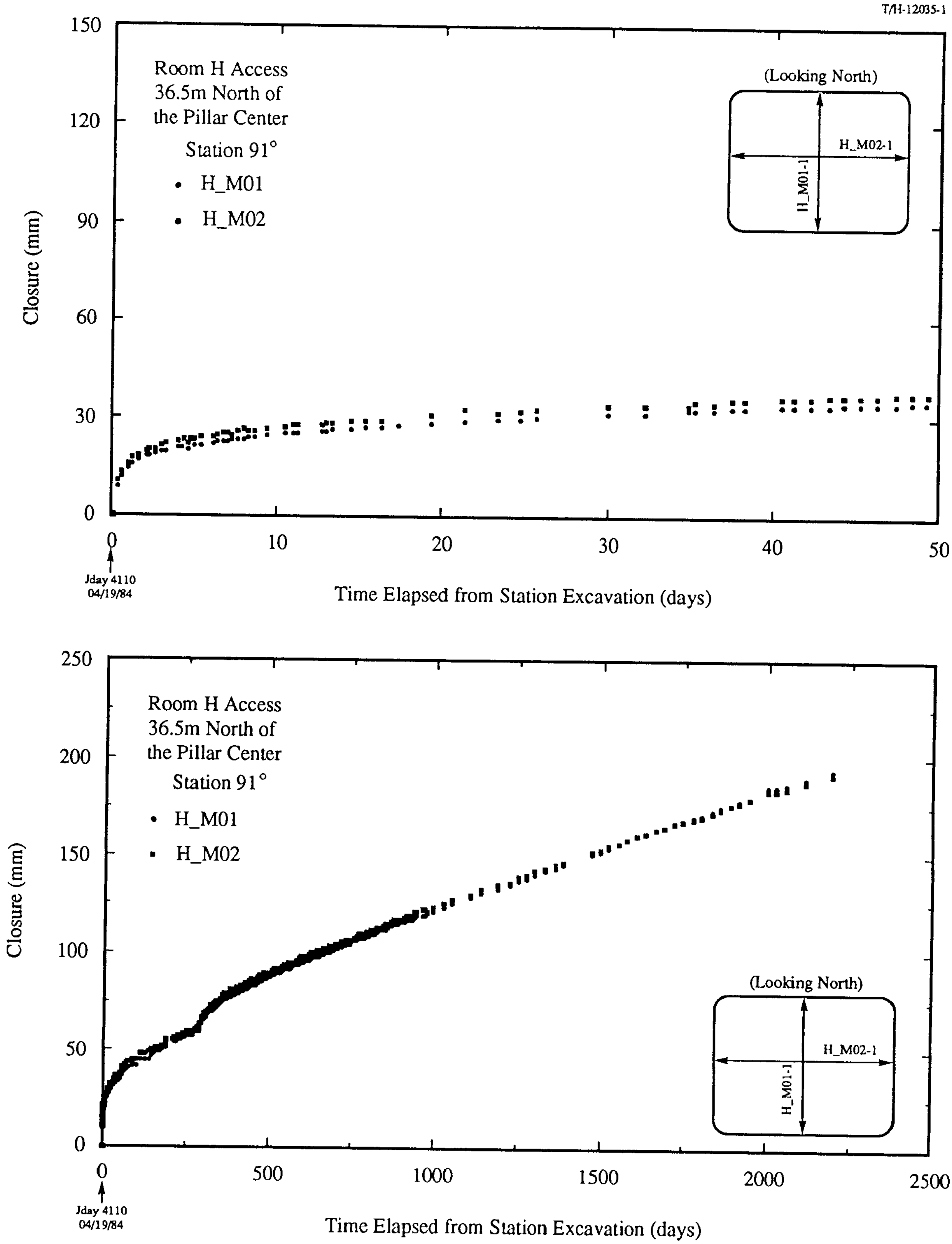


Figure 5.5.1. Mining Sequence Gages H_M0x-x, Room H Entry, Station 90°

Table 5.5.3a. Mining Sequence Gages H_M1x-x, Room H, Station 178°

H_M11 - H_M15 PI Comments

03/03/92 RLJ [98%] This set of Mining Sequence Closure Gages (3 vertical and 1 horizontal) was installed radially outward and due west of the Room H pillar. They were initially measured less than 4 hours after the first mining machine pass, except for H_M15 which was installed after pass 2. Early results (top graph) are similar in closure magnitude and slope from data recorded in the 5.5 x 5.5 m rooms even though the test room geometries are very different. Gage disruption due to mining required 8 reinstallations. Long term data (bottom graph) clearly show thermal effects caused by activation of the pillar heater, this is especially true for the horizontal gage H_M12. This acceleration in closure occurs about day 383, corresponding to heater activation. (DEM)

Gage Information

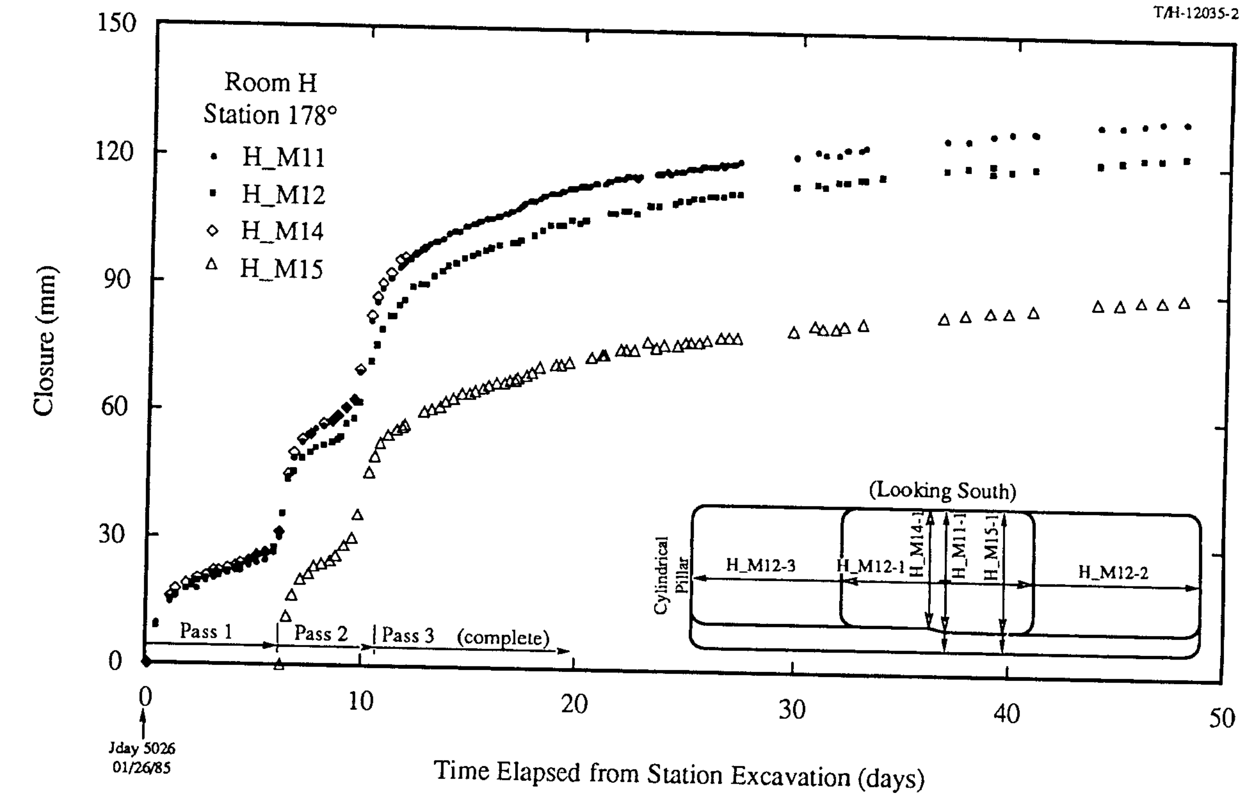
Gage Number	Gage Type	Gage Orient.	Record		Gage Manf.	Installation Date	Drawing Number
H_M11-1	CONV	V	T	MAN	SNL	1/26/85	T91025-000A
H_M12-1	CONV	H	T	MAN	SNL	1/26/85	T91025-000A
H_M12-2	CONV	H	T	MAN	SNL	2/1/85	T91025-000A
H_M12-3	CONV	H	T	MAN	SNL	2/5/85	T91025-000A
H_M14-1	CONV	V	T	MAN	SNL	1/26/85	T91025-000A
H_M15-1	CONV	V	T	MAN	SNL	2/1/85	T91025-000A

Gage Location

	Gage Coordinates							
					Local		Room	
Gage Number	R1 (m)	R2 (M)	T1 (deg)	T2 (deg)	Z1 (m)	Z2 (m)	Z1 (m)	Z2 (m)
H_M11-1	10.98	10.95	179.20	179.10	-1.61	1.38	-1.56	1.42
H_M12-1	8.53	12.45	178.80	179.20	-0.05	-0.05	-0.01	-0.01
H_M12-2	8.53	16.34	178.80	179.40	-0.05	-0.05	-0.01	-0.01
H_M12-3	5.54	16.38	177.20	179.80	-0.05	-0.05	-0.01	-0.01
H_M14-1	10.64	10.64	179.20	179.20	-0.83	1.33	-0.78	1.38
H_M15-1	12.21	12.24	178.90	179.00	-1.61	1.38	-1.56	1.42

Gage Length Upon Installation

		Pass 1		Pass 2		Pass 3		Pass 4 + Trim -Final-	
Gage Number	Dir	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)
					--				
H M11	V	-1	2.59		7.70		--	-1	3.05
H M12	H	-1	4.10	-2	--	-3	10.92	-3	10.93
H M14	v	-1	2.59		--		--		xx
H M15	v	-1	2.60				--		3.01



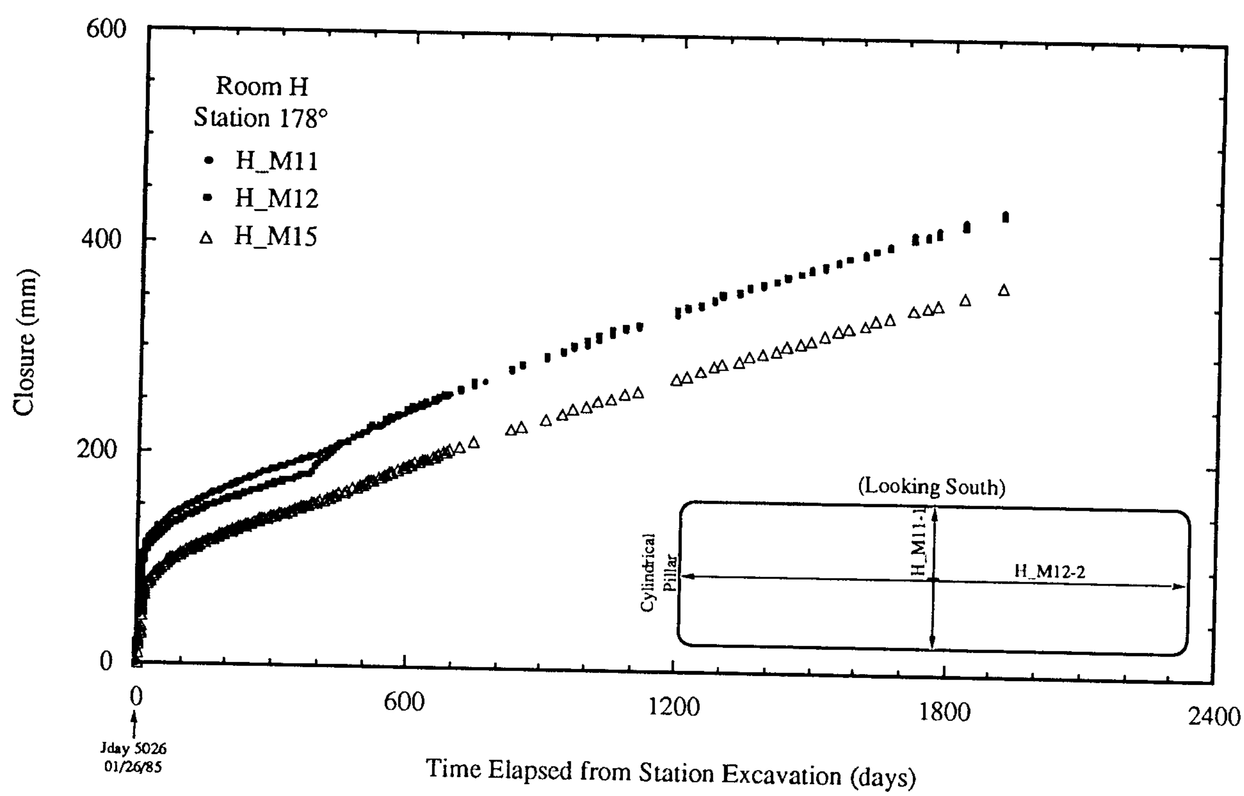


Figure 5.5.2a. Mining Sequence Gages H_M1x-x, Room H, Station 178°

Table 5.5.3b. Mining Sequence Gages H_M2x-x, Room H, Station 268°

H_M21 - H_M25 PI Comments

03/03/92 RLJ [97%] This set of Mining Sequence Closure Gages (3 vertical and 1 horizontal) was installed radially outward and due south of the Room H pillar. They were initailly measured less than 5 hours after the first mining machine pass, except for H_M25 which was installed after pass 2. Early results (top graph) are similar in closure magnitude and slope from data recorded in the 5.5 x 5.5 m rooms even though the test room geometries are very different. Gage disruption due to mining required 8 reinstallations. Long term data (bottom graph) clearly show the thermal effects caused by activation of the pillar heater, especially for the horizontal gage H_M22. The acceleration in closure occurs about day 382, corresponding to heater activation. (DEM)

Gage Information

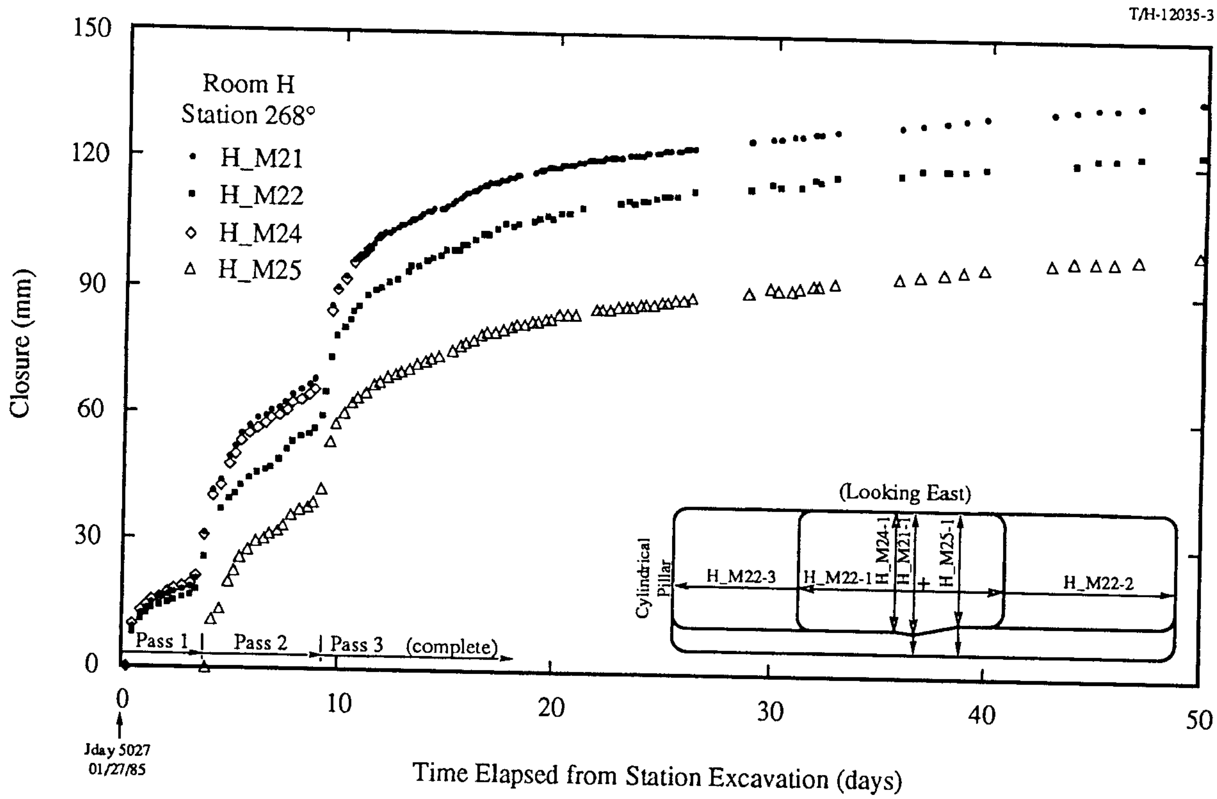
Gage Number	Gage Type	Gage Orient.	—— Record ——		Gage Manf.	Installation Date	Drawing Number
H_M21-1	CONV	V	T	MAN	SNL	1/27/85	T91025-000A
H_M22-1	CONV	H	T	MAN	SNL	1/27/85	T91025-000A
H_M22-2	CONV	H	T	MAN	SNL	1/31/85	T91025-000A
H_M22-3	CONV	H	T	MAN	SNL	2/5/85	T91025-000A
H_M24-1	CONV	V	T	MAN	SNL	1/27/85	T91025-000A
H_M25-1	CONV	V	T	MAN	SNL	1/31/85	T91025-000A

Gage Location

				Gage Coordinates				
					—— Local ——		—— Room ——	
Gage Number	R1 (m)	R2 (M)	T1 (deg)	T2 (deg)	Z1 (m)	Z2 (m)	Z1 (m)	Z2 (m)
H_M21-1	10.80	10.80	269.60	269.60	-1.70	1.41	-1.80	1.30
H_M22-1	8.13	12.47	269.50	269.70	-0.14	-0.14	-0.25	-0.25
H_M22-2	8.13	16.39	269.50	269.70	-0.14	-0.14	-0.25	-0.25
H_M22-3	5.56	16.44	267.10	269.40	-0.23	-0.05	-0.34	-0.16
H_M24-1	10.37	10.37	269.60	269.60	-1.20	1.41	-1.31	1.30
H_M25-1	11.74	11.74	269.40	269.50	-1.70	1.38	-1.80	1.27

Gage Length Upon Installation

		Pass 1		Pass 2		Pass 3		Pass 4 + Trim -Final-	
Gage Number	Dir	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)
H M21	V	-1	2.65		--		--	-1	3.16
H M22	H	-1	4.51	-2	8.20	-3	10.62	-3	10.95
H M24	v	-1	2.61		--		--		xx
H M25	v	-1	2.43		--		--	-1	3.14



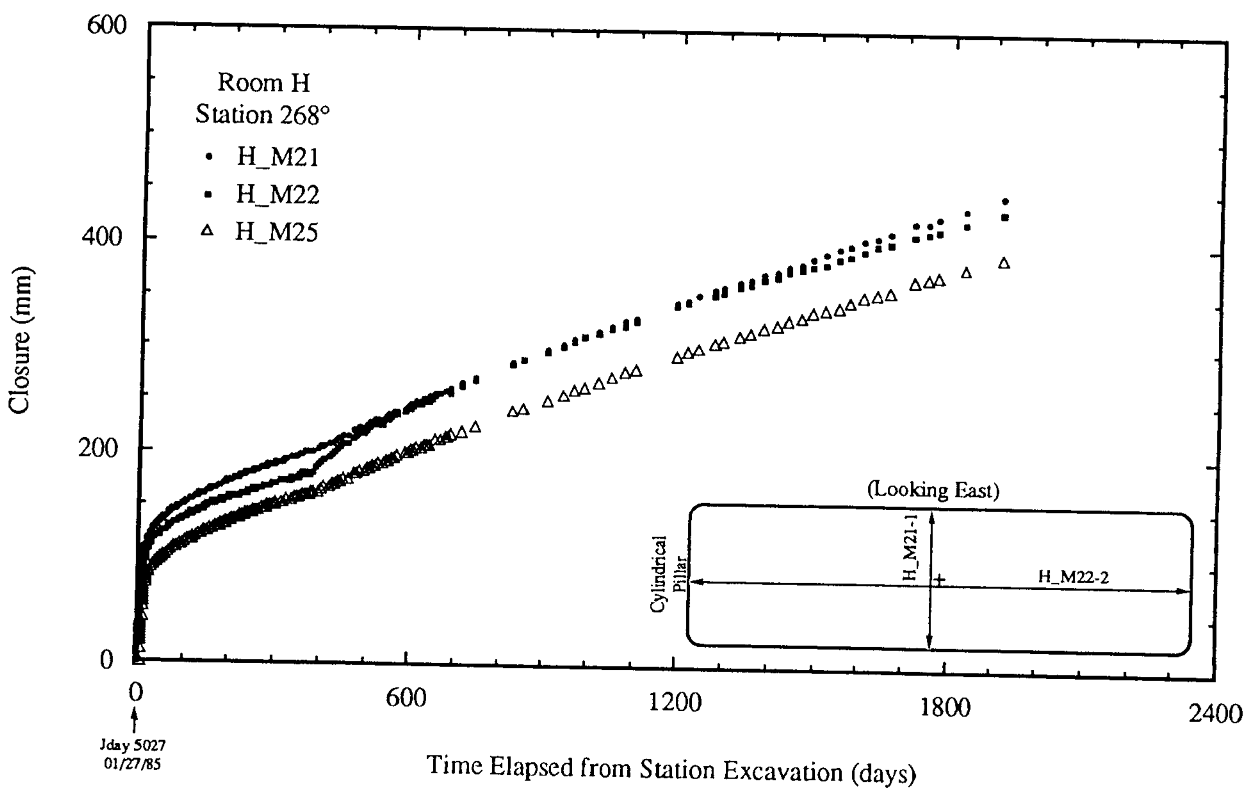


Figure 5.5.2b. Mining Sequence Gages H_M2x-x, Room H, Station 268°

Table 5.5.3c. Mining Sequence Gages H_M3x-x, Room H, Station 360°

H_M31 - H_M35 PI Comments

03/03/92 RLJ [98%] This set of Mining Sequence Closure Gages (3 vertical and 1 horizontal) was installed radially outward and due east of the Room H pillar. They were initially measured less than 8 hours after the first mining machine pass, except for H_M35 which was installed after pass 2. Early results (top graph) are similar in closure magnitude and slope from data recorded in the 5.5 x 5.5 m rooms even though the test room geometries are very different. A centerline vertical gage (H_M34) for pass one was never installed at this station. Gage disruption due to mining required 7 reinstallations. Long term data (bottom graph) clearly show the thermal effects caused by the activation of the pillar heater, especially for the horizontal gage H_M32. The acceleration in closure occurs about day 381, corresponding to heater activation. (DEM)

Gage Information

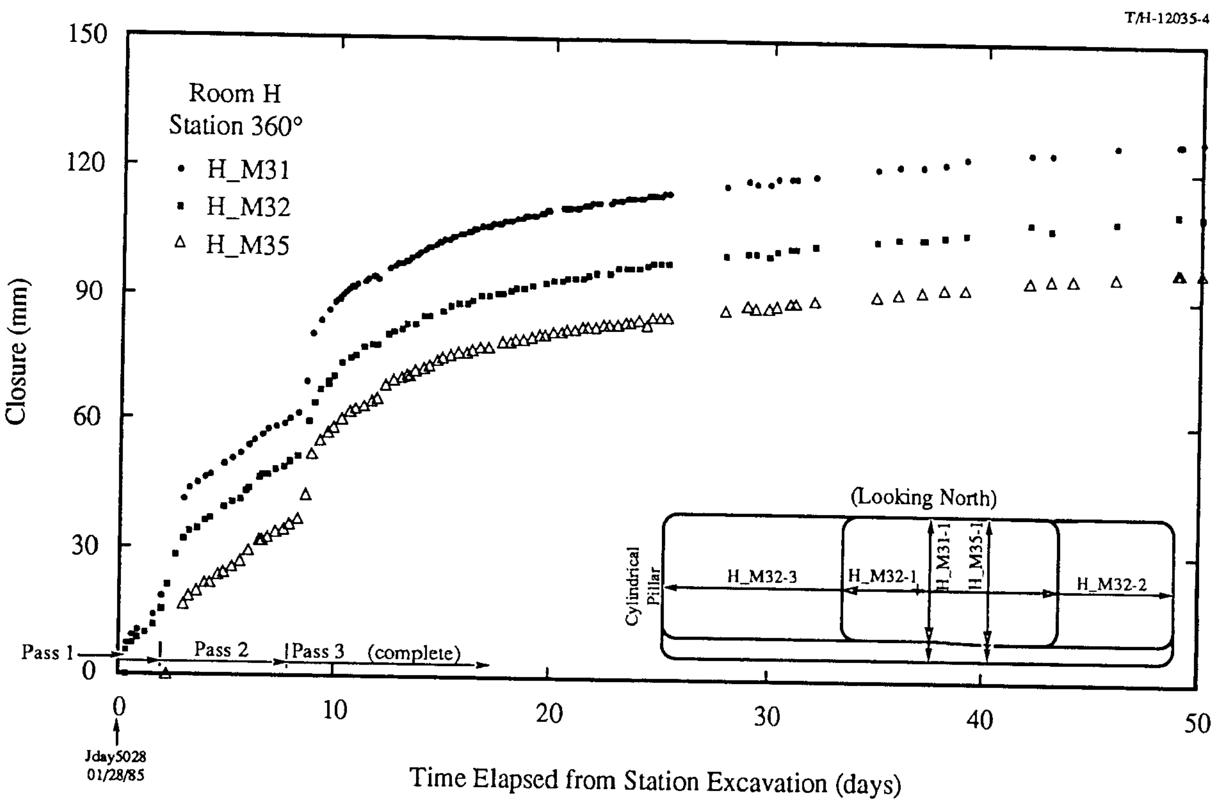
Gage Number	Gage Type	Gage Orient.	—— Record ——		Gage Manf.	Installation Date	Drawing Number
H_M31-1	CONV	V	T	MAN	SNL	1/28/85	T91025-000A
H_M32-1	CONV	H	T	MAN	SNL	1/28/85	T91025-000A
H_M32-2	CONV	H	T	MAN	SNL	1/30/85	T91025-000A
H_M32-3	CONV	H	T	MAN	SNL	2/6/85	T91025-000A
H_M35-1	CONV	V	T	MAN	SNL	1/30/85	T91025-000A

Gage Location

	Gage Coordinates							
					—— Local ——		—— Room ——	
Gage Number	R1 (m)	R2 (M)	T1 (deg)	T2 (deg)	Z1 (m)	Z2 (m)	Z1 (m)	Z2 (m)
H_M31-1	11.27	11.20	0.03	0.00	-1.59	1.40	-1.56	1.42
H_M32-1	9.14	13.52	359.90	0.00	-0.05	-0.05	-0.02	-0.02
H_M32-2	9.14	16.43	359.90	0.00	-0.05	-0.05	-0.02	-0.02
H_M32-3	5.57	16.48	0.20	0.90	-0.09	0.00	-0.07	0.02
H_M35-1	12.48	12.48	0.00	0.20	-1.59	1.43	-1.56	1.46

Gage Length Upon Installation

		Pass 1		Pass 2		Pass 3		Pass 4 + Trim -Final-	
Gage Number	Dir	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)
H M31	V	-1	2.65		--		--	-1	3.02
H M32	H	-1	4.61	-2	7.04	-3	10.69	-3	11.05
H M35	v	-1	2.68		--		--	-1	3.09



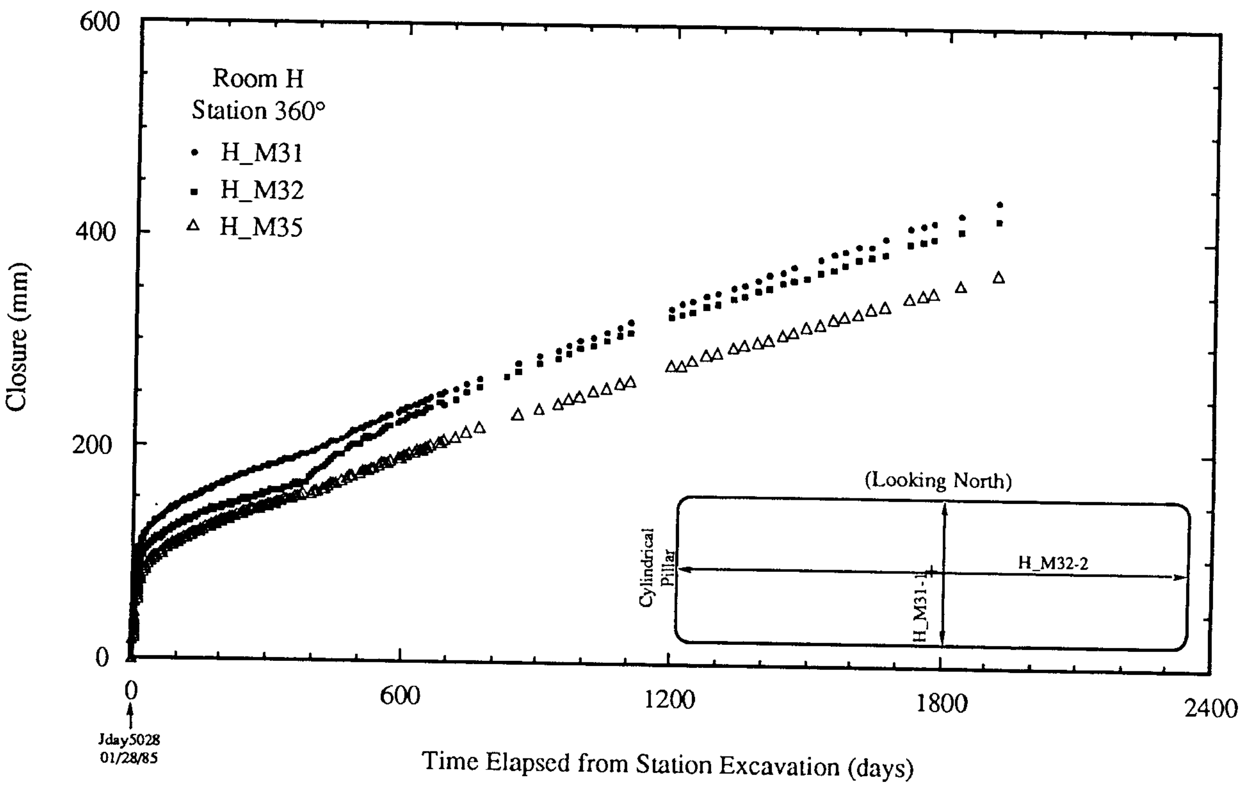


Figure 5.5.2c. Mining Sequence Gages H_M3x-x, Room H, Station 360°

5.6 ISBT Mining (Drilling) Sequence Closure Data

The Intermediate Scale Borehole Test is a unique test that was fielded considerably after the TSI tests to provide an understanding of the "scale effect" in salt, if any. The purpose was to perhaps resolve a three fold discrepancy between the predicted and observed room closure behavior that existed at that time, but which has since been resolved [25]. The ISBT consists of a 0.91 m (3.0 ft) diameter hole, drilled from Room C2 through an old pillar into Room C1. The excavation of Rooms C1 and C2 started on 3/17/84 and was finished on 4/9/84 for what was intended to be rooms for the demonstration of high level radioactive canister emplacement equipment, which never came to fruition. Some 6.7 years later, the drilling of the ISBT borehole through the pillar between the rooms began on 12/3/90 and was completed on 12/13/90. The pillar had been heavily instrumented previously to observe the change in pillar response caused by the drilling of the hole. As the drilling of the hole progressed, drilling (mining) sequence closure stations were established between the drill bit and the excavation face. These stations were the result of the equivalent of single pass excavation. Data were recorded from these stations briefly, until they were replaced by remote closure gages.

The location guide given in Table 5.6.1 shows the schematic placement of the gages at each station. Gage designations suggest both the location and the orientation of the gage.

The appropriate mining (drilling) sequence gage information is given in Tables 5.6.2a-g and the mining sequence closure data are displayed in Figures 5.6.1a-g. Please note, because monitoring of the mining sequence gages was for only a short period of time before they were replaced by remote gages, a single 50 day graph of the data is all that can be given.

Table 5.6.1. ISBT Mining Sequence Closure Gages Location Guide

Station	Direction		Relative Location: north	Relative Location: center	Relative Location: south
C2ST-09	Vertical	roof		C2M01	
	Horizontal	mid	C2M02		-1
	Vertical	floor		-1	
C2ST-06	Vertical	roof		C2M21	
	Horizontal	mid	C2M22		-1
	Vertical	floor		-1	
C2ST-03	Vertical	roof		C2M41	
	Horizontal	mid	C2M42		-1
	Vertical	floor		-1	
C2ST 00	Vertical	roof		C2M61	
	Horizontal	mid	C2M62		-1
	Vertical	floor		-1	
C2ST 03	Vertical	roof		C2M71	
	Horizontal	mid	C2M72		-1
	Vertical	floor		-1	

Table 5.6.1. ISBT Mining Sequence Closure Gages Location Guide (Cont.)

Station	Direction		Relative Location: north	Relative Location: center	Relative Location: south
C2ST 06					
	Vertical	roof		C2M81	
	Horizontal	mid	C2M82		-1
	Vertical	floor		-1	
C2ST 09					
	Vertical	roof		C2M91	
	Horizontal	mid	C2M92		-1
	Vertical	floor		-1	

As is apparent, because the ISBT was drilled in a single pass, the data require no special reduction procedures to correct for mined out closure points. As previously noted, the gages measured all of the displacement except for that deformation which occurs in advance of the drilling face prior to the emplacement of the gage. The amount of this deformation, while unmeasured, is thought to be small [23].

The measured closures in the ISBT are small compared to those normally associated with the TSI tests because the hole diameter is much less than the TSI test room dimensions, or for that matter the diameter of Room Q. The relatively small displacements accentuate the scatter in the data. However, the trends of these data are clear.

Measured vertical closures are greater than the horizontal closures, which is opposite of the trend in Room Q. This is undoubtedly the result of preexisting stress field in the pillar, which appears to have a large vertical component. By contrast in Room Q, it appears that only the stratigraphy controls the relative displacements.

Although one would expect the displacements to scale with the initial room diameter for excavations into an initial lithostatic stress field, the severe three-dimensional stress field in the pillar precludes such easy analysis. The experiment has been analyzed in a preliminary manner by Arguello [26] using a simplified constitutive model. Even though this analysis involved an extensive three-dimensional calculation, additional complexity of the analysis will be necessary to fully simulate this test.

Although not yet available, a data report which includes all of the remotely measured data will be published.

[text continues on page 172]

Table 5.6.2a. Mining Sequence Gages C2M0x-x, ISBT, Station -09 m

C2M01 - C2M02 PI Comments

03/11/92 RLJ [95%] This set of Mining Sequence Closure Gages (1 vertical and 1 horizontal) was installed very close to the borehole collar (less than one meter). They were first measured less than 3 hours after excavation. Data were collected for about 40 days, then the gage was replaced with a remotely read gage. The closure magnitude is much different for these gages, in fact closure is reduced by more than 98% when compared to closure in larger rectangular rooms. Gage disruption due to mining required no reinstallations. It is apparent that the horizontal closure as measured by C2M02 for this station almost at the rib of Room C2 is very nearly nonexistant and is quite different than the closures at stations deeper into the pillar. (DEM)

Gage Information

Gage Number	Gage Type	Gage Orient.	—— Record ——		Gage Manf.	Installation Date	Drawing Number
C2M01-1	CONV	V	T	MAN	SNL	12/3/90	
C2M02-1	CONV	H	T	MAN	SNL	12/3/90	

Gage Location

	Gage Coordinates							
					—— Local ——		—— Room ——	
Gage Number	X1 (m)	X2 (m)	Y1 (m)	Y2 (m)	Z1 (m)	Z2 (m)	Z1 (m)	Z2 (m)
C2M01-1	-8.86	-8.86	0.00	0.00	-0.46	0.46	-0.01	0.92
C2M02-1	-8.81	-8.86	-0.47	0.47	0.00	0.00	0.46	0.46

Gage Length Upon Installation

		Pass 1		Pass 2		Pass 3		Pass 4 + Trim -Final-	
Gage Number	Dir	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)
C2M01	V	-1	0.95		None		None	-1	0.95
C2M02	H	-1	0.97		None		None	-1	0.97

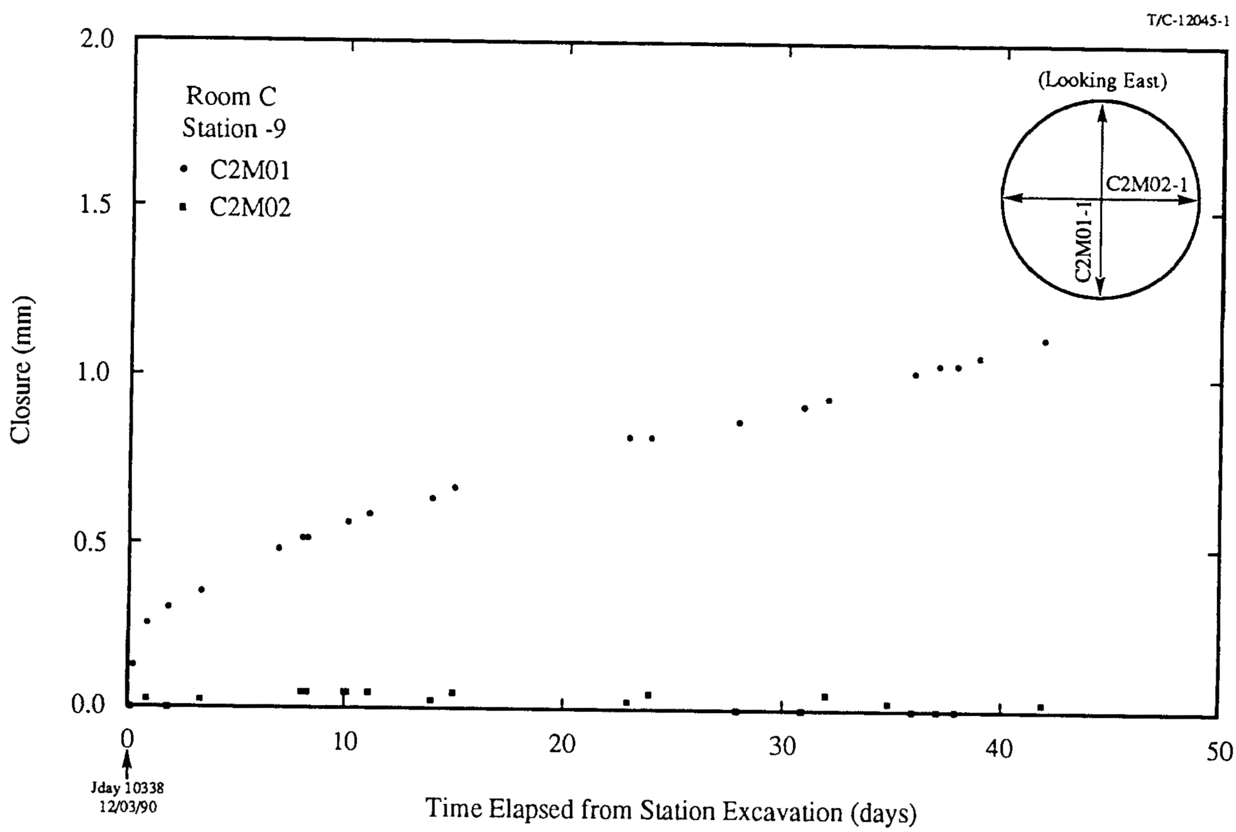


Figure 5.6.1a. Mining Sequence Gages C2M0x-x, ISBT, Station -09 m

Table 5.6.2b. Mining Sequence Gages C2M2x-x, ISBT, Station -06 m

C2M21 - C2M22 PI Comments

03/18/92 RLJ [98%] This set of Mining Sequence Closure Gages (1 vertical and 1 horizontal) was installed one sixth the distance between rooms C1 and C2. They were first measured about 4 hours after excavation. Data were collected for about 39 days, then the gage was replaced with a remotely read closure gage. The closure magnitude is much lower for these gages in this small diameter excavation, in fact closure is reduced by more than 98% when compared to closure in larger rectangular rooms. The horizontal displacement is less than the vertical, probably as a result of the stresses in the pillar. Gage disruption due to mining required no reinstallations. (DEM)

Gage Information

Gage Number	Gage Type	Gage Orient.	—— Record ——		Gage Manf.	Installation Date	Drawing Number
C2M21-1	CONV	V	T	MAN	SNL	12/6/90	
C2M22-1	CONV	H	T	MAN	SNL	12/6/90	

Gage Location

					Gage Coordinates			
					—— Local ——		—— Room ——	
Gage Number	X1 (m)	X2 (m)	Y1 (m)	Y2 (m)	Z1 (m)	Z2 (m)	Z1 (m)	Z2 (m)
C2M21-1	-6.12	-6.12	0.00	0.00	-0.48	0.48	-0.17	0.79
C2M22-1	-6.12	-6.12	-0.48	0.48	0.00	0.00	0.31	0.31

Gage Length Upon Installation

		Pass 1		Pass 2		Pass 3		Pass 4 + Trim -Final-	
Gage Number	Dir	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)
C2M21	V	-1	0.95		None		None	-1	0.95
C2M22	H	-1	0.96		None		None	-1	0.96

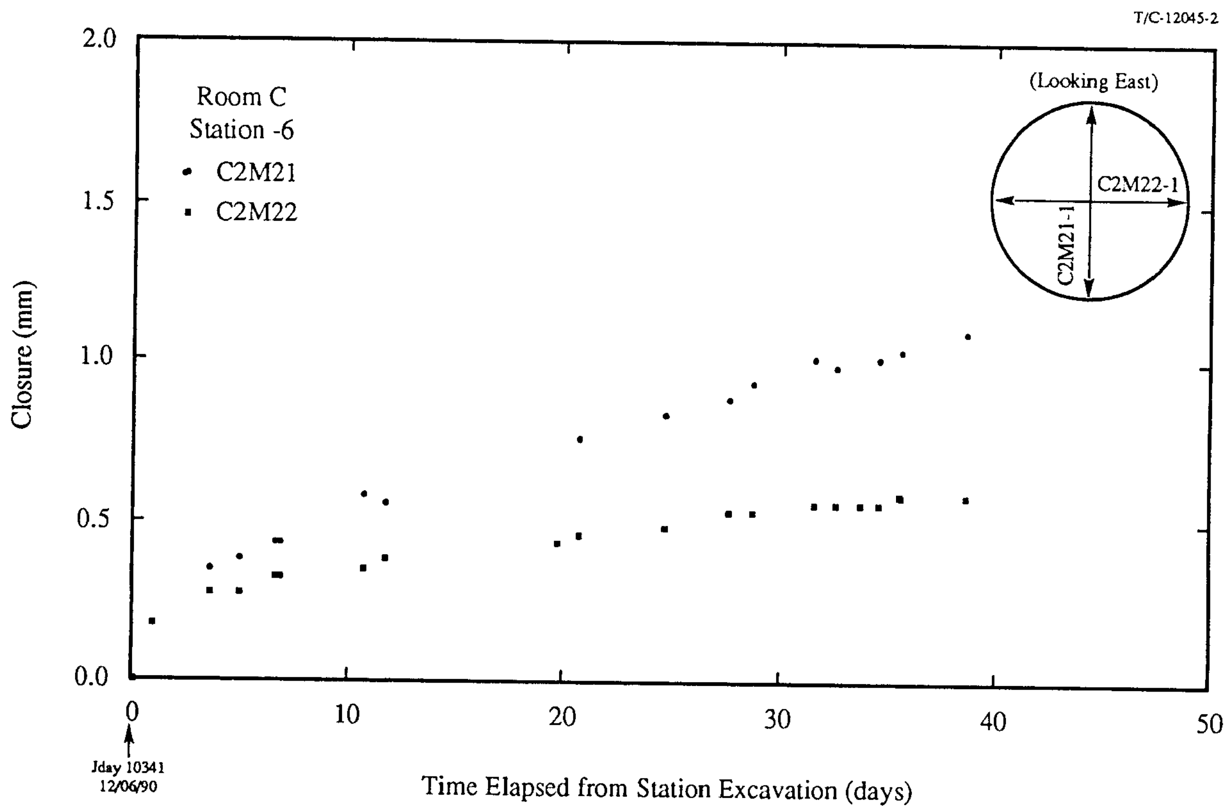


Figure 5.6.1b. Mining Sequence Gages C2M2x-x, ISBT, Station -06 m

Table 5.6.2c. Mining Sequence Gages C2M4x-x, ISBT, Station -03 m

C2M41 - C2M42 PI Comments

03/19/92 RLJ [98%] This set of Mining Sequence Closure Gages (1 vertical and 1 horizontal) was installed one third the distance between rooms C1 and C2. They were first measured about 2 hours after excavation. Data were collected for about 34 days, then the gage was replaced with a remotely read closure gage. The closure magnitude is much lower for these gages in this small excavation, in fact closure is reduced by more than 98% when compared to closure in larger rectangular rooms. The horizontal displacement is less than the vertical, probably as a result of the stresses in the pillar. Gage disruption due to mining required no reinstallations. (DEM)

Gage Information

Gage Number	Gage Type	Gage Orient.	—— Record ——		Gage Manf.	Installation Date	Drawing Number
C2M41-1	CONV	V	T	MAN	SNL	12/7/90	
C2M42-1	CONV	H	T	MAN	SNL	12/7/90	

Gage Location

	Gage Coordinates							
					—— Local ——		—— Room ——	
Gage Number	X1 (m)	X2 (m)	Y1 (m)	Y2 (m)	Z1 (m)	Z2 (m)	Z1 (m)	Z2 (m)
C2M41-1	-3.08	-3.08	0.00	0.00	-0.48	0.48	-0.30	0.65
C2M42-1	-3.08	-3.08	-0.48	0.48	0.00	0.00	0.17	0.17

Gage Length Upon Installation

		Pass 1		Pass 2		Pass 3		Pass 4 + Trim -Final-	
Gage Number	Dir	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)
C2M41	V	-1	0.95		None		None	-1	0.95
C2M42	H	-1	0.95		None		None	-1	0.95

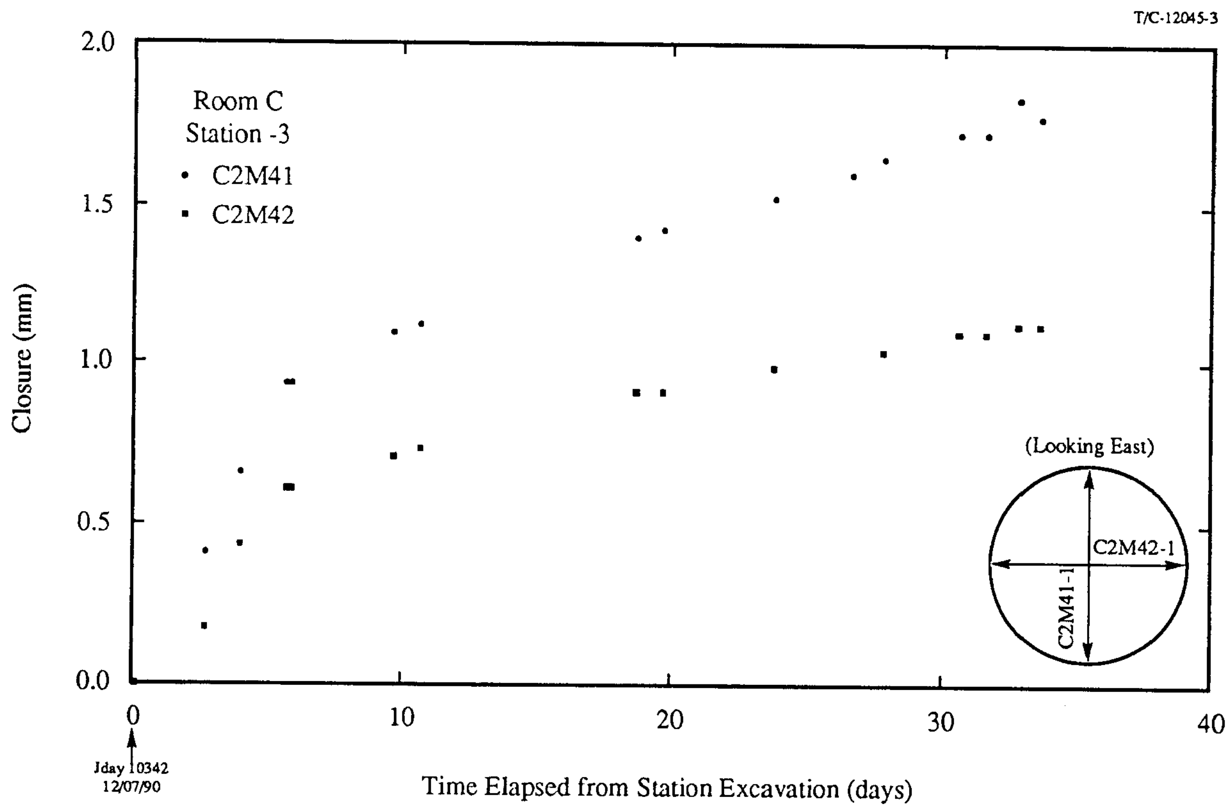


Figure 5.6.1c. Mining Sequence Gages C2M4x-x, ISBT, Station -03 m

Table 5.6.2d. Mining Sequence Gages C2M6x-x, ISBT, Station 00 m

C2M61 - C2M62 PI Comments

05/07/92 RLJ [96%] This set of Mining Sequence Closure Gages (1 vertical and 1 horizontal) was installed one half the distance between rooms C1 and C2. They were first measured about 4 hours after excavation. Data were collected for only 17 days, then the gage was replaced with a remotely read closure gage. The closure magnitude is much lower for these gages in this small diameter test, in fact closure is reduced by more than 98% when compared to closure in larger rectangular rooms. The horizontal displacement is less than the vertical, probably as a result of the stresses in the pillar. Gage disruption due to mining required no reinstallations. (DEM)

Gage Information

Gage Number	Gage Type	Gage Orient.	—— Record ——		Gage Manf.	Installation Date	Drawing Number
C2M61-1	CONV	V	T	MAN	SNL	12/10/90	
C2M62-1	CONV	H	T	MAN	SNL	12/10/90	

Gage Location

					Gage Coordinates			
					—— Local ——		—— Room ——	
Gage Number	X1 (m)	X2 (m)	Y1 (m)	Y2 (m)	Z1 (m)	Z2 (m)	Z1 (m)	Z2 (m)
C2M61-1	-0.04	-0.04	0.00	0.00	-0.48	0.48	-0.48	0.48
C2M62-1	-0.04	-0.04	-0.48	0.48	0.00	0.00	0.00	0.00

Gage Length Upon Installation

		Pass 1		Pass 2		Pass 3		Pass 4 + Trim -Final-	
Gage Number	Dir	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)
C2M61	V	-1	0.96		None		None	-1	0.96
C2M62	H	-1	0.976		None		None	-1	0.96

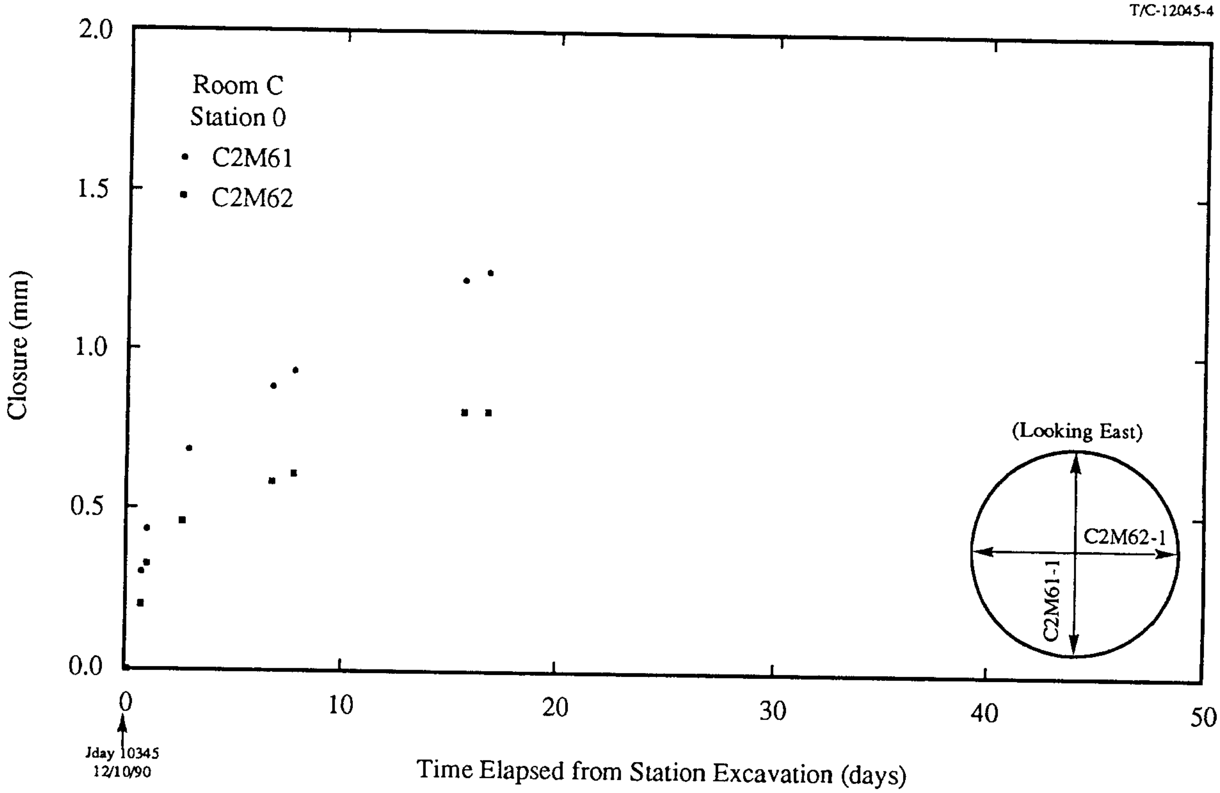


Figure 5.6.1d. Mining Sequence Gages C2M6x-x, ISBT, Station 00 m

Table 5.6.2e. Mining Sequence Gages C2M7x-x, ISBT, Station +03 m

C2M71 - C2M72 PI Comments

05/07/92 RLJ [93%] This set of Mining Sequence Closure Gages (1 vertical and 1 horizontal) was installed two thirds the distance between rooms C1 and C2. They were first measured about 5 hours after excavation. Data were collected for about 37 days, then the gage was replaced with a remotely read closure gage. The closure magnitude is much lower for these gages in this small diameter test, in fact closure is reduced by more than 98% when compared to closure in larger rectangular rooms. The horizontal closure is less than the vertical, probably as a result of the stresses in the pillar. Gage disruption due to mining required no reinstallations. (DEM)

Gage Information

Gage Number	Gage Type	Gage Orient.	Record		Gage Manf.	Installation Date	Drawing Number
C2M71-1	CONV	V	T	MAN	SNL	12/11/90	
C2M72-1	CONV	H	T	MAN	SNL	12/11/90	

Gage Location

Gage Number	X1 (m)	X2 (m)	Y1 (m)	Y2 (m)	Local Z1 (m)	Local Z2 (m)	Room Z1 (m)	Room Z2 (m)
C2M71-1	3.01	3.01	0.00	0.00	-0.33	0.63	-0.48	0.48
C2M72-1	3.01	3.01	-0.48	0.48	0.00	0.00	-0.15	-0.15

Gage Coordinates

Gage Length Upon Installation

Gage Number	Dir	Pass 1 Gage	Pass 1 Length (m)	Pass 2 Gage	Pass 2 Length (m)	Pass 3 Gage	Pass 3 Length (m)	Pass 4 + Trim -Final- Gage	Pass 4 + Trim -Final- Length (m)
C2M71	V	-1	0.96		None		None	-1	0.9560.97
C2M72	H	-1	0.97		None		None	-1	

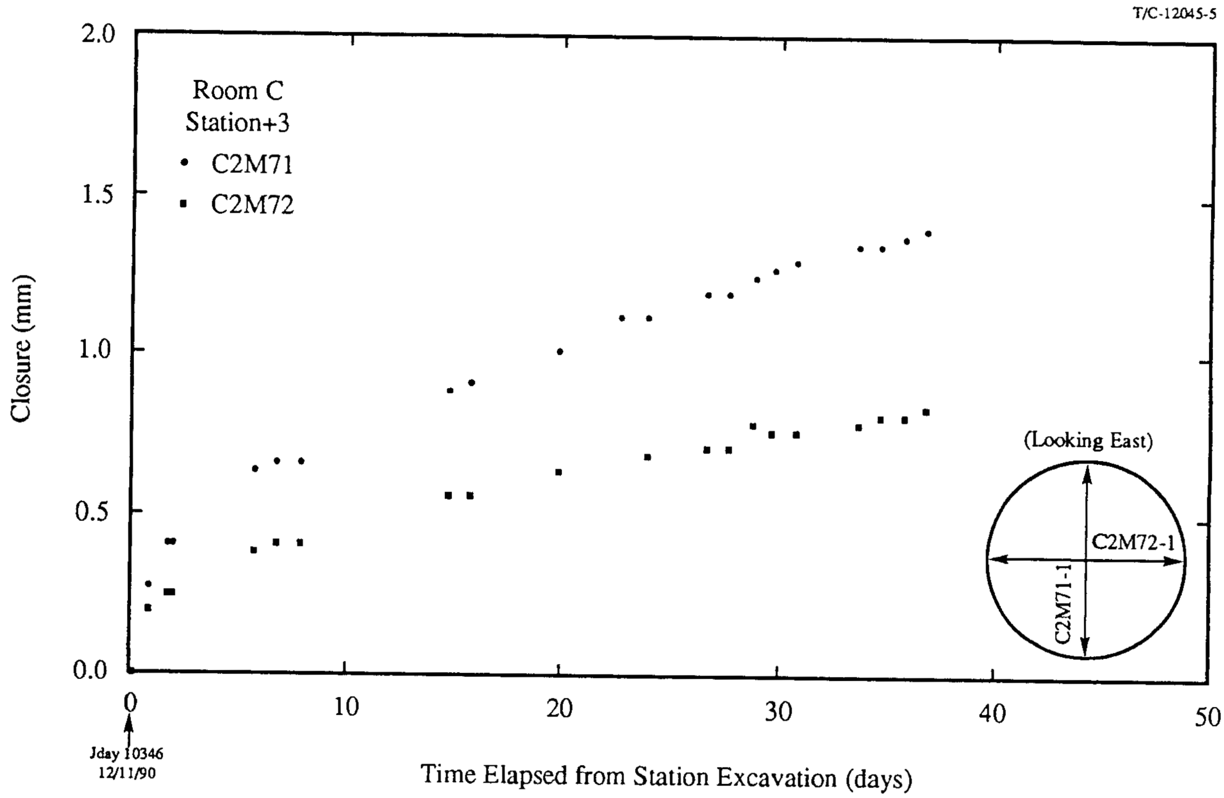


Figure 5.6.1e. Mining Sequence Gages C2M7x-x, ISBT, Station +03 m

Table 5.6.2f. Mining Sequence Gages C2M8x-x, ISBT, Station +06 m

C2M81 - C2M82 PI Comments

05/07/92 RLJ [95%] This set of Mining Sequence Closure Gages (1 vertical and 1 horizontal) was installed five sixths the distance between rooms C1 and C2. They were first measured about 4 hours after excavation. Data were collected for about 36 days, then the gage was replaced with a remotely read closure gage. The closure magnitude is much lower for these gages in this small diameter test, in fact closure is reduced by more than 98% when compared to closure in larger rectangular rooms. The horizontal closure is less than the vertical, perhaps as the result of the stress field in the pillar. Gage disruption due to mining required no reinstallations. (DEM)

Gage Information

Gage Number	Gage Type	Gage Orient.	Record		Gage Manf.	Installation Date	Drawing Number
C2M81-1	CONV	V	T	MAN	SNL	12/12/90	
C2M82-1	CONV	H	T	MAN	SNL	12/12/90	

Gage Location

					Gage Coordinates			
					Local		Room	
Gage Number	X1 (m)	X2 (m)	Y1 (m)	Y2 (m)	Z1 (m)	Z2 (m)	Z1 (m)	Z2 (m)
C2M81-1	6.05	6.05	0.00	0.00	-0.48	0.48	-0.79	0.17
C2M82-1	6.05	6.05	-0.48	0.48	0.00	0.00	-0.31	-0.31

Gage Length Upon Installation

		Pass 1		Pass 2		Pass 3		Pass 4 + Trim -Final-	
Gage Number	Dir	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)
C2M81	V	-1	0.96		None		None	-1	0.96
C2M82	H	-1	0.97		None		None	-1	0.97

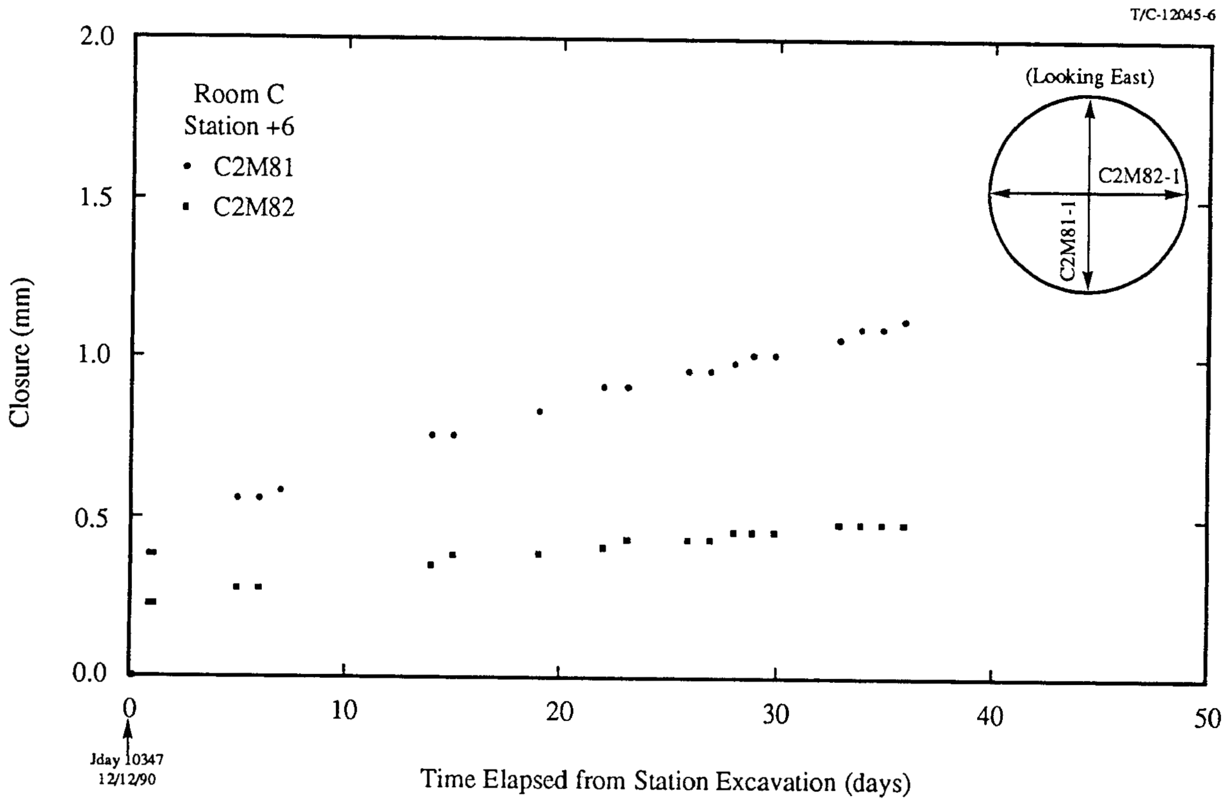


Figure 5.6.1f. Mining Sequence Gages C2M8x-x, ISBT, Station +06 m

Table 5.6.2g. Mining Sequence Gages C2M9x-x, ISBT, Station +09 m

C2M91 - C2M92 PI Comments

05/07/92 RLJ [93%] This set of Mining Sequence Closure Gages (1 vertical and 1 horizontal) was installed less than one meter from the borehole break out into Room C1. They were first measured less than 3 hours after excavation. Data were collected for about 40 days, then the gage was replaced with a remotely read gage. The closure magnitude is much different for these gages in a small diameter excavation, in fact closure is reduced by more than 98% when compared to closure in larger rectangular rooms. The closures measured at this station are less than at stations in the middle of the pillar; moreover, they differ from those measured at the collar of the hole. Because this unsupported hole would be expected to undergo larger displacements, the smaller measured closures compared to the pillar center are a result of missing considerable displacement that occurs before the gages are installed. The behavior at both the collar and break out stations are quite complex. Gage disruption due to mining required no reinstallations. (DEM)

Gage Information

Gage Number	Gage Type	Gage Orient.	Record		Gage Manf.	Installation Date	Drawing Number
C2M91-1	CONV	V	T	MAN		12/13/90	
C2M92-1	CONV	H	T	MAN		12/13/90	

Gage Location

	Gage Coordinates							
					Local		Room	
Gage Number	X1 (m)	X2 (m)	Y1 (m)	Y2 (m)	Z1 (m)	Z2 (m)	Z1 (m)	Z2 (m)
C2M91-1	8.79	8.79	0.00	0.00	-0.48	0.48	-0.93	0.03
C2M92-1	8.79	8.79	-0.48	0.48	0.00	0.00	-0.45	-0.45

Gage Length Upon Installation

		Pass 1		Pass 2		Pass 3		Pass 4 + Trim -Final-	
Gage Number	Dir	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)
C2M91	V	-1	0.96		None		None	-1	0.96
C2M92	H	-1	0.96		None		None	-1	0.96

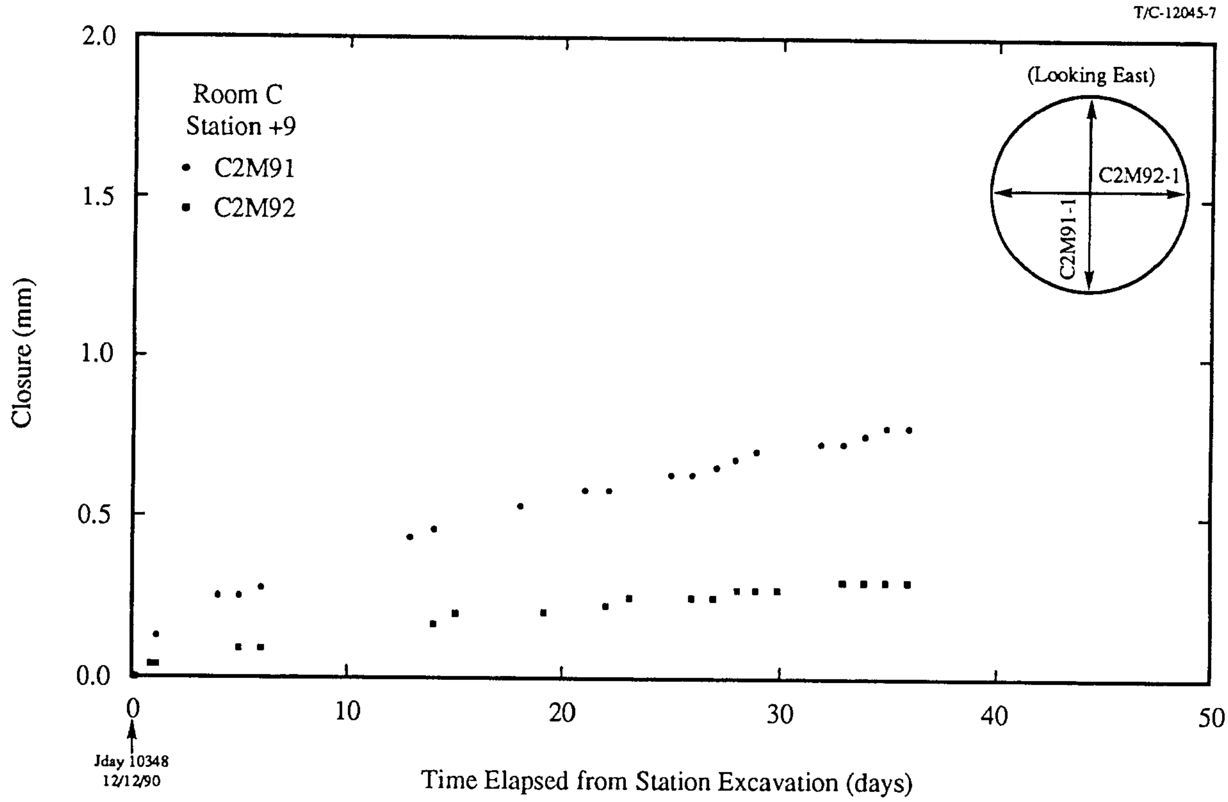


Figure 5.6.1g. Mining Sequence Gages C2M9x-x, ISBT, Station +09 m

5.7 Room Q Mining Sequence Closure Data

The Brine lnflow Test (Room Q) is a cylindrical room excavated for the purpose of determining the inflow of brine from the formation. However, it was possible to also install and monitor mining sequence gages during the excavation of the room. The room was bored in a single pass using a tunnel boring machine. Excavation started on the day shift of 7/12/89 and ended on the day shift of 8/8/89. At the planned mining sequence station location, the boring operation was halted and the machine backed away from the mining face. In this manner it was possible for the geotechnical crew to emplace the mining sequence closure station immediately at the mining face, just as in the case of the conventional mining of the test rooms. The manual mining sequence measurements have become infrequent because the room access is restricted; however, remote gages were also installed. The room remains active and readings will continue as long as possible.

A location guide which shows the schematic placement of the gages in each gage station is given in Table 5.7.1.

Mining sequence closure information is given in Tables 5.7.2a-d. The data are presented in Figures 5.7.1a-d. Because of the single pass mining there is no early detail in the closure histories and only a single graph of 350 days span is given.

Reduction of the data was straightforward because none of the initial closure points were mined out. Data at the +54 m station are perturbed by the junction of Room Q and instrument alcove. Operationally this station could not be emplaced until 25 days after the boring machine had mined the location. The vertical and horizontal mining sequence closures are not identical, as would be expected from the cylindrical symmetry, because of the bedded stratigraphy.

Table 5.7.1. Room Q Mining Sequence Closure Gages Location Guide

Station	Direction		Relative Location: south	center	north
QPST 52					
	Vertical	roof		QPM01	
	Horizontal	mid	QPM02		-1
	Vertical	floor		-1	
QPST 28					
	Vertical	roof		QPM31	
	Horizontal	mid	QPM32		-1
	Vertical	floor		-1	
QPST-04					
	Vertical	roof		QPM51	
	Horizontal	mid	QPM52		-1
	Vertical	floor		-1	
QPST 34					
	Vertical	roof		QPM81	
	Horizontal	mid	QPM82		-1
	Vertical	floor		-1	

[text continues on page 182]

Table 5.7.2a. Mining Sequence Gages QPM0x-x, Room Q, Station +52 m

QPM01 - QPM02 PI Comments

03/24/92 RLJ [88%] This set of Mining Sequence Closure Gages (1 vertical and 1 horizontal) was installed near the Room Q collar (1.5m) in what is now the airlock. Almost 29 days elapsed between the mining of the station and when the first measurments were acquired. Data were collected for about 270 days and then discontinued because of limited room access. Thereafter, measurements were acquired remotely. Note that the closure magnitude in Room Q is much less than in rooms with large square or retangular cross-sections. Because this station is next to a large instrumentation room rib, the closures differ from those under more uniform conditions further into the room excavation. Interpretation of the closures near the collar of the room is difficult. (DEM)

Gage Information

Gage Number	Gage Type	Gage Orient.	—— Record ——		Gage Manf.	Installation Date	Drawing Number
QPM01-1	CONV	V	T	MAN	SNL	8/10/89	T91025-000A
QPM02-1	CONV	H	T	MAN	SNL	8/10/89	T91025-000A

Gage Location

	Gage Coordinates							
					—— Local ——		—— Room ——	
Gage Number	X1 (m)	X2 (m)	Y1 (m)	Y2 (m)	Z1 (m)	Z2 (m)	Z1 (m)	Z2 (m)
QPM01-1	52.73	52.73	0.00	0.00	-1.46	1.46	-1.87	1.05
QPM02-1	52.73	52.73	-1.46	1.46	0.00	0.00	-0.41	-0.41

Gage Length Upon Installation

		Pass 1		Pass 2		Pass 3		Pass 4 + Trim -Final-	
Gage Number	Dir	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)
QPM01	V	-1	2.91		None		None	-1	2.91
QPM02	H	-1	2.91		None		None	-1	2.91

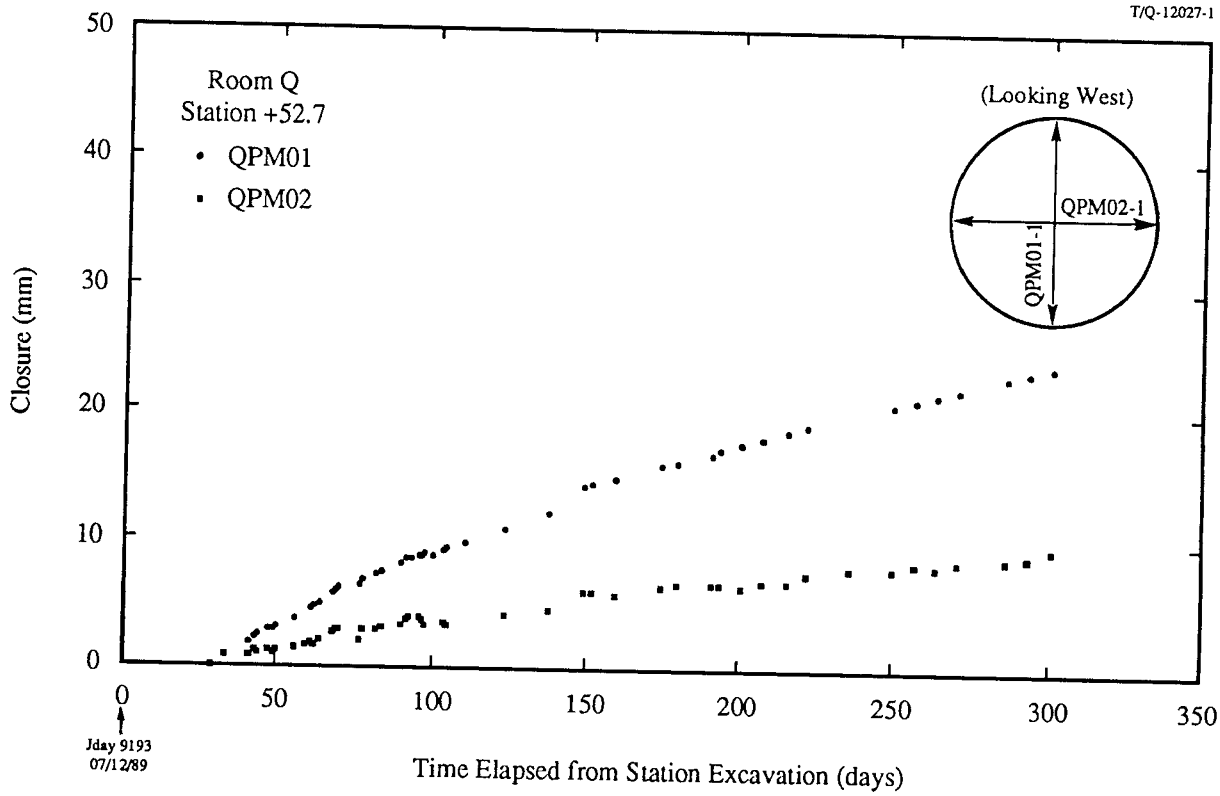


Figure 5.7.1a. Mining Sequence Gages QPM0x-x, Room Q, Station +52 m

Table 5.7.2b. Mining Sequence Gages QPM3x-x, Room Q, Station +28 m

QPM31 - QPM32 PI Comments

03/24/92 RLJ [93%] This station of Mining Sequence Closure Gages (1 vertical and 1 horizontal) was installed in the east portion of Room Q about 26m from the collar. Gages were first measured less than 4 hours after excavation. Data were collected for about 270 days, then discontinued because limited room access. Thereafter, measurements were acquired remotely. Note that the closure magnitude in Room Q is less than in rooms with large square or retangular cross-sections. The horizontal closure is greater than the vertical because of the effect of the bedded stratigraphy. (DEM)

Gage Information

Gage Number	Gage Type	Gage Orient.	Record		Gage Manf.	Installation Date	Drawing Number
QPM31-1	CONV	V	T	MAN	SNL	7/24/89	T91025-000A
QPM32-1	CONV	H	T	MAN	SNL	7/24/89	T91025-000A

Gage Location

	Gage Coordinates							
					Local		Room	
Gage Number	X1 (m)	X2 (m)	Y1 (m)	Y2 (m)	Z1 (m)	Z2 (m)	Z1 (m)	Z2 (m)
QPM31-1	28.04	28.04	0.00	0.00	-1.46	1.46	-1.82	1.10
QPM32-1	28.04	28.04	-1.46	1.46	0.00	0.00	-0.36	-0.36

Gage Length Upon Installation

		Pass 1		Pass 2		Pass 3		Pass 4 + Trim -Final-	
Gage Number	Dir	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)
QPM31	V	-1	2.95		None		None	-1	2.95
QPM32	H	-1	2.92		None		None	-1	2.92

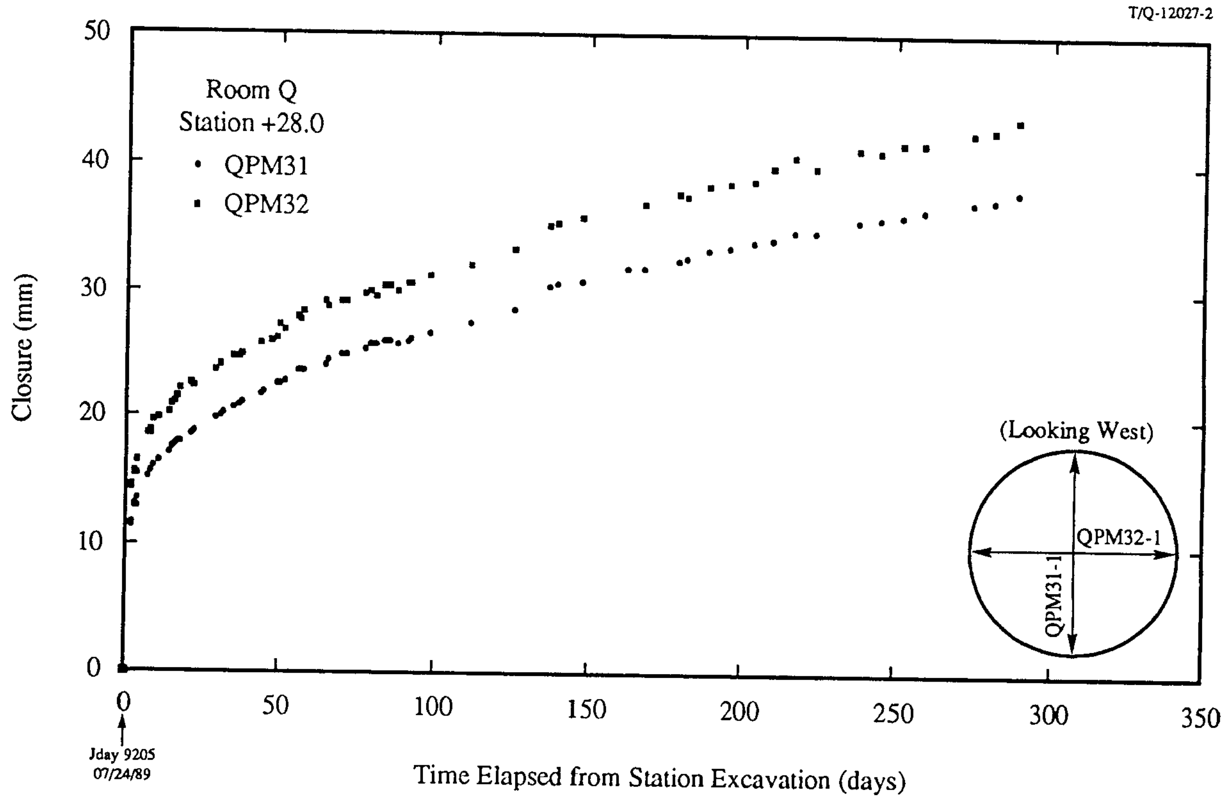


Figure 5.7.1b. Mining Sequence Gages QPM3x-x, Room Q, Station +28 m

Table 5.7.2c. Mining Sequence Gages QPM5x-x, Room Q, Station -04 m

QPM51 - QPM52 PI Comments

03/25/92 RLJ [91%] This station of Mining Sequence Closure Gages (1 vertical and 1 horizontal) was installed in the center portion of Room Q about 58m from the collar. Gages were first measured less than 3 hours after excavation. Data were collected for about 285 days, then discontinued because of limited access. Thereafter, measurements were acquired remotely. Note that the closure magnitude in Room Q is less than in rooms with large square or retangular cross-sections. The horizontal closures are greater than the vertical because of the effect of the bedded stratigraphy. (DEM)

Gage Information

Gage Number	Gage Type	Gage Orient.	Record		Gage Manf.	Installation Date	Drawing Number
QPM51-1	CONV	V	T	MAN	SNL	7/27/89	T91025-000A
QPM52-1	CONV	H	T	MAN	SNL	7/27/89	T91025-000A

Gage Location

					Gage Coordinates			
					Local		Room	
Gage Number	X1 (m)	X2 (m)	Y1 (m)	Y2 (m)	Z1 (m)	Z2 (m)	Z1 (m)	Z2 (m)
QPM51-1	-3.66	-3.66	0.00	0.00	-1.46	1.46	-1.46	1.46
QPM52-1	-3.66	-3.66	-1.46	1.46	0.00	0.00	0.00	0.00

Gage Length Upon Installation

		Pass 1		Pass 2		Pass 3		Pass 4 + Trim -Final-	
Gage Number	Dir	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)
QPM51	V	-1	2.91		None		None	-1	2.91
QPM52	H	-1	2.93		None		None	-1	2.93

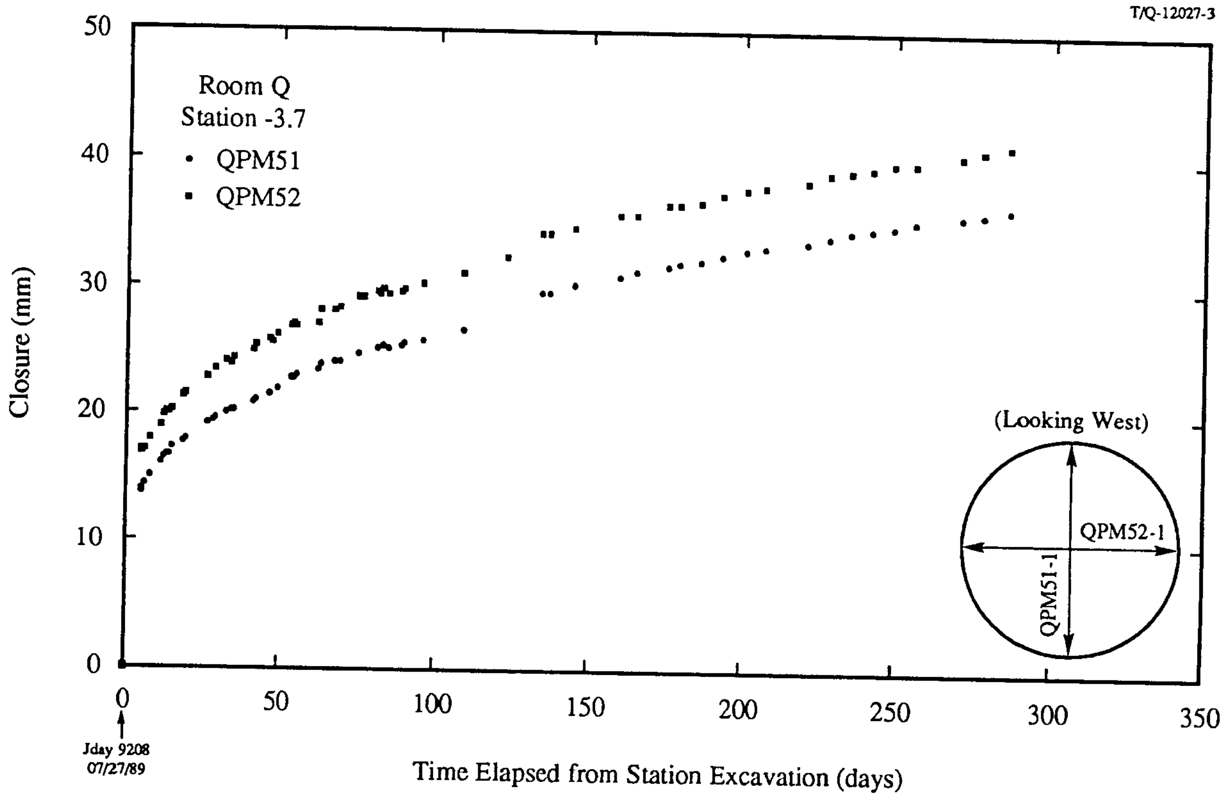


Figure 5.7.1c. Mining Sequence Gages QPM5x-x, Room Q, Station -04 m

Table 5.7.2d. Mining Sequence Gages QPM8x-x, Room Q, Station -34 m

QPM81 - QPM82 PI Comments

03/26/92 RLJ [92%] This station of Mining Sequence Closure Gages (1 vertical and 1 horizontal) was installed in the west portion of Room Q about 89m from the collar. Gages were first measured less than 4 hours after excavation. Data were collected for about 281 days, then discontinued because of limited room access. Thereafter, measurements were acquired remotely. Note that the closure magnitude in Room Q is less than in rooms with large square or retangular cross-sections. The horizontal closures are greater than the vertical because of the effect of the bedded stratigraphy. (DEM)

Gage Information

Gage Number	Gage Type	Gage Orient.	—— Record ——		Gage Manf.	Installation Date	Drawing Number
QPM81-1	CONV	V	T	MAN	SNL	8/1/89	T91025-000A
QPM82-1	CONV	H	T	MAN	SNL	8/1/89	T91025-000A

Gage Location

	Gage Coordinates							
					—— Local ——		—— Room ——	
Gage Number	X1 (m)	X2 (m)	Y1 (m)	Y2 (m)	Z1 (m)	Z2 (m)	Z1 (m)	Z2 (m)
QPM81-1	-34.44	-34.44	0.00	0.00	-1.46	1.46	-0.56	2.36
QPM82-1	-34.44	-34.44	-1.46	1.46	0.00	0.00	0.90	0.90

Gage Length Upon Installation

		Pass 1		Pass 2		Pass 3		Pass 4 + Trim -Final-	
Gage Number	Dir	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)	Gage	Length (m)
QPM81	V	-1	2.91		None		None	-1	2.91
QPM82	H	-1	2.92		None		None	-1	2.92

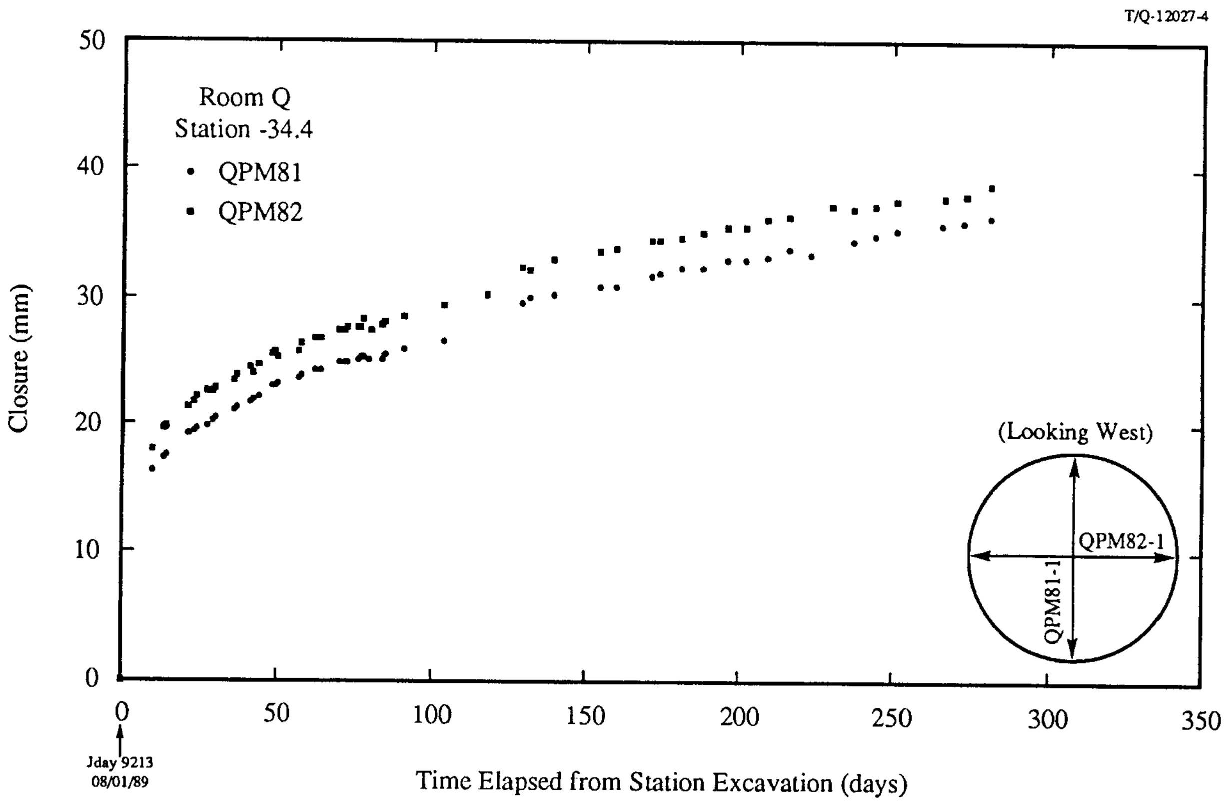


Figure 5.7.1d. Mining Sequence Gages QPM8x-x, Room Q, Station -34 m

6 INTERPRETATION AIDS

Interpretation of in situ test data from the TSI tests involves some interesting, but often ignored or unrecognized, factors arising from the time-dependent response of the salt. These important factors must be understood before undertaking any meaningful analysis of the in situ data. Ignoring the factors may contribute to failure of the analyses used to predict the observed in situ behavior, and certainly causes confusion in interpretation of numerical studies.

Analysts have a marked tendency to take in situ data at face value. The analyst must realize that in situ data represent only part of (1) the displacements that occur during the mining of an opening, and (2) the stress histories that are induced around the mined opening. Even for the temperature measurements, the mined openings and underground operations activity can influence the observed values. Often the test investigator and the analyst may think that nothing has happened before we arrived and started to make measurements. However, significant events can and often do occur before gage installation and beginning of measurement. Proper interpretation requires that the in situ test investigators recognize both the need to minimize "lost" or "unmeasured" displacements insofar as possible in the measurements, and to recognize the influence of fielding activity on both stress and temperature measurements. In turn, the numerical analyst must recognize the consequences of typical model abstractions and accepted assumptions, such as instantaneous excavation, introduced more or less routinely into the calculations, which may not be permissible for actual in situ conditions and the detailed configuration of gages.

In obtaining the displacement results presented in this report, we took every care to reduce the "lost" displacements to the smallest possible quantity. Further, the interpretation recognizes where the lost displacements reside. Schematically, the salt displacements for both closures and extensometers can be reconstructed (in terms of following the trajectory of a material point in the salt) as a mining face of an opening approaches, passes, and recedes from the plane of the point. If the face velocity is constant, the points will move in time according to the constitutive laws for the creep of salt. A non-constant face velocity introduces an additional pseudo time-dependent term. This situation can be illustrated. In the Figure 6.0.1, two material points, E′ and C, for example, represent an extensometer and closure point, respectively. Trajectory lines for vertical displacements are drawn through the two points. For both points E′ and C, the points undergo displacements before the mining face reaches them. The point E is constructed so that it does not undergo any displacement in the time frame of interest; however, even this point will eventually undergo displacement.

Although the E′ and C displacements are in general three-dimensional, we show here the vertical component of the displacement field because only this component influences the vertical closure and extensometer results. Displacements of this type are the result of the far-field, stress-strain influence of the opening on the surrounding salt. Measurement of these displacements can be obtained only through very special experimental efforts, and they usually are unrecognized. Notice that point C actually starts above the eventual line of the opening, but the displacement brings the point down to become a surface point as the face approaches the plane of the point. Point displacements in advance of the mining face cannot be measured at the face, even very quickly, because the mining operation

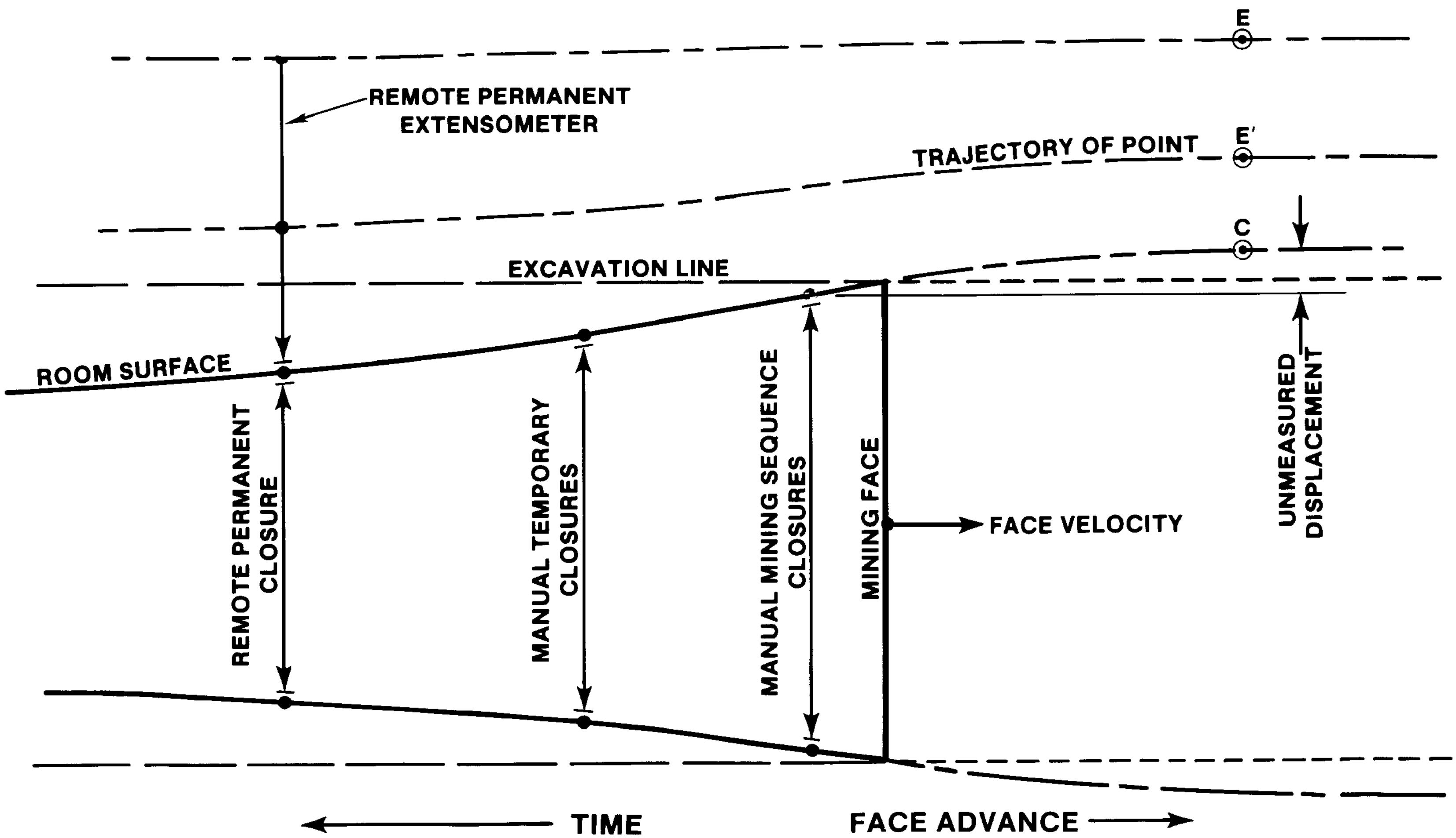


Figure 6.0.1. Particle Trajectories for Displacements during Mining

essentially mines out the displaced material. After the mining face has passed, both points E and C continue to displace with time. However, now the investigator potentially has access to these points and can install instruments to measure their displacements. Recall that the points continue to displace from creep, even though the advance of the face may stop or hesitate. Gage installation can be represented on the trajectory curves of the points.

At the WIPP, the early, mining sequence closure gages were installed within about 1 m of the mining face, and within less than 1 hour of opening the intended gage station. This is noted on the trajectory curve of the surface point C. As operations permitted, the mining sequence gages were supplemented by the temporary closure gages, as shown. Again, as operations and hole drilling permitted, the permanent closure stations were established. It is clear that the mining sequence data represents the earliest possible data. However, even for these data, the small amount of strain in the salt mass just ahead of the excavation face of the first mining pass represents a displacement of point C that is not measured by the mining sequence gages. Because this lost displacement can not be readily reconstructed, it essentially remains lost data.

Although similar reconstructions are required for the extensometer data, as shown by the significant "lost" displacement for the trajectory of point E, we are concerned here only with the closure data. Discussion of the extensometer data interpretation can be found in the data reports of the individual tests.

Recognition of the events explained above permits an abstract or schematic reconstruction of measured and "unmeasured" displacements. Such a reconstruction is illustrated for closure measurements in Figure 6.0.2.

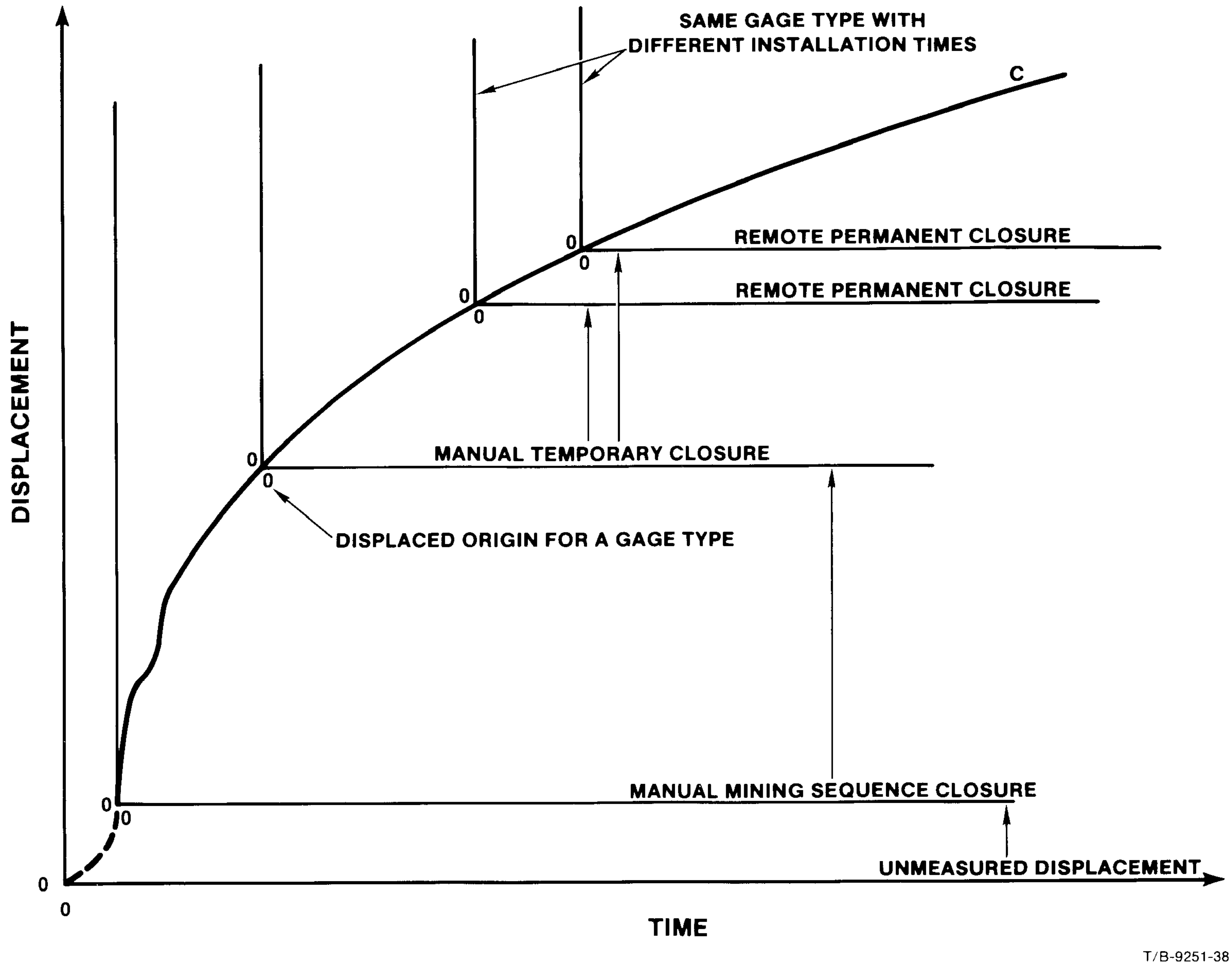


Figure 6.0.2. Reconstruction Schematic for Closure Measurements

The ability to reconstruct a complete displacement curve is perhaps the measure of the success of any analysis of in situ data. As a corollary, numerical simulations that ignore the realities of collecting field data may also be less than successful.

7 SUMMARY

A wealth of technical information and data for the early closures as measured concurrently with the single and multipass mining of the Thermal/Structural Interactions (TSI), the Intermediate Scale Borehole Test (ISBT), and the Brine lnflow (Room Q) in situ tests is presented in this report. These data include extensive structural mining sequence data taken during the excavation of the test rooms, beginning in May of 1984 and extending into January 1985, the excavation of Room Q in July and August of 1989, and the drilling of the ISBT in December of 1990. Typically, the mining sequence measurements consist of those closure data taken during the actual mining of the test room, typically a duration of about a month, and for some time, typically about a month, thereafter. However, in many cases, the mining sequence closure gages have remained active as a check on the remote closure gage data, with data obtained for as long as 2800 days.

The intent of this report is to make the results of these large-scale, in situ tests available to analysts and other interested persons. The presentation of the data is organized to permit easy access to data of a given type of gage or specific gage for a given test room.

Because of the complex nature of the time-dependent response of underground openings in salt, interpretation aids are required to put the data into proper context. For proper analysis, it is essential the interpretation framework be understood. In fact, the mining sequence closure data presented here form the basis for the temporary and permanent closure gage data of the individual test room data reports.

The data of the mining sequence closure gages forms a final data set and no update of this report is planned or required.

REFERENCES

[1] R. V. Matalucci, C. L. Christensen, T. O. Hunter, M. A. Molecke, and D. E. Munson, 1982, Waste Isolation Pilot Plant (WIPP) Research and Development Program: In Situ Testing Plan, March 1982, SAND81-2628, Sandia National Laboratories, Albuquerque, NM.

[2] D. E. Munson and R. V. Matalucci, 1984, "Planning, Developing, and Fielding of Thermal/Structural Interactions In Situ Tests for the Waste Isolation Pilot Plant (WIPP)," Proc. Waste Management Symp. '84, U. of Arizona, Tucson, AZ, pp. 317-333.

[3] R. V. Matalucci and D. E. Munson, 1988, "Planning, Developing, and Organizing In Situ Tests for the Waste Isolation Pilot Plant (WIPP)," Proc. of 2nd International Conf. on the Mech. Behavior of Salt, Trans Tech Publications, Clausthal, Germany, pp. 329-360.

[4] D. E. Munson, R. V. Matalucci, and T. M. Torres, 1988, "Implementation of Thermal/Structural Interactions In Situ Tests at the Waste Isolation Pilot Plant Facility," Proc. of 2nd International Conf. on the Mech. Behavior of Salt, Trans Tech Publications, Clausthal, Germany, pp. 361.390.

[5] D. E. Munson, R. L. Jones, D. L. Hoag, and J. R. Ball, 1988, Mining Development Test (Room D): In Situ Data Report (March 1984 - May 1988) Waste Isolation Pilot Plant (WIPP) Thermal/Structural Interactions Program, SAND88-1460, Sandia National Laboratories, Albuquerque, NM.

[6] D. E. Munson, S. V. Petney, T. L. Christian-Frear, J. R. Ball, R. L. Jones, and C. L. Northrop-Salazar, 1992, Geomechanical Evaluation (Room G): In Situ Data Report (December 1984 - November 1990), SAND92-0582, Sandia National Laboratories, Albuquerque, NM.

[7] D. E. Munson, R. L. Jones, D. L. Hoag, and J. R. Ball, 1987, Heated Axisymmetric Pillar Test (Room H): In Situ Data Report (February 1985 - April 1987) Waste Isolation Pilot Plant (WIPP) Thermal/Structural Interactions Program, SAND87-2488, Sandia National Laboratories, Albuquerque, NM.

[8] D. E. Munson, R. L. Jones, J. R. Ball, R. M. Clancy, D. L. Hoag, and S. V. Petney, 1990, Overtest for Simulated Defense High-Level Waste (Room B): In Situ Data Report (May 1984 - February 1988) Waste Isolation Pilot Plant (WIPP) Thermal/Structural Interactions Program, SAND89-2671, Sandia National Laboratories, Albuquerque, NM.

[9] D. E. Munson, S. V. Petney, R. M. Clancy, J. R. Ball, R. L. Jones, and C. L. Northrop-Salazar, 1991, 18W/m^2 Mockup for Defense High-Level Waste (Rooms A): In Situ Data Report: Vol. I - Mechanical Response Gages (February 1985 - June 1990), SAND90-2748, Sandia National Laboratories, Albuquerque, NM.

[10] D. E. Munson, S. V. Petney, T. L. Christian-Frear, J. R. Ball, R. L. Jones, and C. L. Northrop-Salazar, 1992, $18W/m^2$ Mockup for Defense High-Level Waste (Rooms A): In Situ Data Report: Vol. II - Thermal Response Gages (February 1985 - June 1991, SAND90-2749, Sandia National Laboratories, Albuquerque, NM.

[11] D. E. Munson, T. M. Torres, and D. A. Blankenship, 1986, "Early Results from the Thermal/Structural In Situ Test Series at the WIPP," Proc. 27th U.S. Rock Mech. Symp., Soc. Mining Eng., Littleton, CO, pp. 923-930.

[12] J. T. McIlmoyle, R. V. Matalucci, and H. C. Ogden, 1987, The Data Acquisition System for the Waste Isolation Pilot Plant In Situ Tests, SAND86-1031, Sandia National Laboratories, NM.

[13] D. E. Munson, J. R. Ball, and R. L. Jones, 1990, "Data Quality Assurance Controls through the WIPP In Situ Data Acquisition, Analysis, and Management System," Proc. 1st International Topical Meeting on High Level Radioactive Waste Management, ANS/ASCE, New York, NY, pp. 1337-1350.

[14] R. D. Krieg, 1984, Reference Stratigraphy and Rock Properties for the Waste Isolation Pilot Plant (WIPP) Project, SAND83-1908, Sandia National Laboratories, Albuquerque, NM.

[15] D. E. Munson, A. F. Fossum, and P. E. Senseny, 1989, Advances in Resolution of Discrepancies between Predicted and Measured In Situ Room Closures, SAND88-2948, Sandia National Laboratories, Albuquerque, NM.

[16] D. E. Munson, T. M. Torres, and R. L. Jones, 1987, "Pseudostrain Representation of Multipass Excavations in Salt," Proc. 28th U.S. Symp. on Rock Mechanics, A. A. Balkema, Boston, MA, pp. 853-862.

[17] D. E. Munson, T. M. Torres, and R. L. Jones, 1988, "Results of a Large, In Situ, Heated Axisymmetric Pillar Test at the Waste Isolation Pilot Plant (WIPP)," Proc. 29th U.S. Symp. on Rock Mechanics, A. A. Balkema, Boston, MA, pp. 641-651.

[18] D. E. Munson, A. F. Fossum, and P. E. Senseny, 1989, "Approach to First Principles Model Prediction of Measured WIPP In Situ Room Closure in Salt," Proc. 30th U.S. Symp. on Rock Mechanics, A. A. Balkema, Rotterdam, Netherlands, pp. 673-680.

[19] D. E. Munson, K. L. DeVries, and G. D. Callahan, 1990, "Comparison of Calculations and In Situ Results of a Large, Heated Test Room at the Waste Isolation Pilot Plant (WIPP)," Proc. 31st U.S. Symp. on Rock Mechanics, A. A. Balkema, Rotterdam, Netherlands, pp. 389-396.

[20] WIPP Project Management Department, 1990, WIPP Manual Data Reduction Procedures: WIPP Procedures 232-236, Sandia WIPP Central Files, Waste Management and Transportation Library, Sandia National Laboratories, Albuquerque, NM.

[21] WIPP Project Management Department, 1990, WIPP Remote Data Reduction Procedures: WIPP Procedures 293-300, Sandia WIPP Central Files, Waste Management and Transportation Library, Sandia National Laboratories, Albuquerque, NM.

[22] WIPP Project Management Department, 1990, Quality Assurance Program Plan for the Waste Isolation Pilot Plant (WIPP), WIPP/QAPP Revision 0, Sandia WIPP Central Files, Waste Management and Transportation Library, Sandia National Laboratories, Albuquerque, NM.

[23] J. G. Arguello, D. E. Munson, and D. S. Preece, 1987, "Preliminary Results of the Three-Dimensional Modeling of the WIPP Room D Excavation Sequence", Proc. 28th U.S. Symp. on Rock Mechanics, University of Arizona, Tucson, AZ, pp. 863-872.

[24] D. E. Munson, R. L. Jones, and K. L. DeVries, 1991, "Analysis of Early Creep Closures in Geomechanically Connected Underground Rooms in Salt", Proc. 32nd U.S. Symp. on Rock Mechanics, A. A. Balkema, Brookfield, MA, pp. 881-888.

[25] D. E. Munson and K. L. DeVries, 1991, "Development and Validation of a Predictive Technology for Creep Closure of Underground Rooms in Salt", Proc. 7th International Congress on Rock Mechanics, A. A. Balkema, Brookfield, MA, pp. 127-134.

[26] J. G. Arguello, 1991, Pretest 3D Finite Element Analysis of the WIPP Intermediate-Scale-Borehole Test, SAND90-2055, Sandia National Laboratories, Albuquerque, NM.

DISTRIBUTION

Federal Agencies

US Department of Energy (5)
Office of Civilian Radioactive Waste Management
Attn: Deputy Director, RW-2
Associate Director, RW-10
Office of Program Administration and Resources Management
Associate Director, RW-20
Office of Facilites Siting and Development
Associate Director, WR-30
Office of Systems Integration and Regulations
Associate Director, RW-40
Office of External Relations and Policy
Forrestal Building
Washington, DC 20585

US Department of Energy (4)
WIPP Project Integration Office
Attn: W.J. Arthur III
L.W. Gage
P.J. Higgins
D.A. Olona
PO Box 5400
Albuquerque, NM 87115-5400

US Department of Energy
Attn: National Atomic Museum Library
Albuquerque Operations Office
PO Box 5400
Albuquerque, NM 87185-5400

US Department of Energy (4)
WIPP Project Site Office (Carlsbad)
Attn: R. Becker
V. Daub
J. Lippis
J.A. Mewhinney
PO Box 3090
Carlsbad, NM 88221

US Department of Energy
Research & Waste Management Division
Attn: Director
PO Box E
Oak Ridge, TN 37831

US Department of Energy
Attn: E. Young
Room E-178
GAO/RCED/GTN
Washington, DC 20545

US Department of Energy
Office of Environmental Restoration and Waste Management
Attn: J. Lytle, EM-30
Washington, DC 20585-0002

US Department of Energy (3)
Office of Environmental Restoration and Waste Management
Attn: M. Frei, EM-34 (Trevion II)
Washington, DC 20585-0002

US Department of Energy
Office of Environmental Restoration and Waste Management
Attn: S. Schneider, EM-342 (Trivion II)
Washington, DC 20585-0002

US Department of Energy (2)
Office of Environment, Safety and Health
Attn: C. Borgstrom, EH-25
R. Pelletier, EH-231
Washington, DC 20585

US Department of Energy (2)
Idaho Operations Office
Fuel Processing and Waste Managment Division
785 DOE Place
Idaho Falls, ID 83402

US Environmental Protection Agency (2)
Radiation Programs (ANR-460)
Attn: R. Guimond
Washington, DC 20460

US Geological Survey
Water Resources Divison
Attn: R. Livingston
Suite 200
4501 Indian School, NE
Albuquerque, NM 87110

Boards

Defense Nuclear Facilities Safety Board
Attn: D. Winters
Suite 700
625 Indiana Ave., NW
Washington, DC 20004

Nuclear Waste Technical Review Board (2)
Attn: D.A. Deere
S.J.S. Parry
Suite 910
1100 Wilson Blvd.
Arlington, VA 22209-2297

Advisory Committee on Nuclear Waste
Nuclear Regulatory Commission
Attn: R. Major
7920 Norfolk Ave.
Bethesda, MD 20814

State Agencies

Environmental Evaluation Group (3)
Attn: Library
Suite F-2
7007 Wyoming, NE
Albuquerque, NM 87109

NM Bureau of Mines and Mineral Resources
Socorro, NM 87801

NM Energy, Minerals, and Natural Resources Department
Attn: Library
2040 S. Pacheco
Santa Fe, NM 87505

NM Environment Department (2)
Secretary of the Environment
Attn: J. Espinosa
1190 St. Francis Drive
Santa Fe, NM 87503-0968

NM Environment Department
WIPP Project Site
Attn: P. McCasland
PO Box 3090
Carlsbad, NM 88221

Laboratories/Corporations

Battelle Pacific Northwest Laboratories (2)
Attn: H.C. Burkholder, P7-41
R.E. Westerman, P8-37
Battelle Blvd.
Richland, WA 99352

INTERA Inc.
Attn: J.F. Pickens
Suite 300
6850 Austin Center Blvd.
Austin, TX 78731

INTERA Inc.
Attn: W. Stensrud
PO Box 2123
Carlsbad, MN 88221

IT Corporation
Attn: R.F. McKinney
Regional Office - Suite 700
5301 Central, NE
Albuquerque, NM 87108

Los Alamos National Laboratory
Attn: B. Erdal, CNC-11
PO Box 1663
Los Alamos, NM 87544

RE/SPEC, Inc.
Attn: W.Coons
S.V. Petney
J.R. Ball
Suite 300
4775 Indian School, NE
Albuquerque, NM 87110-3927

RE/SPEC, Inc.
Attn: G.D. Callahan
A.F. Fossum
T.W. Pfeifle
J.L. Ratigan
PO Box 725
Rapid City, SD 57709

Savannah River Laboratory
Attn: N. Bibler
M.J. Plodinec
G.G. Wicks
Aiken, SC 29801

Southwest Research Institute (2)
Center for Nuclear Waste
Regulatory Analysis
Attn: P.K. Nair
6220 Culebra Road
San Antonio, TX 78228-0510

SAIC
Attn: G. Dymmel
101 Convention Center Dr.
Las Vegas, NV 89109

SAIC
Attn: H.R. Pratt
10260 Campus Point Dr.
San Diego, CA 92121

SAIC
Attn: J. Tollison
2109 Air Park Rd., SE
Albuquerque, NM 87106

Tech Reps Inc. (3)
Attn: J. Chapman
R. Jones
C. Northrop-Salazar
T. Peterson
5000 Marble, NE
Albuquerque, NM 87110

Westinghouse Electric
Corporation (5)
Attn: Library
C. Cox
L. Fitch
R. Kehrman
L. Trego
PO Box 2078
Carlsbad, NM 88221

Universities

University of New Mexico
Geology Department
Attn: Library
Albuquerque, NM 87131

University of Washington
Attn: G.R. Heath
College of Ocean and Fishery
Sciences
583 Henderson Hall
Seattle, WA 98195

Individuals

P. Drez
8816 Cherry Hills Rd., NE
Albuquerque, NM 87111

D. W. Powers
Star Route Box 87
Anthony, TX 79821

Libraries

Thomas Brannigan Library
Attn: D. Dresp
106 W. Hadley St.
Las Cruces, NM 88001

Government Publications Department
General Library
University of New Mexico
Albuquerque, NM 87131

Hobbs Public Library
Attn: M. Lewis
509 N. Ship St.
Hobbs, NM 88248

New Mexico Junior College
Pannell Library
Attn: R. Hill
Lovington Highway
Hobbs, NM 88240

New Mexico State Library
Attn: N. McCallan
325 Don Gaspar
Santa Fe, NM 87503

New Mexico Tech
Martin Speere Memorial Library
Campus Street
Socorro, NM 87810

WIPP Public Reading Room
Carlsbad Public Library
Attn: Director
101 S. Halagueno St.
Carlsbad, NM 88220

National Academy of Sciences
WIPP Panel

Charles Fairhurst, Chairman
Department of Civil and
Mineral Engineering
University of Minnesota
500 Pillsbury Dr., SE
Minneapolis, MN 55455-0220

Howard Adler
Oak Ridge Associated Universities
Medical Sciences Division
PO Box 117
Oak Ridge, TN 37831-0117

Ina Alterman
Board on Radioactive Waste
Management
GF456
2101 Constitution Ave.
Washington, DC 20418

John D. Bredehoeft
Western Region Hydrologist
Water Resources Division
US Geological Survey (M/S 439)
345 Middlefield Road
Menlo Park, CA 94025

Fred M. Ernsberger
250 Old Mill Road
Pittsburgh, PA 15238

Rodney C. Ewing
Department of Geology
University of New Mexico
Albuquerque, NM 87131

B. John Garrick
PLG, Inc.
Suite 400
4590 MacArthur Blvd.
Newport Beach, CA 92660-2027

Leonard F. Konikow
US Geological Survey
431 National Center
Reston, VA 22092

Peter B. Myers
National Academy of Sciences
Board on Radioactive Waste
Management
2101 Constitution Ave.
Washington, DC 20418

Jeremiah O'Driscoll
Jody Incorporated
505 Valley Hill Drive
Atlanta, GA 30350

Christopher G. Whipple
Clement International
Suite 1380
160 Spear St.
San Francisco, CA 94105

Foreign Addresses

Studiecentrum Voor Kernenergie
Centre D'Energie Nucleaire
Attn: A. Bonne
SCK/CEN
Boeretang 200
B-2400 Mol, BELGIUM

Atomic Energy of Canada, Ltd. (3)
Whiteshell Research Establishment
Attn: B. Goodwin
M. Stevens
D. Wushke
Pinewa, Manitoba, CANADA ROE 1LO

Francois Chenevier, Director (2)
ANDRA
Route du Panorama Robert Schumann
B.P. 38
92266 Fontenay-aux-Roses CEDEX
FRANCE

Jean-Pierre Olivier
OECD Nuclear Energy Agency
Division of Radiation Protection
and Waste Management
38, Boulevard Suchet
75016 Paris, FRANCE

Claude Sombret
Centre D'Etudes Nucleaires
De La Vallee Rhone
CEN/VALRHO
S.D.H.A. BP 171
30205 Bagnols-sur-Ceze, FRANCE

Bundesministerium fur Forschung und
Technologie
Postfach 200 706
5300 Bonn 2, GERMANY

Gesellschaft fur Reaktorsicherheit
(GES) (2)
Attn: B. Baltes
W. Muller
Schwertnergasse 1
D-5000 Cologne, GERMANY

Bundesanstalt fur Geowissenschaften
und Rohstoffe
Attn: M. Langer
Postfach 510 153
3000 Hannover 51, GERMANY

Hahn-Meitner-Institut fur
Kernforschung
Attn: W. Lutze
Glienicker Strasse 100
100 Berlin 39, GERMANY

Institut fur Tieflagerung (2)
Attn: K. Kuhn
Theodor-Heuss-Strasse 4
D-3000 Braunschweig, GERMANY

Physikalisch-Technische
Bundesanstalt
Attn: P. Brenneke
Postfach 3345
D-3300 Braunschweig, GERMANY

Shingo Tashiro
Japan Atomic Energy Research Inst.
Tokai-Mura, Ibaraki-Ken, 319-11
JAPAN

Netherlands Energy Research
Foundation ECN
Attn: L.H. Vons
3 Westerduinweg
PO Box 1
1755 ZG Petten, THE NETHERLANDS

Svensk Karnbransleforsorjning AB
Attn: F. Karlsson
Project KBS
Karnbranslesakerhet
Box 5864
10248 Stockholm, SWEDEN

Nationale Genossenschaft fur die
Lagerung Radioaktiver Abfalle (2)
Attn: S. Vomvoris
P. Zuidema
Hardstrasse 73
CH-5430 Wettingen, SWITZERLAND

D.R. Knowles
British Nuclear Fuels, plc
Risley, Warrington, Cheshire WA3 6AS
1002607 UNITED KINGDOM

AEA Technology
Attn: J.H. Rees
D5W/29 Culham Laboratory
Abington, Oxfordshire OX14 3DB
UNITED KINGDOM

AEA Technology
Attn: W.R. Rodwell
044/A31 Winfrith Technical Centre
Dorchester, Dorset DT2 8DH
UNITED KINGDOM

AEA Technology
Attn: J.E. Tinson
B4244 Harwell Laboratory
Didcot, Oxfordshire OX11 ORA
UNITED KINGDOM

Sandia Internal

1502	J.C. Cummings
1561	H.S. Morgan
6000	D.L. Hartley
6100	R. W. Lynch
6117	W.R. Wawersik
6119	E.D. Gorham
6119	Staff (14)
6121	J.R. Tillerson
6121	Staff (7)
6121	D.E. Munson (25)
6300	D.E. Miller
6302	T.E. Blejwas, Acting
6303	W.D. Weart
6303	S.Y. Pickering
6305	S.A. Goldstein
6341	A.L. Stevens
6341	Staff (6)
6341	WIPP Central Files (10)
6342	D.R. Anderson
6342	Staff (20)
6343	T.M. Schultheis
6343	Staff (2)
6345	R.C. Lincoln
6345	Staff (9)
6347	D.R. Schafer
7141	Technical Library (5)
7151	Technical Publications
7613-2	Document Processing for DOE/OSTI (10)
8523-2	Central Technical Files
9300	J.E. Powell
9323	J.T. McIlmoyle

☆ U.S. GOVERNMENT PRINTING OFFICE 1993—774-122/80,062