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1	/	Cog.Eng. JF McCormick	[signature]	2/1/96	S7-12	cc: RE Raymond			S7-12	3	–
1	/	Cog. Mgr. DW Hamilton	[signature]	2/1/96	S7-12	KS Witwer			L6-13	3	–
1	/	QA ML McElroy	[signature]	2/1/96	S7-07	GL Ralston			H5-68	3	–
1	/	Safety JA Harvey	[signature]	2/1/96	S7-07	MJ Schliebe			L6-13	3	–
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18.	19.	20.	21. DOE APPROVAL (if required)
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Test Report for Drill String Seal Pressure Test

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Abstract:

A basic question was asked concerning the drill string which is used in rotary mode coring operations: "...what is the volume leak rate loss in a drill rod string under varying conditions of the joint boxes and pins being either dry or coated with lubricant...". A variation of this was to either have an o-ring installed or absent on the drill rod that was grooved on the pin. A series of tests were run with both the o-ring grooved Longyear drill rod and the plain pin end rod manufactyured by Diamond Drill. Test results show that drill rod leakage of both types is lowered dramatically when thread lubricant is applied to the threaded joints and the joints made up tight. The Diamond Drill rod with no o-ring groove has virtually no leakage when used with thread lubricant and the joints are properly tightened.

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TEST REPORT FOR DRILL STRING SEAL PRESSURE TEST

PREPARED BY

JIM F. MCCORMICK

Characterization Equipment Engineering
Tank Waste Remediation System

Westinghouse Hanford Company
Richland, Washington
January 1996

Table of Contents

Drill String
Seal Pressure Test

1.0 Introduction

The basic problem was: "...to determine the volume leak rate loss in a drill rod string under varying conditions of the joint boxes and pins being either dry or with lubricant...". A variation of this was to either have an o-ring installed or absent on the drill rod that was grooved on the pin.

In order to provide data on the leak rate of a typical drill string joint seal assembly, used with rotary coring work, a series of tests were performed in the 305 Building, Engineering Test Laboratory (ETL). The original test plan (WHC-SD-WM-TP-427) was for the Longyear o-ring type drill rod that is typically used for rotary drilling. Additional tests were performed using "Diamond Drill" rod without the o-ring grooves. Nitrogen gas is normally used during the sampling effort to pressurize the drill string during the rotary coring process and sampler changes. Nitrogen also provides bit cooling and removal of waste cuttings from the bottom of the core hole. Testing was started and finished during January 1996.

2.0 Test Equipment and Method

Laboratory air was used in in place of nitrogen for the testing efforts. The test consists of: 1) screwing the box and pin threaded connections together on several joints of drill rod, 2) installing a blanking flange on one end of the string and a pressure inlet adapter on the other end, 3) pressurizing the length of drill string to approximately 100 psig, and 4) measuring the elapsed time between 10 psig pressure drops down to a minimum of 10 psig or a total elapsed time of 10 minutes, whichever comes first.

2.1 Test Equipment

The Longyear drill rod dimensions are 2.25-inch o.d. by 1.916-inch i.d. pipe with a 0.167-inch wall thickness. An o-ring groove is cut near the base of the pin end for an extra sealing surface when a rubber o-ring is installed in the groove. The test string consisted of three 1-foot, one 2-foot, one 5-foot and one 19-inch sections of pipe used in the 141 3/8-inch test length. Sealing of the threaded joints is by thread interference fit, o-ring rubber seal, lubricant on the threads and joint makeup.

The Diamond Drill rod consisted of 2.25-inch o.d. by 1.916-inch i.d. pipe with a 0.167-inch wall thickness. There is no o-ring groove at the base of the pin thread connection. Sealing of the string is by thread interference fit, lubricant on the threads and joint makeup. This test string consisted of four 1-foot, one 2-foot, one 6-inch, one 5-inch and one 19-inch section with an o-ring groove from the Longyear test string. Length of the string without the o-ring groove joint was 142 5/8-inches. This test string arrangement was 143 5/8-inches long when the 19-inch o-ring joint replaced one 1-foot joint and the 6-inch joint.

Other equipment used was a small sub with a blanking plate welded on the end and an air pressure inlet adapter consisting of an old test bit, tees, nipples, shut off valve, pressure gauge, stop watch and thread lubricants. An Ashcroft temperature compensated and calibrated test gauge (SN 002-31-04-044) was used for all tests. See photos in Appendix C.

2.2 Test Method

2.2.1 Longyear

Three arrangements of the test were run with the Longyear grooved drill rod. Each variation was repeated three times.

A.) The drill string was made up dry (no thread lubricant) and with no pin end rubber o-rings installed. Refer to Table 1.

B.) The drill string was made up with no pin end rubber o-rings installed, but lubricant was put on the joint pin threads. Refer to Table 2.

C.) The drill string was made up with the pin o-rings installed and lubricant was put on the pin threads. New o-rings were installed after each pressure run. Refer to Table 3.

The drill string joints were disconnected after each pressure run, the joints selected at random and made up again for the next pressure run. The third and last run of each test sequence was the beginning joint placement of the next table variation. Jet-Lube thread lubricant was used on these joints.

2.2.2 Diamond Drill

Four arrangements of the test were run with the Diamond Drill rod. Each variation was repeated three times.

A.) The drill string was made up dry (no thread lubricant).

B.) The drill string was made up dry with no thread lubricant. One 19-inch o-ring type joint was included and 18 inches (2 joints) of plain pin pipe was removed.

C.) The drill string in item B) above had Dow D-111 thread lubricant applied to the pin threads.

D.) The drill string was tested with no o-ring type joint in the string; the two joints (18 inches) of plain pin pipe were added to the test string. All pins were lubricated with Dow D-111.

The drill string joints were disconnected after each pressure run, the joints selected at random and made up again for the next pressure run. The third and last run of each test sequence was the beginning joint placement of the next table variation.

The pressure test in variation D) above was run only once. This test was essentially the fourth sequence of C) with the o-ring joint removed during the fourth pressure run.

All pressure tests required the drill string to be pressured to about 100 psig (which was the laboratory maximum limit). A maximum starting pressure was read and recorded. The shut off valve was closed to trap the air volume and pressure within the test string and the stop watch was started at the time of valve closure. The pressure drop between each 10 psig pressure point was read to a minimum of 10 psig or an elapsed total time of 10 minutes, whichever came first. Volume rate loss was then calculated and used for a graphics representation of the drill string pressure versus volume leak rate. Refer to Appendix A for the hand written copies of the laboratory data tables and calculations. Appendix B contains graphic forms of the data for each arrangement of the drill rod.

3.0 Test Results

3.1 Longyear O-Ring Pipe

A look at Graph 1, Appendix B, shows the assembled dry o-ring type drill rod is leaking quite readily. A moisture check of the joints showed that all joints were leaking.

Graph 2 shows the affect of having a lubricant on the joint threaded connections with no o-ring installed. The flow rate loss dropped from an average above 12.0 cf/hr as shown on Graph 1 to an average below 1.4 cf/hr on Graph 2.

Graph 3 shows virtually no air flow rate or pressure loss when an o-ring is installed and thread lubricant applied.

These graphs show the reading between pressure points and the associated flow rate loss that results during the measured time period.

Note: Caution must be used when the pipe joints are made up with both an o-ring and lubricant on the pin end. If the joint is made up too fast, the lubricant will pile up ahead of the thread interference fit and cause the lubricant to wash the rubber o-ring out of its groove. A potential leak path is thus created.

3.2 Diamond Drill Pipe

Graph 4 shows the dry joint make up of a pipe that has no o-ring groove. Flow rate loss and pressure was very minimal during the 10 minute test period.

Graph 5 shows the leakage that occurs when an o-ring joint is added to the string. All air leakage took place at the o-ring joint box and pin.

Graph 6 shows again that leakage is reduced when lubricant is applied to the drill rod threads and the o-ring joint is left in the test string. All leakage was at the o-ring joint box and pin connections.

Graph 7 without the o-ring joint shows no air leakage during the 10 minute test with thread lubricant applied to the pin ends.

These graphs show the pressure reading between graph points and the associated flow rate loss that results during the measured time period.

4.0 Conclusions and Recommendations

4.1 Conclusions

Test results show that drill rod leakage is lowered dramatically when thread lubricant is applied to the pipe threads and the joints made up tight. This is true even when the o-ring type drill rod (Longyear) has the rubber seal either missing or damaged. The Diamond Drill rod with no o-ring groove has virtually no leakage with thread lubricant and tight joint make up.

4.2 Recommendations

Use the o-ring grooved pipe and get it out of the tank farm supply inventory. Order only non-grooved pipe; it is not necessary to have the extra rubber o-ring for a seal.

Diamond Drill rod can also be purchased cheaper than the o-ring type drill rod.

Omitting the o-ring groove will strengthen the joint box and pin connections during rotary or push sampling operations. This will help eliminate broken drill rod in the tanks, expensive fishing jobs to retrieve broken tools inside the tanks and lost sampling time.

The RMCS crews must pay close attention to their final make up of joints that have o-ring seals. It is possible to wash an o-ring out of its groove with the thread lubricant and thus have a low rate leaking joint.

5.0 Appendix A - Data Tables and Calculations

DATA SHEET: LEAK OFF TEST OF DRILL STRING SEALS

TABLE 1. PRESSURE/TIME (PSIG/SEC) DRY NO O-RINGS

RUN										
1	98/0	90/4s	80/11	70/20	60/30	50/42	40/57	30/1:15	20/1:41	10/2:23
2	99/0	90/3s	80/9s	70/15	60/23	50/32	40/45	30/59	20/1:20	10/1:53
3	98/0	90/5s	80/15	70/29	60/44	50/1:02	40/1:25	30/1:53	20/2:35	10/3:39
Σ	295/0	270/12	240/35	210/64	180/97	150/136	120/187	90/247	60/336	30/475
M̄	98.3/0	90/4s	80/11.67	70/21.3	60/32.3	50/45.3	40/62.3	30/82.3	20/112	10/158.3

TABLE 2 PINS ONLY — LUBRICANT NO O-RINGS

RUN										
1	98/0	97/10:00	X	/						
2	99/0	98/10:00	X							
3	98/0	90/6:22	85/10:00	X						
Σ	295/0	285/1582	85/600							
M̄	98.3/0	95/527.3	85/600							

*INST. = INSTANT

JM

DATA SHEET: LEAK OFF TEST OF DRILL STRING SEALS

TABLE 3 PRESSURE/TIME (PSIG/SEC) CHANGE O-RINGS O-RINGS + LUB.

RUN										
1	99/0	98.5/10:00	X	/	/	/	/	/	/	/
2	98/0	97/10:00	X							
3	100/0	99/10:00	X							
M	297/0	294.5/10:00								
MI	99/0	98.2/10:00								

RUN										
1										
2										
3										
M										
MI										

*INST. = INSTANT

JM

DATA SHEET: LEAK OFF TEST OF DRILL STRING SEALS

DIAMOND DRILL ROD

TABLE 4 PRESSURE/TIME (PSIG/SEC) (1) DRY L-142 5/8"

RUN										
1	98/0	91 1/4 / 10:00	X	/	/	/	/	/	/	/
2	98/0	92 / 10:00	X							
3	98/0	95 1/2 / 10:00	X							
Σ	98/0	278.75 / 30:00								
$\bar{M}$	98/0	92.92 / 10:00								

TABLE 7 L-142 5/8" (4) DIAMOND DRILL ROD W/O-111

RUN										
1	97.5/0	97.25 / 10:00								
2										
3										
Σ										
$\bar{M}$										

*INST. = INSTANT

JM

DATA SHEET: LEAK OFF TEST OF DRILL STRING SEALS

TABLE 6 PRESSURE/TIME (PSIG/SEC) L-143 5/8" (3) DIAMOND DRILL ROD W/O-RING & O-111

RUN										
1	98/0	95.5/10:00	X	/	/	/	/	~~TOOL LEAKS~~ MINOR @ O-RING ~~PIN~~ & ~~BOX~~		
2	98/0	97/10:00	X				MINOR ~~NO LEAKS~~ @ ~~BLANK SUB~~ O-RING JT BOX			
3	98/0	97.5/10:00	X							
Σ	294/0	290/30:00								
M̄	98/0	96.67/10:00								

USE C-LEAK ON JTS TO FIND LEAKS

TABLE 5 L-143 5/8" (2) DIAMOND DRILL ROD + O-RING — DRY

307/165

368/1330

378

RUN										
1	98/0	90/4:27	82/10:00	X			O-RING JT LEAK BLANK SUB LEAK			
2	99/0	90/2:45	80/6:08	70 1/4/10:00	X		BLANKING SUB LEAK O-RING JT LEAK			
3	98/0	90/6:18	81/10:00	X			BLANK SUB LEAK O-RING JT LEAK			
Σ	295/0	270/910	243/1568	70 1/4/10:00						
M̄	98.3/0	90/273.?	81/522.67	70 1/4/10:00						

*INST. = INSTANT

TEMP. COMPENSATED
ASHCROFT-TEST GAUGE
H_2O CALIB.
7-26-96 EXPIRE
002-31-04-048
1/4% - 200 PSIG

JT

LONGYEAR

JTS: 3-1', 1-2', 1-19", 1-5'
BIT + BLANKING PLATE
TOTAL LENGTH - 141 3/8"
PIPE I.D. - 1.916"

$V = \frac{\pi d^2}{4} \times L = 0.785 d^2 L$
$= 0.785(1.916)^2(141.375)$
$= 407.4$ IN³ - TEST STRING
≈ 408 IN³ " " + INLET CONNECTIONS ←

$A = \frac{\pi d^2}{4} = 0.785 d^2$
$= 0.785(1.916)^2$
$= 2.882$ IN² - DRILL PIPE

PROBLEM: FIND THE VOLUME LOSS RATE IN AN ASSEMBLED DRILL STRING

DIAMOND DRILL

JT: 4-1' 1-2' 1-19" (O-RING)
1-6" 1-5'
BIT + BLANKING PLATE
1) TOTAL LENGTH - 142 5/8" W/O O-RING JT (7 JT)
2) " " W/ O-RING & OMIT 1-1' & 1-6" = 143 5/8" (6 JT)

VOLUMES

1) DIAMOND DRILL; $V_{DD} = 0.785(1.916)^2(142.625)$
$= 411$ IN³ TEST STRING
≈ 411.6 IN³ " " + INLET CONNECTIONS ←

2) DIAMOND DRILL + O-RING JOINT:
$V_{DD} = 0.785(1.916)^2(143.625)^*$
$= 413.9$ IN³ TEST STRING
≈ 414.5 IN³ " " + INLET CONNECTIONS ←

JM

DETERMINE THE VOLUME RATE LOSS IN A STRING OF LONGYEAR AND A STRING OF DIAMOND DRILL - UNDER VARYING CONDITIONS OF THE JOINT BOXES & PINS BEING EITHER DRY OR WITH LUBRICANT.

1. LONGYEAR

$V_{DS} = 408 \text{ IN}^3$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \quad T_1 = T_2$$

$$\therefore P_1V_1 = P_2V_2$$

1) FROM TABLE 1

USING AVERAGE OF NUMBERS

a) 98.3 → 90 PSIG t = 4 SEC

$P_1V_1 = P_2V_2$

$98.3(408) = 90V_2$

$V_2 = 445.6 \text{ IN}^3$

$V_2 - V_1 = 445.6 - 408 = 37.6 \text{ IN}^3$

$Q = V_{LOSS}/t$

$= \frac{37.6 \text{ IN}^3}{4 \text{ SEC}} = 9.4 \text{ IN}^3/\text{SEC}$

Q = 19.6 CF/HR = 0.33 CFM

$$\frac{\text{IN}^3}{\text{SEC}} \cdot \frac{1 \text{ CF}}{1728 \text{ IN}^3} \cdot \frac{60 \text{ SEC}}{1 \text{ MIN}} \times \frac{1 \text{ CF}}{28.8 \text{ MIN}} = 0.0347 \text{ CFM}$$

$$\frac{\text{IN}^3}{\text{SEC}} \times \frac{\text{CF}}{1728 \text{ IN}^3} \cdot \frac{3600 \text{ SEC}}{\text{HR}} \times 2.083 \text{ CF/H}$$

b) 90 → 80 PSIG, t = 7.67 SEC

$P_1V_1 = P_2V_2$

$(90)408 = 80V_2$

$V_2 = 459 \text{ IN}^3$

$V_2 - V_1 = 459 - 408 = 51 \text{ IN}^3$

$Q = V_{LOSS}/t = 51 \text{ IN}^3/7.67 \text{ SEC} = 6.65 \text{ IN}^3/\text{S}$

$Q = 6.65 \text{ CI/S} (2.083)$

$= 13.85 \text{ CF/HR} = 0.23 \text{ CFM}$

c) 80 → 70 PSIG, t = 9.63 S

$P_1V_1 = P_2V_2$

$80(408) = 70V_2$

$V_2 = 466.3 \text{ IN}^3$

$V_2 - V_1 = 466.3 - 408$

$\Delta V = 58.3 \text{ IN}^3$

$Q = V_{LOSS}/t = \frac{58.3}{9.63}$

$= 6.05 \text{ CI/S} (2.083)$

$Q = 12.61 \text{ CF/HR} = 0.22 \text{ CFM}$

d) 70 → 60 PSIG, t = 11.0 s

$$P_1V_1 = P_2V_2$$
$$70(408) = 60\,V_2$$
$$V_2 = 476\ \text{IN}^3$$
$$V_2 - V_1 = 476 - 408 = 68\ \text{IN}^3$$
$$Q = \frac{V_{LOSS}}{t} = 68/11$$
$$Q = 6.18\ \text{IN}^3/\text{s}\ (2.083)$$
$$Q = 12.9\ \text{CF/HR} = 0.22\ \text{CFM}$$

e) 60 → 50 PSIG, t = 13 s

$$P_1V_1 = P_2V_2$$
$$60(408) = 50\,V_2$$
$$V_2 = 489.6\ \text{IN}^3$$
$$V_2 - V_1 = 489.6 - 408 = 81.6\ \text{IN}^3$$
$$Q = V_L/t = 81.6/13$$
$$= 6.3\ \text{IN}^3/\text{SEC}\ (2.083)$$
$$Q = 13.1\ \text{CF/HR} = 0.22\ \text{CFM}$$

f). 50 - 40 PSIG, t = 17 s

$$P_1V_1 = P_2V_2$$
$$50(408) = 40\,V_2$$
$$V_2 = 510\ \text{IN}^3$$
$$V_2 - V_1 = 510 - 408 = 102\ \text{IN}^3$$
$$Q = V_L/t = 102/17 = 6.0\ \text{IN}^3/\text{SEC}\ (2.083)$$
$$Q = 12.5\ \text{CF/HR} = 0.21\ \text{CFM}$$

g) 40 → 30 PSIG, t = 20 s

$$P_1V_1 = P_2V_2$$
$$40(408) = 30\,V_2$$
$$V_2 = 544\ \text{IN}^3$$
$$V_2 - V_1 = 544 - 408 = 136\ \text{IN}^3$$
$$Q = V_L/t = 136/20 = 6.8\ \text{IN}^3/\text{s}\ (2.083)$$
$$Q = 14.2\ \text{CF/HR} = 0.24\ \text{CFM}$$

JM

h) 30 – 20 PSIG, t = 29.7 s

$P_1V_1 = P_2V_2$

$30(408) = 20V_2$

$V_2 = 612\ IN^3$

$V_2 - V_1 = 612 - 408 = 204\ IN^3$

$Q = V_L/t = 204/29.7 = 6.9\ IN^3/s\ (2.083)$

$Q = 14.3$ CF/HR = 0.24 CFM

i) 20 → 10 PSIG, t = 46.3 s

$P_1V_1 = P_2V_2$

$20(408) = 10V_2$

$V_2 = 816\ IN^3$

$V_2 - V_1 = 816 - 408 = 408\ IN^3$

$Q = V_L/t = 408/46.3 = 8.81\ IN^3/s\ (2.083)$

$Q = 18.4$ CF/HR = 0.31 CFM

98.3-90	90-80	80-70	70-60	60-50	50-40	40-30	30-20	20-10		
19.6	13.85	12.61	12.9	13.1	12.5	14.2	14.3	18.4		Q CF/HR

ΔP – PRESSURE DROP (PSIG)

– GRAPH OF TABLE 1

2) FROM TABLE 2

USING AVERAGE NUMBERS

a) 98.3 → 95 PSIG, t = 527.3 SEC

$P_1V_1 = P_2V_2$

$98.3(408) = 95V_2$

$V_2 = 422.2\ IN^3$

$V_2 - V_1 = 422.2 - 408$

$V_2 = 14.2\ IN^3$

$Q = V_L/t = 14.2/527.3 = 0.0269\ IN^3/s\ (2.083)$

$Q = 0.056$ CF/HR = 0.001 CFM

b) 95 → 85 PSIG, t = 72.7 s

$P_1V_1 = P_2V_2$

$95(408) = 85V_2$

$V_2 = 456\ IN^3$

$V_2 - V_1 = 456 - 408 = 48\ IN^3$

$Q = V_L/t = 48/72.7 = 0.6602\ IN^3/s\ (2.083)$

$Q = 1.38$ CF/HR = 0.023 CFM

– GRAPH OF TABLE 2

JT

3) FROM TABLE 3

USING AVERAGE NUMBERS

99 → 98.2 PSIG, t = 600 s

$P_1V_1 = P_2V_2$

$99(408) = 98.2\ V_2$

$V_2 = 411.3\ IN^3$

$V_2 - V_1 = 411.3 - 408 = 3.3\ IN^3$

$Q = V_L/t = 3.3/600 = 0.0055\ IN^3/s$ (2.083)

Q = 0.0115 CF/HR = 0.0002 CFM

— PUT DOT ON GRAPH —

— NO PRESSURE LOSS —

2. DIAMOND DRILL

$V_1 = 411.6\ IN^3$ (NO O-RING JT)

$V_2 = 414.5\ IN^3$ (W/O-RING JT)

1) FROM TABLE 4

USING AVERAGE NUMBERS

98 → 92.9 PSIG, t = 600 s

$P_1V_1 = P_2V_2$

$98(411.6) = 92.9\ V_2$

$V_2 = 434.2\ IN^3$

$V_2 - V_1 = 434.2 - 411.6 = 22.6\ IN^3$

$Q = V_L/t = \frac{22.6}{600} = 0.0377\ IN^3/s$ (2.083)

Q = 0.078 CF/HR = 0.0013 CFM

— PUT DOT ON GRAPH —

2) FROM TABLE 5

a) $V = 414.5\ IN^3$

98.3 → 90 PSIG, t = 270 s

$P_1V_1 = P_2V_2$

$98.3(414.5) = 90\ V_2$

$V_2 = 452.7\ IN^3$

$V_2 - V_1 = 452.7 - 414.5 = 38.2\ IN^3$

$Q = V_L/t = 38.2/270 = 0.142\ IN^3/s$ (2.083)

Q = 0.29 CF/HR = 0.0048 CFM

JT

b) 90 → 81 PSIG, t = 252.7 s

$P_1V_1 = P_2V_2$

$90(414.5) = 81\,V_2$

$V_2 = 460.56\ IN^3$

$V_2 - V_1 = 460.56 - 414.5 = 46.1\ IN^3$

$Q = V_L/t = 46.1/252.7 = 0.182\ IN^3/s\ (2.083)$

Q = 0.38 CF/HR = 0.0063 CFM

c) 81 → 70 1/4 PSIG, t = 77.7s

$P_1V_1 = P_2V_2$

$81(414.5) = 70.25\,V_2$

$V_2 = 478\ IN^3$

$V_2 - V_1 = 478 - 414.5 = 63.4\ IN^3$

$Q = V_L/t = \frac{63.4}{77.7} = 0.816\ IN^3/s\ (2.083)$

Q = 1.7 CF/HR = 0.028 CFM

— PLOT GRAPH FOR TABLE 5

3. FROM TABLE 6

98 → 96.7 PSIG, t = 600s

$P_1V_1 = P_2V_2$

$98(414.5) = 96.7\,V_2$

$V_2 = 420.1\ IN^3$

$V_2 - V_1 = 420.1 - 414.5 = 5.8\ IN^3$

$Q = V_L/t = 5.8/600 = 0.0093\ IN^3/SEC\ (2.083)$

Q = 0.019 CF/HR = 0.0003 CFM

— PLOT POINT ON GRAPH —

— NO PRESSURE LOSS —

4. FROM TABLE 7

97.5 → 97.25 PSIG, t = 600S

$P_1V_1 = P_2V_2$

$97.5(411.6) = 97.25\,V_2$

$V_2 = 410.5\ IN^3$

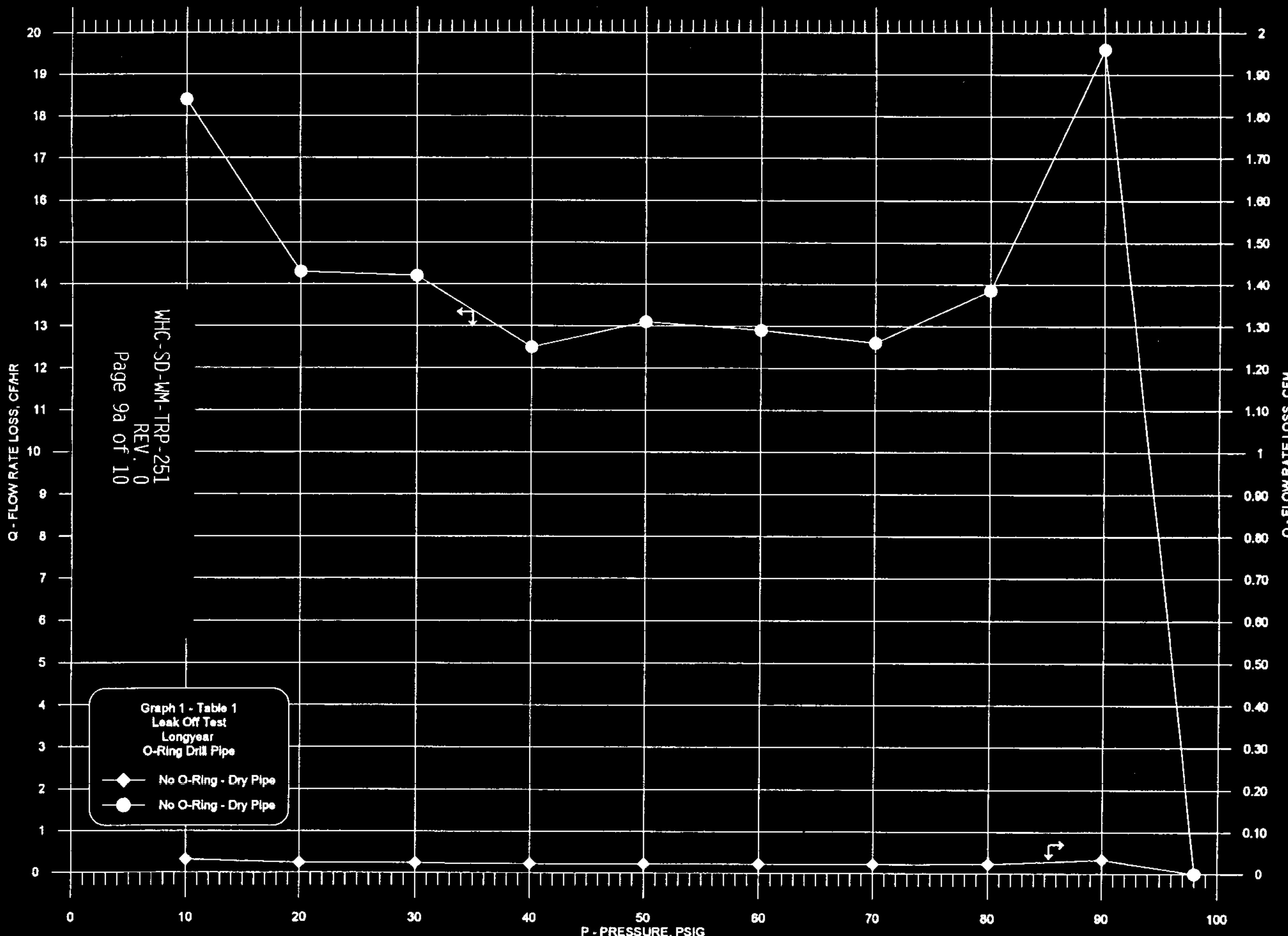
— NO PRESSURE LOSS —

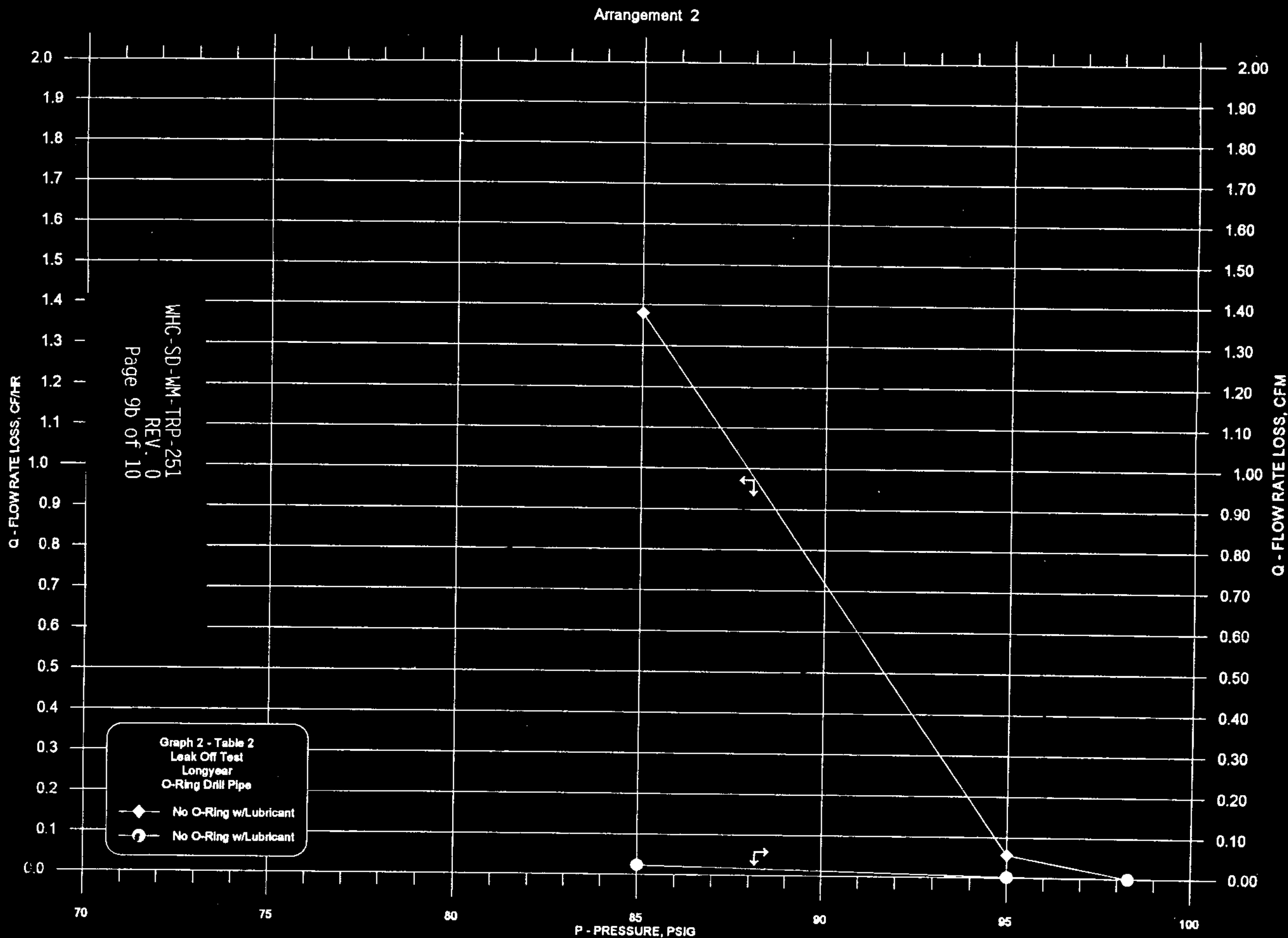
PLOT POINT ON GRAPH

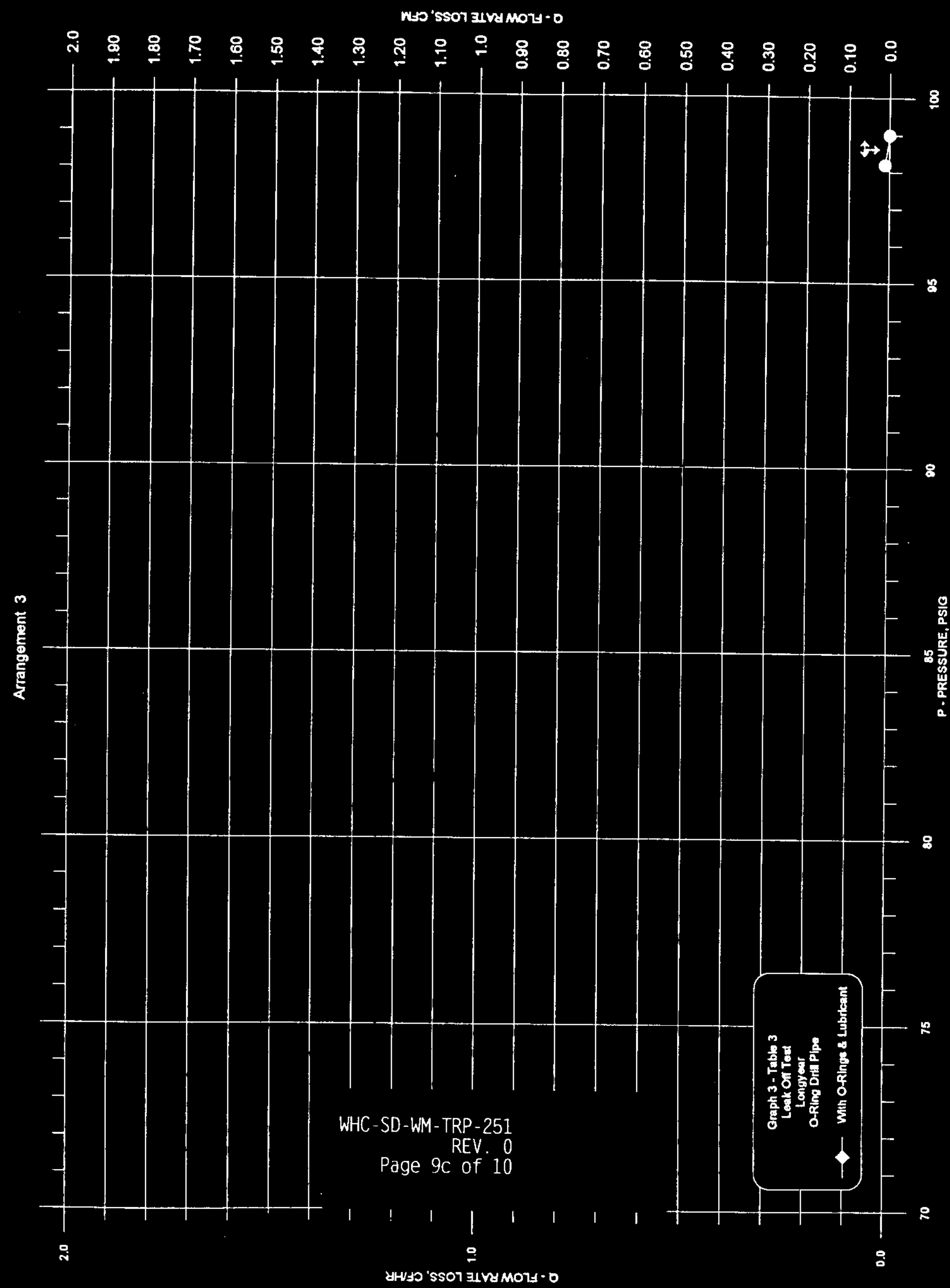
JM

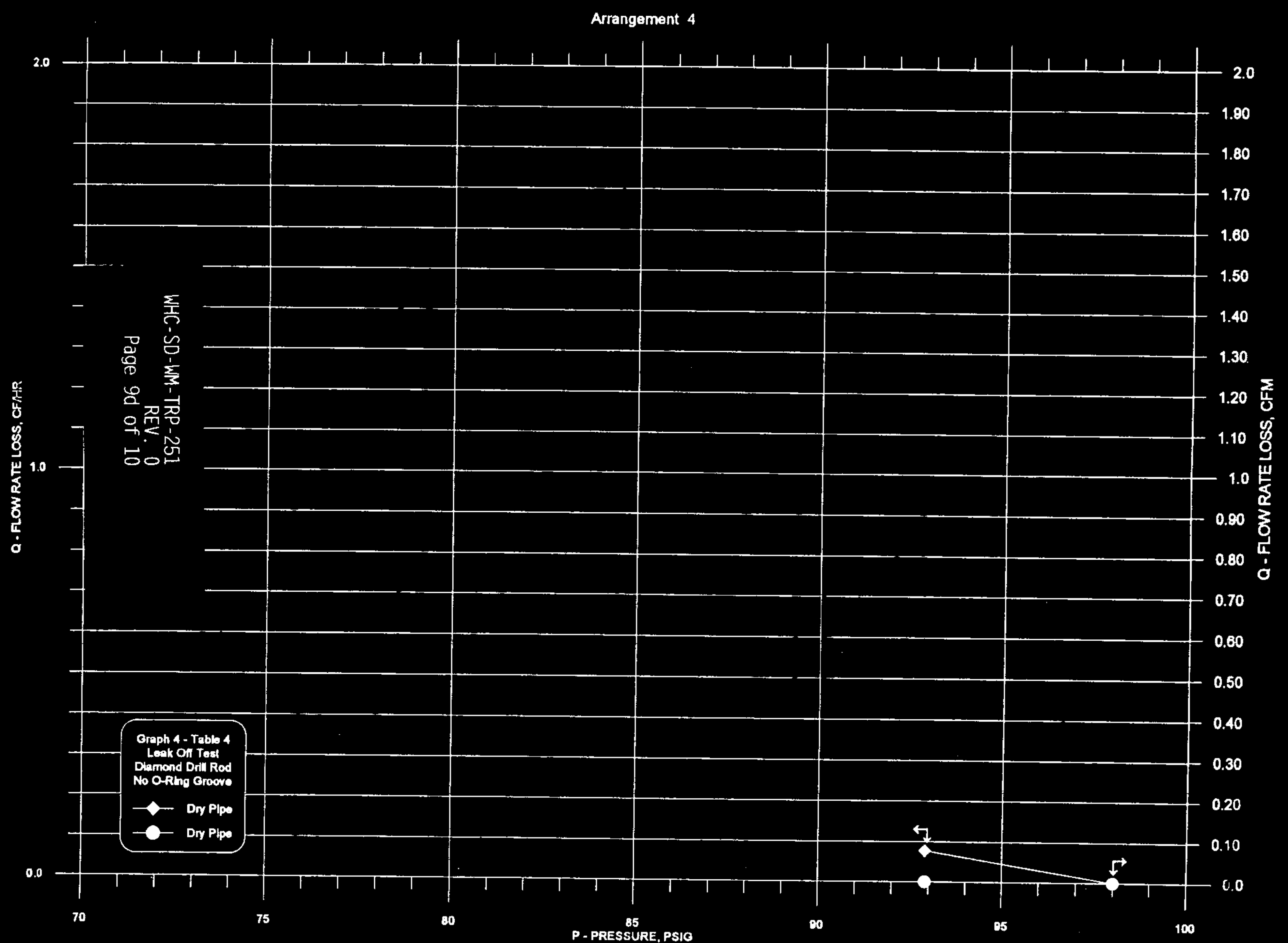
6.0 Appendix B - Data Graphics

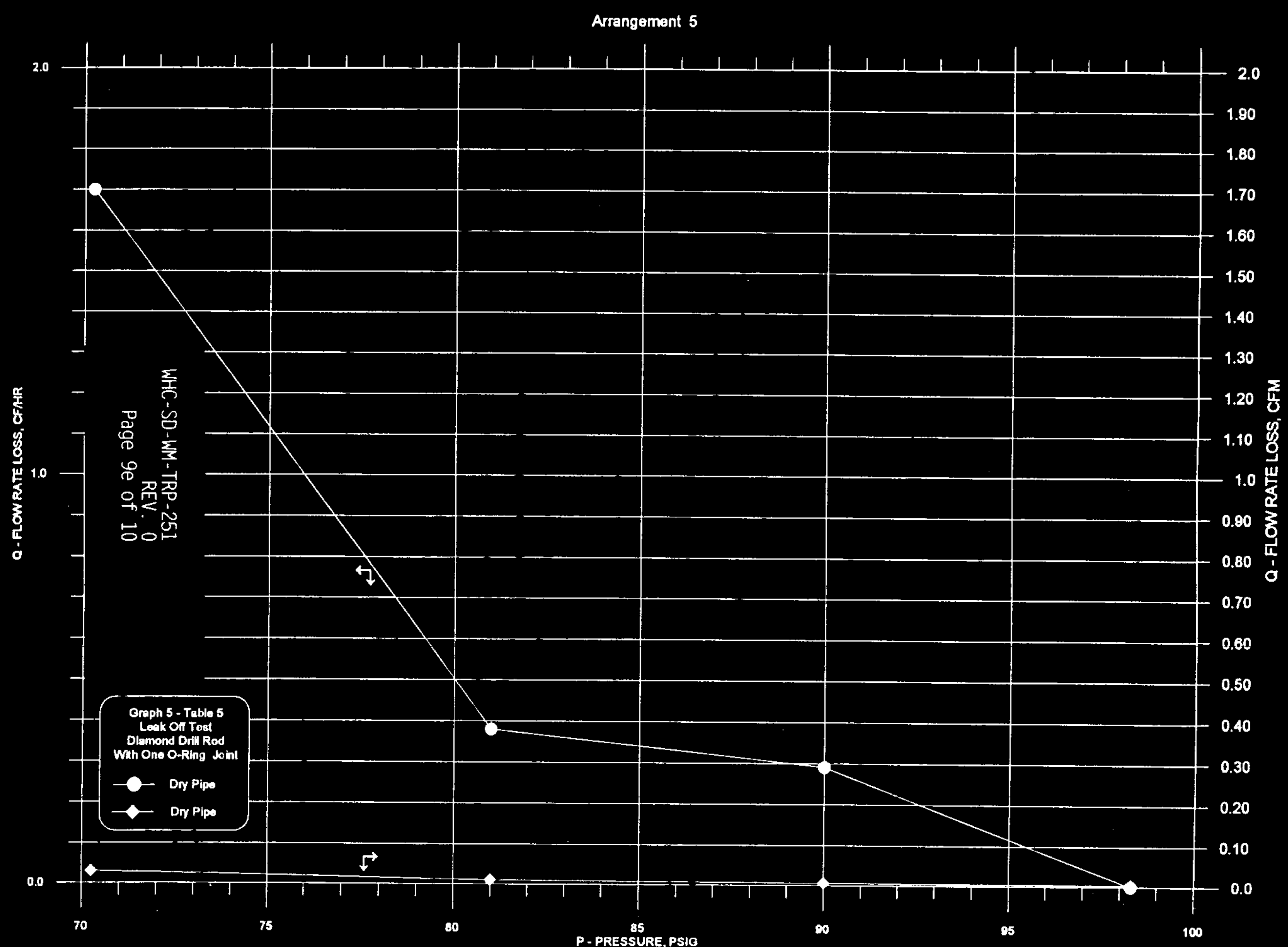
Arrangement 1

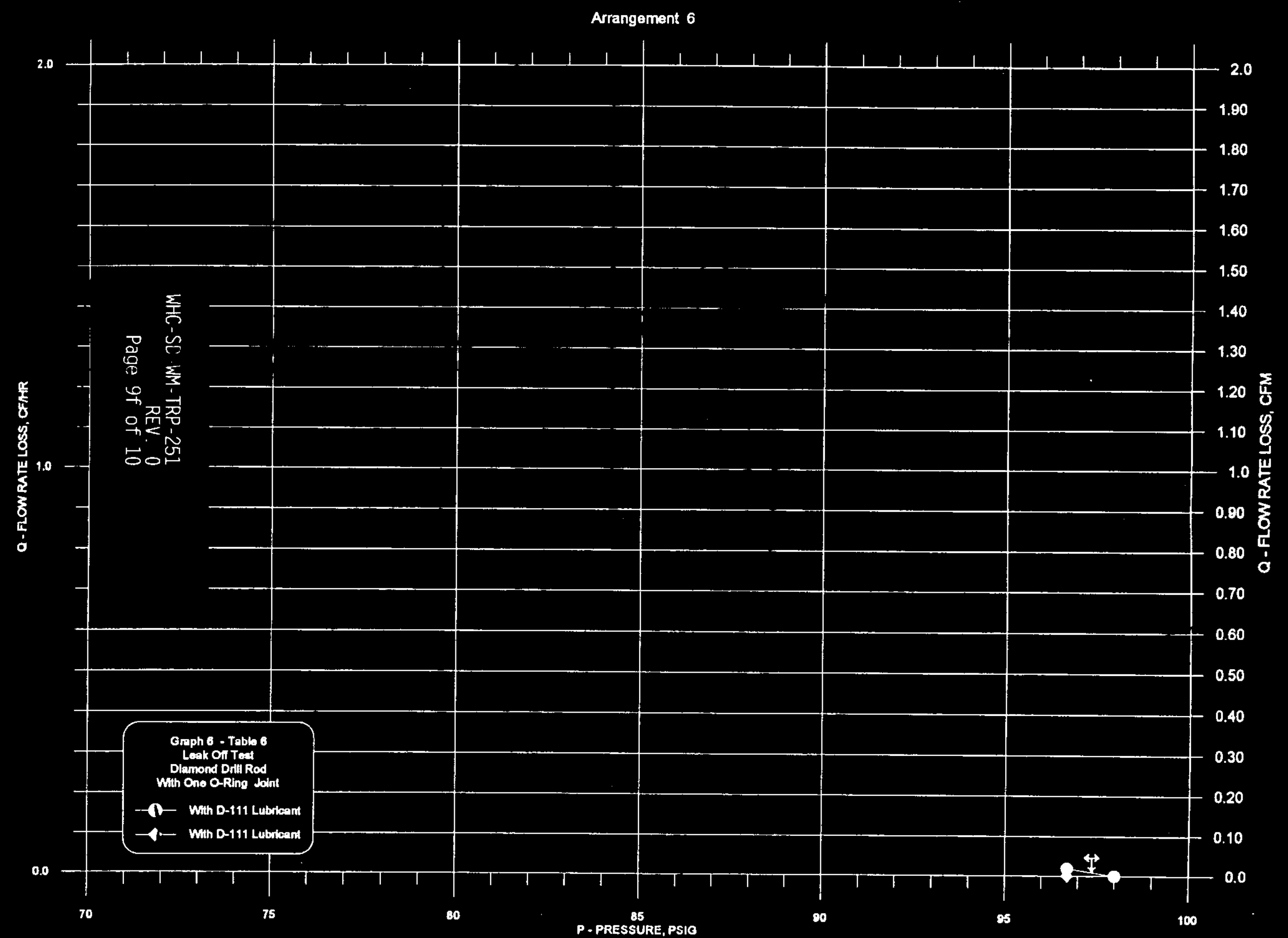


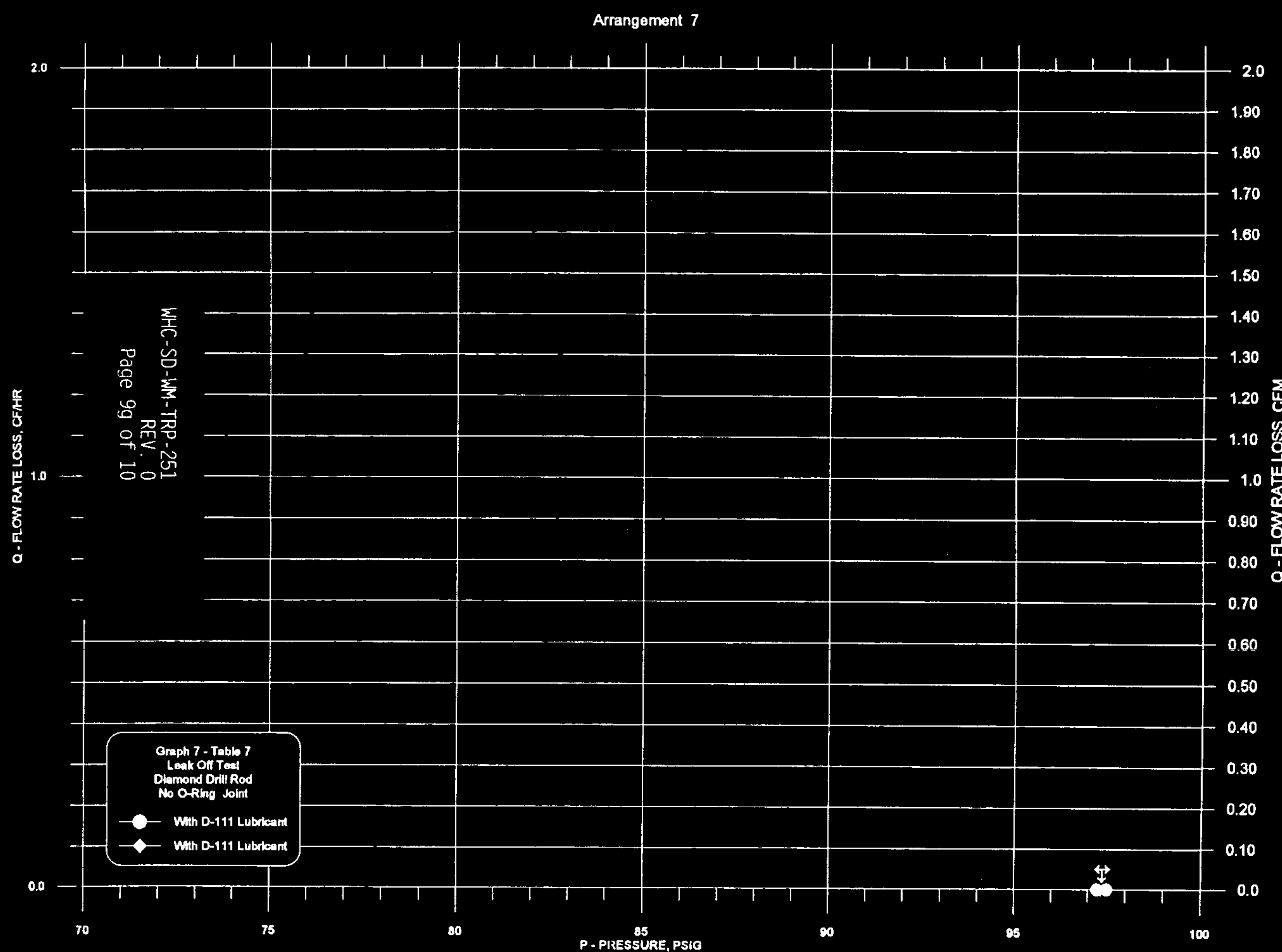

Arrangement 2
Q - FLOW RATE LOSS, CF/HR
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Q - FLOW RATE LOSS, CFM
2.00
1.90
1.80
1.70
1.60
1.50
1.40
1.30
1.20
1.10
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
70
75
80
85
90
95
100
P - PRESSURE, PSIG
Graph 2 - Table 2
Leak Off Test
Longyear
O-Ring Drill Pipe
No O-Ring w/Lubricant
No O-Ring w/Lubricant


Arrangement 3
Q - FLOW RATE LOSS, CFM
2.0
1.90
1.80
1.70
1.60
1.50
1.40
1.30
1.20
1.10
1.0
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.0
70
75
80
85
90
95
100
P - PRESSURE, PSIG
Q - FLOW RATE LOSS, CF/HR
2.0
1.0
0.0
Graph 3 - Table 3
Leak Off Test
Longyear
O-Ring Drill Pipe
With O-Rings & Lubricant

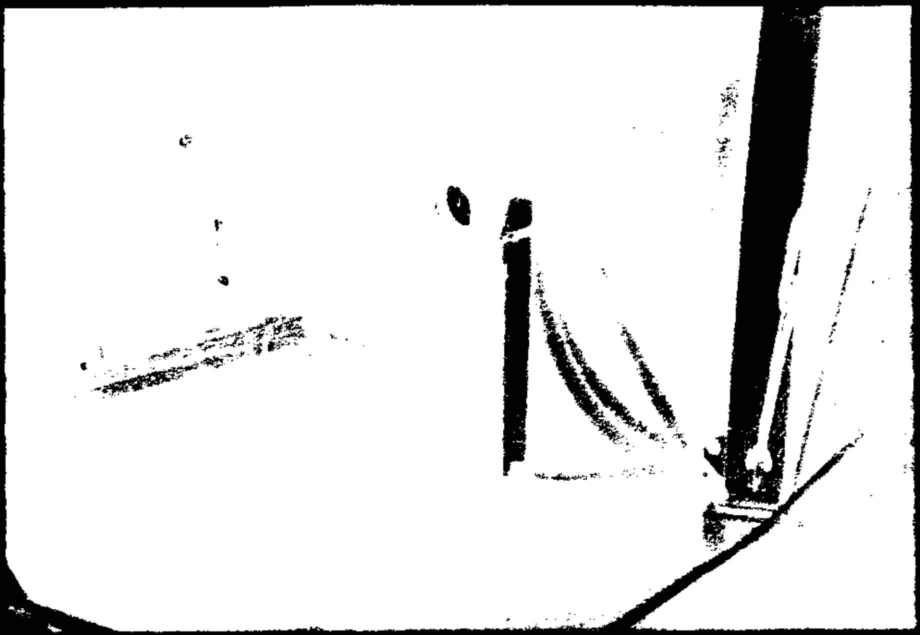

Arrangement 4
Q - FLOW RATE LOSS, CF/HR
2.0
1.0
0.0
Q - FLOW RATE LOSS, CFM
2.0
1.90
1.80
1.70
1.60
1.50
1.40
1.30
1.20
1.10
1.0
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.0
P - PRESSURE, PSIG
70
75
80
85
90
95
100
Graph 4 - Table 4
Leak Off Test
Diamond Drill Rod
No O-Ring Groove
Dry Pipe
Dry Pipe


Arrangement 5
Q - FLOW RATE LOSS, CF/HR
2.0
1.0
0.0
Q - FLOW RATE LOSS, CFM
2.0
1.90
1.80
1.70
1.60
1.50
1.40
1.30
1.20
1.10
1.0
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.0
70
75
80
85
90
95
100
P - PRESSURE, PSIG
Graph 5 - Table 5
Leak Off Test
Diamond Drill Rod
With One O-Ring Joint
Dry Pipe
Dry Pipe


Arrangement 6
Graph 6 - Table 6
Leak Off Test
Diamond Drill Rod
With One O-Ring Joint
With D-111 Lubricant
With D-111 Lubricant
Q - FLOW RATE LOSS, CF/HR
Q - FLOW RATE LOSS, CFM
P - PRESSURE, PSIG
2.0
1.0
0.0
2.0
1.90
1.80
1.70
1.60
1.50
1.40
1.30
1.20
1.10
1.0
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.0
70
75
80
85
90
95
100

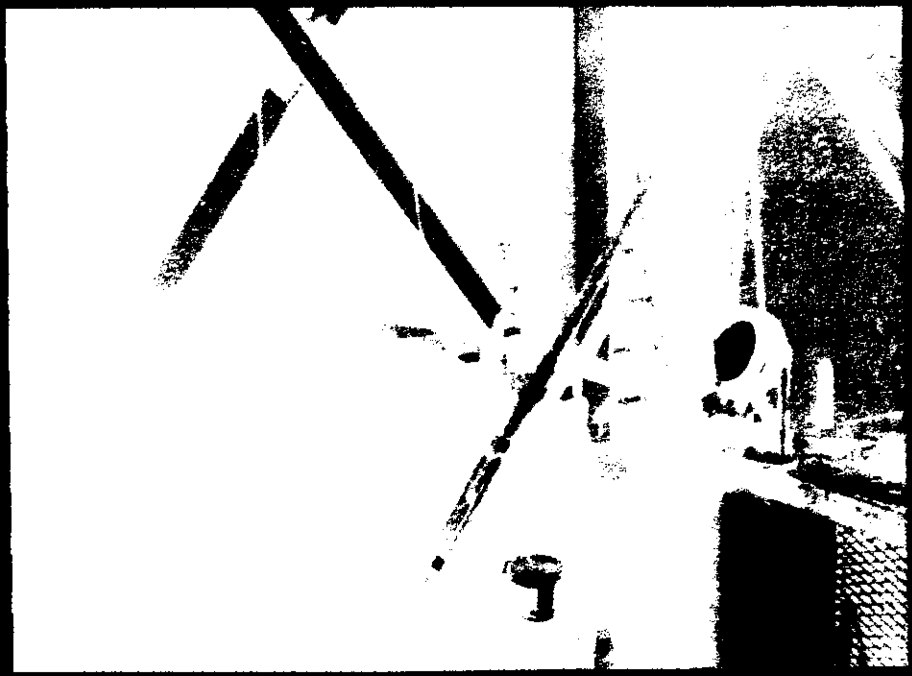

Arrangement 7
Q - FLOW RATE LOSS, CF/HR
Q - FLOW RATE LOSS, CFM
P - PRESSURE, PSIG
Graph 7 - Table 7
Leak Off Test
Diamond Drill Rod
No O-Ring Joint
With D-111 Lubricant
With D-111 Lubricant

7.0 Appendix C - Photos



Bench test assembly and air hose attached to inlet manifold. Steel cage in background to which the Longyear drill rod was tied down.

Bench test assembly in 305 Building test pit.



Bench clamp stand and Diamond Drill rod test string. Inlet connections and pressure gauge.

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