NUREG/CR-6360

Summary of Air Permeability Data From Single-Hole Injection Tests in Unsaturated Fractured Tuffs at the Apache Leap Research Site: Results of Steady-State Test Interpretation

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The University of Arizona

Prepared for
U.S. Nuclear Regulatory Commission

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ABSTRACT

This document summarizes air permeability estimates obtained from single hole pneumatic injection tests in unsaturated fractured tuffs at the Covered Borehole Site (CBS) within the larger Apache Leap Research Site (ALRS). Only permeability estimates obtained from a steady state interpretation of relatively stable pressure and flow rate data are included. Most of the reported data were produced as part of work culminating in a doctoral dissertation, entitled "In-situ Air Permeability Tests and Their Interpretation in Unsaturated Fractured Tuff," by Guzman (1995). This dissertation complements the present report by providing additional details about the methods of testing, test interpretation, and statistical analysis of the data. Tests were conducted in five boreholes inclined at 45° to the horizontal, and one vertical borehole. Five of the boreholes are 30 m long, one has a length of 45 m. Air injection was accomplished using a straddle packer assembly. Over 180 borehole segments were tested by setting the packers 1 m apart. Additional tests were conducted in segments of lengths 0.5, 2.0, and 3.0 m in one borehole, and 2.0 m in another borehole, bringing the total number of tests to over 270. Tests were conducted by maintaining a constant injection rate until air pressure became relatively stable and remained so for some time. The injection rate was then incremented by a constant value and the procedure repeated. Three or more such incremental steps were conducted in each borehole segment while recording the air injection rate, pressure, temperature, and relative humidity. For each relatively stable period of injection rate and pressure, air permeability was estimated by treating the rock around each test interval as a uniform, isotropic porous medium within which air flows as a single phase under steady state, in a pressure field exhibiting prolate spheroidal symmetry. For each permeability estimate we list the corresponding injection rate, pressure, temperature and relative humidity. We also present selected graphs which show how the latter quantities vary with time; logarithmic plots of pressure versus time which demonstrate the importance of borehole storage effects during the early transient portion of each incremental test period; and semilogarithmic plots of pressure versus recovery time at the end of each test sequence. A description of field operating procedures used to insure compliance with QA/QC requirements is included.

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FOREWORD

This technical report was prepared by The University of Arizona under their research project with the Waste Management Branch in the Office of Nuclear Regulatory Research (FIN L1282). The report provides data summaries and research results from air permeability experiments conducted in the field using single-hole pneumatic injection tests in unsaturated, heterogeneous, fractured rock. Specifically, the report includes tables of over 270 air permeability estimates and corresponding field data obtained from controlled tests in packed-off intervals of the shallow boreholes at the Apache Leap Research Site. The provided tables only list permeability estimates interpreted by means of steady-state formulae, and data which are relatively stable in time during the corresponding tests periods. Data retrieval instructions for accessing the tables in ASCII format through an anonymous FTP connection are given. Selected plots of measured variables versus time are also included to illustrate transient effects during the air injection tests. The research reported provides insights into conducting and interpreting single-hole air injection tests for estimating permeability values for partially saturated, heterogeneous, fractured rock. The lessons learned are relevant to site characterization and data analysis issues related to modeling unsaturated flow and transport in fractured rock.

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0. EXECUTIVE SUMMARY

This document summarizes air permeability estimates obtained from single hole pneumatic injection tests in unsaturated fractured tuffs at the Covered Borehole Site (CBS) within the larger Apache Leap Research Site (ALRS). The ALRS is situated in central Arizona approximately 100 miles (160 km) north of Tucson, on a 1,000 km^2 remnant of a dacite ash-flow sheet, at an elevation of 1,200 m. above sea level. Its thickness averages 300 m. Climate is temperate and dry, with mean annual precipitation of less than 50 cm. The regional water table lies at a variable depth greater than 600 m, with an intervening perched water zone at an approximate depth of 150 m.

The CBS includes 22 vertical and slanted boreholes drilled by conventional rotary methods to a maximum depth of 30 m into slightly welded unsaturated tuff. The tuff has an average porosity of about 17% and contains numerous fractures at varying orientations, many of them near vertical. The boreholes are uncased except for about 1.8 m near the surface. They extend over a horizontal area of approximately 55 m by 35 m. This report lists air permeability data obtained within six boreholes at the CBS which extend over a horizontal area of 32 m by 20 m. Shortly after the completion of drilling, these and other boreholes were covered with a thick, 1,500 m^2 plastic sheet to prevent infiltration and evaporation at the surface.

Only permeability estimates obtained from a steady state interpretation of relatively stable pressure and flow rate data are listed in the report. Most of the reported data were produced as part of work culminating in a doctoral dissertation, entitled "In-situ Air Permeability Tests and Their Interpretation in Unsaturated Fractured Tuff," by Guzman (1995). This dissertation complements the present report by providing additional details about the methods of testing, test interpretation, and statistical analysis of the data. Tests were conducted in five boreholes inclined at 45° to the horizontal, and one vertical borehole. Five of the boreholes are 30 m long, one has a length of 45 m. Air injection was accomplished using a straddle packer assembly. Over 180 borehole segments were tested by setting the packers 1 m apart. Additional tests were conducted in segments of lengths 0.5, 2.0, and 3.0 m in one borehole, and 2.0 m in another borehole, bringing the total number of tests to over 270.

Tests were conducted by maintaining a constant injection rate until air pressure became relatively stable and remained so for some time. The injection rate was then incremented by a constant value and the procedure repeated. Three or more such incremental steps were conducted in each borehole segment while recording the ai · injection rate, pressure, temperature, and relative humidity. For each relatively stable period of injection rate and pressure, air permeability was estimated by treating the rock around each test interval as a uniform, isotropic porous medium within which air flows as a single phase under steady state, in a pressure field exhibiting prolate spheroidal symmetry. For each permeability estimate we list the corresponding injection rate, pressure, temperature and relative humidity.

The report also includes selected plots which illustrate how the latter quantities vary with time; logarithmic plots of pressure versus time which demonstrate the importance of borehole storage effects during the early transient portion of each incremental test period; and semilogarithmic plots of pressure versus recovery time at the end of each test sequence. A description of field operating procedures used to insure compliance with QA/QC requirements is included.

1. SITE DESCRIPTION AND BOREHOLE LOCATION

The Apache Leap Research Site (ALRS) is situated in central Arizona approximately 100 miles (160 km) north of Tucson, on a 1,000 km^2 remnant of a dacite ash-flow sheet (Peterson, 1961), at an elevation of 1,200 m above sea level. Its thickness is highly variable and averages about 300 m. Climate is temperate and dry, with mean annual precipitation of less than 50 cm. The regional water table lies at a variable depth greater than 600 m, with an intervening perched water zone at an approximate depth of 150 m.

Figure 1.1 indicates two borehole research sites currently in operation: (1) the Covered Boreholes Site (CBS) with the slanted borehole Y2 as reference, and (2) the Deep Boreholes Site (DBS) with a deeper slanted borehole as references. The CBS is contained in the vadose zone, in an upper layer of slightly welded tuff with an average porosity of approximately 17% (Rasmussen, et al., 1990; Geddis, 1994). The predominant fracture set is near vertical, but fractures exist at all

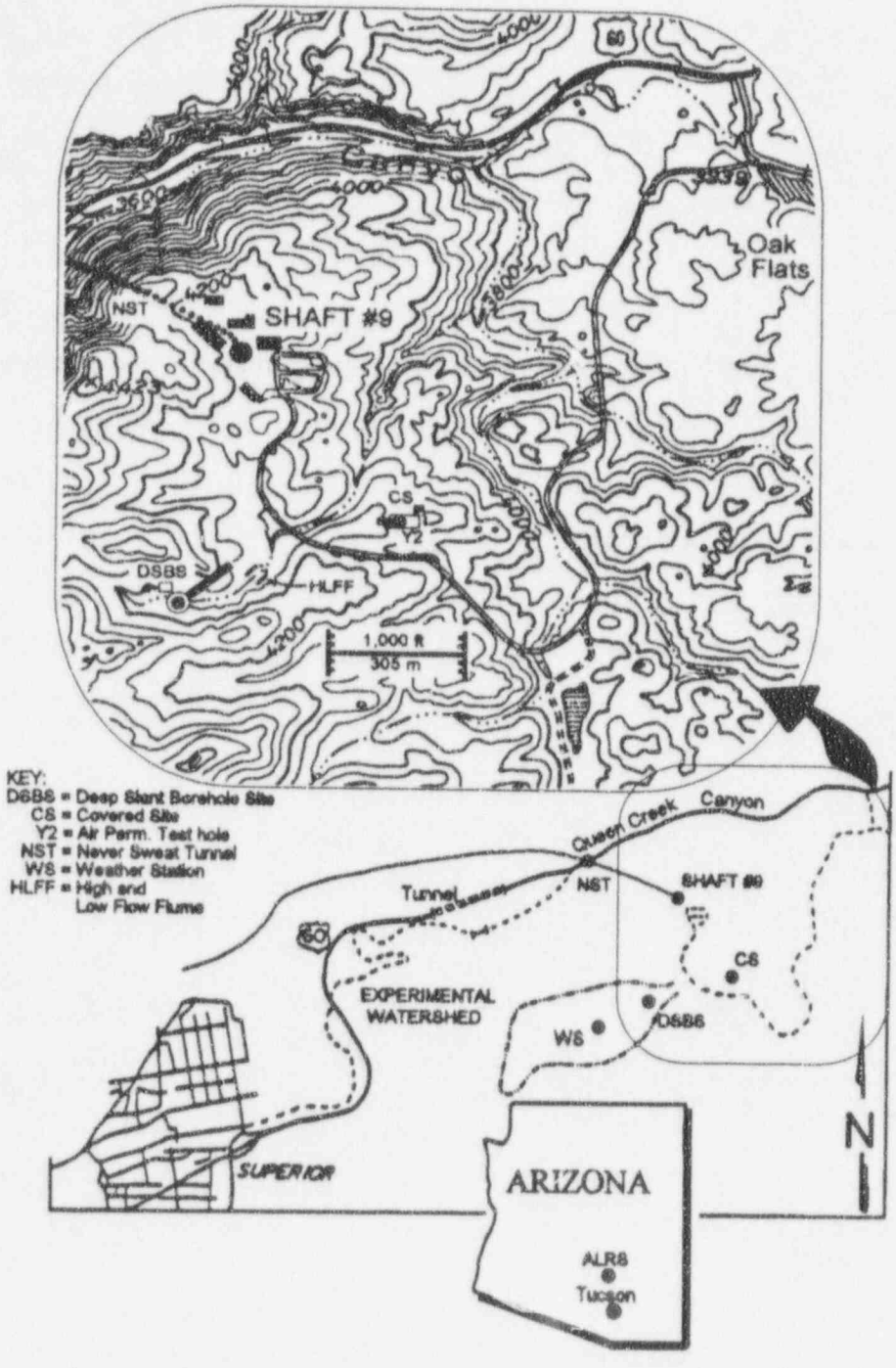

Figure 1.1 Location map for the Apache Leap Research Site (ALRS) from Geddis (1994).

orientations. To date, air permeability testing has been performed primarily at the CBS. This site consists of a cluster of 22 vertical or slanted (45° down from horizontal) boreholes that have been drilled to a maximum vertical depth of 30 m. The suite of boreholes covers a surface area of approximately 55 m by 35 m, yielding an experimental tuff block on the order of 60,000 m^3. Sixteen boreholes are depicted in Figure 1.2 which is a plan view of the V, W, X, Y, and Z series boreholes. These boreholes were drilled with conventional rotary methods using water as the cooling and chip circulating fluid. Oriented core was retrieved from all these holes and is in The University of Arizona Core Storage Facility. The boreholes are uncased except for about 1.8 m near the surface. Shortly after the completion of drilling, these boreholes were covered with a thick, 1,500 m^2 plastic sheet to prevent infiltration and evaporation at the surface.

This report lists air permeability data obtained within six of the covered boreholes. These extend over an area of 32 m by 20 m, to a depth of 30 m, yielding a three-dimensional block of rock on the order of 20,000 m^3.

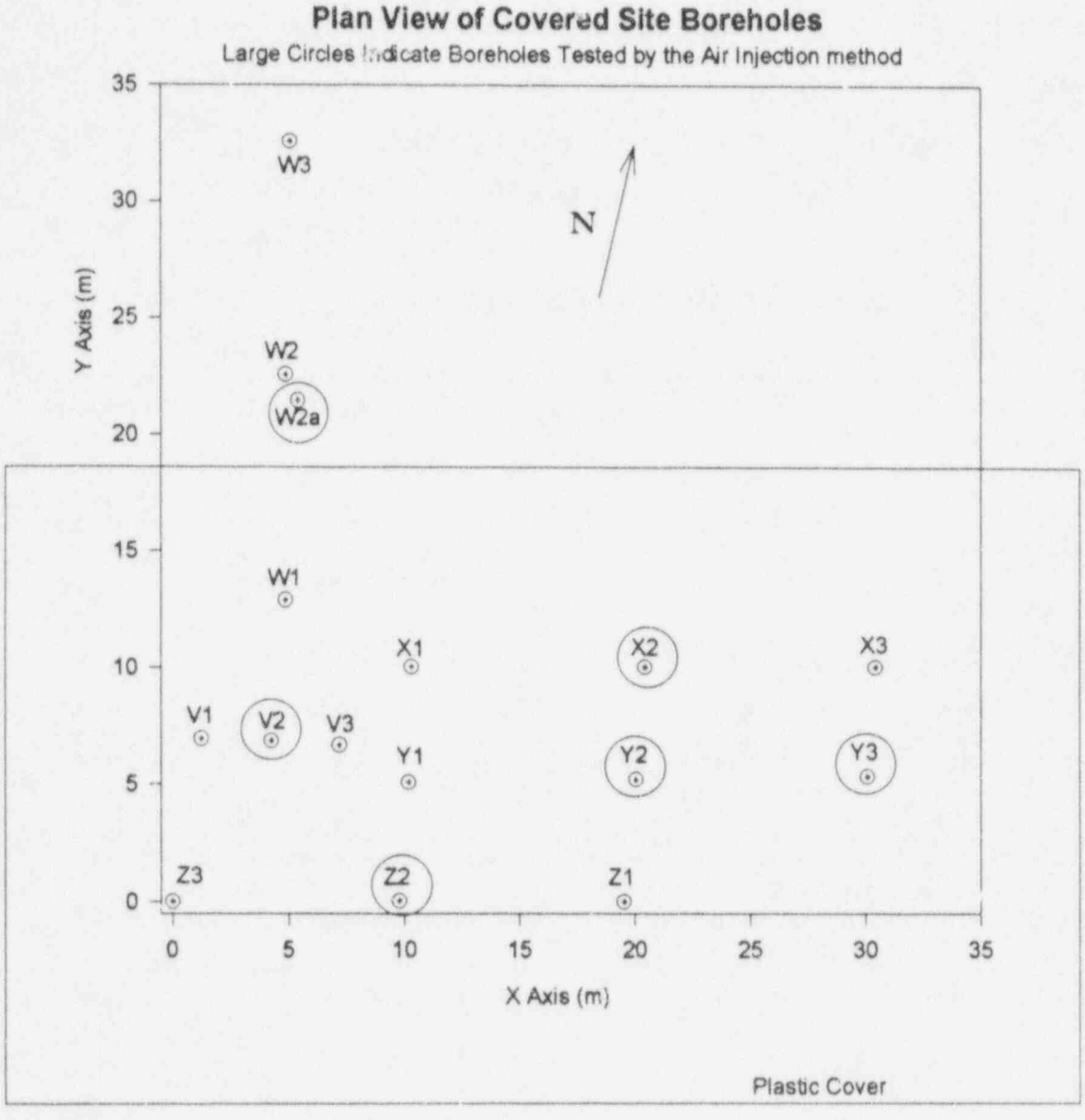

Figure 1.2 Schematic plan view of pertinent borehole locations at the ALRS-CBS.

Table 1 lists the locations of the six boreholes subjected to air permeability testing. Recently surveyed wellhead locations (indicated by marking points) are given with references to the coordinates shown in Fig. 1.2, with origin at the lower lip of the casing in borehole Z3. The same system of coordinates will be used in all future references to the CBS. The table also includes information regarding the approximate length and dip of each tested borehole.

Table 1. Locations of boreholes subjected to air permeability testing.

ID	M.P.* (X) (m)	M.P. (Y) (m)	M.P. (Z) (m)	Borehole Length† (m)	B.B. (X) (m)	B.B. (Y) (m)	B.B. (Z) (m)	General Dip Direction
V2	4.24	6.84	0.01	30	4.2	6.8	-30.0	vertical
W2a	5.42	21.46	-0.03	30	5.4	0.2	-21.2	SSE
X2	20.44	10.03	-0.02	30	-0.8	10.0	-21.2	WSW
Y2	20.04	5.20	-0.31	30	-1.2	5.2	-21.5	WSW
Y3	30.07	5.35	-0.27	45	-1.8	5.3	-32.0	WSW
Z2	9.80	0.03	-0.20	30	31.0	0.0	-21.4	ENE

*Borehole locations are referenced to an origin located at the lower lip of surface casing Z3.
†Borehole Length is approximate
M.P. = Coordinates of Marking Point, taken as lower surface casing lip for slanted holes,
B.B. = Coordinates of Borehole Bottom (approximate).

Figure 1.3 is a three dimensional view of all the 1.0 m scale air permeability test locations, viewed toward the Northeast. The points in the figure represent the centers of the tested borehole segments. These segments are located without either gap or overlap along the entire tested length of each borehole.

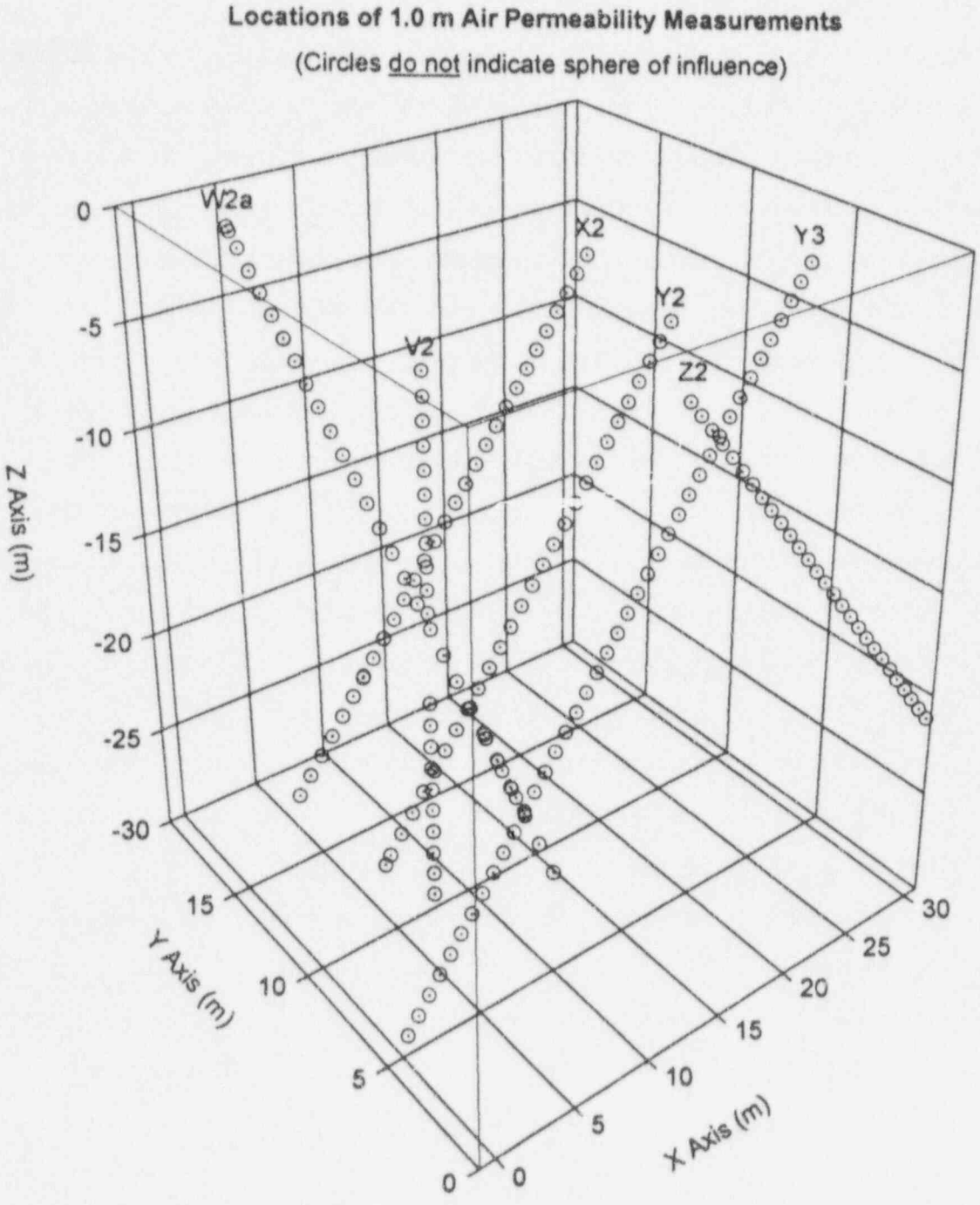

Figure 1.3 Schematic 3D view of 1.0 meter air permeability test locations (surface perspective looking toward the Northeast, overlapping circles indicate re-tested locations, refer to Fig. 1.2 for plan view).

2. DESCRIPTION OF TESTS

Figure 2.1 is a schematic diagram of the air injection system. It consists of a straddle packer assembly made out of two rubber bladders, a set of flow meters and flow controllers, pressure regulators and valves, and an electronic monitoring system to collect real-time field data. The distance between bladders can be adjusted to test different interval lengths. Interval pressure (P), temperature (T), and relative humidity (RH) are measured in the injection interval. A series of flow controllers and flow meters on the surface supply a constant injection flow rate (Q) that can be adjusted between 10 and 20,000 standard cm^3/min (sccm).

Test location is defined as distance along a borehole from the marking point listed in Table 1 to the middle of the test (injection) interval. A Field Operating Procedure outlining the steps taken during an air injection test is included in Appendix A.1. Prior to each air injection test, the packers are inflated to isolate the test interval, and the resulting pressure is allowed to dissipate back to atmospheric. The test commences by injecting air into the packed off interval at a constant rate Q. This continues until the pressure P stabilizes so that it increases by not more than 1 mm Hg in 30 minutes. The test continues by incrementing Q and monitoring P until it attains a new stable value. Most tests include three or more such step increments of Q. Injection is then discontinued and the pressure allowed to recover to atmospheric. The packers are deflated, the instrument is repositioned in the borehole, and testing resumes until the entire length of the borehole has been tested. We found that testing at multiple injection rates is essential to properly characterize rock permeability in the vicinity of each test interval (Guzman, 1995). The method has proved reliable in that repeated testing of selected intervals, over several years, has given highly reproducible permeability estimates (Guzman, 1995; Bassett, et al., 1994). This is due in part to a strict quality assurance and quality control (QA/QC) procedure at each stage of testing.

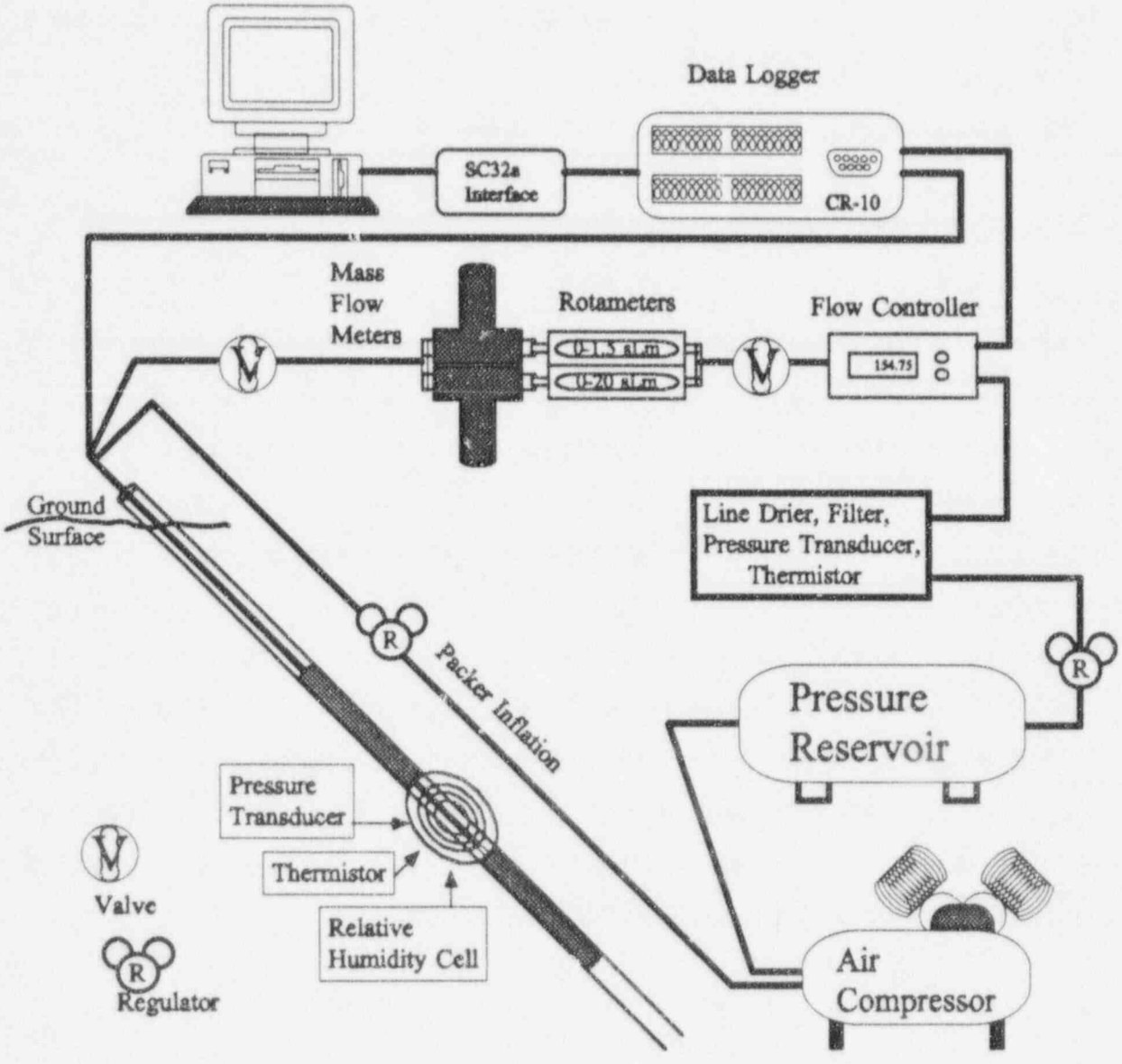

Figure 2.1 Schematic diagram of the air injection system.

An important aspect of our QA/QC procedure is to periodically check the integrity of the straddle packer system by means of a "zero permeability" test. This test checks the system for leaks by injecting air into an impermeable PVC pipe having an inside diameter equal to that of the boreholes (approximately 10 cm). The Field Operating Procedure (FOP) for the zero permeability test is reproduced in Appendix A.2. Under normal operating conditions, the system is tested for leaks once every other week, or each time a component is replaced or re-calibrated. A periodic re-calibration

of the pressure transducers, and factory re-calibration of the electronic flow meters and controllers, are performed as part of the QA/QC procedure.

3. ESTIMATION OF PERMEABILITY

When air is injected into a rock that contains water at partial saturation, the latter acts to block its movement. Hence the permeability one computes for the air is lower than one would compute in the absence of a water phase. It follows that the computed air permeability is less than the intrinsic permeability of the rock. Guzman (1995) was able to demonstrate computationally that the higher is the applied pressure during a test, the closer is the computed air permeability to this intrinsic value.

The air permeabilities listed in Appendix B of this report were computed with the aid of equation (1) below. This equation has been adapted from an analytical expression by Hvorslev (1951; see also Hsieh et al., 1983). It assumes that, during each relatively stable period of injection rate and pressure, air is the only mobile phase within the rock near the test interval, and is controlled by a steady state pressure field with prolate spheroidal symmetry. Such symmetry implies that the rock forms a uniform, isotropic porous continuum. The equation reads

$$k = Q_{sc} \frac{\mu \ln(L/r_w)}{\pi L (p^2 - p_o^2)} \frac{T p_{sc} Z}{T_{sc}} \qquad (1)$$

where:

- k = permeability,
- Q_{sc} = volumetric flow rate at standard conditions,
- μ = dynamic viscosity of air at standard conditions (1.81×10^{-5} N s/m^2),
- ln = natural logarithm operator,
- L = length of test interval,
- r_w = borehole radius (0.05 m),
- T = air temperature in the test interval in degrees Kelvin,

p_{sc} = pressure at standard conditions (101.3 kPa),
T_{sc} = temperature at standard conditions (293.16° K),
Z = air compressibility (1 1/Pa),
π = 3.1416,
p = air pressure in the injection interval, and
p_o = ambient air pressure .

4. DESCRIPTION OF DATA TABLES AND SELECTED GRAPHS

4.1 Description of Data Tables in Appendix B

Appendix B contains tables which list all air permeability estimates obtained at the CBS to date by means of the above methodology. The tables are arranged according to borehole and length of injection interval (taken to represent the scale of a test). Table 2 below provides information about the tables in Appendix B. Each table in the appendix is accompanied by a graphic permeability profile along the length of the corresponding borehole. The profiles depict the range of permeability values and the corresponding range of pressures applied in each test interval. An asterisk in the first column implies that transient data for the test are plotted in Appendix C.

Table 2 also includes the names of ASCII files which contain the data tabulated in Appendix B. The files can be obtained by an anonymous file transfer protocol (FTP) call to the Internet node <**anonymous@transport.hwr.arizona.edu**>. This node is hosted by an IBM RISC-6000 work station in the Department of Hydrology and Water Resources at The University of Arizona in Tucson. To log in, declare the user ID <**anonymous**> and use your real user ID as password. The files are located in a sub-directory named **K.SS**. Use the FTP commands **cd**, **ls**, **get**, or **mget** to access this directory and download the desired files to your computer.

Table 2. Summary of Appendix B data tables and corresponding ASCII filenames.

Table ID	Borehole	Scale of Test	Number of Intervals Tested	ASCII Filename
B-1	V2	1.0 m	21	v2-1m.dat
B-2	W2a	1.0 m	37	w2a-1m.dat
B-3	X2	1.0 m	30	x2-1m.dat
B-4	X2	2.0 m	10	x2-2m.dat
B-5	Y2	0.5 m	54	y2-05m.dat
B-6	Y2	1.0 m	28	y2-1m.dat
B-7	Y2	2.0 m	14	y2-2m.dat
B-8	Y2	3.0 m	9	y2-3m.dat
B-9	Y3	1.0 m	39	y3-1m.dat
B-10	Z2	1.0 m	28	z2-1m.dat
		Total	270	

4.2 Description of Appendix C

Appendix C contains plots of measured quantities versus time for 56 single-hole air permeability tests at the CBS. Three types of plots are generated for each air permeability test. The first type illustrates injection flow rate and interval pressure with time on the lower portion of the plot, and temperature and relative humidity versus the same time scale on the upper portion of the plot. In some cases, temperature and/or relative humidity data are not available due to malfunctioning sensors. This real-time depiction of the measured test variables is termed the "Test" plot. Figure 4.1 is an example of a typical Test plot, and exhibits behavior which we find to be characteristic of two phase flow: the pressure rapidly rises to a peak before decreasing toward a stable value while the

incremental injection rate is held constant. The phenomenon becomes more pronounced as the rate of injection increases. Such behavior has been observed in more than 90% of the tests at the CBS. It has been shown computationally to result from the displacement of water by air during the injection test (Guzman, 1995).

The second type of plot generated for each air injection test shows interval pressure versus log dimensionless recovery time. The upper plot in Figure 4.2 is an example of this type of plot, which is termed a "Recovery" plot. The third type of plot depicts log injection pressure versus log time and is used to determine the extent of time over which the increasing interval pressure is influenced by borehole storage effects. The lower plot on Figure 4.2 is an example of this type of plot which is termed a "Storage" plot. The straight broken line on each Storage plot indicates a unit slope characteristic of wellbore storage effects. To obtain an interpretable test, the pressure response measured in the field should extend well beyond this unit slope behavior. Figures 4.1 and 4.2 represent a complete set of plots for an air injection test and are examples of Appendix C plots. Figure 4.3 is atypical but is included to illustrate an interesting pressure response to more than one week of continuous injection.

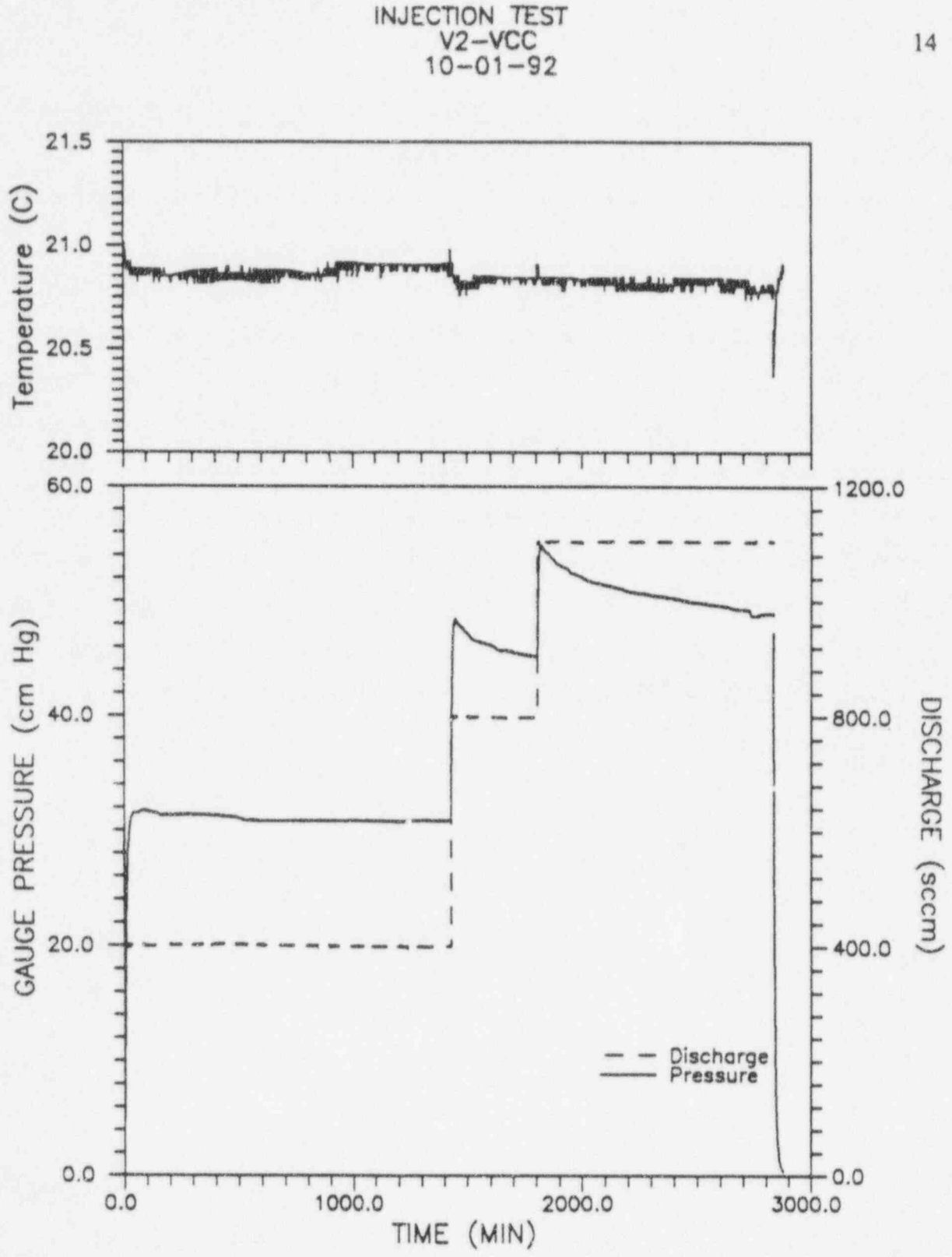

Figure 4.1 Example of a Test plot. The upper graph shows interval temperature with time, but relative humidity is missing. The lower graph shows injection flow rate and interval pressure with time, for a single air injection test.

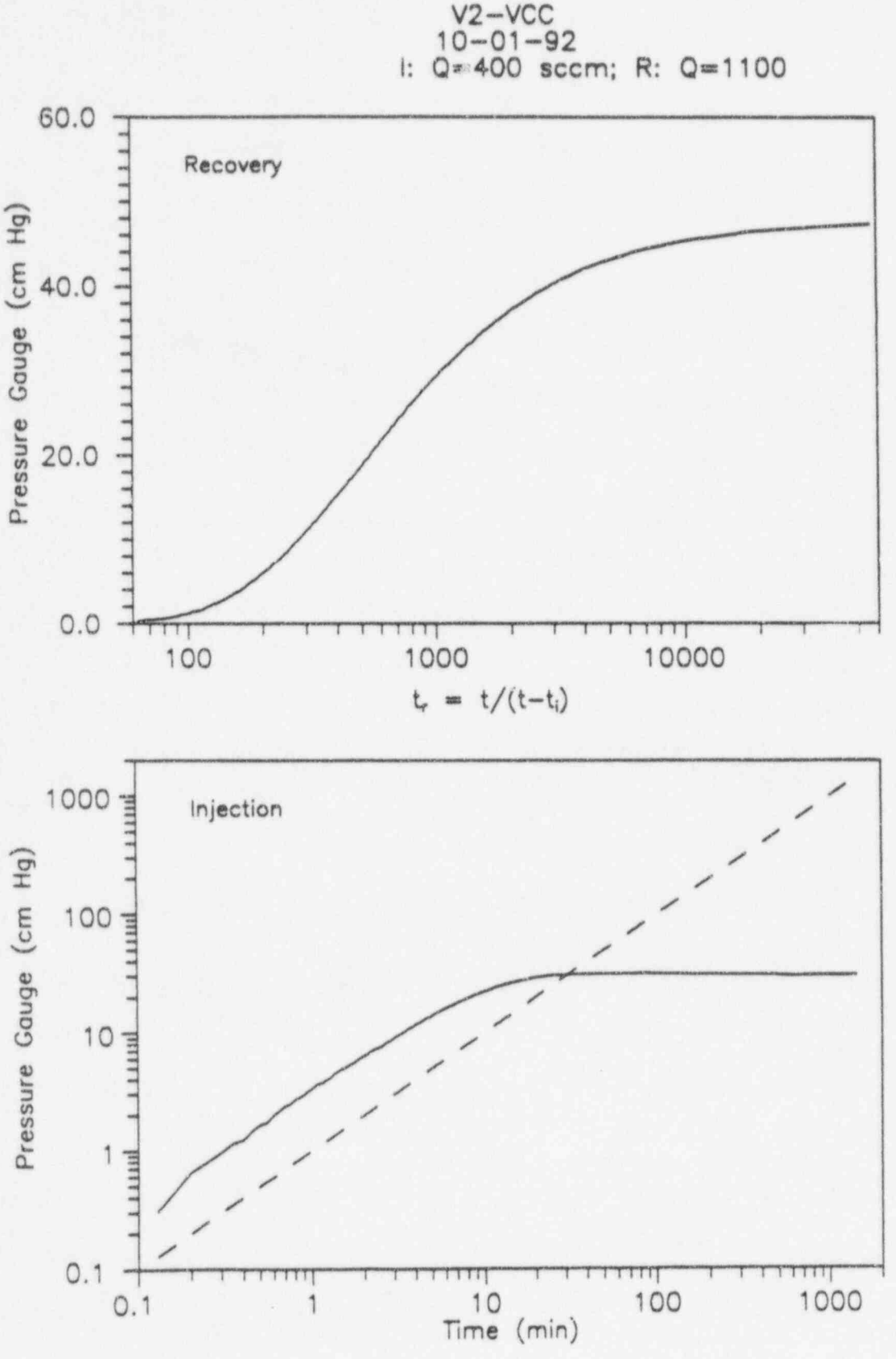

Figure 4.2 Example of a Recovery plot (top) and a Storage plot (bottom). See text for discussion.

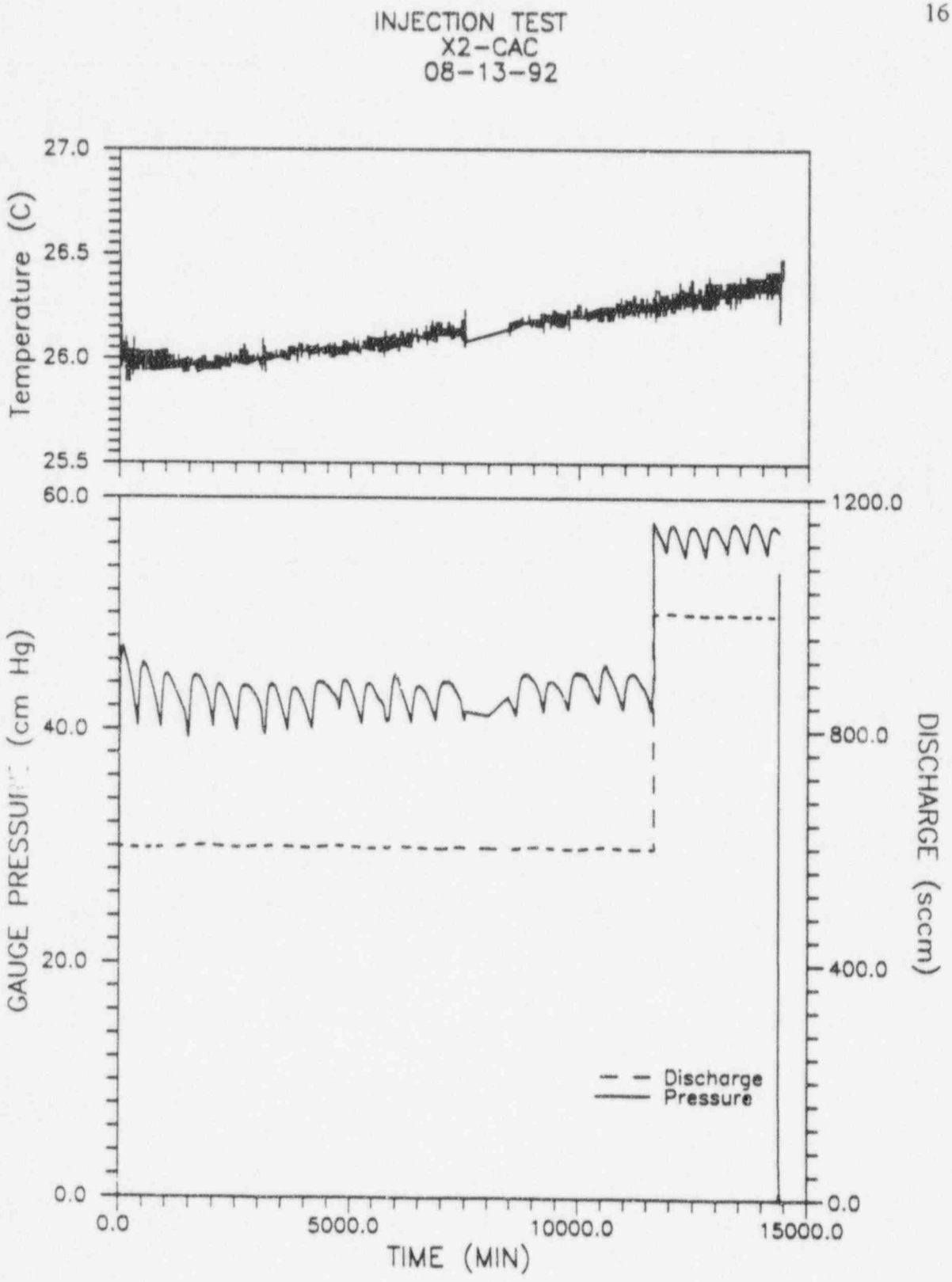

Figure 4.3 Example of an atypical Test plot. This graph depicts the interval pressure response over a week of continuous injection.

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APPENDIX A: Field Operating Procedures (FOP)

A.1 Testing Procedures and Equipment for Air Permeability Measurements

Figure 2.1 above is a schematic diagram of the air injection system employed for air permeability testing at ALRS. This field operating procedure is included to provide details on the testing procedure, to list the types of equipment used, and to provide a reference for future application of the method.

A.1.1 Equipment:

(1) Campbell (CR10) data logger,
(2) Data logger software (PC208),
(3) Straddle packer system with adjustable test interval length,
(4) Relative humidity probes (Campbell HMP 35c, Vaisala 50Y),
(5) Temperature probes (YSI 44034 thermistor, or Geokon 4500 temperature transducer).
(6) Pressure transducers (Geokon 4500, Druck PDCR 930),
(7) Injection interval volume minimizer,
(8) Down hole measuring tape (metric),
(9) Computer and SC32a Optically Isolated Interface,
(10) Sierra mass floss controllers and meters to cover ranges of 0-0.1 standard liters per minute (sLm) to 0-20 sLm,
(11) Rotameter; visual back-up flow meters,
(12) Valves,
(13) Pressure regulators,
(14) Air compressor,
(15) Air pressure reservoir tank,
(16) 12 V batteries for data logger power backup,
(17) 10 kW continuous use generator for AC power,
(18) Miscellaneous tools and equipment,
(19) Log Books.

A.1.2 Testing procedure:

1. Check oil in generator and gas level in the propane tank. Turn on valve at propane tank and start generator. Air pressure reservoir tank should be charged to 110 psi before starting a test. (reservoir tank set for 120 psi max).

2. Position straddle packer in borehole to desired depth using winch and push rods. Tape should read ± 2 mm of desired depth before testing.

3. Load the appropriate software program into the data logger (single.dld for system 1 and single2.dld for system 2);

   a. Write down the program name (single.dld or single2.dld) and the date and time of creation in the test booklet at the beginning of each test.

b. Connect the computer to the data logger. Type [term single] or [term single2]. An options menu will appear on screen. Type [D] to download program to the data logger. When prompted, type the program name to be downloaded (single or single2). Downloading will take a minute or two. When completed, type [esc] to return to the menu.

c. Set the time and date by selecting [K] from the menu. The screen will automatically return to the menu after a few seconds. Type [M] to monitor the test. Adjust decimal places by hitting [D], and the locations displayed by pressing [L].

4. Set scan rates to 10 sec. for table 1 input and 20 sec. for table 2 input. Table 1 corresponds to input locations 1 through 7 and table 2 corresponds to input locations 8 through 12. Set scan rates by typing [T7H] [enter] and then [*1] [10] [enter] for table 1 and [*2] [20] [enter] for table 2. Typing [*0] and [esc] returns the screen to monitor.

5. Set valve for injection line to closed and set valve immediately downstream of the flow meters to exhaust.

6. Check pressure gauges and regulators. The pressure gauge on the air holding tank should read 110 psi or greater. The pressure regulator for the packers should be set to 80 psi. The regulator for the injection line (from the air holding tank to the shed) should be set to 50 psi and the gauge in the shed should read about the same. The regulator inside the shed controls pressure at flow meters, P(f), and should be set to at least 25 psi to ensure that P(f) is in excess of 100 cm Hg during testing. At high injection rates, the P(f) regulator may need upward adjustment. This is necessary to maintain a positive pressure differential for the mass flow controllers.

7. Prepare the field book by recording all relevant information about the test; date, time, borehole, test ID#, distance along the borehole, operator, weather conditions, etc. Stamp the book a few times with the data format stamp to ensure speedy data collection at the beginning of the test.

8. Connect the appropriate packer line (sys. 1 or sys. 2). Packers will begin to inflate.

9. Monitor the pressure change within the interval caused by inflating the packers. This change is recorded on the monitor as P(p). Record the maximum P(p) value; it should occur within the first few minutes after connecting the packer line. Compare this value to those of previous tests to decide on an initial flow rate for the test. If P(p) fails to reach a maximum and continues to increase with time, packers should be retrieved and leak tested.

10. After recording the maximum P(p), exhaust the interval and set scan rates to 3 sec. and 20 sec. (for Table 1 and Table 2 respectively). When p(p) has returned to zero, turn injection valve back to open. P(p) should remain at or very close to zero. Record this information in the log book as the baseline.

11. Select the flowmeter needed to maintain the initial flow rate, based on the P(p) max. obtained during packer inflation. Turn the valve corresponding to the selected meter to test. Set the flow rate on the flow controller. Make sure you are using the proper flow controller and the proper channel.

12. Select a starting time for the test a few minutes a head of the current time. It is good to begin the test on an even minute.

13. One second before the selected starting time turn injection valve to test. After 30 seconds, freeze the screen by typing [T7H] and record the data. Press [esc] to return the screen to monitor. Data is recorded every time the scan rates are changed and every half hour thereafter. Table A.1 contains suggested scan rates and times.

Table A.1 Suggested data logger scan rates

Time Span (min)	Table 1 Scan Rate (sec)	Table 2 Scan Rate (sec)
0-3	3	20
3-7	6	20
7-15	10	20
15-25	15	30
25-40	30	60
40-60	60	120
60-120	120	240
>120	240	480

14. When interval pressure P(p) changes less than 1 mm Hg within one half hour, equilibrium is attained, and a new flow rate is selected.

Increase the flow rate as follows:

a. Take the last data reading at the existing flow rate.
b. Set the new higher rate on the appropriate flow meter by turning the control knob slowly until the new rate is reached, without going past the desired level.
c. Reset the scan rates for table 1 and table 2 to 3 sec. and 20 sec. respectively.
d. Record the data in the same way as before.

When testing, a maximum number of flow rates should be attempted, with special attention to flow rates which result in P(p) values between 1 cm Hg and 10 cm Hg and between 90 cm Hg and 110 cm Hg. Ten flow rates for a test is good. As a rule, P(p) values should not exceed 120 cm Hg during testing. P(f) should always be maintained 20 cm Hg higher than P(p) to ensure a required pressure differential for the flow meters. For example, if while testing, P(p) is at 105 cm Hg, P(f) should be set to at least 130 cm Hg. Adjust P(f) with the regulator inside the shed.

15. Download data to diskette. Exit to DOS by hitting [esc] and selecting [Q].
Type [dwnld "filename".raw] [enter] for system 1 or [dwnld2 "filename.raw] [enter] for system 2. This batch file records the data from the data logger memory to the computer hard drive. Insert a diskette into the computer and type [copy "filename".raw a:] [enter]. After downloading return to screen monitor by typing [term single] or [term single2] and press [M] when the menu appears.

A.2 Zero Permeability Test

In order to conduct the testing effectively, it is necessary to ensure the straddle packer system described above is free of leaks that could impact the air permeability results. Of particular importance is the integrity of the test interval. An effective leak testing procedure has been developed. The zero permeability test is designed to determine the air leakage rate out of a straddle packer system under static positive gauge pressure. The leakage rate determined could be used to correct the obtained measurements. The necessary equipment and procedures are outlined as follows:

A.2.1 Equipment:

(1) Air compressor,
(2) Air filter,
(3) In-line desiccator,
(4) System 1 or System 2 air injection straddle packer assembly,
(5) Twenty feet of 4" I.D. PVC pipe, with >100 psi burst strength,
(6) Soap solution,
(7) Field book.

A.2.2 Procedure:

1. Record in the field book the date and name of the person conducting the test.

2. Rid the straddle packer of large debris along the rubber bladders and place it into the PVC pipe.

3. Connect the injection line from the compressor to the desiccator box and then into the flowmeter outlet for the active interval.

4. Download the appropriate program (zeroperm.dld) to the data logger and if necessary zero the flow meters and pressure transducers.

5. Connect packer line to the compressor and pressurize packers to 80 psig. As the packers are inflated a slight positive pressure will register on the pressure transducer in the interval. If this pressure does not stabilize or the stabilized value is greater than 2 centimeters of mercury, deflate the system and check for leakage along the body of the straddle packers using soap solution. Otherwise, open control valves and allow interval pressure to dissipate.

6. Record initial time and align control valves to allow metered airflow into the test interval of the straddle packer system. Allow for pressure buildup until a pressure of 75 cm Hg is achieved in the interval. Close all valves to isolate the straddle packer system from atmospheric pressure.

7. After all valves have been closed, record the time and the maximum pressure reached inside the test interval. The time at which the pressure reaches this maximum marks the beginning of the zero permeability test. Over the next one hour period, write down the following information at ten minute intervals:

(a) time,
(b) pressure at the test interval,
(c) temperature at the interval,
(d) barometric pressure.

8. The rate at which pressure is being lost from the system should be linear for most of the duration of the test. Use the following equation to translate this rate of pressure decay to a standard flow rate.

$$Q = \frac{(P_1T_1 - P_2T_2)}{T_1T_2} \frac{VT_{sc}}{P_{sc}\Delta t} \qquad \textbf{(B-1)}$$

where:

Q = Injection flow rate (standard cm^3 /min or sccm),
V = total system volume (cm^3),
P_1 = absolute pressure at time one (cm Hg),
P_2 = absolute pressure at time two (cm Hg),
P_{sc} = absolute pressure at standard conditions (76.0 cm Hg),
T_1 = absolute temperature at time one (K = °C + 273.16),
T_2 = absolute temperature at time two (K = °C + 273.16),
T_{sc} = temperature at standard conditions (293.16 K),
t = time interval; $t_2 - t_1$ (min).

9. Starting with the second 10 minute reading, use the equation outlined above to compute the leakage rate over a given time period. Write down the time and computed leakage rate in the field book. If the leakage rate exceeds 5 sccm for any given 10 minute interval, stop the test and locate the leak. Once the source of the leakage has been found and rectified, repeat the zero permeability test procedure.

10. After the test is completed, download test information from the data logger and store on floppy.

APPENDIX B: Air Permeability Data Tables

Note:

The following is a brief description of the data table headings:

Graph App. C = An asterisk indicates that the graph for these flow rates appears in Appendix C.

Test ID = Test identifier that indicates borehole and interval name, month/day of flow rate initiation, and flow step.

Z* (m) = Position of test in borehole measured from marking point to middle of injection interval.

Q (sccm) = Constant injection flow rate in standard cubic centimeters per minute.

T (°C) = Temperature of injection interval in degrees Celsius.

Patm (cm Hg) = Surface atmospheric pressure in cetimeters of mercury.

Pss (cm Hg) = Relatively steady interval pressure at which permeability is calculated.

L (m) = Distance between inflated packers (length of isolated borehole/scale of test).

k(sq m) = Permeability calculated with Equation 1.

Table B.1 Permeability measurements for borehole V2 - 1.0 m scale.

Graph App. C	Test ID	Z* (m)	Q (sccm)	T (°C)	Patm (cm Hg)	Pss (cm Hg)	L (m)	k (sq m)
	vaa0730a	2.37	4.94	27.74	66.21	50.97	1.01	8.83E-18
	vaa0730b	2.37	14.84	27.74	66.16	64.38	1.01	1.96E-17
	vaa0730c	2.37	24.80	27.75	66.09	77.33	1.01	2.56E-17
	vaa0520a	2.37	20.07	23.02	65.03	75.37	1.01	2.13E-17
	vaa0520b	2.37	40.00	23.09	64.88	89.66	1.01	3.35E-17
	vaa0520c	2.37	60.01	23.14	65.03	101.97	1.01	4.17E-17
	vab0507a	3.38	39.89	20.05	65.19	92.88	1.01	3.13E-17
	vab0507b	3.38	49.90	20.08	65.28	97.54	1.01	3.65E-17
	vac0513a	4.37	49.95	19.94	65.21	79.20	1.01	4.90E-17
	vac0513b	4.37	100.04	19.94	64.97	99.11	1.01	7.17E-17
	vba0902a	5.37	34.90	23.34	65.87	52.95	1.01	5.88E-17
	vba0902b	5.37	50.10	23.39	65.87	59.48	1.01	7.26E-17
	vba0902c	5.37	75.17	23.38	65.69	67.12	1.01	9.30E-17
	vbb0909a	6.37	39.90	22.45	65.72	60.68	1.01	5.62E-17
	vbb0909b	6.37	70.00	22.42	65.96	68.11	1.01	8.44E-17
	vbb0909c	6.37	99.80	22.53	65.91	75.10	1.01	1.05E-16
	vbb0911a	6.37	100.54	22.53	65.88	75.21	1.01	1.06E-16
*	vbc0915a	7.37	39.90	21.85	65.96	41.73	1.01	9.02E-17
*	vbc0915b	7.37	79.90	21.83	65.87	48.89	1.01	1.48E-16
*	vbc0915c	7.37	149.98	21.83	65.83	56.87	1.01	2.29E-16
*	vca0923a	8.37	201.00	21.38	65.90	0.77	1.01	3.22E-14
*	vca0923b	8.37	600.00	21.27	65.89	2.20	1.01	3.33E-14
*	vca0923c	8.37	1201.00	21.15	65.86	4.01	1.01	3.61E-14
*	vca0923d	8.37	1954.00	21.15	65.86	6.24	1.01	3.71E-14
	vca0915a	8.37	201.00	21.38	65.90	0.77	1.01	3.22E-14
	vca0915b	8.37	600.00	21.27	65.89	2.20	1.01	3.33E-14
	vca0915c	8.37	1201.00	21.15	65.86	4.01	1.01	3.61E-14
	vca0915d	8.37	1954.00	21.15	65.86	6.24	1.01	3.71E-14
	vcb0924a	9.37	98.70	21.04	65.65	23.23	1.01	4.49E-16
	vcb0924b	9.37	299.74	21.04	65.45	29.94	1.01	1.02E-15
	vcb0924c	9.37	802.20	20.98	65.43	40.55	1.01	1.89E-15
	vcb0924d	9.37	1601.30	20.90	65.79	49.04	1.01	2.95E-15
	vcc0930a	10.37	39.80	20.88	66.15	5.63	1.01	8.37E-16
	vcc0930b	10.37	79.80	20.84	66.08	10.24	1.01	8.94E-16
	vcc0930c	10.37	140.00	20.87	65.99	16.22	1.01	9.51E-16
*	vcc1001a	10.37	399.00	20.88	65.80	30.91	1.01	1.30E-15
*	vcc1001b	10.37	799.20	20.84	65.46	45.21	1.01	1.64E-15
*	vcc1001c	10.37	1103.87	20.77	65.64	48.99	1.01	2.04E-15
	vda1007a	11.37	151.10	20.74	65.92	12.21	1.01	1.40E-15
	vda1007b	11.37	500.50	20.66	65.92	27.93	1.01	1.83E-15
	vda1007c	11.37	1001.00	20.63	65.86	39.20	1.01	2.44E-15
	vda1007d	11.37	1601.80	20.57	65.73	42.88	1.01	3.50E-15
	vda0506a	11.37	499.51	21.02	65.72	11.64	1.01	4.82E-15
	vda0506b	11.37	1000.75	20.91	65.69	20.66	1.01	5.20E-15
	vda0506c	11.37	1599.70	20.91	65.54	28.22	1.01	5.81E-15
	vdb1009a	12.37	299.79	20.65	65.67	37.58	1.01	7.71E-16
	vdb1009b	12.37	601.53	20.66	65.74	54.14	1.01	9.77E-16

Table B.1 Permeability measurements for borehole V2 - 1.0 m scale (continued).

Graph App. C	Test ID	Z* (m)	Q (sccm)	T (°C)	Patm (cm Hg)	Pss (cm Hg)	L (m)	k (sq m)
	vec0304a	16.37	50.07	20.49	65.87	19.02	1.01	2.85E-16
	vec0304b	16.37	99.81	20.52	65.98	26.73	1.01	3.84E-16
	vec0304c	16.37	198.16	20.50	66.22	37.45	1.01	5.08E-16
	vec0304d	16.37	498.34	20.44	65.94	64.71	1.01	6.39E-16
*	vfa0310a	17.37	49.87	20.48	65.57	63.46	1.01	6.59E-17
*	vfa0310b	17.37	69.98	20.45	65.55	73.45	1.01	7.60E-17
*	vfa0310c	17.37	99.95	20.48	65.83	81.93	1.01	9.32E-17
	vfb0318a	18.37	50.02	20.46	65.89	42.92	1.01	1.09E-16
	vfb0318b	18.37	100.35	20.42	65.93	62.37	1.01	1.35E-16
	vfb0318c	18.37	197.73	20.44	65.74	76.94	1.01	2.01E-16
	vfc0325a	19.37	50.03	20.41	65.60	51.72	1.01	8.62E-17
	vfc0325b	19.37	100.08	20.39	65.57	73.25	1.01	1.09E-16
	vfc0325c	19.37	174.99	20.39	65.16	90.57	1.01	1.43E-16
	vga0225a	20.37	50.05	20.20	65.75	55.79	1.01	7.80E-17
	vga0225b	20.37	99.88	20.20	65.63	74.53	1.01	1.06E-16
	vga0225c	20.37	119.94	20.18	65.60	79.45	1.01	1.95E-16
	vgb0401a	21.37	50.02	20.31	65.33	57.78	1.01	7.49E-17
	vgb0401b	21.37	84.92	20.31	65.39	69.34	1.01	9.98E-17
	vgb0401c	21.37	150.02	20.36	65.66	86.06	1.01	1.31E-16
	vgc0408a	22.37	49.78	20.28	65.78	8.10	1.01	7.17E-16
	vgc0408b	22.37	250.26	20.29	65.78	48.37	1.01	4.69E-16
	vgc0408c	22.37	400.70	20.27	65.60	69.66	1.01	4.67E-16
	vgc0408c	22.37	651.31	20.23	65.69	98.03	1.01	4.72E-16
	vgc0603a	22.37	49.90	20.31	64.83	7.52	1.01	7.88E-16
	vgc0603b	22.37	99.98	20.29	64.84	14.69	1.01	7.68E-16
	vgc0603c	22.37	149.80	20.29	65.56	22.39	1.01	7.10E-16
	vgc0603d	22.37	197.76	20.26	65.53	29.81	1.01	6.72E-16
	vha0422a	23.37	49.92	20.19	65.31	121.15	1.01	2.67E-17
	vhb0429b	24.37	24.81	20.27	65.55	91.10	1.01	2.00E-17
	vhc0527a	25.37	20.07	20.14	65.15	104.51	1.01	1.33E-17

Table B.2 Permeability measurements for borehole W2a - 1.0 m scale.

Graph App. C	Test ID	Z* (m)	Q (sccm)	T (°C)	Patm (cm Hg)	Pss (cm Hg)	L (m)	k (sq m)
	Waa'702a	2.55	1027.60	25.92	65.86	16.46	1.00	7.06E-15
	Waa'702b	2.55	5003.95	25.64	65.89	46.29	1.00	1.02E-14
	Waa'702c	2.55	12004.50	25.80	65.57	81.44	1.00	1.16E-14
	Waa0625a	2.75	251.89	25.23	65.98	5.85	0.98	5.28E-15
	Waa0625b	2.75	3501.70	24.73	65.91	39.99	0.98	8.60E-15
	Waa0625c	2.75	7012.78	24.58	66.00	59.34	0.98	1.04E-14
	Waa0625d	2.75	11972.60	24.97	65.90	83.27	0.98	1.13E-14
	Wab0708a	3.53	30.24	24.74	65.75	22.38	1.00	1.47E-16
	Wab0708b	3.53	99.51	24.71	65.88	28.95	1.00	3.57E-16
	Wab0708c	3.53	501.50	24.65	66.15	52.18	1.00	8.70E-16
	Wab0708d	3.53	1991.11	24.67	66.02	104.38	1.00	1.35E-15
	Wac0715a	4.53	50.41	23.72	66.13	60.70	1.00	7.16E-17
	Wac0715b	4.53	149.59	23.73	66.04	80.85	1.00	1.45E-16
	Wac0715c	.53	249.57	23.78	66.32	93.25	1.00	1.97E-16
	Wba0722a	5.53	99.97	22.88	66.05	86.31	1.00	8.80E-17
	Wba0722b	5.53	149.57	22.88	66.18	89.14	1.00	1.26E-16
	Wba0722c	5.53	199.55	22.89	65.90	96.19	1.00	1.51E-16
	Wbb0729a	6.53	50.41	22.24	66.30	31.16	1.00	1.64E-16
	Wbb0729b	6.53	199.91	22.23	66.25	50.63	1.00	3.57E-16
	Wbb0729c	6.53	598.99	22.23	66.45	72.28	1.00	6.69E-16
	Wbc'0805a	7.53	49.98	21.71	66.05	27.83	1.00	1.86E-16
	Wbc'0805b	7.53	199.16	21.71	66.19	38.86	1.00	4.95E-16
	Wbc'0805c	7.53	1499.69	21.68	65.84	93.37	1.00	1.18E-15
	Wbc0913a	7.55	10.03	22.83	65.35	16.89	1.02	6.57E-17
	Wbc0913b	7.55	19.79	22.79	65.33	19.66	1.02	1.09E-16
	Wbc0913c	7.55	39.99	22.78	65.34	23.70	1.02	1.78E-16
	Wbc0913d	7.55	49.95	22.77	65.38	25.05	1.02	2.09E-16
	Wbc0913e	7.55	100.05	22.79	65.53	31.49	1.02	3.19E-16
	Wbc0913f	7.55	197.80	22.78	65.65	39.51	1.02	4.79E-16
	Wbc0913g	7.55	400.57	22.77	65.90	55.38	1.02	6.31E-16
	Wbc0913h	7.55	600.19	22.78	65.99	64.40	1.02	7.75E-16
	Wbc0913i	7.55	999.54	22.82	65.86	77.44	1.02	1.01E-15
	Wbc0913j	7.55	1200.34	22.77	65.92	81.97	1.02	1.12E-15
	Wbc0913k	7.55	1401.45	22.80	65.88	86.80	1.02	1.21E-15
	Wbc0913l	7.55	1985.47	22.82	65.82	99.62	1.02	1.41E-15
	Wca0812a	8.53	100.40	21.33	65.97	21.10	1.00	5.13E-16
	Wca0812b	8.53	499.56	21.29	66.12	30.34	1.00	1.67E-15
	Wca0812c	8.53	4999.99	21.02	65.91	84.78	1.00	4.49E-15
	Wca0812d	8.53	8009.01	21.17	66.1[illegible]	105.91	1.00	5.24E-15
*	Wcb0819a	9.53	100.41	21.08	66.07	11.67	1.00	9.87E-16
*	Wcb0819b	9.53	999.97	20.99	66.03	33.09	1.00	3.02E-15
*	Wcb0819c	9.53	7998.38	20.80	66.34	102.51	1.00	5.47E-15
	Wcc0825a	10.53	100.00	20.87	66.10	62.59	1.00	1.35E-16
	Wcc0825b	10.53	198.38	20.86	66.35	73.63	1.00	2.15E-16
	Wcc0825c	10.53	350.42	20.83	66.26	88.94	1.00	2.93E-16

Table B.2 Permeability measurements for borehole W2a - 1.0 m scale (continued).

Graph App. C	Test ID	Z* (m)	Q (sccm)	T (°C)	Patm (cm Hg)	Pss (cm Hg)	L (m)	k (sq m)
	Wda'0830a	11.53	50.42	20.76	65.99	33.34	1.00	1.51E-16
	Wda'0830b	11.53	248.78	20.69	65.87	58.52	1.00	3.68E-16
	Wda'0830c	11.53	999.28	20.68	66.04	113.41	1.00	5.91E-16
	Wda0831a	11.55	49.64	20.88	65.75	28.19	1.02	1.79E-16
	Wda0831b	11.55	600.23	20.77	65.76	85.65	1.02	5.23E-16
	Wdb0907a	12.55	49.87	20.63	65.89	38.29	1.02	1.24E-16
	Wdb0907b	12.55	197.59	20.74	65.90	66.67	1.02	2.42E-16
	Wdb0907c	12.55	399.20	20.74	65.79	99.19	1.02	2.83E-16
	Wdc0917a	13.55	19.73	20.82	65.60	13.61	1.02	1.62E-16
	Wdc0917b	13.55	34.98	20.79	65.52	17.39	1.02	2.20E-16
	Wdc0917c	13.55	197.59	20.74	65.48	37.73	1.02	5.03E-16
	Wdc0917d	13.55	599.95	20.29	65.57	63.98	1.02	7.78E-16
	Wdc0917e	13.55	1200.54	20.11	65.49	87.73	1.02	1.01E-15
*	Wea0923a	14.55	20.07	20.75	65.83	6.63	1.02	3.55E-16
*	Wea0923b	14.55	39.85	20.74	65.79	11.41	1.02	3.96E-16
*	Wea0923c	14.55	197.53	19.97	65.70	32.02	1.02	6.11E-16
*	Wea0923d	14.55	1000.74	20.06	65.93	71.73	1.02	1.11E-15
*	Wea0923e	14.55	1250.75	20.06	65.91	80.92	1.02	1.18E-15
*	Wea0923f	14.55	1500.79	20.07	65.78	88.88	1.02	1.24E-15
	Web1001a	15.55	19.99	20.05	65.83	4.12	1.02	5.78E-16
	Web1001b	15.55	39.91	19.98	65.83	7.17	1.02	6.49E-16
	Web1001c	15.55	197.29	19.91	65.79	22.46	1.02	9.22E-16
	Web1001d	15.55	999.56	19.91	65.74	50.19	1.02	1.77E-15
	Web1001e	15.55	1982.50	20.08	65.90	66.10	1.02	2.45E-15
	Wec1005a	16.55	39.92	20.08	65.90	1.62	1.02	2.99E-15
	Wec1005b	16.55	124.72	20.06	65.92	4.78	1.02	3.09E-15
	Wec1005c	16.55	1001.35	20.04	65.78	29.55	1.02	3.40E-15
	Wec1005d	16.55	1983.10	20.06	65.79	43.32	1.02	4.23E-15
	Wfa1006a	17.55	99.50	21.00	65.88	5.55	1.02	2.12E-15
	Wfa1006b	17.55	250.74	20.11	65.87	10.22	1.02	2.80E-15
	Wfa1006c	17.55	999.46	20.09	65.83	26.13	1.02	3.92E-15
	Wfb1008a	18.55	100.89	20.27	65.64	4.05	1.02	2.98E-15
	Wfb1008b	18.55	250.80	20.19	65.66	7.63	1.02	3.83E-15
	Wfb1008c	18.55	1001.60	20.11	65.57	21.86	1.02	4.85E-15
	Wfb1008d	18.55	1983.80	20.06	65.62	33.30	1.02	5.86E-15
	Wfc1009a	19.55	20.07	20.22	65.90	6.44	1.02	3.65E-16
	Wfc1009b	19.55	39.86	20.10	65.89	10.64	1.02	4.26E-16
	Wfc1009c	19.55	197.73	20.07	65.78	30.64	1.02	6.44E-16
	Wfc1014a	19.55	500.75	20.12	65.69	54.62	1.02	7.98E-16
	Wfc1014b	19.55	1002.14	20.10	65.66	74.70	1.02	1.05E-15
	Wfc1014c	19.55	1500.40	20.29	65.66	90.19	1.02	1.22E-15
	Wfc1014d	19.55	1750.40	20.15	65.72	96.10	1.02	1.30E-15
	Wfc1014e	19.55	1951.10	20.10	65.69	101.45	1.02	1.34E-15

Table B.2 Permeability measurements for borehole W2a - 1.0 m scale (continued).

Graph App. C	Test ID	Z* (m)	Q (sccm)	T (°C)	Patm (cm Hg)	Pss (cm Hg)	L (m)	k (sq m)
*	Wga1019a	20.55	14.92	20.28	65.64	1.54	1.02	1.18E-15
*	Wga1019b	20.55	29.97	20.21	65.68	2.78	1.02	1.30E-15
*	Wga1019c	20.55	99.92	20.07	65.76	7.79	1.02	1.49E-15
*	Wga1019d	20.55	195.18	20.10	65.81	14.53	1.02	1.49E-15
*	Wga1019e	20.55	1499.20	20.42	65.90	65.17	1.02	1.89E-15
*	Wga1019f	20.55	1980.50	20.40	66.03	76.96	1.02	1.99E-15
	Wgb1026a	21.55	10.10	20.18	65.66	1.23	1.02	1.00E-15
	Wgb1026b	21.55	24.95	20.07	65.46	2.51	1.02	1.21E-15
	Wgb1026c	21.55	50.03	20.09	65.51	4.28	1.02	1.40E-15
	Wgb1026d	21.55	99.79	20.09	65.51	7.86	1.02	1.48E-15
	Wgb1026e	21.55	194.67	20.06	65.54	14.61	1.02	1.48E-15
	Wgb1026f	21.55	1000.40	20.37	65.78	51.00	1.02	1.74E-15
	Wgb1026g	21.55	1983.59	20.14	65.77	77.14	1.02	1.99E-15
	Wgc1109a	22.55	10.31	20.24	66.13	3.24	1.02	3.80E-16
	Wgc1109b	22.55	19.99	20.08	66.16	5.28	1.02	4.45E-16
	Wgc1109c	22.55	49.95	20.06	66.14	10.83	1.02	5.21E-16
	Wgc1109d	22.55	195.08	20.07	66.03	32.03	1.02	6.01E-16
	Wgc1109e	22.55	500.29	20.21	65.88	56.64	1.02	7.59E-16
	Wgc1109f	22.55	1000.93	20.12	65.79	84.07	1.02	8.93E-16
	Wgc1109g	22.55	1250.75	20.06	65.67	92.53	1.02	9.77E-16
	Wgc1109h	22.55	1501.80	20.39	65.24	97.28	1.02	1.10E-15
*	wha'0329a	23.50	15.06	20.55	65.82	4.78	1.01	3.77E-16
*	wha'0329b	23.50	49.70	20.39	65.77	11.53	1.01	4.91E-16
*	wha'0329c	23.50	194.76	20.47	65.81	34.15	1.01	5.61E-16
*	wha'0329d	23.50	498.93	20.56	65.85	68.36	1.01	5.95E-16
*	wha'0329e	23.50	1199.92	20.20	65.87	101.85	1.01	8.22E-16
*	wha'0329f	23.50	1353.20	20.03	65.89	106.44	1.01	8.69E-16
	Wha1116a	23.55	14.93	20.49	65.87	6.06	1.02	2.90E-16
	Wha1116b	23.55	30.06	20.39	65.81	10.53	1.02	3.25E-16
	Wha1116c	23.55	59.84	20.33	65.82	18.47	1.02	3.50E-16
	Wha1116d	23.55	149.95	20.61	65.83	32.74	1.02	4.52E-16
	Wha1116e	23.55	499.17	20.36	65.83	68.08	1.02	5.95E-16
	Wha1116f	23.55	1002.73	20.45	65.86	92.77	1.02	7.80E-16
	Wha"316a	23.70	14.98	20.85	65.63	4.43	1.01	4.07E-16
	Wha"316b	23.70	49.77	20.38	65.67	11.22	1.01	5.07E-16
	Wha"316c	23.70	998.52	22.79	65.47	91.32	1.01	8.09E-16
	Wha"316d	23.70	1199.00	20.08	65.57	99.66	1.01	8.49E-16
	Wha"316e	23.70	1503.12	20.57	65.66	111.06	1.01	9.11E-16
	whb'0511a	24.50	15.11	19.85	66.13	0.37	1.04	4.91E-15
	whb'0511b	24.50	50.07	20.57	66.08	1.16	1.04	5.15E-15
	whb'0511c	24.50	200.56	20.50	66.07	5.86	1.04	3.97E-15
	whb'0511d	24.50	500.61	20.36	66.07	12.96	1.04	4.26E-15
	whb'0511e	24.50	1989.24	19.42	66.00	42.50	1.04	4.27E-15
	whb'0511f	24.50	4981.80	20.16	66.09	72.12	1.04	5.40E-15
	whb'0511g	24.50	10018.70	20.46	65.94	114.13	1.04	5.71E-15

Table B.2 Permeability measurements for borehole W2a - 1.0 m scale (continued).

Graph App. C	Test ID	Z* (m)	Q (sccm)	T (°C)	Patm (cm Hg)	Pss (cm Hg)	L (m)	k (sq m)
*	Whb1201a	24.55	15.72	20.53	65.85	1.00	1.02	1.92E-15
*	Whb1201b	24.55	49.95	20.42	65.79	2.93	1.02	2.05E-15
*	Whb1201c	24.55	198.18	20.34	65.78	10.53	1.02	2.15E-15
*	Whb1201d	24.55	498.80	20.14	65.97	22.75	1.02	2.29E-15
*	Whb1201e	24.55	1984.73	19.83	65.84	46.28	1.02	3.90E-15
	Whb"0322a	24.90	20.22	20.02	65.24	1.08	1.02	2.30E-15
	Whb"0322b	24.90	49.79	20.03	65.15	1.81	1.02	3.37E-15
	Whb"0322c	24.90	195.47	19.92	65.17	5.75	1.02	4.04E-15
	Whb"0322d	24.90	500.28	19.83	65.11	15.42	1.02	3.40E-15
	Whb"0322e	24.90	1000.40	20.02	65.13	26.87	1.02	3.83E-15
	Whb"0322f	24.90	1990.60	19.69	65.22	43.92	1.02	4.20E-15
	whc'0517a	25.50	51.25	20.16	65.77	19.57	1.04	2.77E-16
	whc'0517b	25.50	201.19	20.26	65.71	40.76	1.04	4.58E-16
	whc'0517c	25.50	1000.19	20.11	65.99	84.91	1.04	8.68E-16
	whc'0517d	25.50	1501.20	20.15	65.88	101.86	1.04	1.01E-15
	Whc1202a	25.55	25.09	20.23	65.78	13.77	1.02	2.03E-16
	Whc1202b	25.55	50.16	20.06	65.78	20.62	1.02	2.59E-16
	Whc1202c	25.55	195.11	20.21	65.83	41.02	1.02	4.46E-16
	Whc"0323a	25.90	9.98	20.07	65.25	4.17	1.02	2.88E-16
	Whc"0323b	25.90	24.99	19.99	65.29	7.49	1.02	3.91E-16
	Whc"0323c	25.90	49.88	20.03	65.37	12.38	1.02	4.55E-16
	Whc"0323d	25.90	100.06	19.65	65.28	21.91	1.02	4.84E-16
	Whc"0323e	25.90	197.65	19.87	65.22	36.06	1.02	5.72E-16
	wia0524a	26.50	10.01	20.34	65.88	2.80	1.04	4.25E-16
	wia0524b	26.50	100.82	20.11	65.77	25.81	1.04	3.97E-16
	wia0524c	26.50	1001.16	20.17	65.82	96.26	1.04	7.29E-16
	wia0524d	26.50	1251.60	20.27	65.80	107.76	1.04	7.76E-16
	Wia'1208a	26.55	9.91	20.28	65.87	4.82	1.02	2.44E-16
	Wia'1208b	26.55	99.82	20.41	65.78	27.19	1.02	3.75E-16
	Wib1214a	27.55	10.04	20.40	65.51	5.55	1.02	2.15E-16
	Wib1214b	27.55	24.95	20.23	65.26	11.07	1.02	2.58E-16
	Wib1214c	27.55	195.05	20.41	65.06	52.74	1.02	3.28E-16
	Wib1214d	27.55	499.72	20.01	65.16	96.65	1.02	3.69E-16
	Wib1214e	27.55	600.80	20.37	65.33	104.57	1.02	3.96E-16
	Wib1214f	27.55	700.00	20.22	65.31	112.04	1.02	4.17E-16
	Wic1221a	28.55	9.98	20.58	65.36	6.60	1.02	1.78E-16
	Wic1221b	28.55	19.95	20.47	65.34	10.57	1.02	2.16E-16
	Wic1221c	28.55	99.90	20.41	65.33	33.57	1.02	2.94E-16
	Wic1221d	28.55	400.08	20.04	65.87	78.69	1.02	3.91E-16
	Wic1221e	28.55	600.28	19.77	65.98	96.02	1.02	4.43E-16
	Wic1221f	28.55	700.23	20.32	65.94	103.09	1.02	4.68E-16

Table B.3 Permeability measurements for borehole X2 - 1.0 m scale.

Graph App. C	Test ID	Z* (m)	Q (sccm)	T (°C)	Patm (cm Hg)	Pss (cm Hg)	L (m)	k (sq m)
	caa0811a	2.51	100.84	29.45	65.54	7.07	0.98	1.77E-15
	caa0811b	2.51	500.57	29.44	65.65	19.78	0.98	2.87E-15
	caa0811c	2.51	1200.80	29.30	65.72	29.16	0.98	4.37E-15
	cab0812a	3.49	498.28	27.71	65.68	1.87	0.98	3.41E-14
	cab0812b	3.49	1000.28	27.58	65.75	4.15	0.98	3.03E-14
	cab0812c	3.49	1799.00	27.55	65.88	7.83	0.98	2.80E-14
*	cac0813a	4.47	599.90	26.17	65.54	43.14	0.98	
*	cac0813b	4.47	999.00	26.35	65.69	57.29	0.98	
	cba0902a	5.45	121.80	25.29	65.78	13.08	0.98	1.09E-15
	cba0902b	5.45	299.10	25.24	65.70	20.45	0.98	1.63E-15
	cba0902c	5.45	598.70	25.24	65.78	29.74	0.98	2.11E-15
	cba0902d	5.45	1499.00	25.16	65.55	49.29	0.98	2.85E-15
	cbb0904a	6.43	100.00	24.16	65.41	48.39	0.98	1.94E-16
	cbb0904b	6.43	118.11	24.23	65.67	52.31	0.98	2.07E-16
	cbb0904c	6.43	203.00	24.17	65.64	65.42	0.98	2.66E-16
	cbc0909a	7.41	149.60	23.26	65.50	70.07	0.98	1.78E-16
	cbc0909b	7.41	180.60	23.33	65.66	71.46	0.98	2.09E-16
	cbc0909c	7.41	238.68	23.37	65.73	78.25	0.98	2.44E-16
	cbc0915a	7.41	119.30	23.46	65.74	62.77	0.98	1.64E-16
	cbc0915b	7.41	180.60	23.44	65.55	71.31	0.98	2.10E-16
	cca0918a	8.39	400.10	23.40	65.43	30.04	0.98	1.39E-15
	cca0918b	8.39	803.10	23.40	65.62	42.07	0.98	1.85E-15
	cca0918c	8.39	1602.50	23.40	65.64	60.41	0.98	2.33E-15
	ccb0923a	9.37	399.10	22.20	65.87	48.97	0.98	7.55E-16
	ccb0923b	9.37	499.20	22.16	65.73	53.48	0.98	8.45E-16
	ccb0923c	9.37	650.54	22.19	65.66	57.59	0.98	1.00E-15
	ccb0923d	9.37	1014.58	22.12	66.11	67.10	0.98	1.27E-15
	ccc0930a	10.35	501.40	21.67	66.02	43.09	0.98	1.11E-15
	ccc1001b	10.35	999.93	21.72	65.83	57.69	0.98	1.53E-15
	ccc1001c	10.35	1298.80	21.71	65.26	66.33	0.98	1.66E-15
	cda1003a	11.33	1808.10	21.20	65.73	2.72	0.98	8.26E-14
	cda1007b	11.33	1003.00	21.24	65.98	1.38	0.98	9.09E-14
*	cdb1007a	12.31	1002.00	21.04	65.95	51.34	0.98	1.78E-15
*	cdb1007b	12.31	1501.00	21.16	65.90	61.99	0.98	2.08E-15
*	cdb1007c	12.31	1902.20	21.08	65.86	65.84	0.98	2.44E-15
	cdc1009a	13.29	72.26	20.96	65.80	17.93	0.98	4.49E-16
	cdc1009b	13.29	149.56	20.94	65.85	27.19	0.98	5.77E-16
	cdc1009c	13.29	598.01	20.92	66.05	51.79	0.98	1.05E-15
	cea1016a	14.27	299.20	20.77	66.02	20.64	0.98	1.58E-15
	cea1016b	14.27	899.27	20.68	66.04	39.53	0.98	2.21E-15
	cea1017c	14.27	1902.70	20.62	66.00	55.00	0.98	3.08E-15
	ceb1021a	15.25	152.10	20.65	65.89	12.76	0.98	1.37E-15
	ceb1021b	15.25	400.20	20.65	65.78	25.16	0.98	1.69E-15
	ceb1021c	15.25	798.90	20.57	65.88	39.44	0.98	4.24E-15

Table B.3 Permeability measurements for borehole X2 - 1.0 m scale (continued).

Graph App. C	Test ID	Z* (m)	Q (sccm)	T (°C)	Patm (cm Hg)	Pss (cm Hg)	L (m)	k (sq m)
	cec1023a	16.23	300.80	20.54	66.14	19.17	0.98	1.72E-15
	cec1023b	16.23	898.47	20.37	66.16	36.87	0.98	2.40E-15
	cec1023c	16.23	1900.00	20.40	66.09	52.89	0.98	3.23E-15
*	cfa0929a	17.21	200.20	20.61	65.81	28.89	0.98	7.19E-16
*	cfa0929b	17.21	599.78	20.46	65.62	49.24	0.98	1.12E-15
*	cfa0929c	17.21	1398.60	20.37	65.68	72.24	0.98	1.58E-15
	cfb1106a	18.19	99.61	20.52	66.04	12.47	0.98	8.25E-16
	cfb1106b	18.19	494.60	20.48	66.06	32.24	0.98	1.55E-15
	cfb1106c	18.19	1201.90	20.37	65.75	54.64	0.98	1.97E-15
*	cfc1112a	19.17	199.60	20.39	66.12	16.09	0.98	1.39E-15
*	cfc1112b	19.17	400.10	20.36	66.15	25.72	0.98	1.64E-15
*	cfc1112c	19.17	600.50	20.35	66.20	32.94	0.98	1.83E-15
*	cfc1112d	19.17	800.92	20.32	66.05	40.30	0.98	1.92E-15
*	cfc1112e	19.17	1000.20	20.40	66.02	46.71	0.98	1.99E-15
*	cfc1112f	19.17	1197.10	20.36	66.31	50.43	0.98	2.16E-15
*	cfc1112g	19.17	1003.00	20.34	66.33	43.96	0.98	2.15E-15
*	cfc1112h	19.17	800.92	20.32	66.25	36.82	0.98	2.14E-15
*	cfc1112i	19.17	601.02	20.43	66.17	29.29	0.98	2.11E-15
*	cfc1112j	19.17	401.73	20.35	66.07	21.15	0.98	2.06E-15
*	cfc1112k	19.17	200.83	20.39	66.15	12.02	0.98	1.93E-15
	cga1120a	20.15	203.40	20.34	64.97	41.37	0.98	4.77E-16
	cga1120b	20.15	703.50	20.38	64.37	73.50	0.98	7.87E-16
	cga1204c	20.15	77.30	20.37	65.27	23.08	0.98	3.63E-16
	cgb1219a	21.13	39.10	20.37	66.14	33.86	0.98	1.16E-16
	cgb1219b	21.13	74.89	20.37	66.68	40.74	0.98	1.76E-16
	cgb0101c	21.13	198.82	20.36	65.96	57.11	0.98	3.06E-16
	cgc0114a	22.11	61.39	20.25	65.99	34.03	0.98	1.81E-16
	cgc0114b	22.11	149.33	20.27	66.41	43.21	0.98	3.26E-16
	cgc0114c	22.11	602.60	20.18	66.38	71.37	0.98	6.88E-16
	cha0121a	23.09	151.35	20.17	66.08	11.32	0.98	1.55E-15
	cha0204b	23.09	198.48	20.16	66.24	13.88	0.98	1.62E-15
	cha0204c	23.09	401.56	20.16	66.33	21.93	0.98	1.97E-15
	cha0205d	23.09	601.28	20.19	66.41	26.96	0.98	2.32E-15
	cha0205e	23.09	799.47	20.15	66.34	30.61	0.98	2.66E-15
	cha0219f	23.09	806.81	20.04	65.72	30.88	0.98	2.67E-15
	cha0219g	23.09	996.50	20.05	65.67	33.34	0.98	3.02E-15
	cha0219h	23.09	801.47	20.10	65.73	27.99	0.98	2.98E-15
	cha0219i	23.09	599.90	20.11	65.77	21.75	0.98	2.99E-15
	cha0219j	23.09	399.47	20.16	65.69	15.87	0.98	2.84E-15
	cha0219k	23.09	200.97	20.20	65.72	9.28	0.98	2.56E-15
	cha0604l	23.09	899.81	20.38	65.36	30.00	0.98	3.10E-15
	cha0604m	23.09	1799.80	20.22	65.21	43.20	0.98	3.99E-15
	chb0601a	24.00	10.10	20.00	65.57	43.04	1.01	2.19E-17
	chb0601b	24.00	49.41	20.00	65.65	59.31	1.01	7.12E-17

Table B.3 Permeability measurements for borehole X2 - 1.0 m scale (continued).

Graph App. C	Test ID	Z* (m)	Q (sccm)	T (°C)	Patm (cm Hg)	Pss (cm Hg)	L (m)	k (sq m)
	chb'0610a	24.07	100.82	20.44	65.69	87.45	0.98	8.76E-17
	chb'0617a	24.07	50.03	20.53	65.64	56.20	1.01	7.75E-17
	chb'0617b	24.07	100.05	20.54	65.71	68.81	1.01	1.18E-16
	chc0625a	25.00	34.94	20.46	65.71	41.81	1.01	7.87E-17
	chc0625b	25.00	74.93	20.38	65.60	55.38	1.01	1.18E-16
*	chc0607a	25.00	10.09	20.00	65.64	30.85	1.01	3.28E-17
*	chc0607b	25.00	99.88	20.00	65.90	68.29	1.01	1.19E-16
*	chc0607c	25.00	401.59	20.00	65.92	132.89	1.01	1.86E-16
	cia0621a	26.00	10.03	20.00	65.99	18.54	1.01	5.85E-17
	cia0621b	26.00	500.70	20.00	65.84	111.32	1.01	3.01E-16
	cib0628a	27.00	15.24	20.00	65.83	12.05	1.01	1.43E-16
	cib0628b	27.00	348.44	20.00	66.01	92.13	1.01	2.75E-16
	cic0709a	28.00	15.04	20.54	66.04	12.52	1.01	1.36E-16
	cic0709b	28.00	397.10	20.00	65.88	97.87	1.01	2.88E-16
	cja0712a	29.00	15.10	19.92	65.75	14.64	1.01	1.15E-16
	cja0712b	29.00	329.70	19.89	65.69	92.29	1.01	2.60E-16
	cjb0715a	30.00	15.02	22.09	66.07	28.02	1.01	5.49E-17
	cjb0715b	30.00	197.30	22.90	66.09	93.53	1.01	1.54E-16

Table B.4 Permeability measurements for borehole X2 - 2.0 m scale.

Graph App. C	Test ID	Z* (m)	Q (sccm)	T (°C)	Patm (cm Hg)	Pss (cm Hg)	L (m)	k (sq m)
*	ja1115a	3.00	501.65	21.38	65.84	2.52	2.01	1.50E-14
*	ja1115b	3.00	1988.40	21.08	65.78	9.98	2.01	1.42E-14
	jb1115a	3.75	250.27	23.49	65.72	1.30	2.01	1.48E-14
	jb1115b	3.75	1985.50	23.30	65.74	11.44	2.01	1.23E-14
	jc1117a	5.75	102.78	24.65	65.59	11.81	2.01	6.22E-16
	jc1117b	5.75	1502.70	24.48	65.47	41.60	2.01	2.14E-15
*	jd1129a	7.75	48.99	23.88	65.99	14.05	2.01	2.43E-16
*	jd1129b	7.75	1978.10	23.71	66.06	63.07	2.01	1.64E-15
*	je1201a	9.75	100.00	23.12	65.81	15.73	2.01	4.38E-16
*	je1201b	9.75	1983.00	22.84	65.55	62.06	2.01	1.68E-15
	jf1208a	11.75	1698.90	21.88	65.81	2.08	2.01	6.18E-14
	jf1208b	11.75	1985.50	21.78	65.75	2.70	2.01	5.54E-14
	jg1213a	13.95	48.32	21.33	65.65	5.88	2.01	6.05E-16
	jg1213b	13.95	1981.20	20.99	65.53	44.63	2.01	2.55E-15
*	jh1215a	15.95	49.00	20.75	65.68	7.08	2.01	5.04E-16
*	jh1215b	15.95	1970.00	20.44	65.66	47.65	2.01	2.33E-15
*	ji1220a	17.95	37.42	20.38	65.90	5.08	2.01	5.42E-16
*	ji1220b	17.95	1974.30	20.14	65.80	43.22	2.01	2.63E-15
	jj1222a	19.95	35.38	20.14	65.95	7.73	2.01	3.30E-16
	jj1222b	19.95	1969.50	19.90	65.74	66.41	2.01	1.51E-15

Table B.5 Permeability measurements for borehole Y2 - 0.5 m scale.

Graph App. C	Test ID	Z* (m)	Q (sccm)	T (°C)	Patm (cm Hg)	Pss (cm Hg)	L (m)	k (sq m)
	jd10313a	2.83	1000.50	16.07	66.08	57.92	0.50	2.26E-15
	jd10314b	2.83	501.70	16.29	65.56	35.81	0.50	2.09E-15
	jd10327d	2.83	[illegible].90	15.27	65.38	29.57	0.50	1.57E-15
	jd10328e	2.83	750.[illegible]	15.30	66.02	4[illegible]	0.50	2.11E-15
	jd20328a	3.33	499.30	[illegible]	66.00	5.54	0.50	1.63E-14
	jd20401b	3.33	750.00	15.64	65.82	8.55	0.50	1.55E-14
	jd20401c	3.33	1000.80	15.90	65.77	11.17	0.50	1.56E-14
	jd20401d	3.33	1502.60	15.89	65.74	16.37	0.50	1.54E-14
	jd20403e	3.33	2500.00	15.67	66.14	26.44	0.50	1.48E-14
	jd30403b	3.83	750.00	16.65	65.96	36.63	0.50	3.03E-15
	jd30407c	3.83	1203.00	16.24	65.60	47.78	0.50	3.50E-15
	jd30407d	3.83	1002.60	16.51	65.53	41.91	0.50	3.44E-15
	jd30407e	3.83	750.00	16.55	65.51	34.38	0.50	3.28E-15
	jd30408f	3.83	499.90	16.67	65.90	27.03	0.50	2.90E-15
	jd40415a	4.33	500.00	17.53	65.70	81.54	0.50	7.19E-16
	jd40415b	4.33	300.00	17.50	65.56	66.97	0.50	5.65E-16
	jd50417a	4.83	201.50	18.03	65.76	61.05	0.50	4.29E-16
	jd50417b	4.83	100.00	18.09	65.59	45.47	0.50	3.12E-16
	jd50423c	4.83	149.20	18.42	65.50	53.00	0.50	3.83E-16
	jd60418a	5.33	351.00	18.20	65.65	52.23	0.50	9.17E-16
	jd60418b	5.33	499.00	18.09	65.65	64.66	0.50	9.86E-16
	jd60423c	5.33	250.00	18.51	65.56	44.40	0.50	8.04E-16
	je10429a	5.83	300.40	19.03	65.80	27.10	0.50	1.75E-15
	je10429b	5.83	501.40	18.79	65.74	39.60	0.50	1.86E-15
	je10429c	5.83	1000.50	18.76	65.69	66.89	0.50	1.89E-15
	je10430d	5.83	301.00	18.82	65.95	27.19	0.50	1.75E-15
	je10430e	5.83	501.60	18.63	65.89	39.20	0.50	1.88E-15
	je10430f	5.83	999.60	18.59	65.80	66.90	0.50	1.89E-15
	je20510a	6.33	101.20	19.36	65.56	73.80	0.50	1.68E-16
	je20731c	6.33	69.90	22.10	66.50	76.10	0.50	1.11E-16
	je20731d	6.33	90.00	22.05	66.44	82.40	0.50	1.29E-16
	je2073'e	6.33	110.00	21.95	66.38	87.44	0.50	1.45E-16
	je30513c	6.83	70.30	19.52	65.75	98.63	0.50	7.79E-17
	je30801d	6.83	69.90	21.60	66.35	101.05	0.50	7.50E-17
	je30801e	6.83	80.00	21.70	66.28	102.15	0.50	8.46E-17
	je30801f	6.83	98.60	21.80	66.22	106.67	0.50	9.80E-17
	je40806c	7.33	100.00	21.17	66.26	49.33	0.50	2.82E-16
	je40806d	7.33	200.00	21.69	66.15	75.93	0.50	3.21E-16
	je40806e	7.33	249.50	21.46	66.22	82.86	0.50	3.54E-16
	je4'1122	7.33	120.20	23.30	65.20	55.87	0.50	2.94E-16
	je51114a	7.83	70.40	23.30	64.09	71.27	0.50	1.26E-16
	je51114b	7.83	99.60	23.35	64.40	78.59	0.50	1.56E-16
	je51114c	7.83	121.00	23.32	64.48	84.20	0.50	1.72E-16

Table B.5 Permeability measurements for borehole Y2 - 0.5 m scale (continued).

Graph App. C	Test ID	Z* (m)	Q (sccm)	T (°C)	Patm (cm Hg)	Pss (cm Hg)	L (m)	k (sq m)
	je60807a	8.33	69.40	21.14	66.35	53.20	0.50	1.78E-16
	je60807b	8.33	109.70	21.07	66.37	68.64	0.50	2.01E-16
	je60807c	8.33	150.00	20.96	66.38	75.82	0.50	2.40E-16
	je61120d	8.33	70.10	23.00	65.30	55.30	0.50	1.74E-16
	je61120e	8.33	108.90	23.02	64.87	63.43	0.50	2.26E-16
	je61120f	8.33	148.50	23.07	65.08	72.48	0.50	2.57E-16
	jf10812d	8.83	100.70	20.90	66.45	59.90	0.50	2.20E-16
	jf10812e	8.83	200.20	20.96	66.47	77.56	0.50	3.10E-16
	jf10812f	8.83	250.00	20.92	66.51	83.97	0.50	3.47E-16
	jf20603c	9.23	250.00	19.83	66.01	69.54	0.50	4.49E-16
	jf30604a	9.74	126.00	19.91	66.03	9.81	0.50	2.28E-15
	jf30604b	9.74	250.00	19.73	65.86	18.50	0.50	2.26E-15
	jf30604c	9.74	500.00	19.89	65.90	30.88	0.50	2.51E-15
	jf30604d	9.74	1000.00	19.92	65.86	50.73	0.50	2.72E-15
	jf30604e	9.74	1500.00	19.92	65.88	66.25	0.50	2.88E-15
	jf40604a	10.33	99.50	20.24	66.00	26.65	0.50	5.93E-16
	jf40605b	10.33	150.00	20.04	66.11	33.94	0.50	6.70E-16
	jf40605c	10.33	249.40	20.02	66.19	42.87	0.50	8.37E-16
	jf40605d	10.33	400.00	20.02	66.13	57.17	0.50	9.31E-16
	jf50610a	10.83	130.00	20.15	66.12	16.69	0.50	1.32E-15
	jf50610b	10.83	300.00	19.89	66.03	29.30	0.50	1.60E-15
	jf50610c	10.83	600.00	20.11	66.02	47.79	0.50	1.76E-15
	jf50610d	10.83	1000.00	20.12	66.07	65.97	0.50	1.93E-15
*	jf60611a	11.33	150.00	20.25	66.39	15.75	0.50	1.62E-15
*	jf60611b	11.33	300.00	20.67	66.28	27.34	0.50	1.73E-15
*	jf60611c	11.33	600.00	20.19	66.19	43.77	0.50	1.96E-15
*	jf60611d	11.33	1200.00	20.19	66.17	66.62	0.50	2.28E-15
	jg10611a	11.83	200.00	20.39	66.17	11.92	0.50	2.93E-15
	jg10611b	11.83	500.00	20.32	66.61	26.00	0.50	3.05E-15
	jg10611c	11.83	1000.00	20.31	66.55	44.58	0.50	3.18E-15
	jg10611d	11.83	1500.00	20.22	66.42	59.34	0.50	3.32E-15
	jg20703a	12.23	150.00	20.18	66.17	10.83	0.50	2.44E-15
	jg20703b	12.23	500.00	19.90	66.10	29.80	0.50	2.61E-15
	jg20703c	12.23	1000.00	19.89	66.02	50.60	0.50	2.73E-15
	jg20703d	12.23	1500.00	19.87	65.96	66.12	0.50	2.89E-15
	jg30704a	12.83	150.00	19.98	66.24	25.75	0.50	9.28E-16
	jg30704b	12.83	300.00	20.51	66.16	40.45	0.50	1.08E-15
	jg30704c	12.83	500.00	20.35	65.10	56.77	0.50	1.19E-15
	jg30704d	12.83	650.00	19.87	66.05	66.12	0.50	1.25E-15
*	jg40708a	13.33	149.00	20.69	66.30	18.67	0.50	1.33E-15
*	jg40708b	13.33	300.00	20.01	66.22	30.12	0.50	1.54E-15
*	jg40708c	13.33	600.00	20.25	66.14	48.10	0.50	1.74E-15
*	jg40708d	13.33	1200.00	20.12	66.10	73.53	0.50	2.00E-15

Table B.5 Permeability measurements for borehole Y2 - 0.5 m scale (continued).

Graph App. C	Test ID	Z* (m)	Q (sccm)	T (°C)	Patm (cm Hg)	Pss (cm Hg)	L (m)	k (sq m)
	jg50709a	13.83	150.00	20.37	66.20	16.42	0.50	1.55E-15
	jg50709b	13.83	300.00	20.30	66.05	28.15	0.50	1.68E-15
	jg50709c	13.83	600.00	20.28	65.97	46.46	0.50	1.83E-15
	jg50709d	13.83	1201.00	20.16	66.05	73.41	0.50	2.01E-15
	jg60710a	14.33	150.00	20.15	66.33	16.13	0.50	1.58E-15
	jg60710b	14.33	300.00	20.24	66.29	26.91	0.50	1.76E-15
	jg60710c	14.33	603.00	20.29	66.25	44.25	0.50	1.94E-15
	jg60710d	14.33	1200.00	20.31	66.09	67.90	0.50	2.23E-15
	jh10715a	14.83	200.00	20.74	66.45	11.62	0.50	3.01E-15
	jh10715b	14.83	400.00	20.10	66.40	20.72	0.50	3.17E-15
	jh10715c	14.83	800.00	20.12	66.36	36.50	0.50	3.26E-15
	jh10715d	14.83	1600.00	20.15	66.25	60.74	0.50	3.44E-15
	jh20715a	15.33	200.00	20.43	66.30	13.16	0.50	2.63E-15
	jh20716b	15.33	400.00	20.30	66.60	22.93	0.50	2.82E-15
	jh20716c	15.33	800.00	20.28	66.52	40.17	0.50	2.90E-15
	jh20716d	15.33	1600.00	20.13	66.49	64.19	0.50	3.19E-15
	jh30813a	15.83	250.00	20.28	66.46	12.80	0.50	3.38E-15
	jh30813b	15.83	749.00	20.13	66.43	31.66	0.50	3.62E-15
	jh30813c	15.83	1401.00	20.16	66.29	50.88	0.50	3.78E-15
	jh30704d	15.83	1900.00	20.11	66.22	62.87	0.50	3.90E-15
*	jh31112e	15.83	301.00	20.47	65.00	15.82	0.50	3.29E-15
*	jh31112f	15.83	649.90	20.25	64.93	30.14	0.50	3.40E-15
*	jh31112g	15.83	1500.00	20.77	64.94	57.15	0.50	3.55E-15
*	jh31112h	15.83	1949.80	20.70	64.92	68.24	0.50	3.64E-15
*	jh31112	15.83	1499.10	20.70	64.88	55.94	0.50	3.64E-15
*	jh31112j	15.83	650.50	20.78	64.77	28.94	0.50	3.58E-15
*	jh31112k	15.83	301.00	20.59	64.70	15.04	0.50	3.50E-15
	jh40813a	16.33	1515.00	20.09	66.19	3.88	0.50	7.22E-14
	jh40813b	16.33	4504.00	19.92	66.24	10.06	0.50	7.91E-14
	jh40813d	16.33	10775.00	19.31	66.23	21.41	0.50	8.22E-14
	jh40819d	16.33	2495.00	20.56	66.30	5.63	0.50	8.09E-14
	jh40819e	16.33	7510.00	19.85	66.40	15.65	0.50	8.14E-14
	jh40819f	16.33	15019.00	19.10	66.45	29.16	0.50	7.98E-14
	jh40819g	16.33	19040.00	19.00	66.45	35.29	0.50	8.06E-14
*	jh50820a	16.83	1020.00	20.29	66.38	45.12	0.50	
*	jh50820b	16.83	1503.00	20.17	66.30	56.84	0.50	
*	jh50820c	16.83	2037.00	20.22	66.25	62.60	0.50	
*	jh50820d	16.83	2500.00	20.09	66.30	66.54	0.50	
	jh50926e	16.83	1950.00	20.12	66.58	59.94	0.50	4.25E-15
	jh50927f	16.83	500.00	20.29	66.50	24.03	0.50	3.34E-15
	jh50927g	16.83	1002.00	20.22	66.37	38.26	0.50	3.86E-15
	jh50927i	16.83	1952.00	20.19	66.50	57.70	0.50	4.47E-15
	jh51008j	16.83	449.20	20.20	66.05	20.41	0.50	3.64E-15
	jh51008k	16.83	900.20	20.28	66.12	37.18	0.50	3.60E-15
	jh60820a	17.33	200.60	20.27	66.60	11.40	0.50	3.07E-15
	jh60820b	17.33	400.00	20.39	66.56	19.62	0.50	3.37E-15
	jh60820c	17.33	1000.00	20.32	66.45	40.50	0.50	3.59E-15
	jh60820d	17.33	1800.00	20.31	66.45	61.89	0.50	3.77E-15

Table B.5 Permeability measurements for borehole Y2 - 0.5 m scale (continued).

Graph App. C	Test ID	Z* (m)	Q (sccm)	T (°C)	Patm (cm Hg)	Pss (cm Hg)	L (m)	k (sq m)
	jj10821a	17.83	200.60	20.23	66.30	8.04	0.50	4.47E-15
	jj10821b	17.83	600.50	20.22	66.15	19.41	0.50	5.14E-15
	jj10821c	17.83	1200.00	20.29	66.20	33.72	0.50	5.40E-15
	jj10821d	17.83	1951.00	20.20	66.20	48.38	0.50	5.62E-15
	jj20827a	18.33	201.00	20.23	66.38	8.88	0.50	4.03E-15
	jj20827b	18.33	499.70	20.46	66.28	17.96	0.50	4.66E-15
	jj20827c	18.33	1000.00	20.35	66.30	31.61	0.50	4.86E-15
	jj20827d	18.33	1902.00	20.21	66.23	50.84	0.50	5.15E-15
	jj30827a	18.83	150.00	20.35	66.26	16.07	0.50	1.58E-15
	jj30827b	18.83	298.30	20.42	66.28	25.74	0.50	1.85E-15
	jj30828c	18.83	500.00	20.31	66.45	37.48	0.50	1.98E-15
	jj30828d	18.83	1200.00	20.32	66.25	62.68	0.50	2.47E-15
	jj30828e	18.83	1500.50	20.30	66.35	71.41	0.50	2.60E-15
	jj40829a	19.33	500.00	20.25	66.48	58.19	0.50	1.13E-15
	jj40901b	19.33	200.00	20.25	66.31	33.78	0.50	8.97E-16
	jj40901c	19.33	700.00	20.34	66.32	69.62	0.50	1.25E-15
	jj50902a	19.83	150.00	20.25	66.41	13.40	0.50	1.93E-15
	jj50902b	19.83	300.00	20.25	66.45	22.54	0.50	2.16E-15
	jj50902c	19.83	600.00	20.25	66.50	37.82	0.50	2.34E-15
	jj50902d	19.83	1200.00	20.31	66.62	61.56	0.50	2.52E-15
	jj60903a	20.33	80.00	20.26	66.31	37.39	0.50	3.17E-16
	jj60903b	20.33	120.00	20.31	66.41	46.66	0.50	3.61E-16
	jj60903c	20.33	200.20	20.20	66.38	57.86	0.50	4.58E-16
	jk10904a	20.83	69.40	20.20	66.08	34.58	0.50	3.03E-16
	jk10904b	20.83	149.60	20.25	65.99	52.46	0.50	3.90E-16
	jk10906c	20.83	220.00	20.25	66.17	65.53	0.50	4.28E-16
	jk20906a	21.33	80.00	20.07	66.33	21.42	0.50	6.11E-16
	jk20906b	21.33	300.00	20.15	66.30	48.30	0.50	8.66E-16
	jk20910c	21.33	200.00	20.06	66.23	36.70	0.50	8.12E-16
	jk20910d	21.33	450.90	20.23	66.33	58.52	0.50	1.02E-15
	jk30911a	21.83	99.50	20.19	66.21	24.89	0.50	6.41E-16
	jk30911b	21.83	200.20	20.21	66.11	39.18	0.50	7.52E-16
	jk30911c	21.83	300.00	20.15	66.10	48.51	0.50	8.63E-16
	jk40912a	22.33	70.00	20.02	66.13	20.56	0.50	5.61E-16
	jk40912b	22.33	200.00	20.17	66.19	40.20	0.50	7.27E-16
	jk40913c	22.33	350.00	20.10	66.14	54.94	0.50	8.58E-16
	jk40915d	22.33	150.00	20.15	66.38	33.27	0.50	6.85E-16
	jk41119f	22.33	99.50	20.27	65.41	23.59	0.50	6.89E-16
	jk41119g	22.33	250.00	20.20	65.59	42.79	0.50	8.47E-16
	jk41119h	22.33	399.80	20.21	65.51	57.44	0.50	9.31E-16
	jk41119i	22.33	599.50	20.07	65.50	72.83	0.50	1.02E-15
	jk50914a	22.83	200.00	20.01	65.15	23.00	0.50	1.43E-15
	jk50914b	22.83	400.00	20.16	66.11	40.46	0.50	1.44E-15
	jk50914c	22.83	700.00	20.18	66.20	59.10	0.50	1.56E-15
	jk50914d	22.83	700.40	20.18	66.26	59.21	0.50	1.56E-15

Table B.5 Permeability measurements for borehole Y2 - 0.5 m scale (continued).

Graph App. C	Test ID	Z* (m)	Q (sccm)	T (°C)	Patm (cm Hg)	Pss (cm Hg)	L (m)	k (sq m)
*	jk60917a	23.33	99.00	20.05	66.29	10.82	0.50	1.61E-15
*	jk60917b	23.33	250.30	19.93	66.21	23.76	0.50	1.70E-15
*	jk60917c	23.33	499.80	19.95	66.09	39.89	0.50	1.83E-15
*	jk60917d	23.33	849.60	20.17	66.06	58.97	0.50	1.90E-15
	jm10918a	23.83	149.20	20.07	66.29	32.48	0.50	7.01E-16
	jm10918b	23.83	300.00	20.12	66.26	50.16	0.50	8.25E-16
	jm10918c	23.83	450.10	20.06	66.39	63.09	0.50	9.18E-16
	jm20924a	24.33	125.20	20.16	66.45	43.15	0.50	4.16E-16
	jm20924b	24.33	249.40	20.07	66.45	63.79	0.50	5.01E-16
	jm20926c	24.33	350.00	19.99	66.69	78.09	0.50	5.34E-16
	jm31007a	24.83	74.60	20.08	66.04	55.22	0.50	1.82E-16
	jm31007b	24.83	150.00	20.05	66.05	78.75	0.50	2.28E-16
	jm31008c	24.83	114.90	20.07	65.97	66.79	0.50	2.18E-16
	jm41009a	25.33	75.90	20.06	66.09	97.30	0.50	8.57E-17
	jm41010b	25.33	75.50	19.90	63.58	98.83	0.50	8.51E-17
	jm51014a	25.83	54.90	19.93	63.53	89.11	0.50	7.18E-17
	jm51014b	25.83	74.60	19.85	63.41	97.30	0.50	8.62E-17
	jm61016a	26.33	55.70	19.97	63.51	75.02	0.50	9.26E-17
	jm61016b	26.33	75.00	19.94	63.68	83.25	0.50	1.08E-16
	jn11019a	26.83	54.50	19.92	64.76	48.92	0.50	1.57E-16
	jn11019b	26.83	74.20	19.90	64.73	58.05	0.50	1.72E-16
	jn11019c	26.83	126.00	20.00	64.55	74.80	0.50	2.08E-16
	jn21021a	27.33	55.30	20.05	64.73	49.77	0.50	1.56E-16
	jn21021b	27.33	80.50	19.90	64.92	60.45	0.50	1.76E-16
	jn21021c	27.33	129.90	19.99	64.82	74.13	0.50	2.17E-16
	jn31023a	27.83	55.30	19.86	64.82	63.31	0.50	1.14E-16
	jn31029b	27.83	79.80	19.95	64.85	77.53	0.50	1.25E-16
	jn41030a	28.33	54.80	19.96	65.07	107.77	0.50	5.38E-17
	jn41101b	28.33	36.00	19.98	64.95	92.15	0.50	4.43E-17
	jn51106a	28.83	35.00	19.98	65.31	60.71	0.50	7.59E-17
	jn51106b	28.83	55.00	19.92	65.23	72.94	0.50	9.34E-17
	jn51106c	28.83	75.50	19.99	65.23	81.27	0.50	1.11E-16
	jn61111	29.93	40.30	19.95	64.84	58.67	0.50	9.19E-17
	jn61111	29.93	78.90	19.92	65.01	81.10	0.50	1.16E-16

Table B.6 Permeability measurements for borehole Y2 - 1.0 m scale.

Graph App. C	Test ID	Z* (m)	Q (sccm)	T (°C)	Patm (cm Hg)	Pss (cm Hg)	L (m)	k (sq m)
	jda0219a	3.07	502.00	15.35	65.70	6.22	0.98	9.59E-15
	jda0219b	3.07	951.50	15.81	65.65	11.35	0.98	9.62E-15
	jda0219c	3.07	1402.20	15.79	65.60	15.85	0.98	9.85E-15
	jda0219d	3.07	1904.10	15.84	65.58	20.74	0.98	9.90E-15
	jdb0225a	4.05	755.00	16.93	65.66	33.07	0.98	2.28E-15
	jdb0225b	4.05	1000.80	16.99	65.63	42.22	0.98	2.25E-15
	jdb0311c	4.05	1700.00	16.95	65.60	54.91	0.98	2.73E-15
	jdc0325a	5.03	399.50	17.99	65.06	57.59	0.98	6.10E-16
	jdc0325b	5.03	499.50	17.85	65.07	63.23	0.98	6.74E-16
	jdc0325c	5.03	620.70	17.89	65.10	71.45	0.98	7.11E-16
	jea0326a	6.01	397.70	18.82	65.21	33.92	0.98	1.18E-15
	jea0326b	6.01	1001.00	18.43	65.02	69.48	0.98	1.19E-15
	jea0401a	6.01	749.90	18.40	65.16	54.20	0.98	1.24E-15
	jeb0402a	6.99	399.80	19.26	65.55	109.50	0.98	2.51E-16
	jeb0409a	6.99	98.60	19.08	65.56	49.87	0.98	1.81E-16
	jeb0409b	6.99	251.80	19.18	65.53	82.95	0.98	2.35E-16
	jec0519a	7.97	199.40	19.90	65.38	74.09	0.98	2.18E-16
	jec0519b	7.97	249.90	19.91	65.29	78.80	0.98	2.52E-16
	jec0519c	7.97	350.70	19.90	65.24	89.67	0.98	2.95E-16
*	jfa0520a	8.95	202.40	20.09	65.13	48.47	0.98	3.88E-16
*	jfa0520b	8.95	301.50	20.10	65.07	58.36	0.98	4.55E-16
*	jfa0520c	8.95	450.20	20.09	65.04	70.13	0.98	5.33E-16
	jfb0527a	9.93	500.50	20.53	65.61	27.40	0.98	1.92E-15
	jfb0527b	9.93	798.60	20.27	65.85	38.61	0.98	2.02E-15
	jfb0527c	9.93	1204.10	20.25	65.84	51.57	0.98	2.12E-15
	jfb0527d	9.93	1606.00	20.19	65.82	62.35	0.98	2.21E-15
	jfc0604a	10.91	500.00	20.60	65.79	31.12	0.98	1.64E-15
	jfc0604b	10.91	999.50	20.49	65.88	50.19	0.98	1.82E-15
	jfc0604c	10.91	1502.80	20.38	65.94	63.38	0.98	2.02E-15
	jga0605a	11.89	500.50	20.59	65.79	18.75	0.98	2.96E-15
	jga0605a	11.89	1200.00	20.50	65.66	37.90	0.98	3.11E-15
	jga0605c	11.89	1802.70	20.53	65.68	51.16	0.98	3.21E-15
	jgb0608a	12.87	602.70	20.59	65.74	30.13	0.98	2.06E-15
	jgb0608b	12.87	1198.50	20.56	65.69	49.93	0.98	2.20E-15
	jgb0608c	12.87	1803.90	20.52	65.64	65.56	0.98	2.33E-15
*	jgc0609a	13.85	499.20	20.68	65.79	26.09	0.98	2.02E-15
*	jgc0609b	13.85	999.80	20.63	65.70	45.10	0.98	2.09E-15
*	jgc0609c	13.85	1501.00	20.65	65.66	59.59	0.98	2.20E-15
*	jgc0609d	13.85	1801.20	20.63	65.76	66.44	0.98	2.28E-15
	jha0610a	14.83	651.40	20.71	65.85	24.28	0.98	2.86E-15
*	jha0611b	14.83	500.30	20.70	65.88	20.55	0.98	2.66E-15
*	jha0611c	14.83	1000.00	20.60	65.80	37.00	0.98	2.67E-15
*	jha0611d	14.83	1502.10	20.64	65.74	50.36	0.98	2.73E-15
*	jha0611e	14.83	1900.80	20.63	65.74	59.58	0.98	2.78E-15

Table B.6 Permeability measurements for borehole Y2 - 1.0 m scale (continued).

Graph App. C	Test ID	Z* (m)	Q (sccm)	T (°C)	Patm (cm Hg)	Pss (cm Hg)	L (m)	k (sq m)
*	jhb0612a	15.81	502.30	20.67	65.92	1.31	0.98	4.80E-14
*	jhb0612b	15.81	1201.10	20.58	65.88	3.22	0.98	4.60E-14
*	jhb0612c	15.81	1951.70	20.50	65.80	5.23	0.98	4.54E-14
	jhb0616d	15.81	749.40	20.61	65.86	1.88	0.98	4.97E-14
	jhb0616e	15.81	1450.40	20.61	65.77	3.78	0.98	4.72E-14
	jhc0615a	16.79	650.30	20.58	65.49	1.74	0.98	4.69E-14
	jhc0615b	16.79	899.60	20.56	65.55	2.30	0.98	4.88E-14
	jhc0615c	16.79	1348.70	20.49	65.52	3.47	0.98	4.81E-14
	jhc0615d	16.79	1798.90	20.55	65.50	4.56	0.98	4.84E-14
	jhc0615e	16.79	1949.90	20.59	65.49	4.94	0.98	4.83E-14
	jja0616a	17.77	300.20	20.78	65.70	6.53	0.98	5.55E-15
	jja0616b	17.77	800.80	20.66	65.67	16.05	0.98	5.64E-15
	jja0616c	17.77	1301.00	20.65	65.73	24.33	0.98	5.71E-15
	jjb0618a	18.75	402.20	20.67	65.79	13.67	0.98	3.37E-15
	jjb0618b	18.75	1000.90	20.53	65.75	29.74	0.98	3.47E-15
	jjb0618c	18.75	1500.20	20.59	65.72	40.83	0.98	3.55E-15
	jjb0618d	18.75	1903.90	20.55	65.66	48.69	0.98	3.62E-15
	jjc0619a	19.73	501.00	20.61	65.73	27.42	0.98	1.91E-15
	jjc0619b	19.73	999.60	20.58	65.70	47.13	0.98	1.98E-15
	jjc0619c	19.73	1501.20	20.63	65.65	62.76	0.98	2.05E-15
	jka0622a	20.71	399.30	20.55	65.86	70.70	0.98	4.64E-16
	jka0622b	20.71	499.30	20.58	65.93	77.54	0.98	5.12E-16
	jka0622c	20.71	602.60	20.56	65.95	83.39	0.98	5.59E-16
*	jkb0623a	21.69	200.90	20.56	65.88	24.50	0.98	
*	jkb0623b	21.69	300.90	20.46	65.76	33.36	0.98	
*	jkb0623c	21.69	400.80	20.46	65.74	38.74	0.98	1.01E-15
	jkb0805d	21.69	100.80	20.51	65.75	13.05	0.98	8.89E-16
	jkb0805e	21.69	198.50	20.53	66.03	23.35	0.98	9.10E-16
	jkb0805f	21.69	401.00	20.55	66.00	38.27	0.98	1.02E-15
	jkb0805g	21.69	601.00	20.37	65.76	48.65	0.98	1.14E-15
	jkb0805h	21.69	701.10	20.37	66.03	53.24	0.98	1.18E-15
*	jkc0625a	22.67	201.70	20.46	65.77	19.25	0.98	1.16E-15
*	jkc0625b	22.67	400.10	20.43	65.72	31.89	0.98	1.28E-15
*	jkc0625c	22.67	600.20	20.43	65.66	42.65	0.98	1.35E-15
*	jkc0625d	22.67	1002.30	20.40	65.65	58.96	0.98	1.49E-15
	jma0626a	23.65	198.40	20.34	65.80	16.55	0.98	1.35E-15
	jma0626b	23.65	600.90	20.35	65.76	39.06	0.98	1.50E-15
	jma0626c	23.65	1001.60	20.30	65.70	56.41	0.98	1.57E-15
	jmb0629a	24.63	100.80	20.27	65.61	41.54	0.98	2.34E-16
	jmb0629b	24.63	152.10	20.33	65.58	49.09	0.98	2.86E-16
	jmb0629c	24.63	202.40	20.38	65.59	55.45	0.98	3.25E-16
	jmb0630e	24.63	247.60	20.33	65.59	61.23	0.98	3.50E-16
	jmb0803f	24.63	48.70	20.33	65.68	26.00	0.98	1.98E-16
	jmb0803g	24.63	101.70	20.38	65.91	38.89	0.98	2.55E-16
	jmb0803h	24.63	200.50	20.37	65.76	56.01	0.98	3.18E-16

Table B.6 Permeability measurements for borehole Y2 - 1.0 m scale (continued).

Graph App. C	Test ID	Z* (m)	Q (sccm)	T (°C)	Patm (cm Hg)	Pss (cm Hg)	L (m)	k (sq m)
	jmc0701a	25.61	99.20	20.34	65.85	97.50	0.98	7.38E-17
	jmc0701b	25.61	120.20	20.34	65.80	98.21	0.98	8.86E-17
	jmc0706c	25.61	35.30	20.27	66.07	63.34	0.98	4.74E-17
	jmc0706d	25.61	45.80	20.33	65.93	66.06	0.98	5.83E-17
	jmc0706e	25.61	64.70	20.34	66.06	76.05	0.98	7.18E-17
	jna0713a	26.59	33.20	20.26	66.05	36.24	0.98	9.05E-17
	jna0713b	26.59	50.40	20.17	65.95	41.65	0.98	1.16E-16
	jna0713c	26.59	66.40	20.23	65.81	48.72	0.98	1.67E-16
	jnb0720a	27.57	37.80	20.13	65.84	35.80	0.98	1.05E-16
	jnb0720b	27.57	58.80	20.24	66.02	45.87	0.98	1.20E-16
	jnb0720c	27.57	100.80	20.27	65.77	61.64	0.98	1.41E-16
	jnc0724a	28.55	40.80	20.20	66.31	61.72	0.98	5.65E-17
	jnc0724a	28.55	51.30	20.22	66.17	64.01	0.98	6.79E-17
	jnc0724a	28.55	74.50	20.18	66.18	78.43	0.98	7.49E-17
	jpa0728a	29.00	33.60	20.17	65.50	52.42	0.98	5.81E-17
	jpa0728a	29.00	47.90	20.12	65.55	58.76	0.98	7.14E-17
	jpa0728a	29.00	58.80	20.17	65.94	62.80	0.98	7.99E-17

Table B.7 Permeability measurements for borehole Y2 - 2.0 m scale.

Graph App. C	Test ID	Z* (m)	Q (sccm)	T (°C)	Patm (cm Hg)	Pss (cm Hg)	L (m)	k (sq m)
	jz1025a	3.00	96.13	23.74	65.77	1.75	2.10	4.06E-15
	jz1025b	3.00	1981.00	23.60	65.70	18.79	2.10	6.92E-15
*	ja0902a	4.00	99.36	21.00	65.78	2.31	2.10	3.14E-15
*	ja0902b	4.00	1980.40	21.00	65.77	23.35	2.10	5.35E-15
	jb0906a	6.10	100.81	20.64	66.23	17.80	2.10	3.68E-16
	jb0906b	6.10	1980.39	19.88	66.02	101.44	2.10	8.14E-16
*	jc0909a	8.10	49.71	21.08	65.92	55.89	2.10	4.63E-17
*	jc0909b	8.10	303.09	21.61	65.73	76.25	2.10	1.87E-16
	jd0913a	10.10	74.23	22.82	65.75	6.60	2.10	8.01E-16
	jd0913b	10.10	1954.50	22.26	65.82	57.03	2.10	1.78E-15
*	je0915a	12.10	74.94	21.25	66.00	5.16	2.10	1.04E-15
*	je0915b	12.10	1958.20	21.09	65.79	47.17	2.10	2.27E-15
*	jf0920a	14.10	149.80	20.71	65.97	7.29	2.10	1.44E-15
*	jf0920b	14.10	1952.70	20.52	65.86	47.81	2.10	2.22E-15
	jg0921a	16.10	400.68	20.38	65.84	1.06	2.10	2.78E-14
	jg0921b	16.10	1983.60	20.13	65.81	4.85	2.10	2.92E-14
	jh0921a	18.10	95.39	20.32	65.88	3.43	2.10	2.01E-15
	jh0921b	18.10	1951.70	20.04	65.82	32.94	2.10	3.51E-15
*	ji0930a	20.10	100.13	20.16	65.50	8.64	2.10	8.09E-16
*	ji0930b	20.10	1957.90	19.96	65.43	63.33	2.10	1.55E-15
	jj1002a	22.10	99.48	20.08	65.39	10.01	2.10	6.88E-16
	jj1002b	22.10	1944.50	19.83	65.28	67.98	2.10	1.40E-15
	jk1006a	24.10	49.10	19.99	65.42	7.39	2.10	4.68E-16
	jk1006b	24.10	1903.70	19.77	65.41	72.57	2.10	1.26E-15
	jl1013a	26.10	35.42	19.83	64.75	56.58	2.10	3.27E-17
	jl1013b	26.10	250.23	19.87	64.76	97.66	2.10	1.10E-16
	jm1018a	28.10	14.51	19.75	65.58	10.32	2.10	9.67E-17
	jm1018b	28.10	196.69	19.77	65.59	70.80	2.10	1.34E-16

Table B.8 Permeability measurements for borehole Y2 - 3.0 m scale.

Graph App. C	Test ID	Z* (m)	Q (sccm)	T (°C)	Patm (cm Hg)	Pss (cm Hg)	L (m)	k (sq m)
	jaa0721a	4.08	98.69	32.02	65.89	2.47	2.99	2.32E-15
	jaa0721b	4.08	1981.40	28.45	65.99	22.11	2.99	4.48E-15
*	jab0726a	6.35	51.74	30.48	66.10	11.48	2.99	2.43E-16
*	jab0726b	6.35	499.23	29.15	65.88	38.30	2.99	5.92E-16
*	jab0726c	6.35	1981.70	29.35	65.77	93.68	2.99	7.26E-16
	jac0803a	9.35	34.03	24.49	65.82	6.20	2.99	3.03E-16
	jac0803b	9.35	1982.10	22.41	65.69	60.23	2.99	1.30E-15
*	jba0811a	12.35	35.40	19.38	65.88	2.78	2.99	7.07E-16
*	jba0811b	12.35	1977.50	18.46	65.70	39.58	2.99	2.18E-15
	jbb0816a	15.35	306.40	19.35	66.08	1.00	2.99	1.72E-14
	jbb0816b	15.35	1979.50	18.80	66.01	5.01	2.99	2.15E-14
	jbc0817a	18.35	50.38	19.91	66.17	1.97	2.99	1.43E-15
	jbc0817b	18.35	1980.30	20.40	66.09	26.80	2.99	3.48E-15
*	jca0819a	21.35	53.08	19.65	66.11	6.24	2.99	4.59E-16
*	jca0819b	21.35	1980.40	19.94	65.92	57.61	2.99	1.36E-15
*	jcb0823a	24.35	34.73	19.78	65.98	6.78	2.99	2.76E-16
*	jcb0823b	24.35	1979.00	19.46	65.85	72.60	2.99	9.97E-16
*	jcc0830a	27.35	14.89	19.72	65.68	10.70	2.99	7.33E-17
*	jcc0830b	27.35	1013.27	19.75	65.80	154.76	2.99	1.71E-16

Table B.9 Permeability measurements for borehole Y3 - 1.0 m scale.

Graph App. C	Test ID	Z* (m)	Q (sccm)	T (°C)	Patm (cm Hg)	Pss (cm Hg)	L (m)	k (sq m)
	YAA0301a	2.55	996.52	18.90	66.30	2.27	1.04	5.18E-14
	YAA0301b	2.55	1997.09	14.95	66.35	4.90	1.04	4.65E-14
	YAA0301c	2.55	5006.55	15.42	66.47	11.25	1.04	4.85E-14
	YAA0301d	2.55	10002.40	15.24	66.47	21.34	1.04	4.77E-14
*	YAb0302a	3.55	504.27	16.78	66.37	10.94	1.04	5.07E-15
*	YAb0302b	3.55	1004.35	15.75	66.30	20.44	1.04	5.05E-15
*	YAb0302c	3.55	3490.00	16.35	66.35	49.18	1.04	6.15E-15
*	YAb0302d	3.55	7000.90	16.38	66.50	74.23	1.04	7.18E-15
*	YAb0302e	3.55	11994.20	16.17	66.30	103.16	1.04	7.77E-15
*	YAc0308a	4.55	100.50	17.22	66.09	1.00	1.04	1.19E-14
*	YAc0308b	4.55	250.23	17.52	66.09	2.19	1.04	1.35E-14
*	YAc0308c	4.55	499.63	17.50	66.15	4.06	1.04	1.43E-14
*	YAc0308d	4.55	5009.80	17.21	66.15	27.49	1.04	1.80E-14
*	YAc0308e	4.55	15024.70	16.76	66.25	52.77	1.04	2.43E-14
*	YAc0308f	4.55	20052.40	16.74	66.22	61.94	1.04	2.63E-14
*	Yba0309a	5.55	102.55	18.11	66.07	6.77	1.04	1.73E-15
*	Yba0309b	5.55	250.91	18.62	66.10	12.79	1.04	2.15E-15
*	Yba0309c	5.55	1000.29	18.19	66.27	29.44	1.04	3.33E-15
*	Yba0309d	5.55	5008.21	17.86	66.32	56.81	1.04	7.38E-15
*	Yba0309e	5.55	14996.00	17.60	66.07	104.88	1.04	9.55E-15
*	Ybb0315a	6.55	51.31	19.55	66.19	14.62	1.04	3.81E-16
*	Ybb0315b	6.55	200.91	19.35	66.14	27.87	1.04	7.17E-16
*	Ybb0315c	6.55	999.27	19.32	66.09	62.99	1.04	1.29E-15
*	Ybb0315d	6.55	3003.20	19.06	66.24	94.37	1.04	2.23E-15
*	Ybb0315e	6.55	3509.47	19.08	66.16	103.07	1.04	2.30E-15
*	Ybb0315f	6.55	4007.70	19.06	65.97	103.80	1.04	2.61E-15
*	Ybb0315a	6.55	4493.49	19.05	65.95	102.01	1.04	3.00E-15
*	Ybc0322a	7.55	34.06	19.23	65.69	4.28	1.04	9.34E-16
*	Ybc0322b	7.55	47.51	19.86	65.63	5.03	1.04	1.11E-15
*	Ybc0322c	7.55	200.96	19.75	65.58	12.79	1.04	1.74E-15
*	Ybc0322d	7.55	500.60	19.68	65.52	23.26	1.04	2.22E-15
*	Ybc0322e	7.55	1000.20	19.51	65.51	35.68	1.04	2.68E-15
*	Ybc0322f	7.55	1990.50	19.53	65.63	51.99	1.04	3.33E-15
*	Ybc0322g	7.55	4508.70	19.10	65.69	75.31	1.04	4.61E-15
*	Ybc0322h	7.55	7005.34	19.03	65.68	91.21	1.04	5.49E-15
*	Ybc0322i	7.55	10004.70	18.37	65.82	99.08	1.04	6.95E-15
*	Ybc0322j	7.55	12045.00	18.61	65.67	106.15	1.04	7.59E-15
	Yca0329a	8.55	50.88	19.09	66.28	4.35	1.04	1.36E-15
	Yca0329b	8.55	100.05	20.05	66.22	6.51	1.04	1.77E-15
	Yca0329c	8.55	200.88	20.11	66.15	10.04	1.04	2.25E-15
	Yca0329d	8.55	1000.13	20.00	66.22	29.77	1.04	3.31E-15
	Yca0329e	8.55	1990.02	19.67	66.45	43.22	1.04	4.17E-15
	Yca0329f	8.55	5006.40	19.71	66.29	71.72	1.04	5.45E-15
	Yca0329g	8.55	8013.57	19.25	66.37	89.09	1.04	6.46E-15
	Yca0329h	8.55	10012.20	19.00	66.33	90.10	1.04	7.94E-15
	Yca0329i	8.55	12010.00	19.28	66.16	96.97	1.04	8.60E-15
	Yca0405a	8.55	1002.03	22.58	65.58	24.98	1.01	4.22E-15
	Yca0405b	8.55	1985.10	20.31	65.70	38.49	1.01	4.95E-15

Table B.9 Permeability measurements for borehole Y3 - 1.0 m scale (continued).

Graph App. C	Test ID	Z* (m)	Q (sccm)	T (°C)	Patm (cm Hg)	Pss (cm Hg)	L (m)	k (sq m)
	Ycb0406a	9.55	15.07	20.24	65.78	0.54	1.01	3.44E-15
	Ycb0406b	9.55	30.00	20.63	65.78	1.08	1.01	3.42E-15
	Ycb0406c	9.55	75.25	20.50	65.75	2.55	1.01	3.59E-15
	Ycb0406d	9.55	195.01	19.37	65.65	5.86	1.01	3.94E-15
	Ycb0406e	9.55	1002.40	20.34	65.57	20.36	1.01	5.30E-15
	Ycb0406f	9.55	1985.70	20.49	65.54	29.91	1.01	6.73E-15
	Ycc0411a	10.55	49.71	20.61	65.75	0.54	1.01	1.14E-14
	Ycc0411b	10.55	100.00	20.84	65.75	1.20	1.01	1.03E-14
	Ycc0411c	10.55	197.71	20.78	65.74	2.39	1.01	1.01E-14
	Ycc0411d	10.55	399.99	20.84	65.75	5.55	1.01	8.59E-15
	Ycc0411e	10.55	800.31	20.71	65.84	9.72	1.01	9.50E-15
	Ycc0411f	10.55	1603.36	20.87	65.84	17.08	1.01	1.03E-14
	Ycc0411g	10.55	7048.60	19.94	65.86	59.77	1.01	1.00E-14
	Ycc0411h	10.55	13828.20	20.06	65.89	86.50	1.01	1.19E-14
	Ycc0411i	10.55	17886.30	19.85	65.88	98.98	1.01	1.27E-14
	Ycc0411j	10.55	21948.20	19.80	65.85	108.10	1.01	1.38E-14
	Yda0426a	11.55	49.82	21.55	65.18	10.30	1.01	5.63E-16
	Yda0426b	11.55	99.94	21.46	65.11	9.68	1.01	1.21E-15
	Yda0426c	11.55	195.06	21.57	65.11	11.46	1.01	1.97E-15
	Yda0426d	11.55	1000.70	21.52	65.25	21.78	1.01	4.94E-15
	Yda0426e	11.55	1986.40	21.26	65.35	30.43	1.01	6.62E-15
	Yda0510a	11.55	1002.44	21.52	65.67	12.92	1.01	8.80E-15
	Yda0510b	11.55	1985.12	21.60	65.64	22.68	1.01	9.31E-15
	Yda0510c	11.55	5189.00	20.55	65.65	54.19	1.01	8.42E-15
	Yda0510d	11.55	9929.80	20.65	65.70	78.80	1.01	9.78E-15
	Yda0510e	11.55	15010.10	20.42	65.62	92.64	1.01	1.18E-14
	Yda0510f	11.55	18073.00	19.92	65.60	94.38	1.01	1.38E-14
	Yda0510g	11.55	19581.00	20.08	65.64	98.25	1.01	1.41E-14
*	Ydb0427a	12.55	49.78	21.44	65.36	9.41	1.01	6.18E-16
*	Ydb0427b	12.55	100.24	21.43	65.36	10.30	1.01	1.13E-15
*	Ydb0427c	12.55	206.41	21.23	65.68	10.87	1.01	2.18E-15
*	Ydb0427d	12.55	1000.50	21.19	65.39	22.54	1.01	4.73E-15
*	Ydb0427e	12.55	1501.40	21.13	65.44	27.55	1.01	5.62E-15
*	Ydb0427f	12.55	1983.10	21.07	65.25	31.93	1.01	6.25E-15
	Ydb0504a	12.55	5510.00	21.71	65.67	76.20	1.01	5.71E-15
	Ydb0504b	12.55	10090.00	22.23	65.67	90.17	1.01	8.29E-15
	Ydb0504c	12.55	12467.00	21.51	65.50	82.97	1.01	1.15E-14
	Ydb0504d	12.55	15021.70	21.05	65.75	82.59	1.01	1.39E-14
	Ydb0504e	12.55	20610.00	20.34	65.77	84.47	1.01	1.84E-14
	Ydc0517a	13.55	15.18	21.92	65.58	4.93	1.01	3.71E-16
	Ydc0517b	13.55	29.48	21.86	65.49	7.75	1.01	4.49E-16
	Ydc0517c	13.55	99.78	22.01	65.52	16.30	1.01	6.81E-16
	Ydc0517d	13.55	197.05	21.93	65.48	23.39	1.01	8.95E-16
	Ydc0517e	13.55	1000.10	21.97	65.59	52.83	1.01	1.69E-15
	Ydc0517f	13.55	1983.75	21.59	65.64	69.45	1.01	2.33E-15
	Ydc0517g	13.55	3820.86	21.34	65.66	97.09	1.01	2.82E-15
	Yea0524a	14.55	10.23	23.76	65.60	3.43	1.01	3.65E-16
	Yea0524b	14.55	3822.32	22.47	65.44	101.91	1.01	2.65E-15

Table B.9 Permeability measurements for borehole Y3 - 1.0 m scale (continued).

Graph App. C	Test ID	Z* (m)	Q (sccm)	T (°C)	Patm (cm Hg)	Pss (cm Hg)	L (m)	k (sq m)
	Yeb0525a	15.55	20.20	22.42	65.44	5.05	1.01	4.83E-16
	Yeb0525b	15.55	3822.85	21.20	65.57	101.08	1.01	2.66E-15
	Yec0601a	16.55	51.22	21.74	65.89	9.59	1.04	6.07E-16
	Yec0601b	16.55	3705.91	20.90	66.02	125.90	1.04	1.83E-15
*	Yfa0607a	17.55	34.44	20.83	65.83	60.22	1.04	4.77E-17
*	Yfa0607b	17.55	100.80	20.64	65.95	73.19	1.04	1.07E-16
*	Yfa0607c	17.55	500.77	20.21	66.02	109.85	1.04	3.01E-16
*	Yfa0607d	17.55	602.00	20.49	66.07	112.21	1.04	3.51E-16
	Yfb0621a	18.55	10.14	19.77	66.20	76.89	1.04	1.01E-17
	Yfb0621b	18.55	49.92	19.44	66.17	102.48	1.04	3.31E-17
*	Yfc0628a	19.55	33.58	20.29	65.98	68.52	1.04	3.91E-17
*	Yfc0628b	19.55	75.57	20.10	66.19	81.04	1.04	6.98E-17
	yfc0819	19.55	30.66	25.78	66.15	67.45	1.02	3.75E-17
	Yga0702a	20.55	9.97	20.22	65.94	5.35	1.04	2.17E-16
	Yga0702b	20.55	501.84	20.02	65.79	49.63	1.04	8.91E-16
	Yga0702c	20.55	1204.00	20.13	65.85	80.17	1.04	1.13E-15
	Ygb0705a	21.55	15.03	21.22	66.17	102.27	1.01	1.02E-17
	Ygc0709a	22.55	10.14	20.01	66.38	96.27	1.01	7.49E-18
	Yha0712a	23.55	10.10	19.79	66.13	1.77	1.01	6.93E-16
	Yha0712b	23.55	1000.27	18.65	65.94	55.08	1.01	1.57E-15
	Yha0712c	23.55	2960.84	20.06	65.93	100.37	1.01	2.07E-15
*	yhb0823a	24.55	34.86	20.85	66.05	32.32	1.02	1.06E-16
*	yhb0823b	24.55	301.61	19.63	66.06	76.36	1.02	3.06E-16
	yhc0906a	25.55	33.61	22.38	66.24	111.28	1.02	2.02E-17
	yia0921a	26.55	34.45	20.73	66.10	55.18	1.02	5.40E-17
	yia0921b	26.55	199.57	20.69	66.12	121.89	1.02	1.04E-16
	yib0930a	27.55	34.88	19.45	65.64	81.32	1.02	3.26E-17
	yic1002a	28.55	34.04	19.42	65.59	69.33	1.02	3.94E-17
*	yja1013a	29.55	35.28	19.23	65.11	42.65	1.02	7.72E-17
*	yja1013b	29.55	346.48	19.39	65.18	104.39	1.02	2.28E-16
*	yjb1018a	30.55	35.32	18.78	65.99	34.17	1.02	1.00E-16
*	yjb1018b	30.55	397.60	18.71	65.95	94.47	1.02	2.99E-16
	yjc1021a	31.55	34.04	19.13	66.05	67.70	1.02	4.06E-17
	yjc1021b	31.55	201.26	19.02	66.03	122.91	1.02	1.04E-16
	yka1025a	32.55	34.46	21.00	65.99	2.90	1.02	1.43E-15
	yka1025b	32.55	1990.00	19.95	66.15	145.94	1.02	7.93E-16
*	ykb1027a	33.55	99.64	19.68	66.37	10.34	1.02	1.09E-15
*	ykb1027b	33.55	1000.70	19.57	66.19	94.03	1.02	7.59E-16

Table B.9 Permeability measurements for borehole Y3 - 1.0 m scale (continued).

Graph App. C	Test ID	Z* (m)	Q (sccm)	T (°C)	Patm (cm Hg)	Pss (cm Hg)	L (m)	k (sq m)
	ykc1101a	34.55	51.28	19.37	65.60	24.75	1.02	2.14E-16
	ykc1101b	34.55	349.64	19.23	65.74	104.40	1.02	2.29E-16
	yla1103a	35.55	41.21	19.27	65.55	28.25	1.02	1.48E-16
	yla1103b	35.55	297.70	19.23	65.58	95.62	1.02	2.21E-16
	ylb1108a	36.55	49.19	19.16	66.23	166.93	1.02	1.59E-17
	ylc1110a	37.55	35.31	19.20	65.61	155.76	1.02	1.27E-17
	y[illegible]117a	38.55	41.64	19.55	65.86	162.39	1.02	1.41E-17
	ymb1129a	39.55	31.17	19.07	66.43	160.72	1.02	1.07E-17
	ymc1201a	40.55	30.69	19.17	66.04	190.58	1.02	8.05E-18
	yme1220a	41.55	37.00	20.03	66.23	205.00	1.02	8.65E-18

Table B.10 Permeability measurements for borehole Z2 - 1.0 m scale.

Graph App. C	Test ID	Z* (m)	Q (sccm)	T (°C)	Patm (cm Hg)	Pss (cm Hg)	L (m)	k (sq m)
	Zaa0702a	2.58	498.91	29.44	65.44	93.70	1.02	3.96E-16
	Zaa0702b	2.58	600.71	29.54	65.58	95.13	1.02	4.66E-16
	Zaa0702c	2.58	700.32	29.59	65.33	101.74	1.02	4.95E-16
	Zab0708a	3.58	49.86	27.32	65.59	39.33	1.02	1.23E-16
	Zab0708b	3.58	99.96	27.34	65.69	44.24	1.02	2.13E-16
	Zab0708c	3.58	197.52	27.32	65.89	54.36	1.02	3.24E-16
	Zab0708d	3.58	501.39	27.33	65.73	82.56	1.02	4.70E-16
	Zac0715a	4.56	50.02	25.82	65.82	33.53	1.02	1.49E-16
	Zac0715b	4.56	197.66	25.82	65.68	51.73	1.02	3.44E-16
	Zac0715c	4.56	599.49	25.82	65.95	78.62	1.02	5.98E-16
	Zba0722a	5.56	49.96	24.64	65.81	38.08	1.02	1.27E-16
	Zba0722b	5.56	197.59	24.64	65.67	55.30	1.02	3.15E-16
	Zba0722c	5.56	600.94	24.64	65.89	79.33	1.02	5.90E-16
	Zbb0729a	6.56	49.72	23.71	65.84	50.00	1.02	8.97E-17
	Zbb0729b	6.56	100.00	23.71	66.18	59.55	1.02	1.43E-16
	Zbb0729c	6.56	197.53	23.73	65.90	74.97	1.02	2.09E-16
	Zbb0729d	6.56	499.87	23.76	66.12	105.36	1.02	3.27E-16
	Zbc0805a	7.56	49.86	22.99	65.77	45.53	1.02	1.01E-16
	Zbc0805b	7.56	197.66	23.03	65.87	75.42	1.02	2.07E-16
	Zbc0805c	7.56	399.23	22.97	65.53	101.78	1.02	2.75E-16
*	Zca0812a	8.56	50.01	22.49	65.69	28.21	1.02	1.81E-16
*	Zca0812b	8.56	197.50	22.54	65.81	50.83	1.02	3.47E-16
*	Zca0812c	8.56	499.87	22.43	65.59	92.99	1.02	3.91E-16
*	Zca0812d	8.56	700.32	22.44	65.84	104.77	1.02	4.61E-16
*	Zcb0819a	9.56	501.30	21.92	65.83	4.74	1.02	1.26E-14
*	Zcb0819b	9.56	1982.29	21.67	65.69	15.45	1.02	1.42E-14
	Zcc0819a	10.56	500.03	21.45	65.81	8.02	1.02	7.26E-15
	Zcc0819b	10.56	1984.40	21.23	65.96	20.66	1.02	1.02E-14
	Zda0820a	11.56	1000.22	21.09	65.84	19.04	1.02	5.66E-15
	Zda0820b	11.56	1984.13	21.00	65.67	29.92	1.02	6.67E-15
	Zdb0825a	12.56	1001.60	21.00	65.80	9.18	1.02	1.26E-14
	Zdb0825b	12.56	1495.99	20.91	65.82	12.79	1.02	1.31E-14
	Zdb0825c	12.56	1984.42	20.88	65.76	15.76	1.02	1.39E-14
	Zdc0826a	13.56	1001.59	20.75	65.96	2.28	1.02	5.31E-14
	Zdc0826b	13.56	1498.86	20.66	65.91	3.47	1.02	5.18E-14
	Zdc0826c	13.56	1985.13	20.69	65.90	4.59	1.02	5.14E-14
	Zea0826a	14.56	200.28	20.85	65.87	7.55	1.02	3.09E-15
	Zea0826b	14.56	999.58	20.72	65.82	21.09	1.02	5.03E-15
	Zea0826c	14.56	1987.50	20.57	65.83	29.69	1.02	6.72E-15
	Zeb0830a	15.56	198.95	20.81	65.66	18.35	1.02	1.18E-15
	Zeb0830b	15.56	1000.18	20.69	65.64	38.74	1.02	2.46E-15
	Zeb0830c	15.56	1983.77	20.54	65.67	51.22	1.02	3.44E-15

Table B.10 Permeability measurements for borehole Z2 - 1.0 m scale (continued).

Graph App. C	Test ID	Z* (m)	Q (sccm)	T (°C)	Patm (cm Hg)	Pss (cm Hg)	L (m)	k (sq m)
*	Zec0831a	16.53	99.61	20.34	66.12	17.48	1.00	6.26E-16
*	Zec0831b	16.53	999.43	20.21	66.05	55.58	1.00	1.58E-15
	Zec0913a	16.53	31.09	21.50	65.59	9.00	1.00	4.07E-16
	Zec0913b	16.53	49.58	21.13	65.59	11.36	1.00	5.05E-16
	Zec0913c	16.53	75.63	20.95	65.95	14.23	1.00	6.00E-16
	Zec0913d	16.53	100.42	20.87	65.74	16.49	1.00	6.78E-16
	Zec0913e	16.53	200.01	20.75	65.89	23.35	1.00	9.10E-16
	Zec0913f	16.53	400.06	20.63	66.04	33.47	1.00	1.19E-15
	Zec0913g	16.53	800.53	20.53	66.22	47.09	1.00	1.56E-15
	Zec0913h	16.53	1000.51	20.43	66.34	52.94	1.00	1.68E-15
	Zec0913i	16.53	1199.32	20.40	66.27	58.40	1.00	1.77E-15
	Zec0913j	16.53	1500.17	20.34	66.19	66.29	1.00	1.87E-15
	Zec0913k	16.53	1750.46	20.30	66.18	70.91	1.00	2.00E-15
	Zec0913l	16.53	1992.66	20.25	66.14	73.22	1.00	2.18E-15
	Zfa0907a	17.53	153.79	21.40	66.14	69.80	1.00	1.80E-16
	Zfa0907b	17.53	199.54	21.09	65.96	79.10	1.00	1.97E-16
	Zfa0907c	17.53	250.90	21.21	66.04	82.16	1.00	2.35E-16
	Zfb0917a	18.53	1000.48	20.16	65.98	1.58	1.00	7.80E-14
	Zfb0917b	18.53	2508.97	19.80	65.88	4.16	1.00	7.29E-14
	Zfb0917c	18.53	9996.15	18.33	65.85	15.09	1.00	7.37E-14
	Zfb0917d	18.53	15990.00	18.50	65.84	22.50	1.00	7.54E-14
	Zfb0917e	18.53	20062.80	18.54	65.88	27.01	1.00	7.65E-14
	Zfc0918a	19.53	50.43	20.38	65.85	34.89	1.00	1.43E-16
	Zfc0918b	19.53	95.39	20.32	65.84	44.06	1.00	2.03E-16
	Zfc0918c	19.53	501.70	20.15	66.09	77.52	1.00	5.07E-16
	Zga0923a	20.53	35.29	20.19	66.29	90.11	1.00	2.89E-17
	Zga0923b	20.53	50.83	20.19	66.15	96.63	1.00	3.78E-17
	Zgb1001a	21.53	35.29	20.03	66.10	98.57	1.00	2.55E-17
	Zgc1005a	22.53	1007.88	19.76	66.20	3.26	1.00	3.74E-14
	Zgc1005b	22.53	2003.88	19.53	66.11	6.01	1.00	3.96E-14
	Zgc1005c	22.53	5000.60	18.82	66.02	13.67	1.00	4.11E-14
	Zgc1005d	22.53	19987.00	18.17	66.07	45.96	1.00	3.99E-14
*	Zha1006a	23.53	31.09	19.99	66.09	36.77	1.00	8.22E-17
	Zha1008a	23.53	50.00	19.80	65.84	43.46	1.00	1.08E-16
	Zha1008b	23.53	149.16	19.81	65.89	70.42	1.00	1.72E-16
	Zha1008c	23.53	298.93	19.78	66.17	92.66	1.00	2.35E-16
	Zha1008d	23.53	400.05	19.78	66.14	102.53	1.00	2.73E-16
*	Zhb1014a	24.53	35.71	19.75	66.04	45.67	1.00	7.22E-17
*	Zhb1014b	24.53	73.96	19.79	66.04	57.80	1.00	1.11E-16
*	Zhb1014c	24.53	402.77	19.74	66.12	105.83	1.00	2.63E-16
*	Zhb1014d	24.53	500.57	19.73	66.05	114.17	1.00	2.92E-16
	Zhc1019a	25.53	34.88	19.72	66.15	59.78	1.00	4.99E-17
	Zhc1019b	25.53	98.43	19.69	66.51	82.03	1.00	9.16E-17
	Zhc1019c	25.53	200.12	19.68	66.52	105.36	1.00	1.31E-16

Table B.10 Permeability measurements for borehole Z2 - 1.0 m scale (continued).

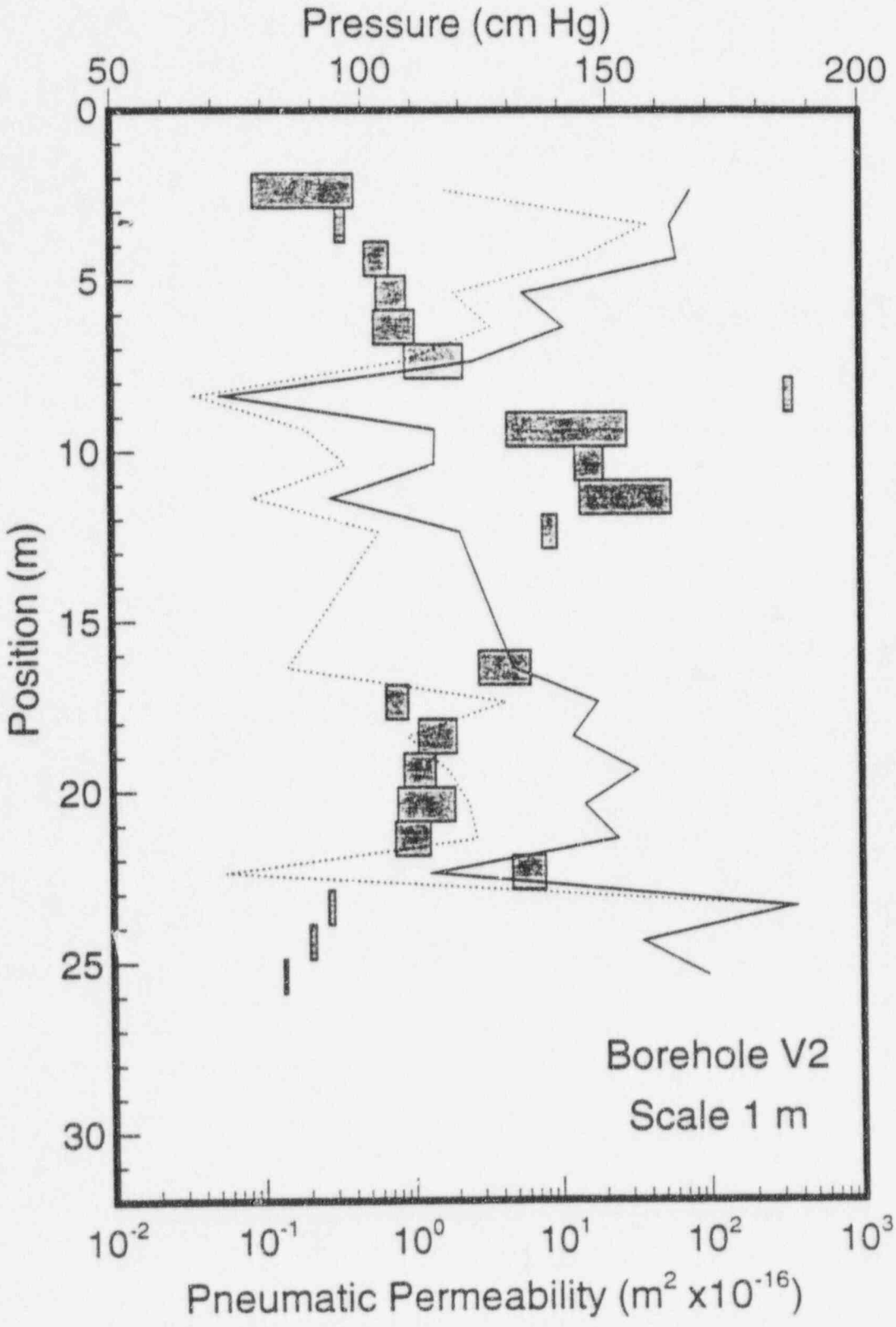
Graph App. C	Test ID	Z* (m)	Q (sccm)	T (°C)	Patm (cm Hg)	Pss (cm Hg)	L (m)	k (sq m)
	Zia1026a	26.53	34.88	19.75	65.85	27.40	1.00	1.31E-16
	Zia1026b	26.53	99.17	19.51	65.82	45.45	1.00	2.02E-16
	Zia1026c	26.53	249.35	19.60	66.25	68.11	1.00	3.00E-16
	Zia1026d	26.53	400.54	19.59	66.15	86.44	1.00	3.48E-16
	Zia1026e	26.53	500.56	19.58	66.16	93.08	1.00	3.92E-16
	Zia1026f	26.53	601.86	19.61	65.65	100.17	1.00	4.26E-16
	Zib1109a	27.53	36.98	19.66	66.51	3.32	1.00	1.34E-15
	Zib1109b	27.53	75.23	19.77	66.47	5.32	1.00	1.68E-15
	Zib1109c	27.53	150.41	19.68	66.48	9.01	1.00	1.93E-15
	Zib1109d	27.53	499.63	19.69	66.54	24.42	1.00	2.13E-15
	Zib1109e	27.53	1980.57	19.38	66.32	56.12	1.00	3.07E-15
	Zib1109f	27.53	3492.79	19.30	66.02	72.19	1.00	3.88E-15
	Zib1109g	27.53	4998.10	19.02	65.75	80.50	1.00	4.80E-15
	Zib1109h	27.53	8496.67	18.82	65.49	101.92	1.00	5.86E-15
*	Zic1116a	28.53	36.18	19.62	66.36	1.74	1.00	2.54E-15
*	Zic1116b	28.53	75.29	19.71	66.36	2.77	1.00	3.29E-15
*	Zic1116c	28.53	150.57	19.59	66.35	4.76	1.00	3.78E-15
*	Zic1116d	28.53	499.55	19.52	66.33	13.51	1.00	4.15E-15
*	Zic1116e	28.53	1977.30	19.28	66.34	40.96	1.00	4.56E-15
*	Zic1116f	28.53	4000.20	18.96	66.34	61.43	1.00	5.49E-15
*	Zic1116g	28.53	10009.20	18.33	66.45	93.36	1.00	7.74E-15
*	Zic1116h	28.53	12058.50	18.22	66.41	91.41	1.00	9.61E-15
	Zja1201a	29.53	34.50	19.58	66.32	1.90	1.00	2.21E-15
	Zja1201b	29.53	100.90	19.63	66.25	3.74	1.00	3.25E-15
	Zja1201c	29.53	250.62	19.45	66.28	8.07	1.00	3.62E-15
	Zja1201d	29.53	999.81	19.40	66.27	28.99	1.00	3.50E-15
	Zja1201e	29.53	2987.60	19.04	66.34	63.15	1.00	3.96E-15
	Zja1201f	29.53	5022.53	18.74	66.17	79.57	1.00	4.87E-15
	Zja1201g	29.53	6988.90	18.61	66.37	88.96	1.00	5.80E-15

APPENDIX C: Graphs of Transient Data for Selected Tests

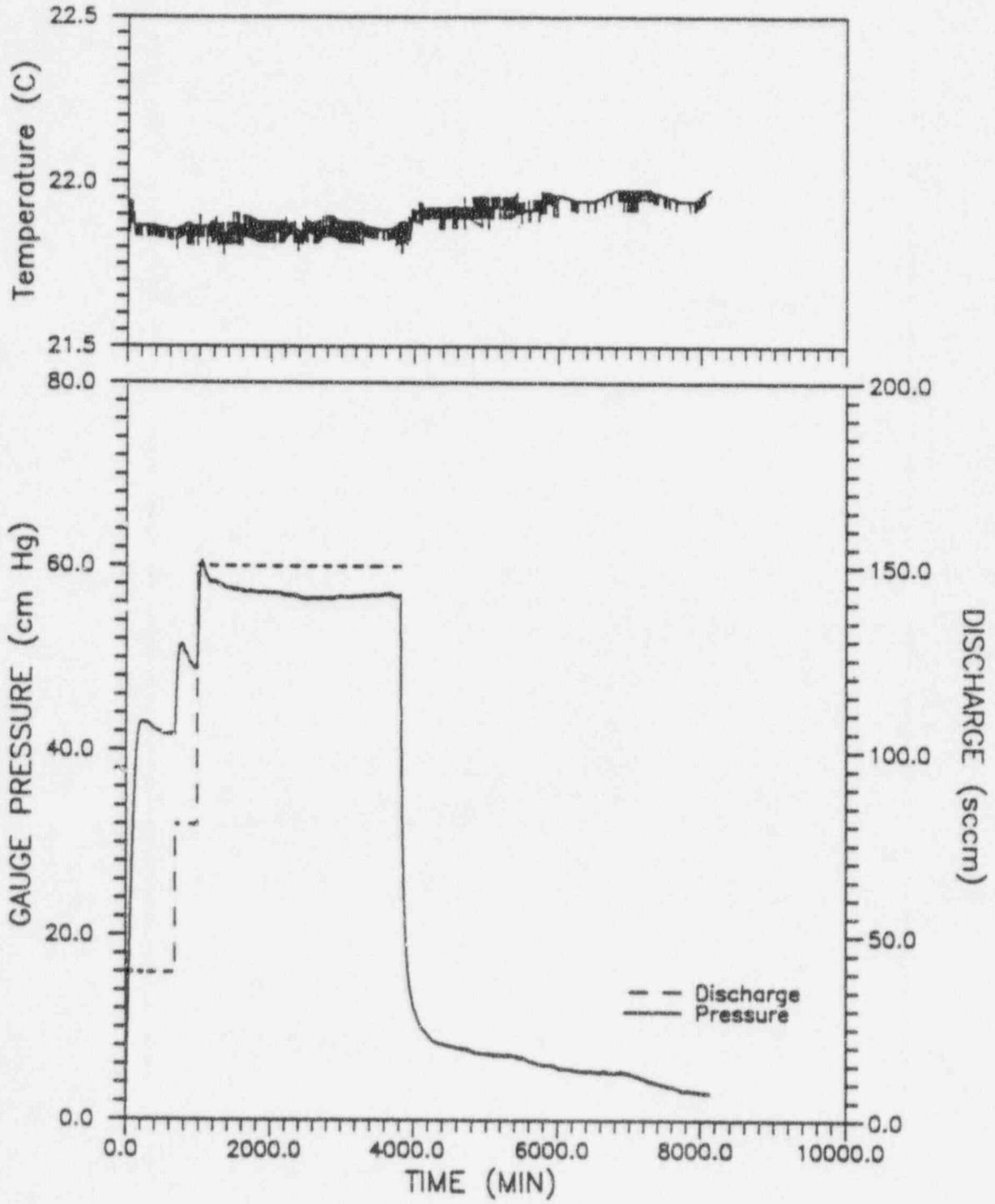
Key to permeability versus depth graphs:

Each set of transient plots is accompaynied by a plot of permeability estimates as a function of position along the borehole. (see page C-3 for example). The permeability data are presented in the form of rectangles which delineate depth intervals and ranges of computed permeabilities (lower abcissa) resulting from each flow rate. Also shown are the minimum (dashed curve) and maximum (solid curve) pressures applied during each test (upper abcissa). In general, there is no indication of a systematic trend as a function of depth. However, a pseudo-periodic behavior becomes more prominent as the scale of measurement is reduced.

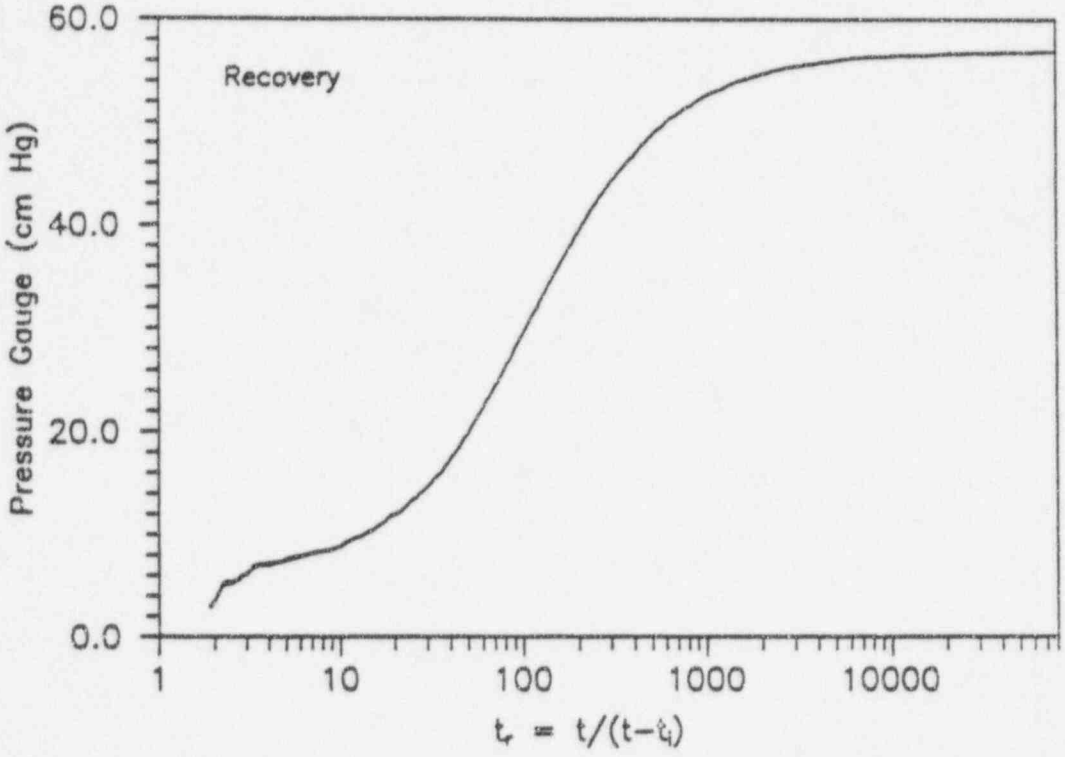
Graphs from Table B.1 V2 - 1.0 m Data

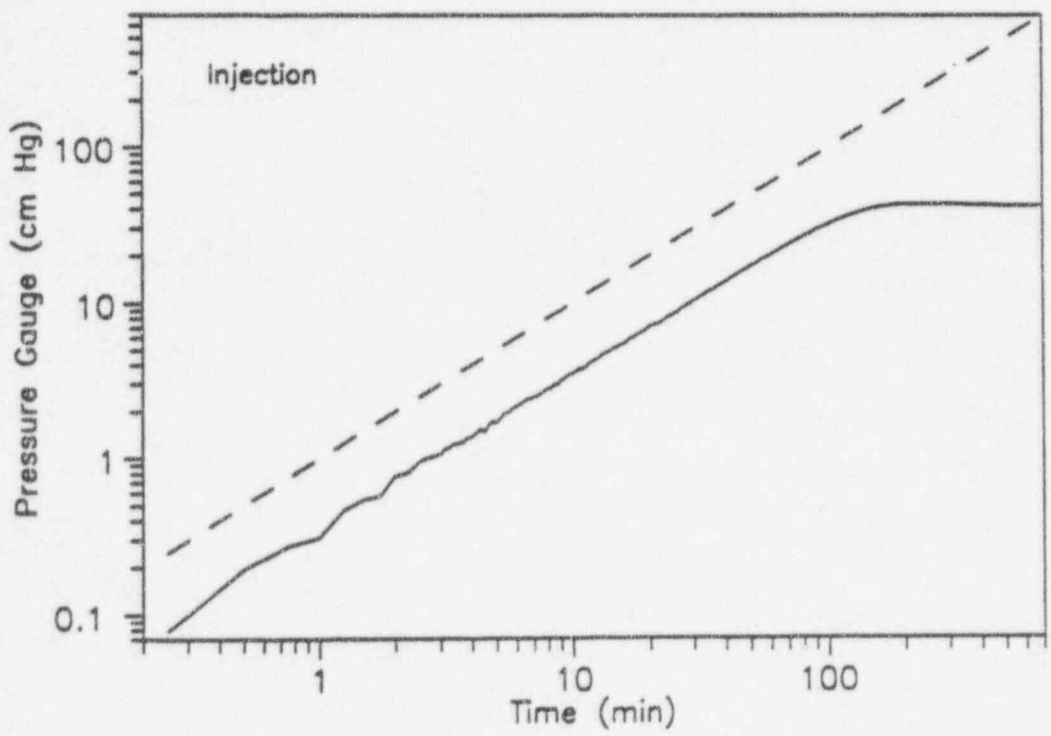

Pressure (cm Hg)
50
100
150
200
0
5
10
15
20
25
30
Position (m)
Borehole V2
Scale 1 m
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
Pneumatic Permeability (m^2 x10^{-16})

INJECTION TEST
V2-VBC
09-15-92

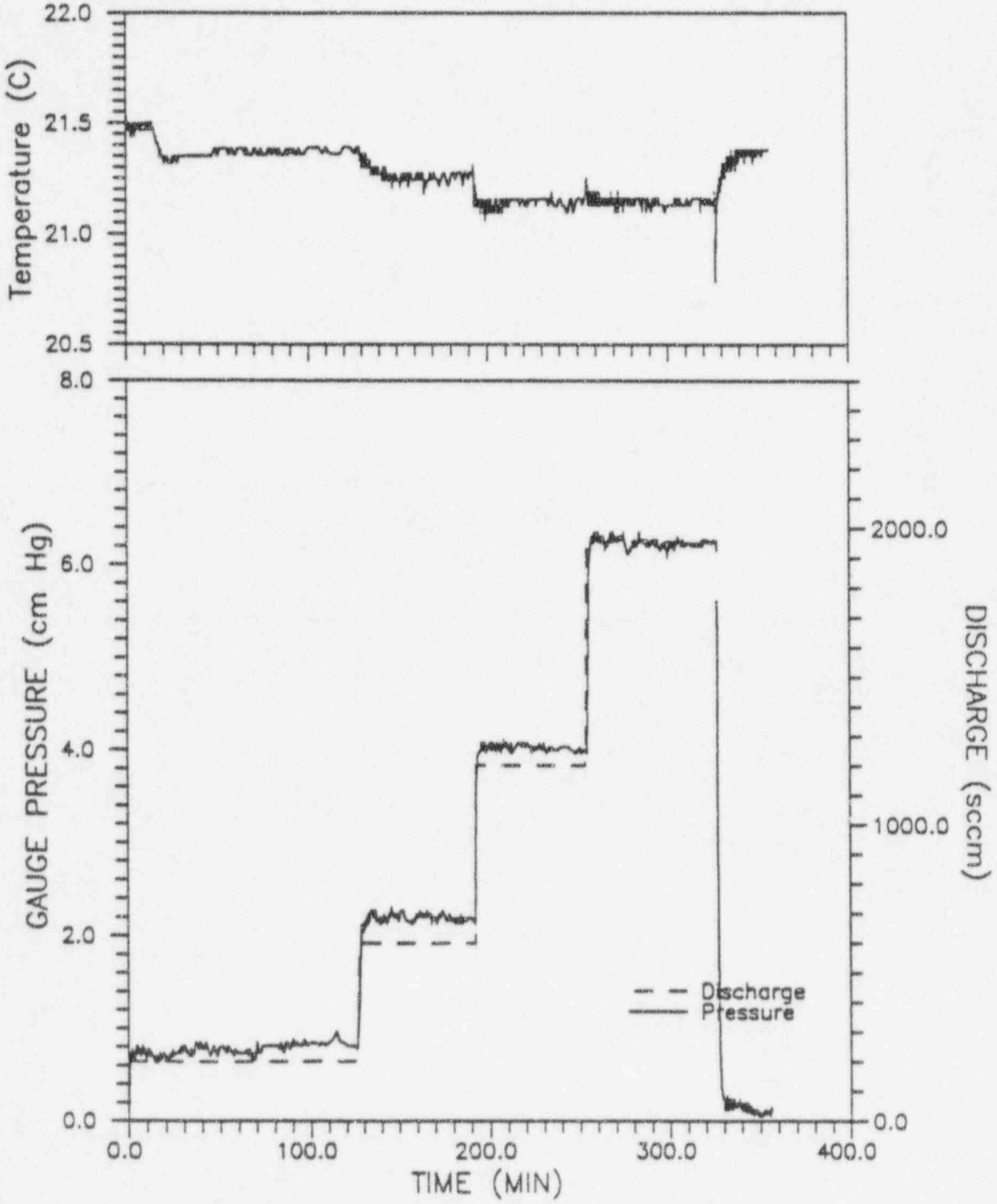


V2-VBC
09-15-92
I: Q=40 sccm; R: Q=150

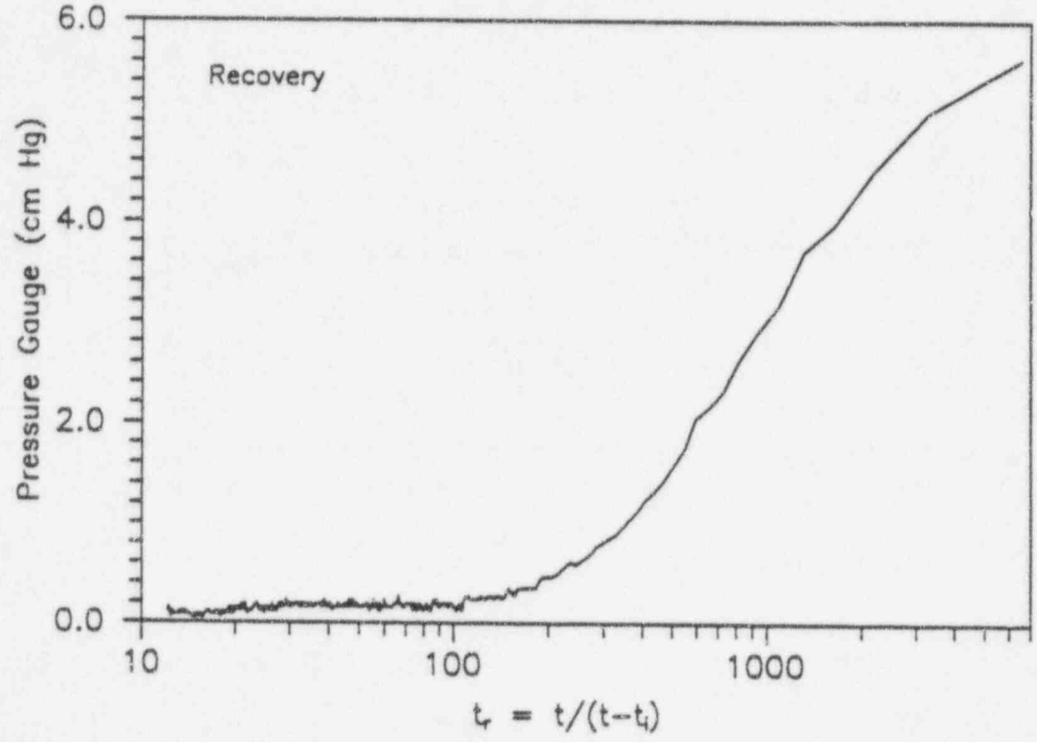


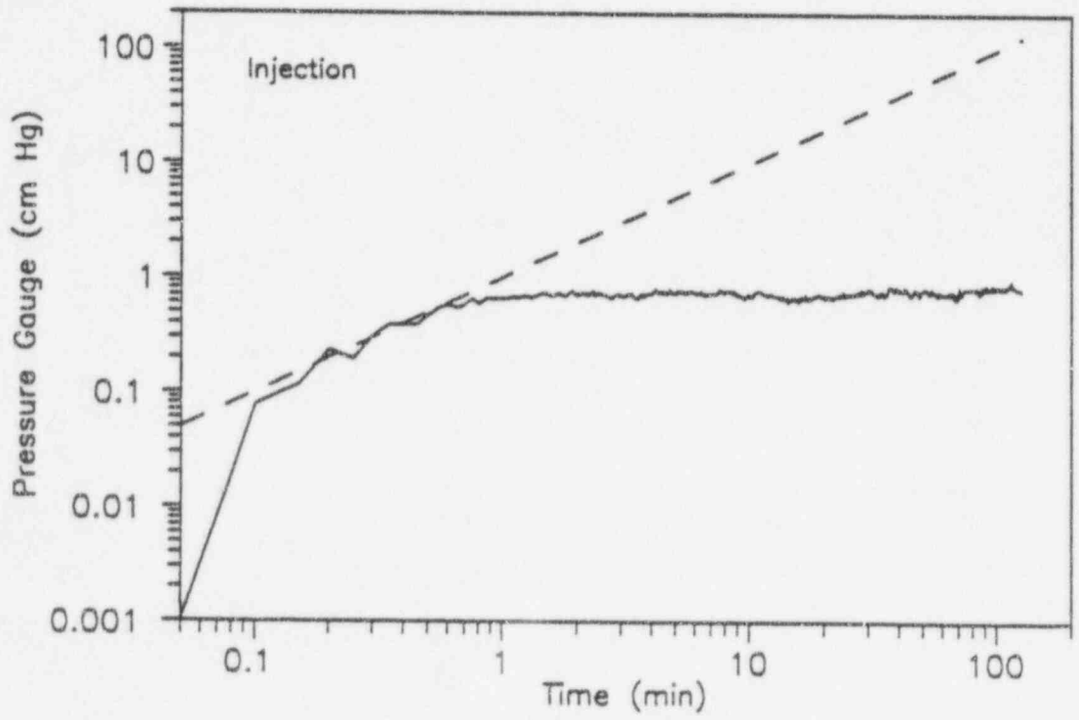


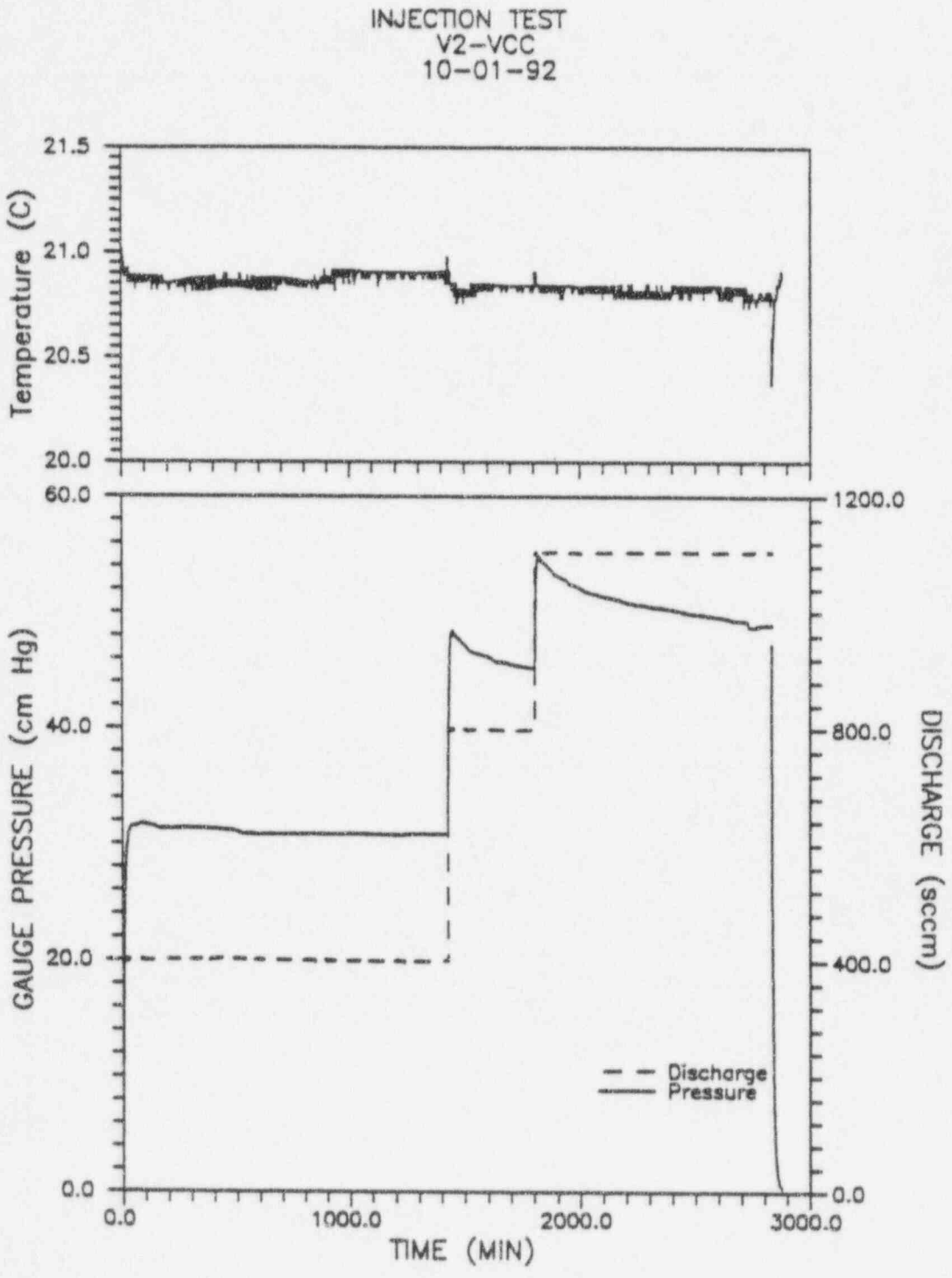
INJECTION TEST
V2-VCA
09-23-92



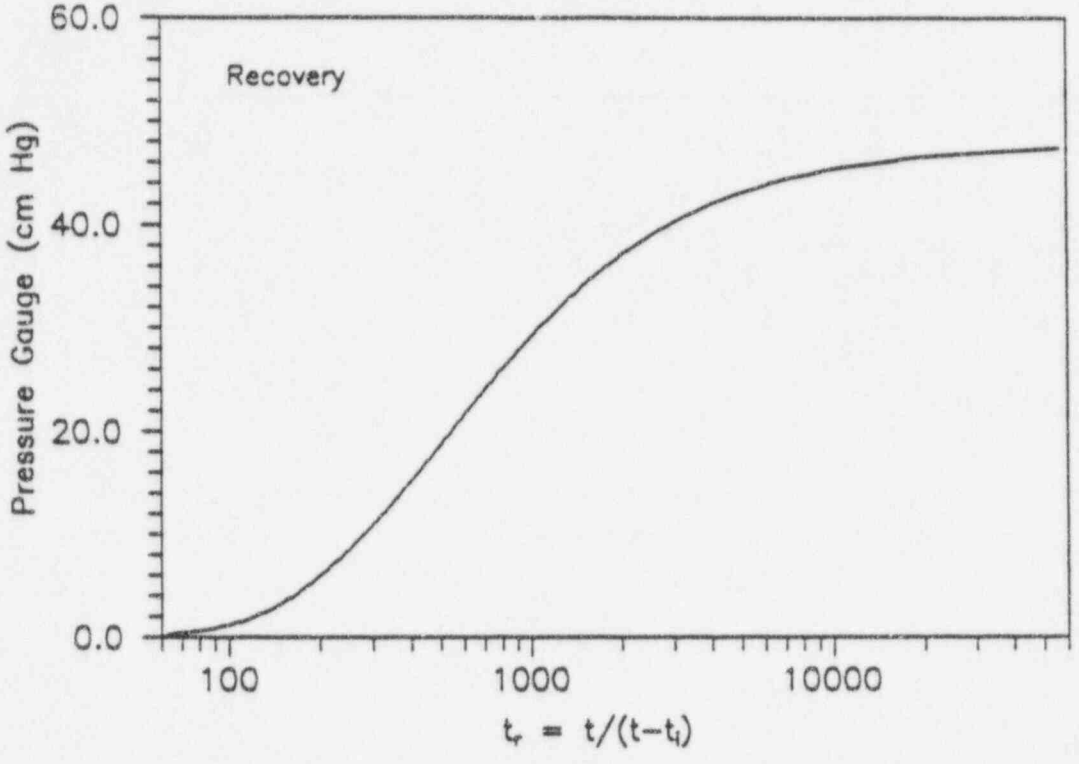
V2-VCA
09-23-92
I: Q=200 sccm; R: Q=1950

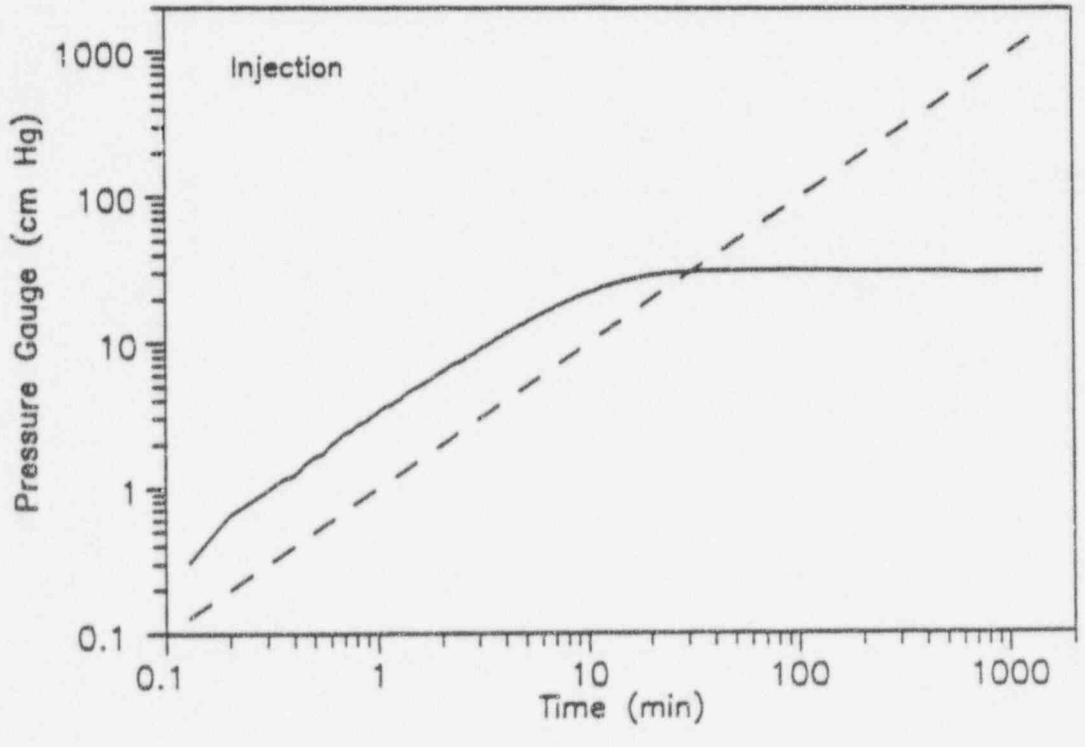




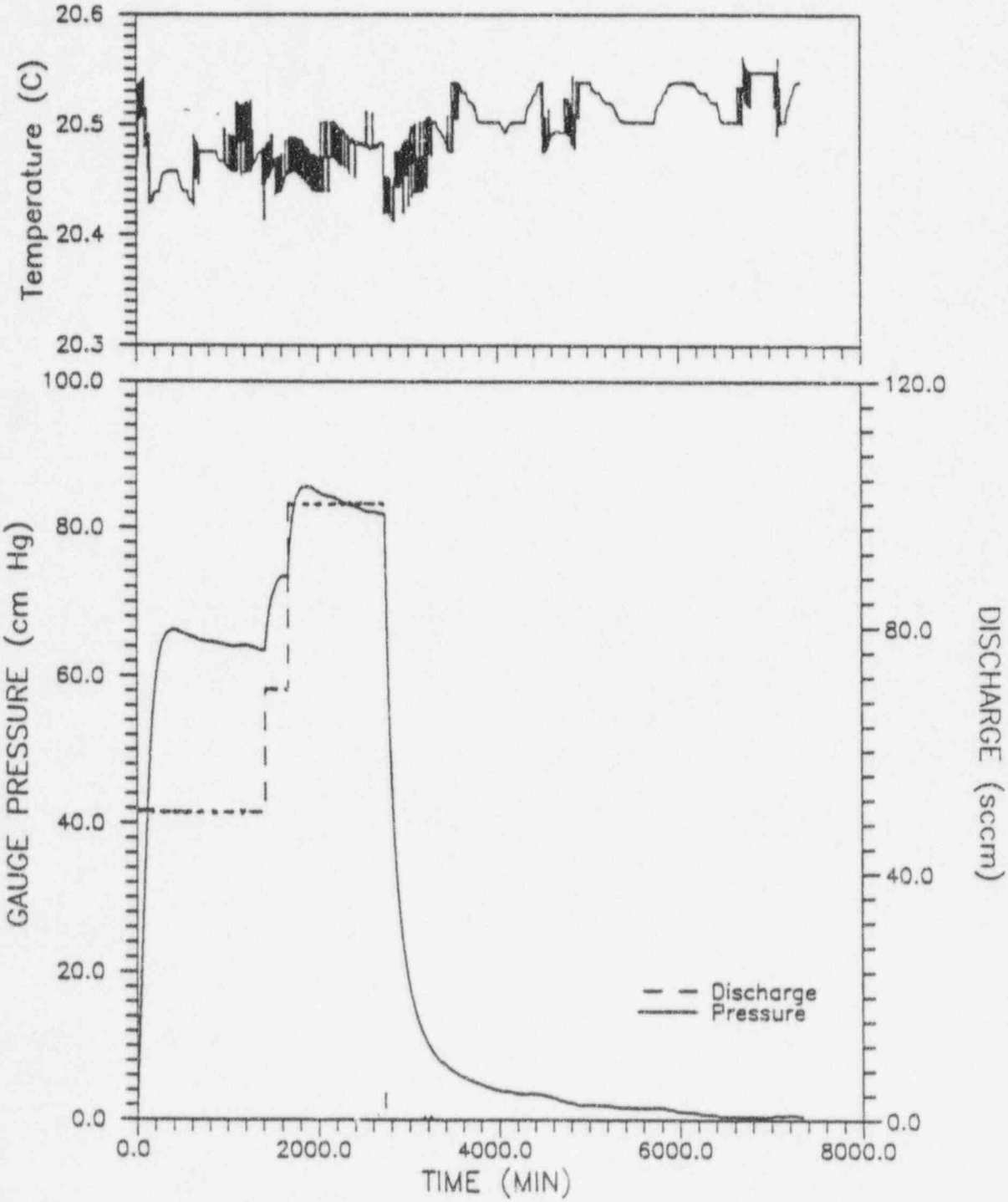

INJECTION TEST
V2-VCC
10-01-92
Temperature (C)
21.5
21.0
20.5
20.0
GAUGE PRESSURE (cm Hg)
60.0
40.0
20.0
0.0
DISCHARGE (sccm)
1200.0
800.0
400.0
0.0
Discharge
Pressure
0.0
1000.0
2000.0
3000.0
TIME (MIN)

V2-VCC
10-01-92
I: Q=400 sccm; R: Q=1100

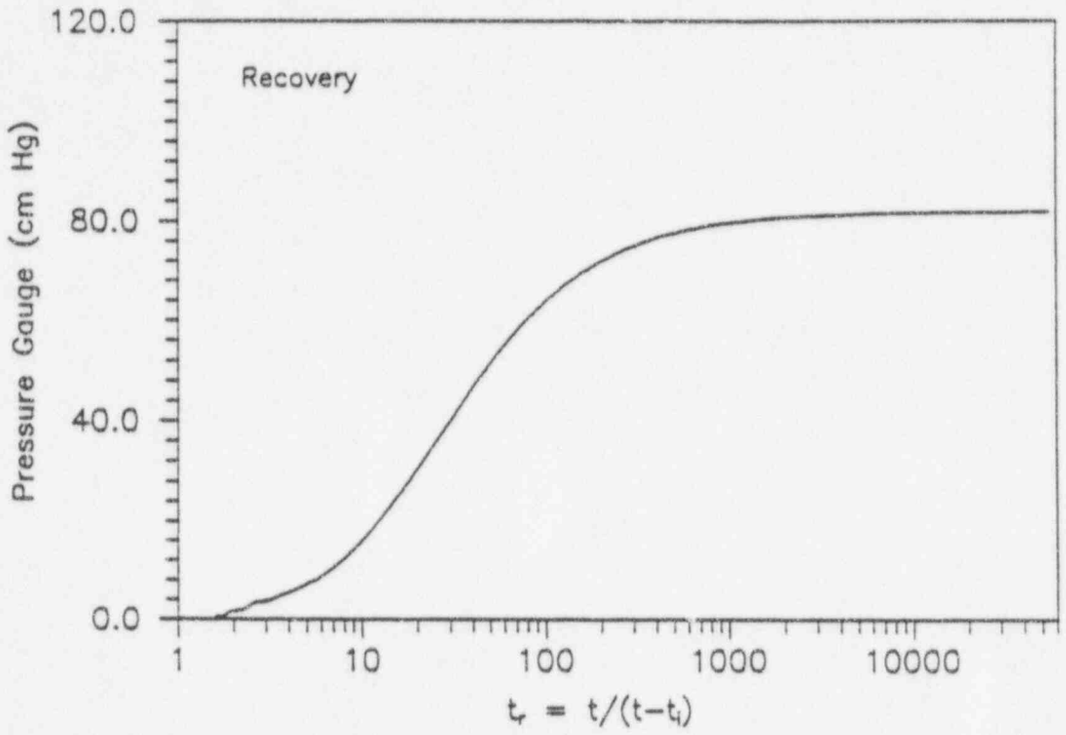


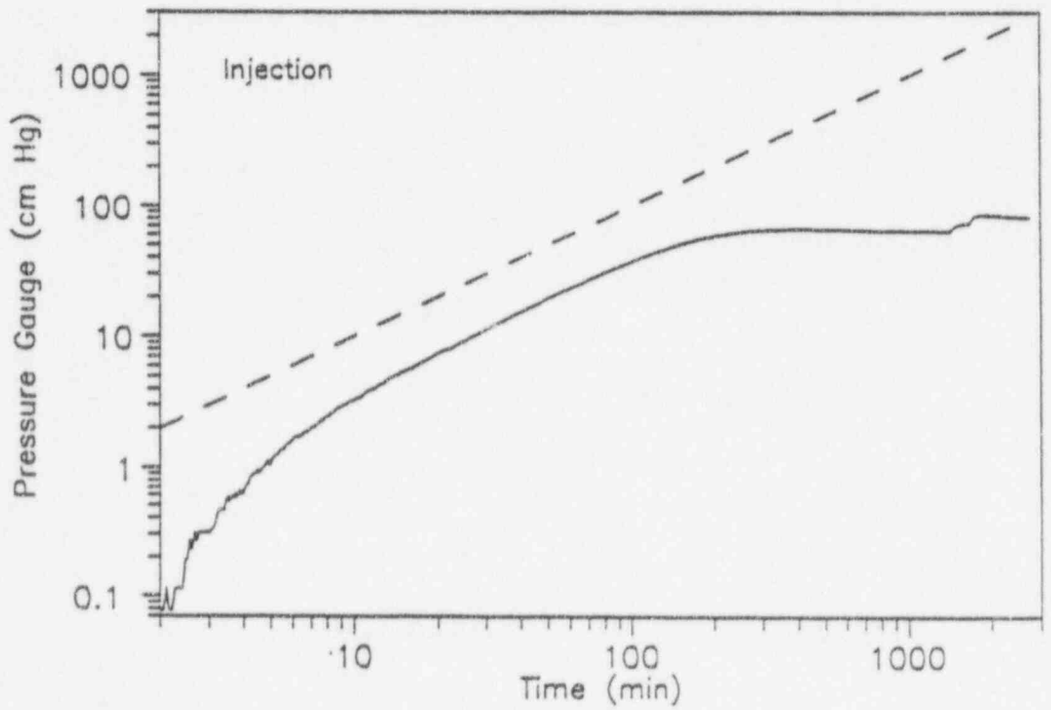


INJECTION TEST
V2-VFA
03-10-93

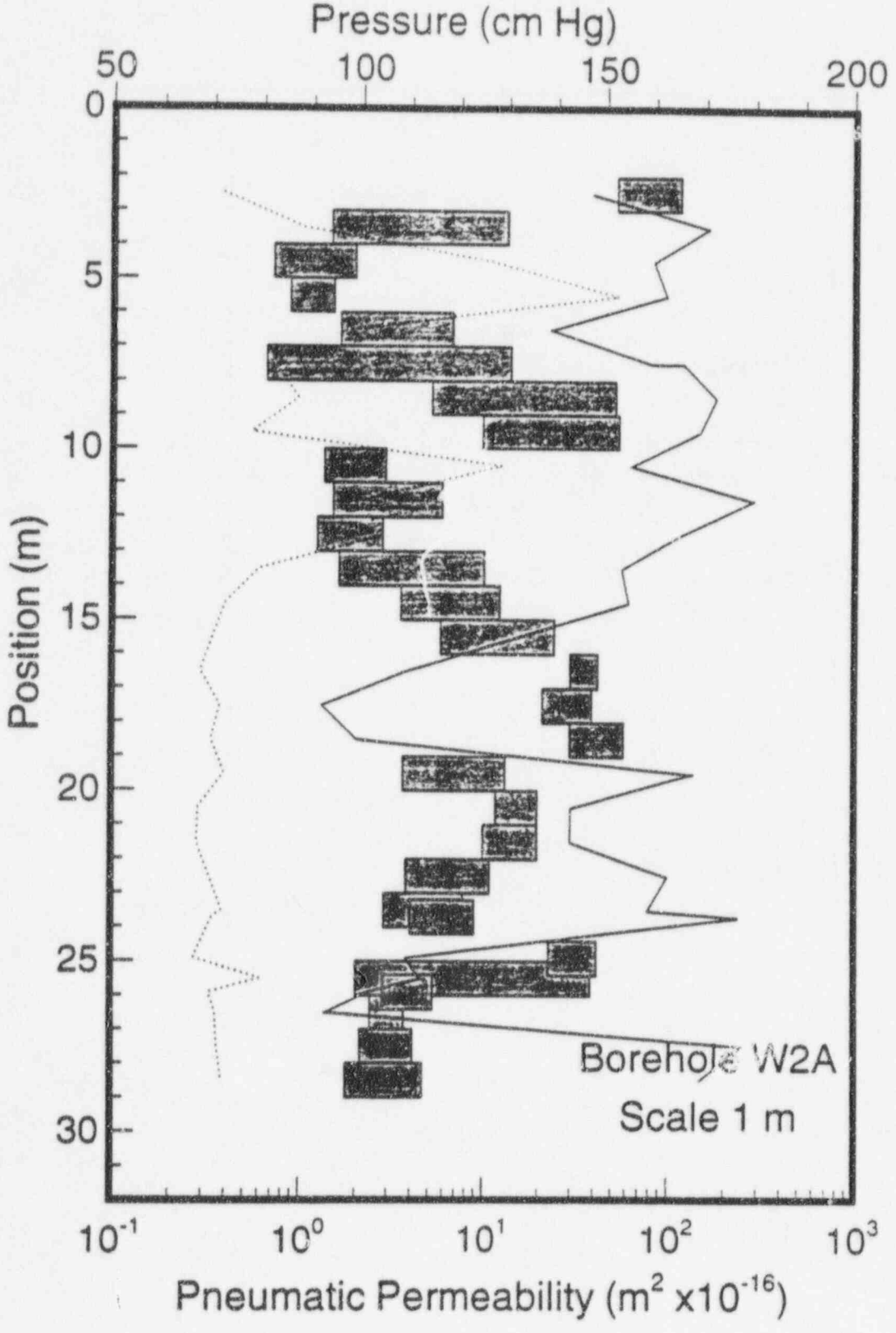


V2-VFA
03-10-93
I: Q=50 sccm; R: Q=100

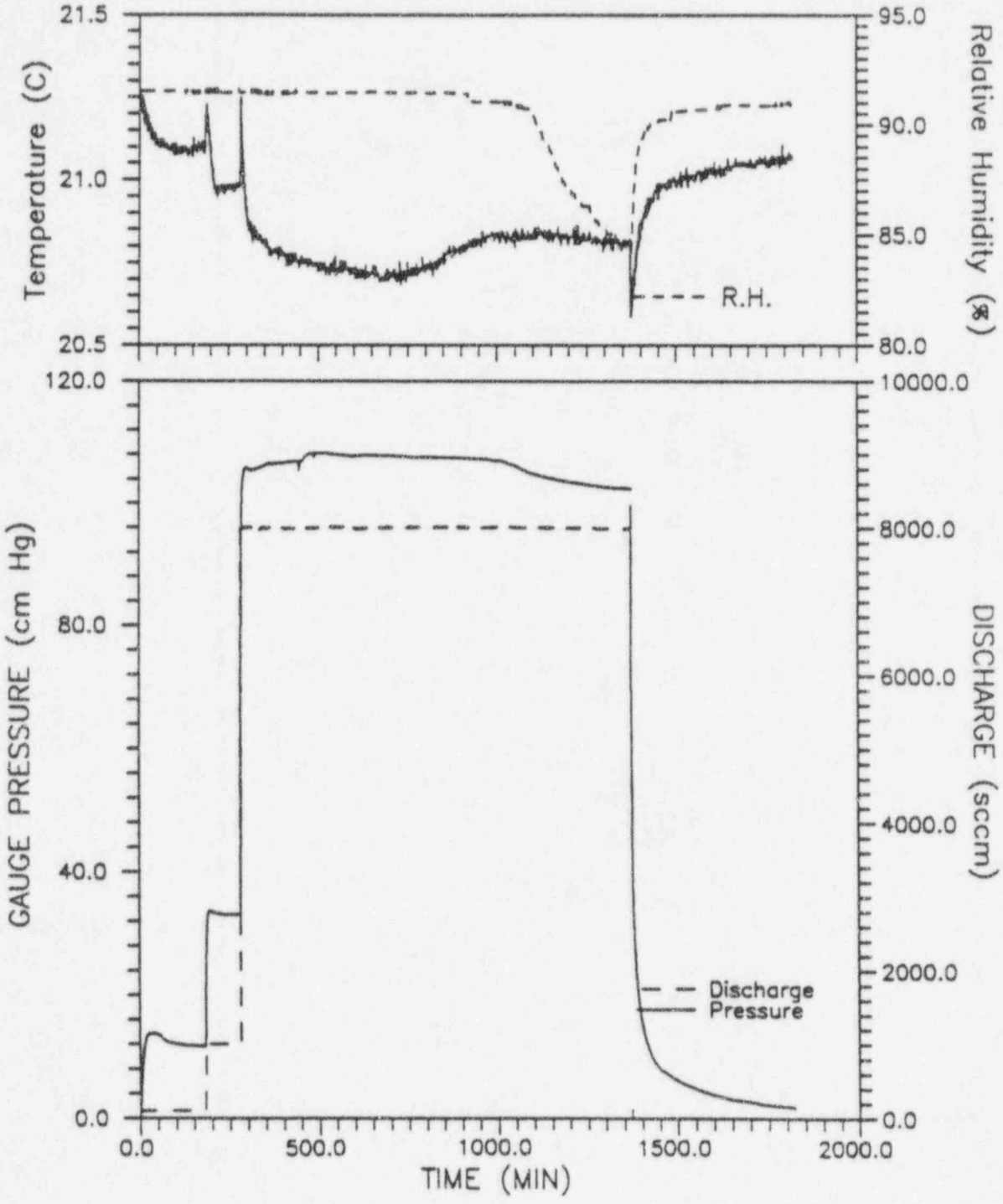




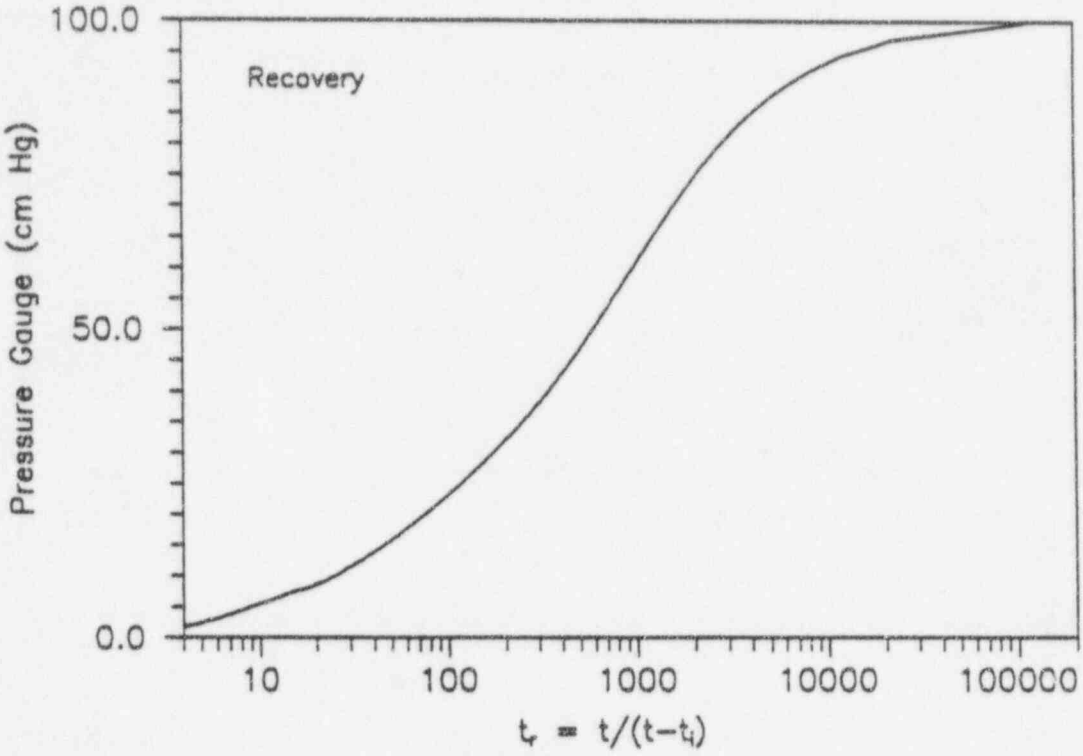
Graphs from Table B.2 W2a - 1.0 m Data

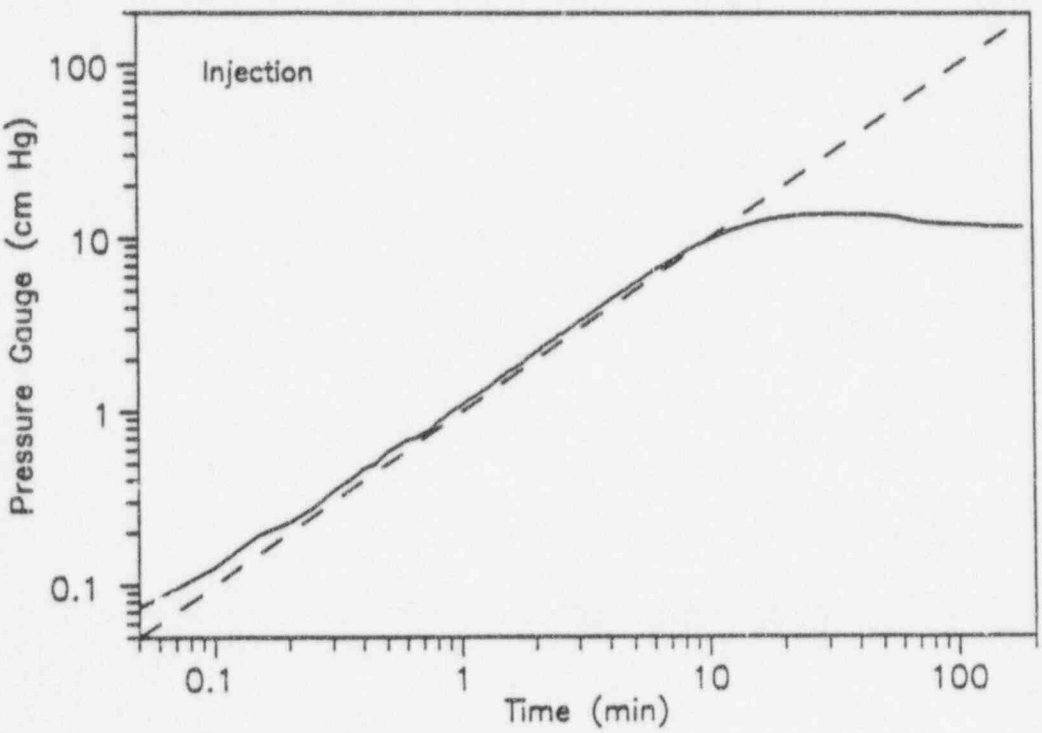

Pressure (cm Hg)
50
100
150
200
0
5
10
15
20
25
30
Position (m)
Borehole W2A
Scale 1 m
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
Pneumatic Permeability (m^2 x10^{-16})

INJECTION TEST
W2a-WCB
08-19-93

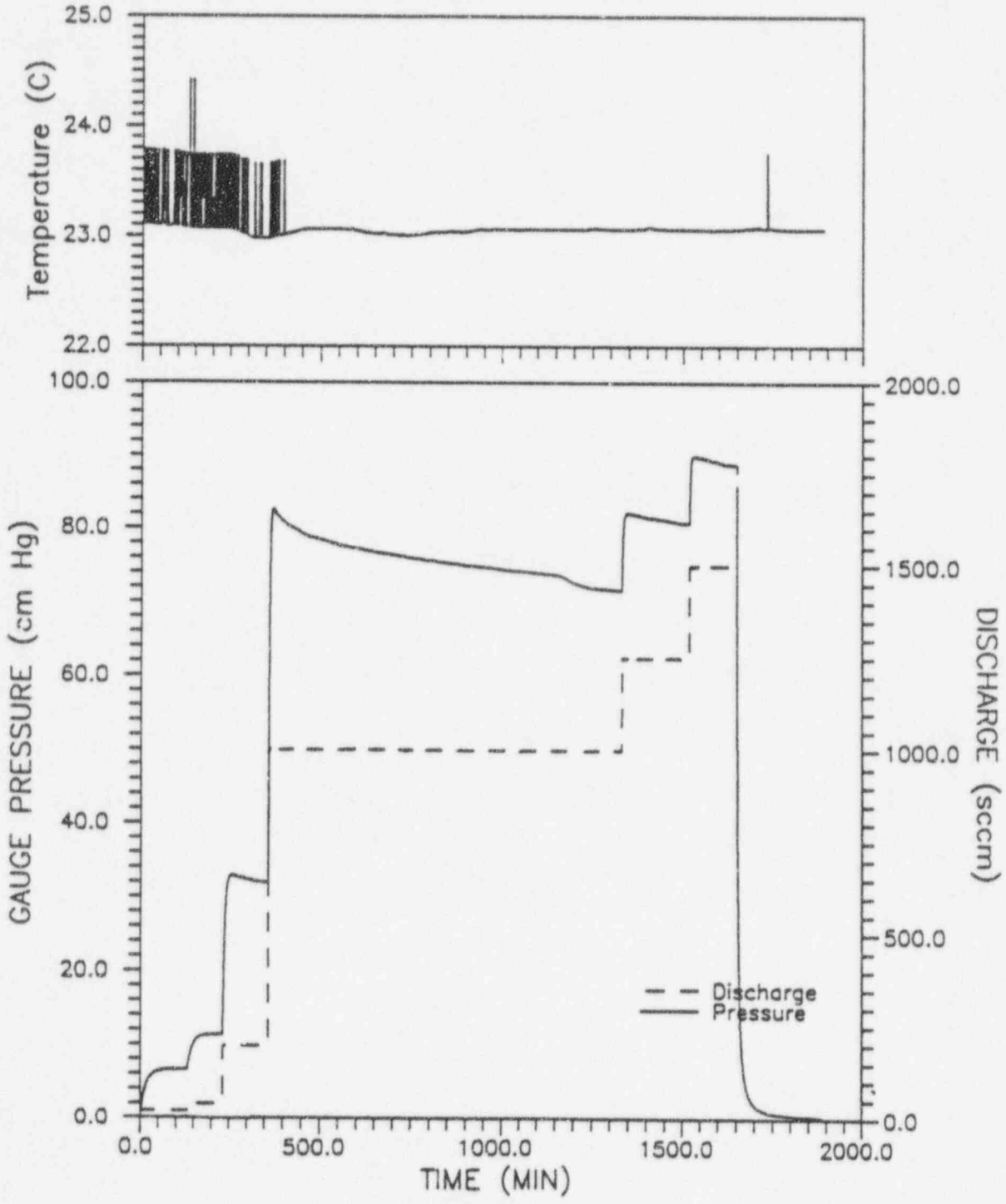


W2a-WCB
08-19-93
I: Q=100 sccm; R: Q=8000

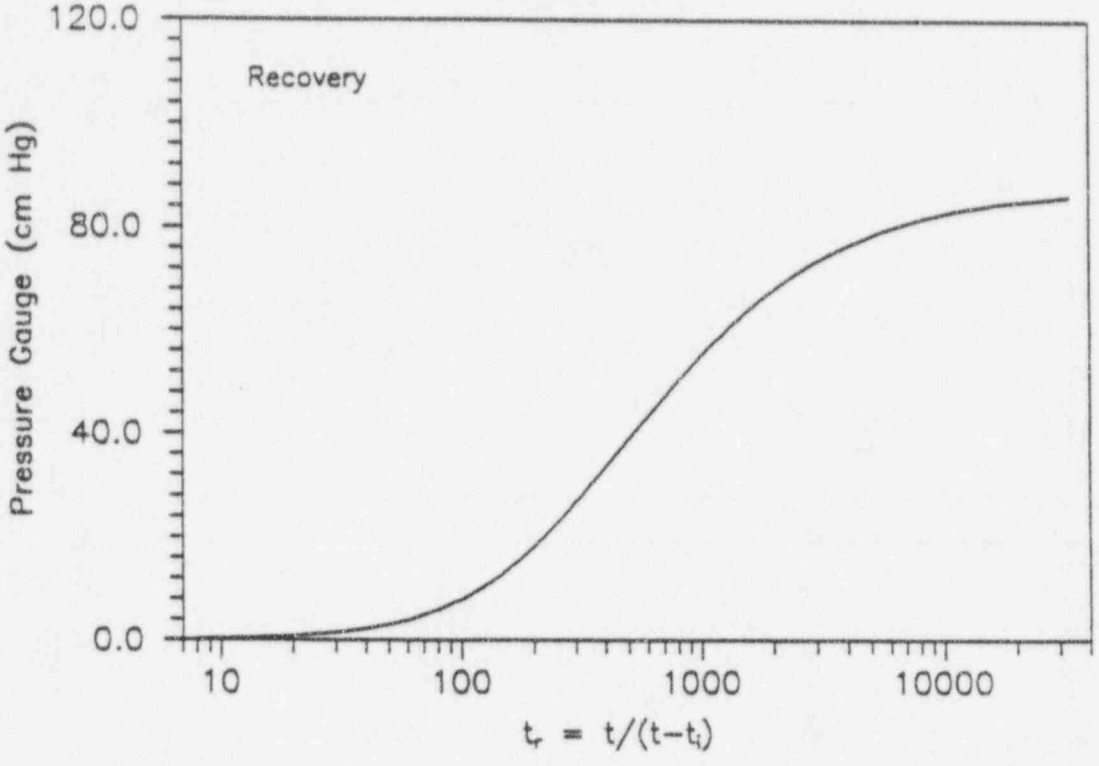


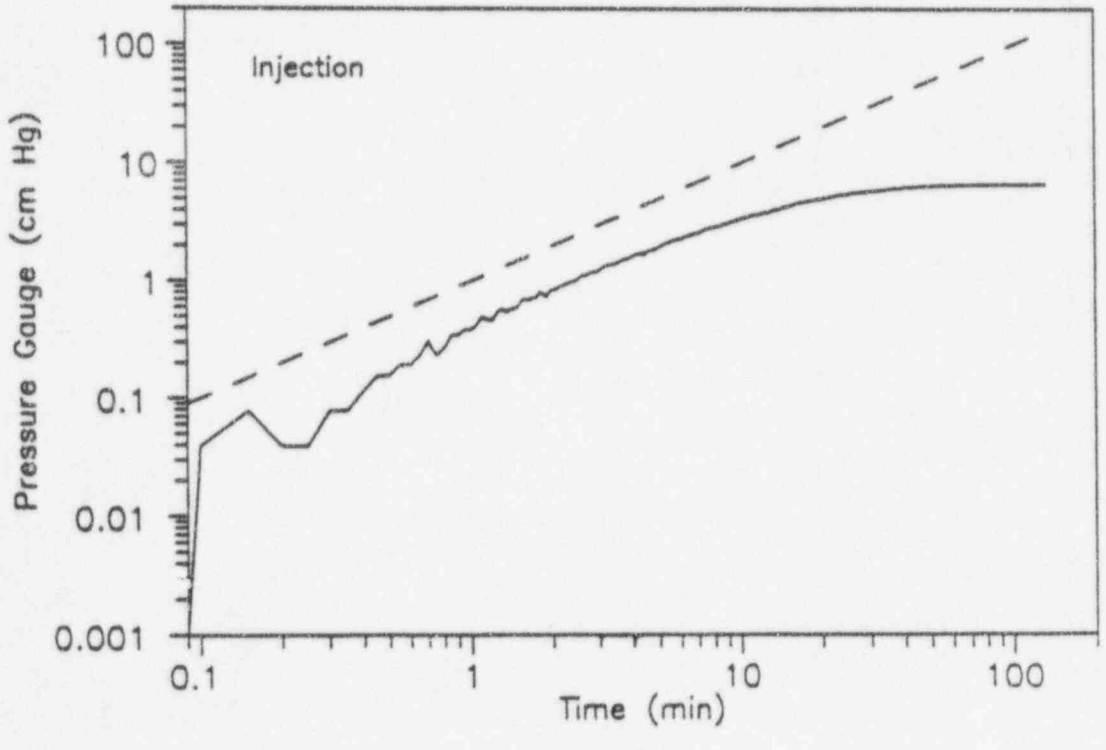


INJECTION TEST
W2a-WEA
09-23-93

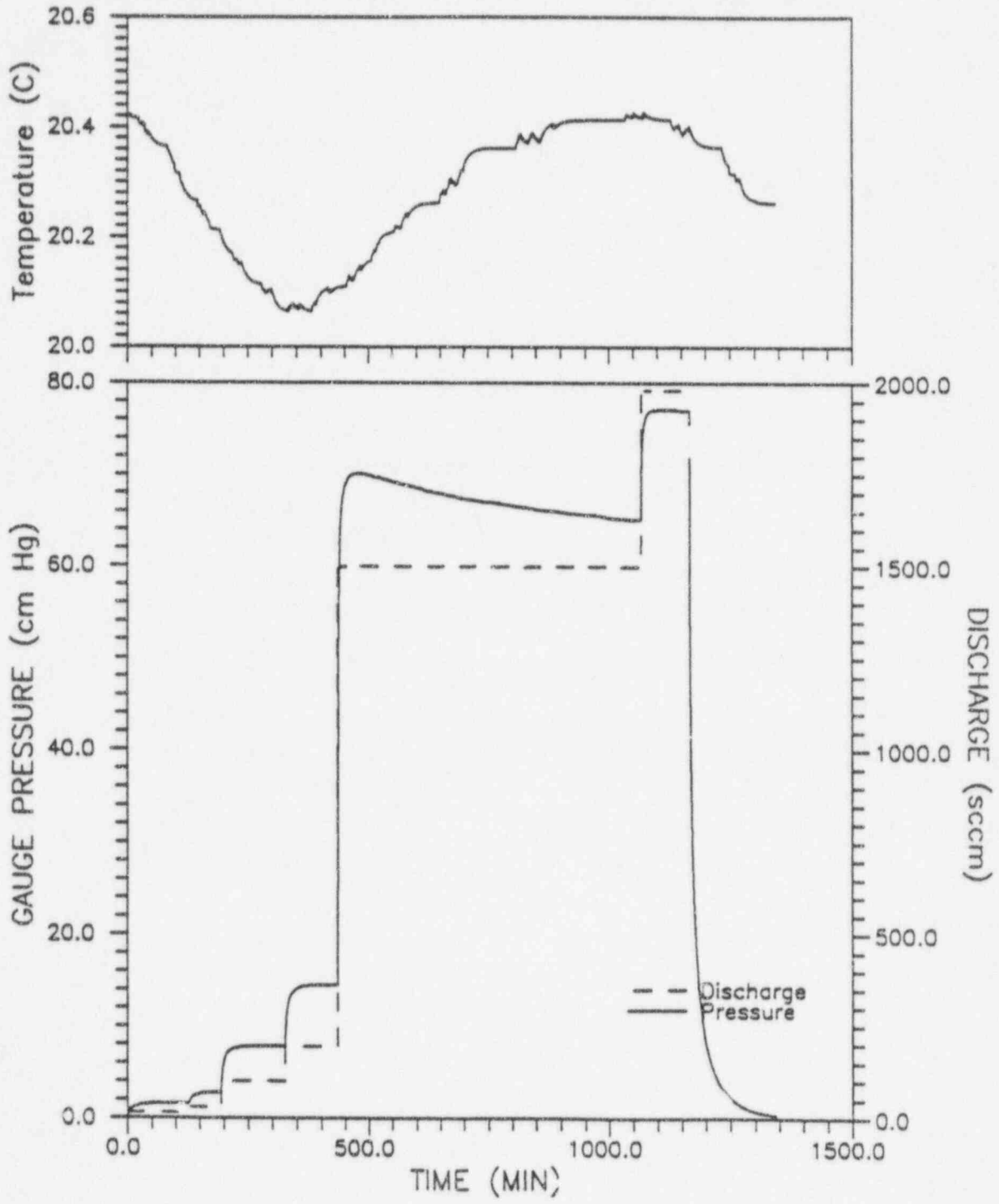


W2a-WEA
09-23-93
I: Q=20 sccm; R: Q=1500

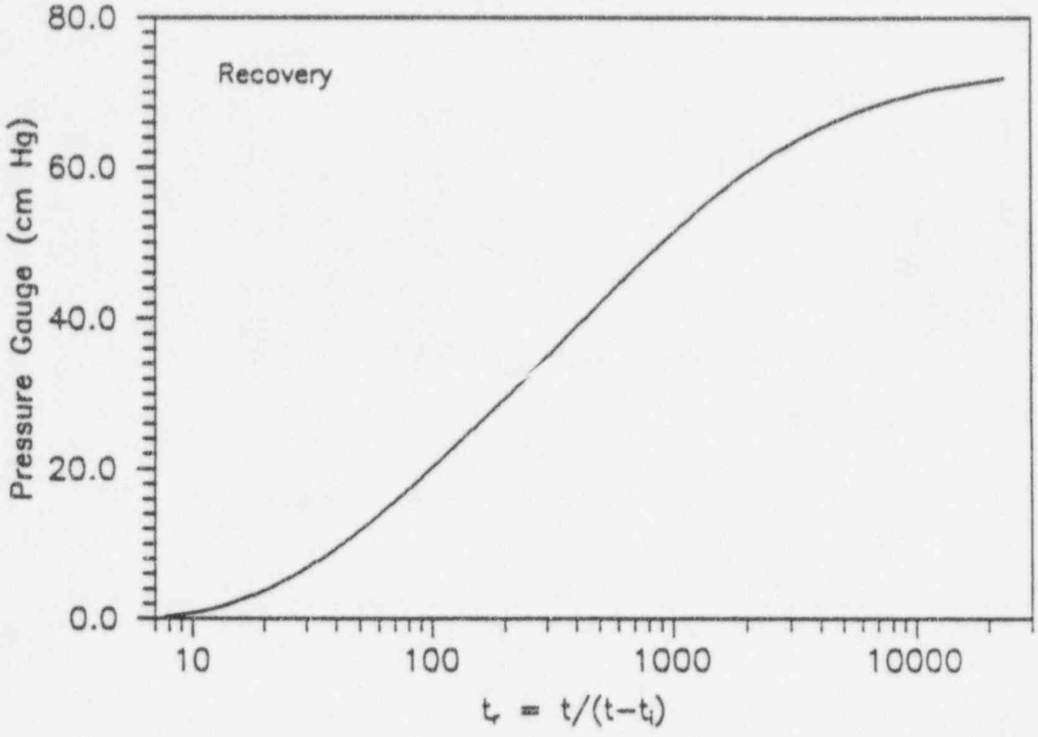


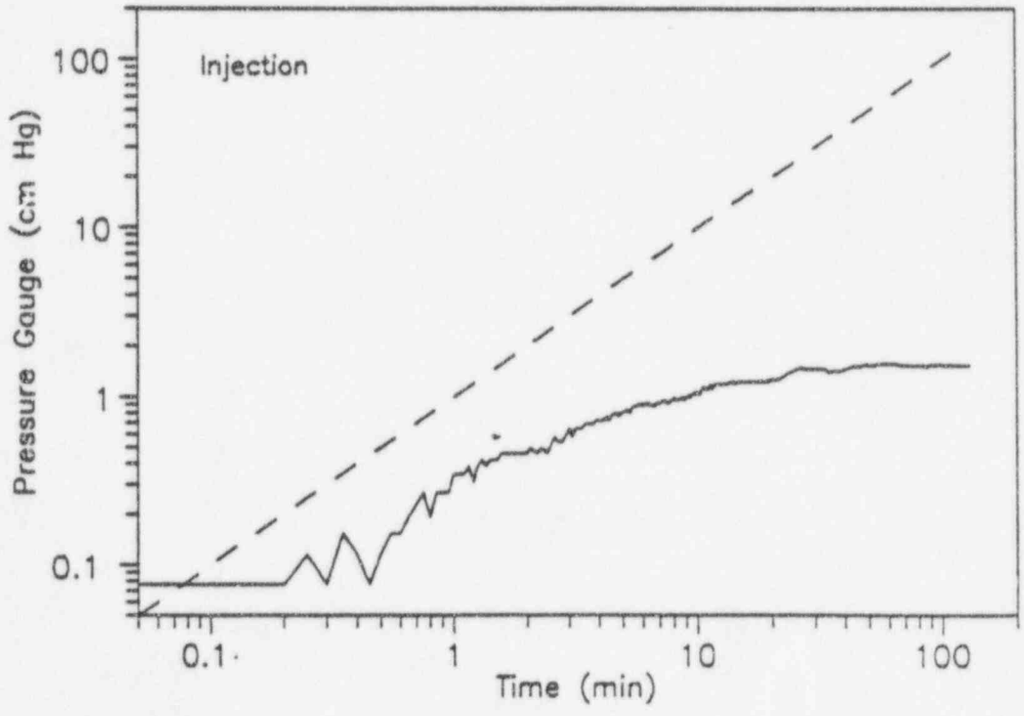


INJECTION TEST
W2a-WGA
10-19-93

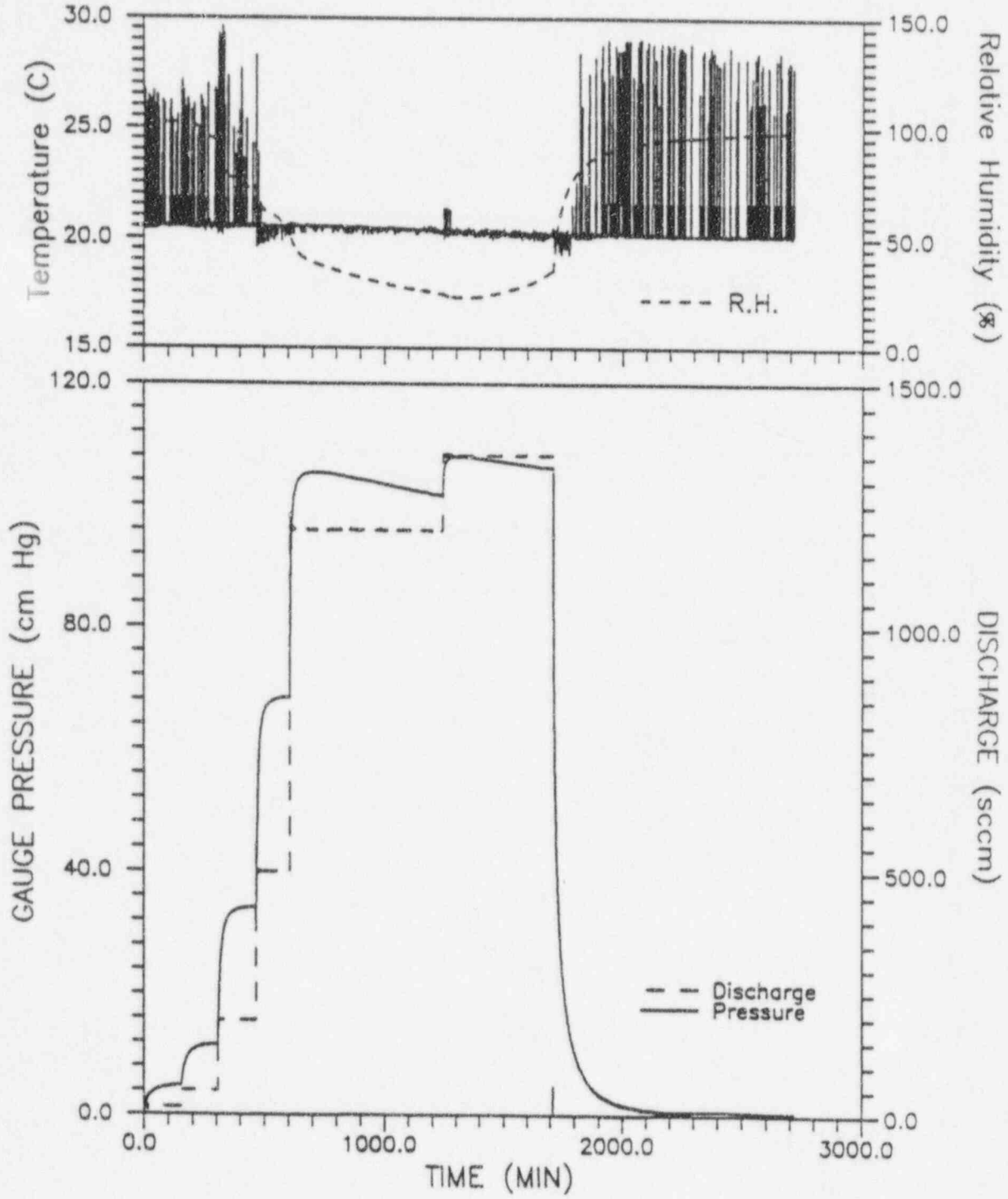


W2a-WGA
10-19-93
I: Q=15 sccm; R: Q=2000

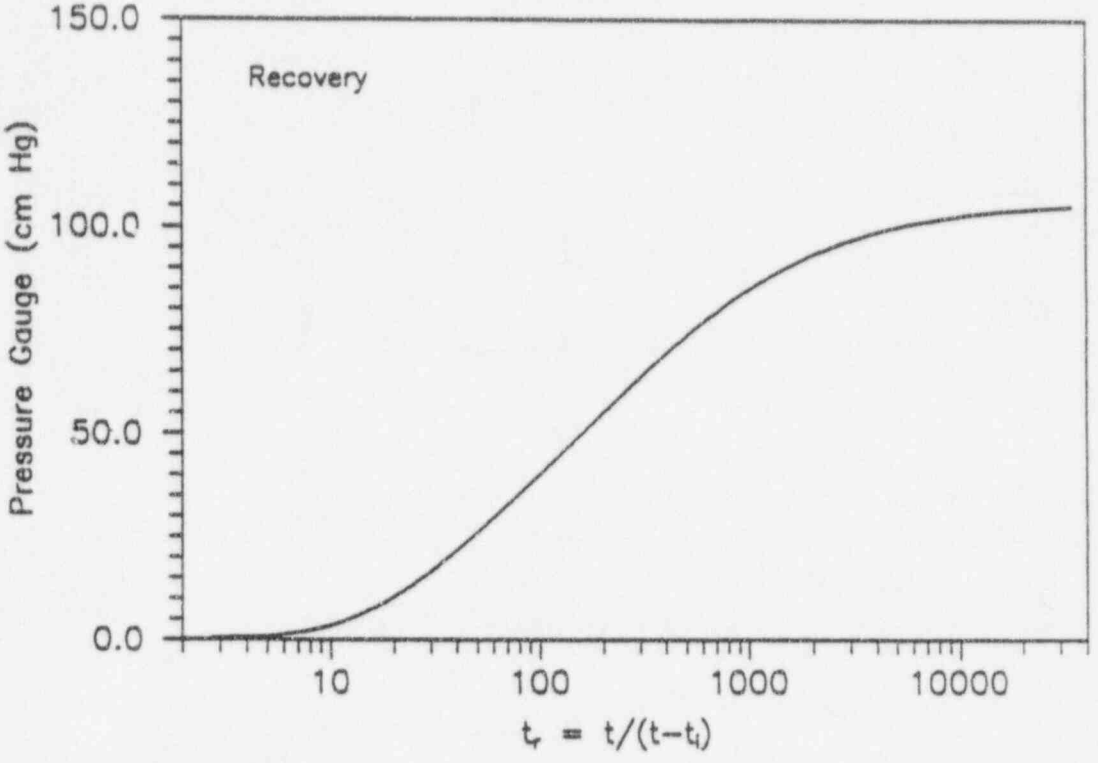


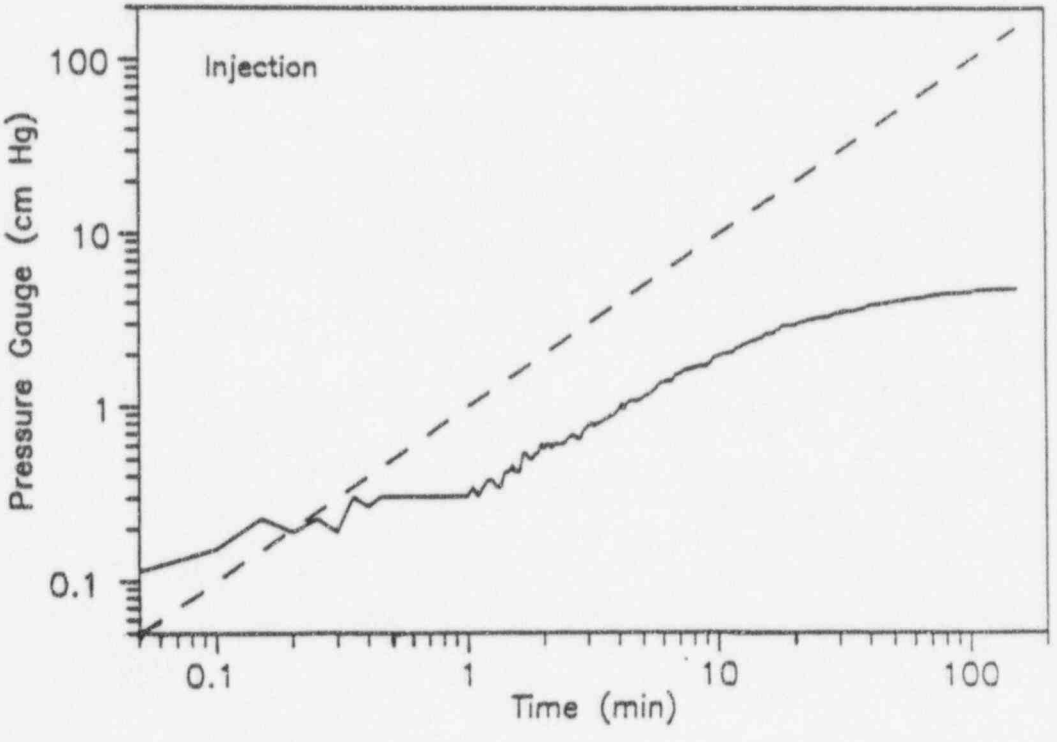


INJECTION TEST
W2a-WHA
03-29-94

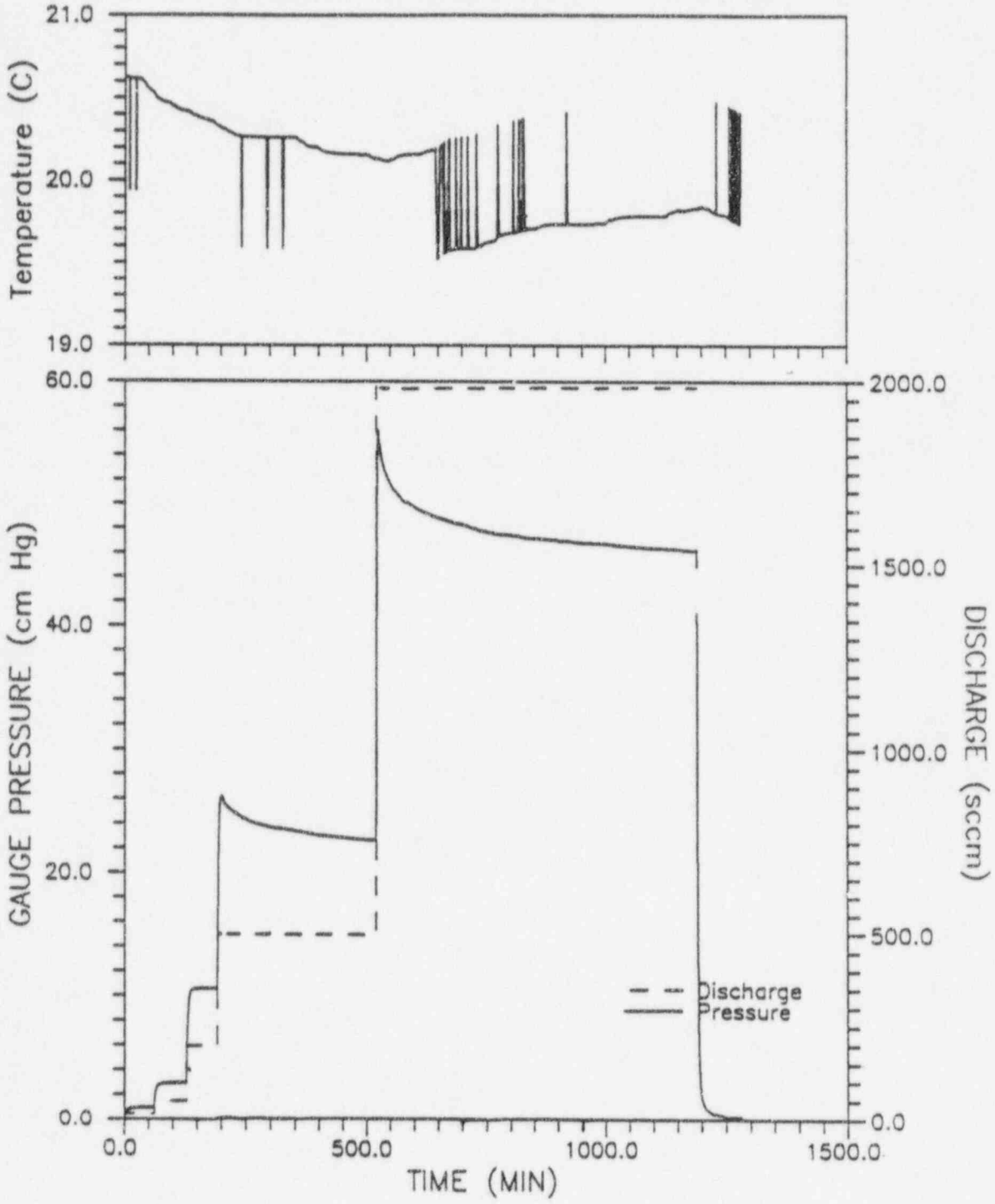


W2a-WHA
03-29-94
I: Q=15 sccm; R: Q=1350

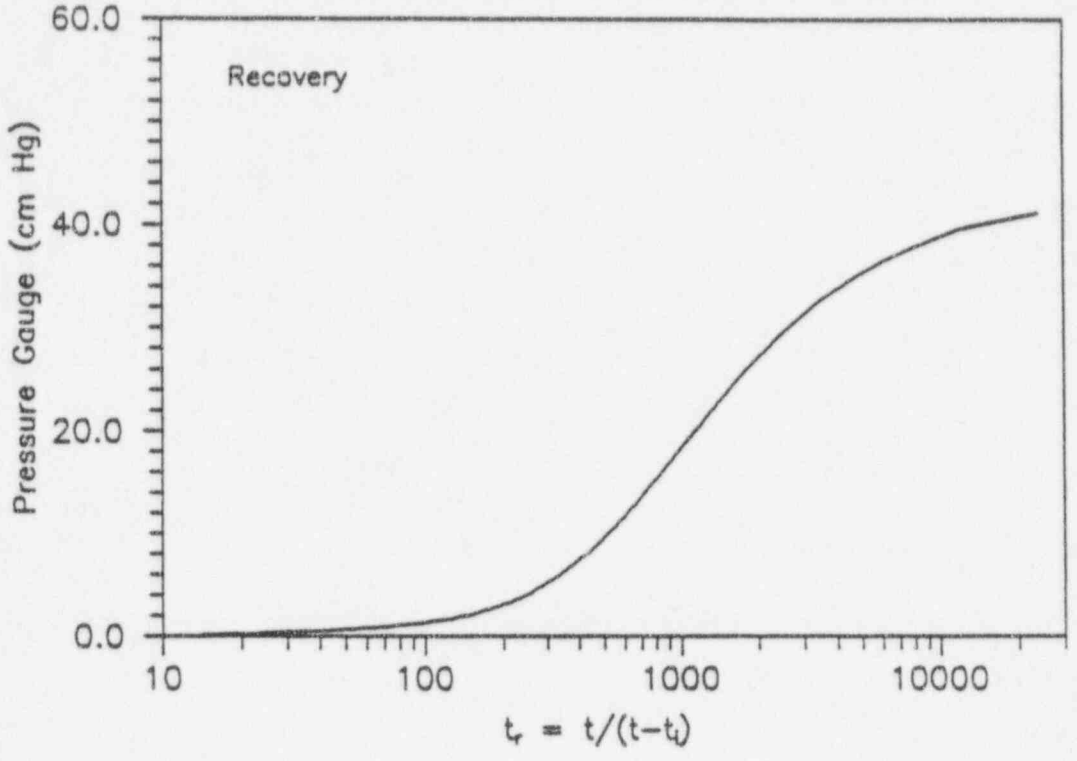


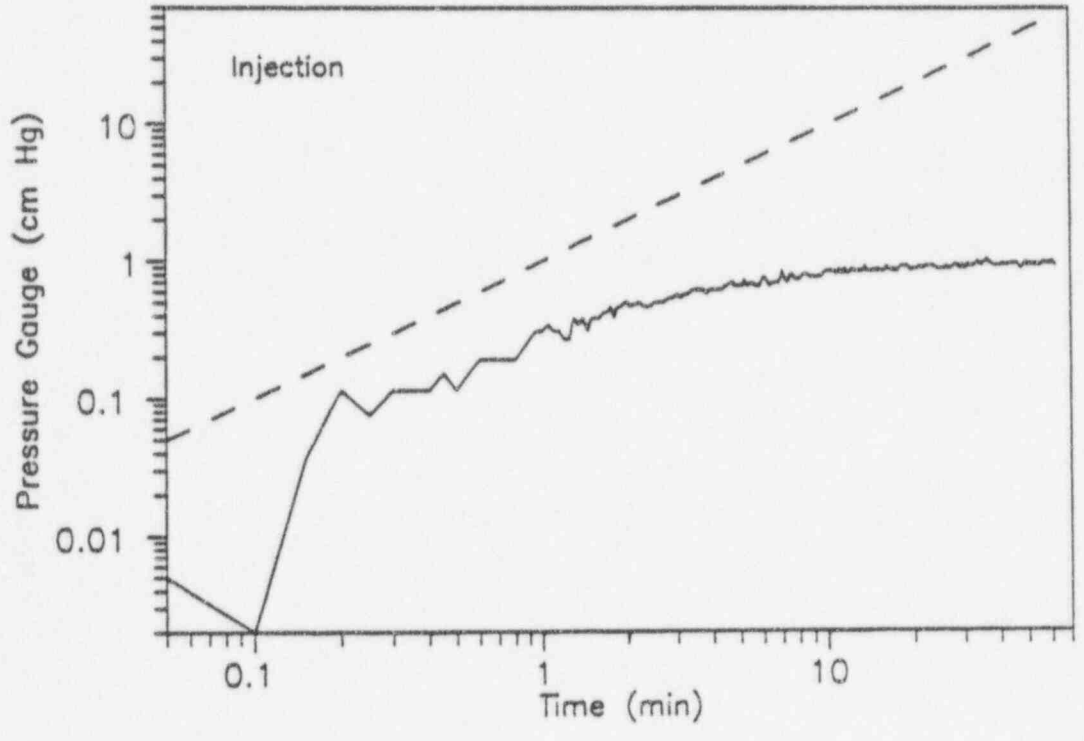


INJECTION TEST
W2a-WHB
12-01-93

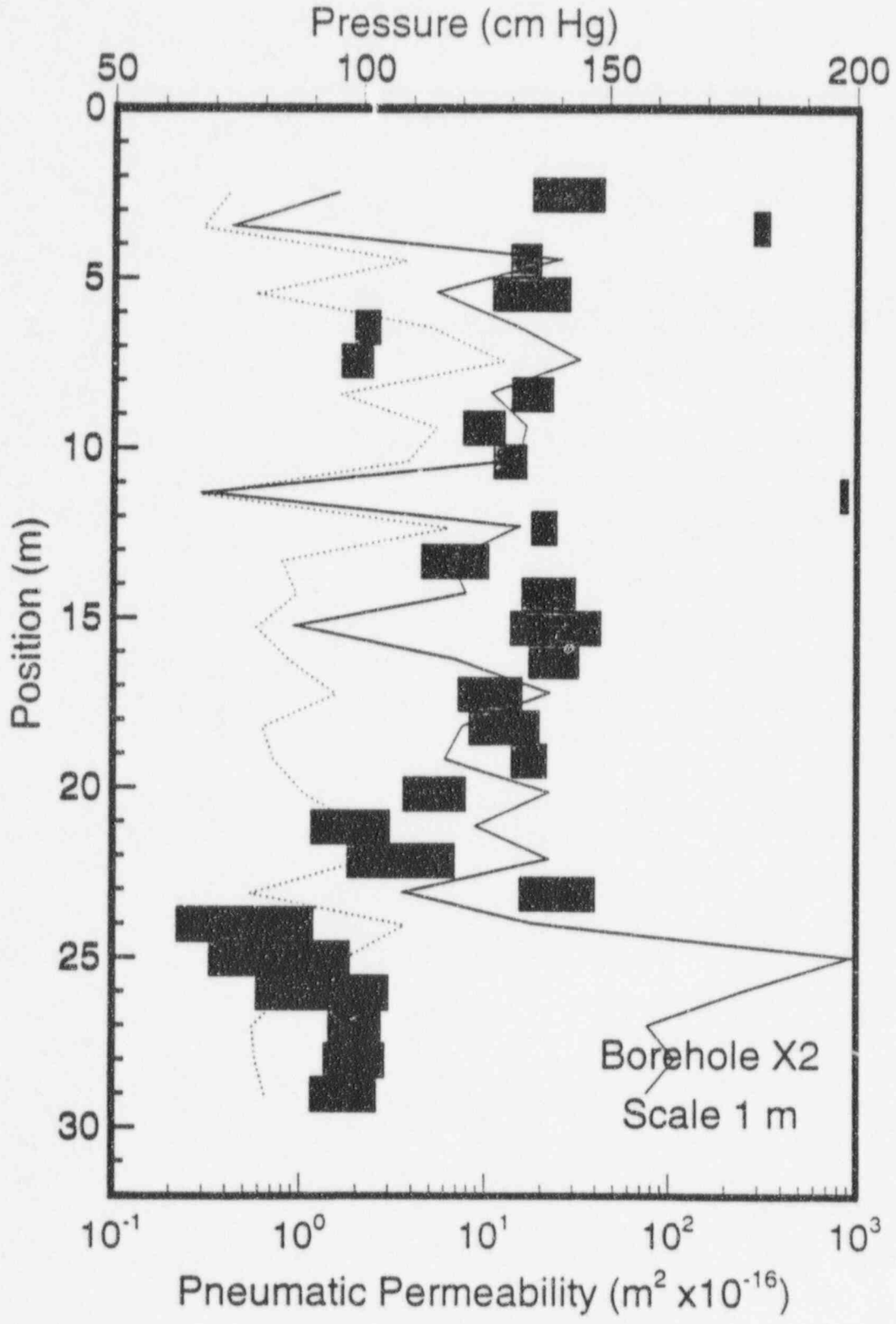


W2a-WHB
12-01-93
I: Q=15 sccm; R: Q=2000

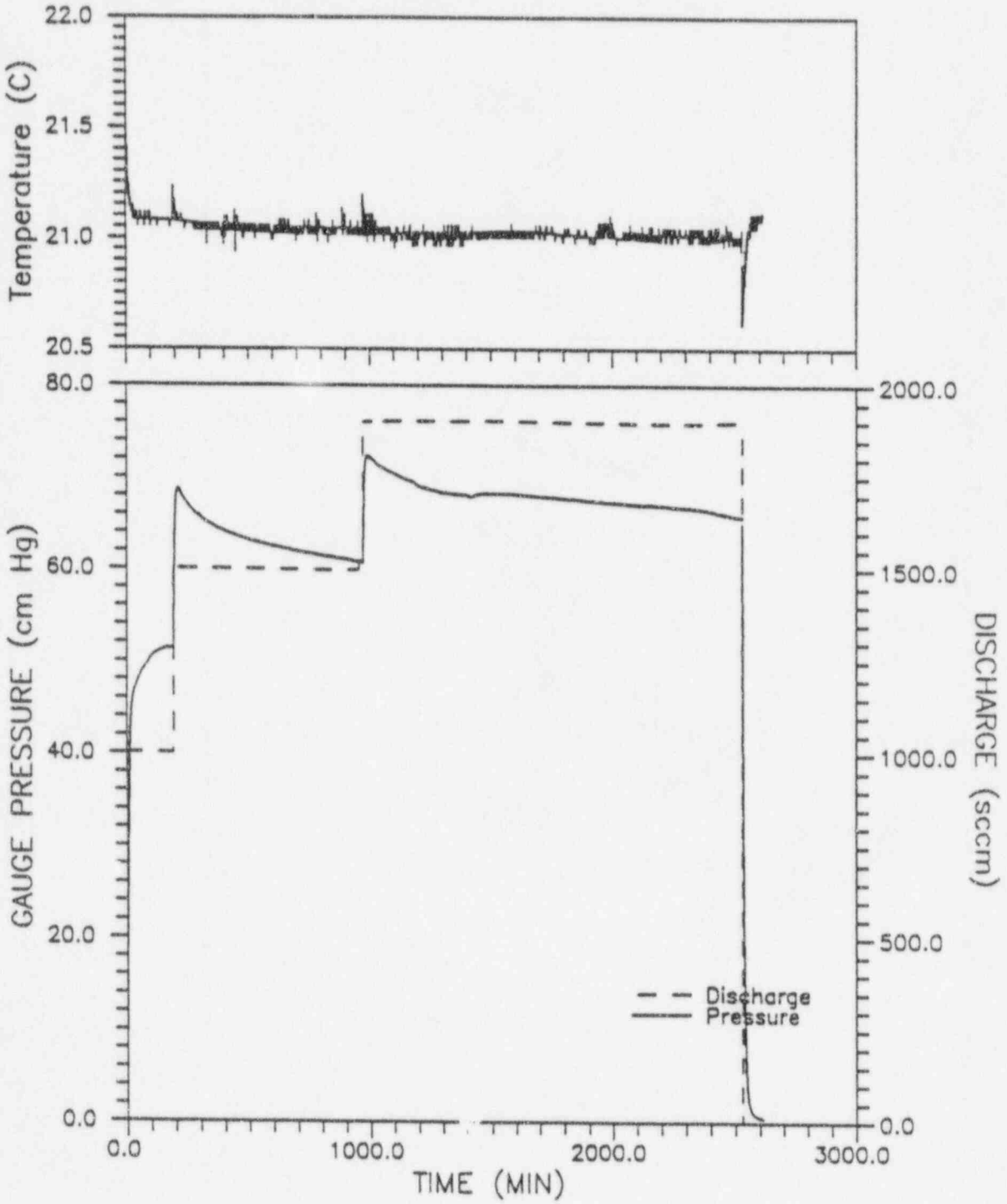




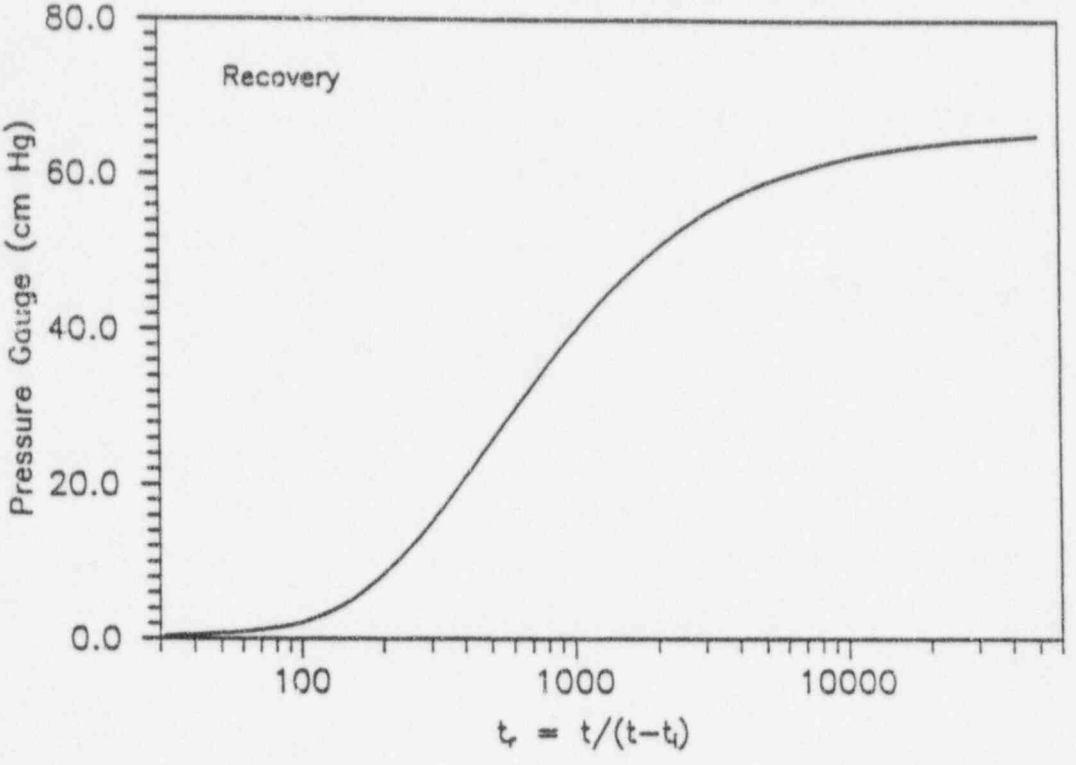
Graphs from Table B.3 X2 - 1.0 m Data

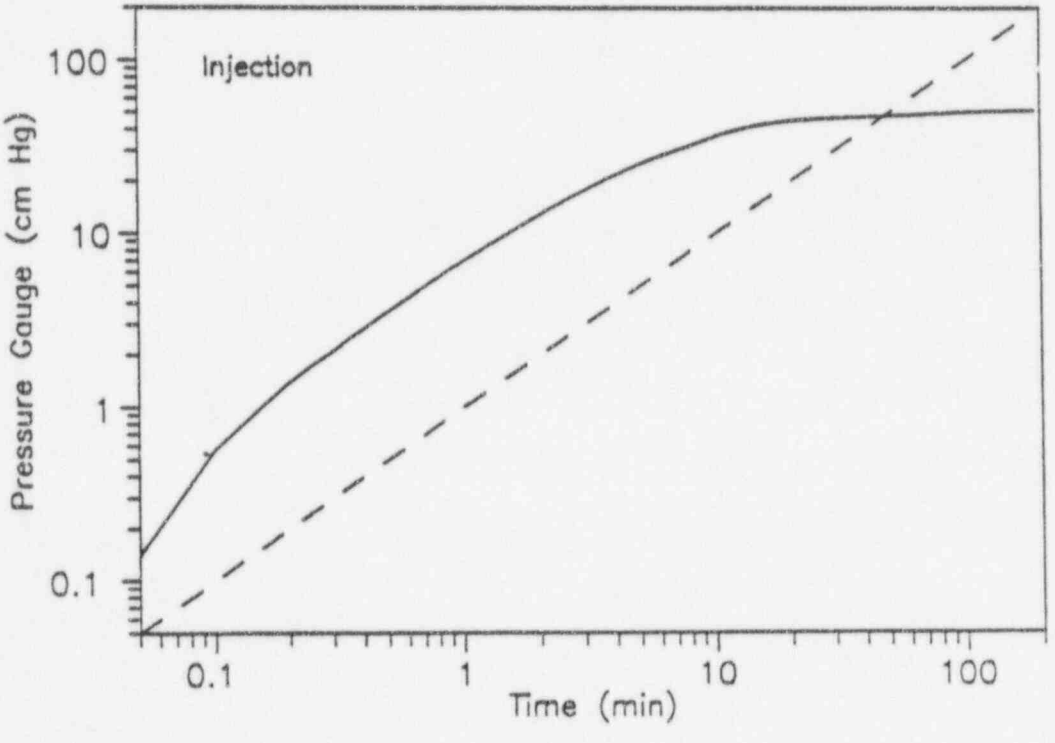

Pressure (cm Hg)
50
100
150
200
0
5
10
15
20
25
30
Position (m)
Borehole X2
Scale 1 m
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
Pneumatic Permeability (m^2 x10^{-16})

INJECTION TEST
X2-CDB
10-07-92

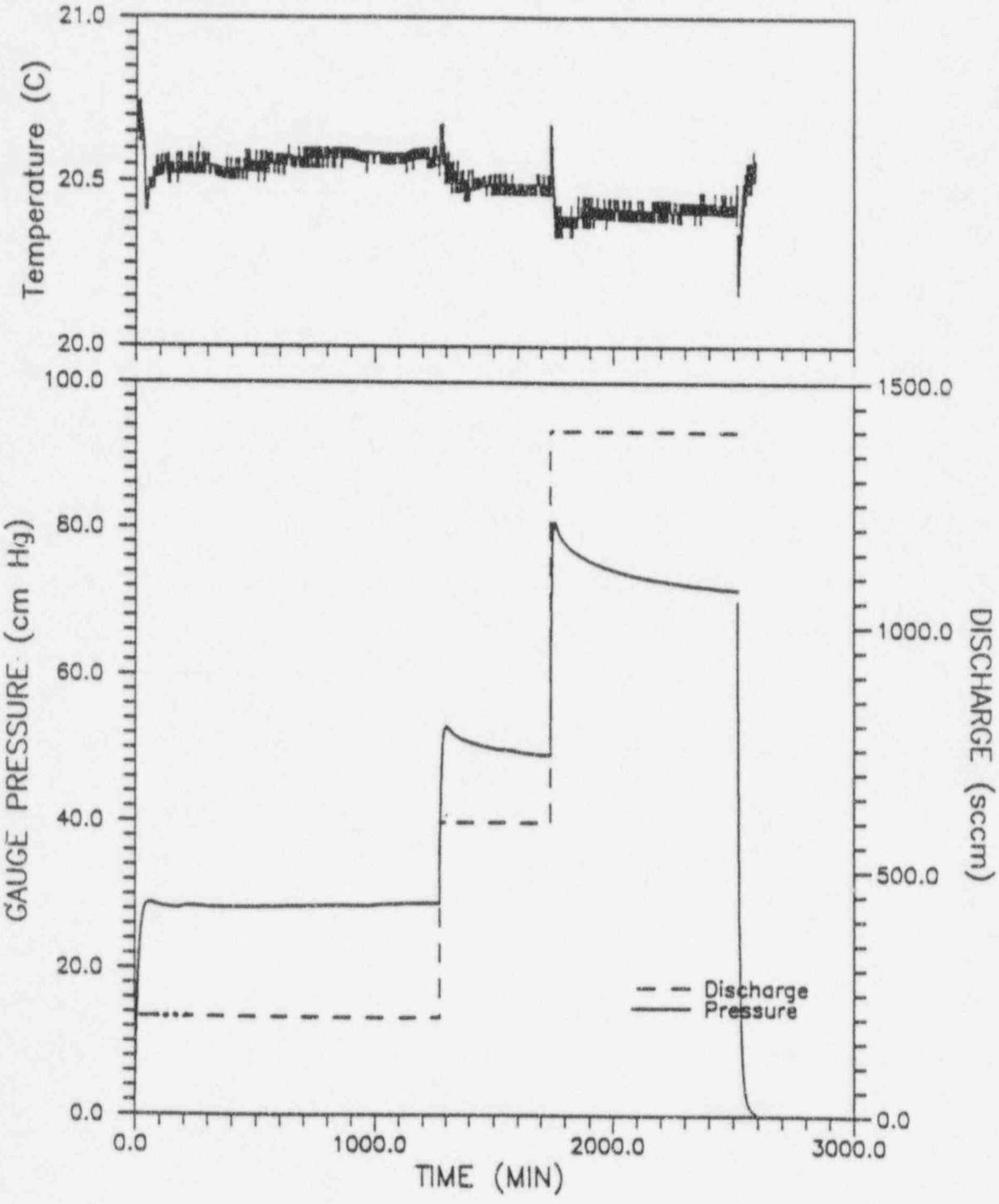


X2-CDB
10-07-92
I: Q=1000 sccm; R: Q=1900 sccm

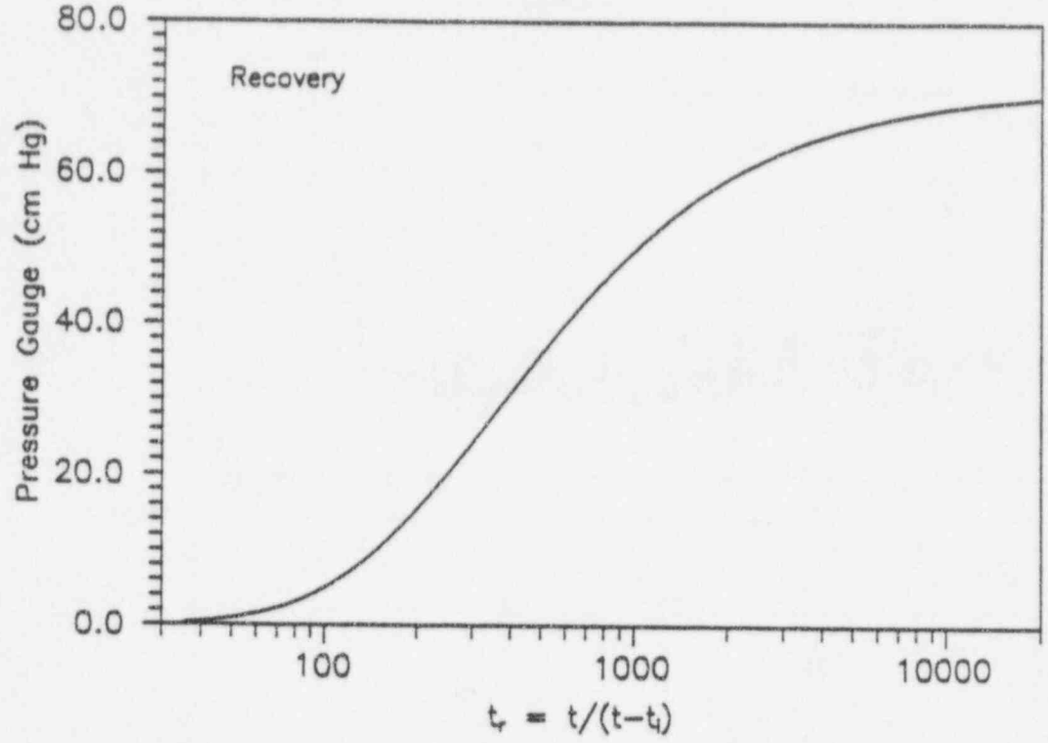


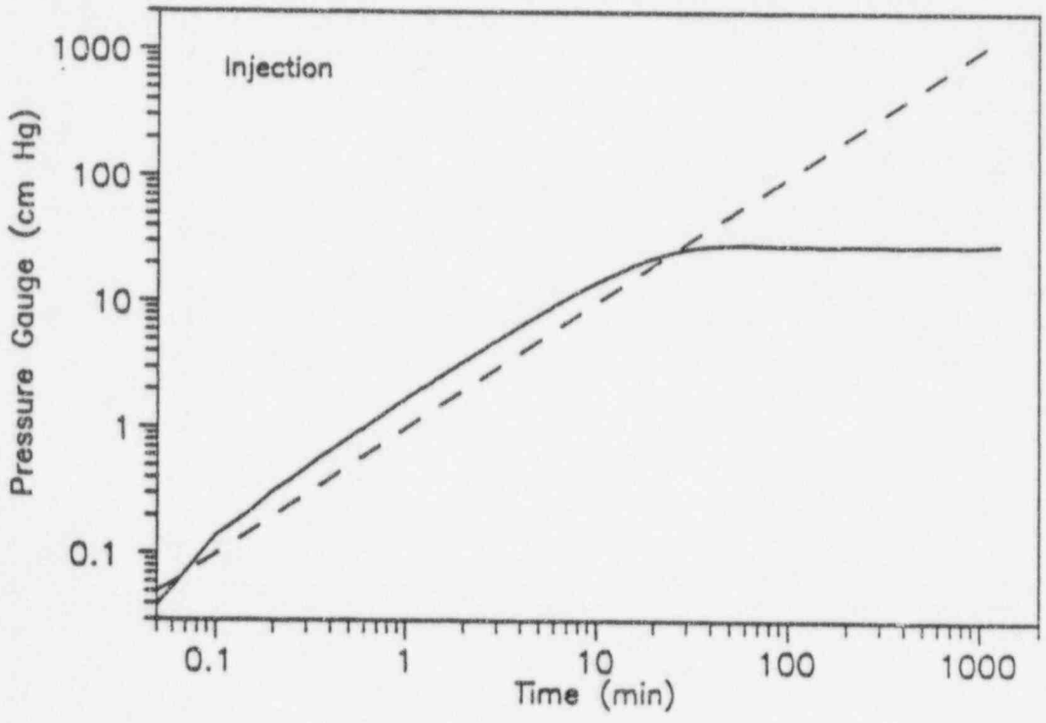


INJECTION TEST
X2-CFA
09-29-92

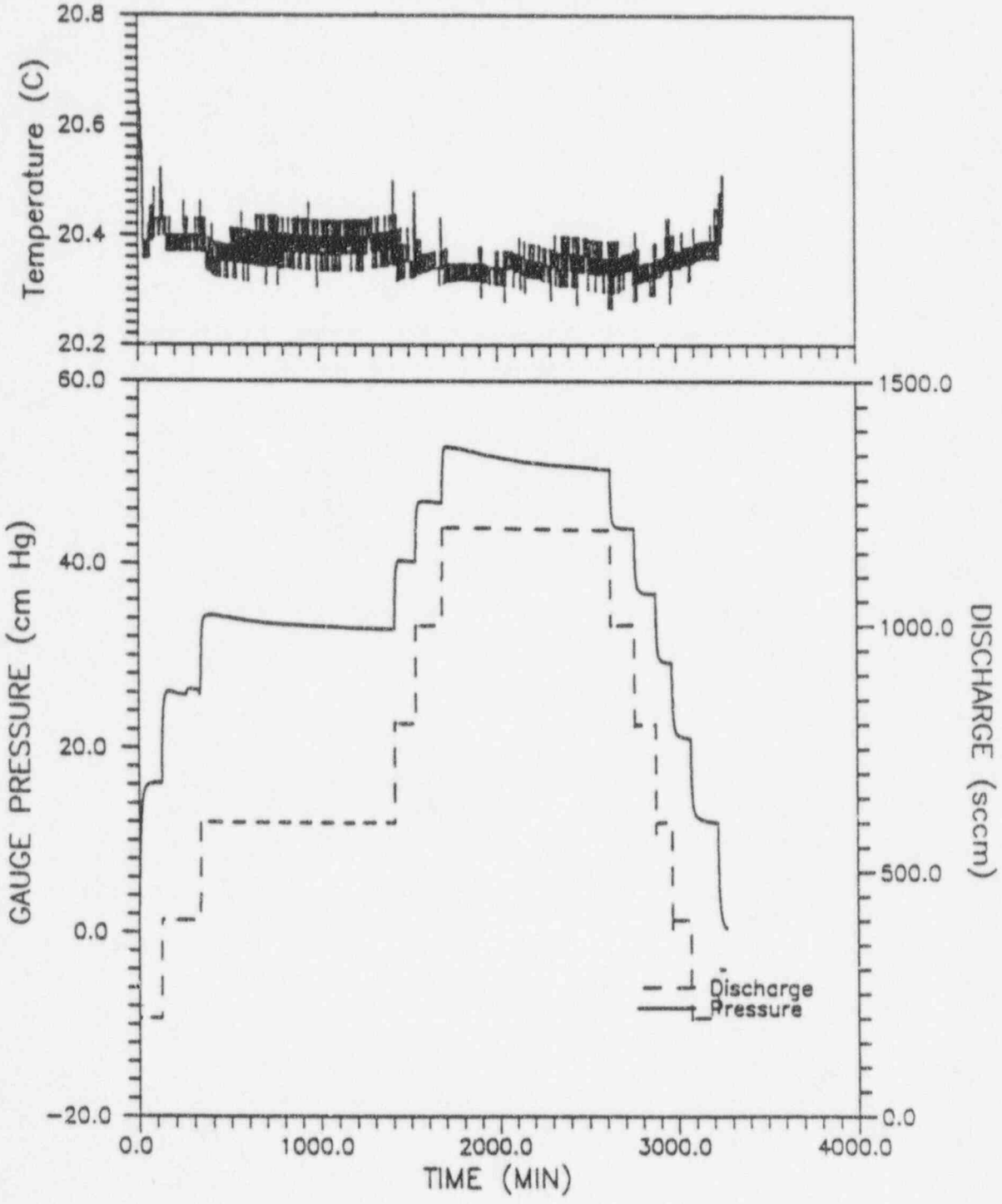


X2-CFA
09-29-92
I: Q=200 sccm; R: Q=1400 sccm

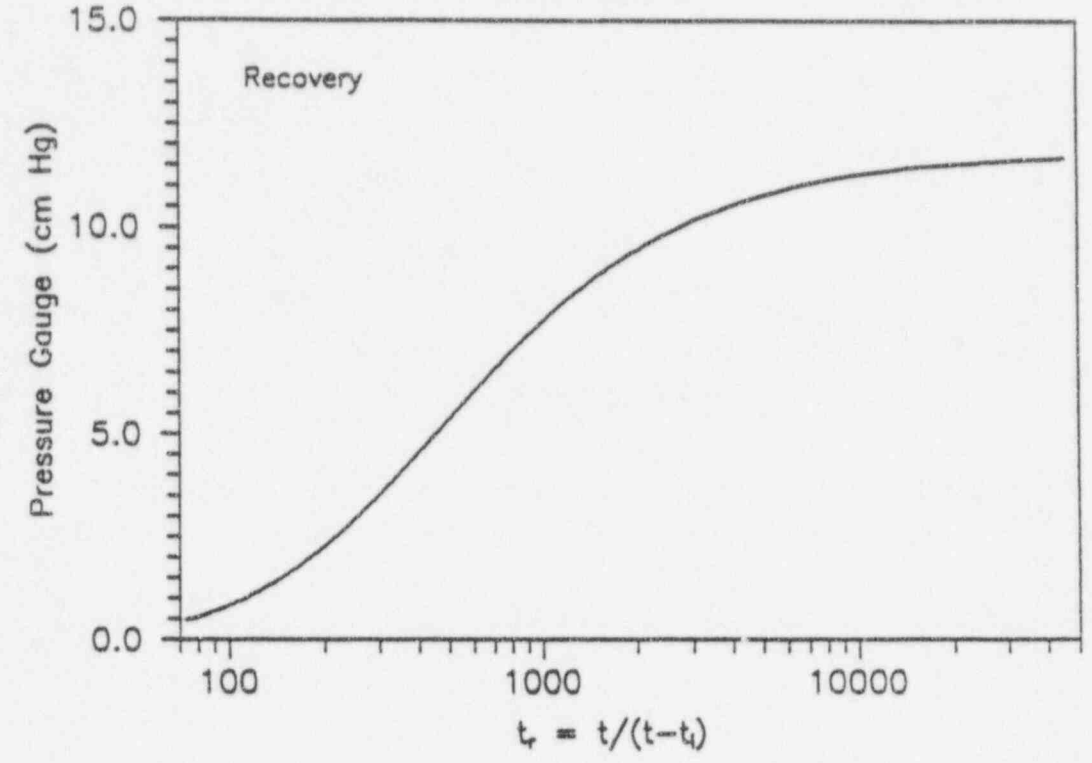


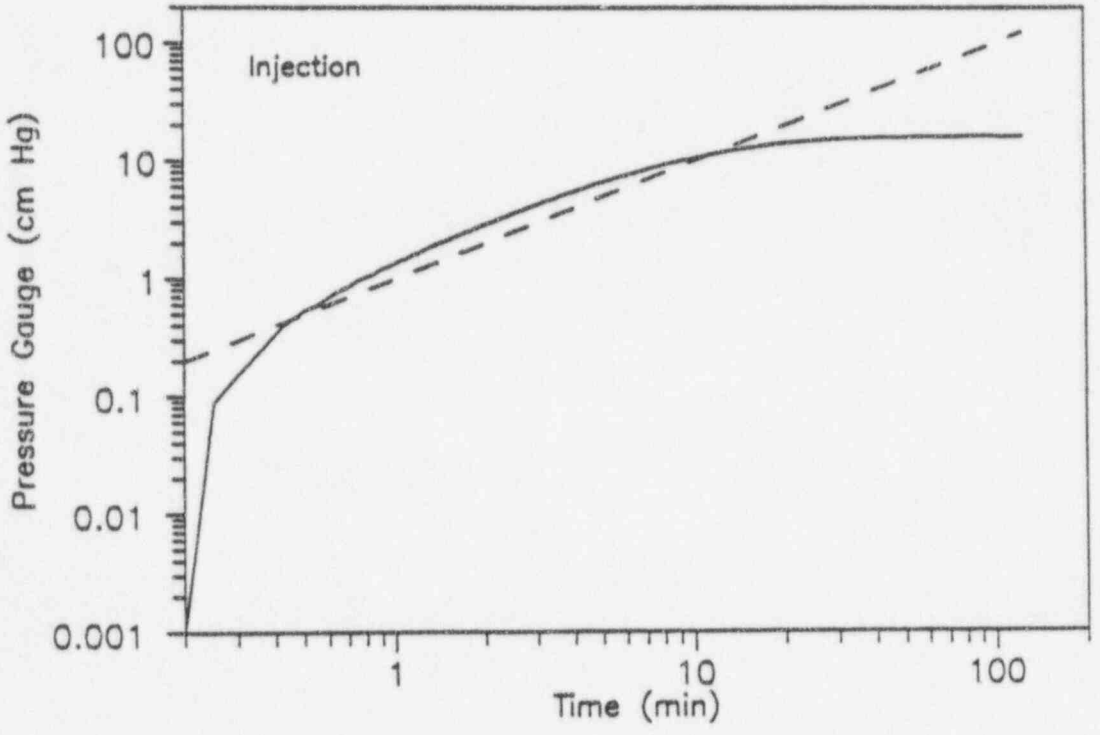


INJECTION TEST
X2--CFC
11-12-92

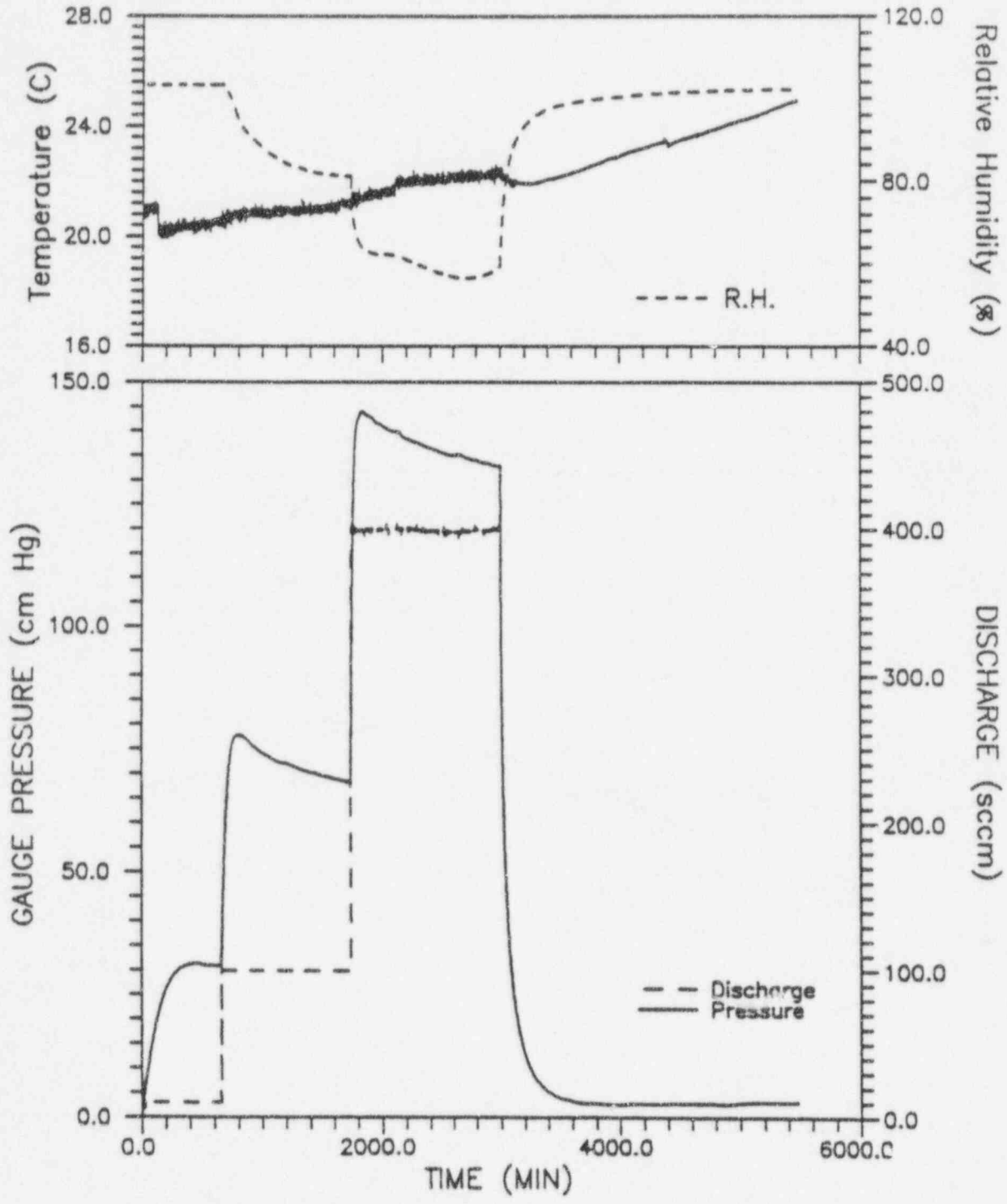


X2-CFC
11-12-92
I: Q=200 sccm; R: Q=200 sccm

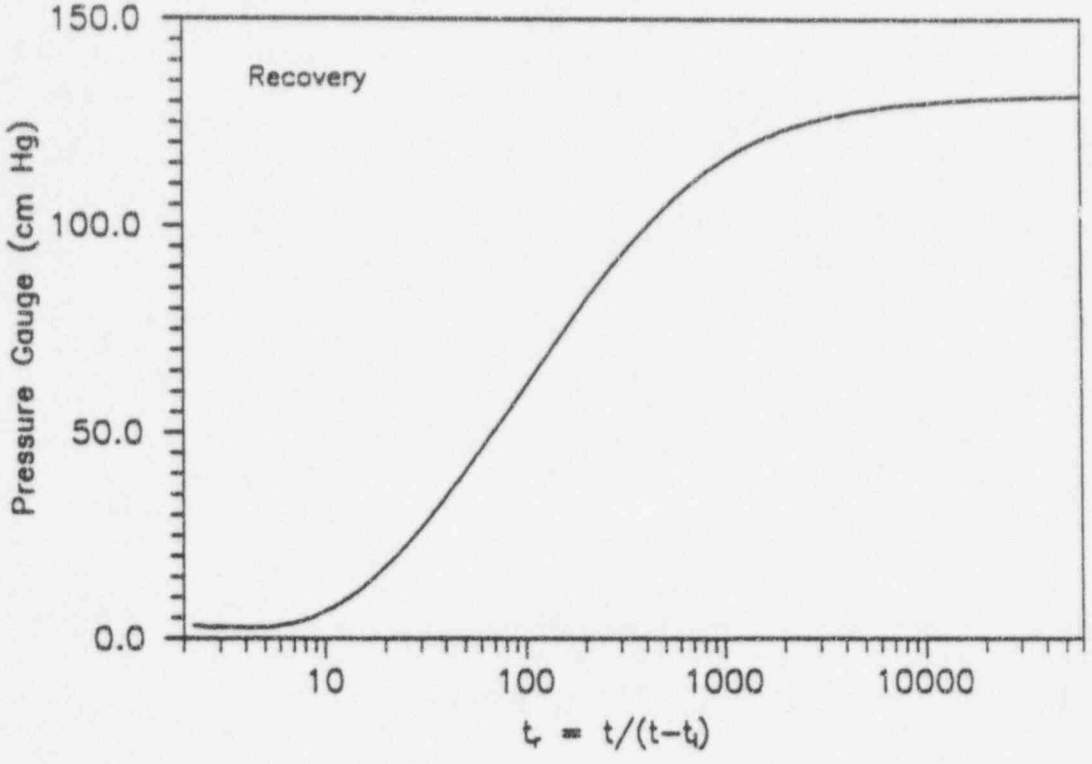


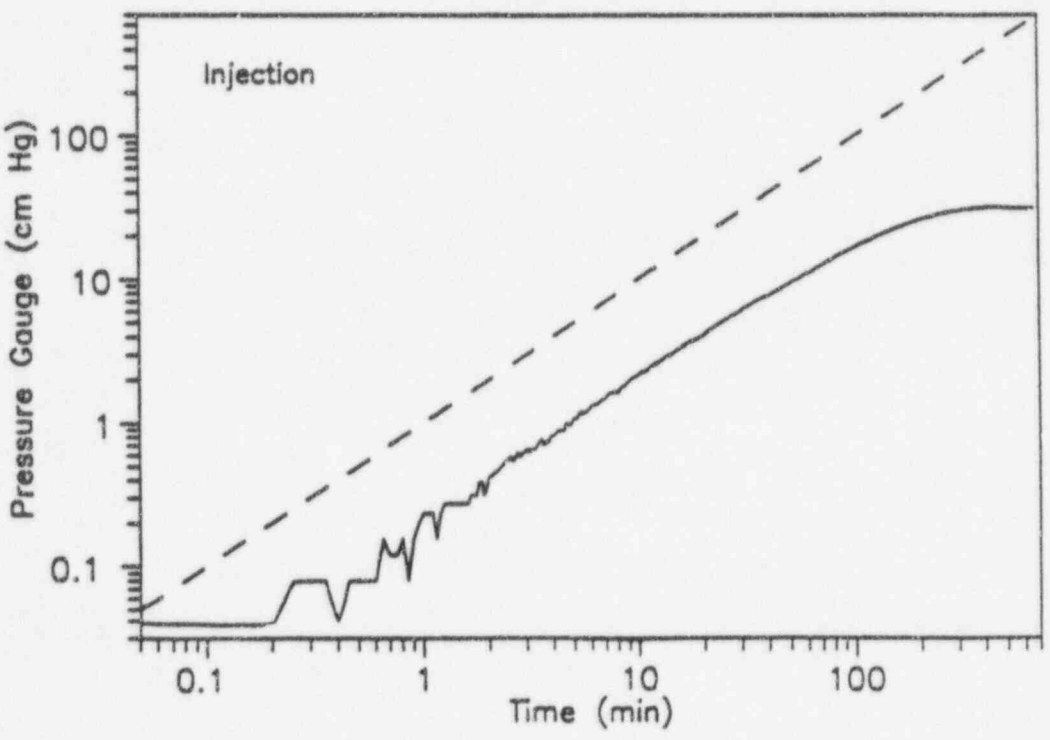


INJECTION TEST
X2-CHC
06-07-94

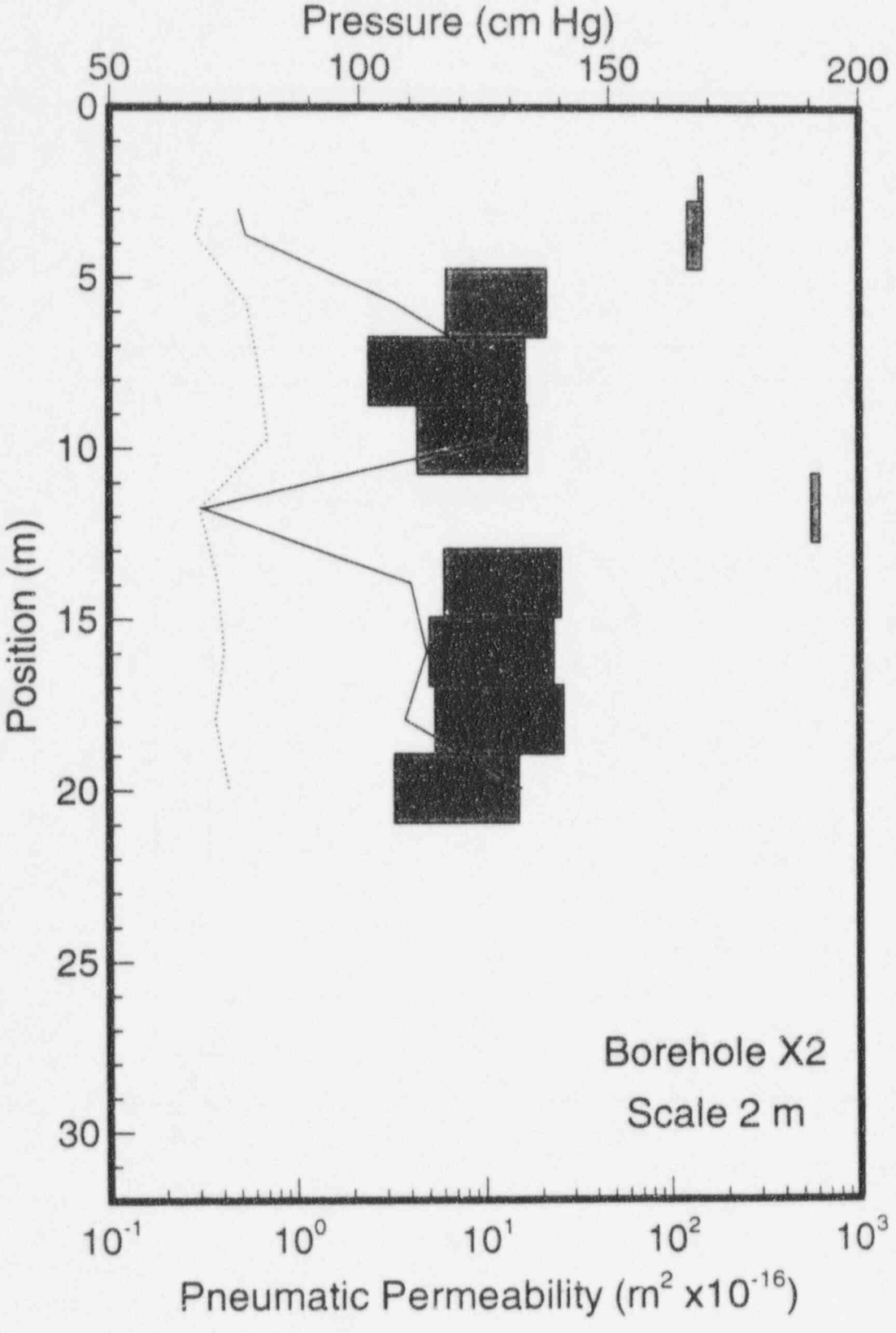


X2-CHC
06-07-94
I: Q=10 sccm; R: Q= 400

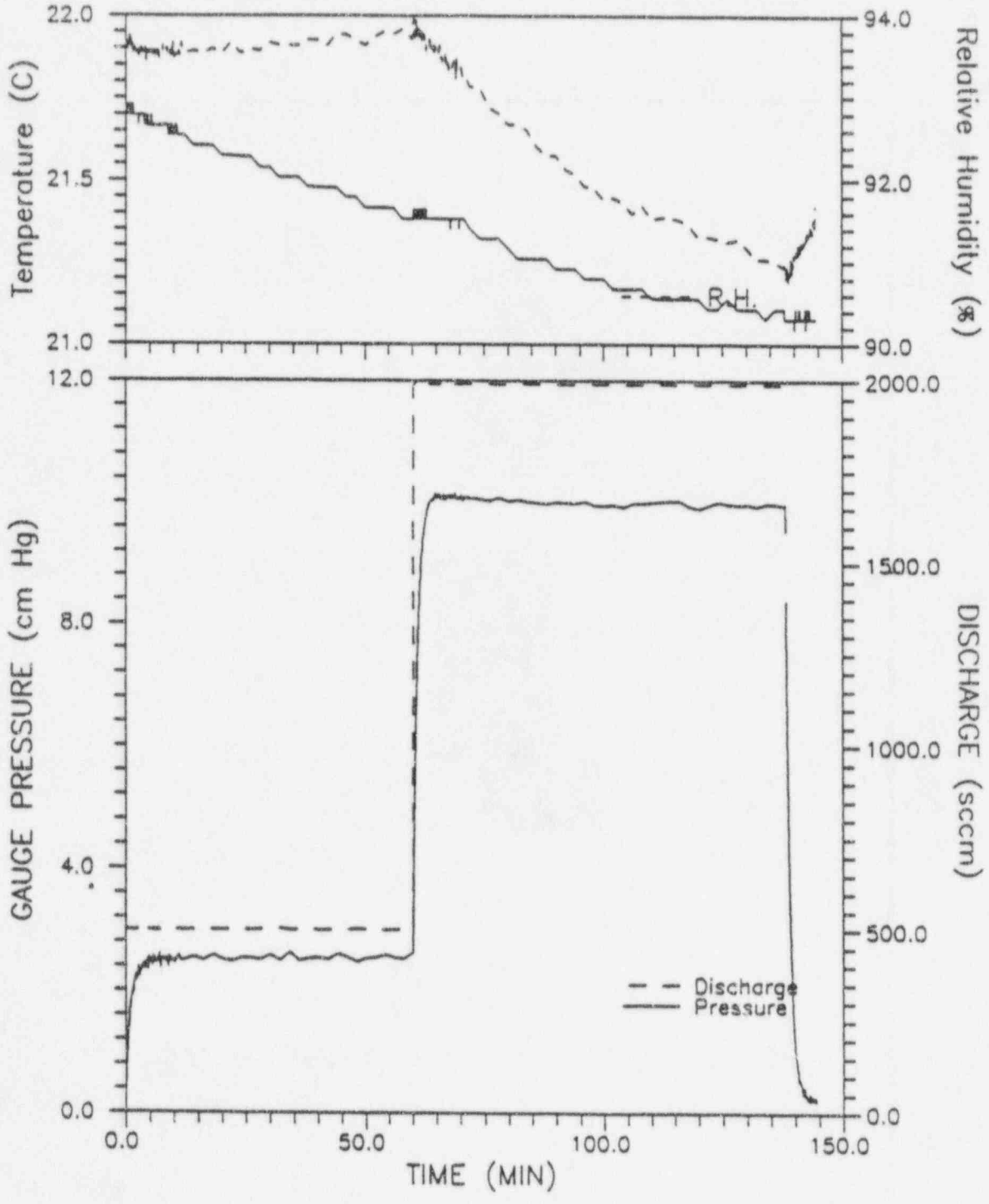




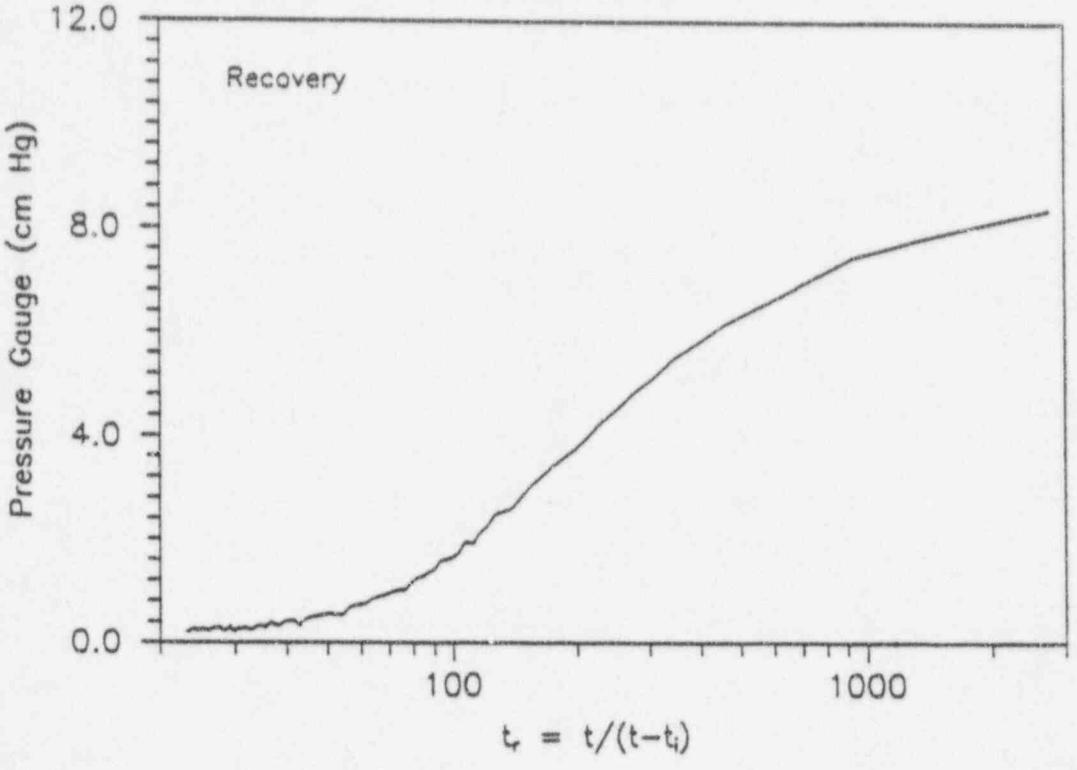
Graphs from Table B.4 X2 - 2.0 m Data

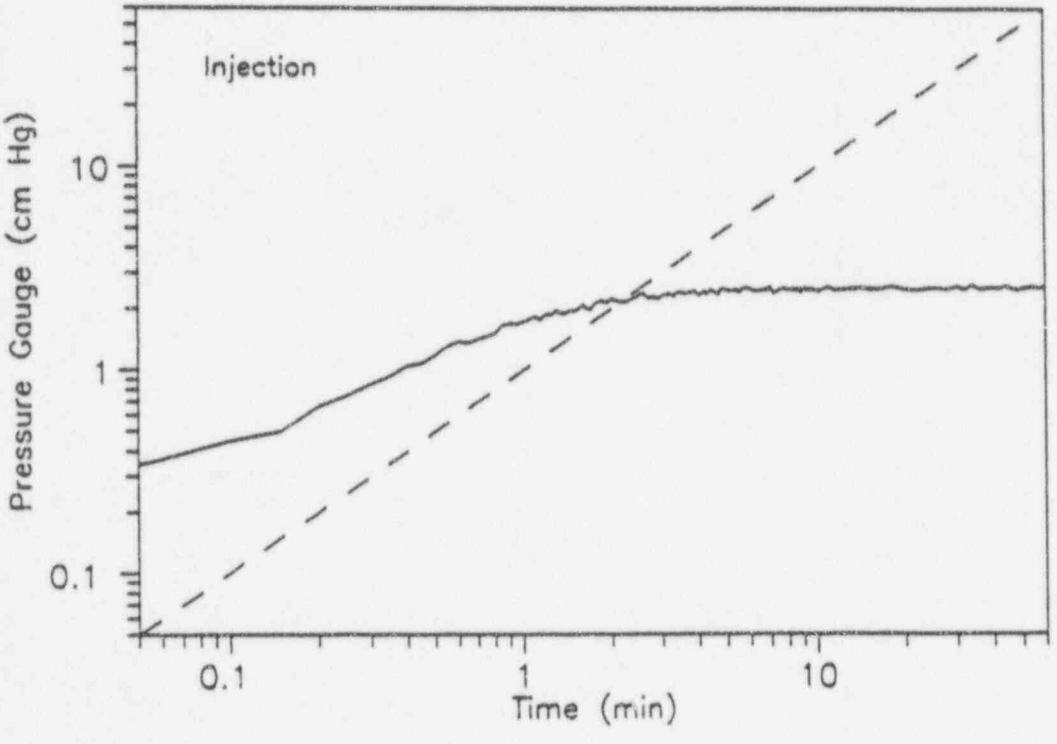

Pressure (cm Hg)
50
100
150
200
0
5
10
15
20
25
30
Position (m)
Borehole X2
Scale 2 m
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
Pneumatic Permeability (m^2 x10^{-16})

INJECTION TEST
X2-JA
11-15-94

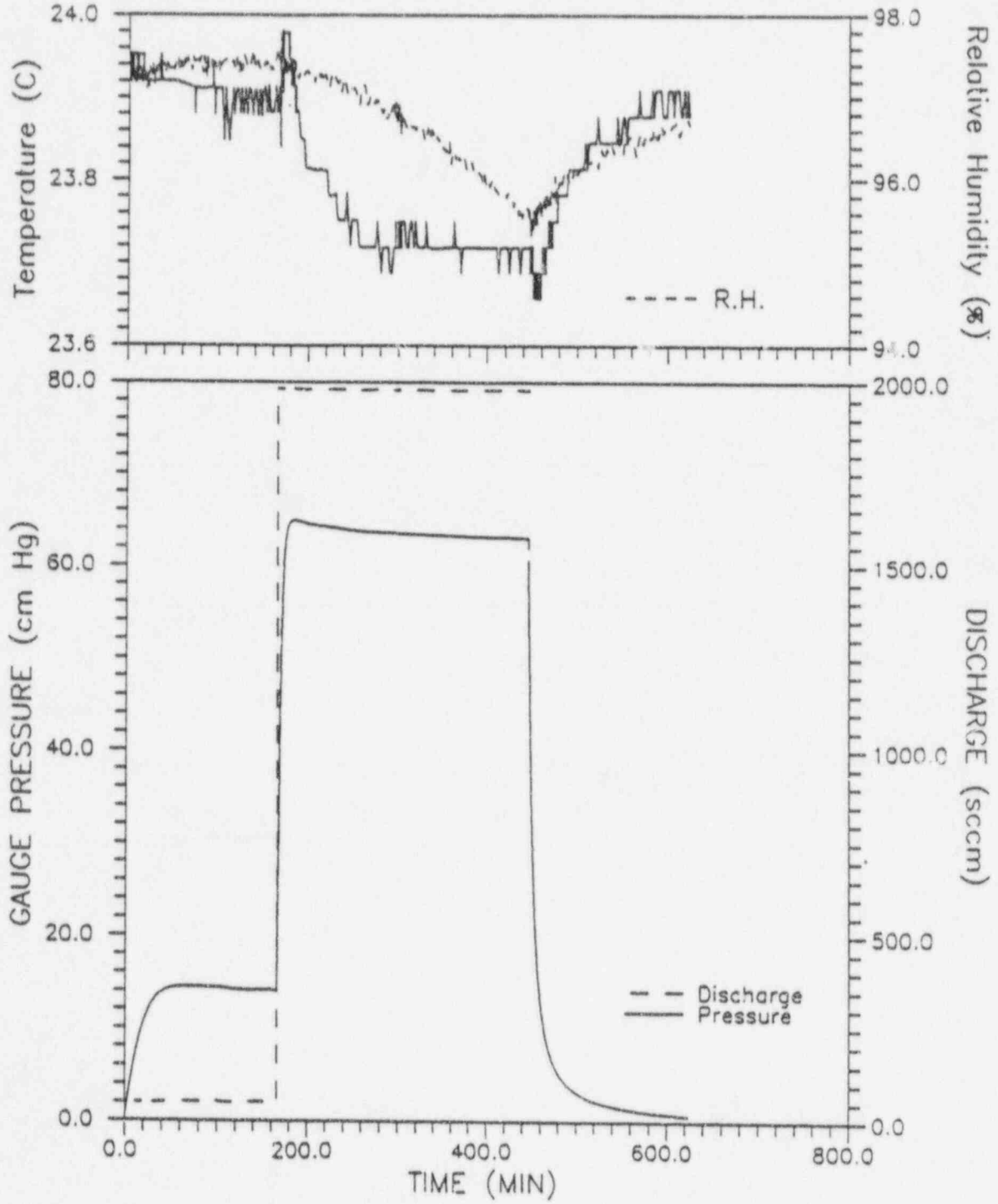


X2-JA
11-15-94
I: Q=500 sccm; R: Q=2000

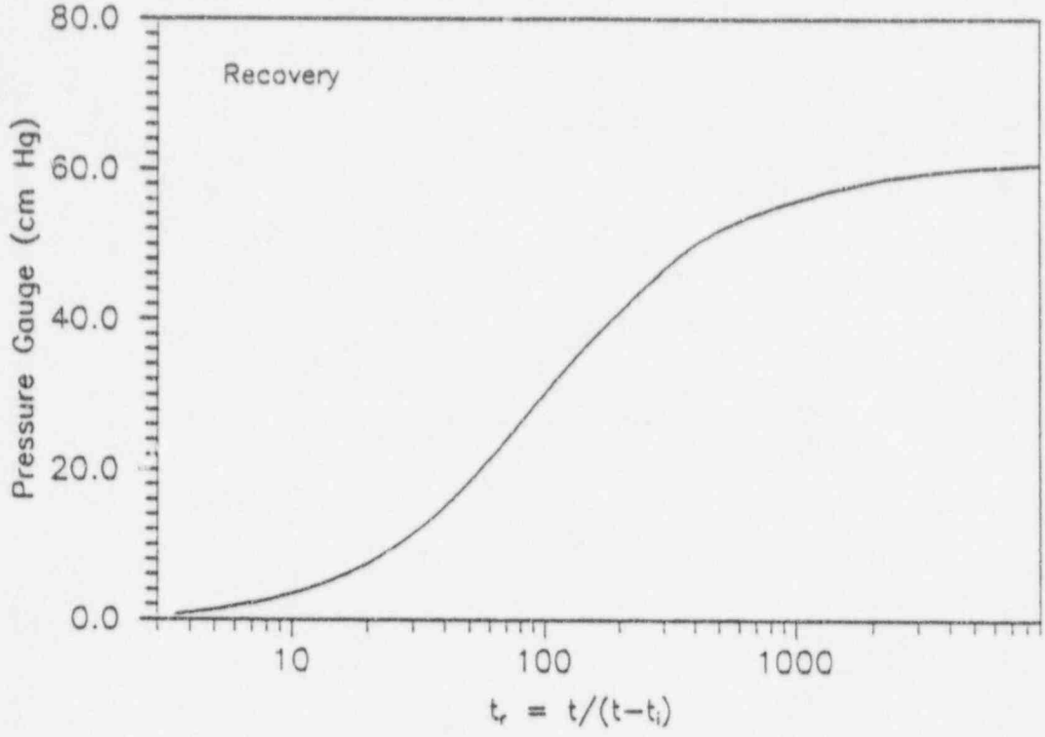


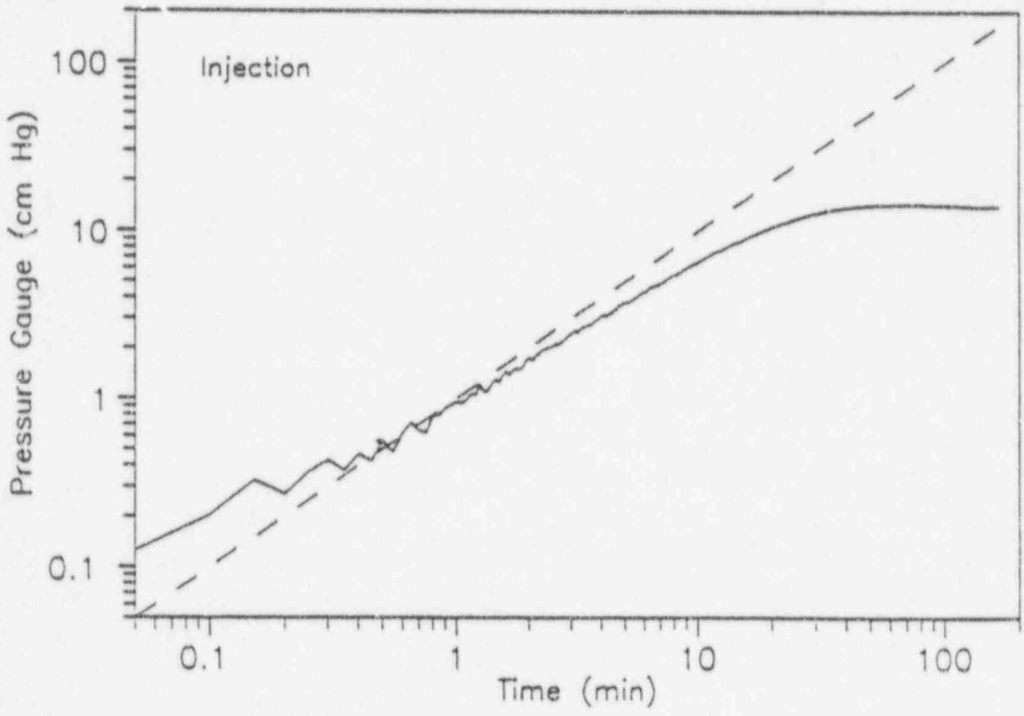


INJECTION TEST
X2-JD
11-29-94

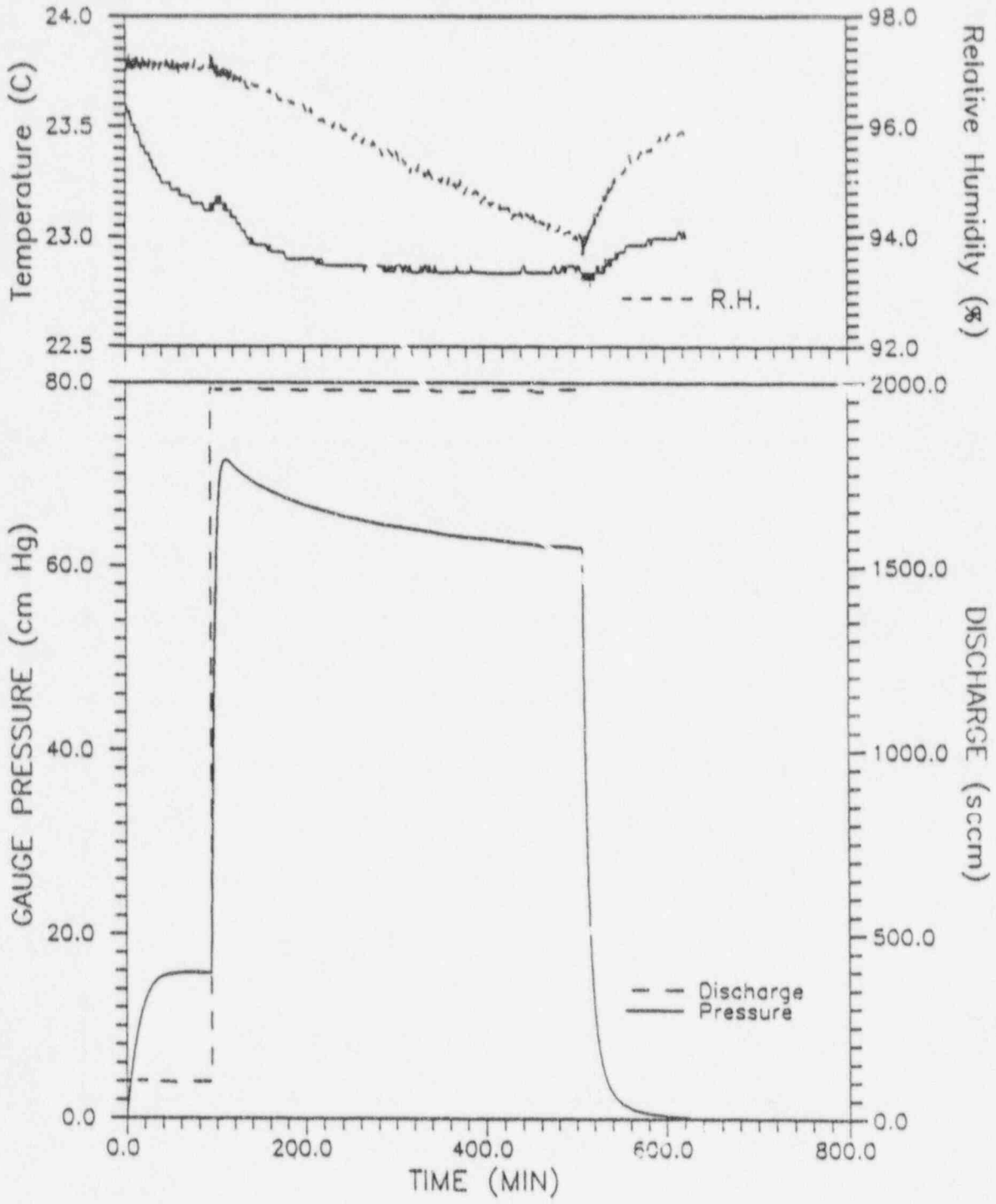


X2-JD
11-29-94
I: Q=50 sccm; R: Q=2000

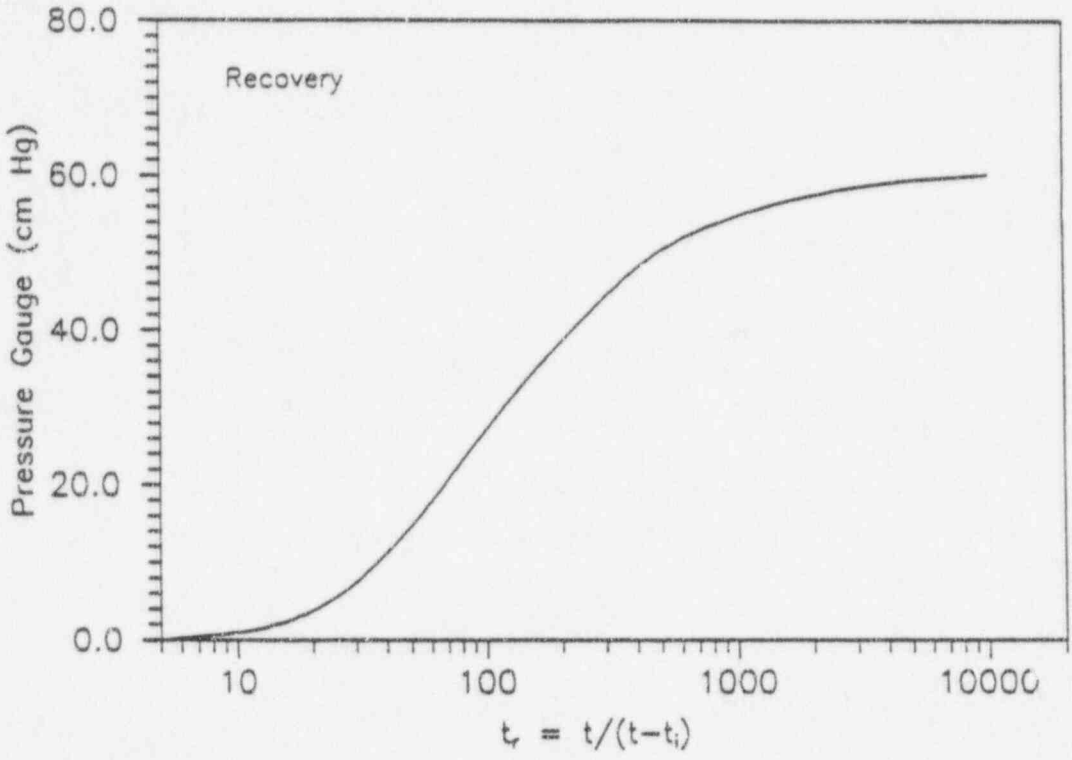


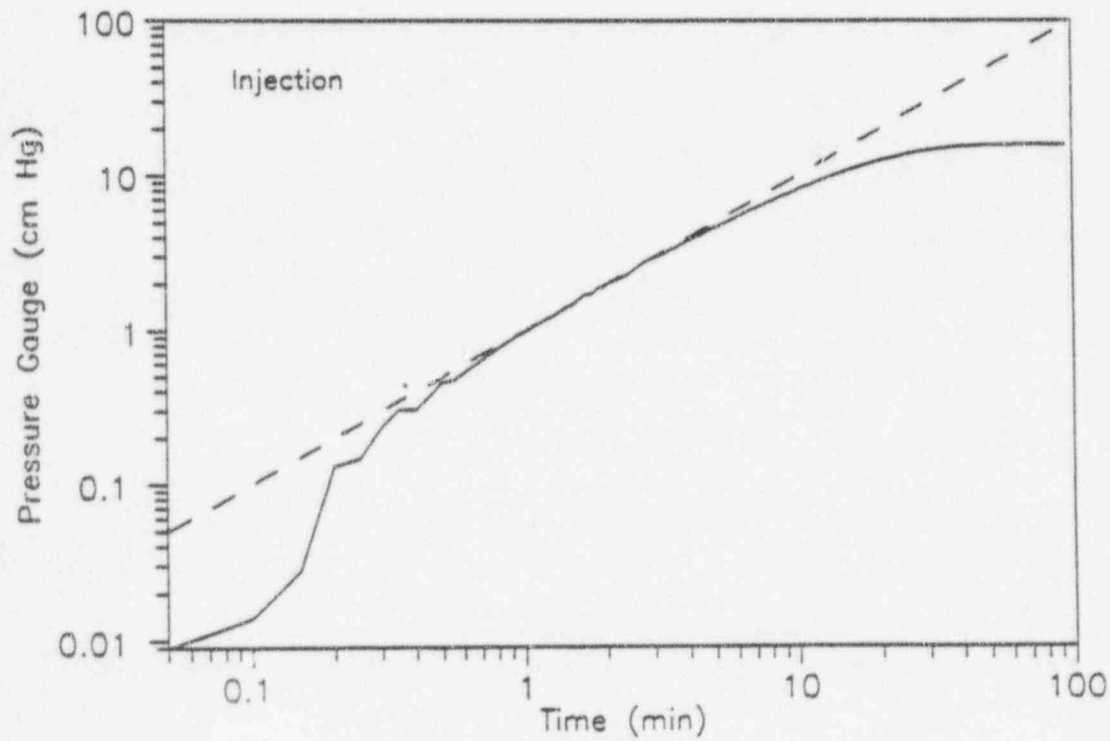


INJECTION TEST
X2-JE
12-01-94

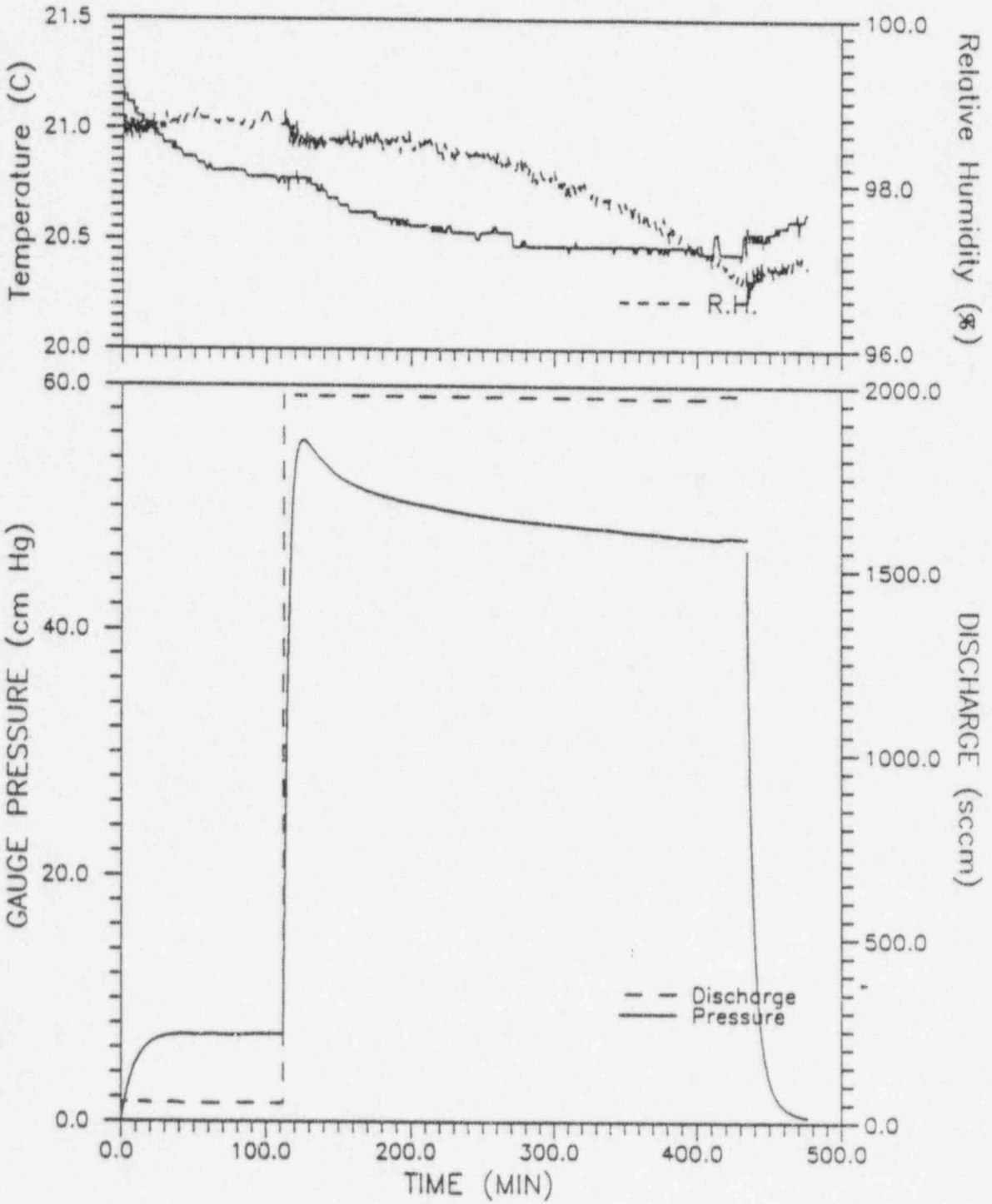


X2-JE
12-01-94
I: Q=100 sccm; R: Q=2000

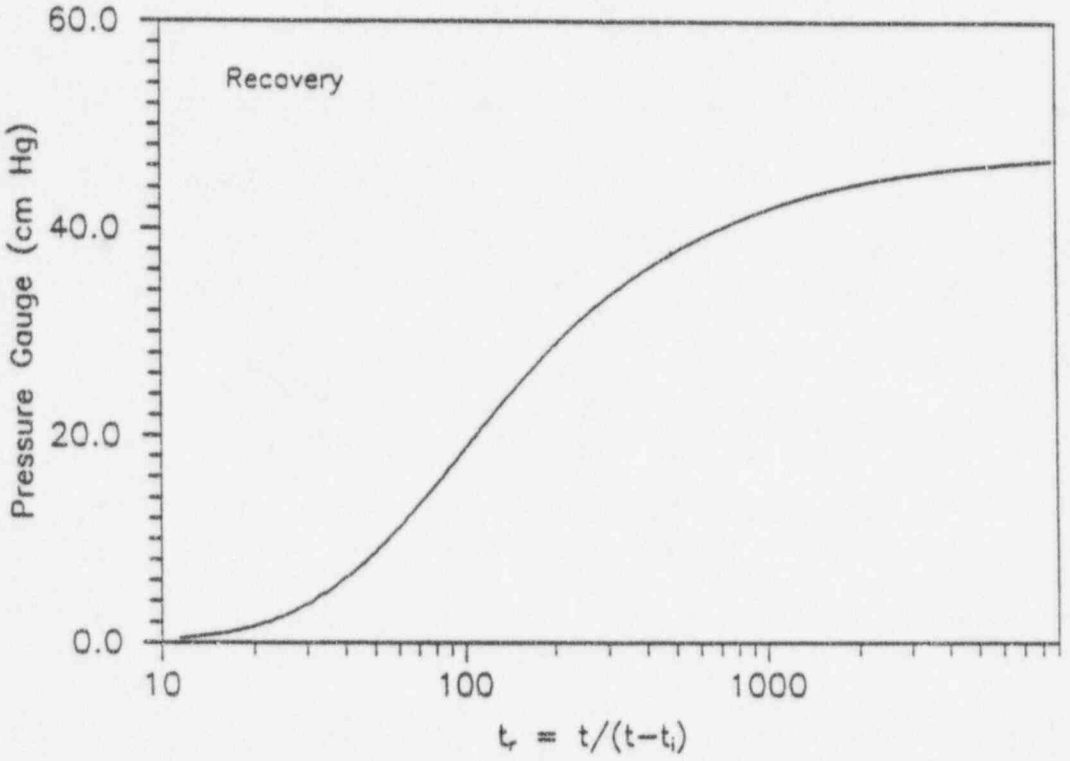


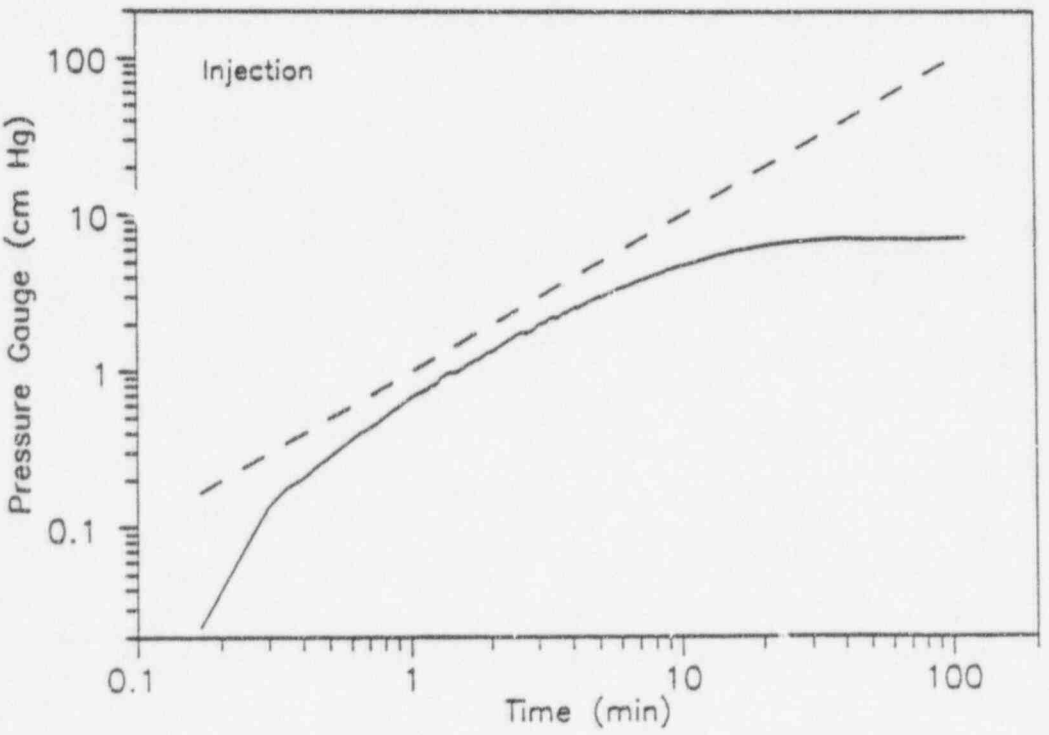


INJECTION TEST
X2-JH
12-15-94

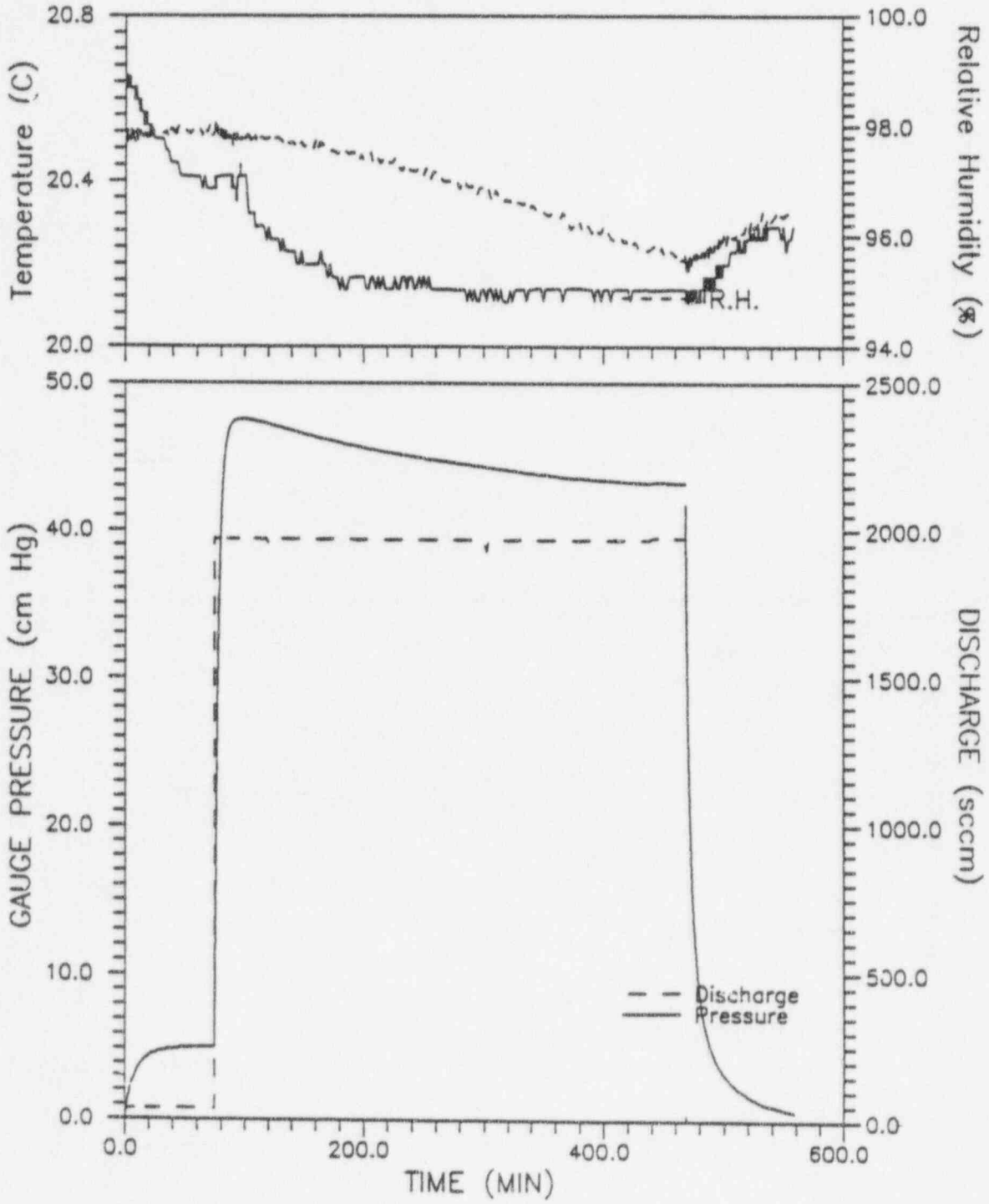


X2-JH
12-15-94
I: Q=50 sccm; R: Q=2000

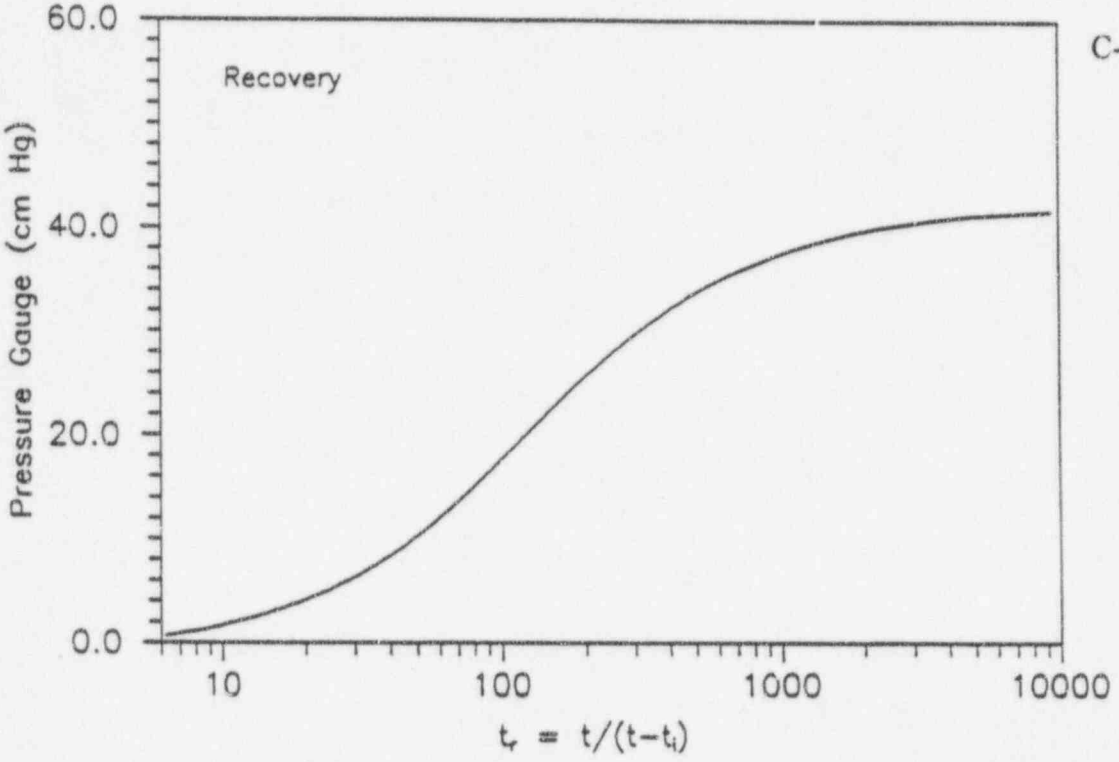


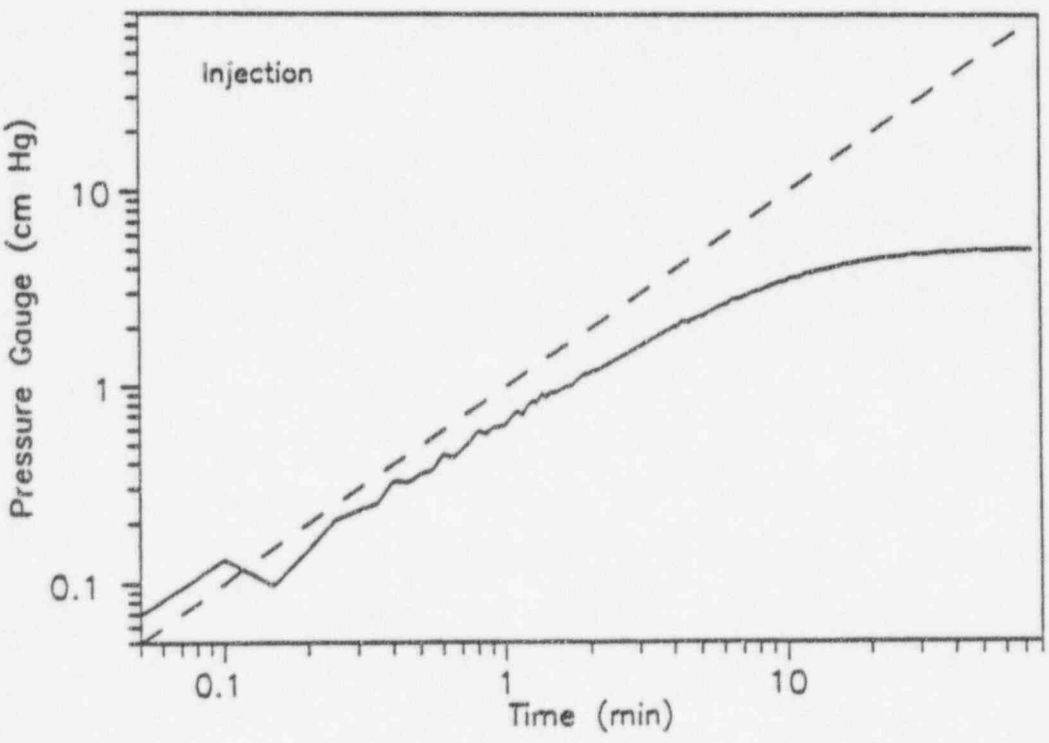


INJECTION TEST
X2-JI
12-20-94

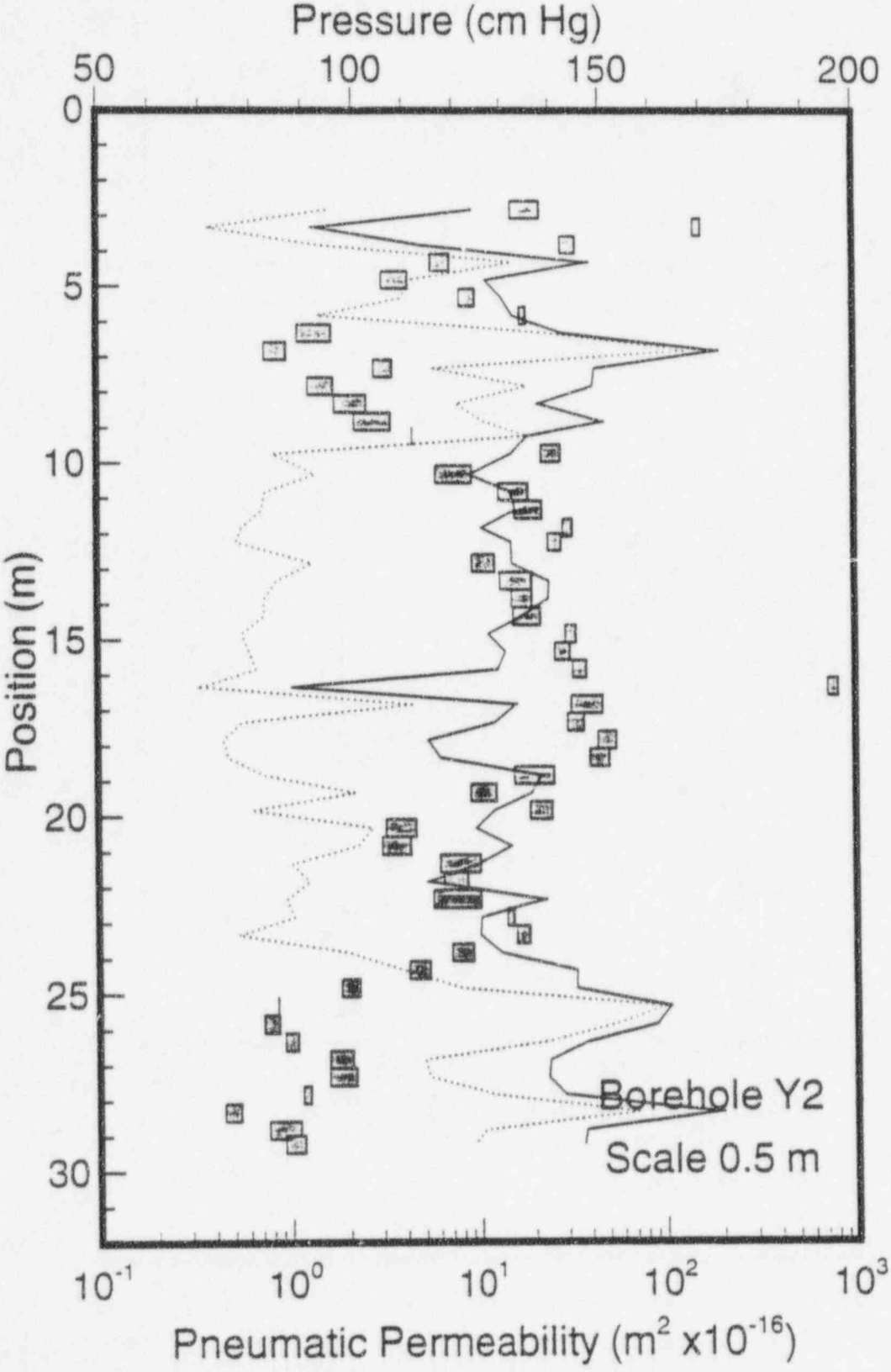


X2-JI
12-20-94
I: Q=35 sccm; R: Q=2000

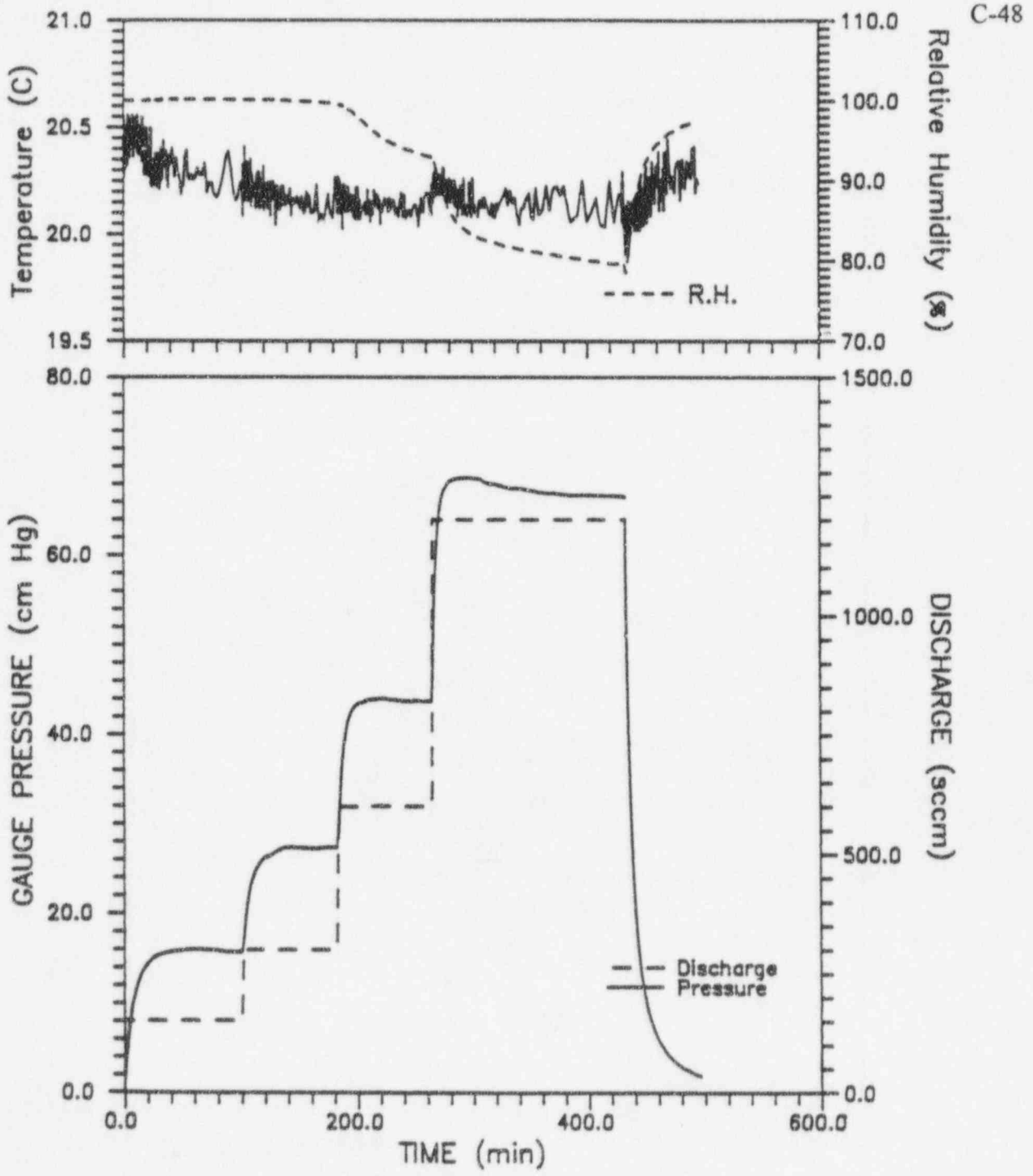




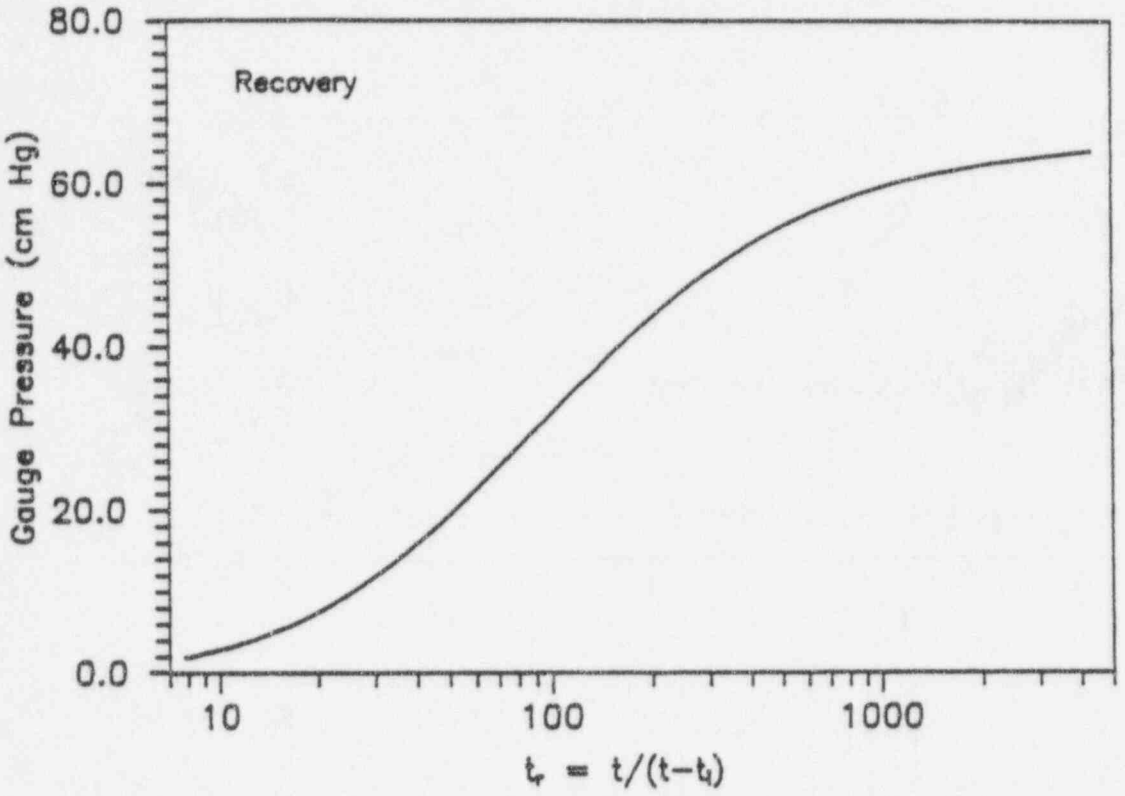
Graphs from Table B.5 Y2 - 0.5 m Data

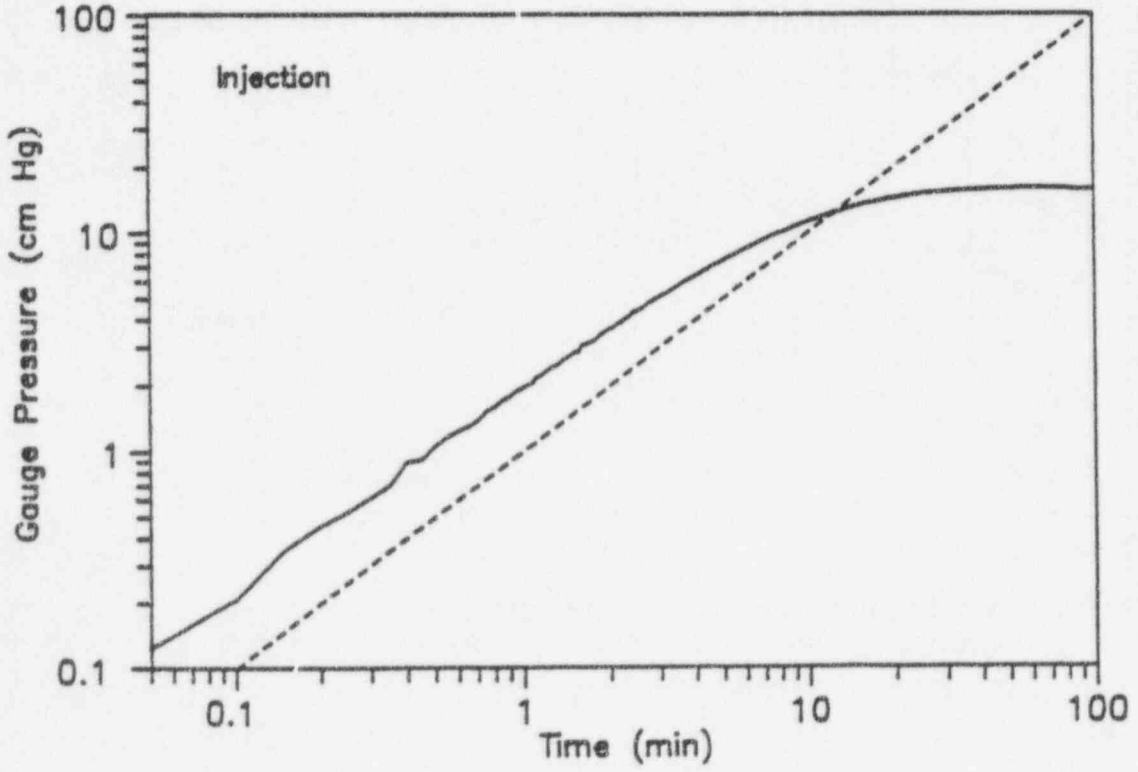

Pressure (cm Hg)
50
100
150
200
0
5
10
15
20
25
30
Position (m)
Borehole Y2
Scale 0.5 m
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
Pneumatic Permeability (m^2 x10^{-16})

INJECTION TEST
Y2-JF6
06-11-91

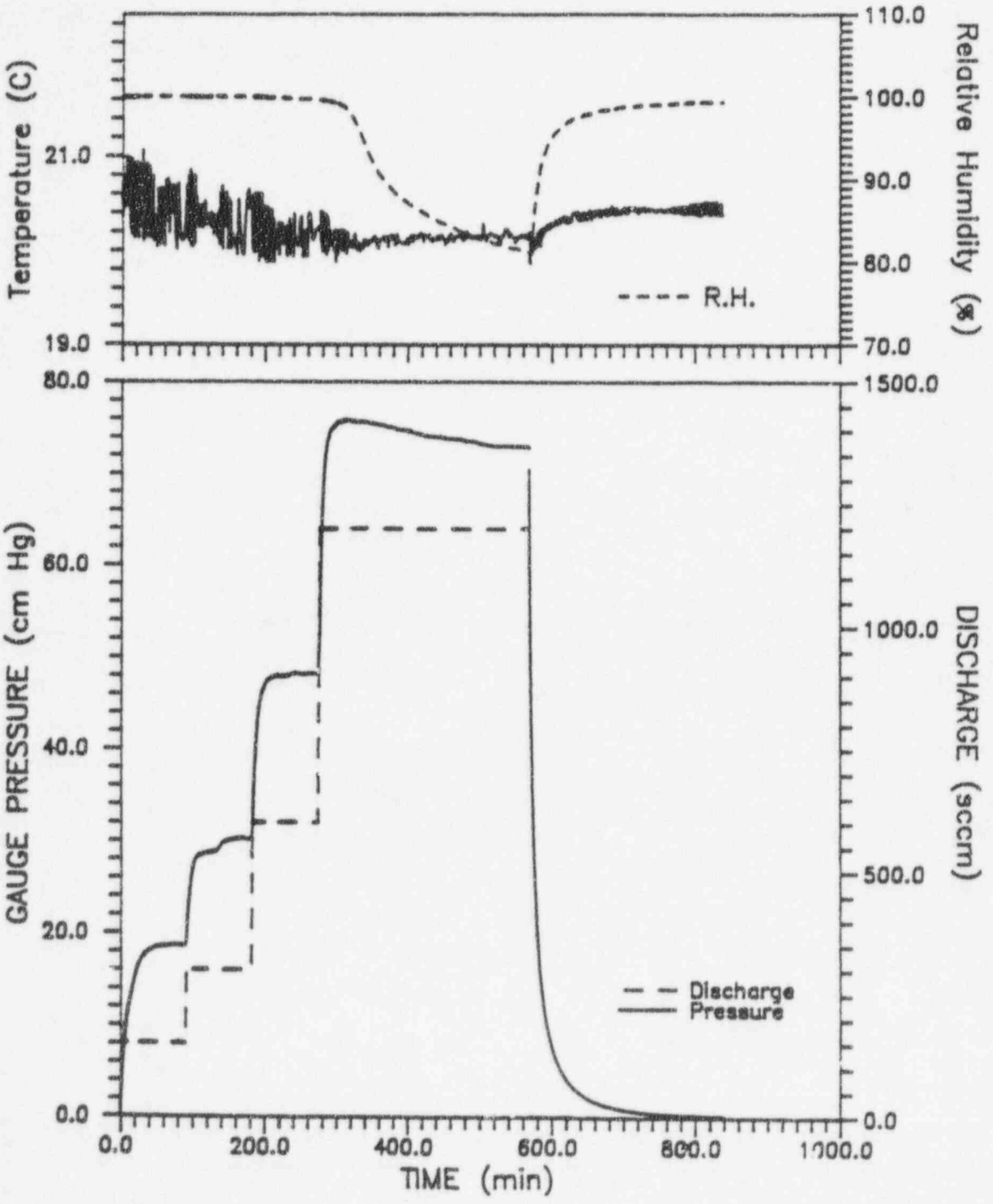


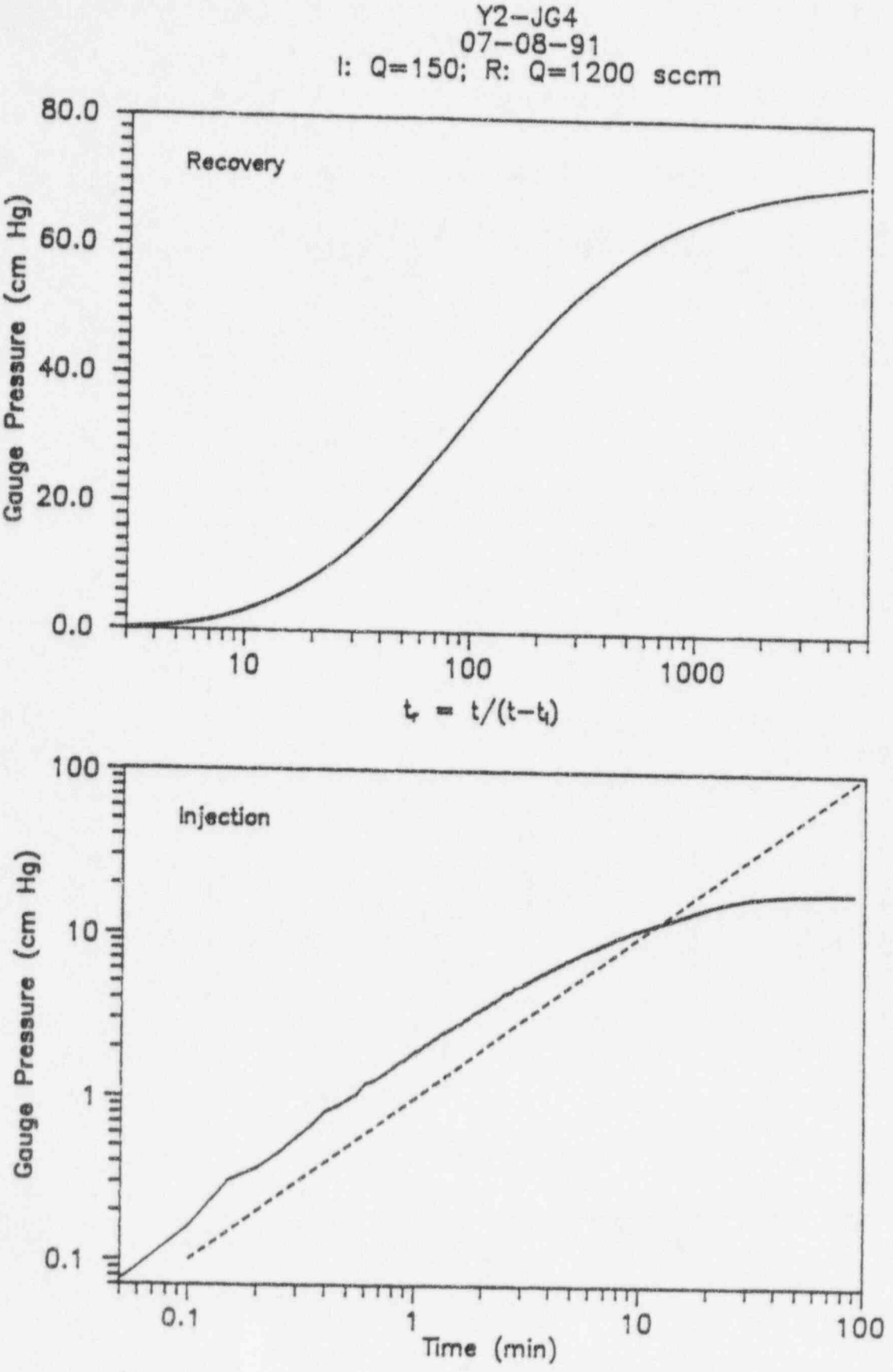
Y2-JF6
06-11-91
I: Q=150; R: Q=1200 sccm



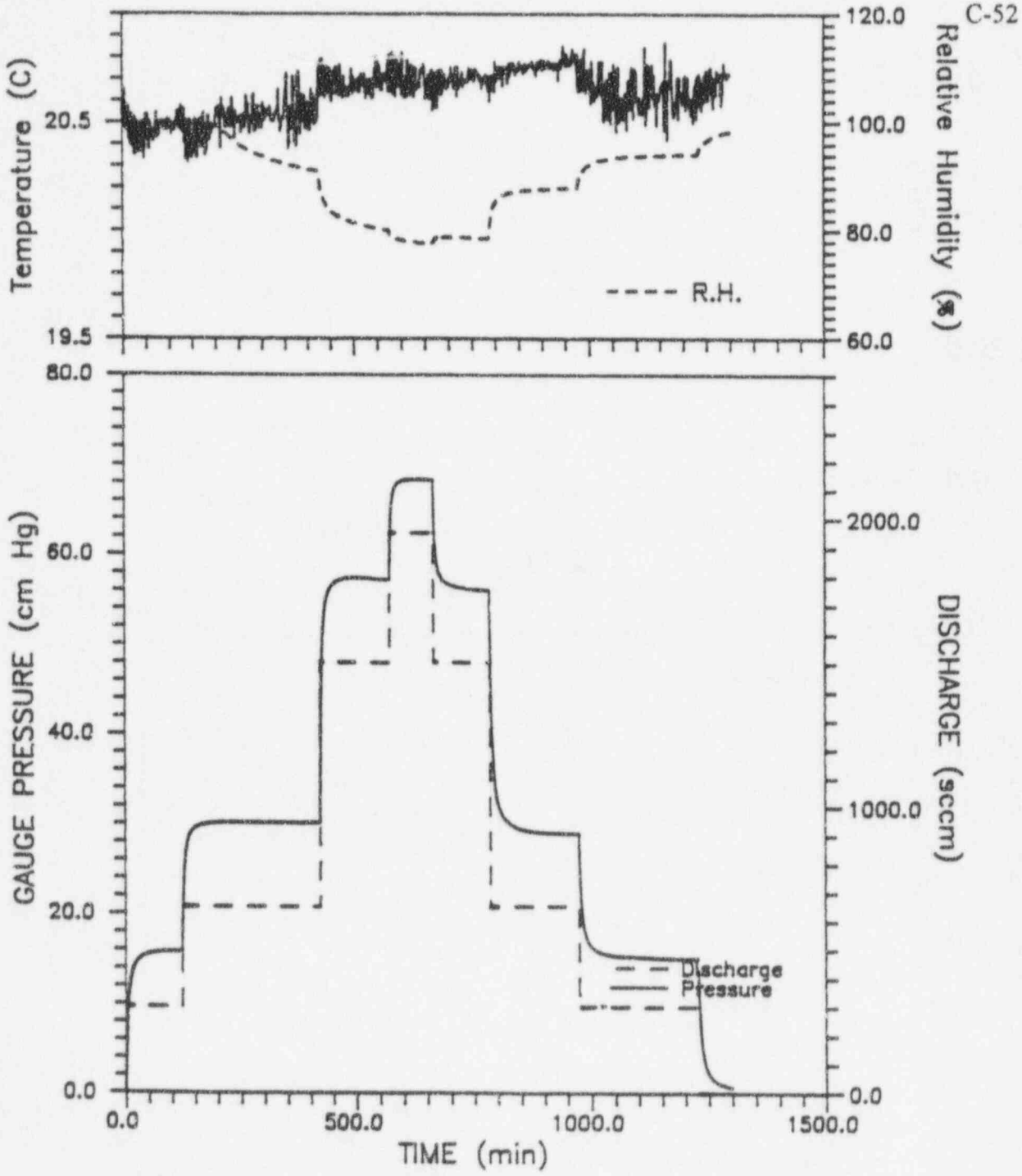


INJECTION TEST
Y2-JG4
07-08-91

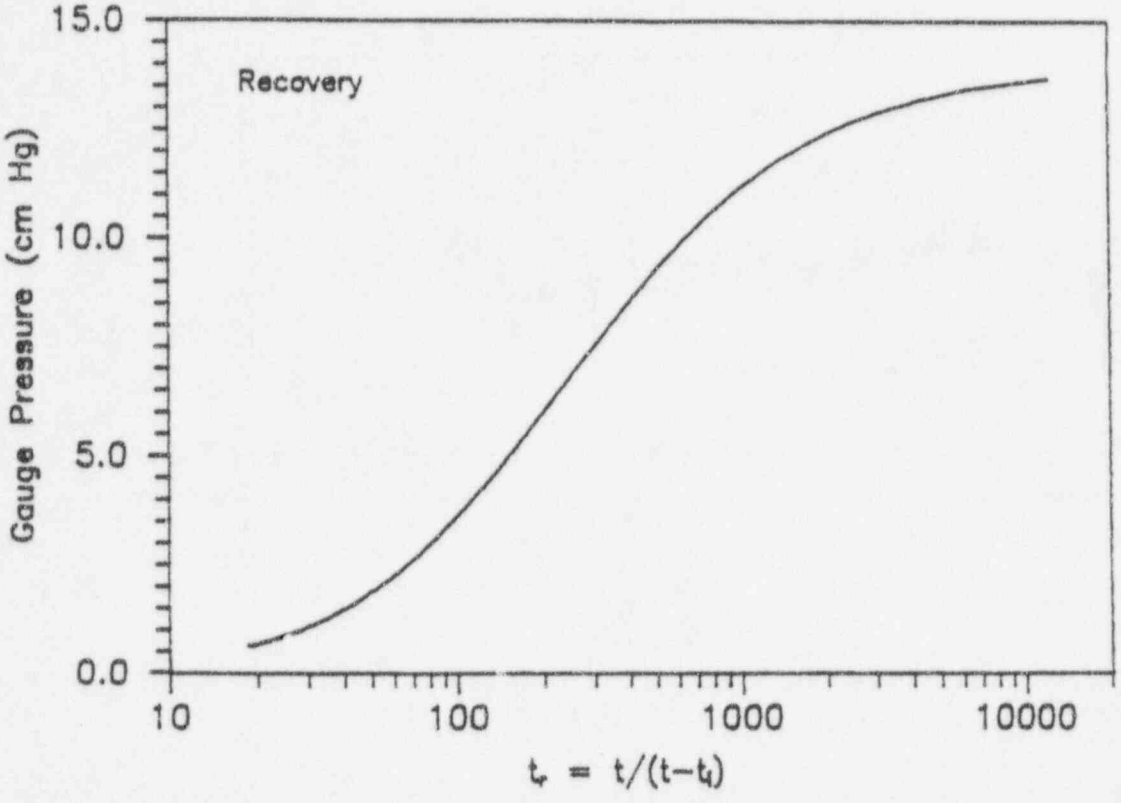


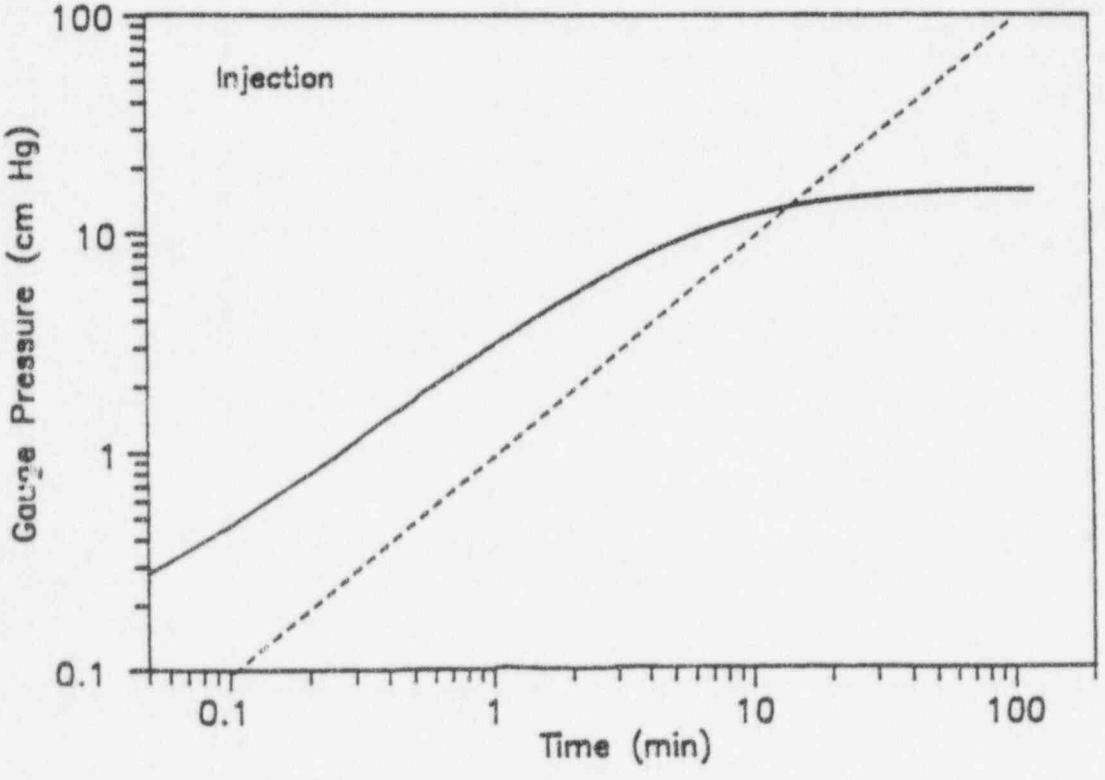

Y2-JG4
07-08-91
I: Q=150; R: Q=1200 sccm
Recovery
Gauge Pressure (cm Hg)
80.0
60.0
40.0
20.0
0.0
10
100
1000
t+ = t/(t-t1)
Injection
Gauge Pressure (cm Hg)
100
10
1
0.1
0.1
1
10
100
Time (min)

INJECTION TEST
Y2-JH3
11-12-91

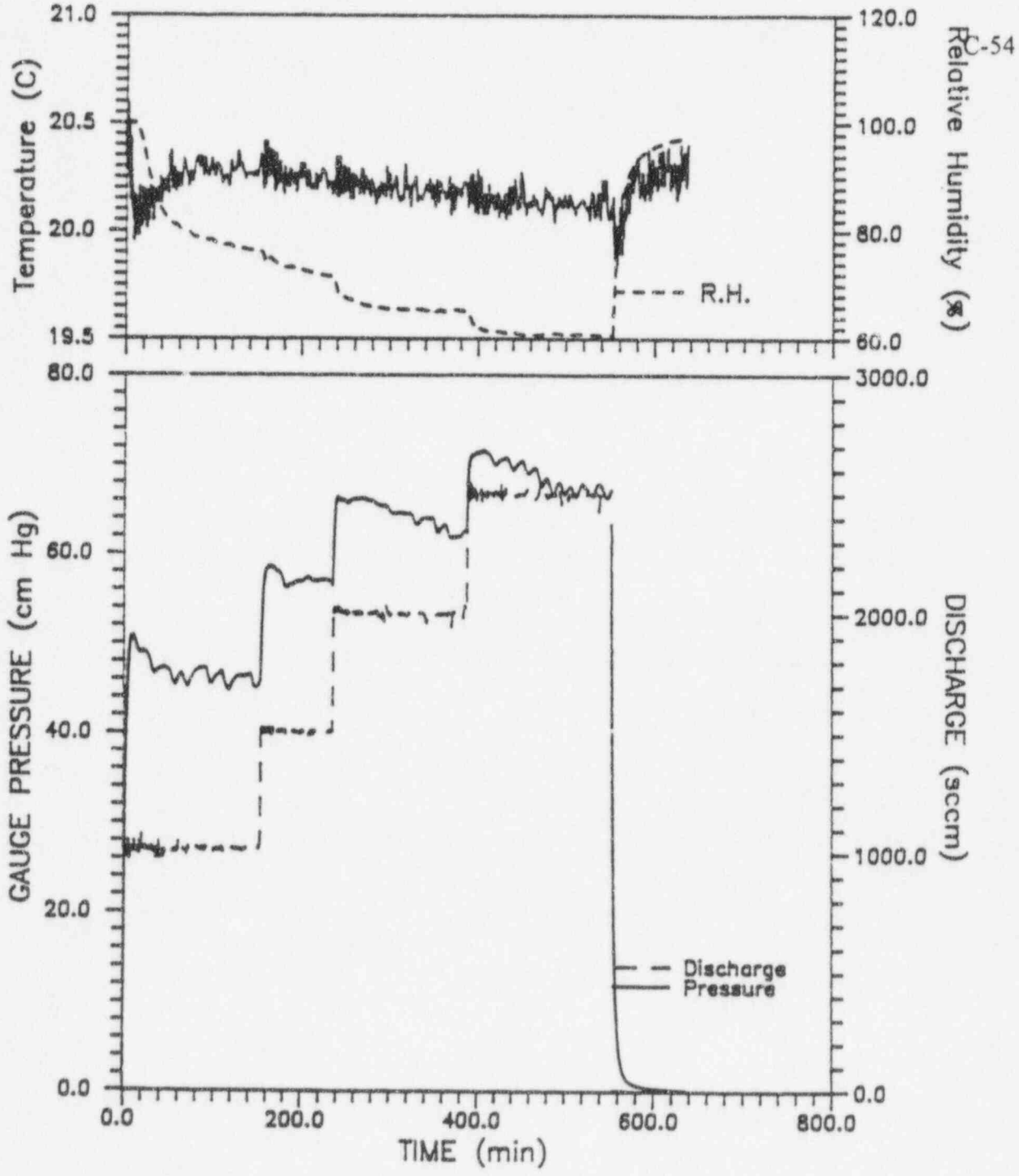


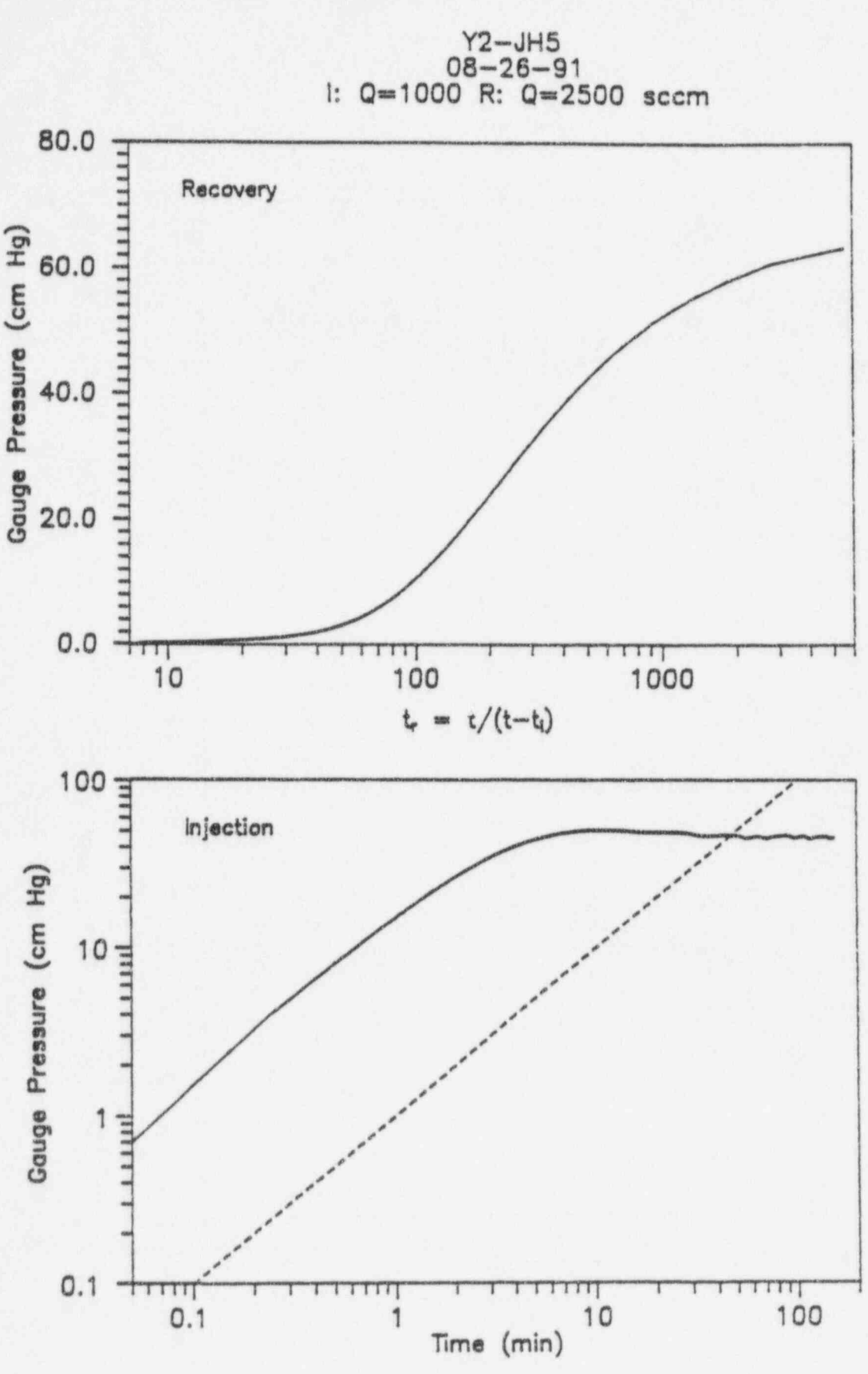
Y2-JH3
11-12-91
I: Q=300; R: Q=300 sccm



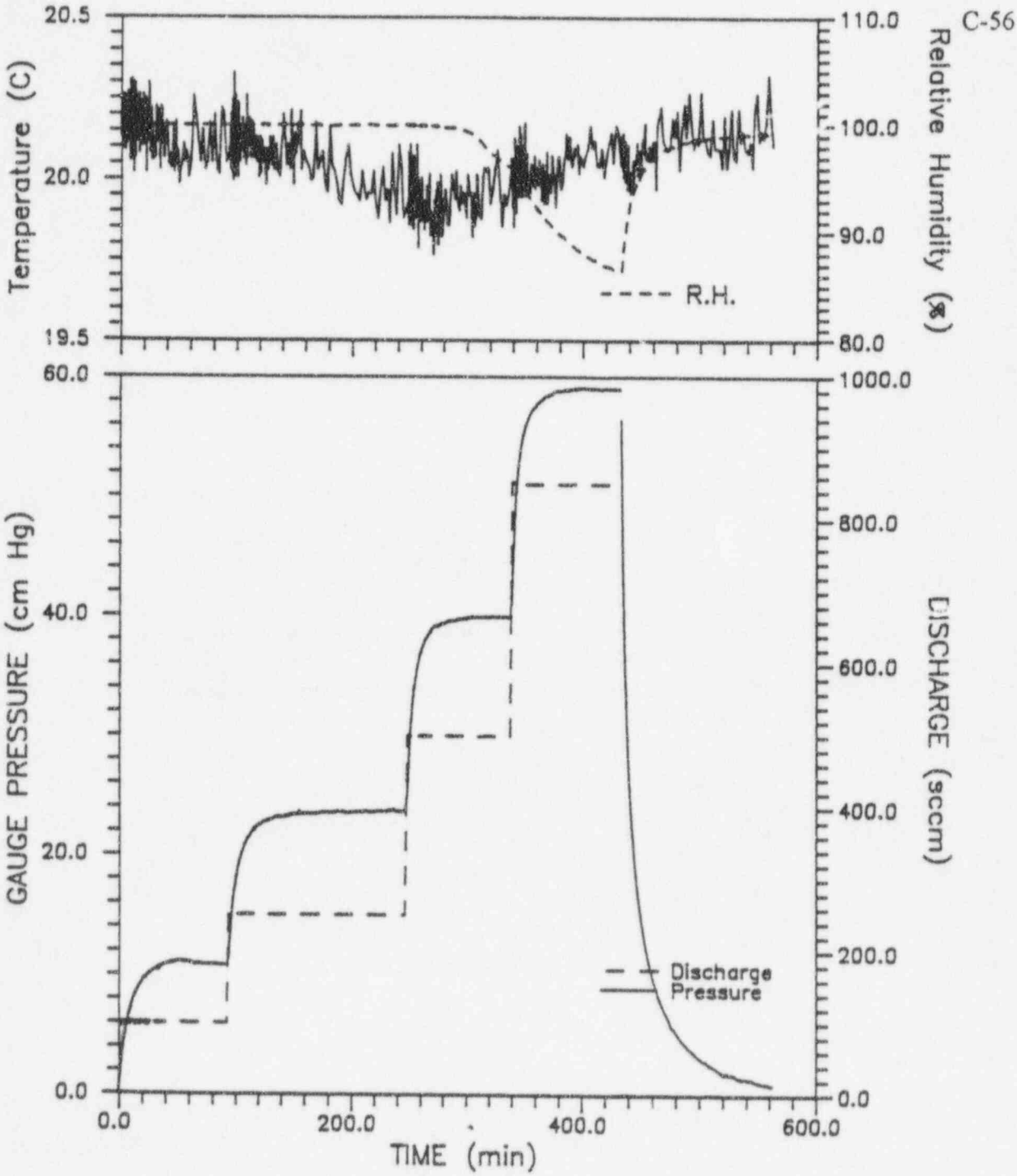


INJECTION TEST
Y2-JH5
08-20-91

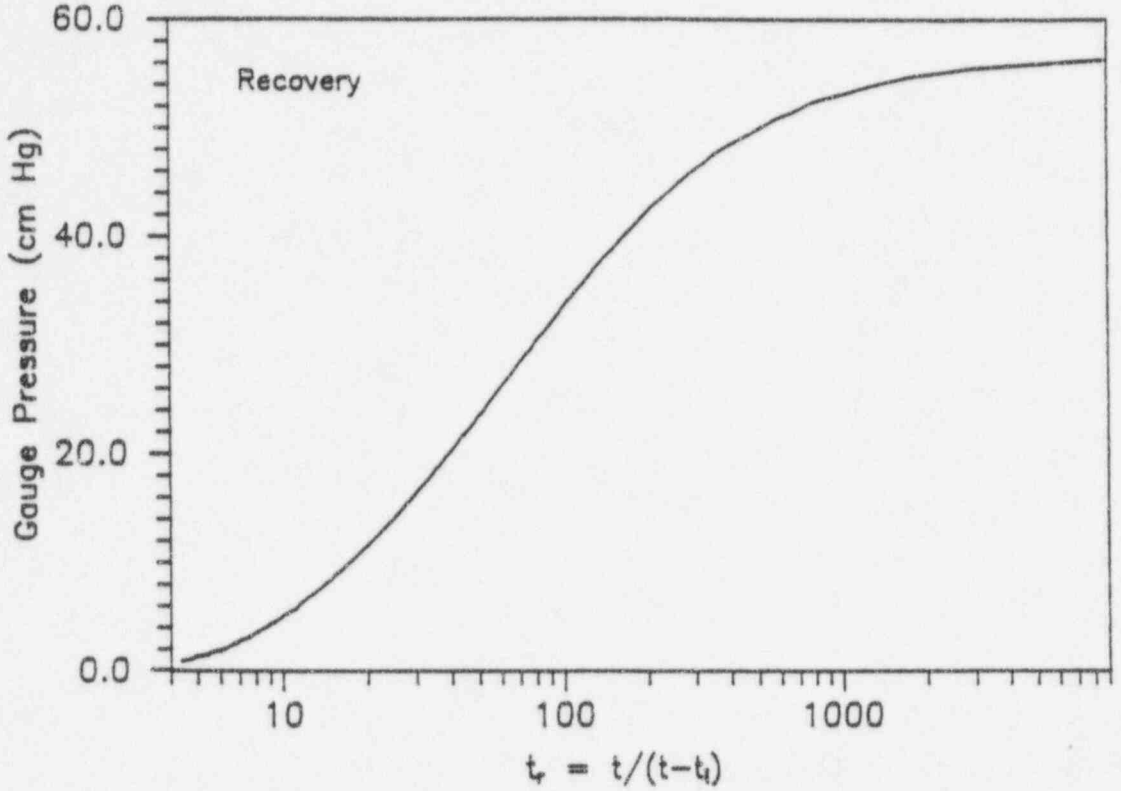


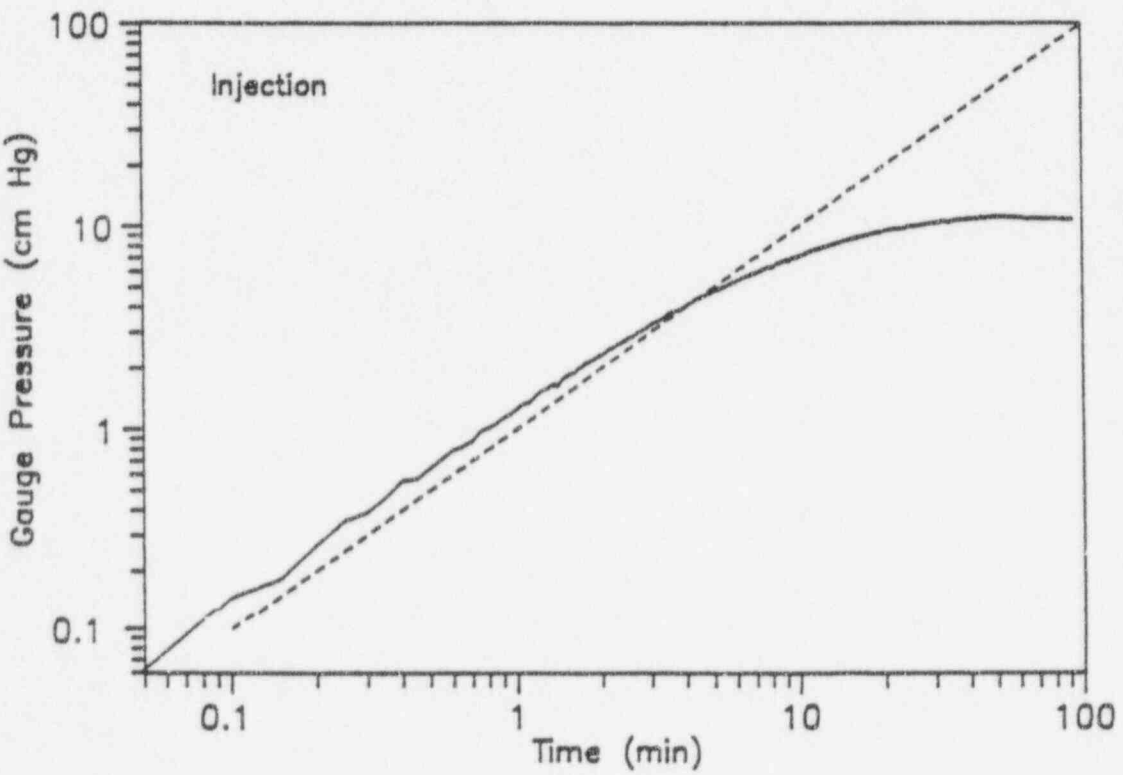

Y2-JH5
08-26-91
I: Q=1000 R: Q=2500 sccm
Recovery
Gauge Pressure (cm Hg)
80.0
60.0
40.0
20.0
0.0
10
100
1000
$t_r = t/(t-t_i)$
Injection
Gauge Pressure (cm Hg)
100
10
1
0.1
0.1
1
10
100
Time (min)

INJECTION TEST
Y2-JK6
09-17-91

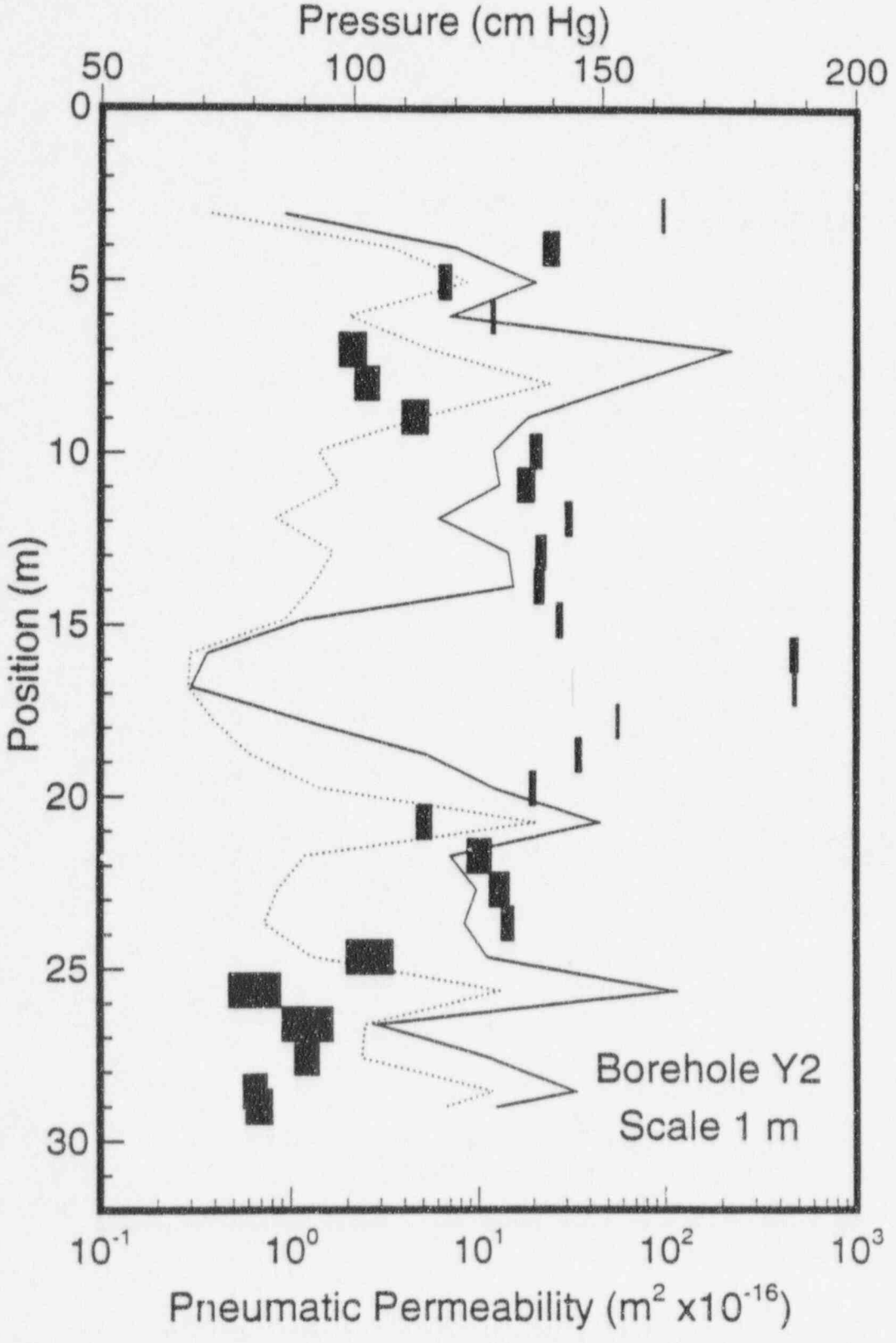


Y2-JK6
09-17-91
I: Q=100; R: Q=850 sccm

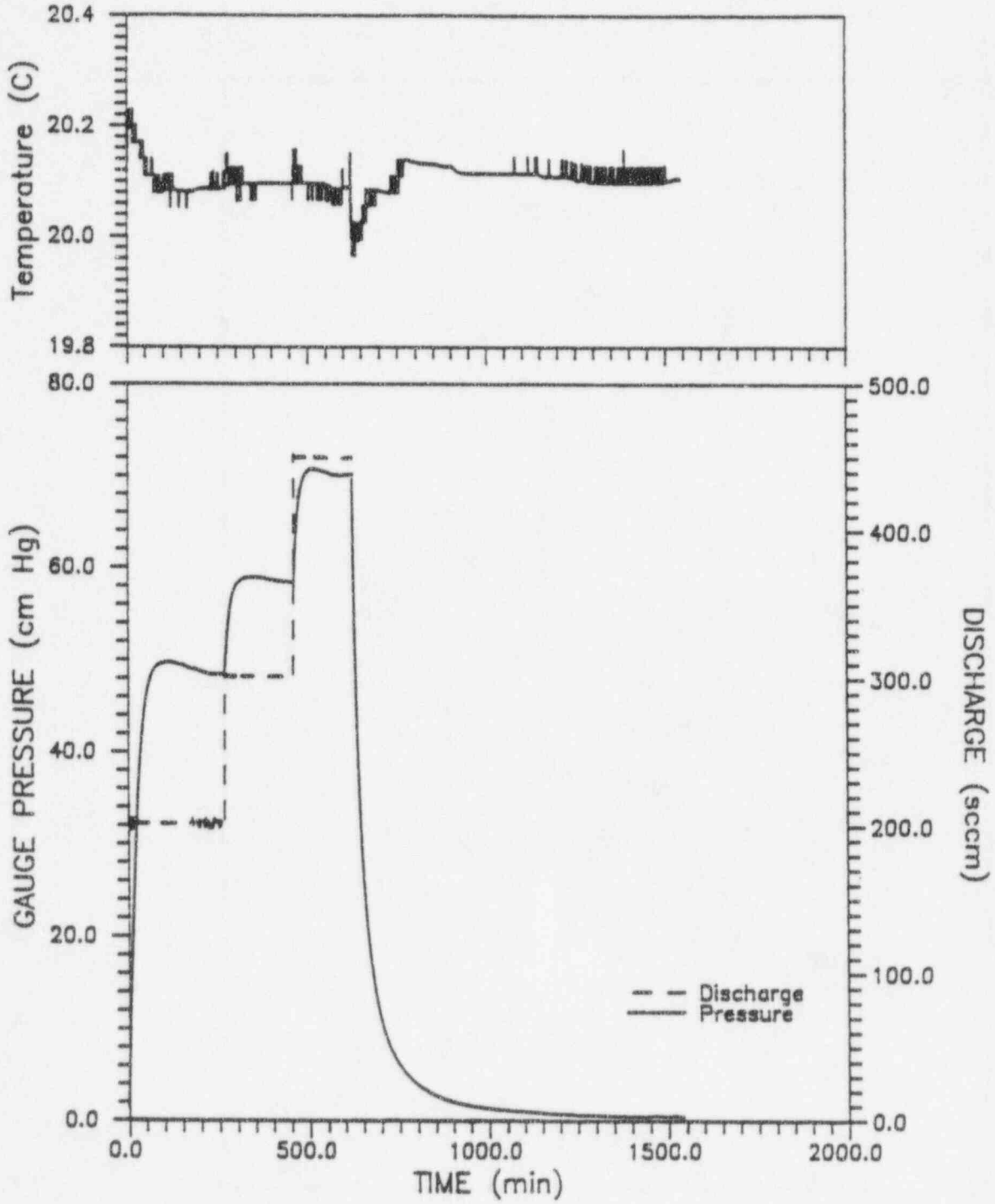


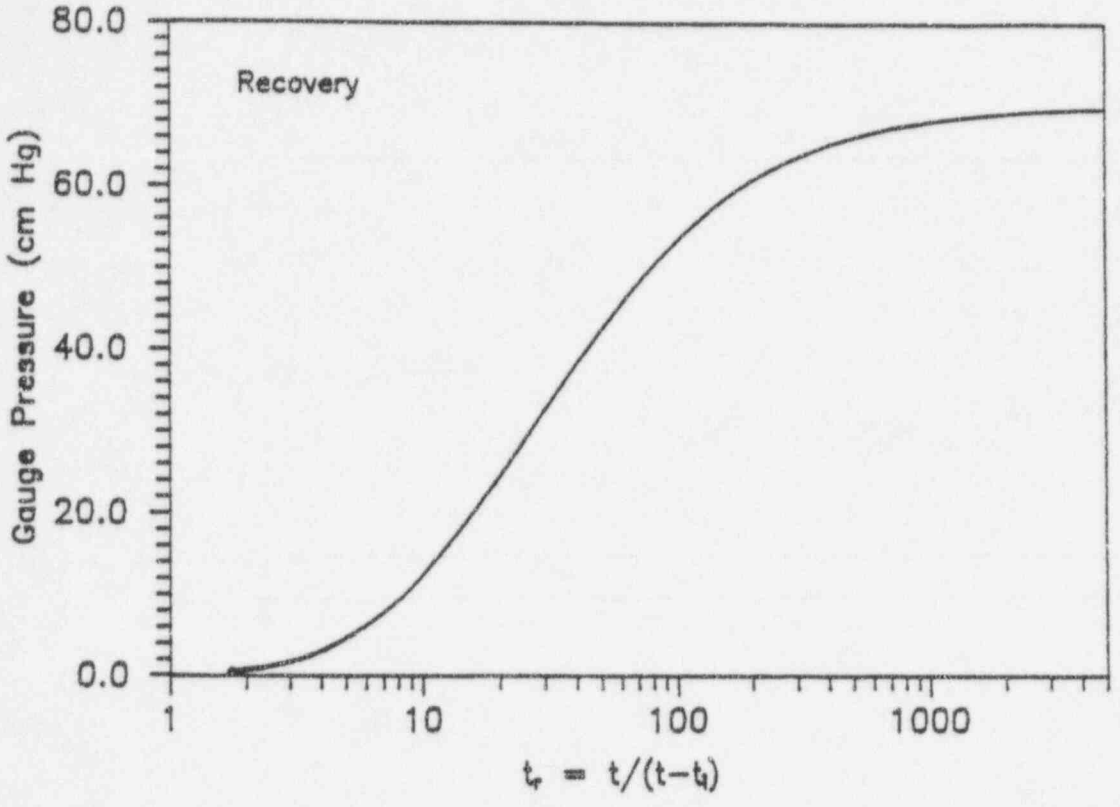


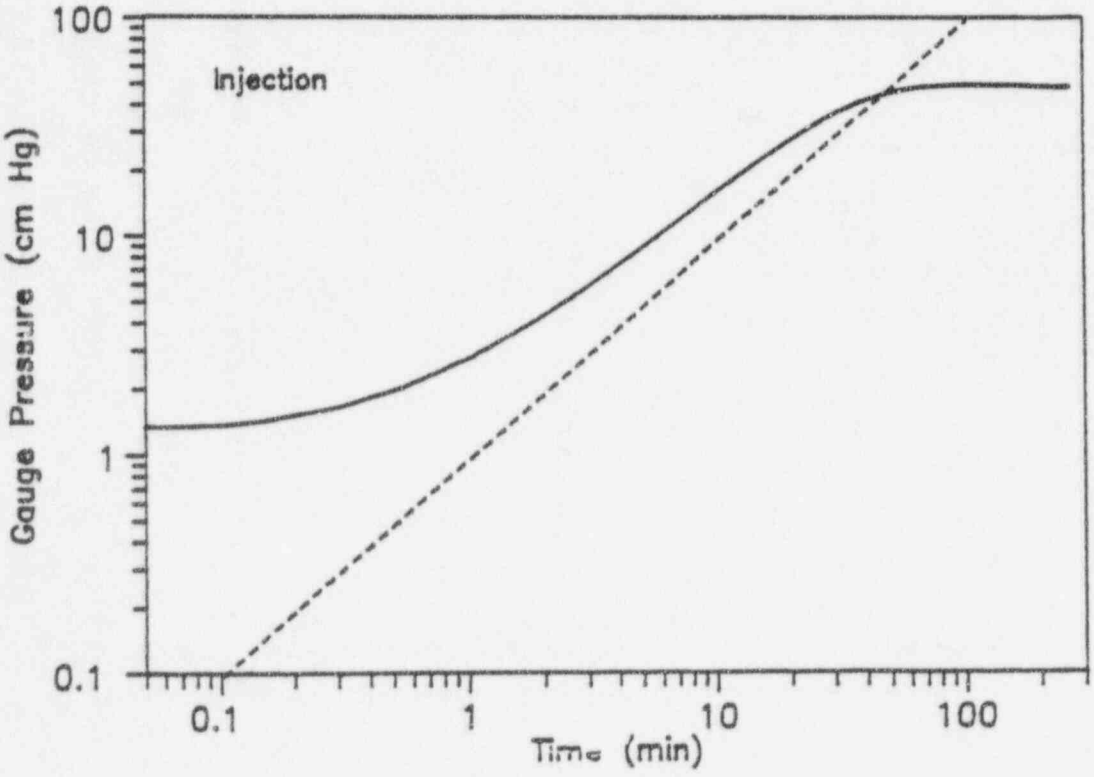
Graphs from Table B.6 Y2 - 1.0 m Data


Pressure (cm Hg)
50
100
150
200
0
5
10
15
20
25
30
Position (m)
Borehole Y2
Scale 1 m
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
Pneumatic Permeability (m^2 x10^{-16})

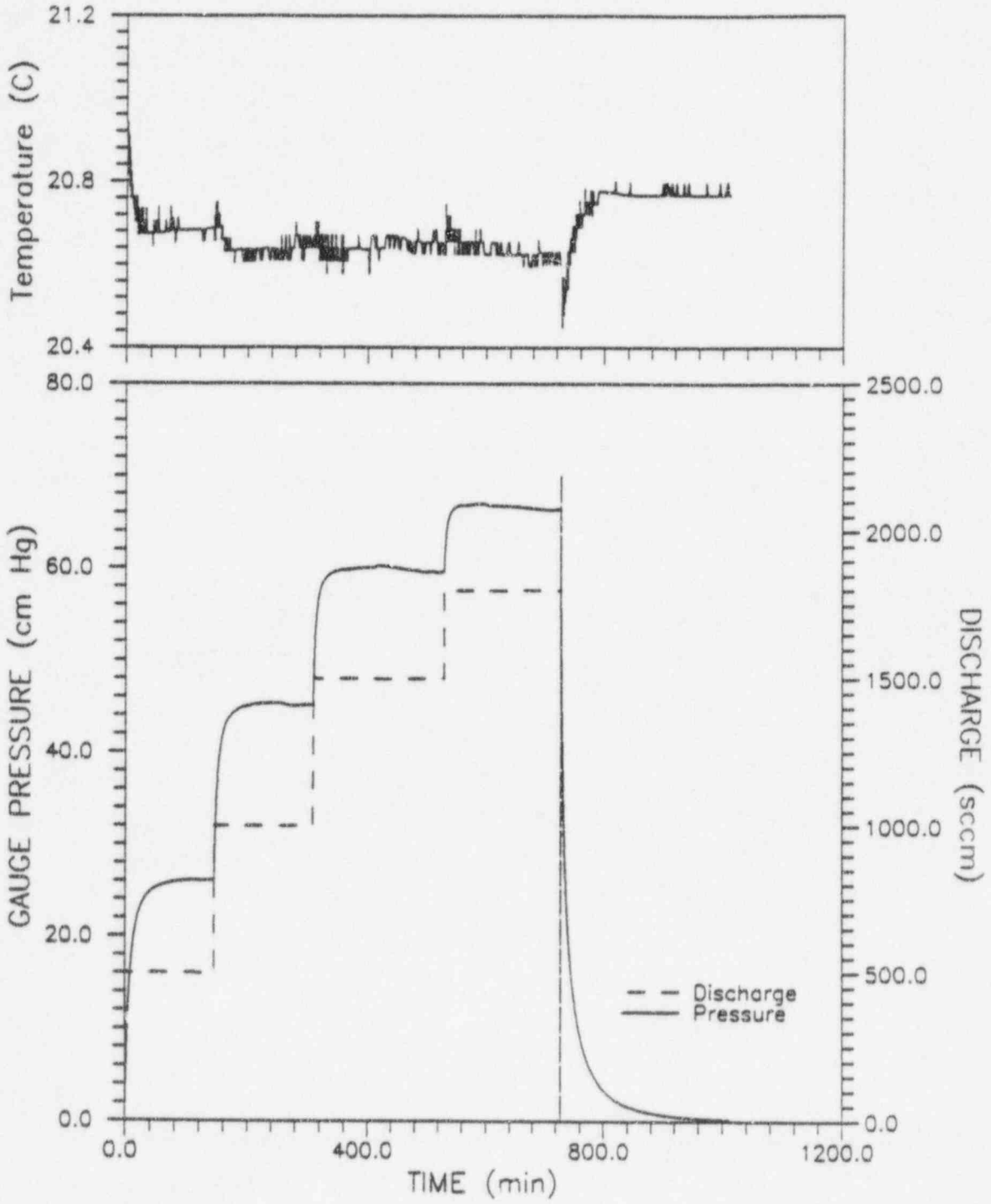
INJECTION TEST
Y2-jfa
05-20-92

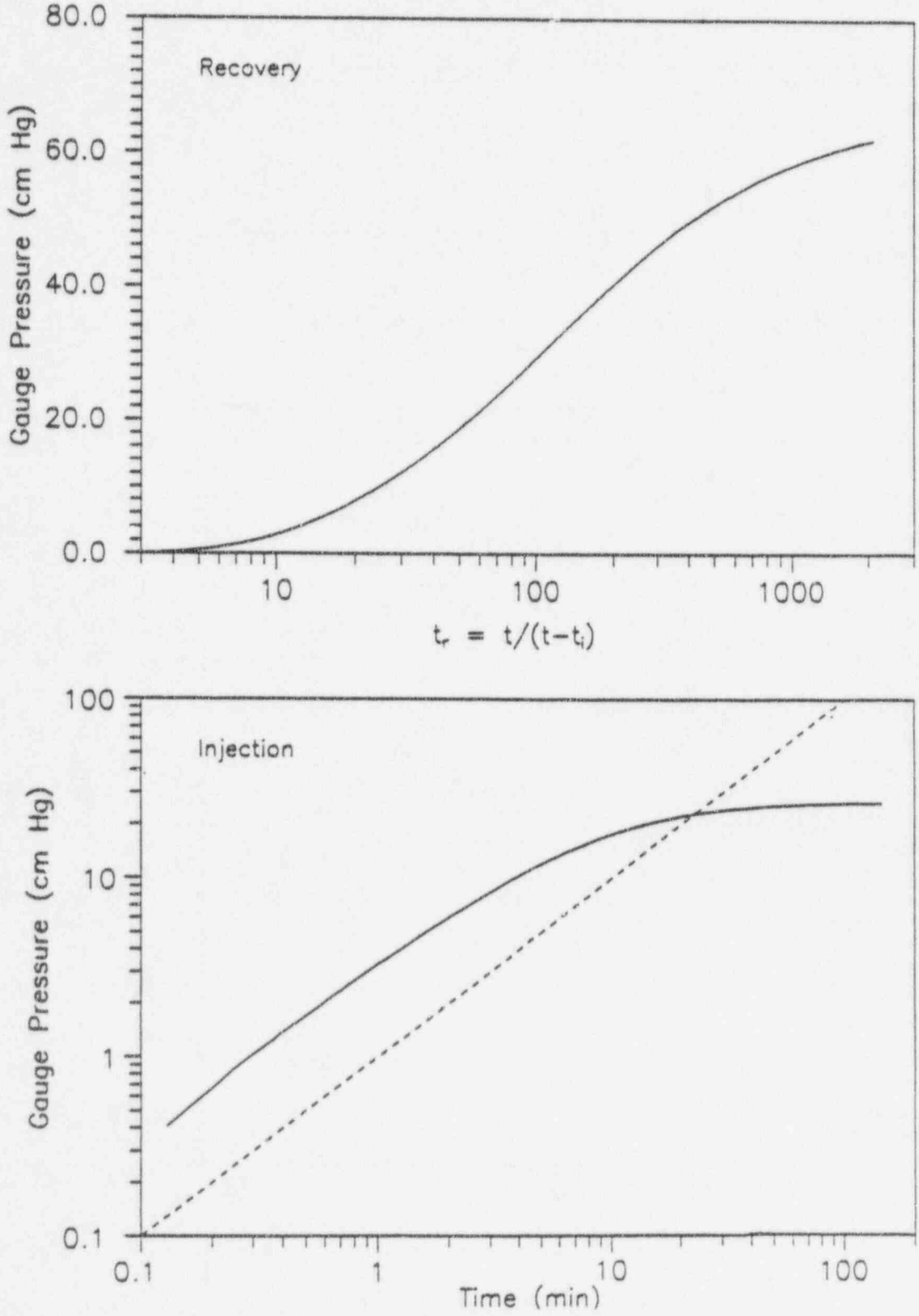



Y2-JFA
05-20-92
I: Q=200; R: Q=450 sccm
Recovery
Gauge Pressure (cm Hg)
80.0
60.0
40.0
20.0
0.0
1
10
100
1000
$t_r = t/(t-t_i)$

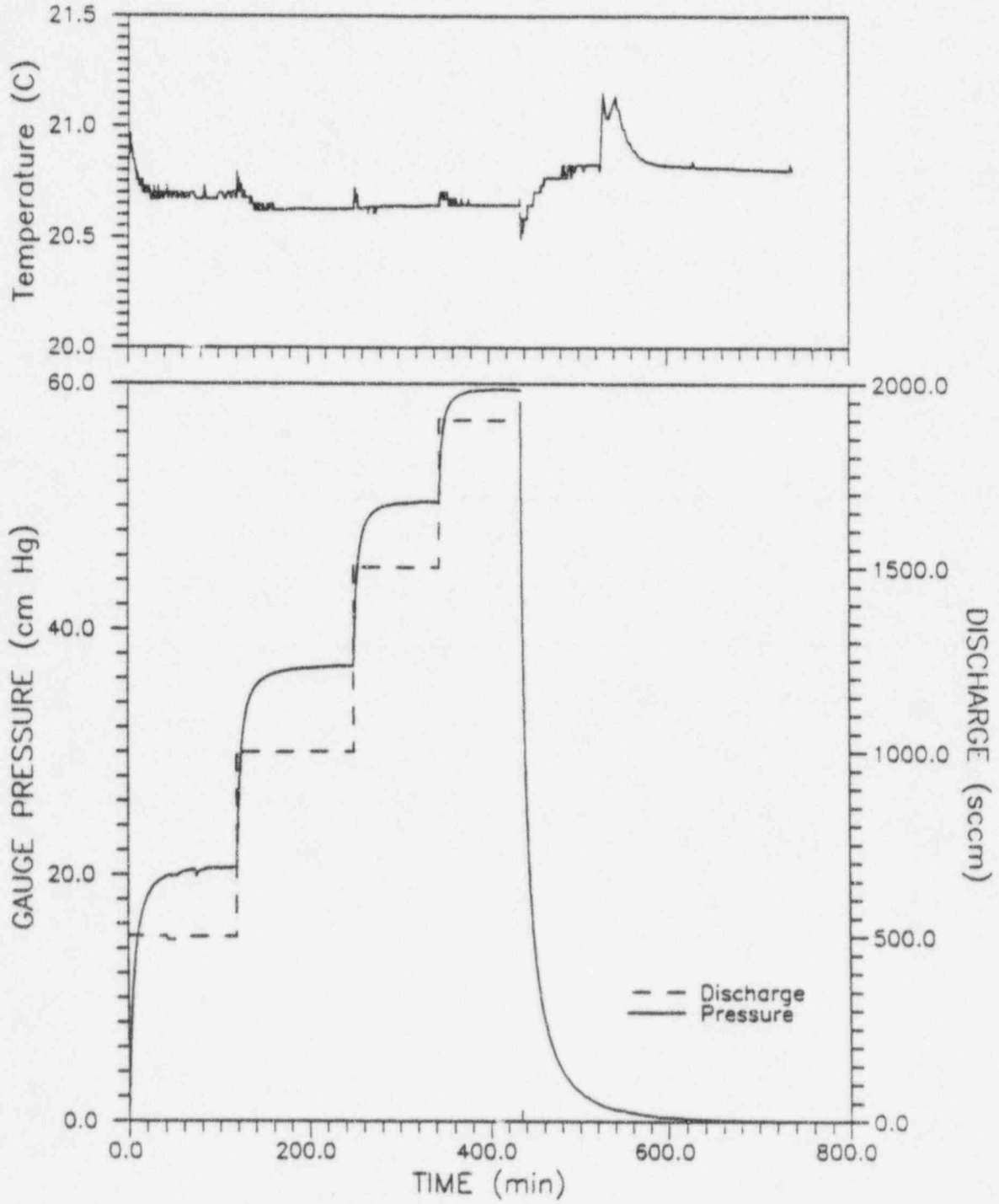

Injection
Gauge Pressure (cm Hg)
100
10
1
0.1
0.1
1
10
100
Time (min)

INJECTION TEST
Y2-JGC
06-09-92

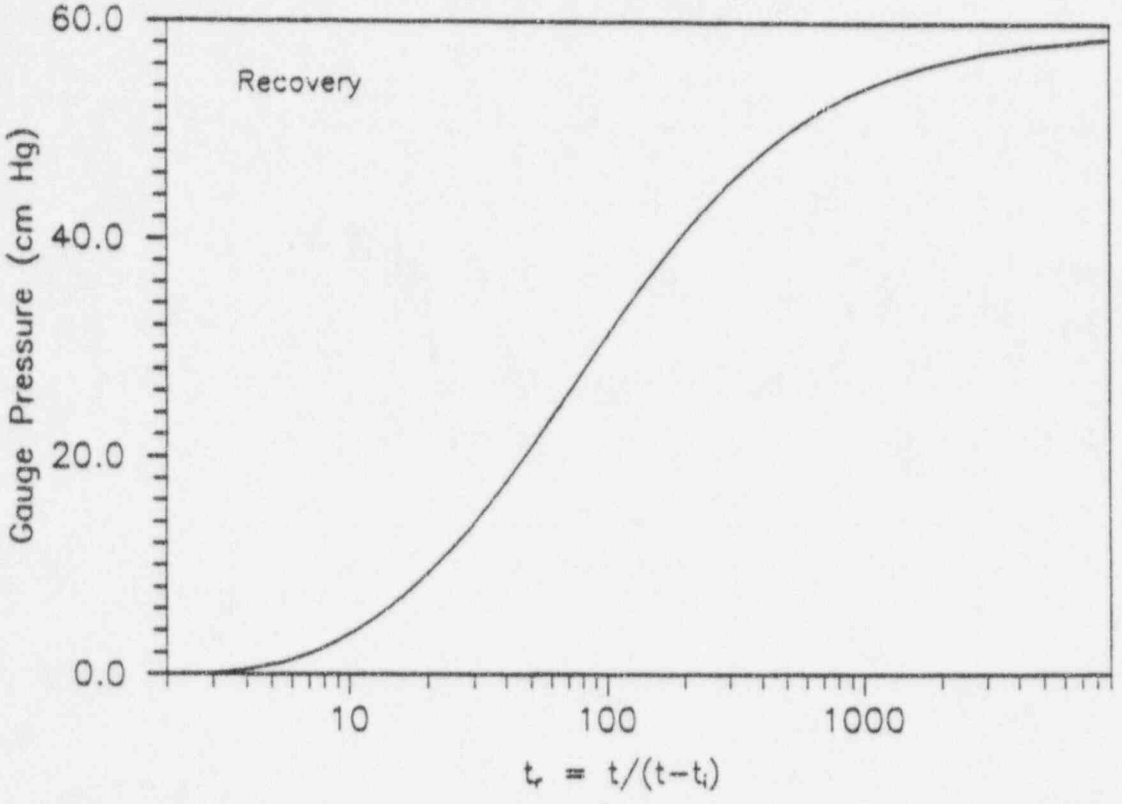


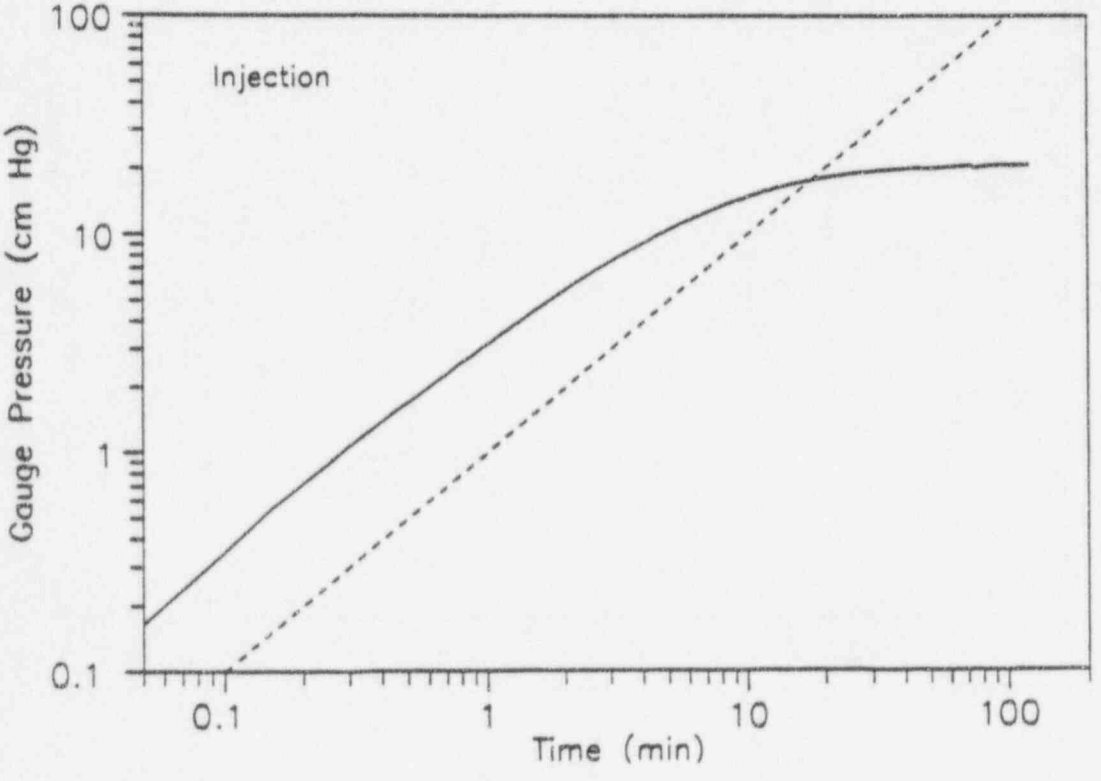

Y2-JGC
06-09-92
I: Q=500; R: Q= sccm
Recovery
Gauge Pressure (cm Hg)
80.0
60.0
40.0
20.0
0.0
10
100
1000
$t_r = t/(t-t_i)$
Injection
Gauge Pressure (cm Hg)
100
10
1
0.1
0.1
1
10
100
Time (min)

INJECTION TEST
Y2-JHA
06-11-92

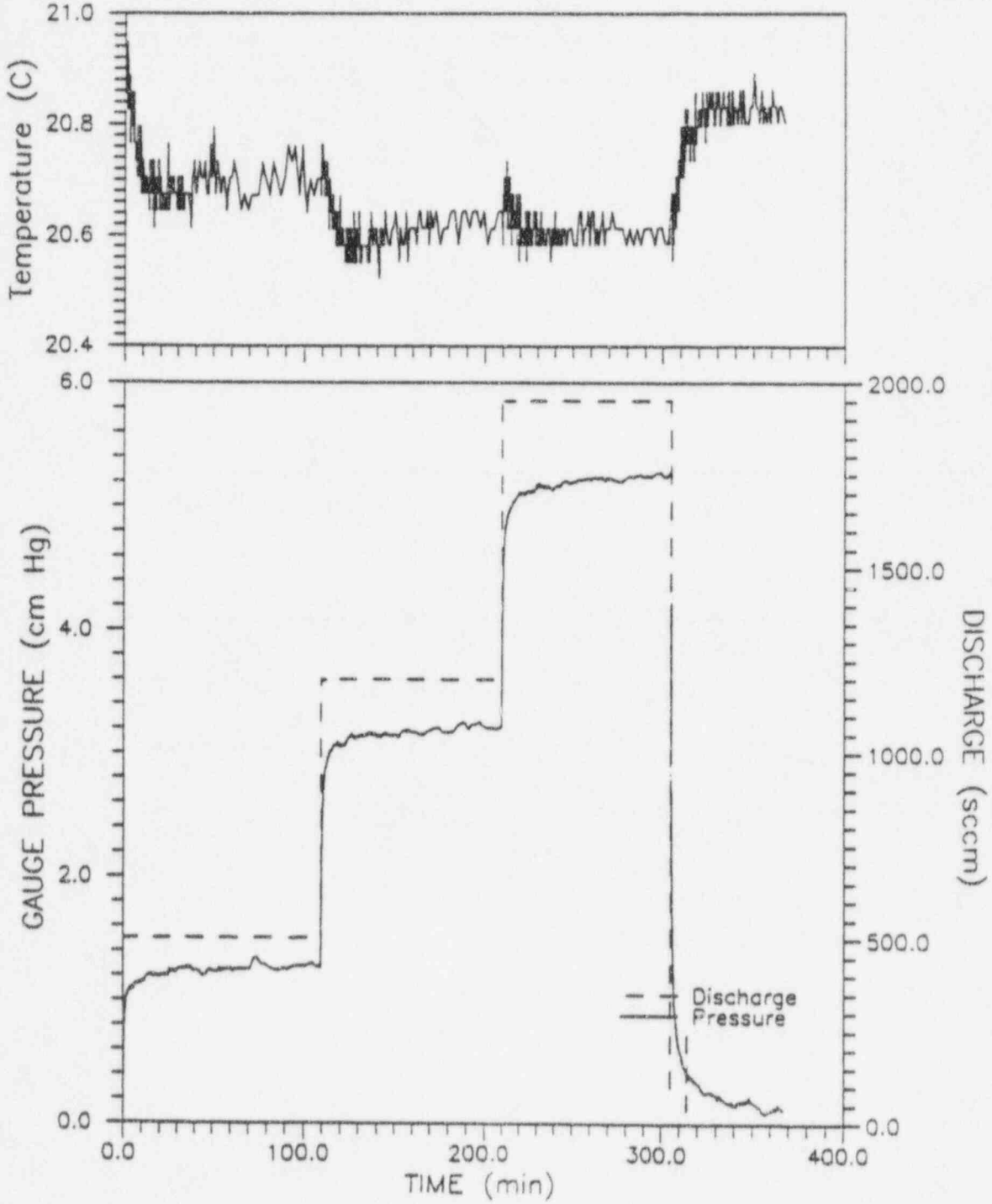


Y2-JHA
06-11-92
I: Q=500; R: Q= sccm

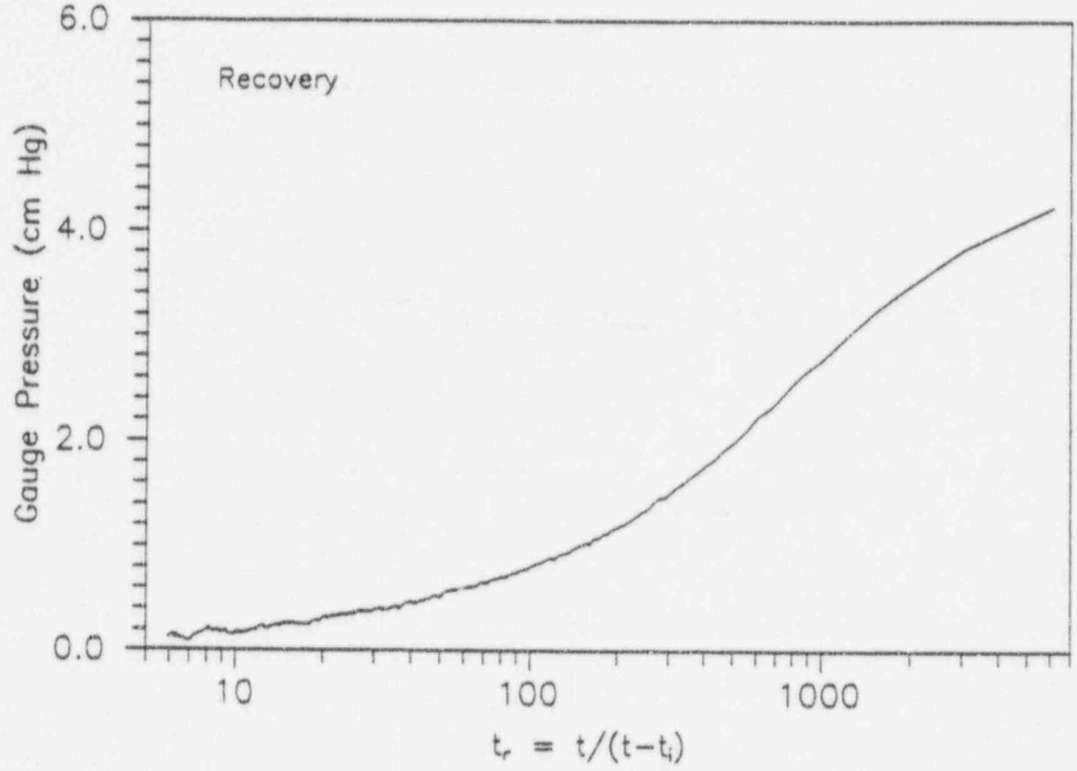


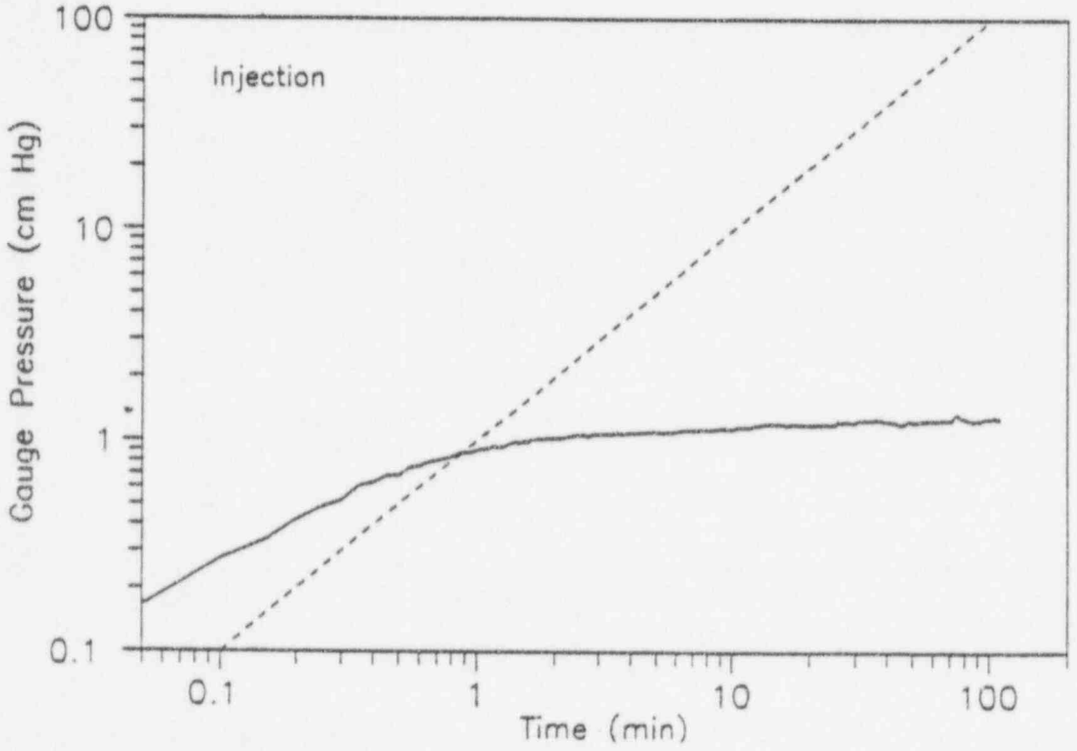


INJECTION TEST
Y2-JHB
06-12-92

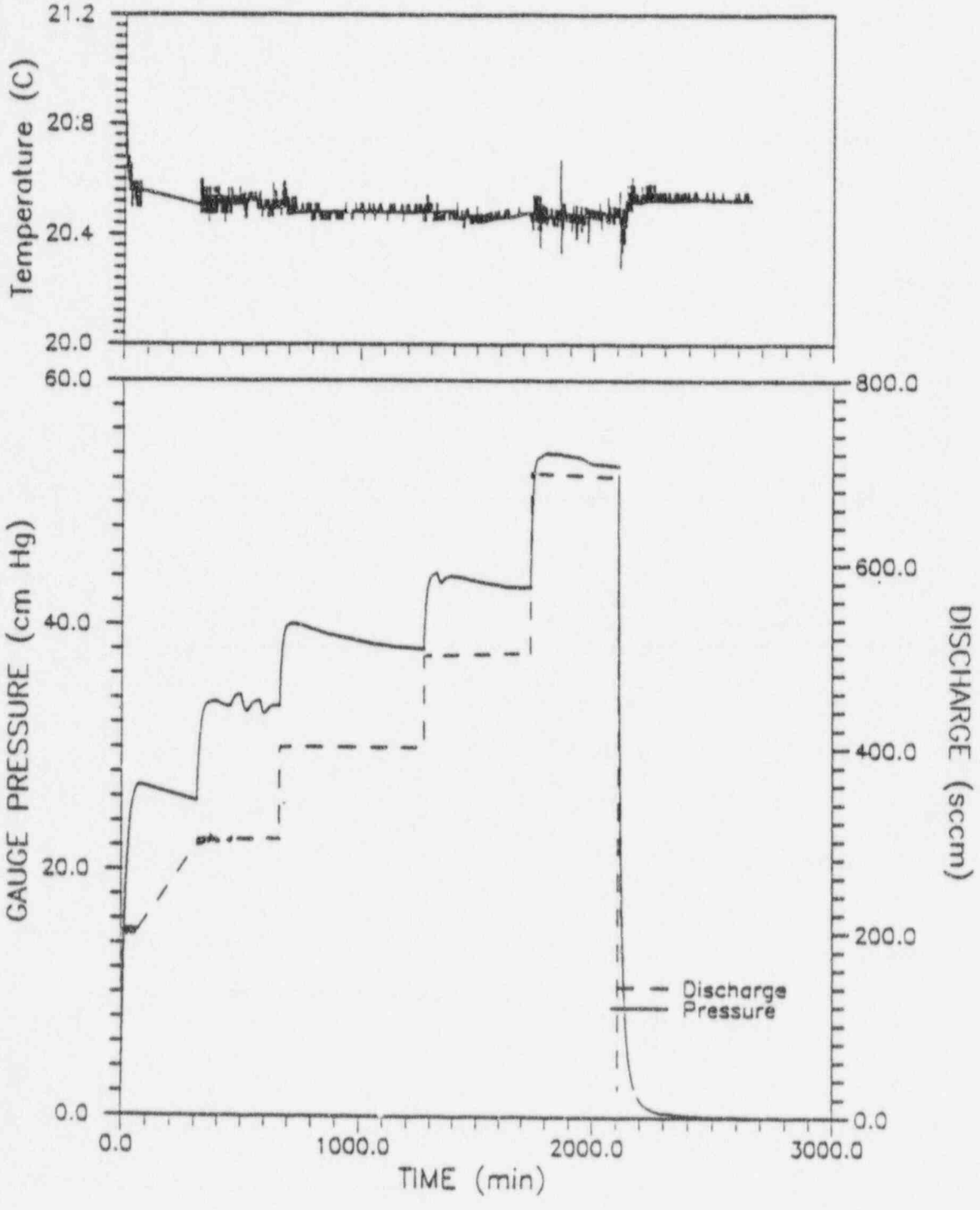


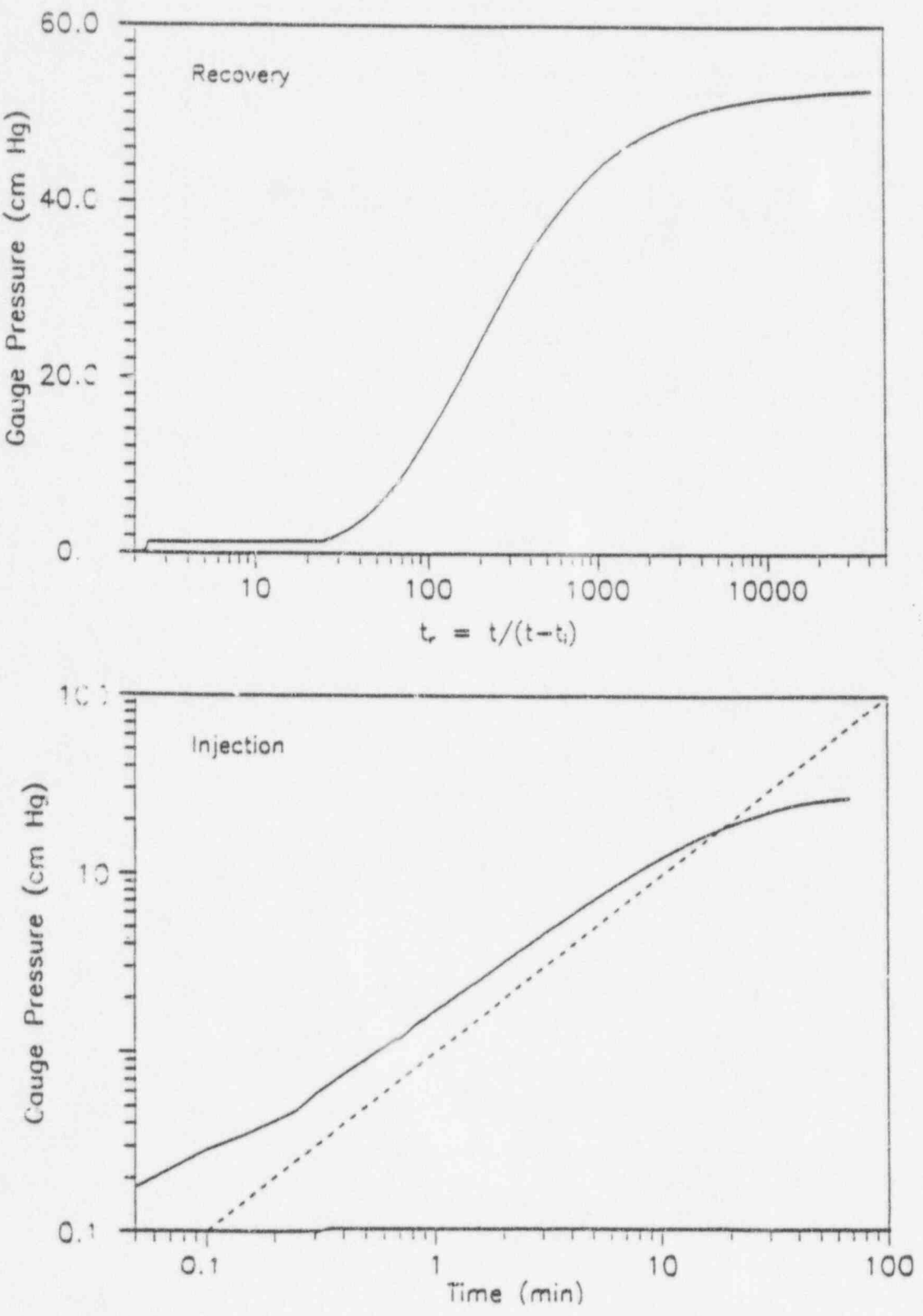
Y2-JHB
06-12-92
I: Q=500; R: Q= sccm



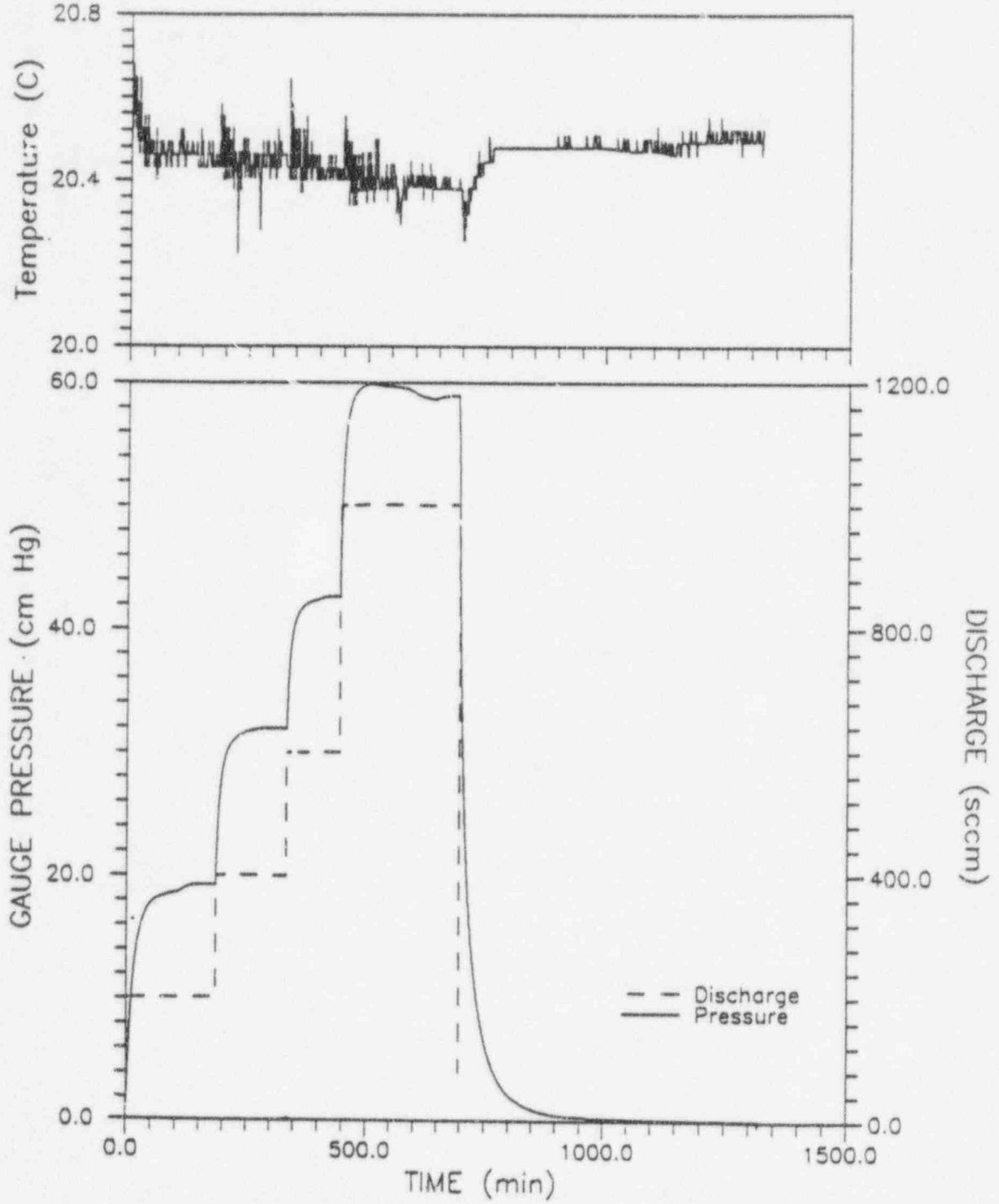


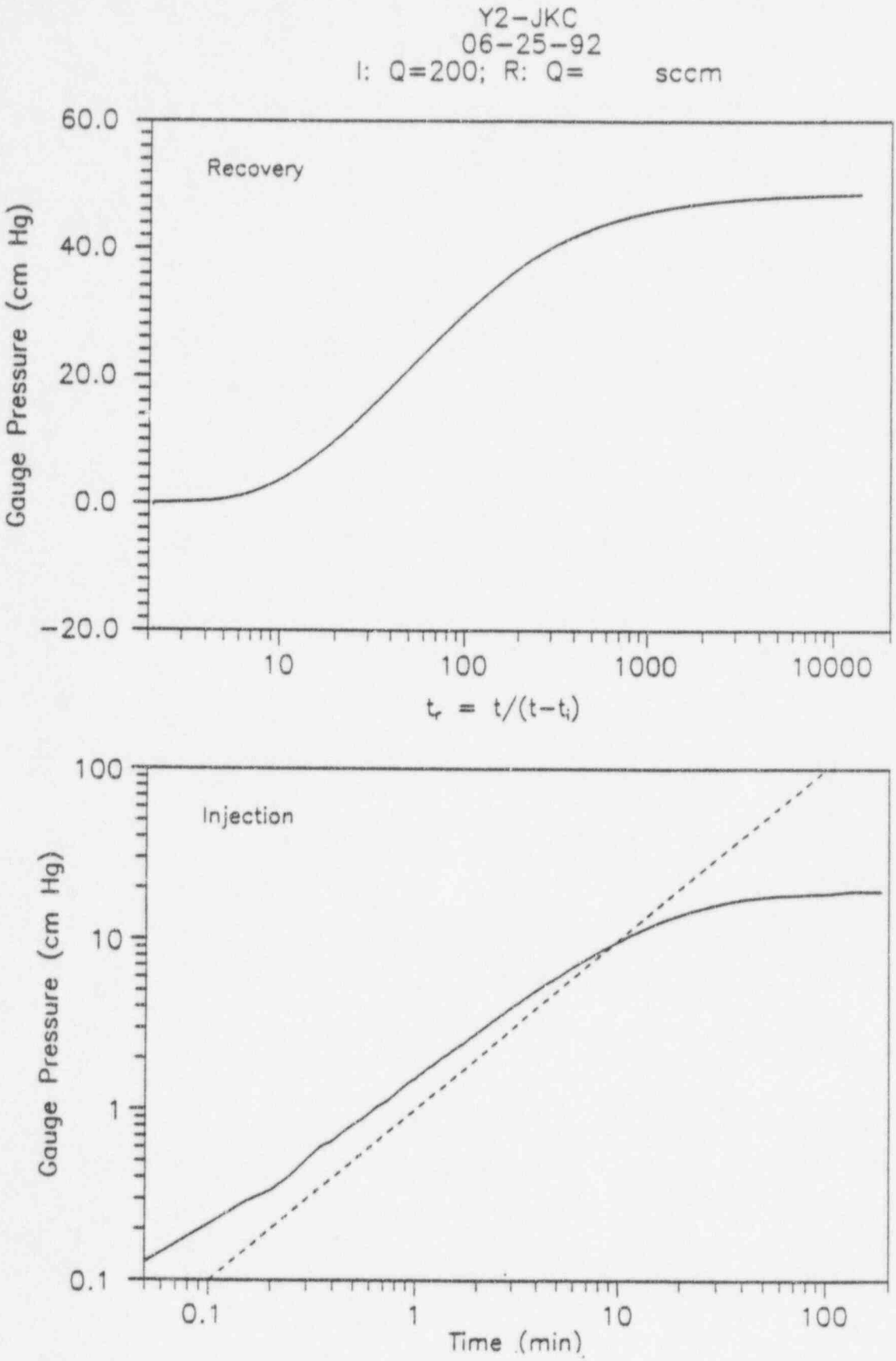
INJECTION TEST
Y2-JKb
06-23-92



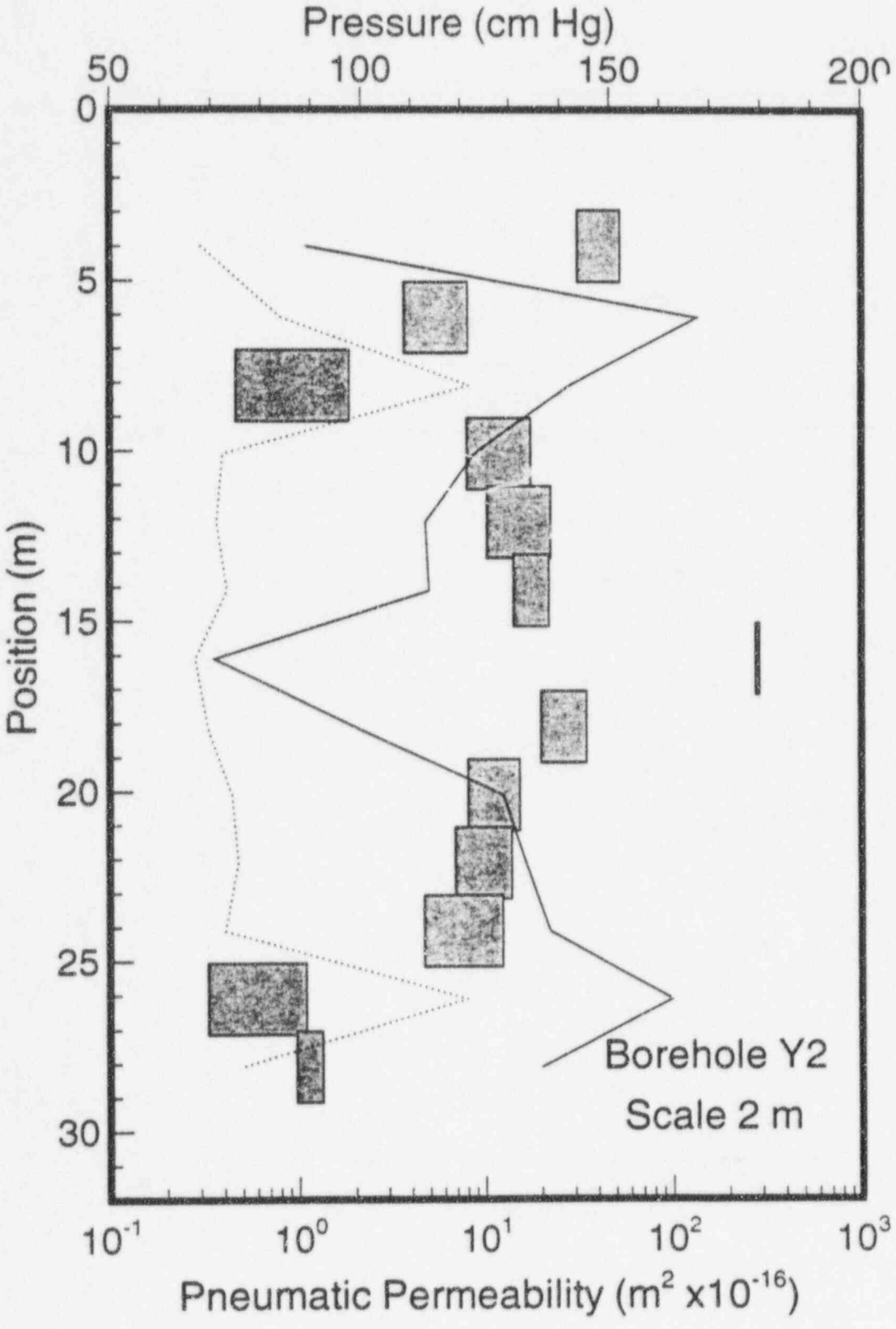

Y2-JKB
06-23-92
I: Q=200; R: Q= sccm
Recovery
Gauge Pressure (cm Hg)
60.0
40.0
20.0
0
10
100
1000
10000
t* = t/(t-ti)
Injection
Gauge Pressure (cm Hg)
10
0.1
0.1
1
10
100
Time (min)

INJECTION TEST
Y2-JKC
06-25-92

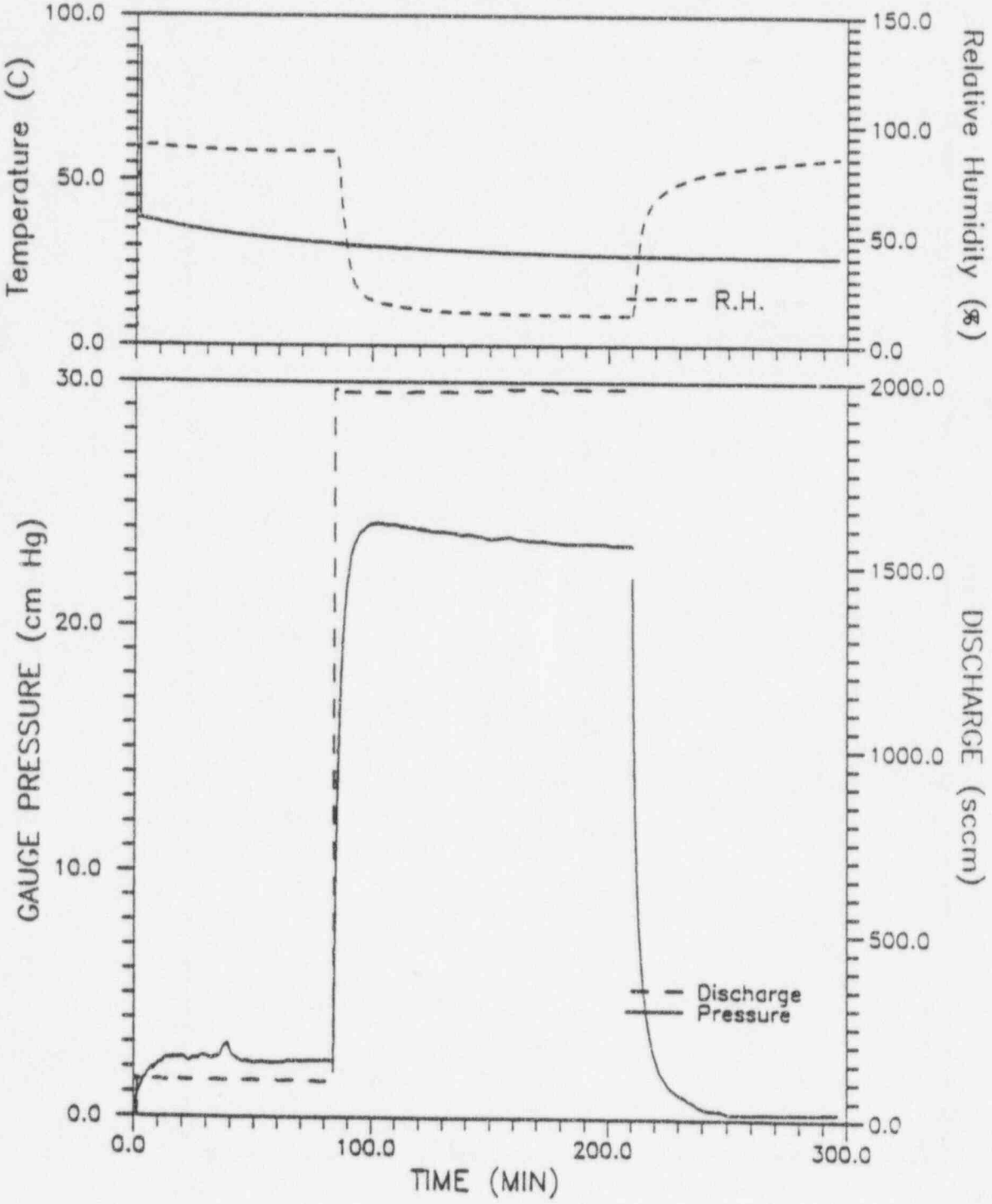



Y2-JKC
06-25-92
I: Q=200; R: Q= sccm
Recovery
Gauge Pressure (cm Hg)
60.0
40.0
20.0
0.0
-20.0
10
100
1000
10000
$t_r = t/(t-t_i)$
Injection
Gauge Pressure (cm Hg)
100
10
1
0.1
0.1
1
10
100
Time (min)

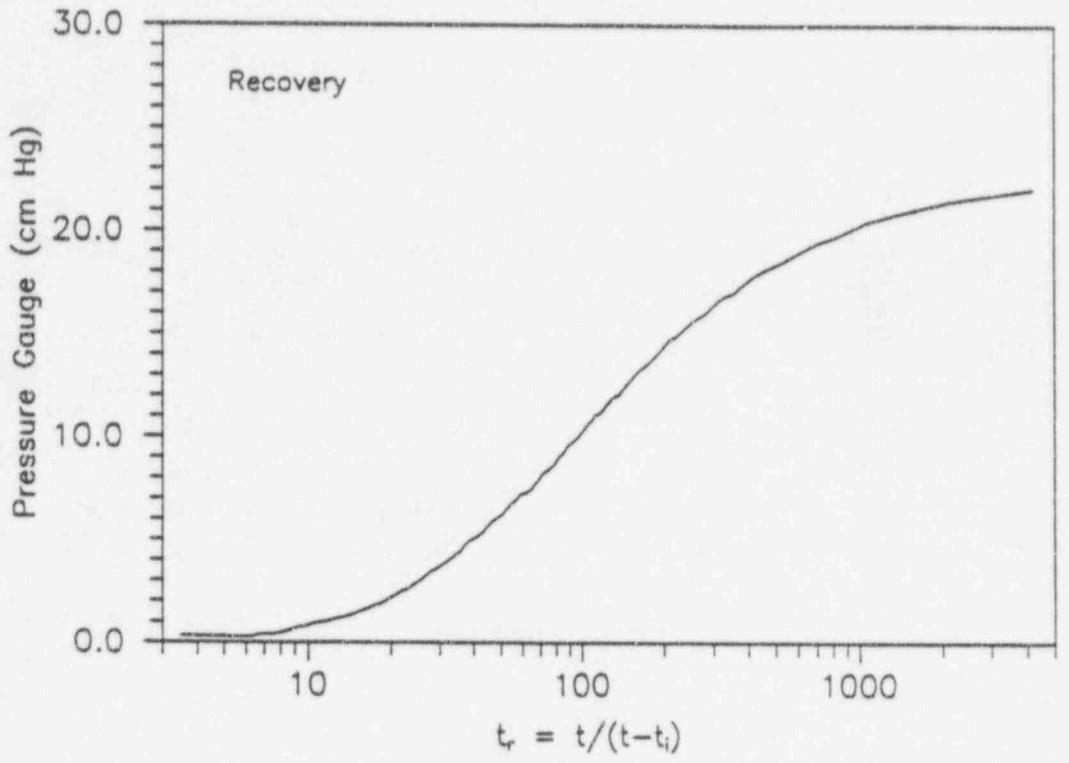
Graphs from Table B.7 Y2 - 2.0 m Data

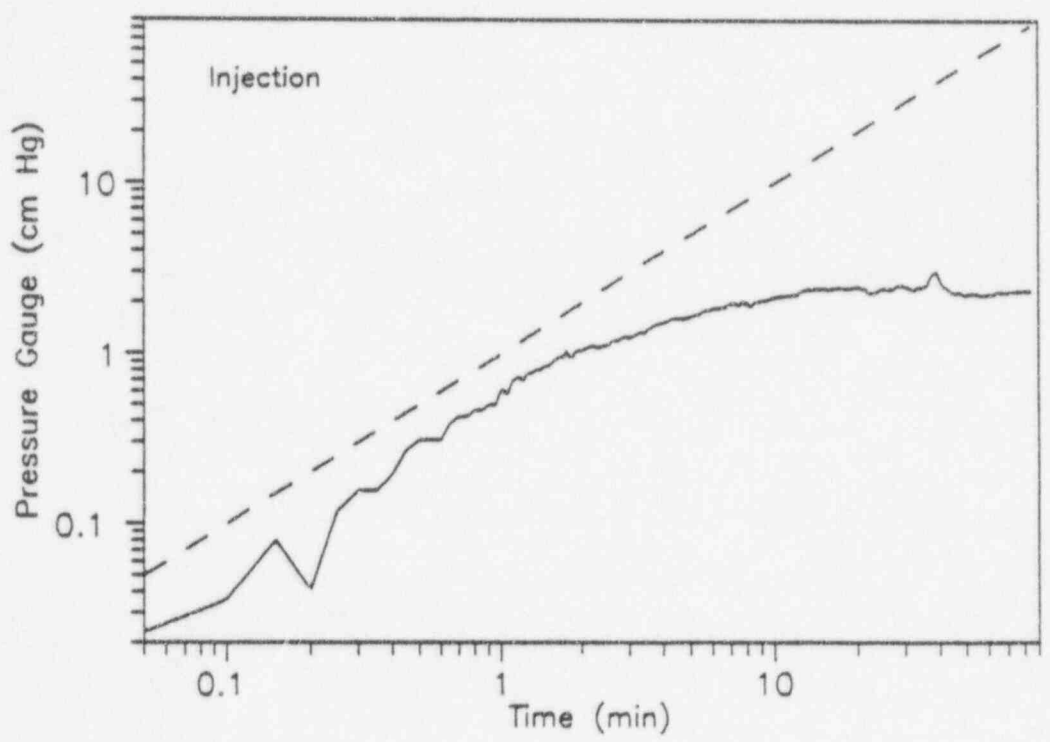

Pressure (cm Hg)
50
100
150
200
0
5
10
15
20
25
30
Position (m)
Borehole Y2
Scale 2 m
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
Pneumatic Permeability (m^2 x10^{-16})

INJECTION TEST
Y2-JA
09-02-94

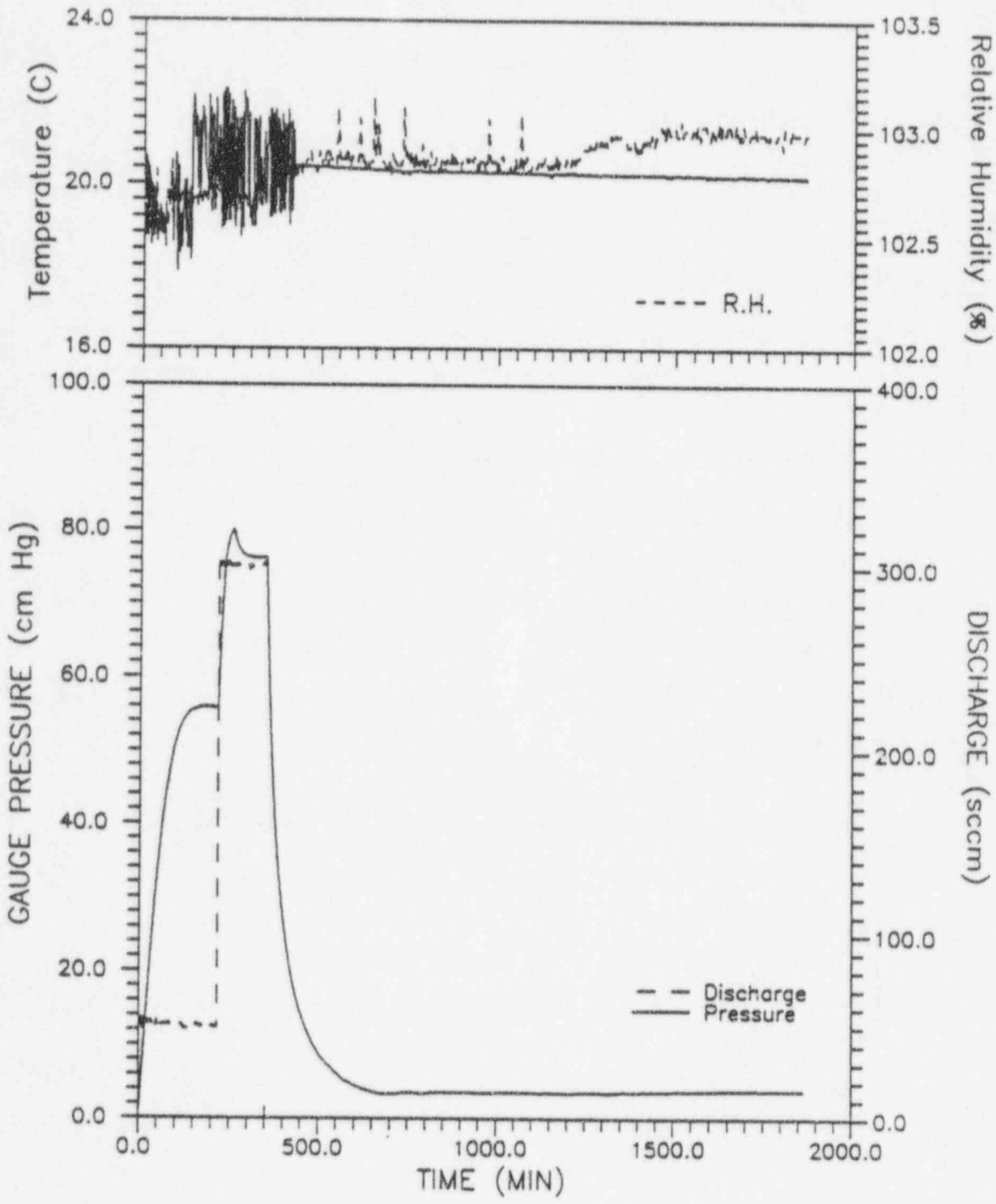


Y2-JA
09-02-94
I: Q=100 sccm; R: Q=2000

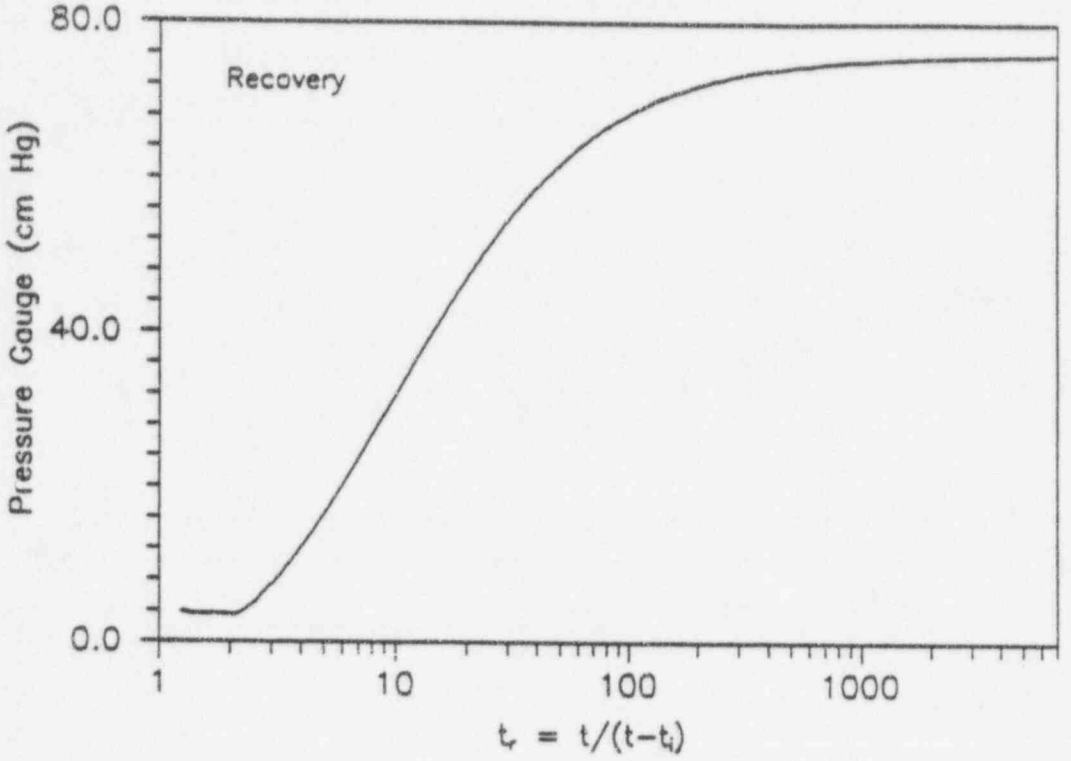


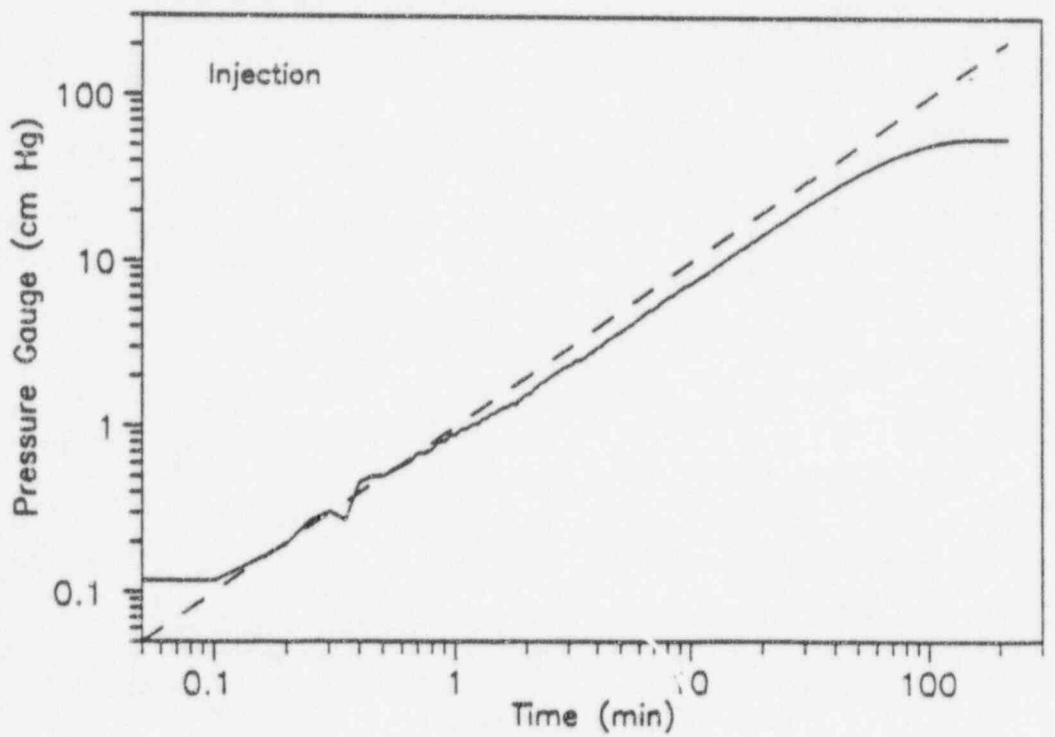


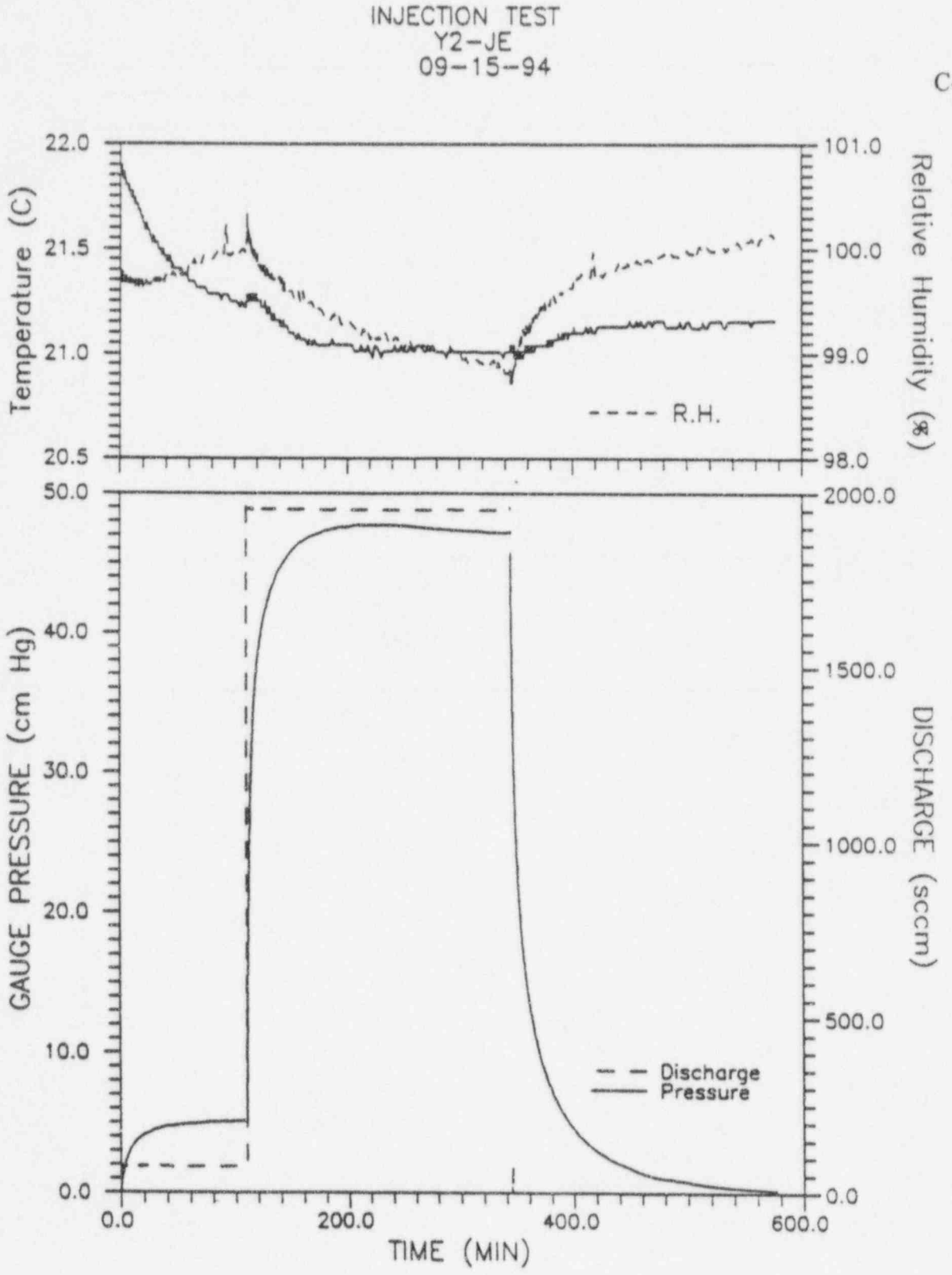
INJECTION TEST
Y2-JC
09-09-94



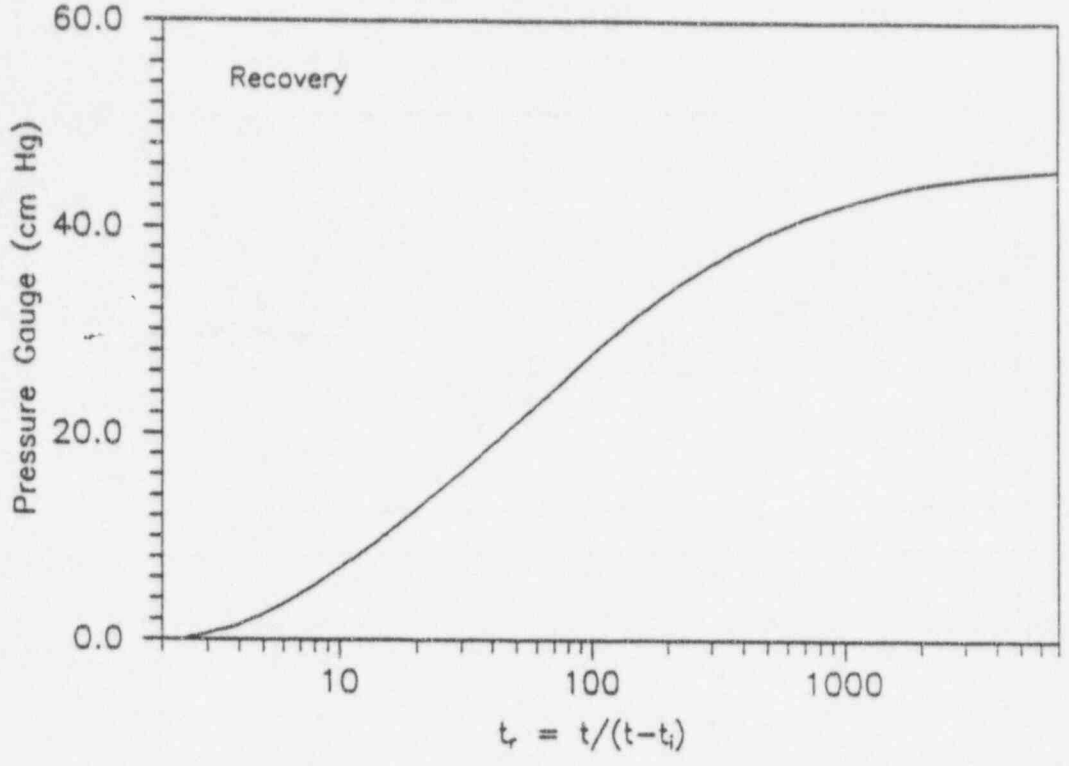
Y2-JC
09-09-94
I: Q=50 sccm; R: Q=300

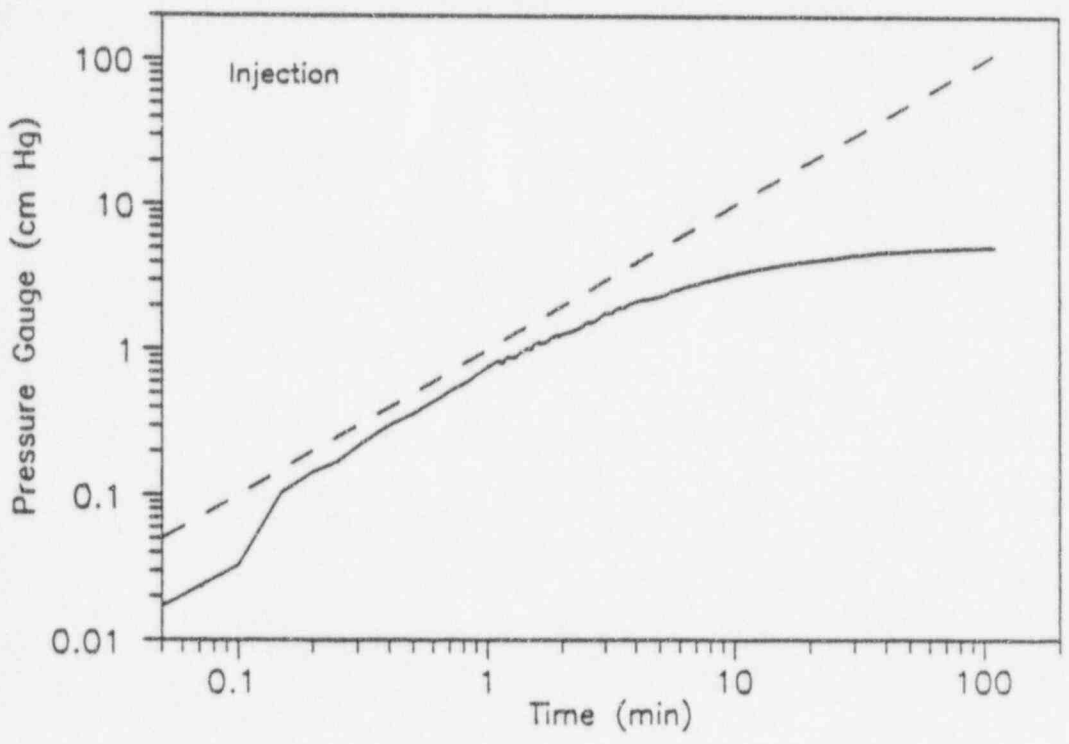




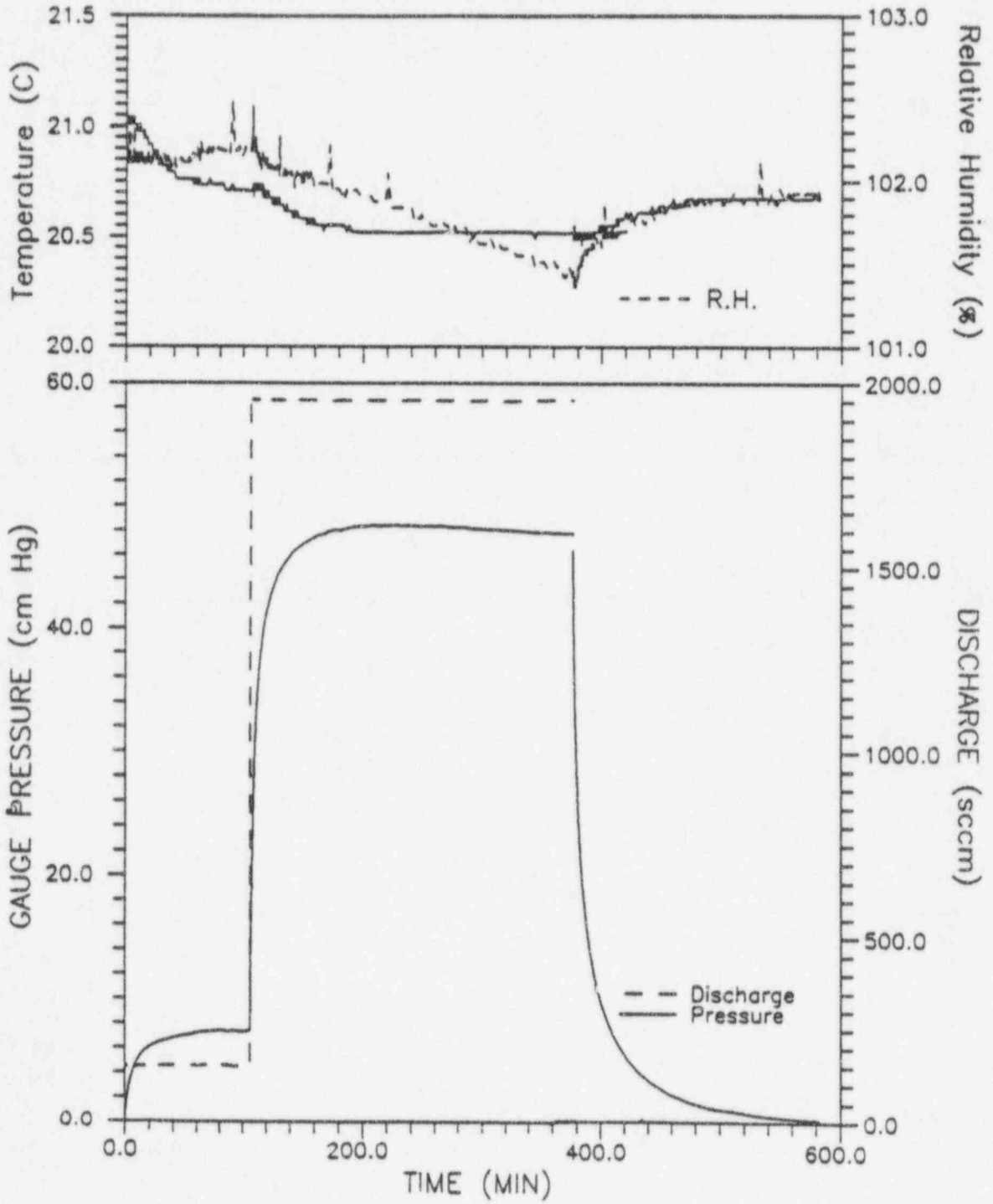

INJECTION TEST
Y2-JE
09-15-94
Temperature (C)
Relative Humidity (%)
R.H.
GAUGE PRESSURE (cm Hg)
DISCHARGE (sccm)
Discharge
Pressure
TIME (MIN)
22.0
21.5
21.0
20.5
101.0
100.0
99.0
98.0
50.0
40.0
30.0
20.0
10.0
0.0
2000.0
1500.0
1000.0
500.0
0.0
0.0
200.0
400.0
600.0

Y2-JE
09-15-94
I: Q=75 sccm; R: Q=2000

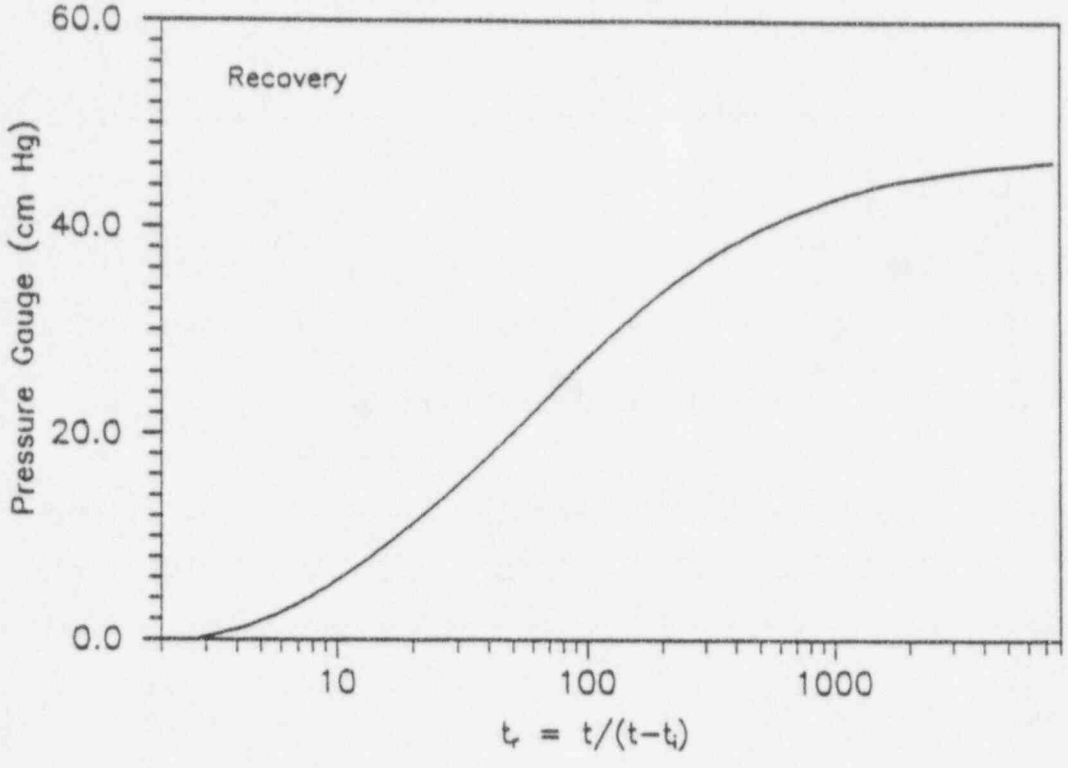


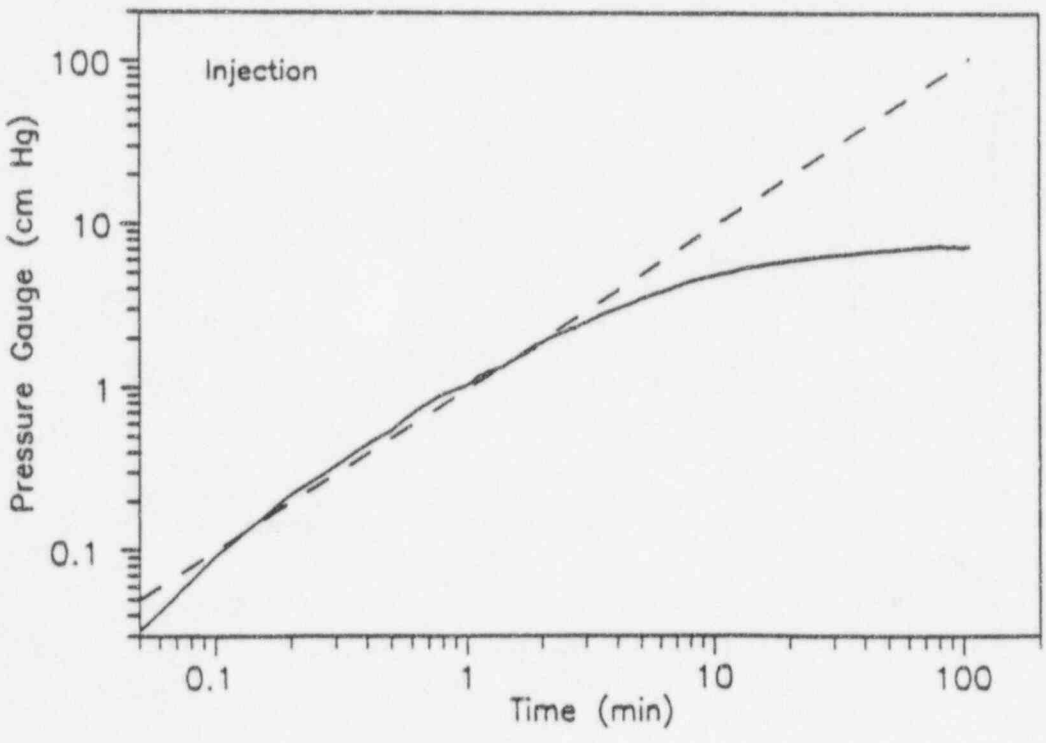


INJECTION TEST
Y2-JF
09-20-94

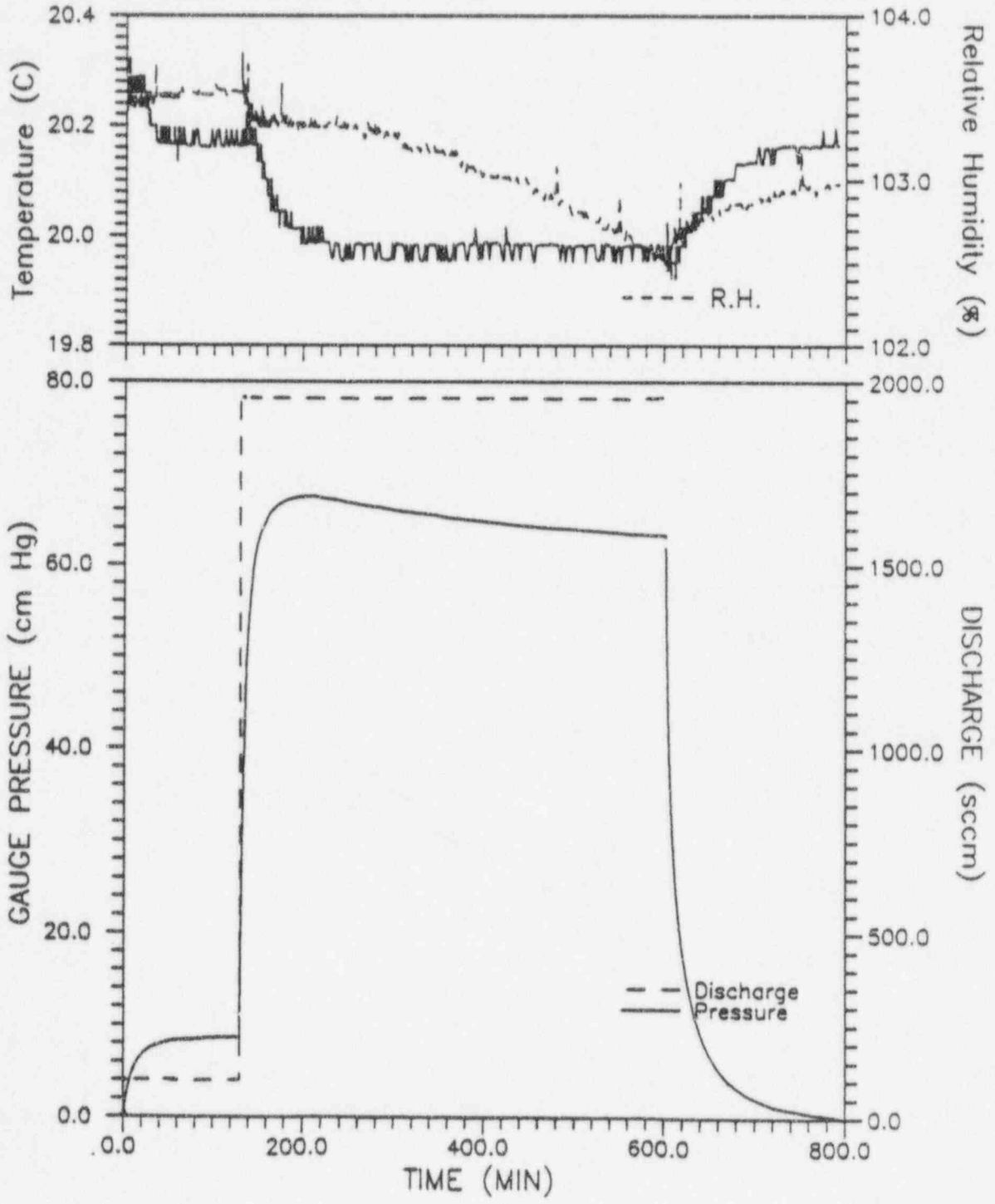


Y2-JF
09-20-94
I: Q=150 sccm; R: Q=2000

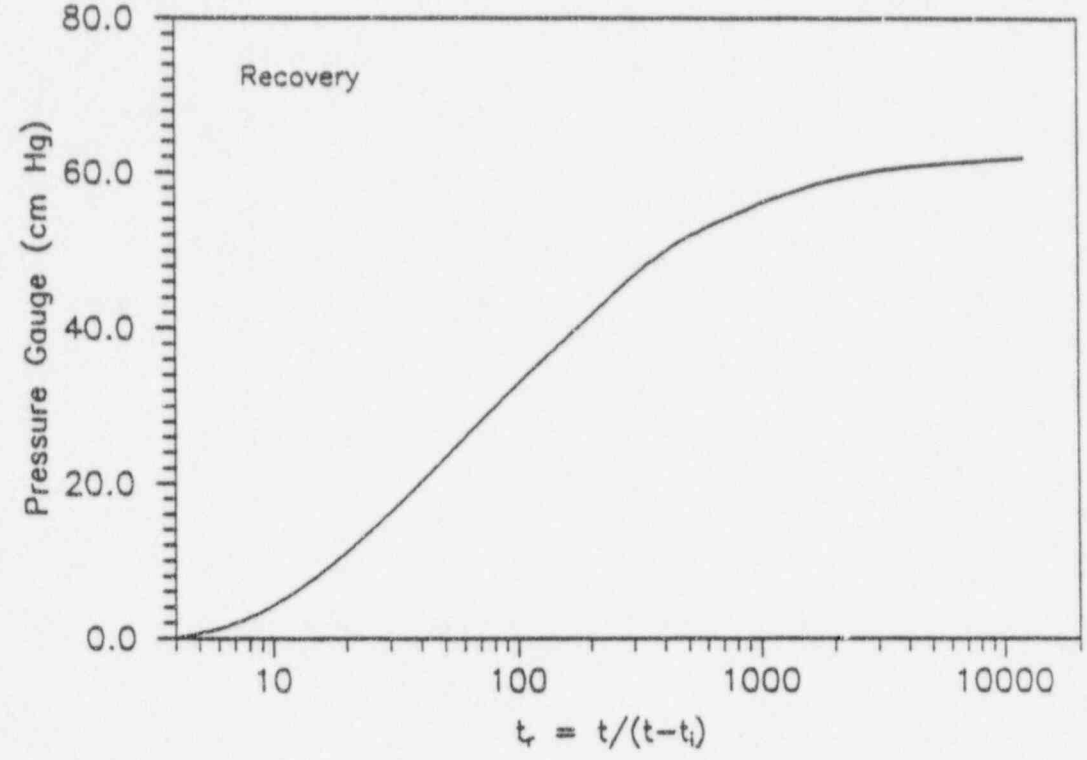


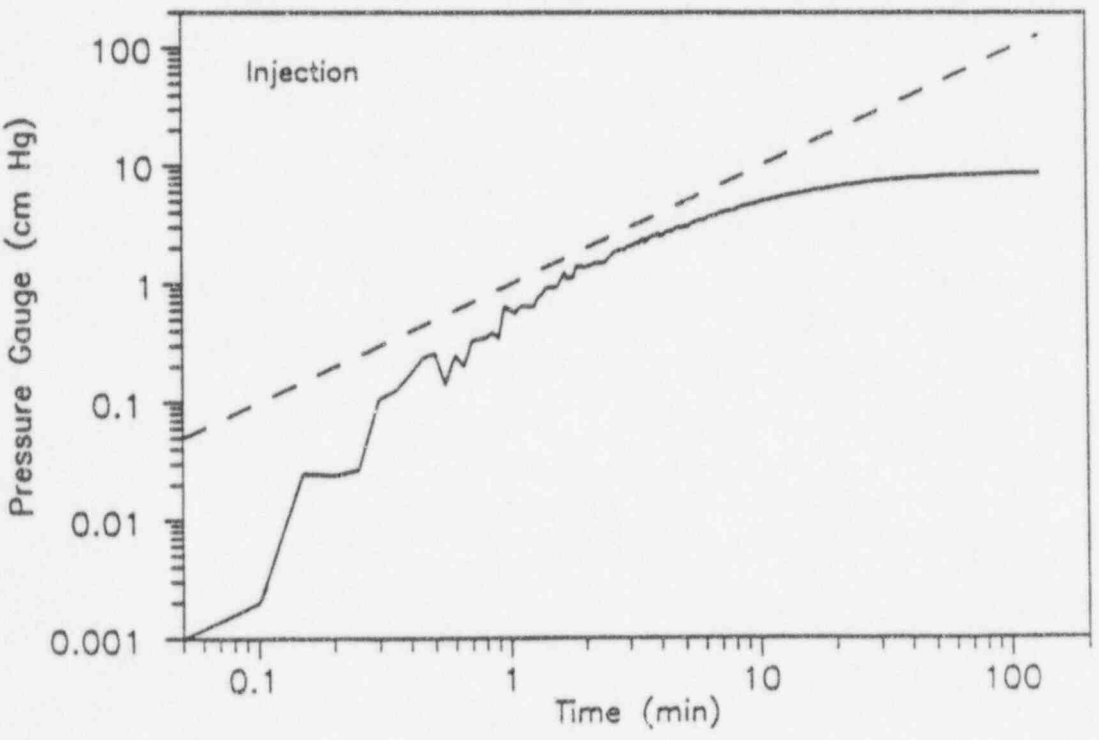


INJECTION TEST
Y2-JI
09-30-94

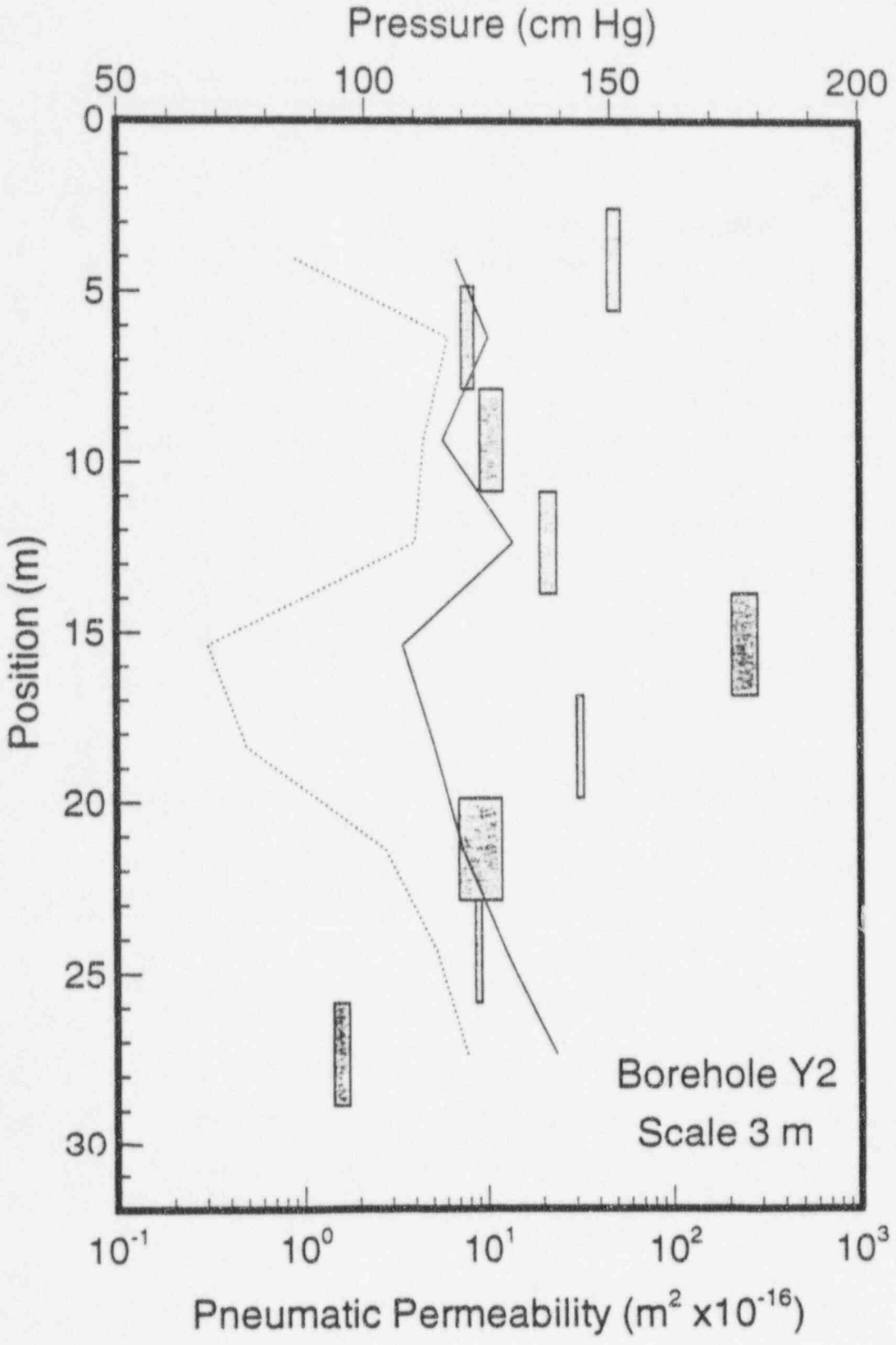


Y2-J1
09-30-94
I: Q=100 sccm; R: Q=2000

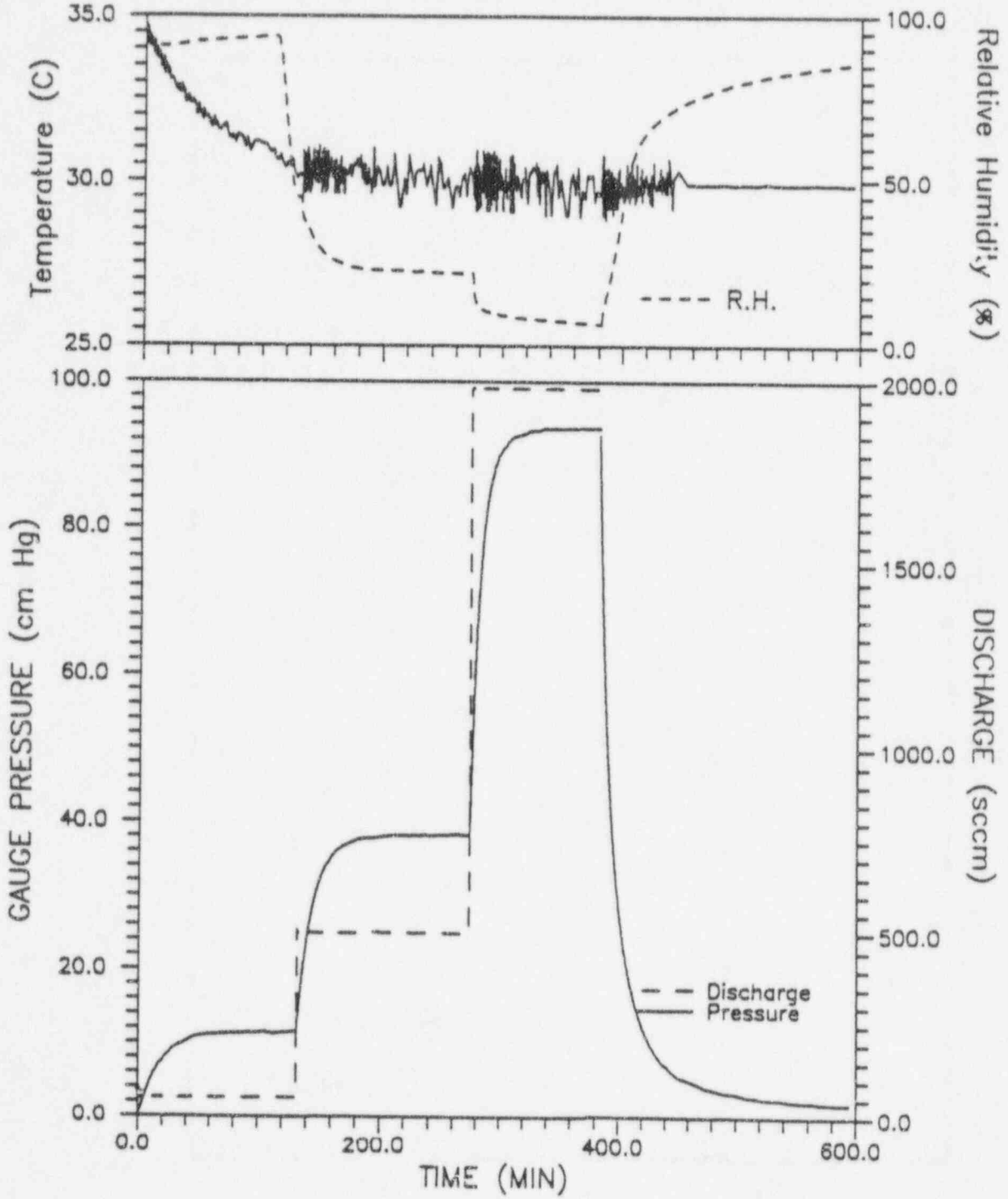




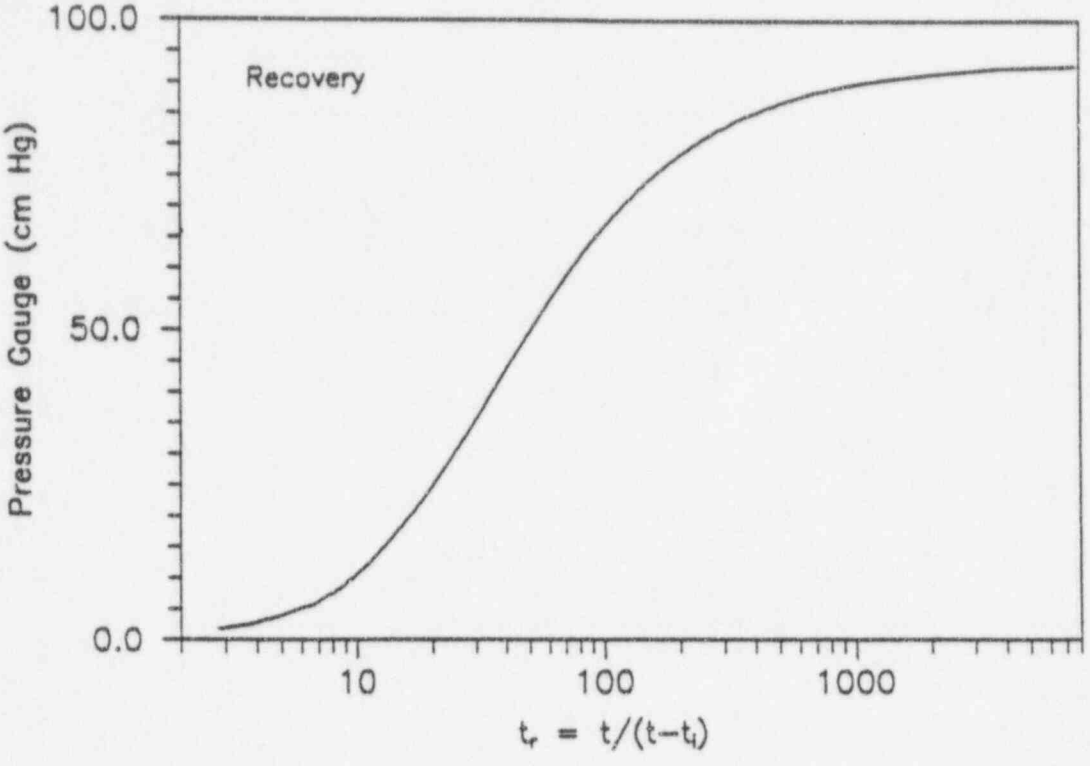
Graphs from Table B.8 Y2 - 3.0 m Data

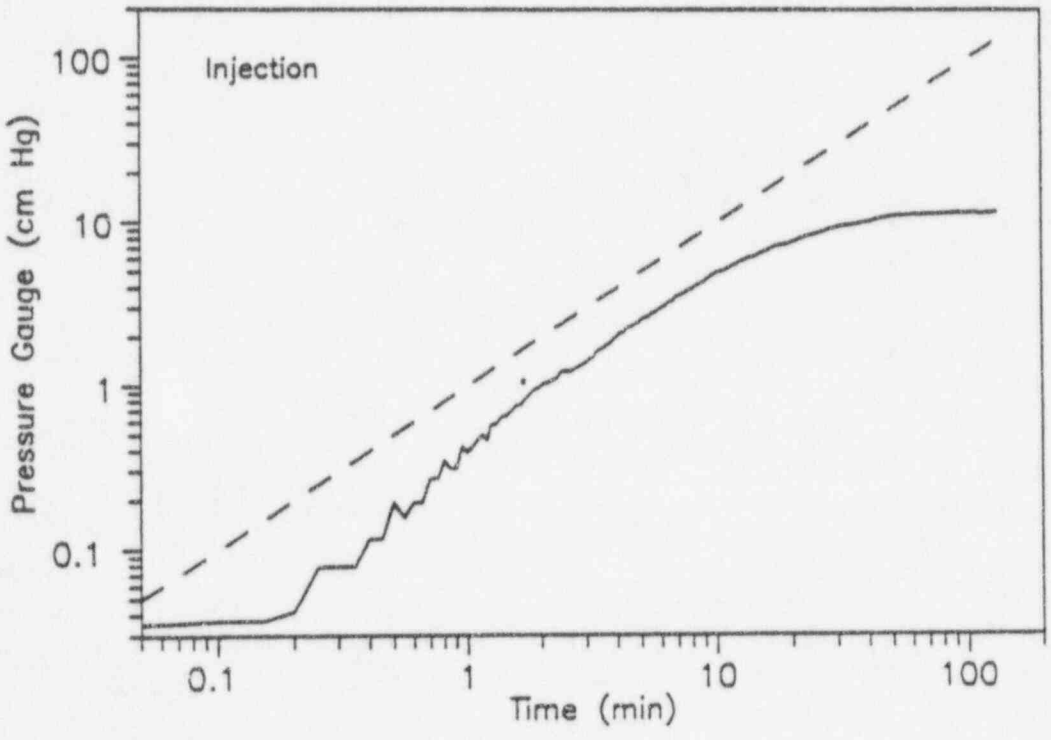

Pressure (cm Hg)
50
100
150
200
0
5
10
15
20
25
30
Position (m)
Borehole Y2
Scale 3 m
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
Pneumatic Permeability (m^2 x10^{-16})

INJECTION TEST
Y2-Y2AB
07-26-9-

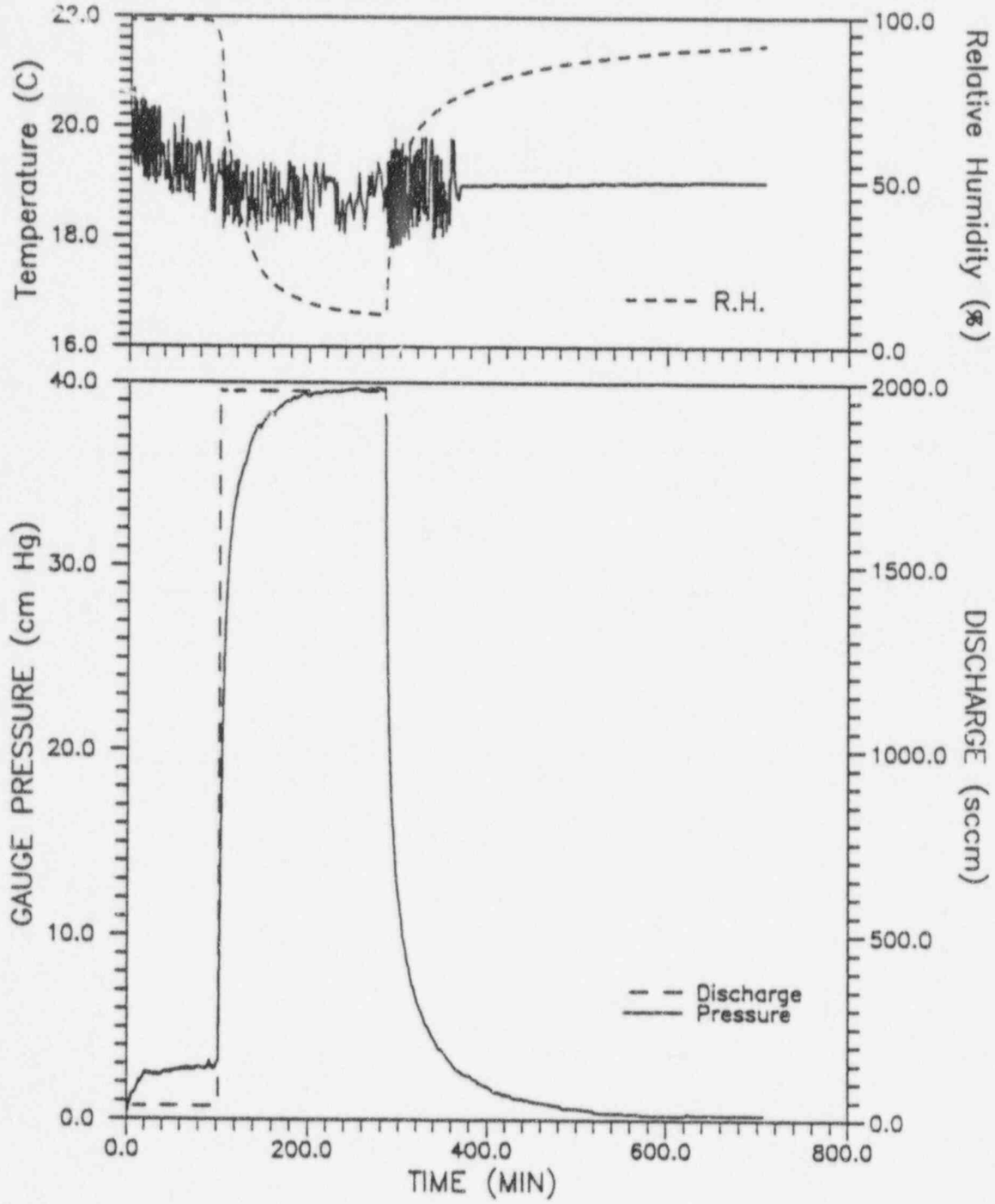


Y2-Y2AB
07-26-94
I: Q=50 sccm; R: Q=2000

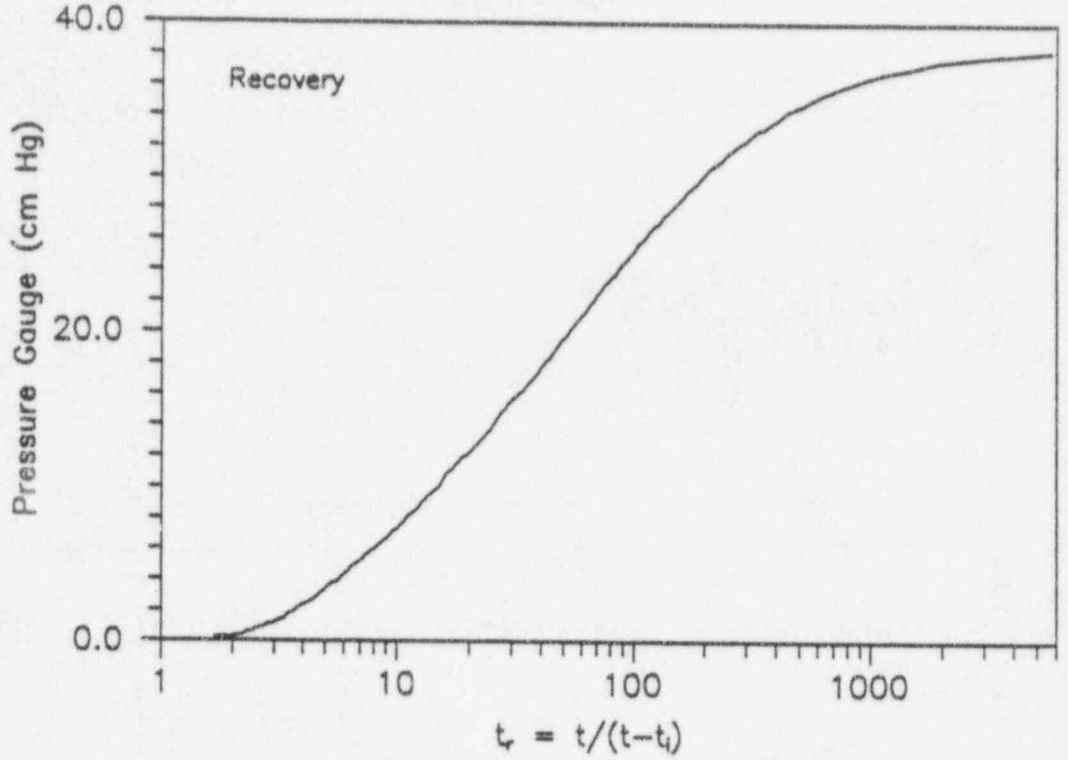


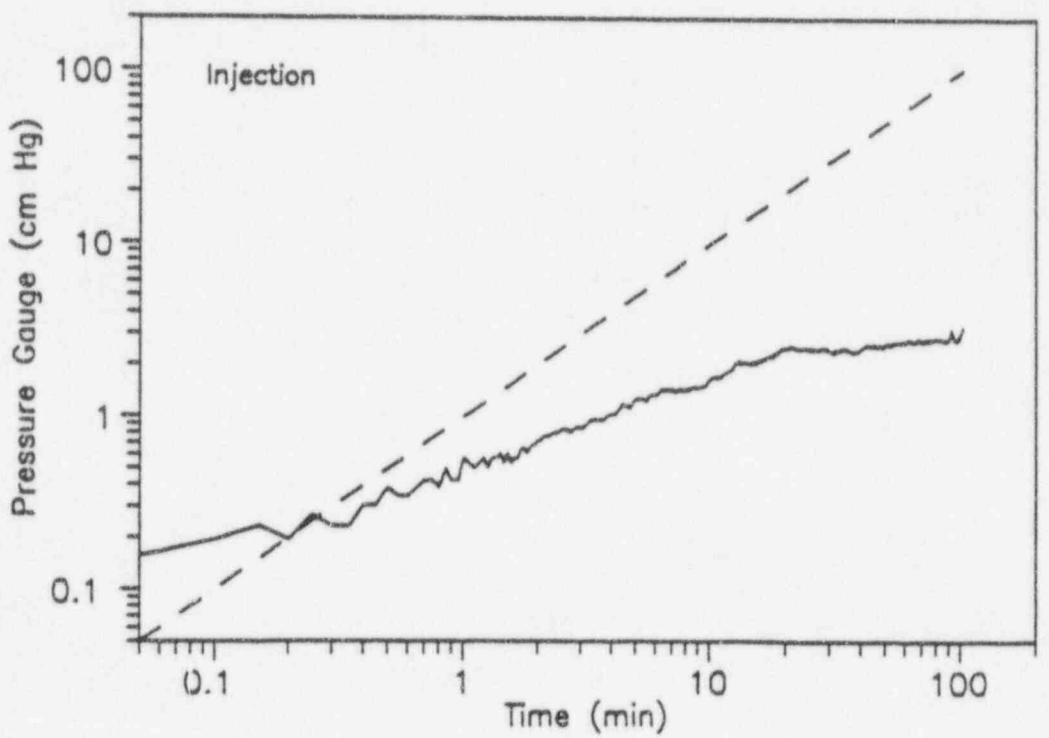


INJECTION TEST
Y2-Y2BA
08-11-94

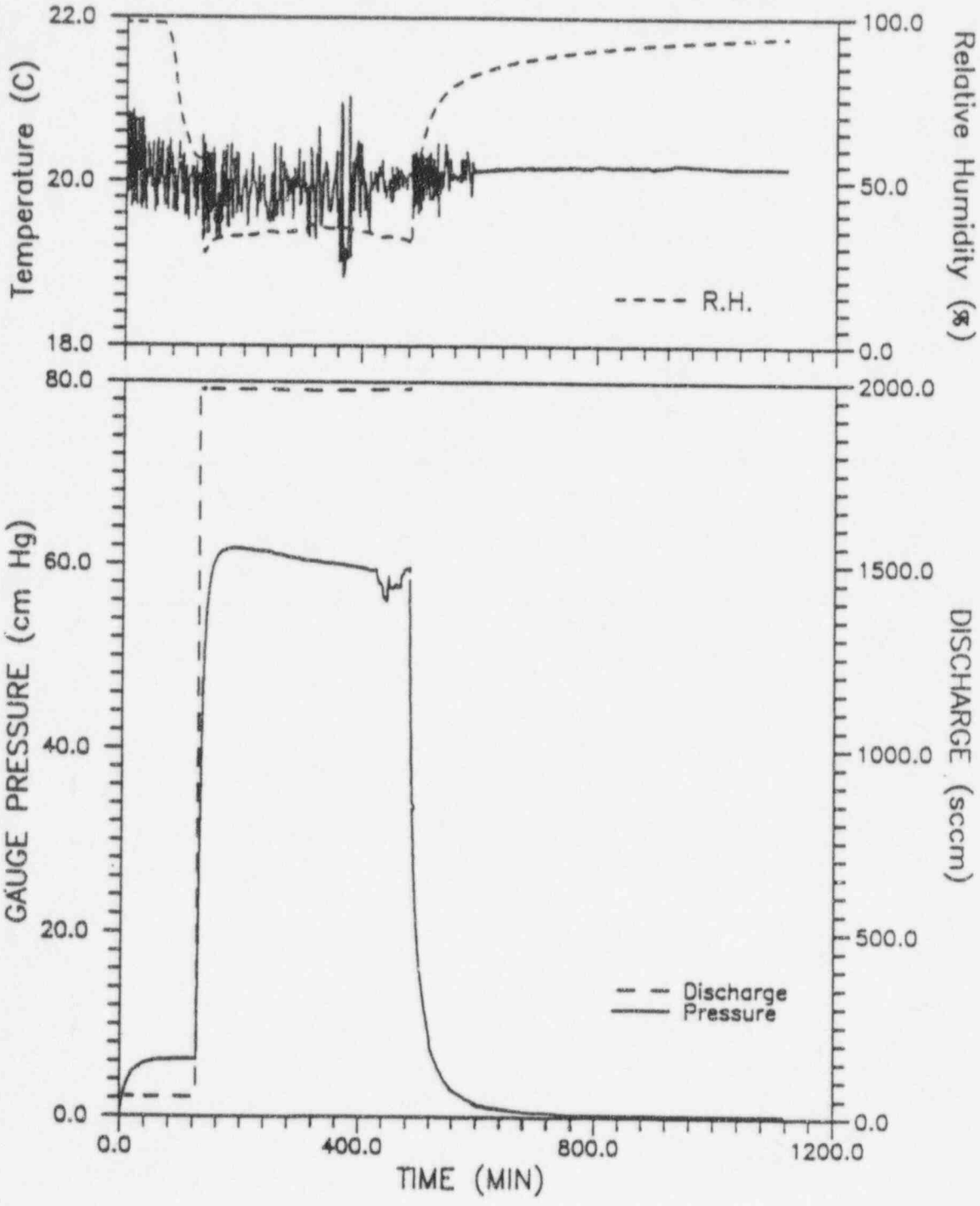


Y2-Y2BA
08-11-94
I: Q=35 sccm; R: Q=2000

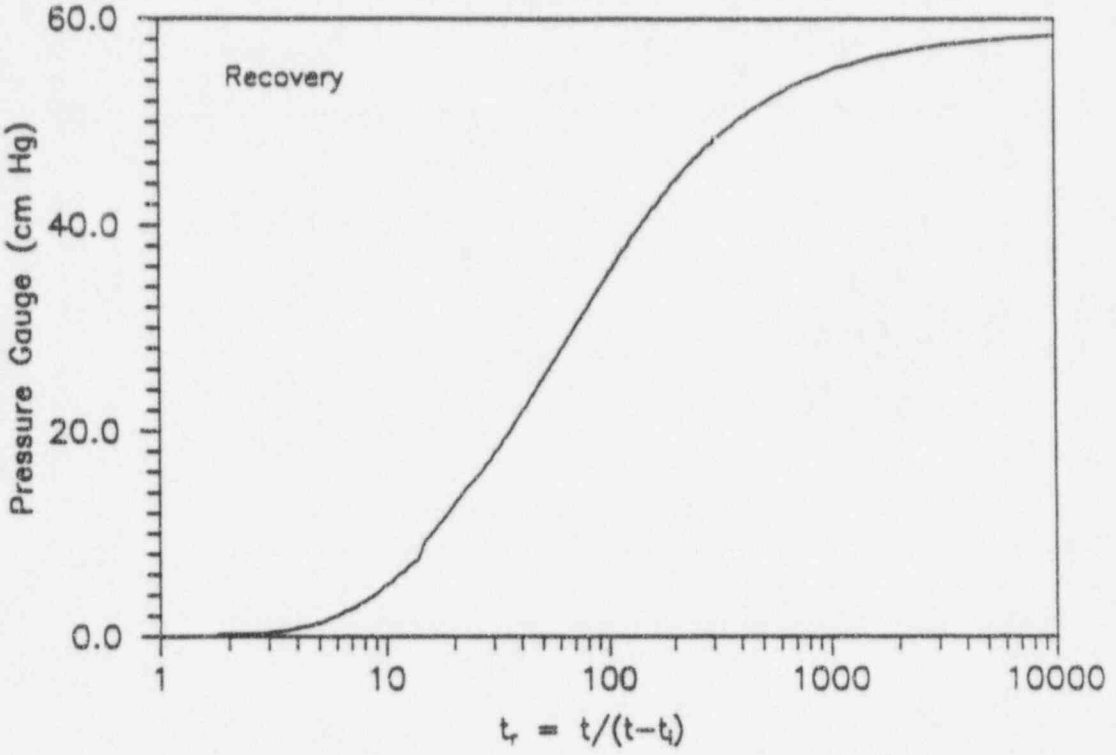


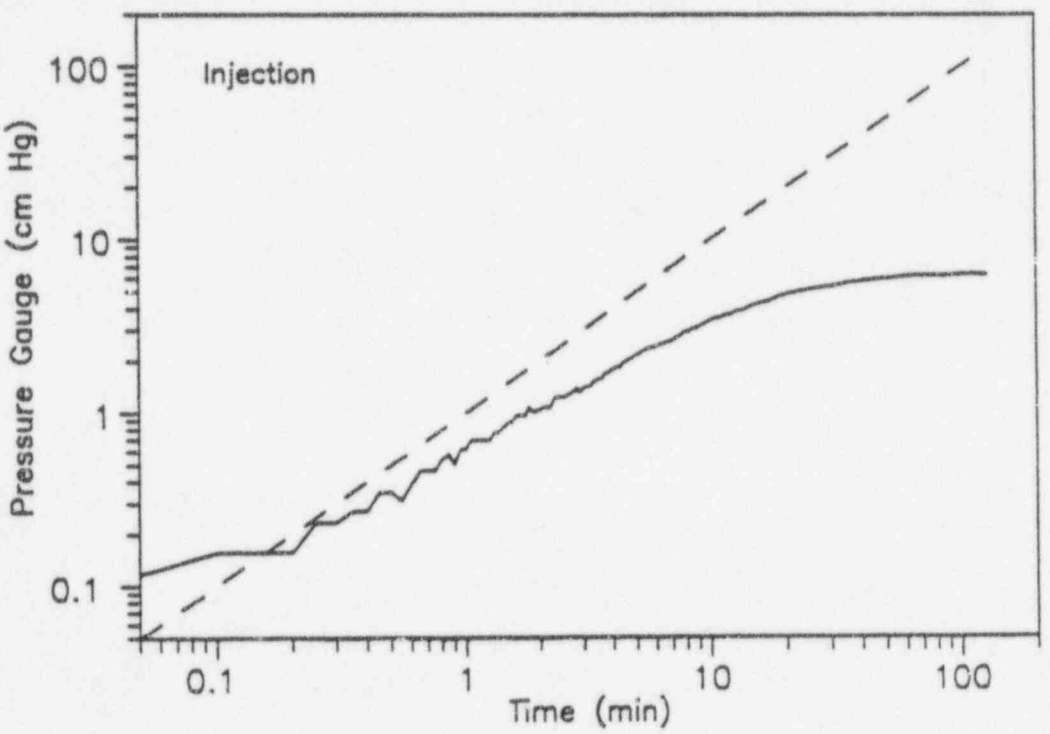


INJECTION TEST
Y2-Y2CA
08-19-94

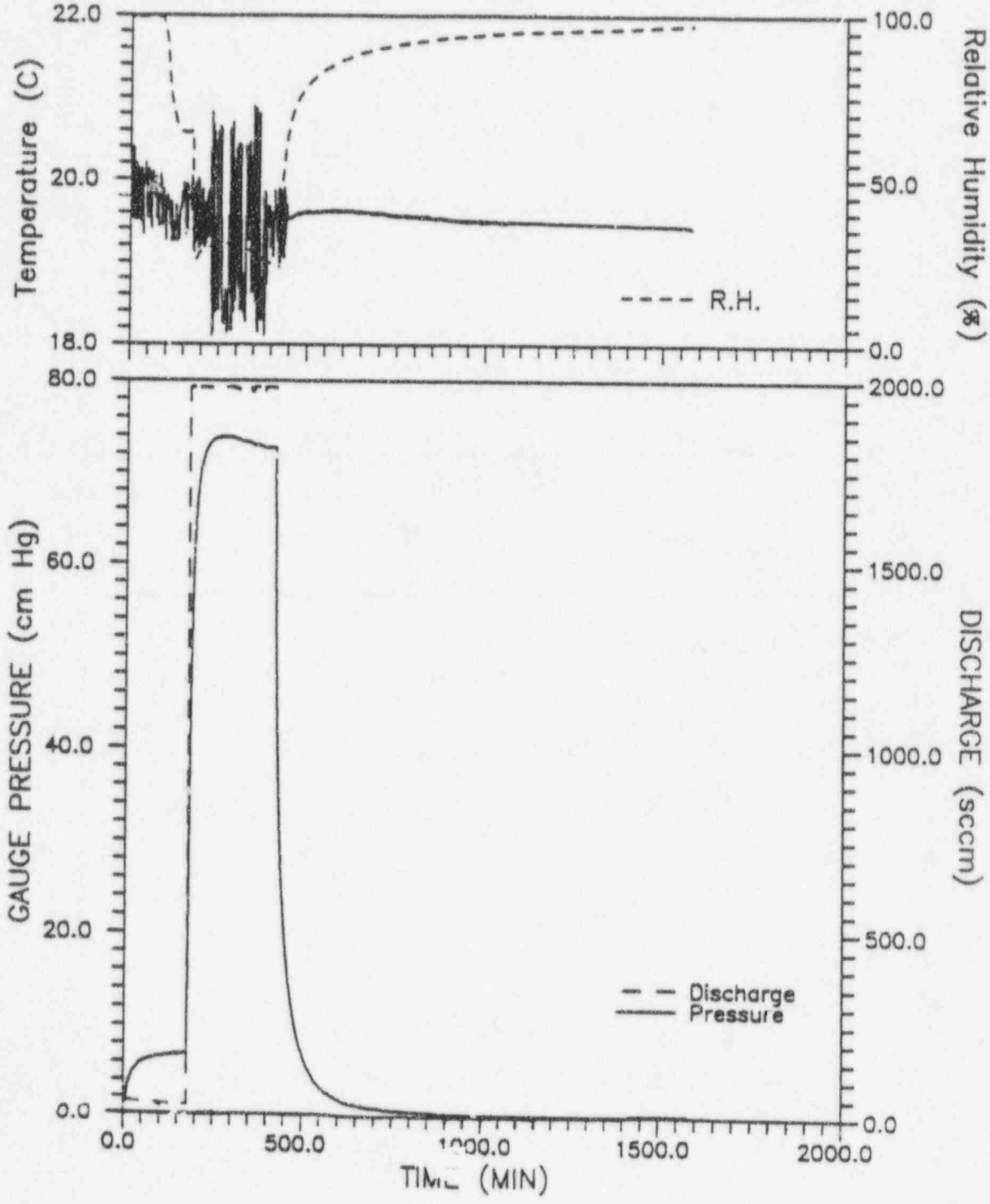


Y2-Y2CA
08--19--94
I: Q=50 sccm; R: Q=2000

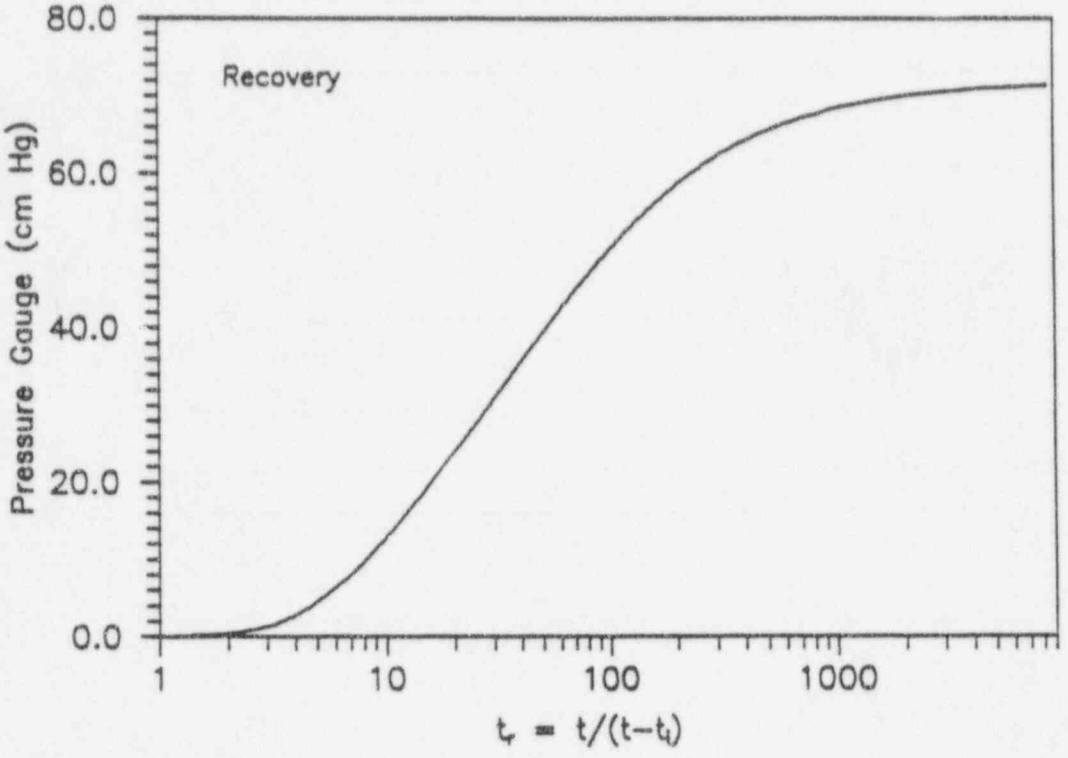


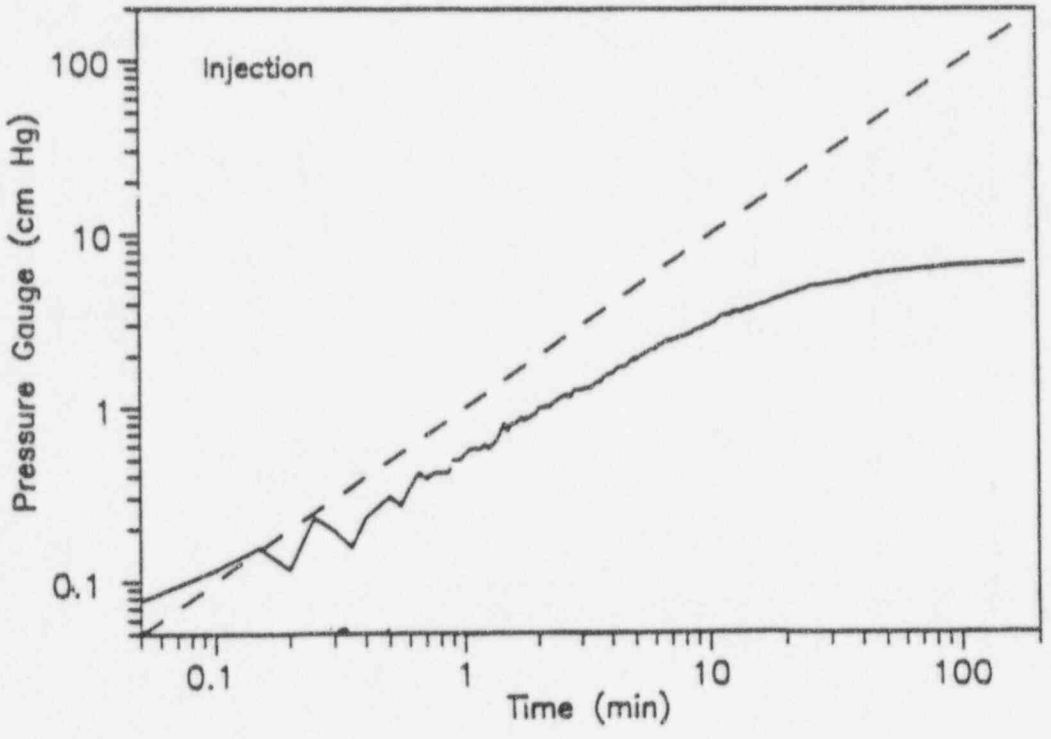


INJECTION TEST
Y2-Y2CB
08-23-94

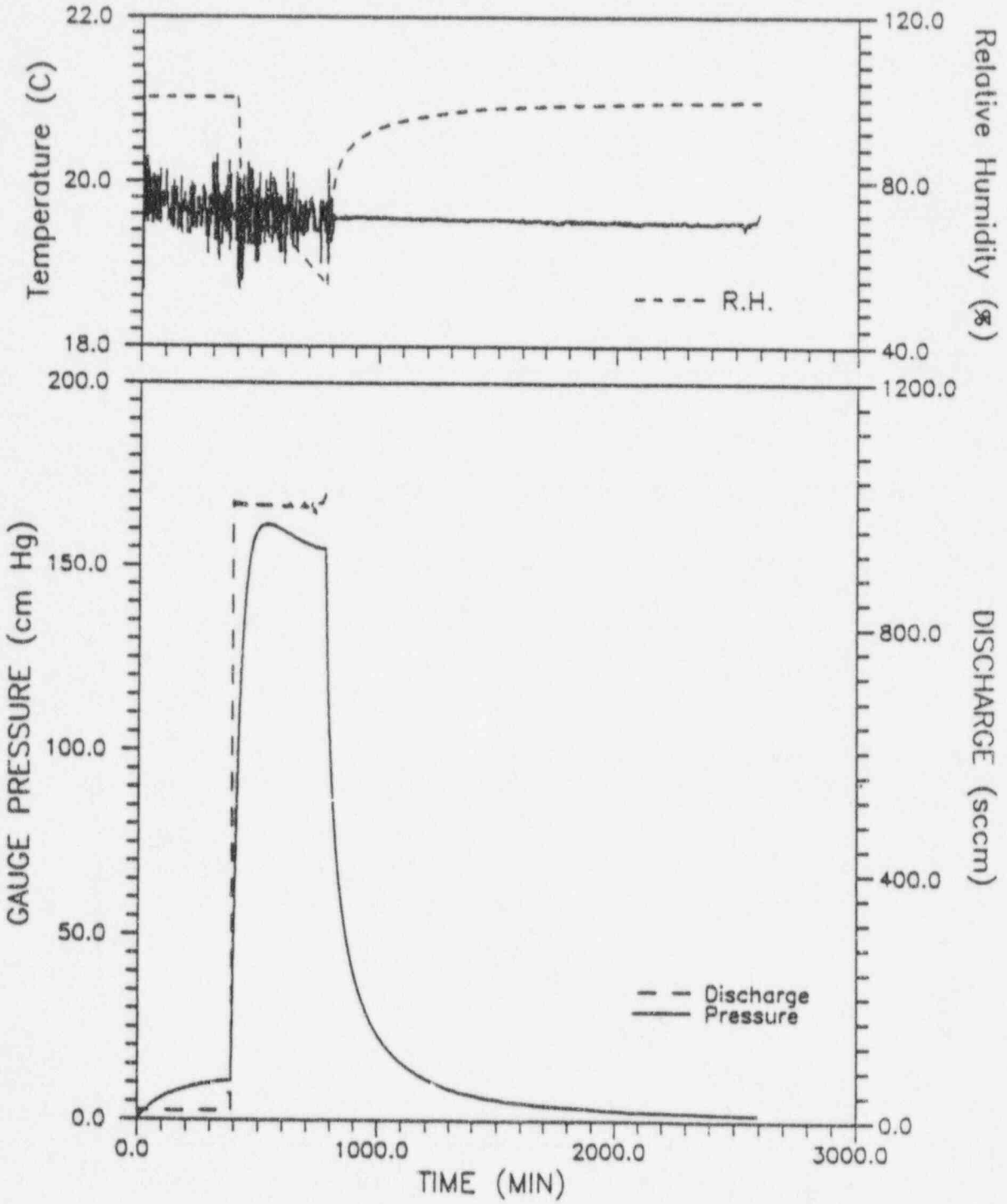


Y2-Y2CB
08-23-94
I: Q=35 sccm; R: Q=2000

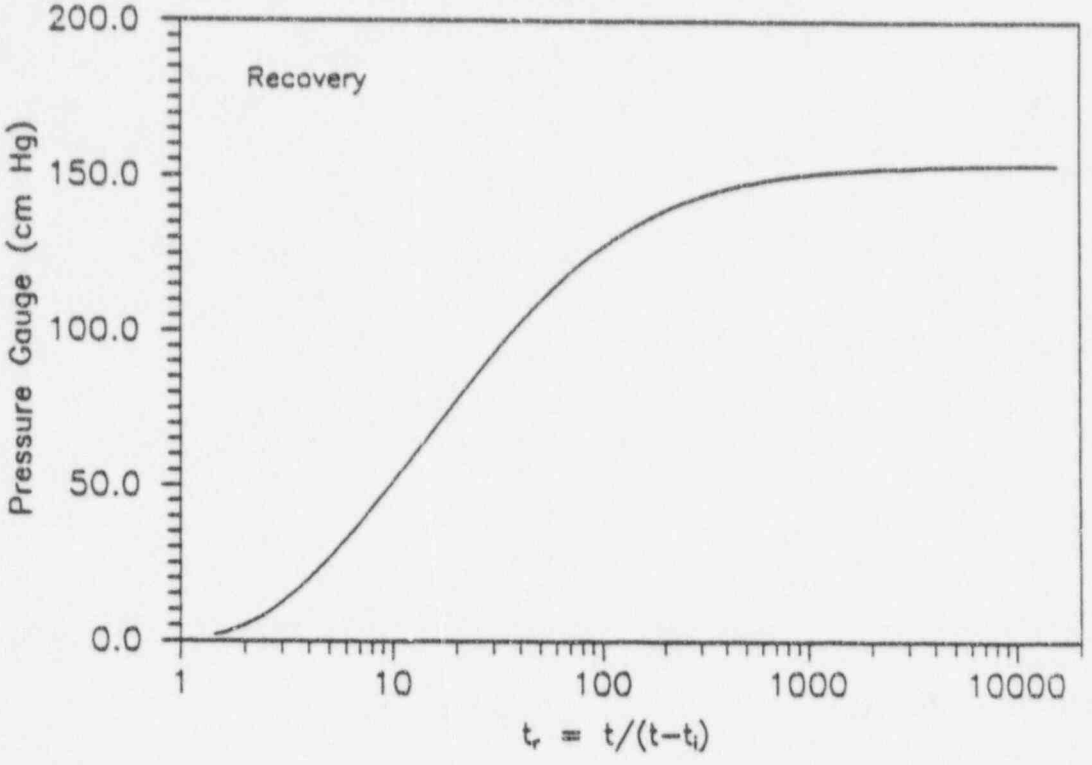


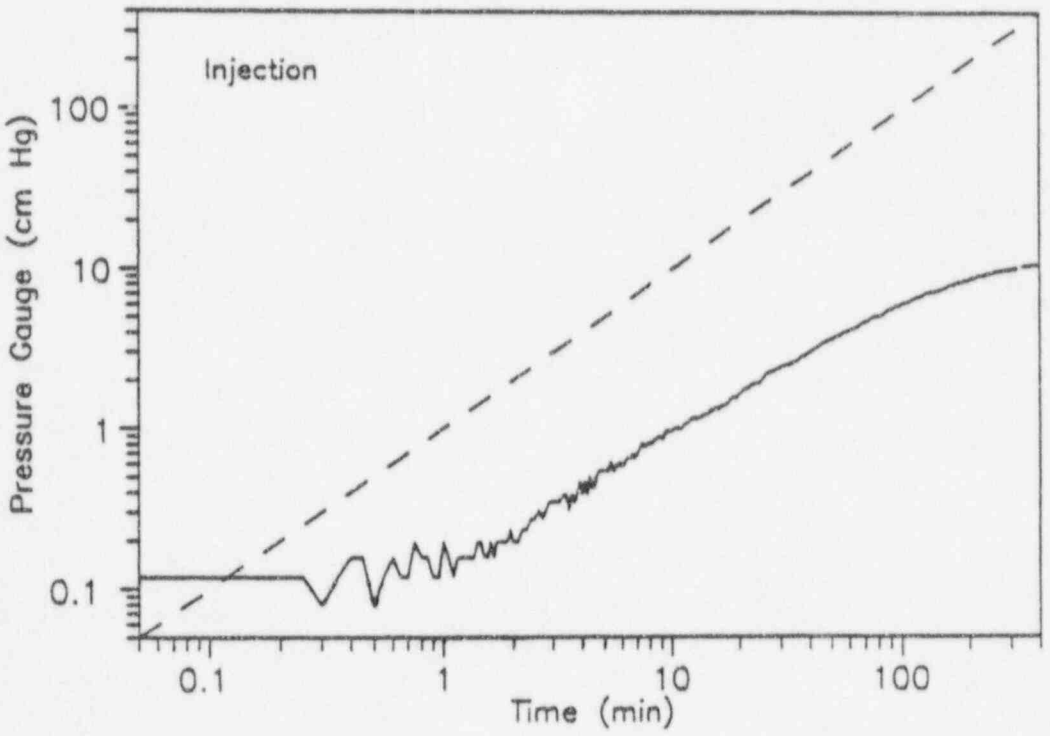


INJECTION TEST
Y2-Y2CC
08-30-94

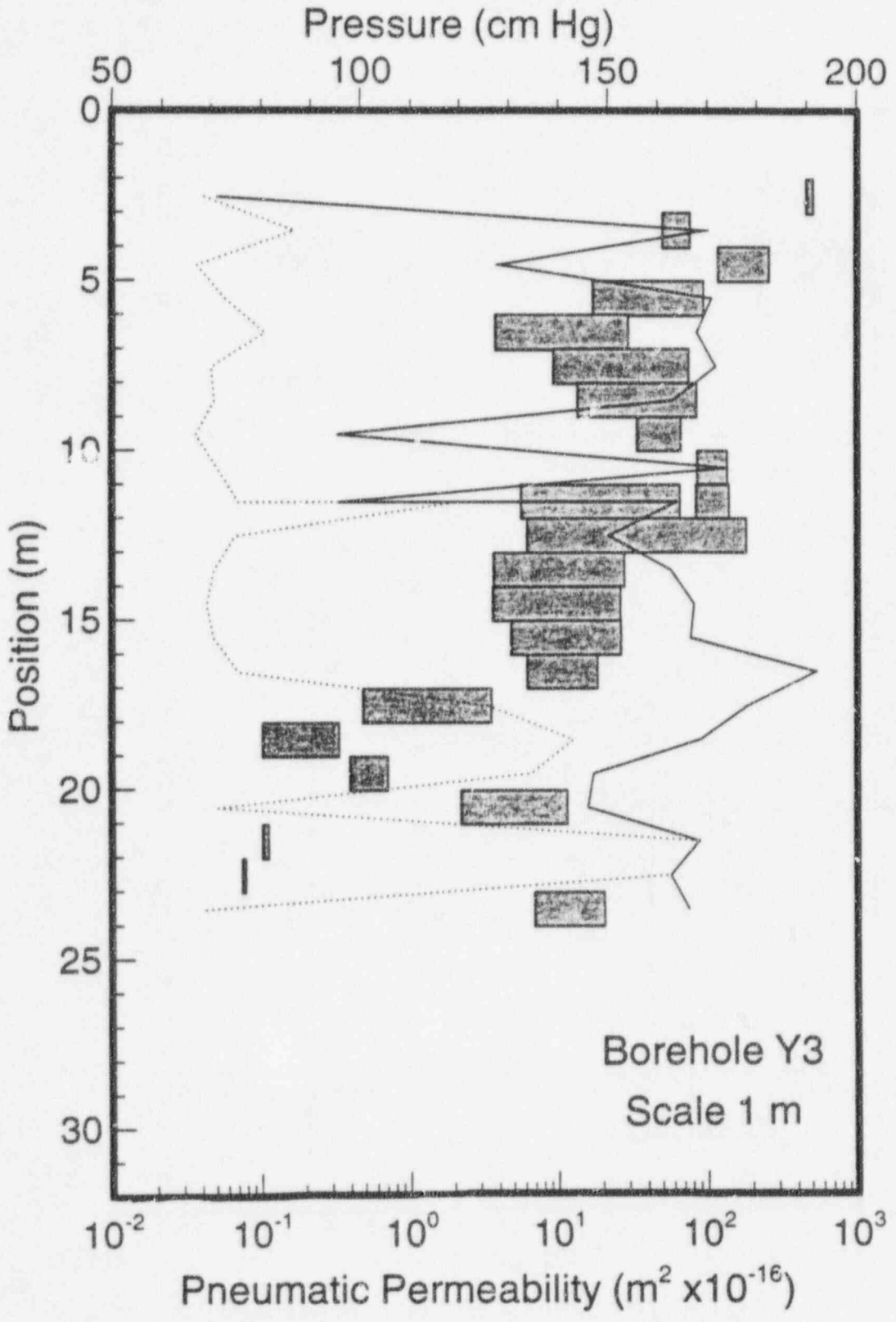


Y2-Y2CC
08-30-94
I: Q=15 sccm; R: Q=1000

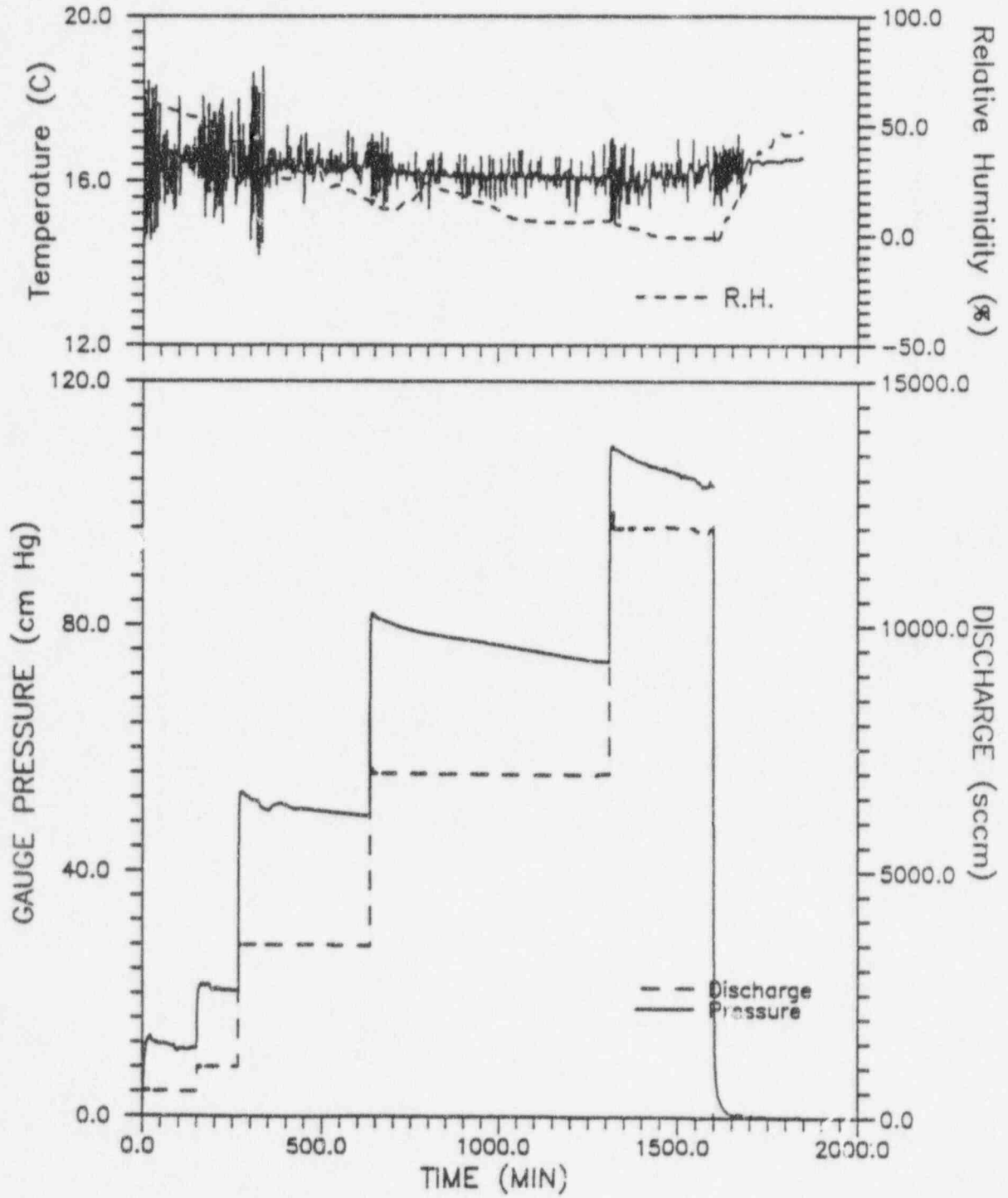




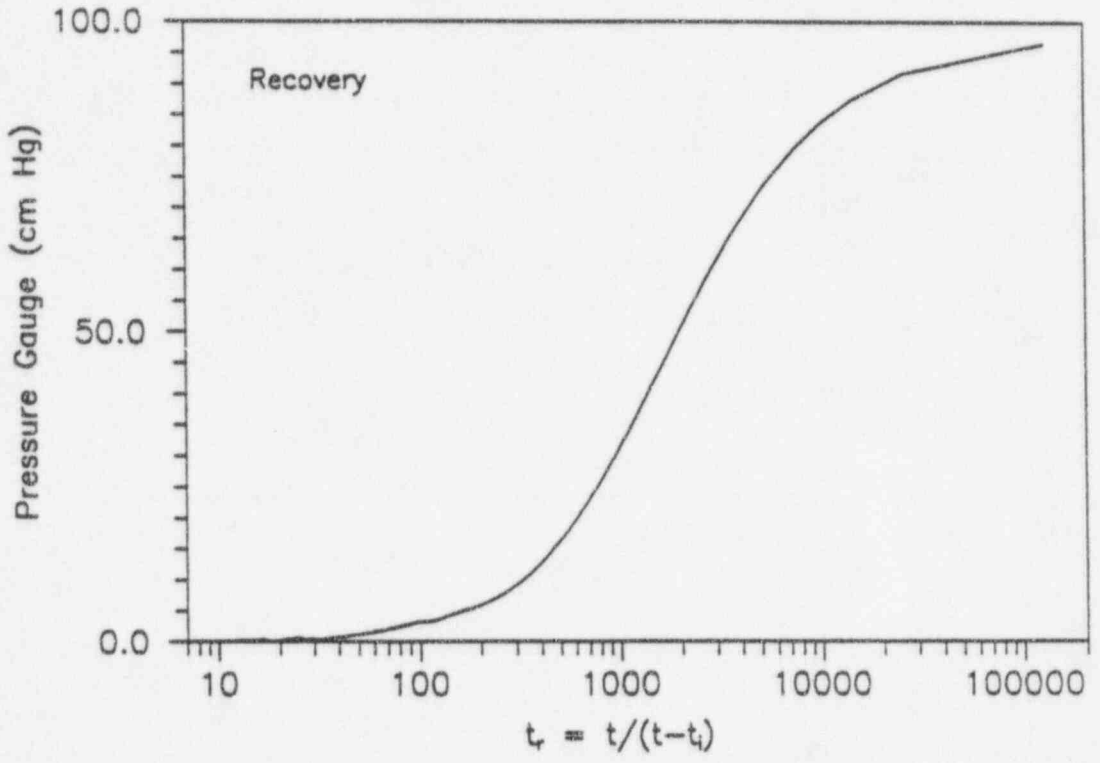
Graphs from Table B.9 Y3 - 1.0 m Data

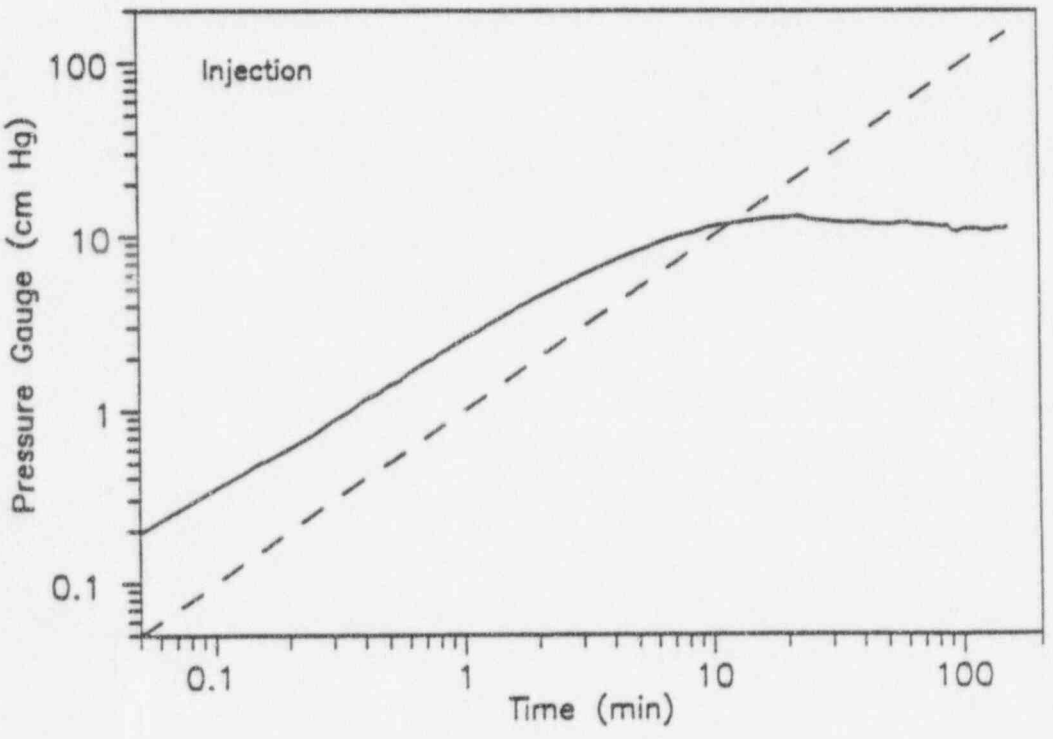

Pressure (cm Hg)
50
100
150
200
0
5
10
15
20
25
30
Position (m)
Borehole Y3
Scale 1 m
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
Pneumatic Permeability (m^2 x10^{-16})

INJECTION TEST
Y3-YAB
03-02-94

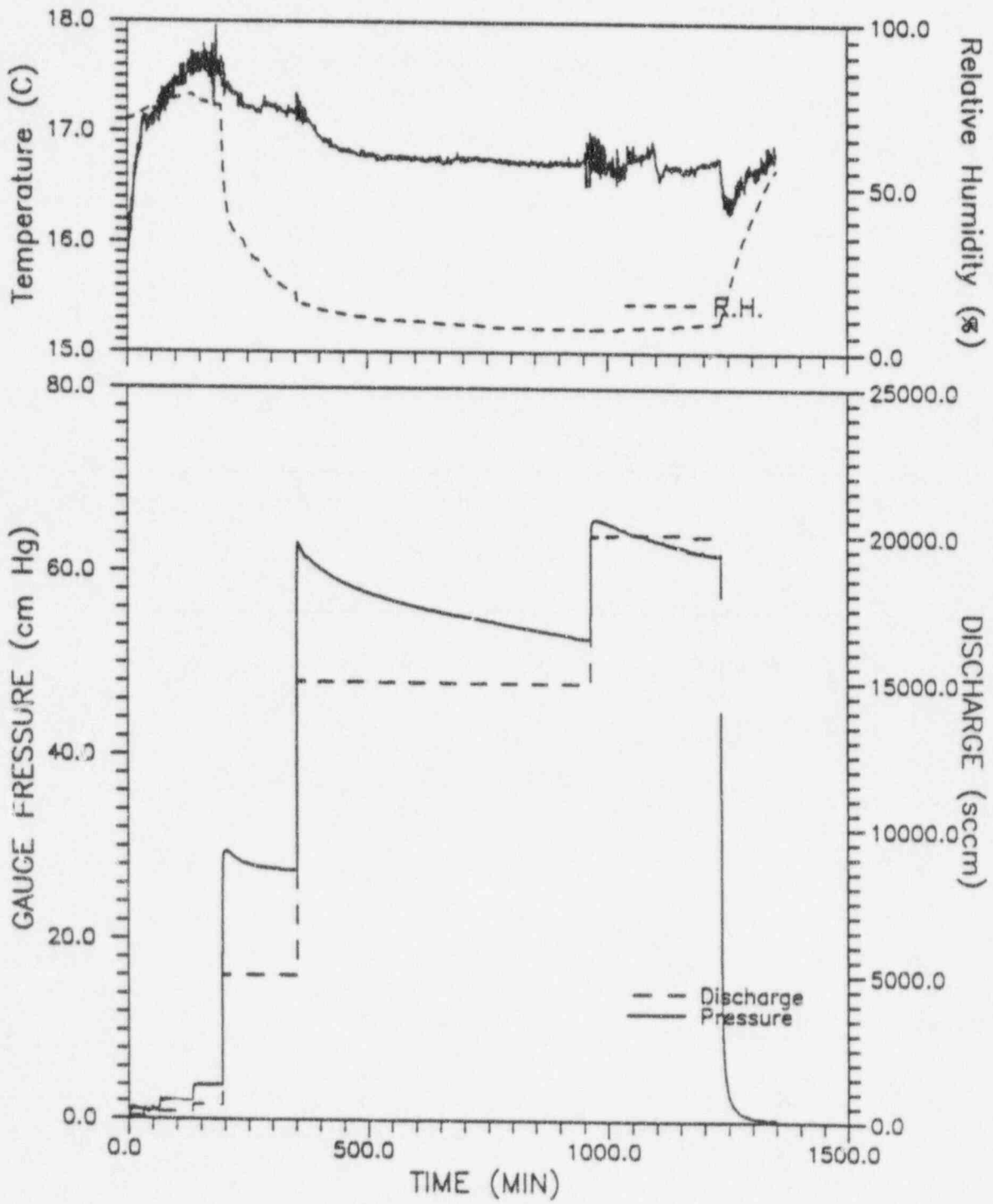


Y3-YAB
03-02-94
I: Q=500 sccm; R: Q=12,000

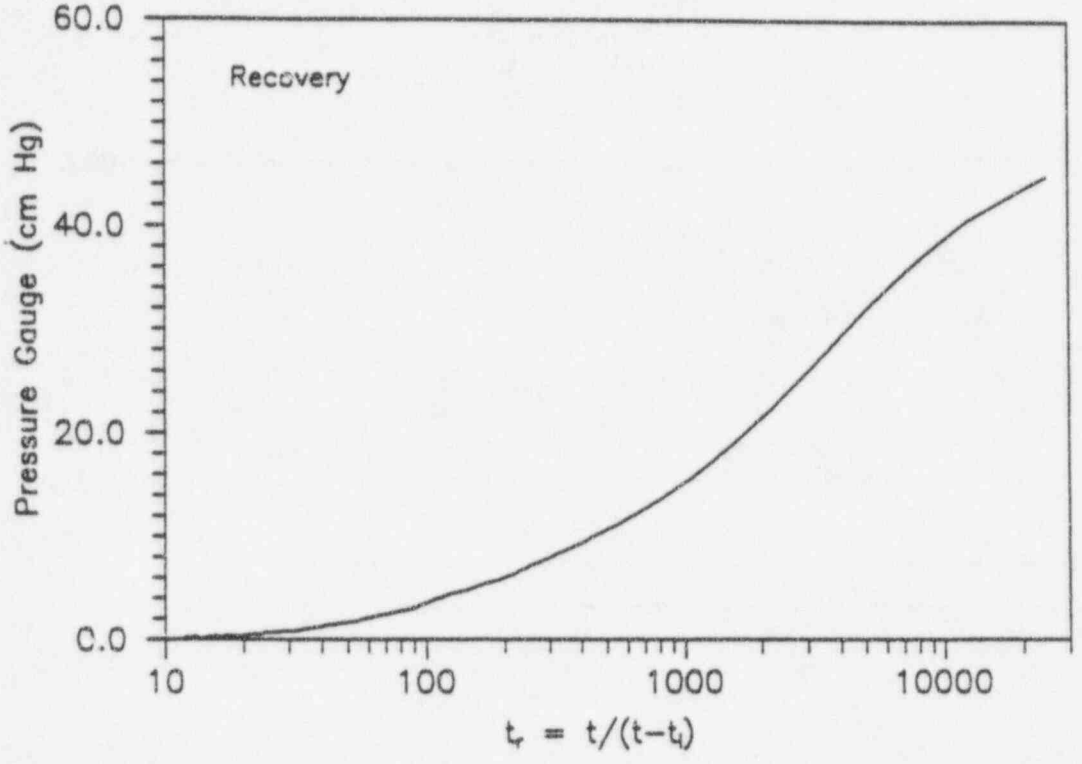


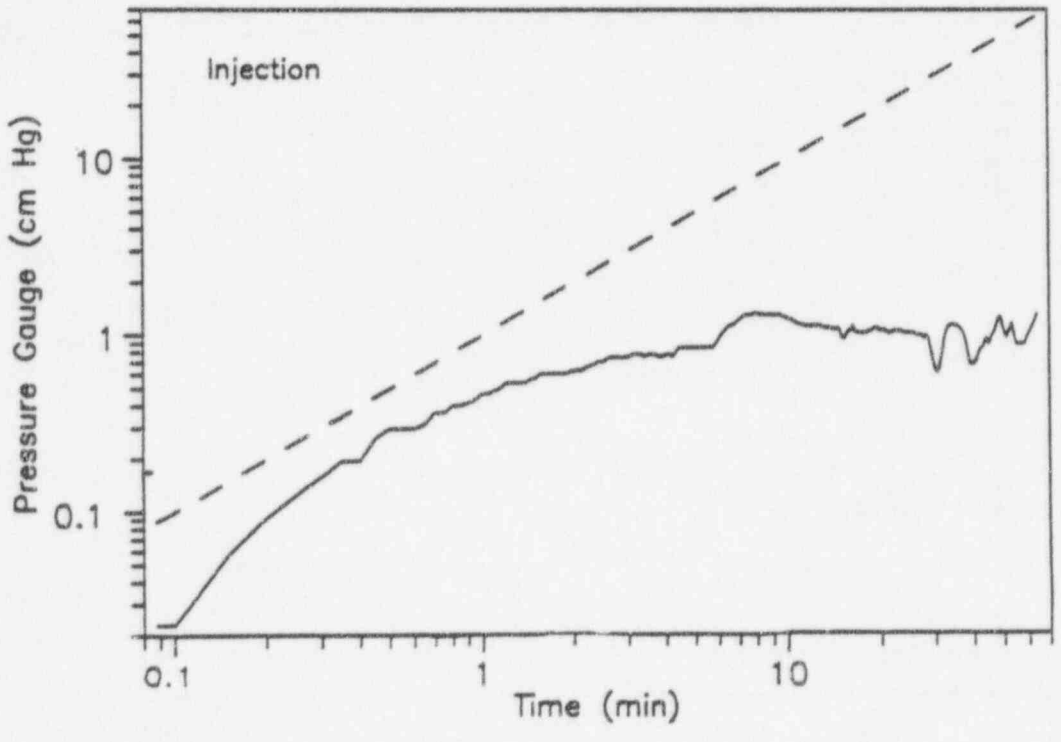


INJECTION TEST
Y3-YAC
03-08-94

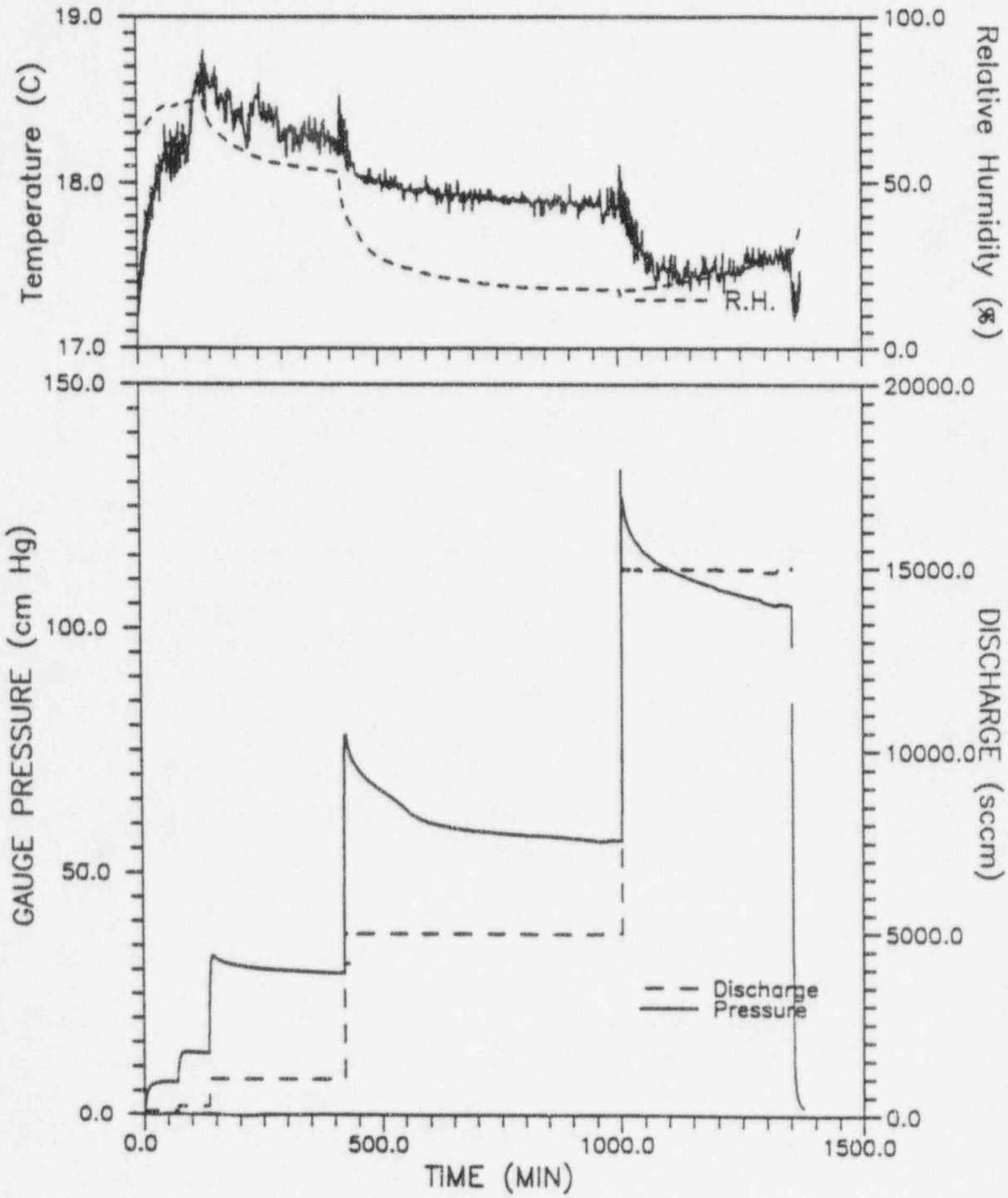


Y3-YAC
03-08-94
I: Q=100 sccm; R: Q=20,000

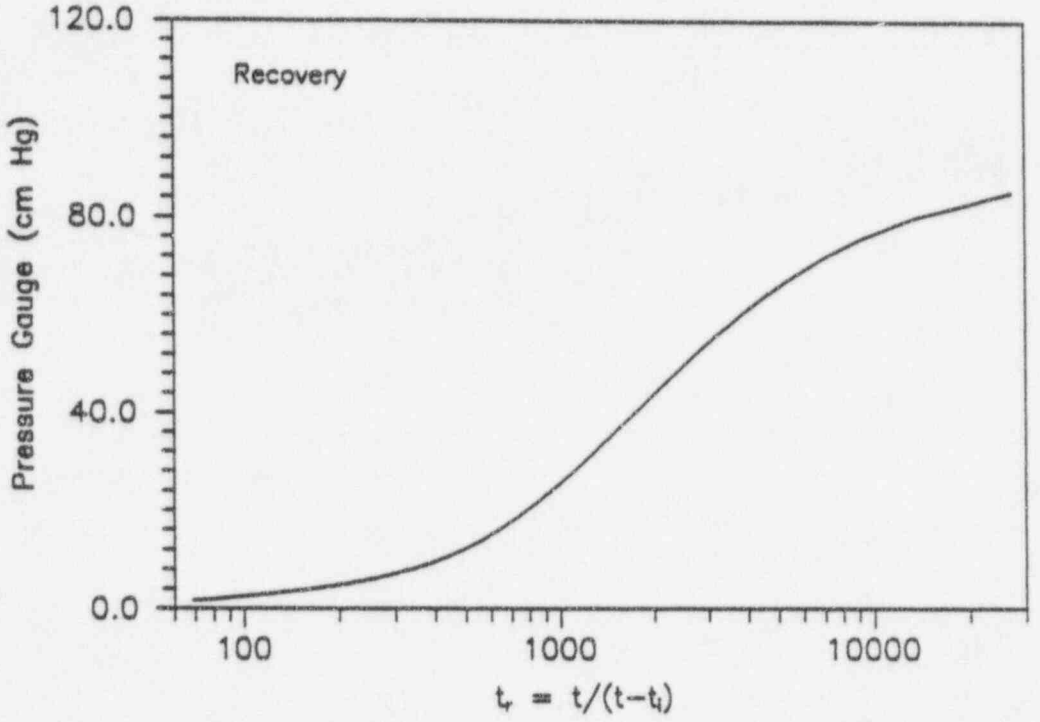


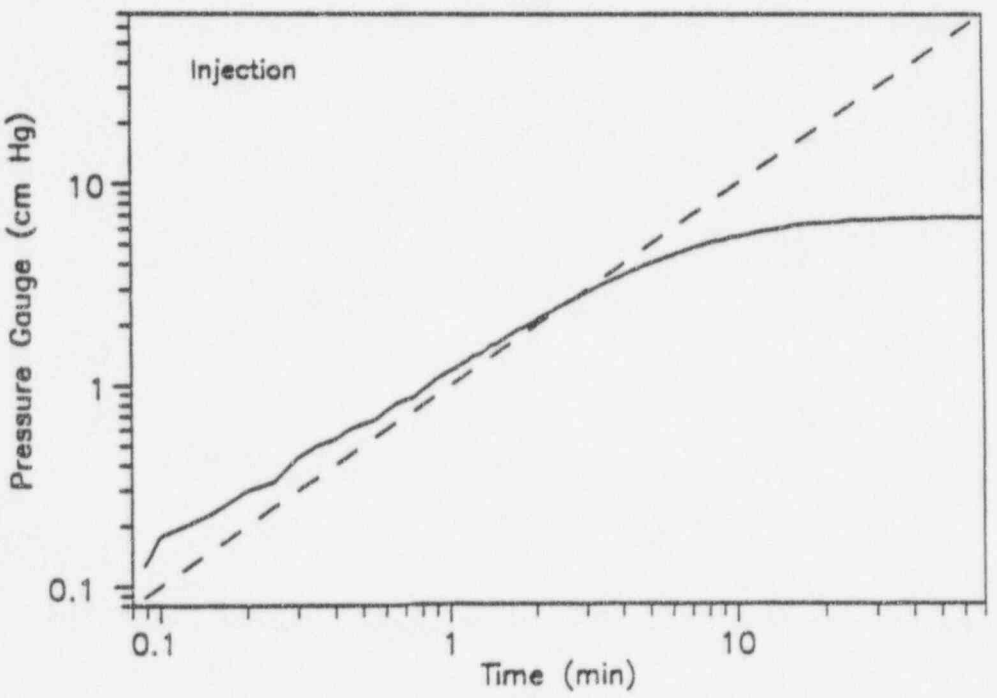


INJECTION TEST
Y3-YBA
03-09-94

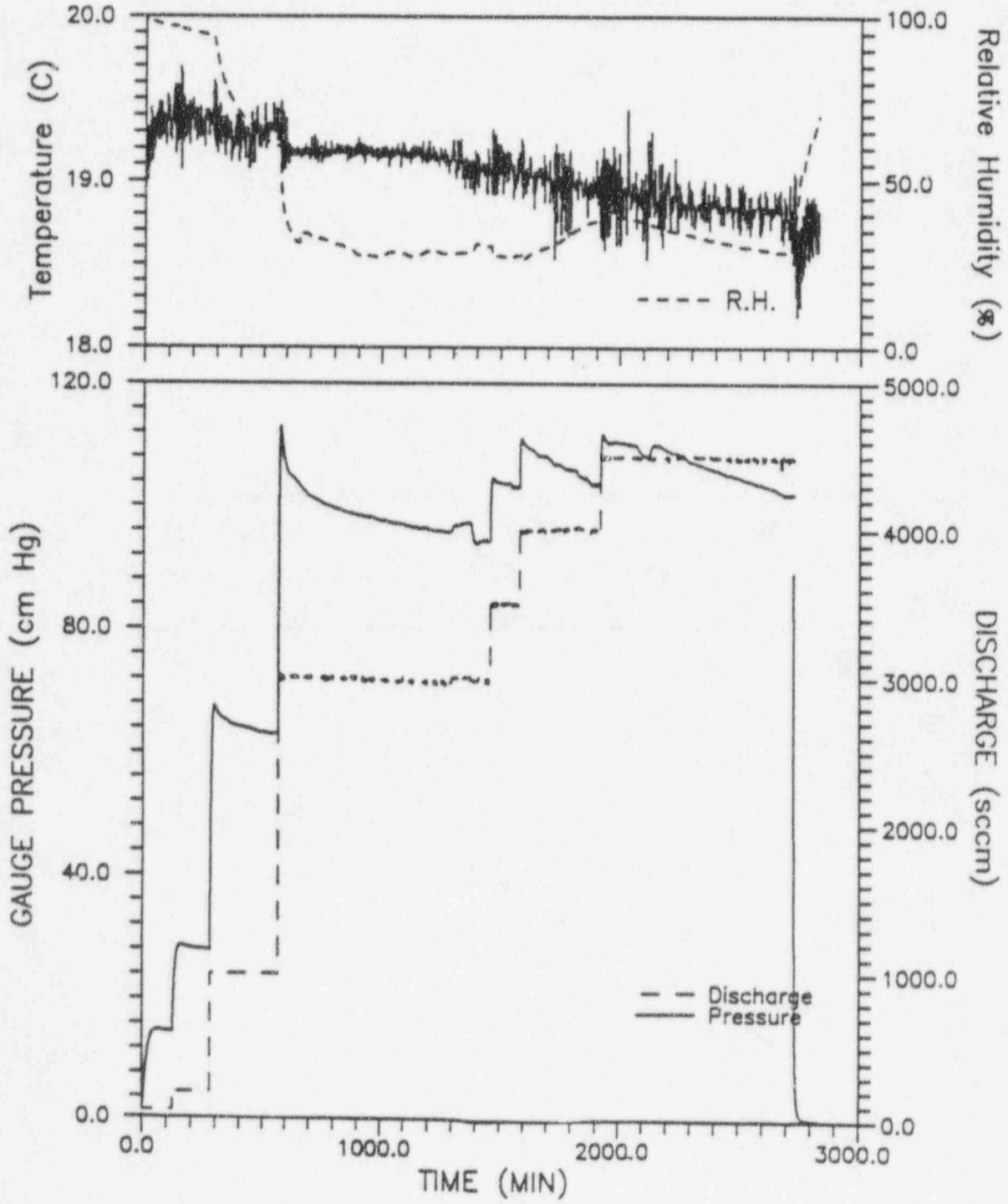


Y3-YBA
03-09-94
I: Q=100 sccm; R: Q=15,000

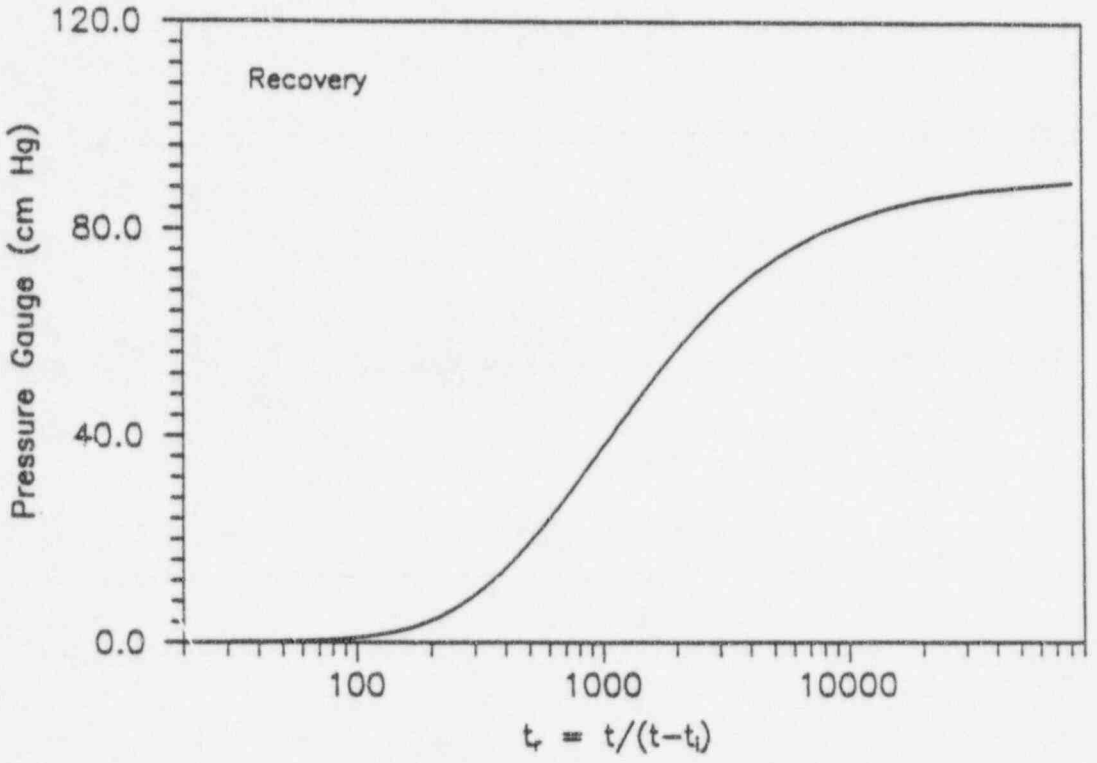


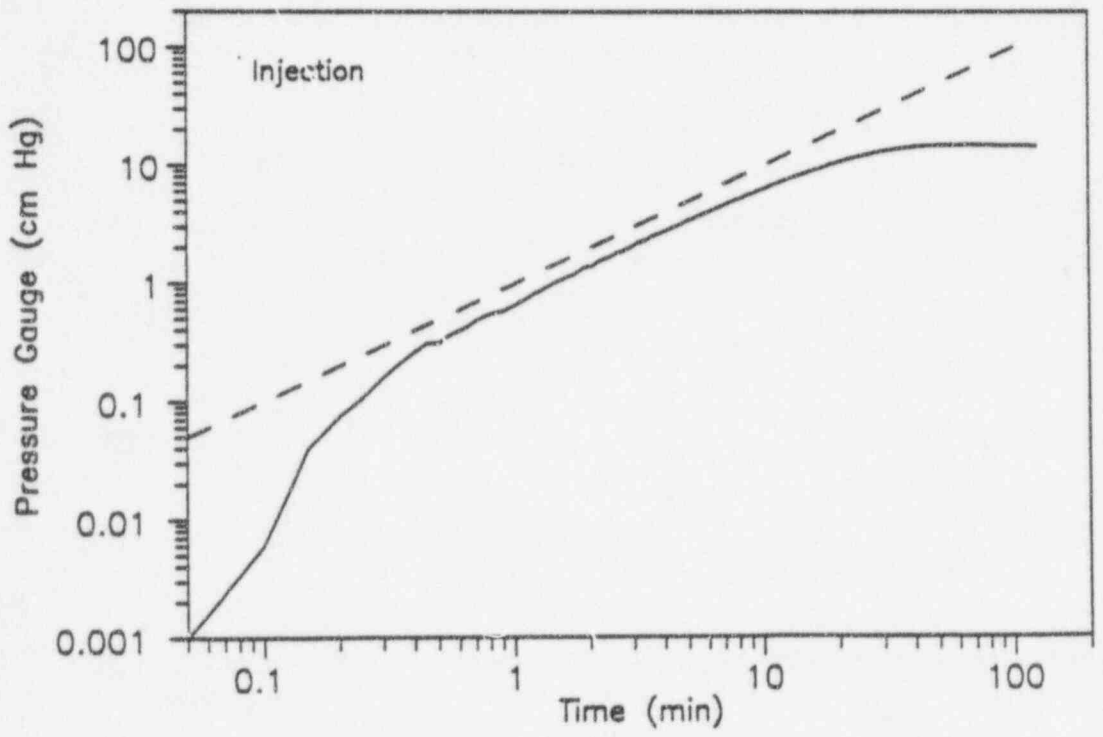


INJECTION TEST
Y3-YBB
03-15-94

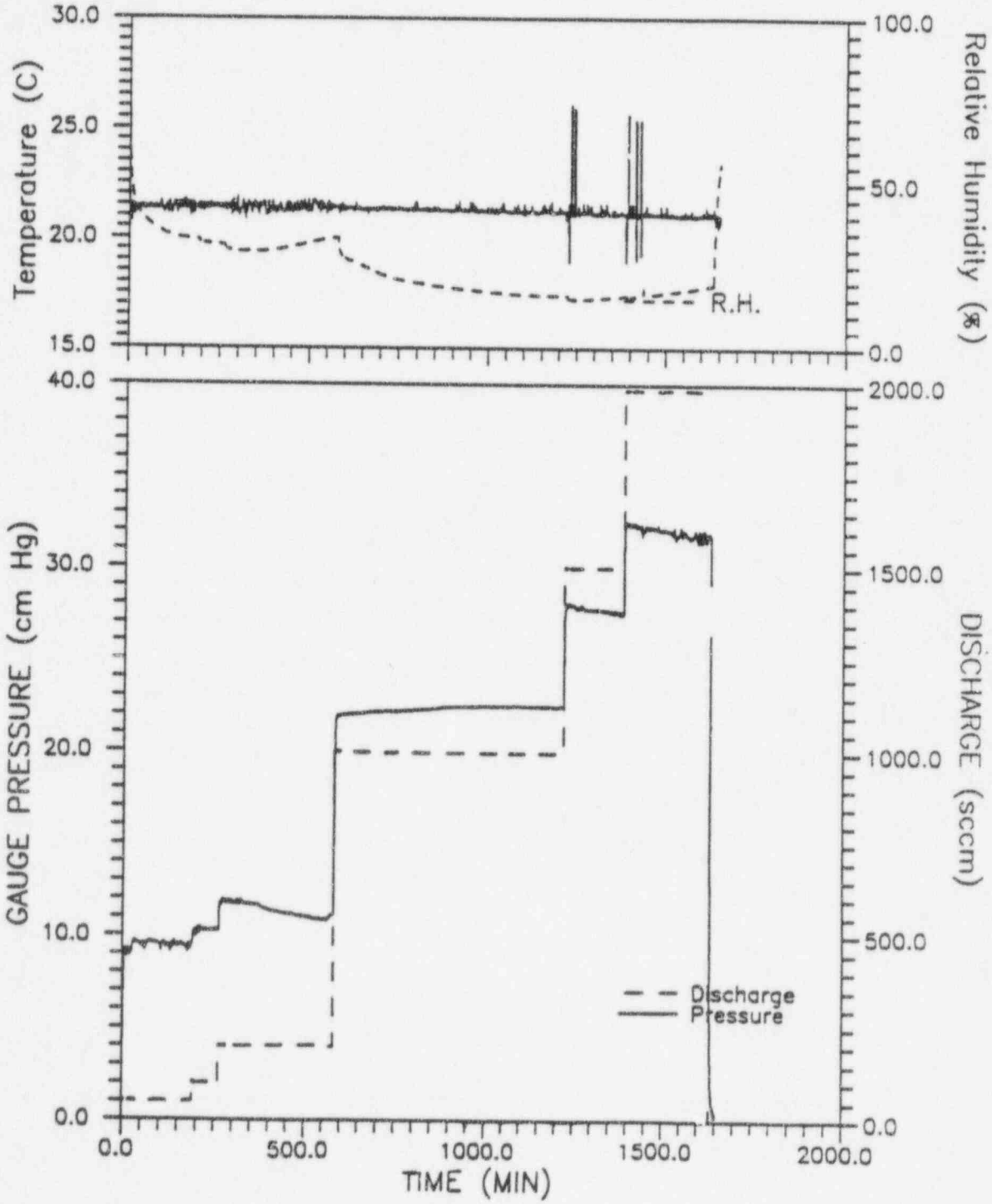


Y3-YBB
03-15-94
I: Q=50 sccm; R: Q=4500

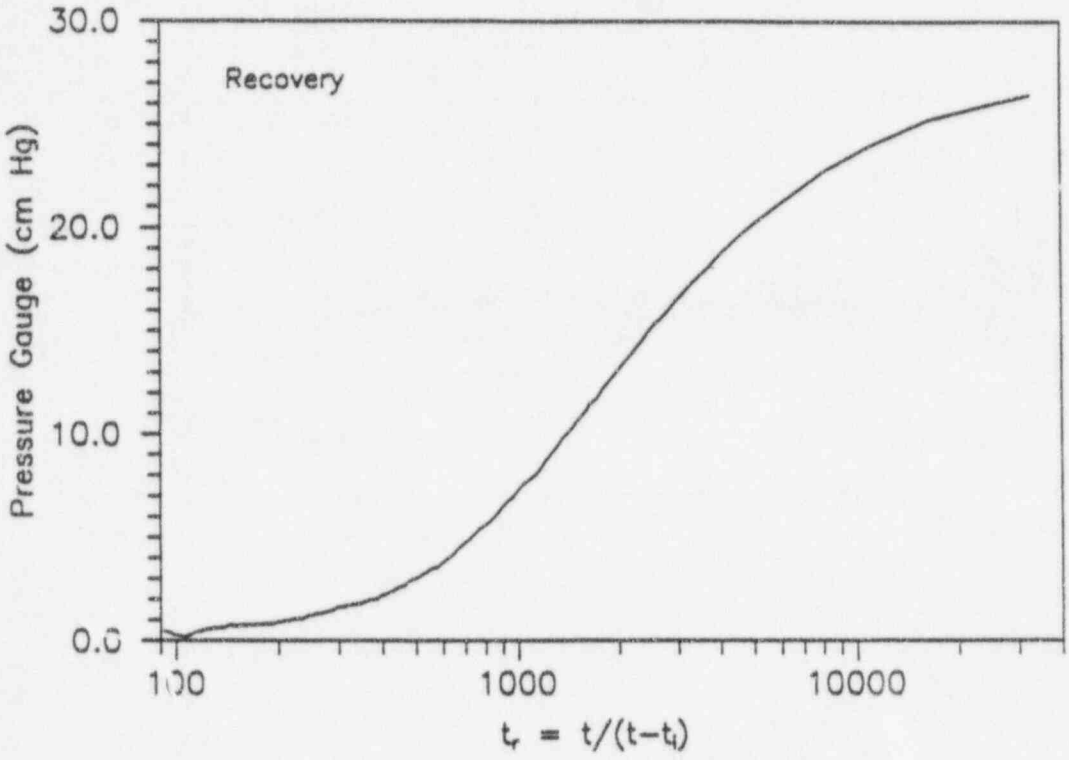


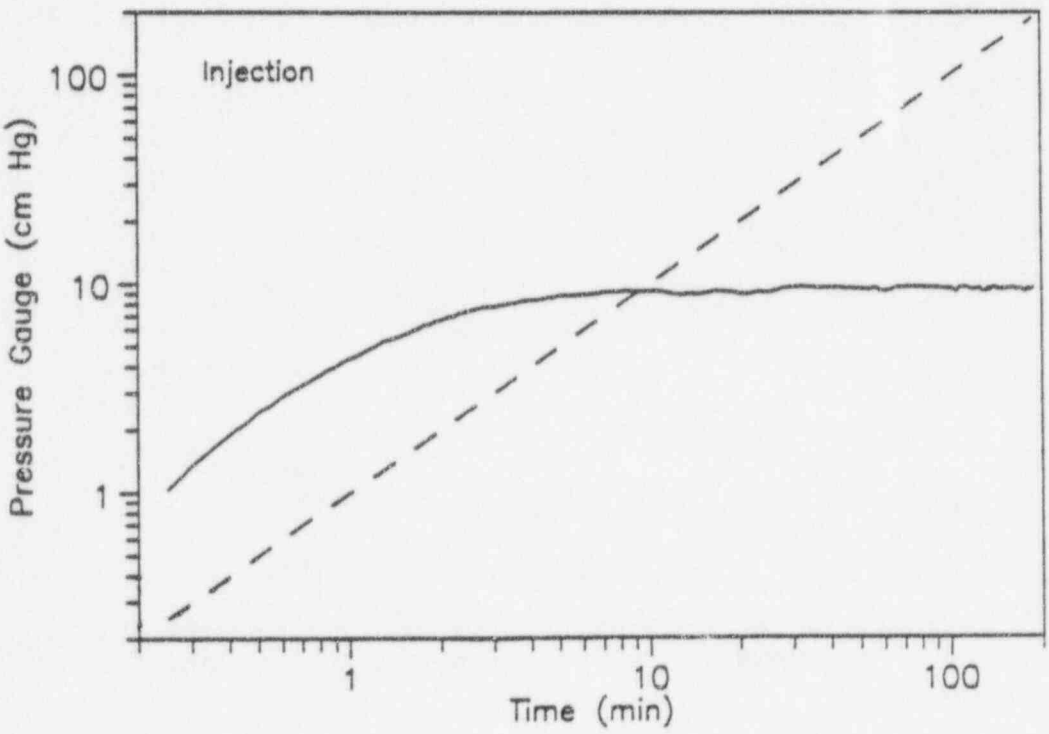


INJECTION TEST
Y3-YDB
04-27-94

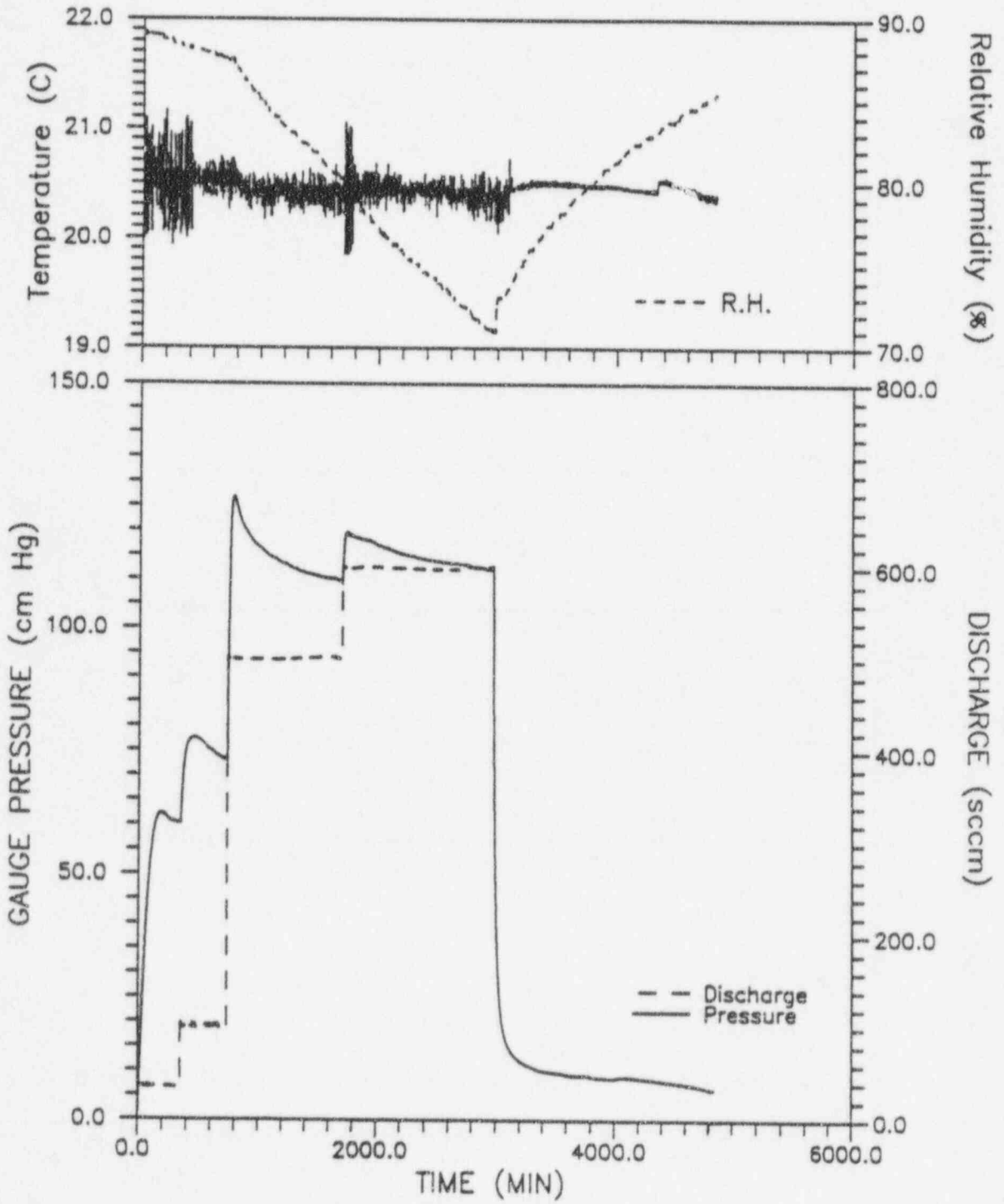


Y3-YDB
04-27-94
I: Q=50 sccm; R: Q=2,000

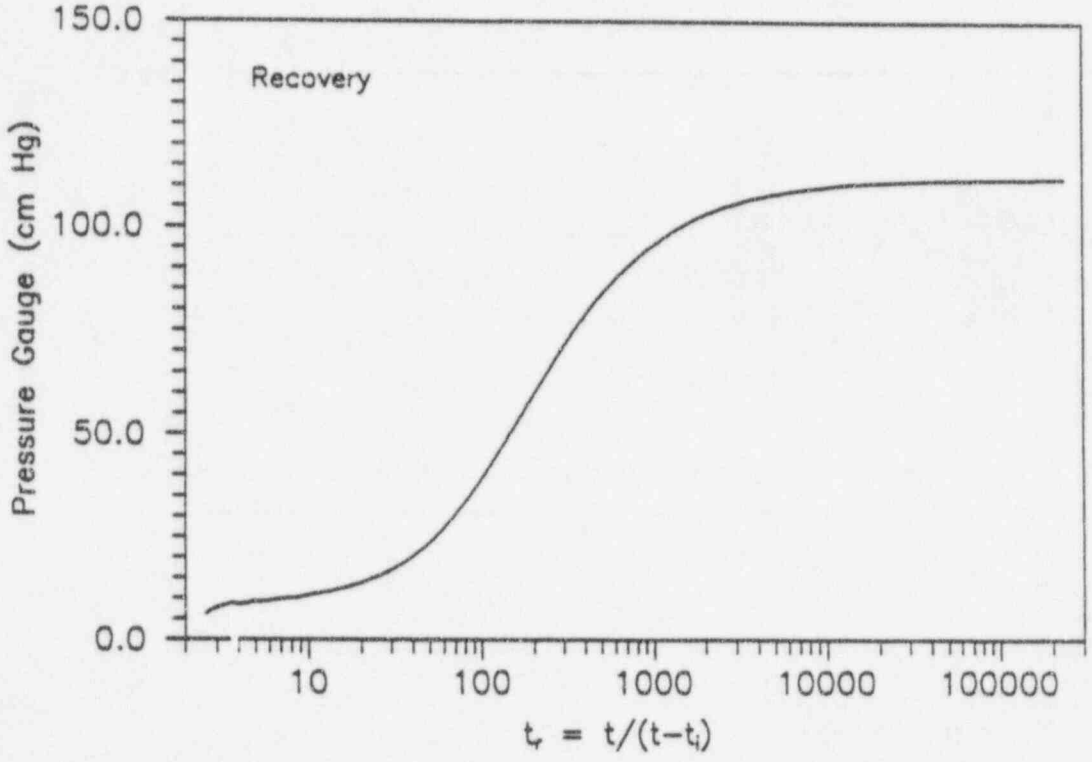


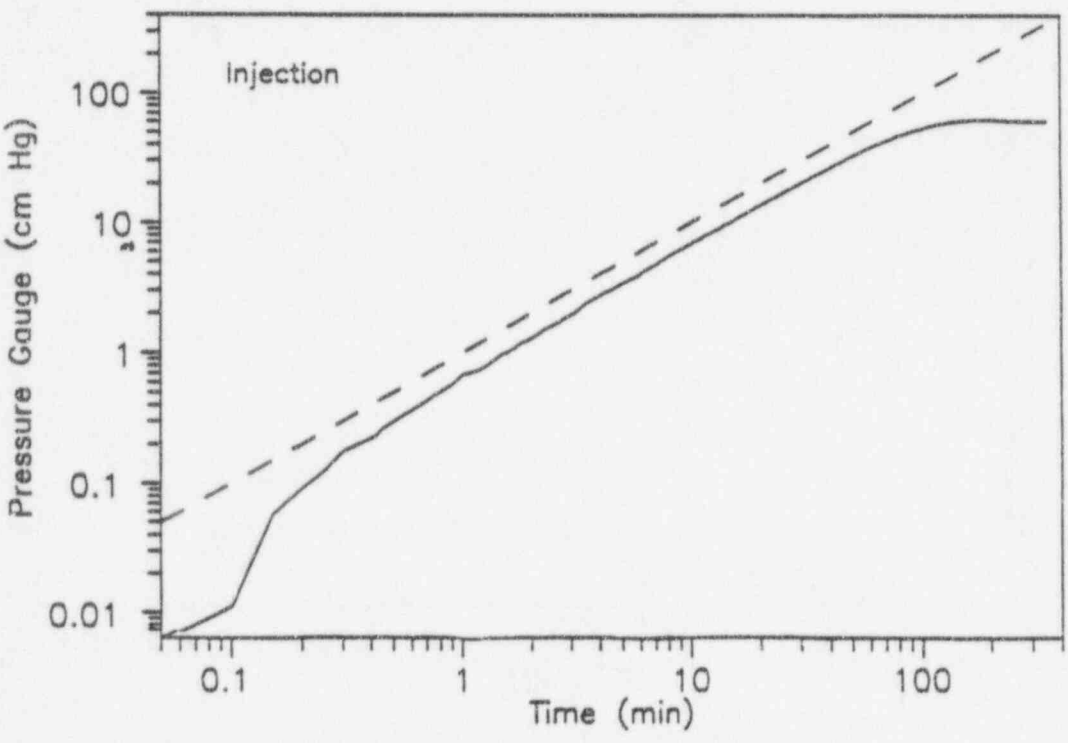


INJECTION TEST
Y3-YFA
06-07-94

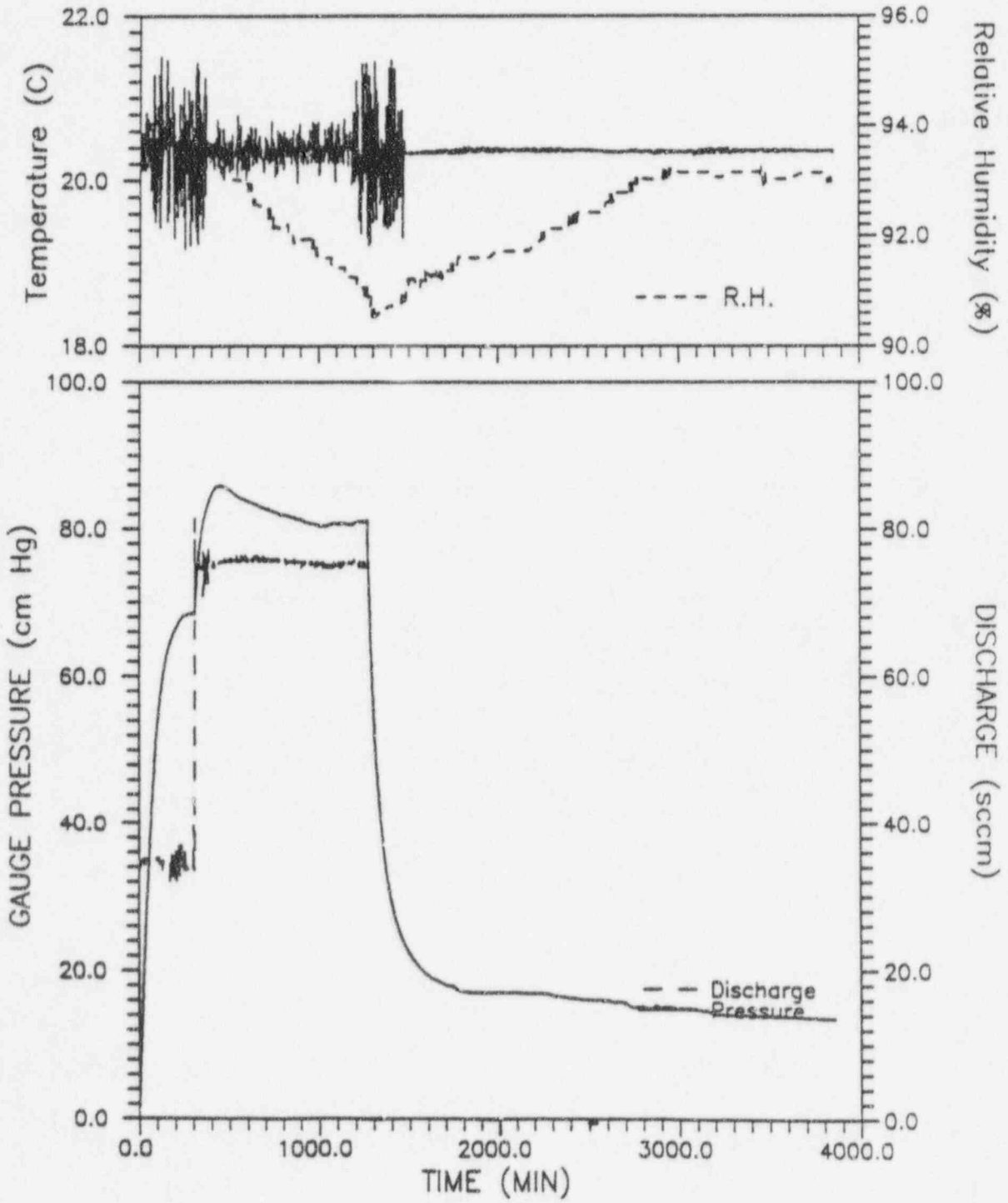


Y3-YFA
06-07-94
I: Q=35 sccm; R: Q= 600

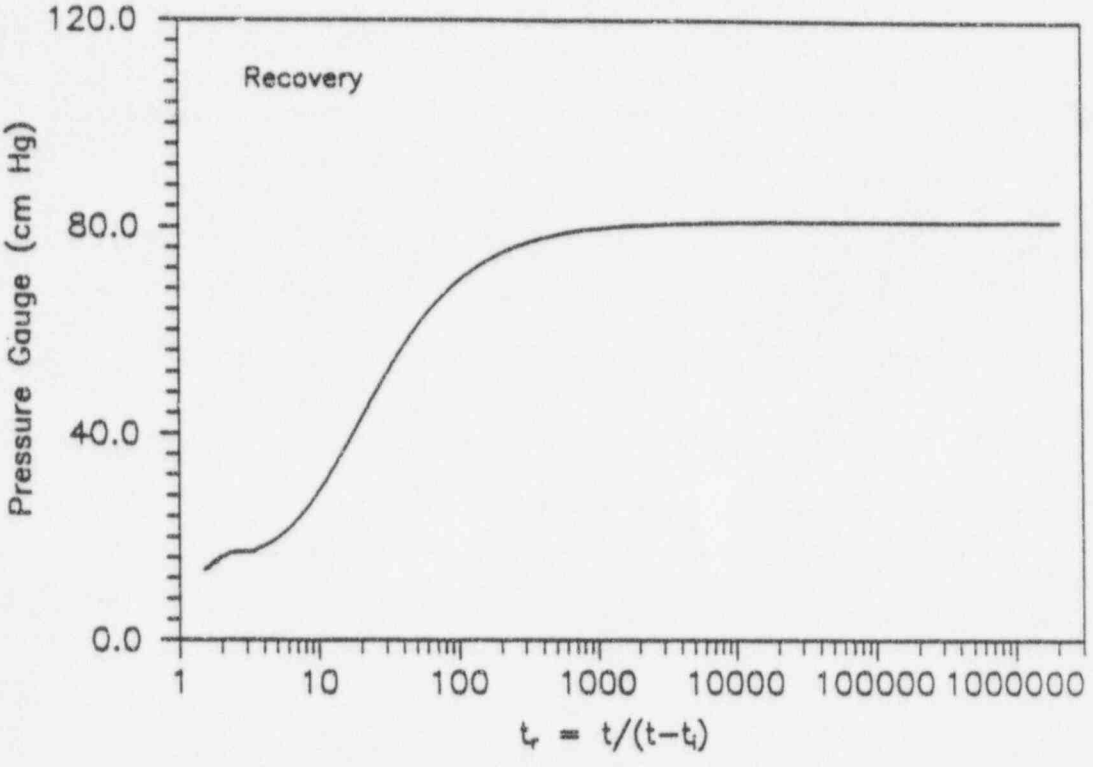


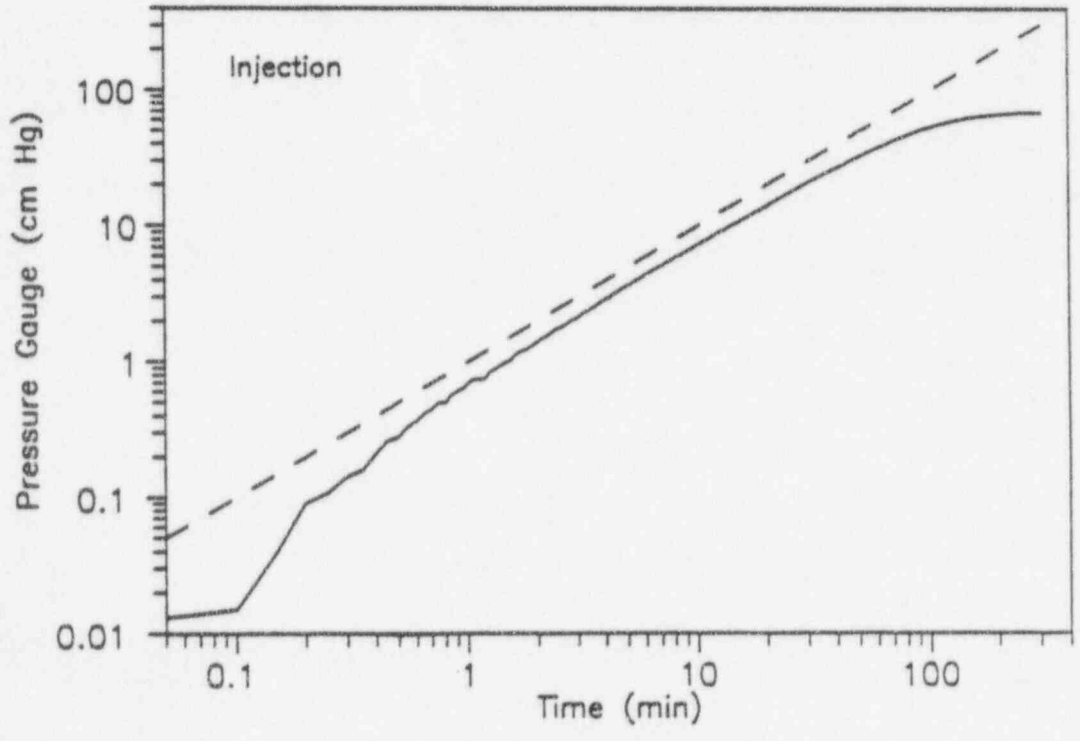


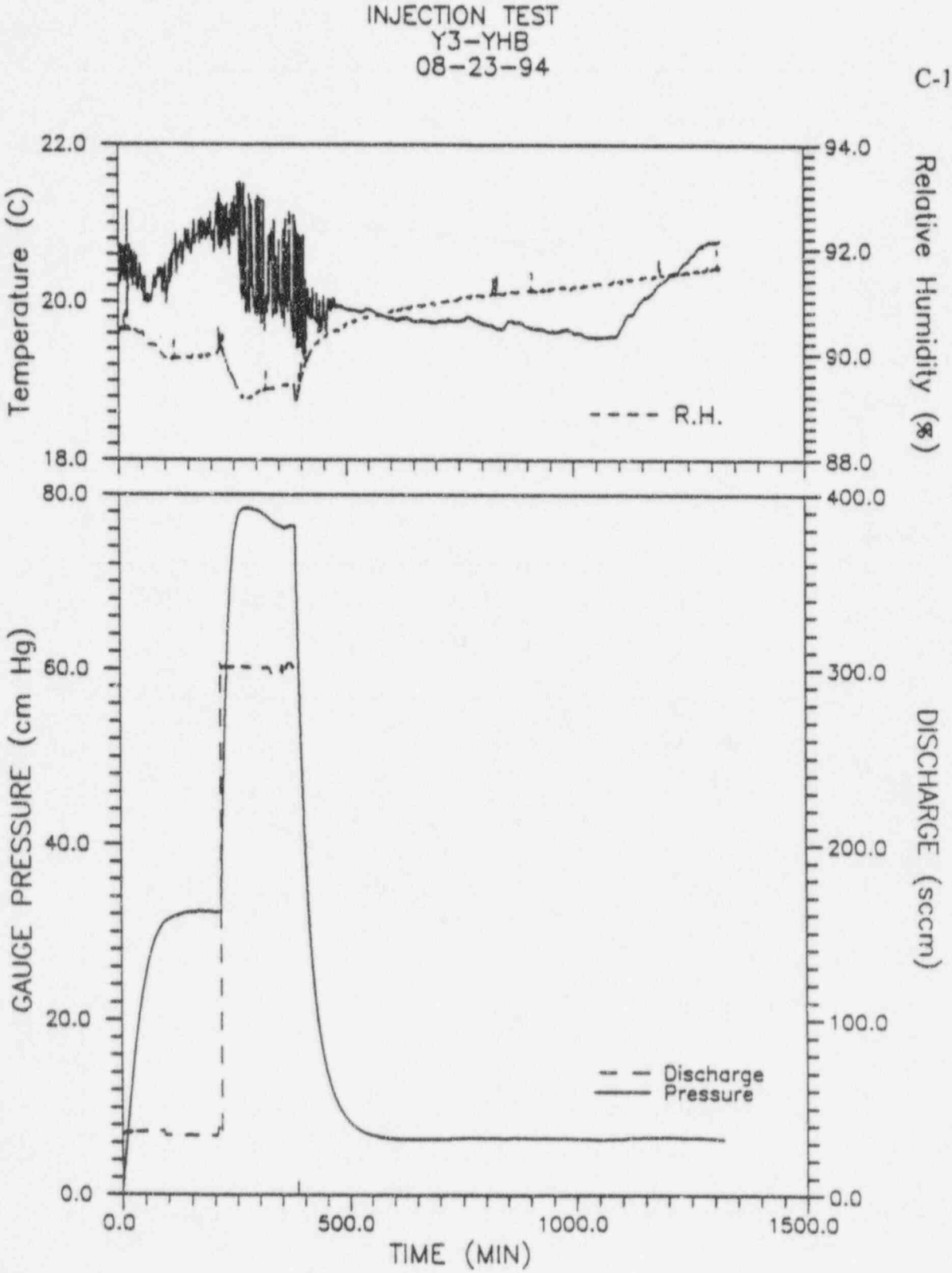
INJECTION TEST
Y3-YFC
06-28-94



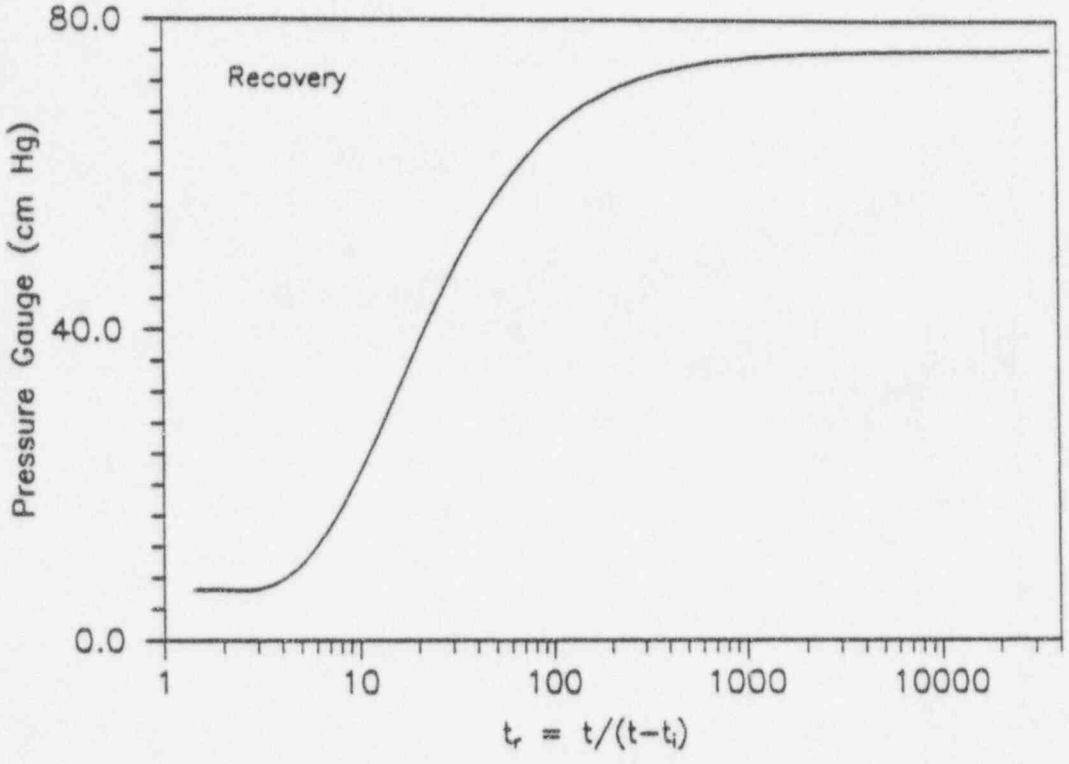
Y3-YFC
06-28--94
I: Q=35 sccm; R: Q= 75

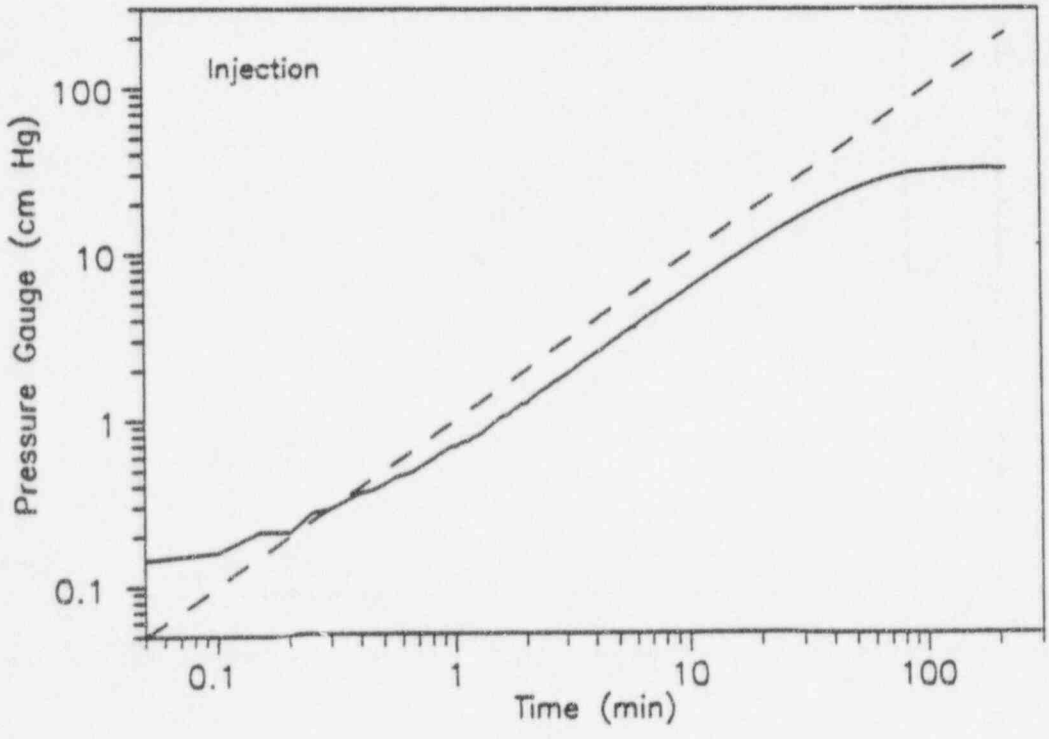




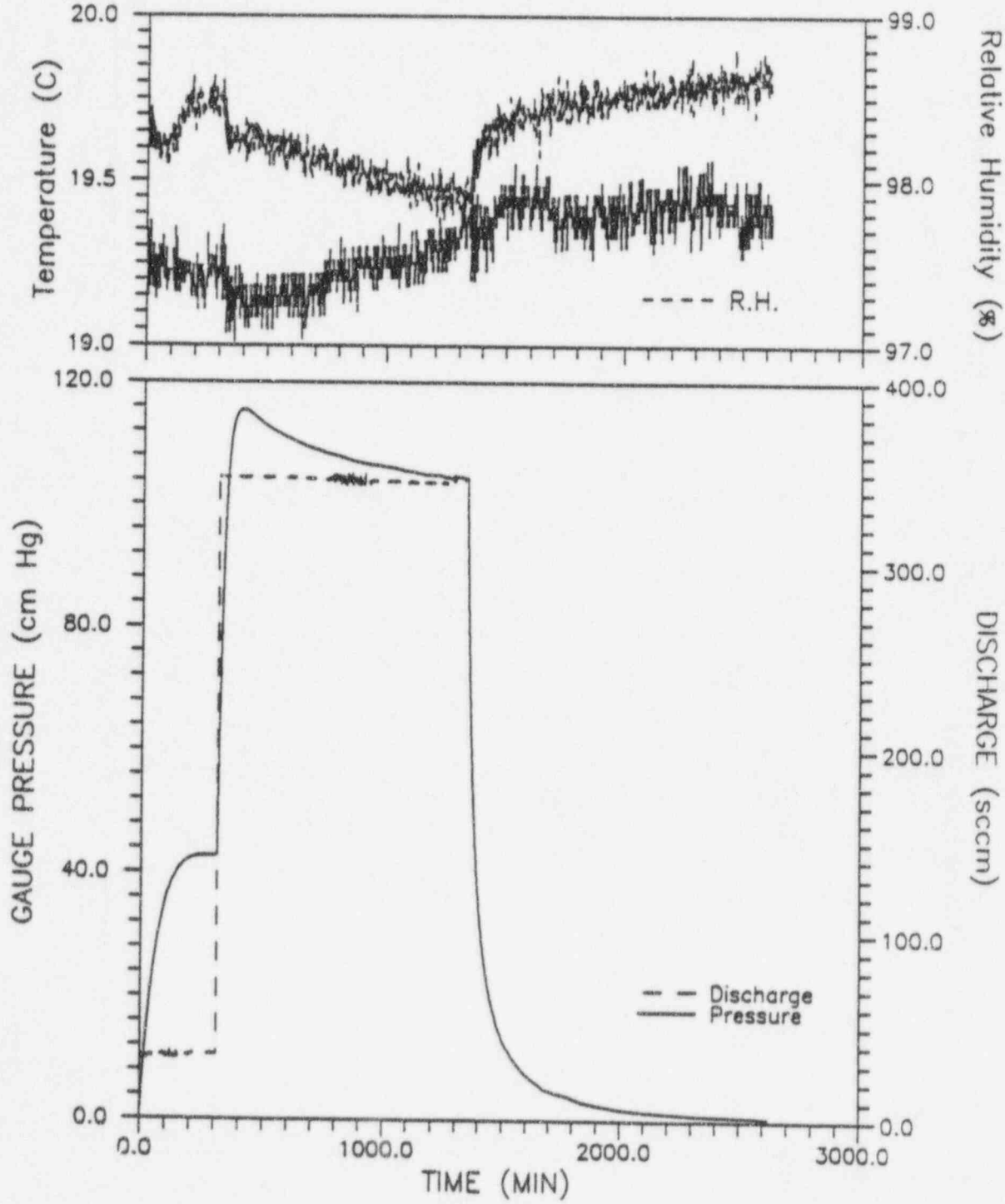

INJECTION TEST
Y3-YHB
08-23-94
Temperature (C)
22.0
20.0
18.0
Relative Humidity (%)
94.0
92.0
90.0
88.0
R.H.
GAUGE PRESSURE (cm Hg)
80.0
60.0
40.0
20.0
0.0
DISCHARGE (sccm)
400.0
300.0
200.0
100.0
0.0
Discharge
Pressure
0.0
500.0
1000.0
1500.0
TIME (MIN)

Y3-YHB
08-23-94
I: Q=35 sccm; R: Q=300

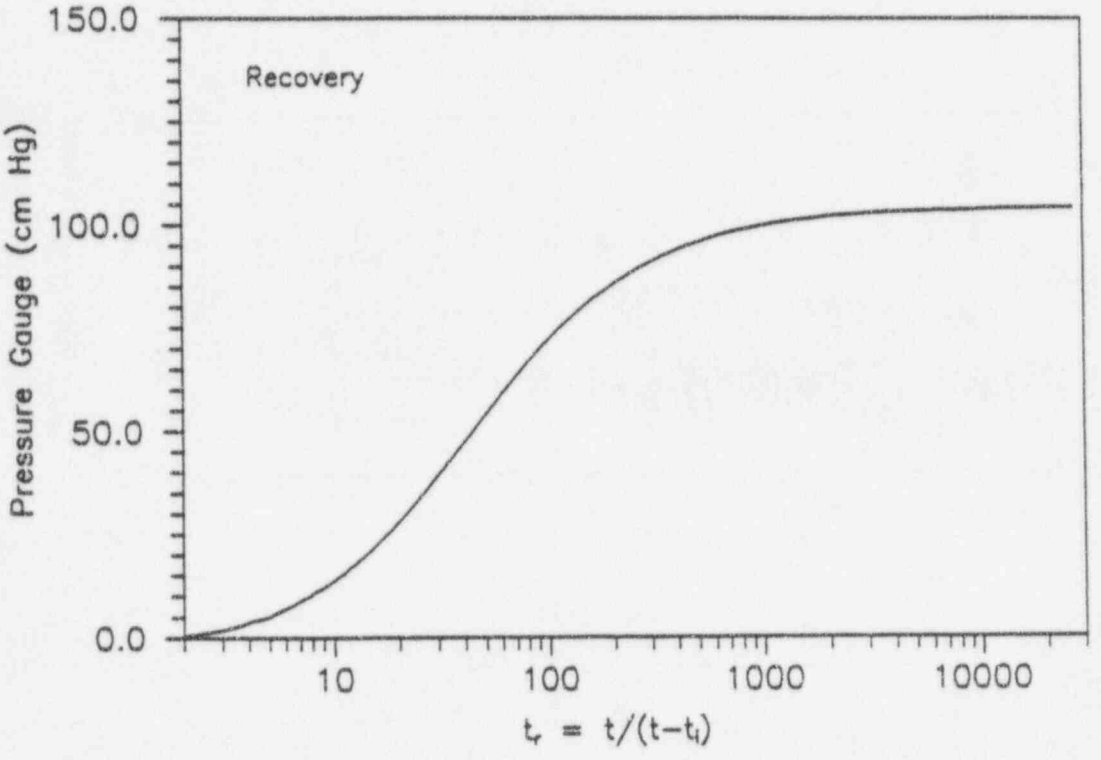


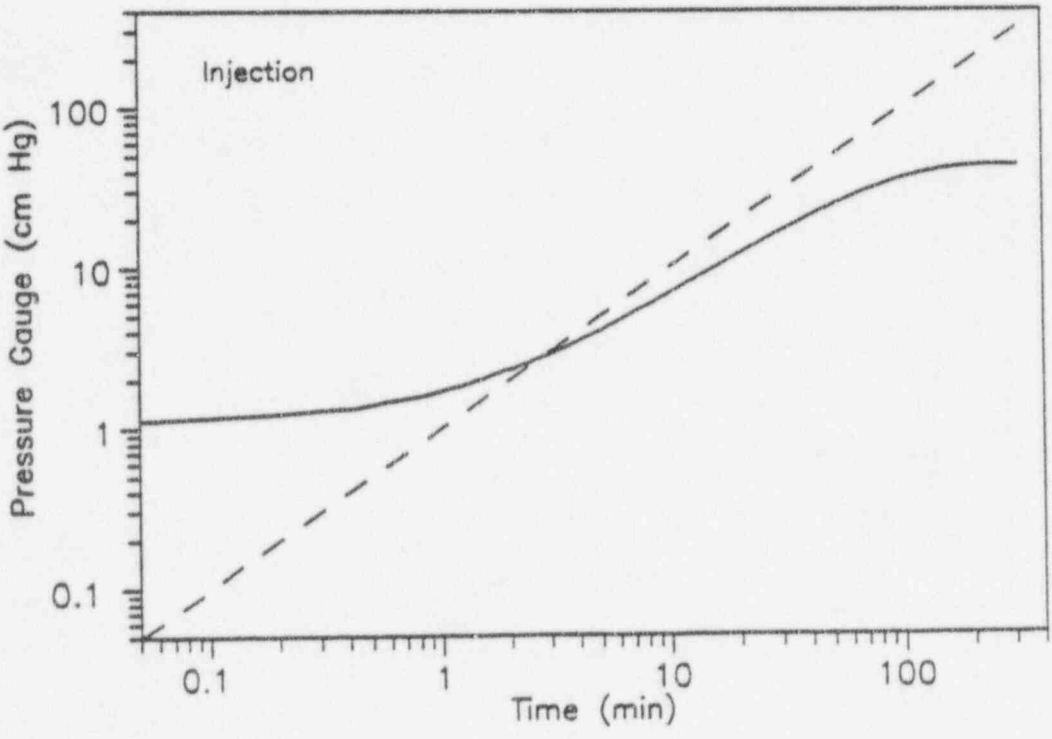


INJECTION TEST
Y3-YJA
10-13-94

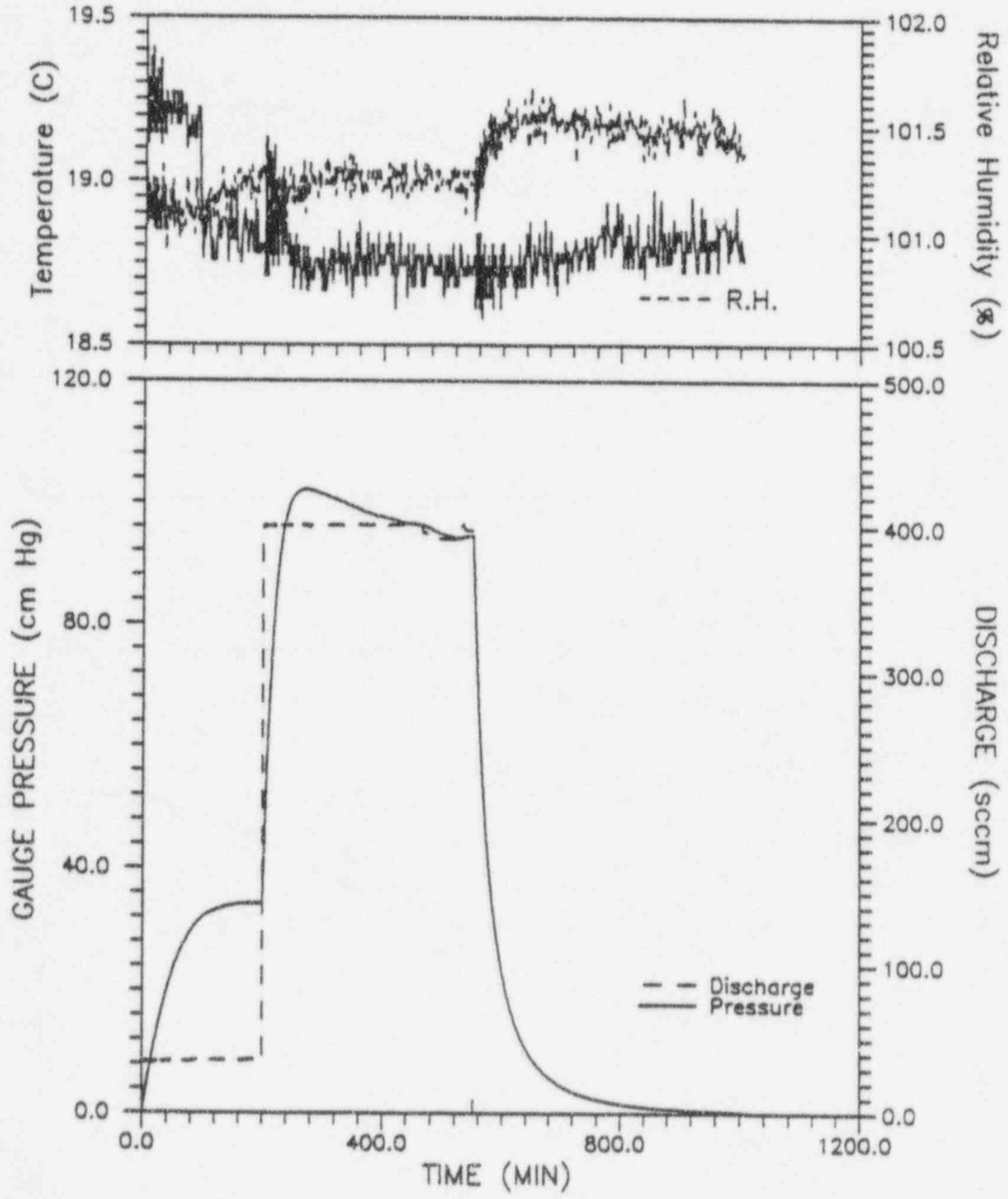


Y3-YJA
10-13-94
I: Q=35 sccm; R: Q=350

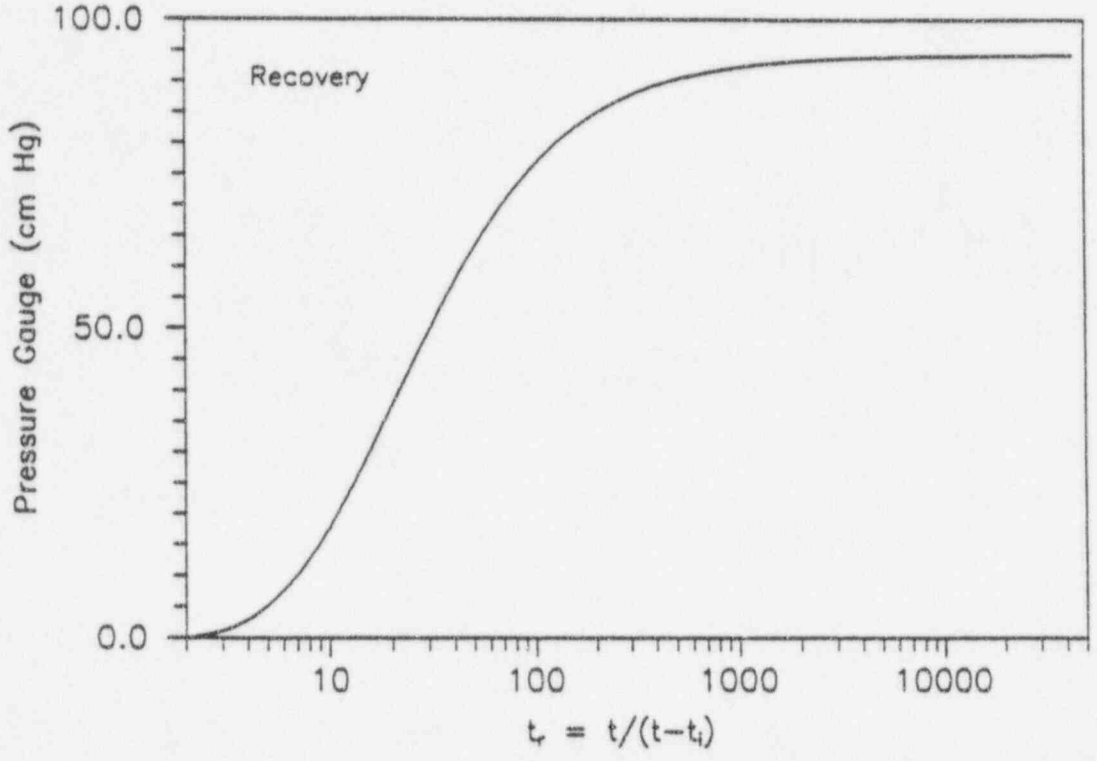


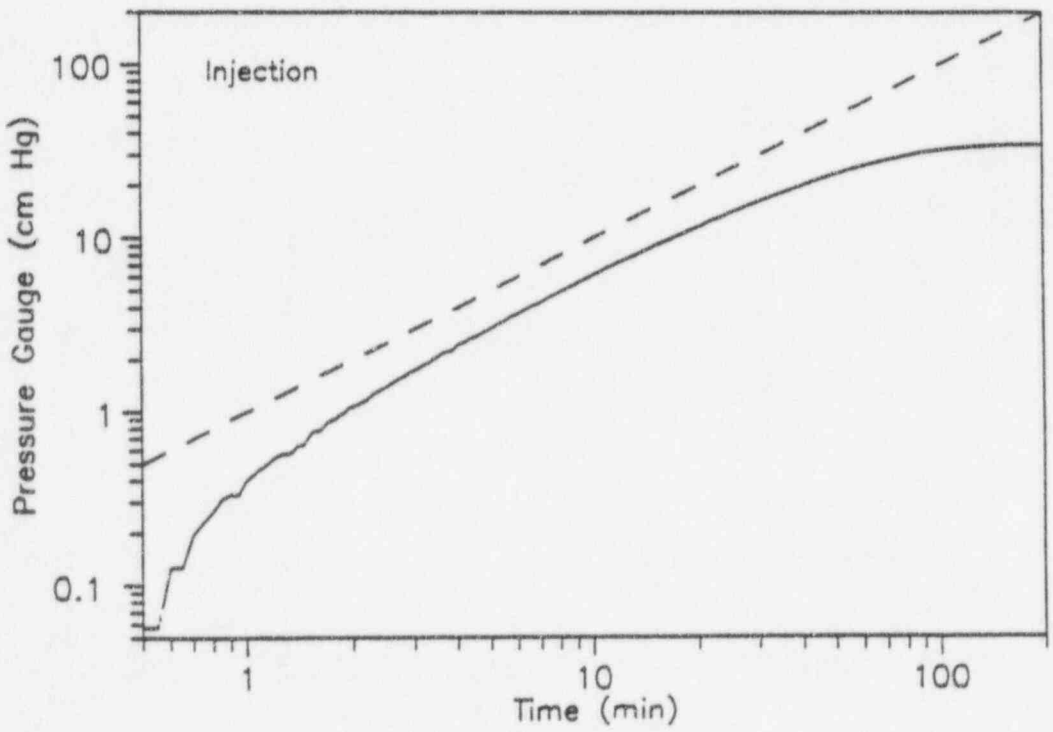


INJECTION TEST
Y3-YJB
10-18-94

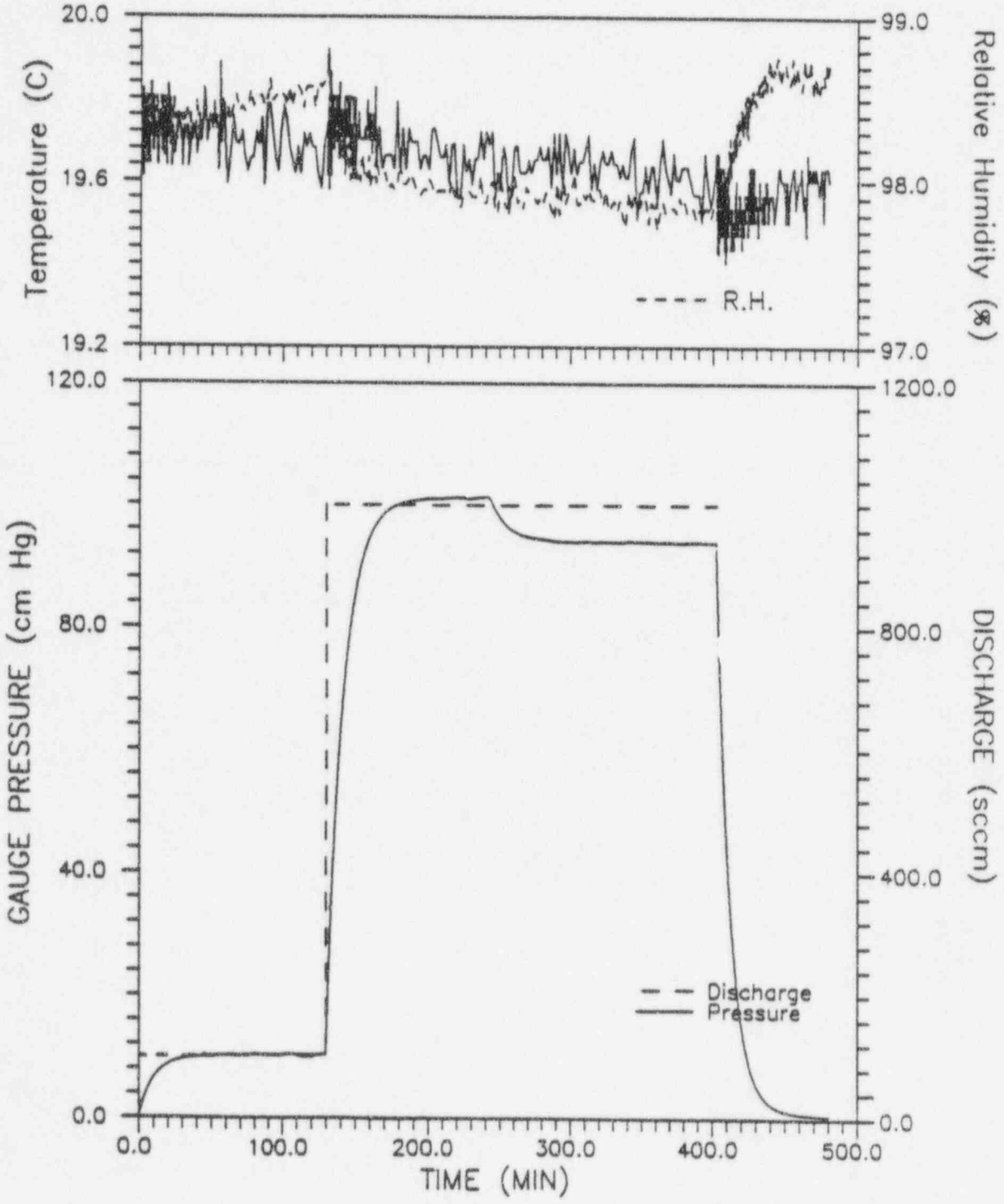


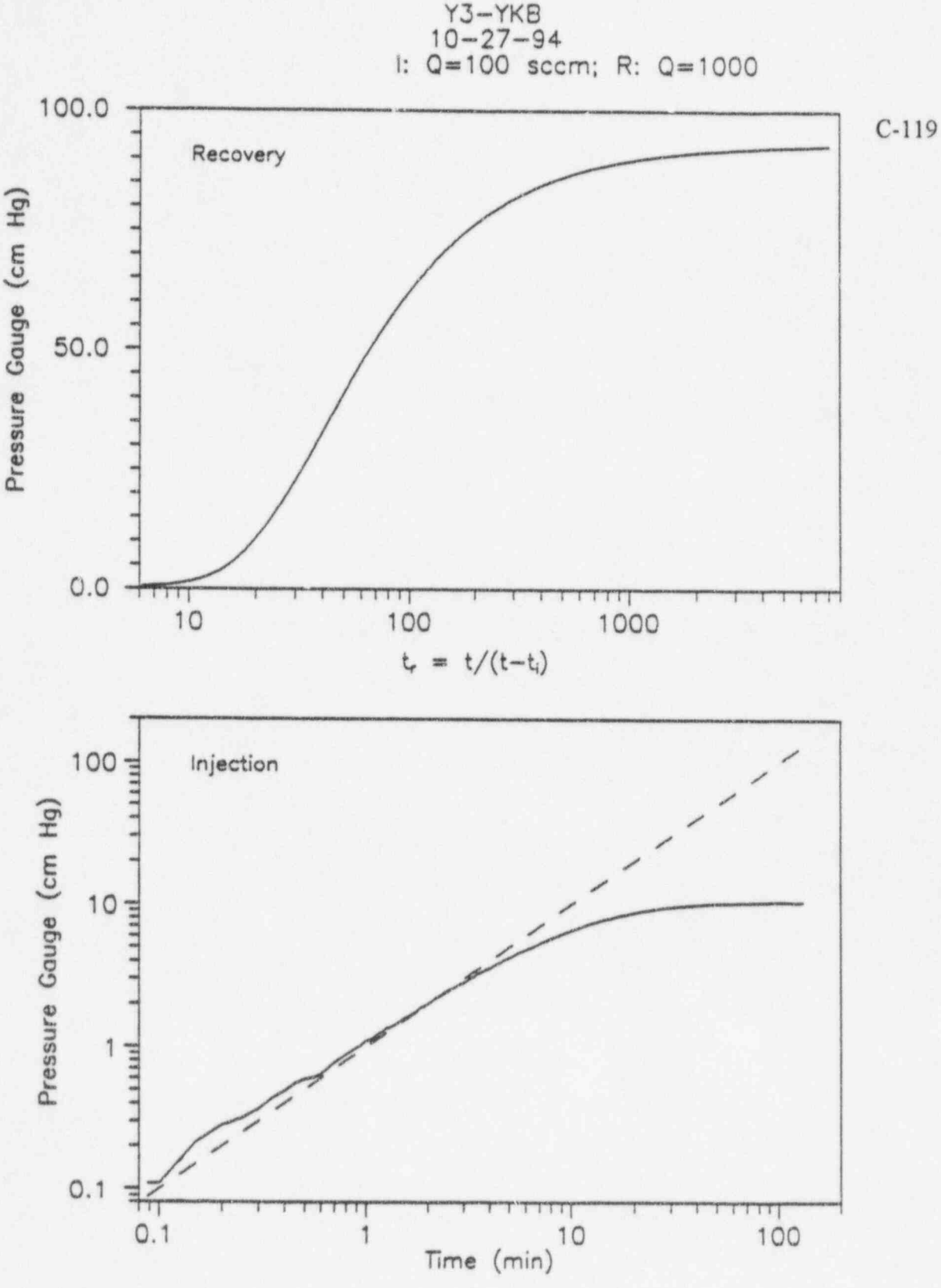
Y3-YJB
10-18-94
I: Q=35 sccm; R: Q=400



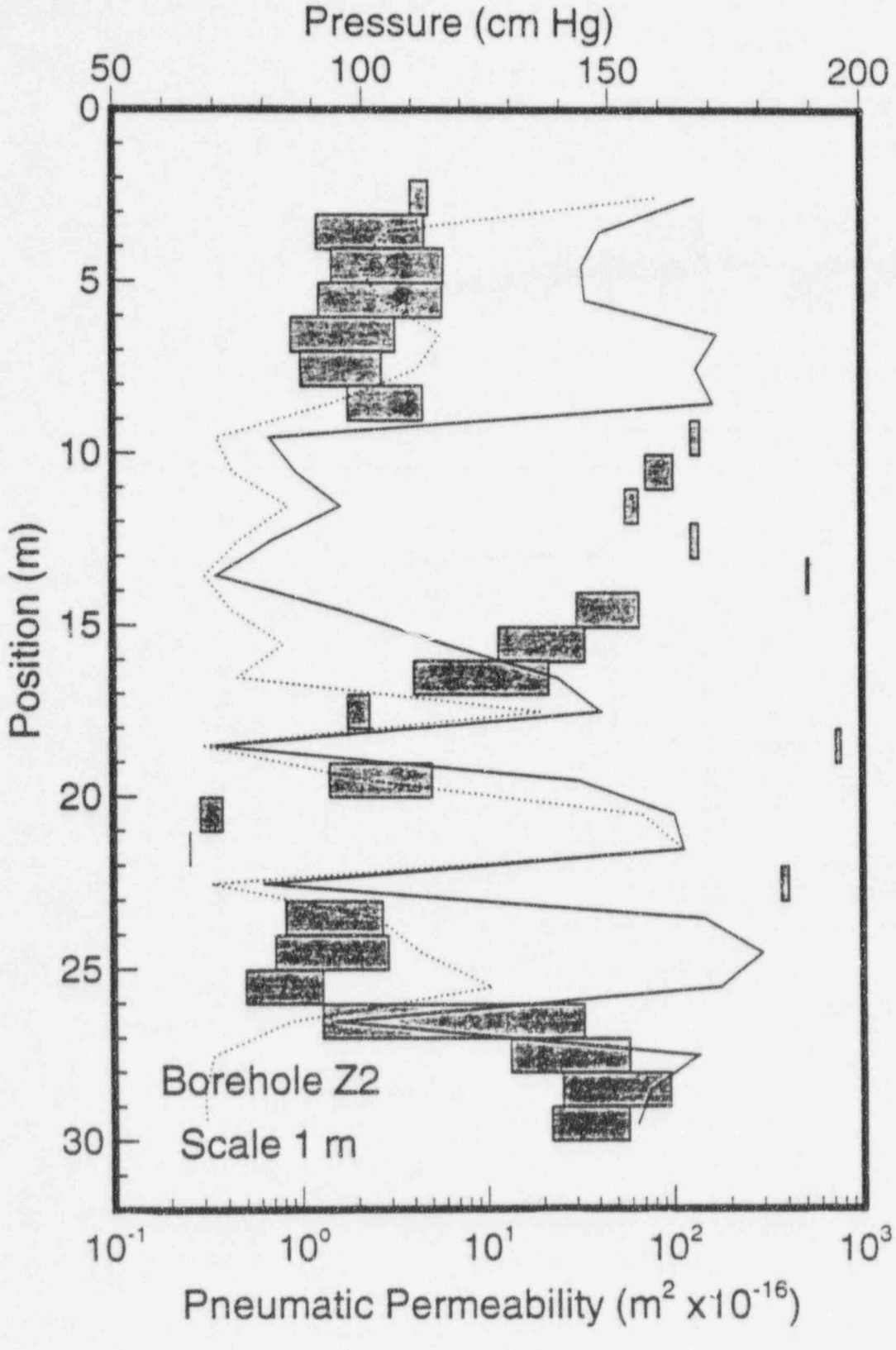


INJECTION TEST
Y3-YKB
10-27-94

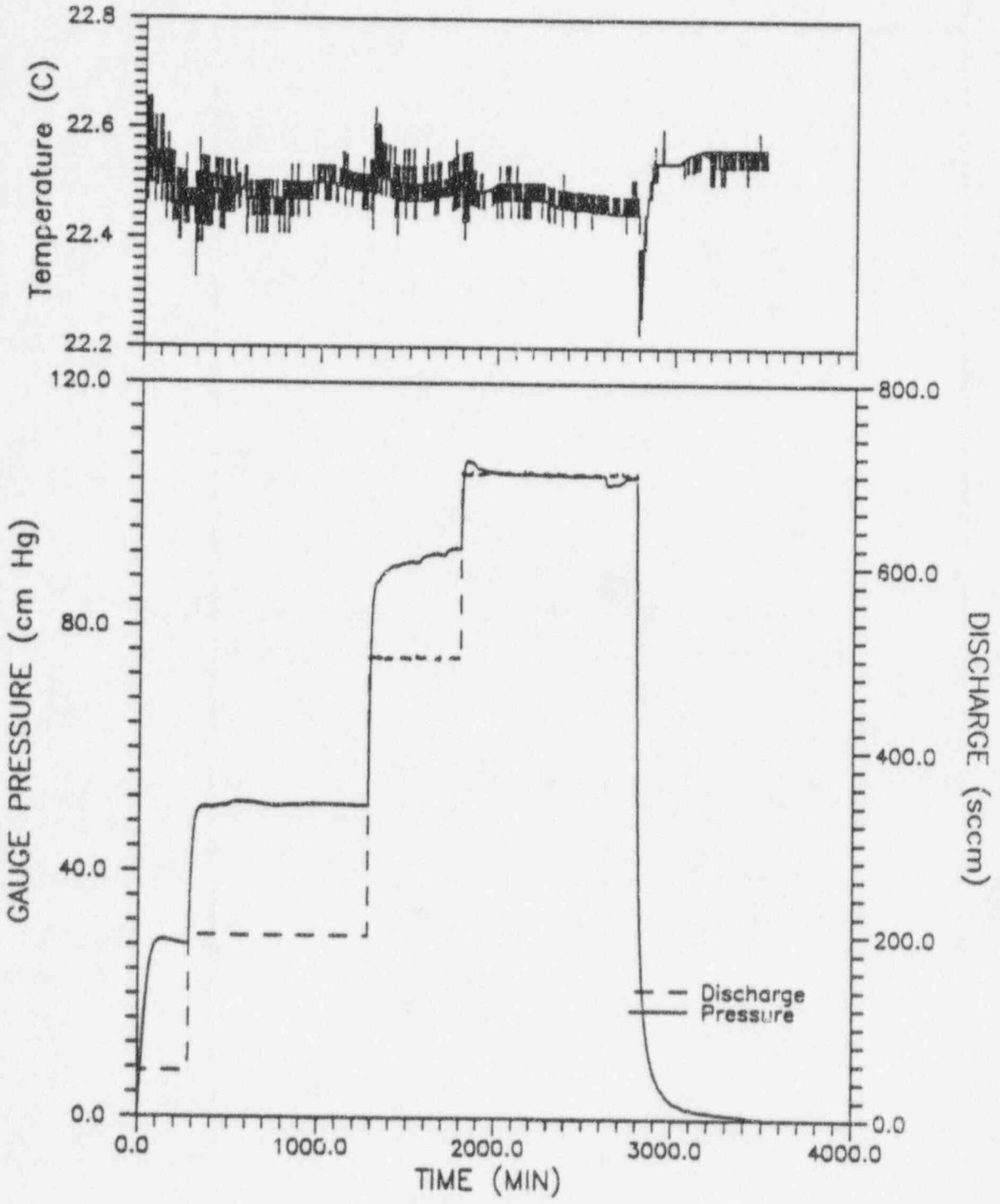



Y3-YKB
10-27-94
I: Q=100 sccm; R: Q=1000
Recovery
Pressure Gauge (cm Hg)
100.0
50.0
0.0
10
100
1000
t_r = t/(t-t_i)
Injection
Pressure Gauge (cm Hg)
100
10
1
0.1
0.1
1
10
100
Time (min)

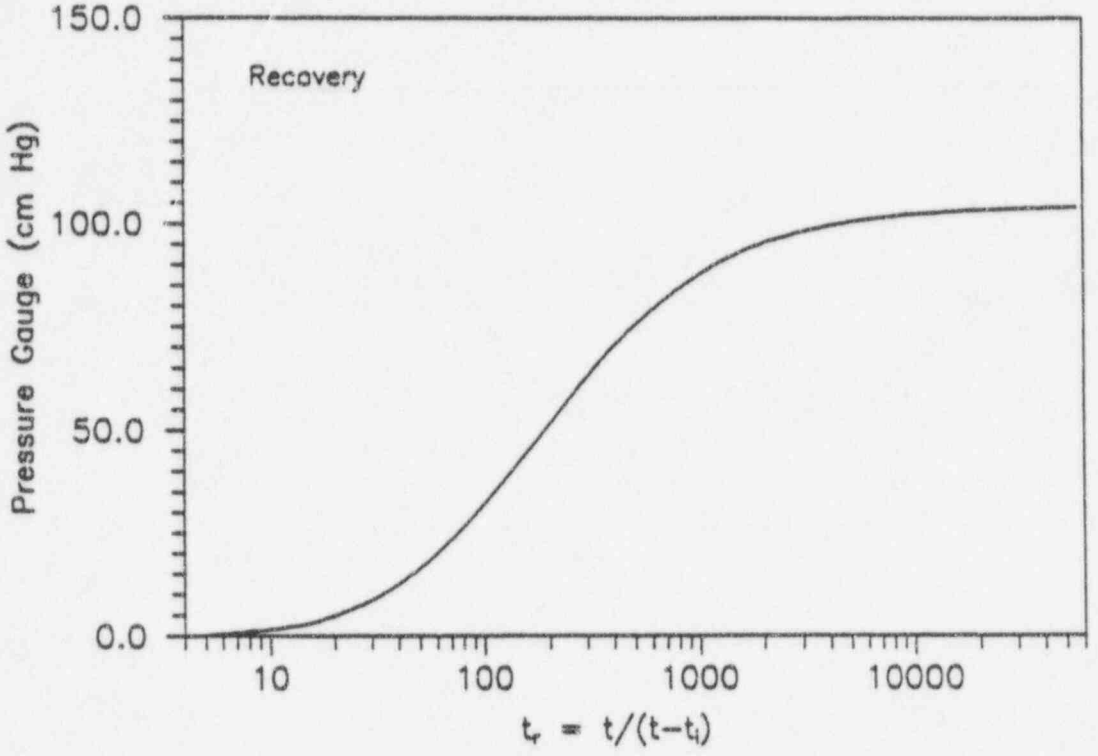
Graphs from Table B.10 Z2 - 1.0 m Data

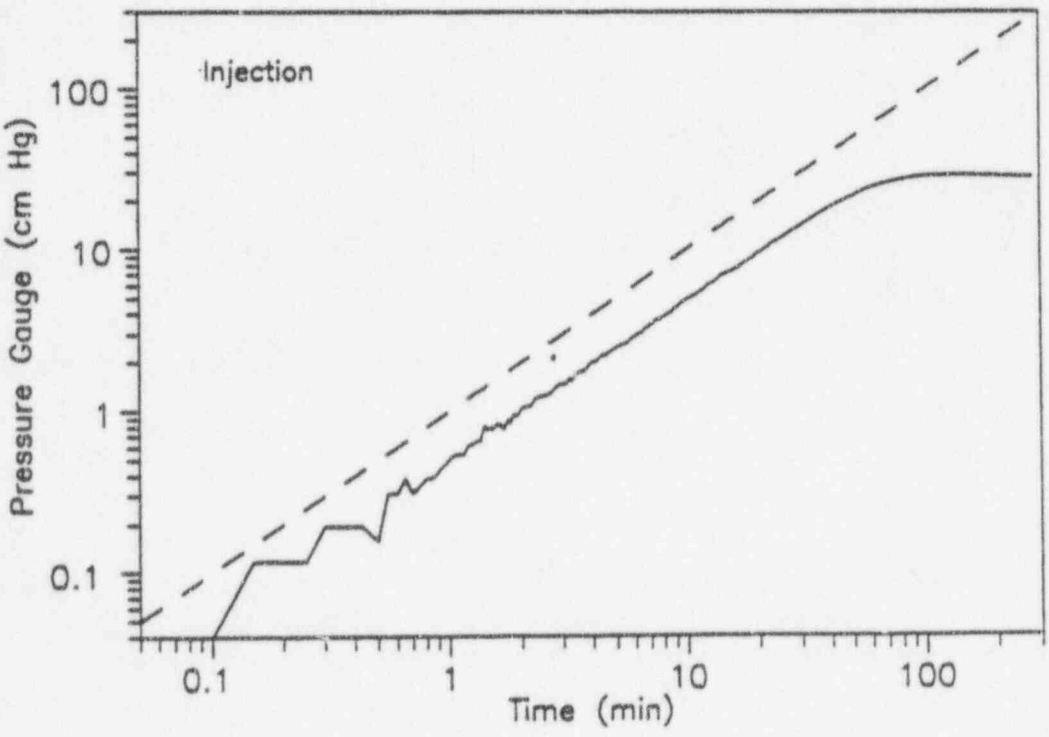

Pressure (cm Hg)
50
100
150
200
0
5
10
15
20
25
30
Position (m)
Borehole Z2
Scale 1 m
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
Pneumatic Permeability ($m^2 \times 10^{-16}$)

INJECTION TEST
Z2-ZCA
08-12-93

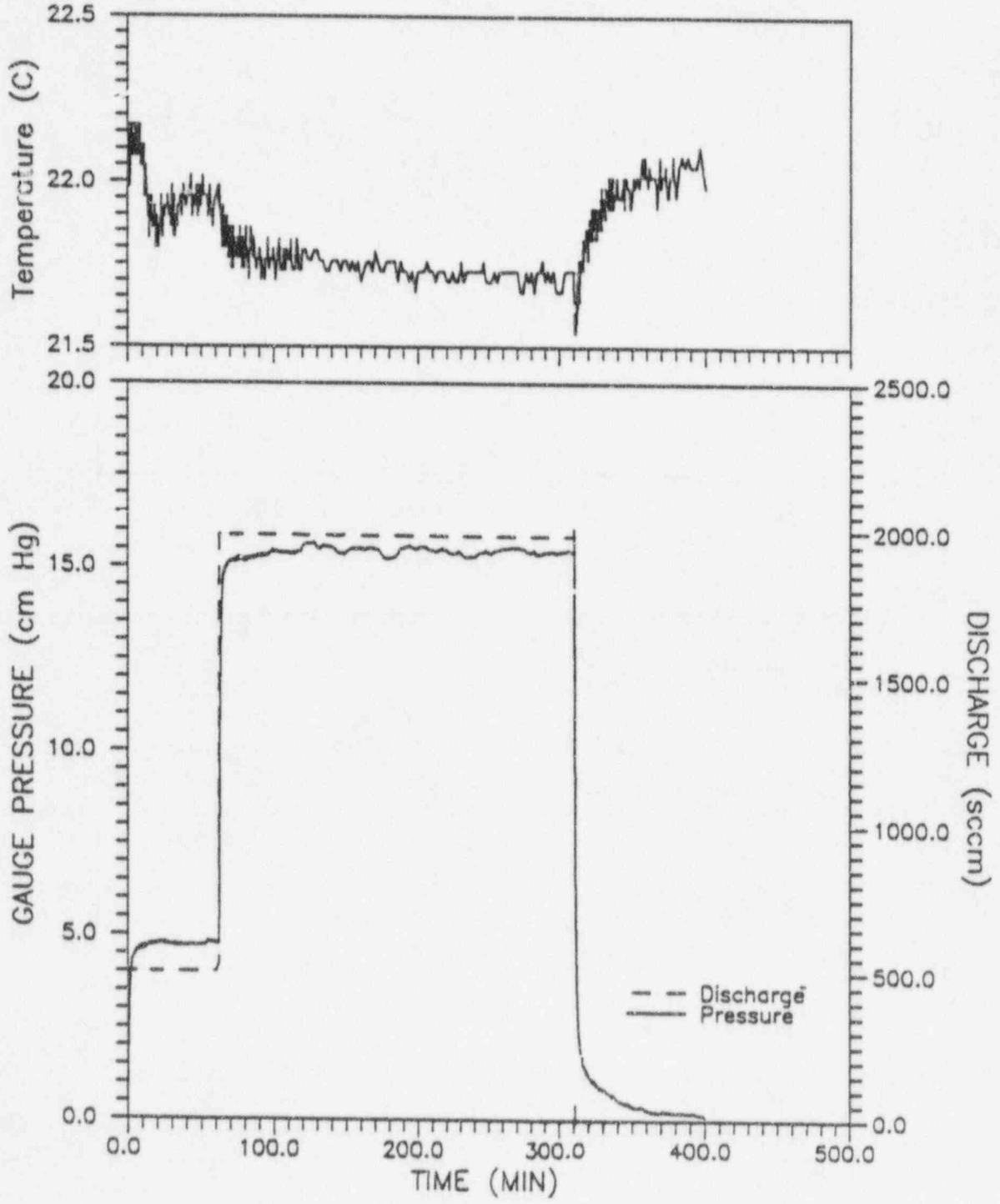


Z2-ZCA
08-12-93
I: Q=50 sccm; R: Q=700

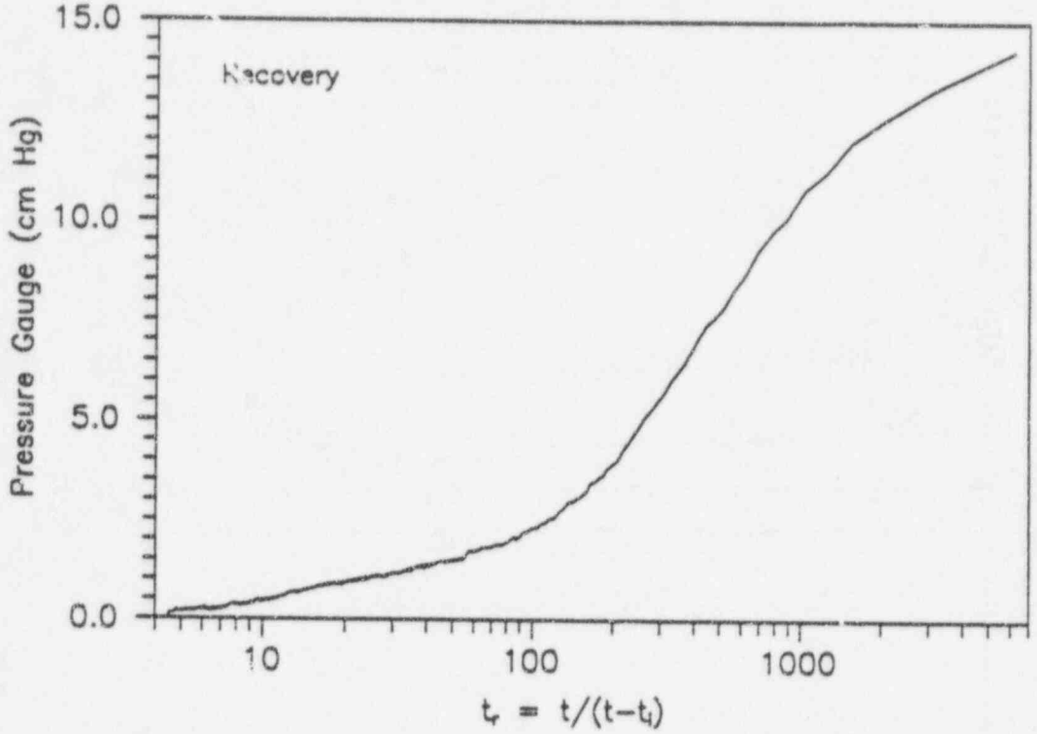


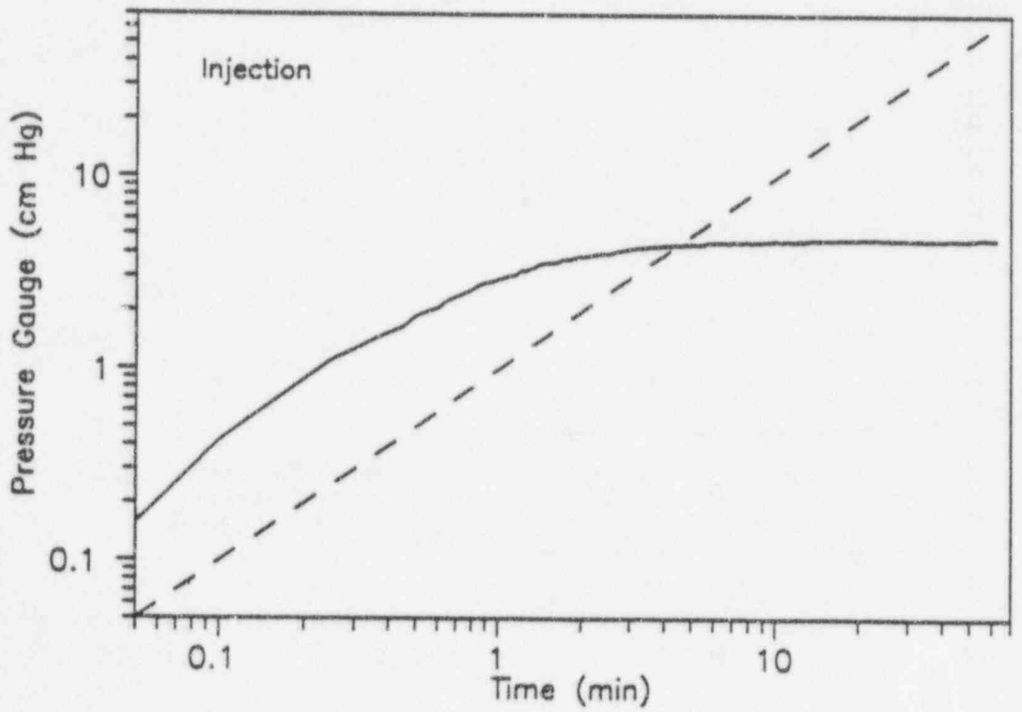


INJECTION TEST
Z2-ZCB
08-19-93

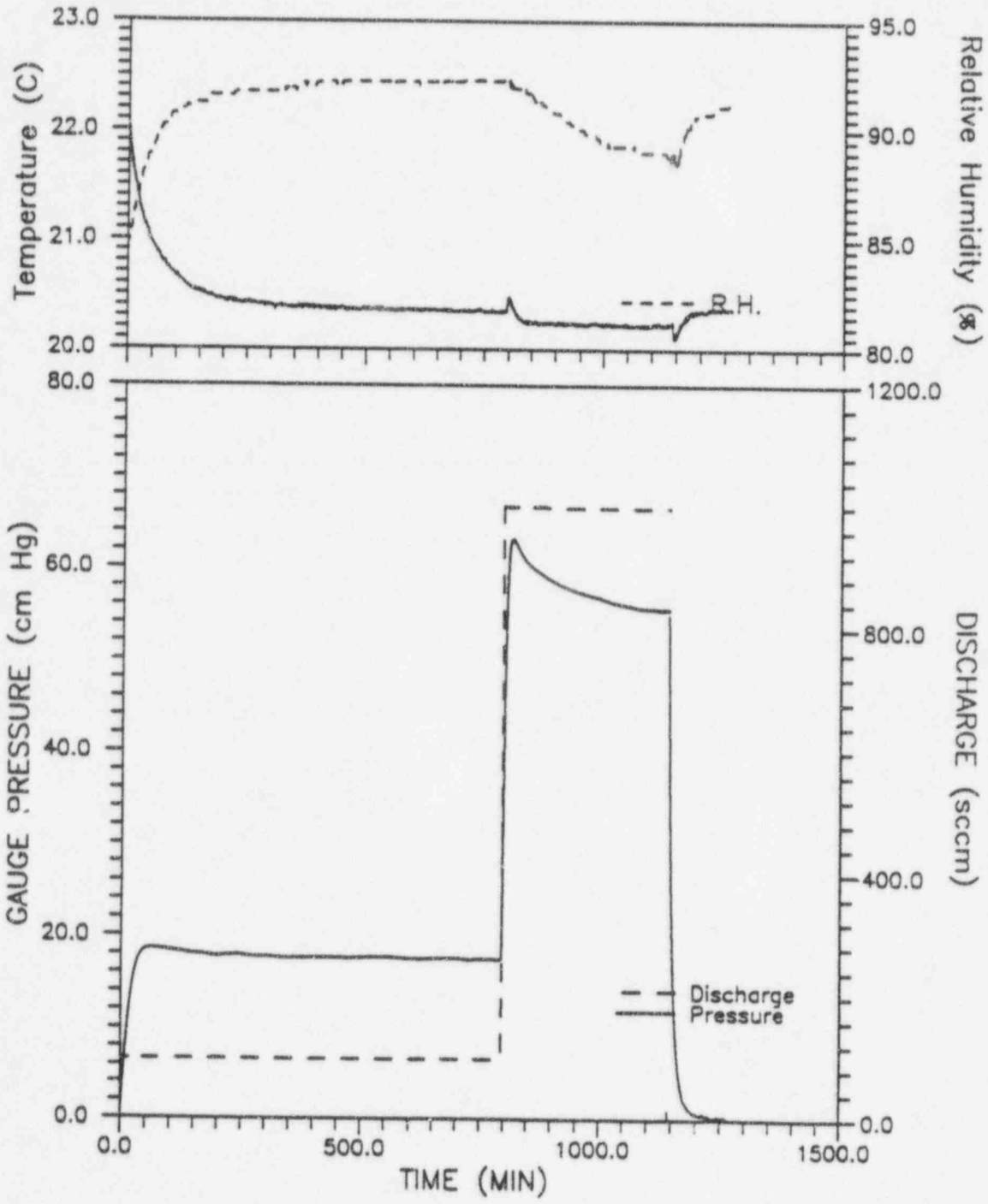


Z2-ZCB
08-19-93
I: Q=500 sccm; R: Q=2000

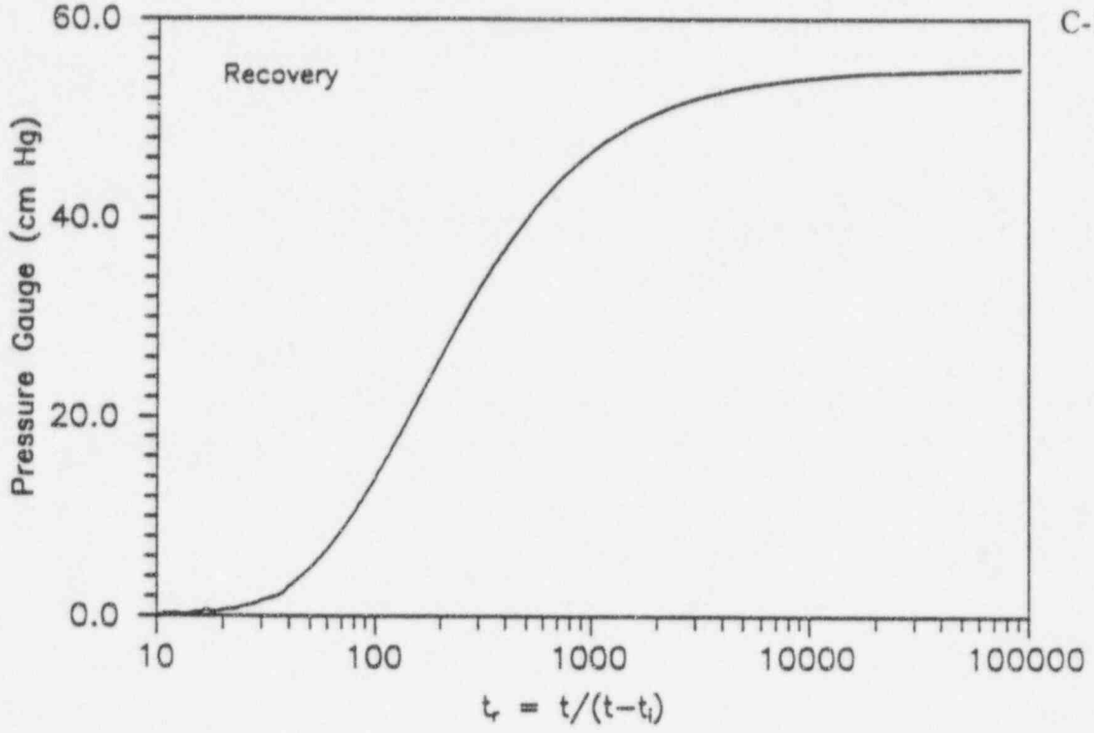


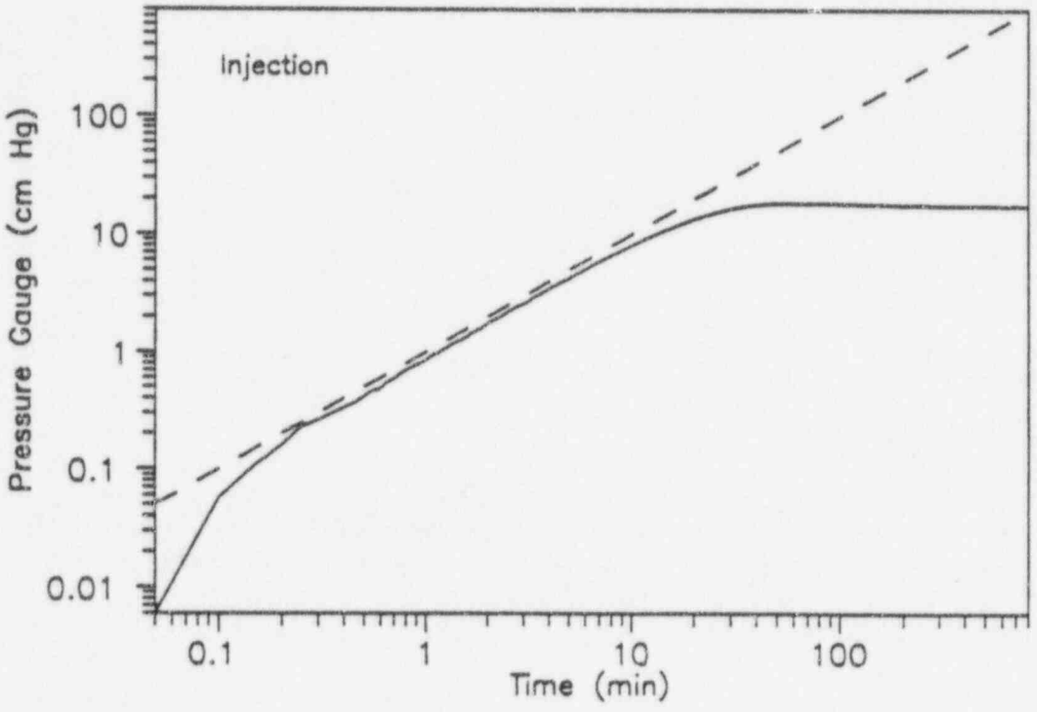


INJECTION TEST
Z2-ZEC
08-31-93

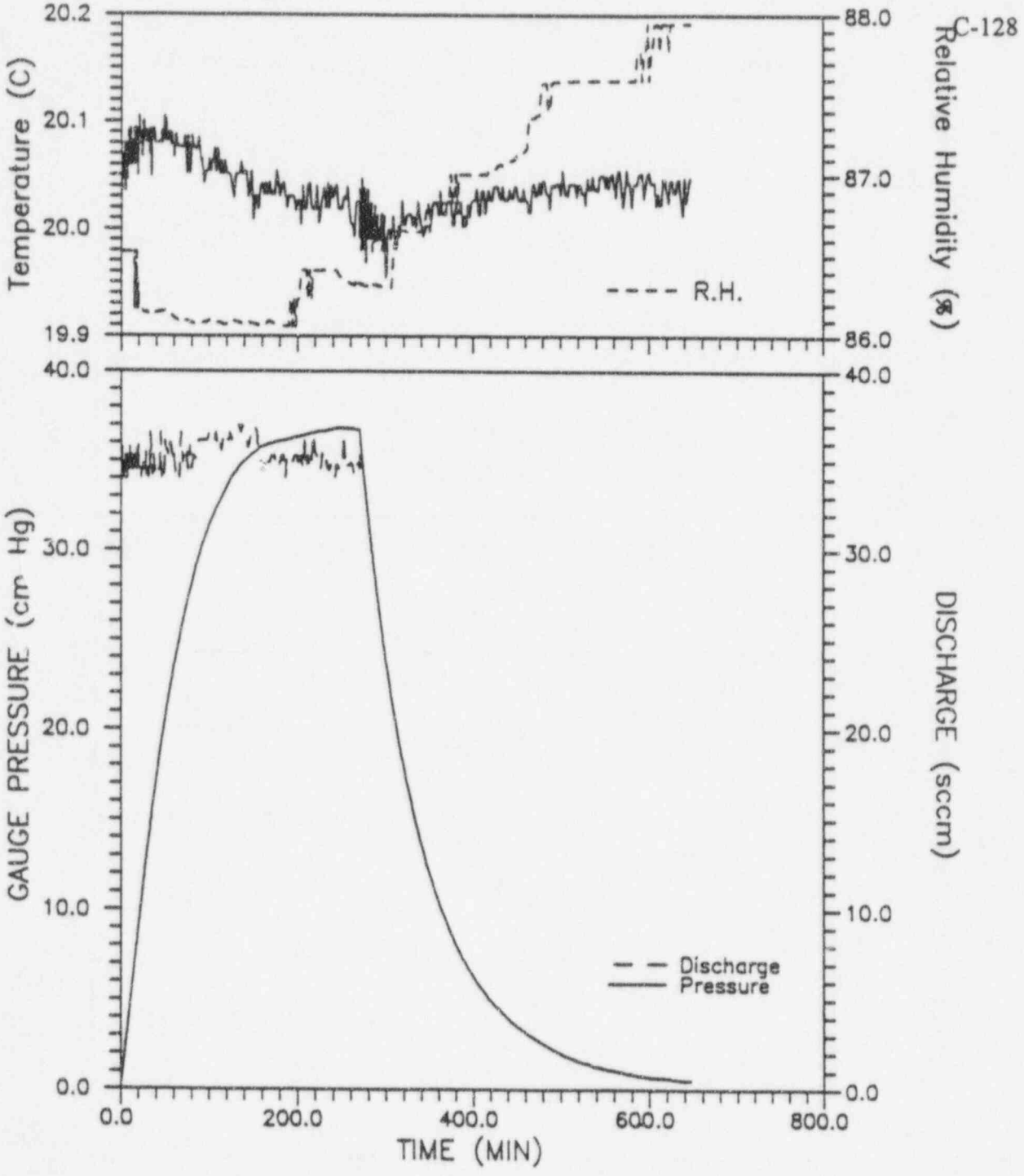


Z2-ZEC
08-31-93
I: Q=100 sccm; R: Q=1000

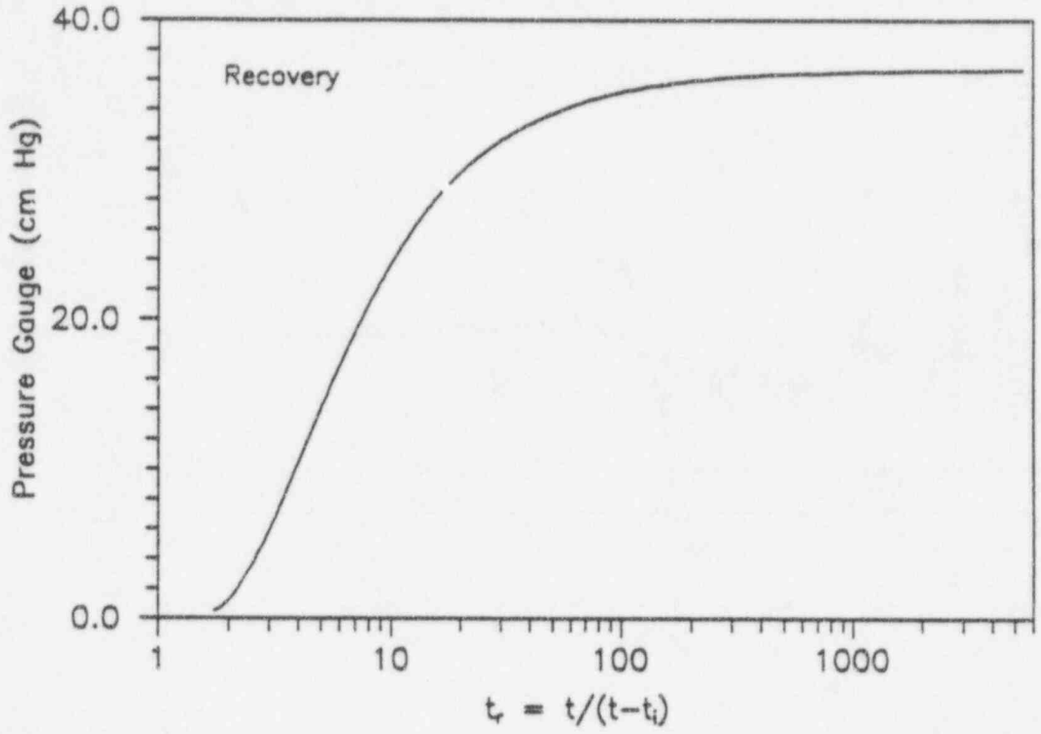


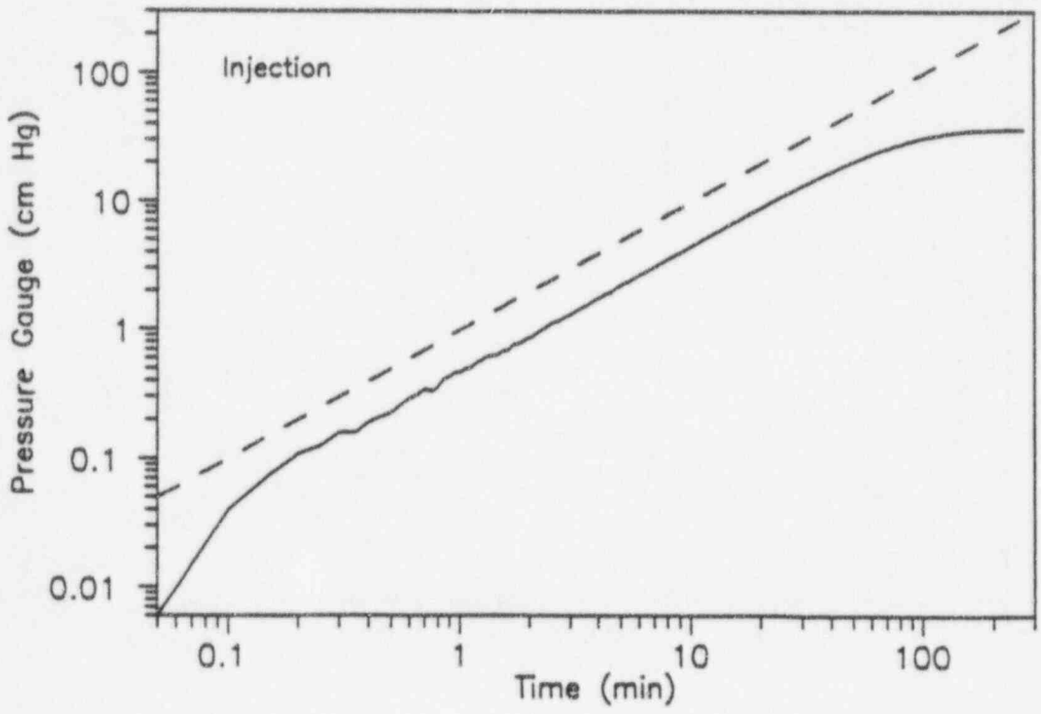


INJECTION TEST
Z2-ZHA
10-06-93

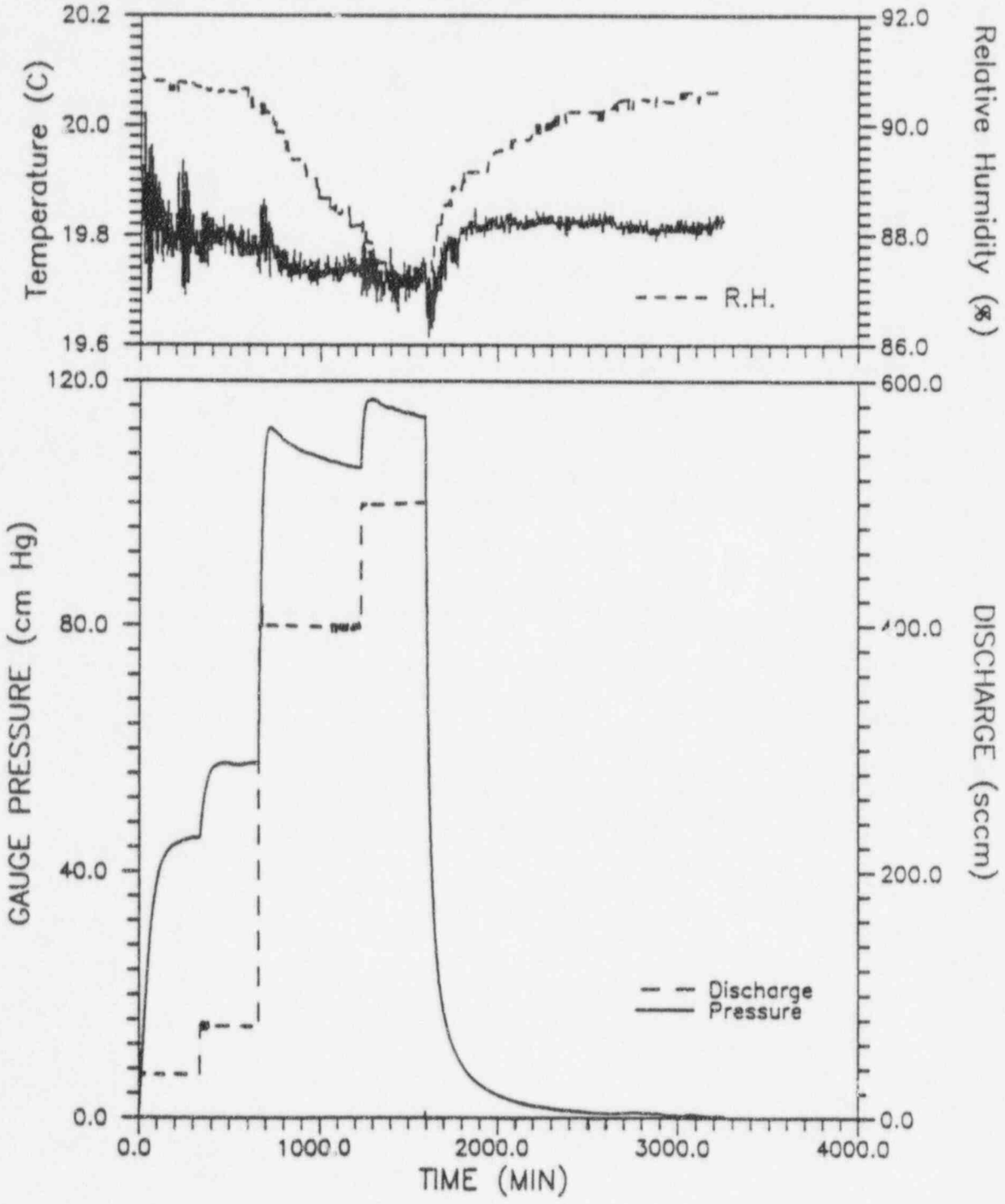


Z2-ZHA
10-06-93
I: Q=35 sccm; R: Q=35

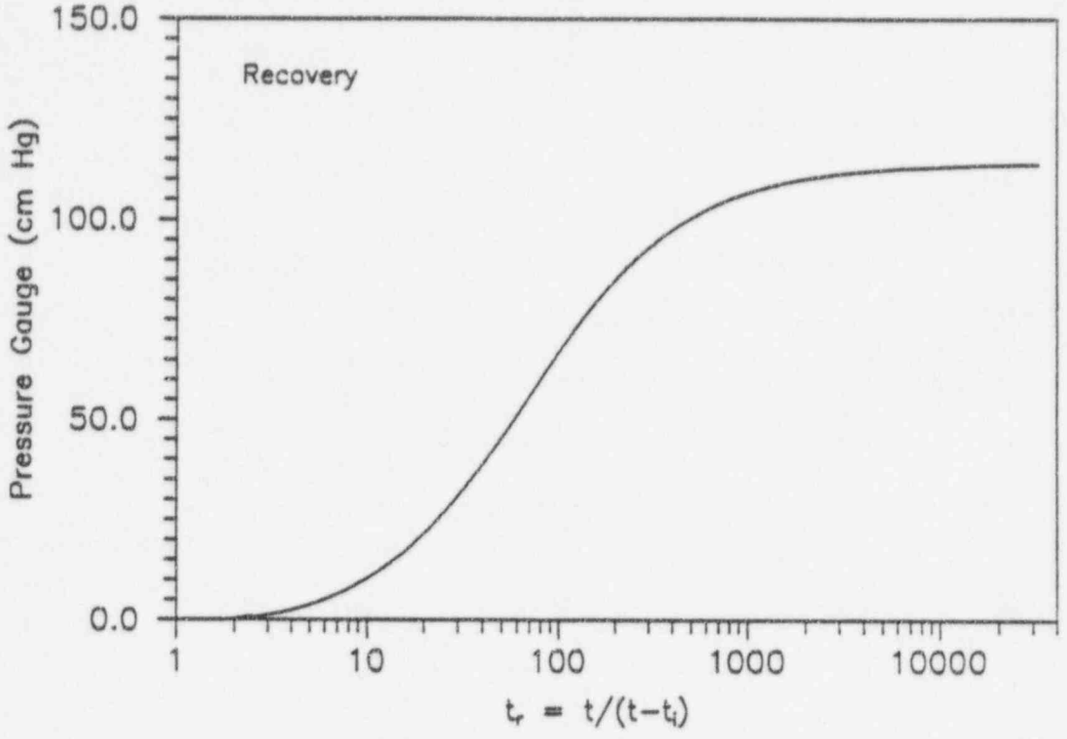


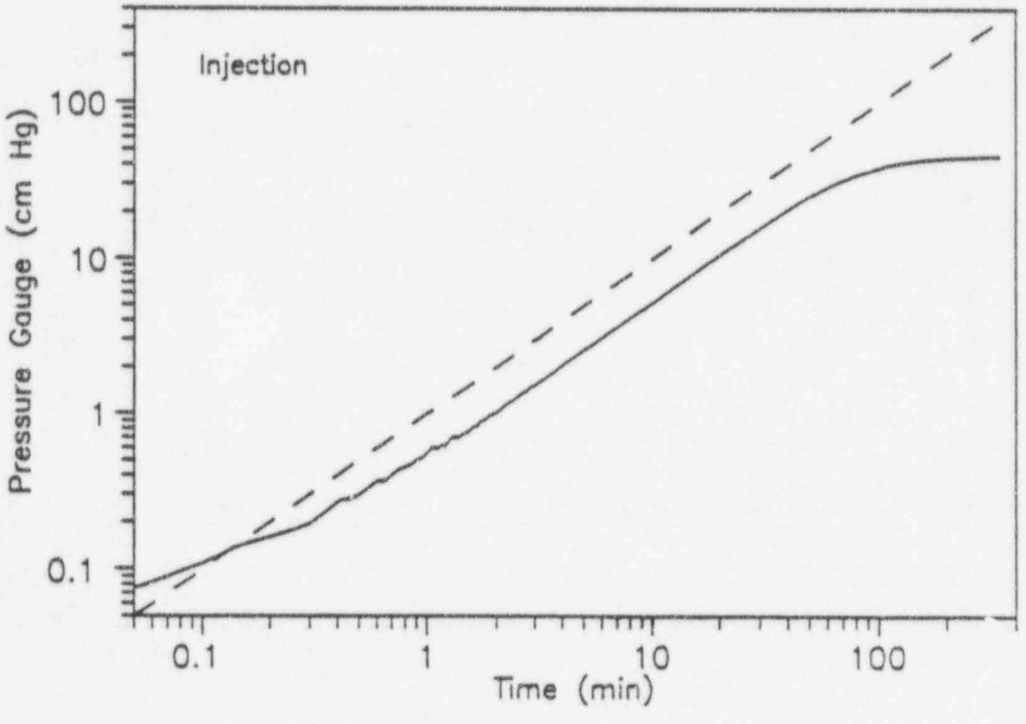


INJECTION TEST
Z2-ZHB
10-14-93

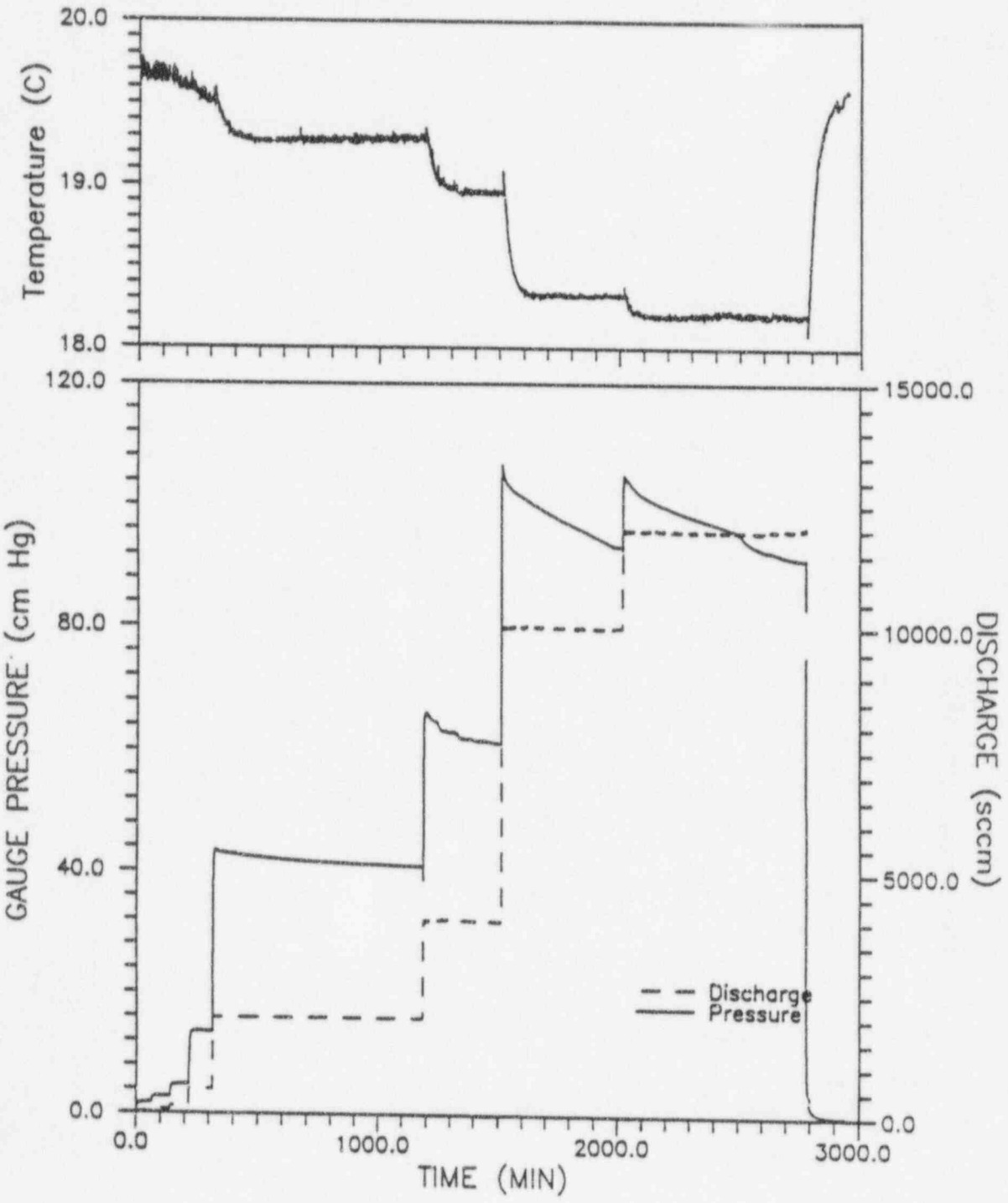


Z2-ZHB
10-14-93
I: Q=35 sccm; R: Q=500

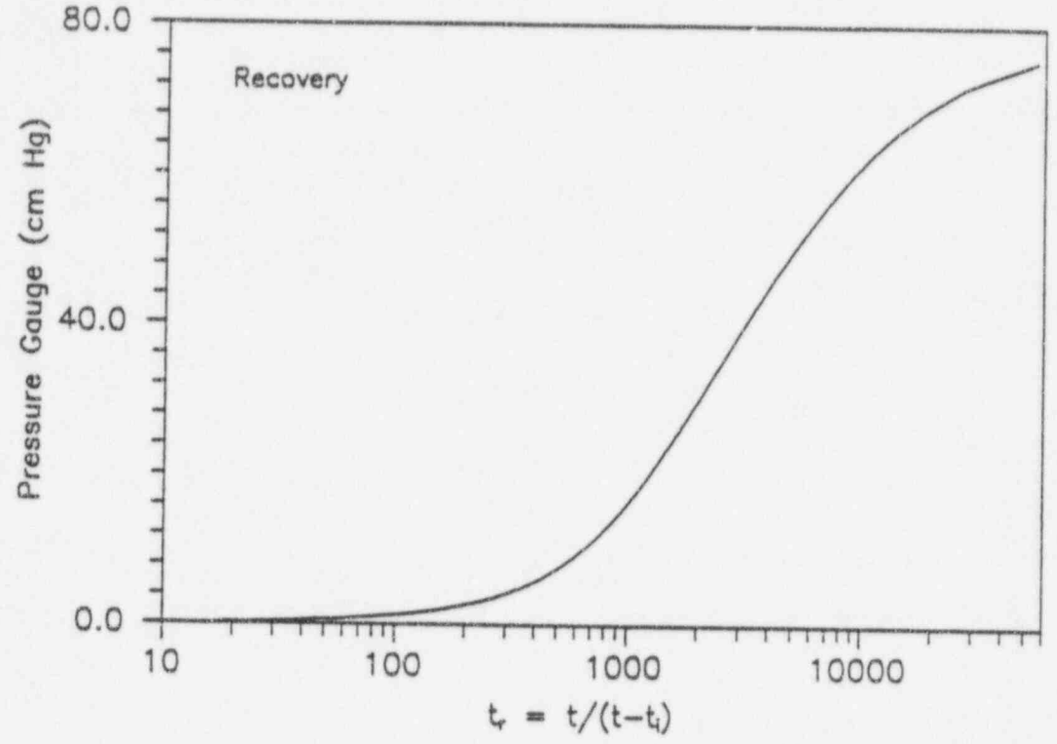


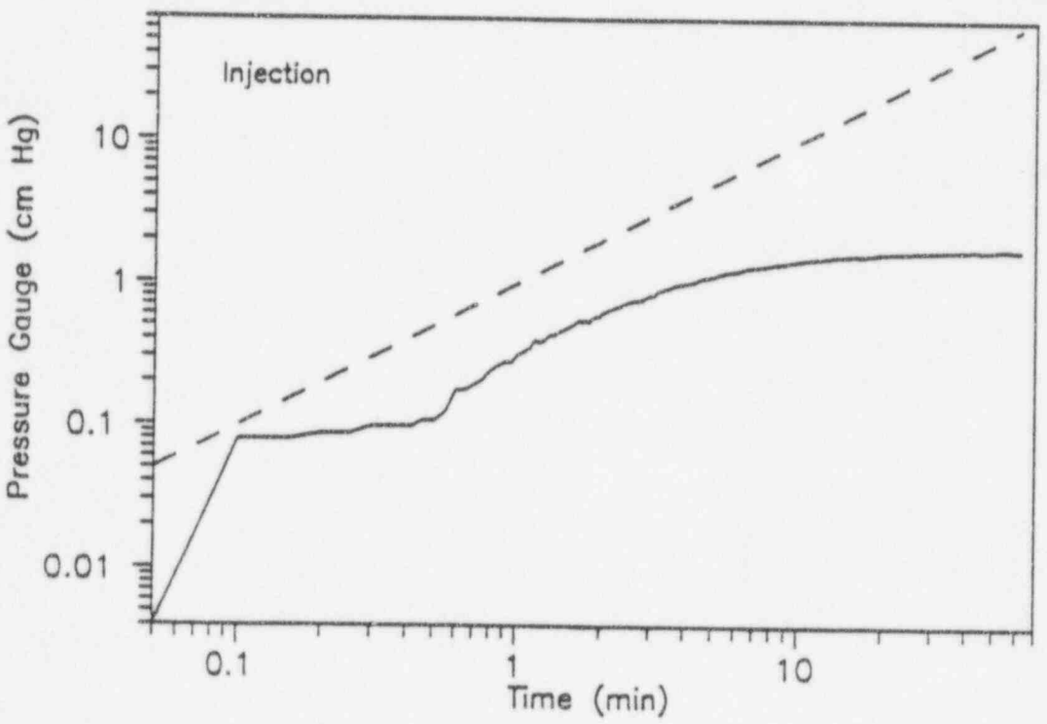


INJECTION TEST
Z2-ZIC
11-16-93



Z2-ZIC
11-16-93
I: Q=35 sccm; R: Q=12000





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(See instructions on the reverse)

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The University of Arizona
Tucson, Arizona 85721

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Washington, D. C. 20555-0001

10. SUPPLEMENTARY NOTES

T. Nicholson, NRC Project Managger

11. ABSTRACT *(200 words or less)*

This document summarizes air permeability estimates obtained from single hole pneumatic injection tests in unsaturated fractured tuffs at the Covered Borehole Site within the larger Apache Leap Research Site. Only permeability estimates obtained from a steady state interpretation of relatively stable pressure and flow rate data are included. Tests were conducted in five boreholes inclined at 45° to the horizontal, and one vertical borehole. Five of the boreholes are 30 m long, one has length of 45 m. Over 180 borehole segments were tested between packers set 1 m apart. Additional tests were conducted in segments of lengths 0.5, 2.0 and 3.0 m in one borehole, and 2.0 m in another borehole, bringing the total number of tests to over 270. Tests were conducted by maintaining a constant injection rate until air pressure became relatively stable and remained so for some time. The injection rate was then incremented by a constant value and the procedure repeated. Three or more such incremental steps were conducted in each borehole segment while recording the air injection rate, pressure, temperature, and relative humidity. A description of field operating procedures used to insure compliance with QA/QC requirements is included.

12. KEY WORDS/DESCRIPTORS *(List words or phrases that will assist researchers in locating the report.)*

Fractured rocks
Unsaturated flow
Air permeability
Site characterization data
Pneumatic injection
Packes testing

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