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SUMMARY REPORT

DESIGN CERTIFICATION TESTS

HIGH PRESSURE OXYGEN FILTER (HPOF) PROGRAM

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LYNDON B. JOHNSON SPACE CENTER

WHITE SANDS TEST FACILITY

LAS CRUCES, NEW MEXICO

SUMMARY REPORT

DESIGN CERTIFICATION TESTS

HIGH PRESSURE OXYGEN FILTER (HPOF) PROGRAM

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1.0 INTRODUCTION

This test report is a summary of the results of Design Certification Tests (DCT) performed on the High Pressure Oxygen Filter (HPOF) developed under contract number NAS9-14466 with the Wintec Division of the Brunswick Corporation. The HPOF was developed as a means of protecting the sealing surfaces in high pressure emergency oxygen systems. Portions of the HPOF Program, including the Design Certification Tests, were performed at the White Sands Test Facility (WSTF) in support of JSC Crew Systems Division.

For clarity, the test results discussed in this test report are presented in three parts. The three parts are: (1) DCT's performed using the final version of the HPOF; (2) DCT's performed using development versions of the HPOF; and (3) additional tests performed using the final version of the HPOF design to investigate performance characteristics of the HPOF not covered by the established DCT's.

2.0 SUMMARY

During the spring and summer of 1976, WSTF performed 12 Design Certification Tests (DCT) on the High Pressure Oxygen Filter (HPOF) developed by the Wintec Division of the Brunswick Corporation under contract NAS9-14466.

The DCT's verified the HPOF would satisfactorily pass a proof pressure test employing a pressure of 1,406.1 Kg/cm^2 (20,000 psia) and a burst pressure test of 2,109.2 Kg/cm^2 (30,000 psia). The HPOF was found to exhibit, under clean conditions and in the forward flow direction (S/N side upstream) a net differential pressure of approximately 2.81 Kg/cm^2 differential (40 psid) at a GN_2 flow rate of 2.72 Kg/hr (6 lbs/hr) and 12.02 Kg/cm^2 differential (171 psid) at 3.63 Kg/hr (8 lbs/hr) at an inlet pressure of 29.177 Kg/cm^2 (415 psia). The tests also indicated that the differential pressure is approximately 30% higher in the reverse (S/N side downstream) flow direction. The application of high pressure (703.07 Kg/cm^2 (10,000 psia) nominal) GN_2 impact cycles was observed to reduce the pressure drop across the HPOF to approximately 50% of the initial value. An explanation for this observation and the forward/reverse flow pressure drop differences was sought but not found.

Comparison of the observed standard bubble point data with the pressure drop characteristics of the specimens failed to indicate any direct correlation between these two filter characteristics. The lack of correlation may be due to uncertainties associated with the bubble point determination.

Two contaminant transmission tests performed using identifiable Fe_2O_3 particulate indicated the maximum particle rating of the HPOF is 10 microns. The largest identifiable particle transmitted by the HPOF was 10x10 microns in size.

The contaminant tolerance of the HPOF under simple flow conditions was found to be satisfactory with the addition of over 100 mg of synthetic contaminant constructed to resemble material found in the Apollo Oxygen Purge System (OPS) and Skylab Secondary Oxygen Pack (SOP). The differential pressure across the HPOF was increased by less than 12.66 Kg/cm^2 (180 psid) after the addition of the 100 mg of synthetic contaminant at a GN_2 flow rate of 3.63 Kg/hr (8 lbs/hr) at an inlet pressure of 29.177 Kg/cm^2 (415 psia).

The contaminant tolerance of the HPOF was found to be limited to less than 16 mg of synthetic contaminant when the contaminant on the HPOF was subjected to 20 high pressure GN_2 impact cycles. Satisfactory flow at 2.72 Kg/hr (6 lbs/hr) through the HPOF could not be obtained at 70.307 Kg/cm^2 (1,000 psia) inlet pressure.

Another contaminant tolerance test performed in both flow directions indicated the HPOF would flow satisfactorily if loaded with approximately 10 mg of synthetic contaminant on each side. During this test the contaminant on each side of the HPOF was subjected to 20 high pressure GN_2 impact cycles.

Another test performed to evaluate the performance of the HPOF beyond the DCT requirements indicated that the contaminant tolerance of the HPOF was much better if the contaminant was hard granular material as opposed to the soft predominantly TFE Teflon synthetic contaminant.

3.0 TEST OBJECTIVES

The tests described in this report are based upon the Acceptance and Certification Test Plan, TP-258 and the Certification Test Procedure TP-260 prepared by the program contractor, the Wintec Division of Brunswick Corporation. Detailed procedures for performance of the DCT's at WSTF are presented in WSTF Test Directive TD-121-025. The objectives of the individual DCT's as outlined in the Test Plan and Test Directive, are summarized in Table I.

In addition to the DCT's, several tests were conducted to further examine the performance characteristics of the HPOF in an attempt to understand its behavior under various meaningful conditions.

4.0 TEST SYSTEM

Figures 1 and 2 are simplified schematics of the two versions of the test system used in this program.

Figure 1 illustrates the test system configuration used to perform the high pressure (703.07 Kg/cm^2 (10,000 psia) nominal) GN_2 pneumatic impact cycles required by the various DCT's. In the actual test system, the test specimen holder is close-coupled, approximately 10 cm (4 inches), below the fast opening (2 milliseconds fully closed - fully open) ECV-1 high pressure isolation valve. The sampler (F-2) is located immediately downstream of the test specimen holder. Approximately 61 cm (2 feet) of 0.8 cm (5/16 inch) I.D. high pressure tubing and fittings comprise the remainder of the system between the sampler and the fast opening vent valve (ECV-2). The test specimen holder is instrumented with 1,055 Kg/cm^2 (15,000 psi) Kistler transducers approximately 1.6 cm (5/8 inches) on each side of the test specimen. The Kistler transducers are used to record the magnitude of the pneumatic impact shock on the test specimen. A 703 Kg/cm^2 (10,000 psia) pressure transducer (PT-3) located between the sampler (F-2) and the vent valve (ECV-2) is used to verify that the test specimen section, upon application of the pneumatic impact shock, has reached stable pressure prior to venting and application of the next pneumatic impact shock.

Figure 2 illustrates the test system configuration used to perform the flow rate versus differential pressure tests required by the various DCT's. In the actual test system, the PCV-1 regulator is used to establish the test specimen inlet pressure for each test as read on pressure transducer PT-3 mounted directly upstream of the test specimen holder. Flow through the specimen is established by manipulation of manual valves MV-4 and MV-6 such that the flow meters (FM-1 and FM-2) are maintained at 3.51 Kg/cm^2 (50 psia) as read by pressure transducer PT-4. The differential pressure across the test specimen holder is sensed by transducers PT-7, PT-8, PT-9, PT-10, PT-11, PT-14, and PT-15 which cover various differential pressure ranges.

Table II is a complete list of the instrumentation utilized to perform the high pressure GN_2 impact cycle and flow rate versus differential pressure tests.

5.0 TEST SPECIMENS

Figure 3 is a copy of The Wintec Division drawing 9-812 "CHS Filter" which describes the final configuration of the HPOF specimens used for the DCT's. The HPOF is a bidirectional filter consisting of a stack of (1) a 5-6 micron Collomated Hole Structure (CHS); (2) a 20x20 square weave wire screen; (3) a Dynalloy X3 filter medium; (4) a 20x20 square weave wire screen, and (5) a 5-6 micron CHS all encapsulated in a stainless steel ring. As noted on the drawing a single Tungsten Inert Gas (TIG) weld is used to bond the two square weave wire screens and the Dynalloy X3 material together and to seal the entire stack into the stainless steel mounting ring.

Figure 4 is a photograph of a typical HPOF specimen. The photograph shows the CHS material (hexagonal structure in center) on the normal flow direction side (S/N side upstream) of the specimen.

All of the specimens used to perform the DCT's were subjected to acceptance tests at the manufacturer prior to delivery to WSTF. Appendix A is a copy of the Wintec Acceptance Test Procedure TP-259.

Table III is a list of the HPOF specimens used for the various Design Certification Tests listed in Table I. Appendix B contains copies of the results of the acceptance tests performed by the manufacturer on the specimens prior to delivery to WSTF.

6.0 TEST PROCEDURE

6.1 Design Certification Tests:

Test Preparation Sheet (TPS) 3-HPF-013 containing detailed procedures was prepared and followed for the conduct of all 12 design certification tests. The following paragraphs briefly outline the sequential steps used to perform each of the DCT's.

6.1.1 Flow Rate Versus Differential Pressure Test System Tare Values (DCT #1):

NOTE: The following steps describe the sequence required to obtain flow rate versus differential pressure data. Reference to these steps will be made in subsequent test procedure descriptions.

a. Configure the test system as illustrated in Figure 2 and install the specimen holder without a specimen.

b. Install a pre-counted particulate sampler at F-2.

c. Open ROV-2, MV-27, and SV-23.

d. Verify MV-4 and MV-6 are closed.

e. Open ECV-1.

f. Adjust PCV-1 to obtain the desired test specimen inlet pressure of 29.177 ± 0.703 Kg/cm^2 (415 ± 10 psia).

g. Adjust MV-4 and MV-6, as required, to obtain a GN_2 flow rate of 14.16 liters/min (0.50 ACFM), as read on FM-1 and FM-2, at a pressure of 3.515 ± 0.141 Kg/cm^2 (50 ± 2 psia) as read on PT-4.

h. Verify all differential pressure transducers are in the zero differential pressure (null) position.

i. Record "zero differential pressure" data values.

NOTE: Zero differential pressure data values are utilized to correct for transducer off-sets due to test system operating pressure.

j. Position the appropriate differential pressure transducer PT-15, PT-14, PT-11, PT-10, PT-9, PT-8, PT-7, or PT-6 to the read or sense position.

k. Record data.

l. Maintain the test specimen inlet pressure at the desired value (set in Step f) and establish the flow rate through the test specimen holder at each of the test values listed below. Maintain flowmeter pressure at 3.515 ± 0.141 Kg/cm^2 (50 ± 2 psia). At each test value perform Steps j and k.

Test Values (± 5%)

Liters/Min	ACFM
25.48	0.9
22.65	0.8
19.82	0.7
16.99	0.6
14.16	0.5
11.33	0.4
8.49	0.3
7.08	0.25
5.66	0.20
3.68	0.13

m. Repeat h through l except perform the flow rate adjustment cited in Step l in the reverse order.

n. Repeat steps h through k.

o. Remove the F-2 particulate sampler and perform a particle count to ascertain the quantity and size of particulate transmitted by the test system (or HPOF when installed). Perform particle count in the following size ranges:

Size Range (Microns)
5-15
16-25
>25

p. Repeat steps b through o at a test specimen inlet pressure of 49.215 $\pm$ 0.703 Kg/cm^2 (700 $\pm$ 10 psia), 70.307 $\pm$ 0.703 Kg/cm^2 (1,000 $\pm$ 10 psia) and 210.92 $\pm$ 3.515 Kg/cm^2 (3,000 $\pm$ 50 psia) to establish the pressure drop characteristics at all test specimen inlet pressures.

6.1.2 Impact Test System Tare Pressure Values (DCT #2):

NOTE: The following steps describe the sequence required to subject the test specimen to high pressure GN_2 impact cycles. Reference to these steps will be made in subsequent test procedure descriptions.

a. Configure test system as illustrated in Figure 1 and install a prototype specimen in the test specimen holder.

b. Install a pre-counted particulate sampler at F-2.

c. Verify ECV-1, ECV-2, and MV-27 are closed.

d. Open ROV-2 and SV-23.

e. Start the intensifier and pressurize the test system upstream of ECV-1 to 703.07 $\pm$ 35.15 Kg/cm^2 (10,000 $\pm$ 500 psia) as read on PT-2.

f. Stop intensifier.

g. Initiate data recording.

h. Open ECV-1.

i. Close ECV-1 when PT-3 indicates stable pressure.

j. Open ECV-2 to vent test specimen holder portion of system.

k. Close ECV-2.

l. Terminate data recording.

m. Repeat steps e through l for 10 successive pneumatic impact shock cycles to verify system repeatability and ability to subject HPOF specimens to GN_2 pneumatic impact shocks of at least 703.07 Kg/cm^2 (10,000 psia) in magnitude.

n. Remove the F-2 particulate sampler and perform a particle count to ascertain the quantity and size of particulate transmitted by the test specimen (if installed). Perform particle count in the following size ranges:

Size Range (Microns)
5-15
16-25
> 25

6.1.3 Proof Pressure (DCT #3):

a. Perform a bubble point and cleanliness verification test on the HPOF following the procedure outlined in the Wintec Division Acceptance Test Procedure TP-259 (refer to Appendix A).

b. Install the HPOF in the test specimen holder.

c. Install the Wintec-supplied proof pressure plug in the holder.

NOTE: The proof pressure plug was designed to fit into the 5.3848 mm (0.212 inch) diameter opening in the HPOF directly on the CHS structure. The opposite end of the plug is 7.823 mm (0.308 inch) diameter and matches the diameter of the flow path within the test specimen holder. Use of this plug amplifies the pressure applied to the large diameter end of the plug so that the proper proof pressure load is applied to the CHS material and subsequently the entire filter stack which constitutes the HPOF.

$$\frac{\text{Applied load (to large end of plug)}}{\left[\dfrac{\text{Plug small diameter area (in contact with CHS)}}{\text{Plug large diameter area (in contact with fluid pressure media)}}\right]} = \text{Proof Load}$$

$$\frac{667.9\ \text{Kg/cm}^2\ (9{,}500\ \text{psia})}{\left[\dfrac{22.773\ \text{mm}^2\ (0.035299\ \text{in}^2)}{48.066\ \text{mm}^2\ (0.074506\ \text{in}^2)}\right]} = 1{,}409.7\ \text{Kg/cm}^2\ (20{,}051\ \text{psia})$$

d. Install the test specimen holder into the hydrostatic proof pressure system.

e. Bleed in the test set-up with filtered (0.45 micron) deionized water.

f. Increase the hydrostatic water pressure to the equivalent proof pressure of $667.9\ {}^{+14.1}_{-0}$ Kg/cm^2 (9,500 ${}^{+200}_{-0}$ psia). Hold proof pressure for a minimum of five minutes.

g. Reduce hydrostatic water pressure to ambient.

h. Remove the HPOF from the test specimen holder and perform a post-test bubble point determiation as outlined in Step a.

6.1.4 <u>Vibration Test (DCT #4)</u>

a. Perform a bubble point and cleanliness verification test on the HPOF following the procedure outlined in the Wintec Division Acceptance Test Procedure TP-259 (refer to Appendix A).

b. Verify that the magnesium alloy vibration test fixture is clean.

c. Flush the vibration test fixture with filtered (0.45 micron) trichlorotrifluoroethane. Filter the effluent through a 0.45 micron silver membrane filter. Perform a particle count of the stainless steel particles and record as the "background count."

d. Assemble the vibration test fixture without a test specimen.

e. Install the vibration fixture on the MB Electronics Model C126 vibration test system and subject the fixture to the following vibration spectrum in the X, Y, and Z axes for 48 minutes in each axis.

Vibration Spectrum

20 to 150 Hz	Increase + 6 db/octave
150 to 300 Hz	0.2 g^2/Hz
300 to 400 Hz	Decrease -6 db/octave
400 to 1000 Hz	0.12 g^2/Hz
1000 to 2000 Hz	Decrease -9 db/octave

f. Remove the vibration test fixture and repeat Step c, except record the particulate data as "vibration background count."

g. Install the HPOF in the vibration test fixture.

h. Repeat steps e and f, except record the particulate data as "HPOF vibration count."

NOTE: Particulate data is examined for the presence of stainless steel particles which would indicate that the integrity of the HPOF is detrimentally influenced by vibration.

i. Repeat step a to obtain post-test bubble point data on the HPOF.

6.1.5 Clean Condition - Flow Rate Versus Differential Pressure (DCT #5):

a. Perform a bubble point and cleanliness verification test on the HPOF following the procedure outlined in the Wintec Division Acceptance Test Procedure TP-259 (refer to Appendix A).

b. Install the HPOF in the test specimen holder.

c. Perform the basic flow rate versus differential pressure test sequence given in paragraph 6.1.1 at the test specimen inlet pressures of 29.177 $\pm$ 0.703 Kg/cm^2 (415 $\pm$ 10 psia), 49.215 $\pm$ 0.703 Kg/cm^2 (700 $\pm$ 10 psia), 70.307 $\pm$ 0.703 Kg/cm^2 (1,000 $\pm$ 10 psia), and 210.92 $\pm$ 3.515 Kg/cm^2 (3,000 $\pm$ 50 psia) to establish the pressure drop characteristics of the HPOF under clean conditions.

d. Repeat step a to obtain post-test bubble point data.

6.1.6 Clean Condition - Impact/Flow Rate Versus Differential Pressure (DCT #6):

a. Perform a bubble point and cleanliness verification test on the HPOF following the procedure outlined in the Wintec Division Acceptance Test Procedure TP-259 (refer to Appendix A).

b. Install the HPOF in the test specimen holder.

c. Perform the basic flow rate versus differential pressure test sequence given in paragraph 6.1.1 at test specimen inlet pressures of 29.177 $\pm$ 0.703 Kg/cm^2 (415 $\pm$ 10 psia), 49.215 $\pm$ 0.703 Kg/cm^2 (700 $\pm$ 10 psia), and 70.307 $\pm$ 0.703 Kg/cm^2 (1,000 $\pm$ 10 psia).

d. Perform the basic high pressure GN_2 impact cycle sequence given in paragraph 6.1.2 for a total of 100 impact cycles.

e. Repeat step c to obtain post-impact flow rate versus differential pressure data to establish the influence of the GN_2 pneumatic impact cycles upon the pressure drop characteristics of the HPOF.

f. Repeat step a to obtain post-test bubble point data.

6.1.7 Contaminant Transmission Test (DCT #7 and #8):

a. Perform a bubble point and cleanliness verification test on the HPOF following the procedure outlined in Wintec Division Acceptance Test Procedure TP-259 (refer to Appendix A).

b. Install the HPOF in the test specimen holder.

c. Add approximately 10 mg of Spec-Industries iron oxide (Fe_2O_3) P/N 1232 having the following particle size range distribution to the specimen mounted in the holder:

Size Range (Microns)	Percent in Size Range
< 3	32
3-5	27
6-10	19
11-15	9
16-25	6
26-50	4
> 50	3

d. Perform the basic high pressure GN_2 impact cycle sequence given in paragraph 6.1.2 for a total of ten impact cycles.

e. Remove the F-2 particulate sampler and examine for the size of the largest Fe_2O_3 particle transmitted by the specimen.

f. Repeat steps c through e nine additional times to add a total of 100 mg of Fe_2O_3 to the HPOF.

6.1.8 Burst Pressure Test (DCT #9):

a. Perform the proof pressure test sequence given in paragraph 6.1.3 except revise step f to read as follows:

"f. Increase the hydrostatic water pressure to $984.3 \begin{smallmatrix} + 14.1 \\ - 0 \end{smallmatrix}$ Kg/cm^2 ($14{,}000 \begin{smallmatrix} + 200 \\ - 0 \end{smallmatrix}$ psia) and hold for one minute to apply an amplified burst pressure load of 2109.2 Kg/cm^2 (30,000 psia) to the test specimen."

6.1.9 Contaminated Condition - Impact/Flow Rate Versus Differential Pressure (DCT #10):

a. Perform a bubble point and cleanliness verification test on the HPOF following the procedure outlined in Wintec Division Acceptance Test Procedure TP-259 (refer to Appendix A).

b. Install the HPOF in the test specimen holder.

c. Perform the basic flow rate versus differential pressure test sequence given in paragraph 6.1.1 to obtain baseline pressure drop data at test specimen inlet pressures of 29.177 $\pm$ 0.703 Kg/cm^2 (415 $\pm$ 10 psia) and 70.307 $\pm$ 0.703 Kg/cm^2 (1000 $\pm$ 10 psia).

d. Add approximately 10 mg of synthetic contaminant having the following composition and particle size range distribution to the HPOF in the holder.

Particulate Composition

Particle Type	Percent by Weight
TFE Teflon	56
Sand	19
Stainless Steel (includes some Fe_3O_4)	25

Size Range Distribution

Size Range (Microns)	Percent by Weight
<15	49
16-25	13
26-50	10
51-100	7
>100	21

Figure 5 is a 5X magnification photograph of this synthetic contaminant mixture designed to simulate material found in the Apollo Oxygen Purge System (OPS) and Skylab Secondary Oxygen Purge (SOP) emergency oxygen systems.

e. Perform the basic high pressure GN_2 impact cycle sequence given in paragraph 6.2 for a total of 10 impact cycles.

f. Perform the basic flow rate versus differential pressure test sequence given in paragraph 6.1.1 at test specimen inlet pressures of 29.177 $\pm$ 0.703 Kg/cm^2 (415 $\pm$ 10 psia) and 70.307 $\pm$ 0.703 Kg/cm^2 (1000 $\pm$ 10 psia) to establish influence of the synthetic contaminant and GN_2 pneumatic impact cycles on the pressure drop characteristics of the HPOF.

g. Repeat steps d, e, and f until 100 mg of synthetic contaminant have been added to the HPOF or until the differential pressure becomes too high to measure.

6.1.10 <u>Contaminated Condition - Flow Rate Versus Differential Pressure (DCT #11)</u>:

a. Perform a bubble point and cleanliness verification test on the HPOF following the procedure outlined in Wintec Division Acceptance Test Procedure TP-259 (refer to Appendix A).

b. Install the HPOF in the test specimen holder.

c. Perform the basic flow rate versus differential pressure test sequence given in paragraph 6.1.1 to obtain baseline pressure drop data at test specimen inlet pressures of 29.177 $\pm$ 0.703 Kg/cm^2 (415 $\pm$ 10 psia) and 70.307 $\pm$ 703 Kg/cm^2 (1000 $\pm$ 10 psia).

d. Add 10 mg of synthetic contaminant to the HPOF in the holder.

NOTE: Composition and particle size range distribution of synthetic contaminant is given in paragraph 6.1.9d.

e. Perform the basic flow rate versus differential pressure test sequence given in paragraph 6.1.1 at test specimen inlet pressures of 29.177 $\pm$ 0.703 Kg/cm^2 (415 $\pm$ 10 psia) and 70.307 $\pm$ 0.703 Kg/cm^2 (1000 $\pm$ 10 psia) to evaluate the influence of the addition of contaminant on the pressure drop characteristics of the HPOF under simple gas flow conditions.

f. Repeat steps d and e nine additional times to add a total of 100 mg of synthetic contaminant to the HPOF.

6.1.11 <u>Contaminated Condition - Impact/Flow Rate Versus Differential Pressure Test Conducted in the Forward and Reverse Flow Directions (DCT #12)</u>:

a. Perform the test sequence outlined in paragraph 6.1.9 with the specimen mounted in the forward (HPOF S/N side upstream) direction until approximately one half of the contaminant actually used to perform the test outlined in paragraph 6.1.9 (DCT #10) has been added to the HPOF.

b. Reverse the HPOF mounted in the test specimen holder so that the S/N side of the HPOF is downstream.

c. Repeat step a to ascertain the performance characteristics of the HPOF loaded (partially) with contaminant on both sides of the filter element.

6.2 Additional Tests:

The additional tests were performed either (1) using development versions of the HPOF or (2) the final version of the HPOF to further evaluate the performance characteristics of the HPOF at the end of the formal DCT's using various portions of the DCT procedures described in paragraph 6.1.

7.0 DESIGN CERTIFICATION TEST RESULTS

7.1 Flow Rates Versus Differential Pressure Test System Tare Values (DCT #1):

Appendix C, Tables 1 through 4, list the flow rate versus differential pressure data observed during four system "tare" value tests. The tests were conducted with GN_2 flow rates ranging from 0.9 to 5.9 Kg/hr (2 to 13 lbs/hr) at nominal test specimen inlet pressures of 29.177 Kg/cm^2 (415 psia), 49.215 Kg/cm^2 (700 psia), 70.307 Kg/cm^2 (1,000 psia) and 210.92 Kg/cm^2 (3,000 psia). The data from these tests were used to develop equations relating test system "tare" differential pressure (expressed in psid) as a function of the actual GN_2 flow through the test specimen holder (expressed in ACFM) for each test specimen inlet pressure. The equations were in subsequent DCT's used to correct observed differential pressure data for the influence of the test system mechanical configuration. Table IV lists the equations relating test system "tare" differential pressure (psid) as a function of the actual GN_2 flow through the test system (ACFM).

At all test specimen inlet pressures and GN_2 flow rates the "tare" differential pressure is less than 0.0014 Kg/cm^2 (0.002 psid) and may be considered insignificant relative to the differential pressure values actually measured during the subsequent DCT's.

7.2 Impact Test System "Tare" Pressure Values (DCT #2):

Table V lists the "tare" high pressure GN_2 impact data acquired using a prototype test specimen in the test specimen holder. This data was obtained using the maximum available pressure (703.1 Kg/cm^2 (10, 000 psia)) that could normally be provided by the gas intensifier. The data indicates that the test system will normally deliver a high pressure GN_2 impact peak pressure that is approximately 95% of the pressure upstream of the fast acting (2 millisecond fully closed-fully open) isolation valve (ECV-1).

The observed high pressure impact values are limited by the 2.3 mm (0.090 inches) diameter flow path through the fast acting isolation valve. As a result of this test, the acceptable range of the pressure upstream of the high speed isolation valve was established to be 703.07 ± 35.15 Kg/cm^2 (10,000 ± 500 psia) for all subsequent high pressure GN_2 impact tests. Figure 6 is a plot of pressure data and fast acting isolation valve (ECV-1) signals recorded during a typical impact cycle. The plot indicates that the time between the opening of ECV-1 and the peak value observed by the Kistler transducer (PT-12) mounted upstream of the test specimen is less than the maximum allowable delay of 50 milliseconds.

7.3 Proof (DCT #3) and Burst (DCT #9) Pressure Test:

The DCT Proof (Test No. 3) and Burst Pressure (Test No. 9) tests were performed in series. HPOF specimen S/N 029 was subjected, using the Wintec proof-burst pressure plug, to a proof pressure at 1,406 Kg/cm^2 (20,000 psia) for five minutes and then the pressure was increased to 2,109 Kg/cm^2 (30,000 psia) and held for the burst pressure test requirement of one minute. Visual examination of the HPOF indicated that it was not effected by the tests. Table VI summarizes the bubble point data obtained on the specimen before and after the proof/burst pressure test. The table also includes the results of the cleanliness verification test performed on the specimen prior to the test. As noted in the table, the specimen satisfactorily met the cleanliness requirements of SN/C-0005, Level 25A (Specification, Contamination Control Requirements for the Space Shuttle Program). The standard bubble point, in terms of water pressure, dropped by 13.0 cm (5.1 inches) of water pressure as a result of the DCT. A factor for conversion of the standard bubble point data, expressed in centimeters (or inches) of water pressure into a micron value for the size of the largest pore in the HPOF has not been developed. No specific standard bubble point requirement has been established for the HPOF.

7.4 Vibration Test (DCT #4):

The vibration DCT was performed as outlined in paragraph 6.1.4 subjecting HPOF S/N 025 to the vibration spectrum cited in JSC 08708 "Design Environments for Crew Systems Division Provided Space Shuttle GFE Hardware."

Table VII is a tabulation of the standard bubble point and cleanliness verification test results obtained before and after the test. The specimen satisfactorily met the cleanliness requirements of SN-C-0005, Level 25A, before and after the vibration test. The standard bubble point, in terms of water pressure, dropped by 29.8 cm (11.73 inches) as a result of the DCT. Subsequent data discussed in paragraph 7.5 suggests the bubble point change is probably insignificant.

Examination of the particulate material flushed from the HPOF and vibration fixture following the vibration excitation indicated the presence of only one stainless steel particle. Based upon this observation, it may be concluded that the mechanical integrity of the HPOF was not affected by the vibration test.

7.5 Clean Condition - Flow Rate Versus Differential Pressure Test (DCT #5):

This design certification test was performed on six different HPOF specimens. The flow rate versus differential pressure characteristics under clean conditions were determined on HPOF specimens serial numbers 021, 022, 023, 025, 027, and 028. Most of these tests were performed in order to obtain baseline pressure drop data for use in other DCT's. None of the tests were performed at an inlet pressure of 210.92 Kg/cm^2 (3,000 psia) as part of the formal DCT's due to system leakage problems. One of the development design HPOF specimens was successfully tested at an inlet pressure of 210.92 Kg/cm^2 (3,000 psia) as discussed in paragraph 9.1.

Appendix C, Tables 5 through 7 list the flow rate versus differential pressure data observed during three tests conducted on HPOF S/N 022 at nominal test specimen inlet pressures of 29.177 Kg/cm^2 (415 psia), 49. 215 Kg/cm^2 (700 psia), and 70.307 Kg/cm^2 (1,000 psia). These tests were conducted over the GN_2 flow rate range 0.9 to 5.9 Kg/hr (2 to 13 lbs/hr).

In order to smooth the data and permit examination of the differential pressure at specific flow rates, the data from each test were least squared using an equation of the form:

> Log (differential pressure) = a + b (log flow rate) + c (log flow rate)^2 + d (log flow rate)^3 where differential pressure is expressed in either SI (Metric) (Kg/cm^2 differential) or conventional (psid) units and flow rate is expressed in SI (Kg/hr or liters/min) or conventional (lbs/hr or SCFM) units.

The log form of the equation was utilized to parallel the fact that the data generally appears as a straight line on log-log plots.

Table VIII is a four-part tabulation of the smooth data observed on HPOF S/N 022 in SI and conventional units for the three nominal test specimen inlet pressures of 29.177 Kg/cm^2 (415 psia), 49.215 Kg/cm^2 (700 psia) and 70.307 Kg/cm^2 (1,000 psia). Figure 7 is a log-log plot of the data given in the table. Table IX is a tabulation of the cleanliness verification and bubble point data acquired on HPOF S/N 022 before and after this DCT.

Appendix C, Tables 8 and 9, list the flow rate versus differential pressure data observed on HPOF specimen S/N 023 during the two tests conducted at normal test specimen inlet pressures of 29.177 Kg/cm^2 (415 psia), and 70.307 Kg/cm^2 (1,000 psia). Figure 8 is log-log plots of the HPOF S/N 023 data given in the tables showing the relationship between differential pressure and GN_2 flow rate expressed in both SI and conventional units. Table X is a tabulation of the standard bubble point and cleanliness verification test data obtained on HPOF S/N 023 prior to the clean condition - pressure drop DCT.

Appendix C, Tables 10 through 12, list the observed flow rate versus differential pressure data acquired on HPOF specimen S/N 025 at the three test specimen inlet pressures normally used for this DCT. Table XI is a tabulation of the smoothed (least squared) experimental data at specific flow rates expressed in both SI and conventional units for HPOF S/N 025. The HPOF S/N 025 data listed in the tables are also illustrated by log-log plots given in Figure 9. Table XII is a tabulation of the standard bubble point and cleanliness verification test data obtained on HPOF S/N 025 prior to the clean condition - flow rate versus differential pressure DCT.

Appendix C, Tables 13 and 14 are tabulations of the pressure drop data observed during two flow rate versus differential pressure tests conducted on test specimen S/N 027. These tests were conducted at nominal test specimen inlet pressures of 29.177 Kg/cm^2 (415 psia) and 70.307 Kg/cm^2 (1,000 psia). Figure 10 is a log-log plot of the data observed on HPOF specimen S/N 027.

Table XIII is a summary of the standard bubble point and cleanliness verification test data observed on this specimen prior to the clean-conditon-flow-rate versus differential pressure test.

Appendix C, Tables 15 and 61 are tabulations of the pressure drop data observed in the clean condition of S/N 28 at 29.177 Kg/cm^2 (415 psia) and 70.307 Kg/cm^2 (1,000 psia) nominal test specimen inlet pressures.

Figure 11 is a log-log plot of the least squared smoothed data listed in the tables in Appendix C. Table XIV is a summary of the cleanliness verification and standard bubble point data obtained on HPOF S/N 028 prior to the DCT.

Appendix C, Tables 17 through 19 are tabulations of the clean condition - flow rate versus differential pressure data obtained at 29.177 Kg/cm^2 (415 psia), 49.215 Kg/cm^2 (700 psia), and 70.307 Kg/cm^2 (1,000 psia) test inlet pressures on HPOF specimen S/N 021. Table XV is a list of the differential pressure at specific flow rates calculated from least square equations of the original data. Figure 12 is a log-log plot of the pressure drop characteristics of S/N 021. Table XVI lists the cleanliness verification and bubble point data obtained on S/N 021 prior to this DCT.

Examination of the clean condition - flow rate versus differential pressure data observed on HPOF specimen S/N 021, 022, 023, 025, 027, and 028 shows that the pressure drop at the two flow rates of specific interest, 2.72 Kg/hr (6 lbs/hr) and 3.63 Kg/hr (8 lbs/hr) is reasonably reproducible as indicated below:

Nominal Test Spec. Inlet Pressure		Flow Rate		Pressure Drop			
				Average		Range	
Kg/cm^2	Psia	Kg/hr	Lbs/hr	Kg/cm^2 Diff.	Psid	Kg/cm^2 Diff.	Psid
29.177	415	2.72	6	7.73	110	6.96-8.44	99-120
70.307	1000	2.72	6	2.81	40	2.60-3.09	37-44
29.177	415	3.63	8	12.02	171	10.76-13.15	153-187
70.307	1000	3.63	8	3.94	56	3.65-4.36	52-62

The above data indicates that the HPOF "clean condition" pressure drop values at the flow rates of specific interest will vary approximately 20% from specimen to specimen.

The standard bubble point of the six HPOF specimens measured prior to the test was found to vary from 139.7 cm (55 inches) to 180.8 cm (71 inches) of water pressure with an average value of 167.6 cm (66 inches) of water pressure. Comparison of the standard bubble point data with the pressure drop characteristics of the individual specimens does not indicate that a direct correlation between bubble point and pressure drop exists. This variation is probably due to uncertainties associated with the measurement of the bubble point.

7.6 <u>Clean Condition - Impact/Flow Rate Versus Differential Pressure Test (DCT #6)</u>:

This design certification test designed to evaluate the influences of high pressure GN_2 impact cycles on the pressure drop characteristics of the HPOF was performed on specimen S/N 021. The flow rate versus differential pressure data obtained on the specimen before and after the high pressure impact cycle portion of the test is listed in Appendix C, Tables 17 through 22. The specimen was subjected to 100 high pressure (703.07 Kg/cm^2 (10,000 psia) nominal) GN_2 impact cycles. Table XVII is a tabulation of typical GN_2 impact pressure data observed during the 100 impact cycles. Tables XV and XVIII are tabulations of differential pressure values for specific flow rates derived through least squared treatment of the original data obtained before (Table XV) and after (Table XVIII) the 100 GN_2 impact cycles. Figure 13 is a log-log plot of the test data which shows the influence of the high pressure impact cycles on the differential pressure at test specimens inlet pressure of 29.177 Kg/cm^2 (415 psia) and 703.07 Kg/cm^2 (1,000 psia). For clarity, the data obtained at 49.215 Kg/cm^2 (700 psia) inlet pressure was not shown in the plots. The differences are similar to those observed at 70.307 Kg/cm^2 (1000 psia) and may be ascertained from the tabular data listed in Tables XV and XVIII.

The data shown in Figure 13 clearly indicates that the HPOF pressure drop is significantly reduced (approximately 50%) by the high pressure GN_2 impact cycles. Table XVI summarizes the initial cleanliness verification data obtained on the specimen prior to DCT #5 and the standard bubble point data obtained after DCT #6.

7.7 Contaminant Transmission Tests (DCT #7 and #8):

The contaminant transmission design certification tests (DCT's) were performed on HPOF specimen S/N 023 (DCT No. 7) and S/N 025 (DCT No. 8). Prior to this DCT, HPOF S/N 023 was evaluated for pressure drop characteristics under clean conditions while HPOF S/N 025 was subjected to the same test followed by the vibration test (DCT #4). The contaminant transmission DCT's were conducted following the procedure outlined in Paragraph 6.1.7 except HPOF S/N 023 was under clean conditions subjected to 10 high pressure GN_2 impact cycles prior to the first addition of the identifiable contaminant Fe_2O_3. High pressure GN_2 impact cycle data obtained as a result of this deviation from the DCT are discussed in paragraph 8.1 of this report. The deviation is considered to have had no detrimental affect upon the results of the contaminant transmission test. Initial bubble point and cleanliness verification tests were conducted on the specimens and the results of the tests are given in Tables XII (S/N 025) and X (S/N 023).

Tables XIX and XX list typical GN_2 impact pressure data acquired during the contaminant transmission tests, DCT No. 7, and No. 8, performed on HPOF specimens S/N 023 and S/N 025 respectively.

On the average, the specimens were subjected to GN_2 pneumatic impact pressure pulses with magnitudes on the order of 667.9 Kg/cm^2 (9,500 psia) or larger during the tests.

Tables XXI and XXII summarize the particulate transmitted data obtained during the two DCT's. As indicated in the tables, the largest identifiable Fe_2O_3 particle transmitted by either HPOF specimen was 10 microns x 10 microns in size.

It should be noted that both HPOF specimens as a result of the first and second additions of Fe_2O_3 did transmit numerous Fe_2O_3 particles that were smaller than three microns. It should also be noted that each specimen transmitted less than 10 particles that were larger than three microns. From the particulate data it may be concluded that the HPOF is an effective filter for particles larger than 10 x 10 microns.

7.8 <u>Contaminated Condition - Impact/Flow Rate Versus Differential Pressure Test (DCT #10)</u>:

Appendix C, Tables 23 through 27 list the flow rate versus differential pressure data acquired during this design certification test (DCT #10) performed using HPOF S/N 027.

Tables XXIII and XXIV list the flow rate versus differential pressure data obtained during this DCT. Table XXIII lists the data obtained at an inlet pressure of 29.177 Kg/cm^2 (415 psia) with the addition of 7.9 mg of synthetic contaminant. Data are presented to illustrate the effect of the contaminant addition and the 10 high pressure GN_2 impact cycles. Table XXIV lists similar data at an inlet pressure of 70.307 Kg/cm^2 (1,000 psia) plus data obtained after the addition of 7.9 more mg of contaminant and 10 more impact cycles.

Table XXV lists the GN_2 high pressure impact cycle data acquired during this DCT. The data indicates that the filter was subjected to impact cycles of the required magnitude.

The smooth data in these tables are illustrated in plots in Figures 13 and 15. Figure 14 illustrates the influence of the contaminant addition and high pressure GN_2 impact cycles on the differential pressure over the normal flow rate range of the data at a nominal test specimen inlet pressure of 29.177 Kg/cm^2 (415 psia) while Figure 15 illustrates the same data as obtained at a nominal test specimen inlet pressure of 70.307 Kg/cm^2 (1,000 psia). The plots indicate that the HPOF has a low contaminant tolerance under the combined situation of synthetic contaminant being present and high pressure GN_2 impact cycles. Specifically, the HPOF will not flow at the desired rates of 2.72 Kg/hr (6 lbs/hr) or 3.63 Kg/hr (8 lbs/hr) at inlet pressures of up to 1,000 psia after the addition of only 15.8 mg of contaminant out of the planned 100 mg loading. The plots also suggest the contaminant tolerance of the HPOF is highly influenced by the high pressure impact cycles which undoubtedly drive the soft contaminants into the pores of the filter. The data suggests that if the contaminant is soft and is driven into the filter by high pressure impact cycles, then the contaminant tolerance of the filter is limited.

The attempts to determine the size and quantity of the particulate transmitted in this and other tests using the synthetic contaminant were unsuccessful. The particulate data under "clean" conditions was found to be highly variable indicating that the test system, and procedure were unsuitable for determining the amount and size of particulate transmitted that resembles material normally found in the test situation.

7.9 Contaminated Condition - Flow Rate Versus Differential Pressure (DCT #11):

The original flow rate versus differential pressure data obtained during DCT #11, designed to evaluate the contaminant tolerance of the HPOF under simple GN_2 flow conditions is listed in Appendix C, Tables 28 through 37.

During this DCT performed on HPOF S/N 022, 105.2 mg of contaminant were added in five increments with the pressure drop characteristic measured after each addition at 29.177 Kg/cm^2 (415 psia) and 70.307 Kg/cm^2 (1,000 psia) inlet pressures. The original data was smoothed by the least squares technique to provide values of differential pressure at specific GN_2 flow rates as listed in Tables XXVI through XXVII. The data from these tables were used to provide plots of the contaminant tolerance of the HPOF at specific flow rates as shown in Figures 16 and 17. The plots clearly indicate that the contaminant tolerance of the HPOF is large under simple flow conditions as contrasted with that observed in DCT #10. Specifically, the HPOF will provide adequate flow capability at 3.63 Kg/hr (8 lbs/hr) with a reasonable differential pressure, even when loaded with 100 mg of synthetic contaminant under simple flow conditions.

The flat portions of the plots are probably due to the amount of contaminant added exceeding the amount that will fill the recess in the surface of the HPOF.

7.10 Contaminated Condition - Impact/Flow Rate Versus Differential Pressure Test Conducted in the Forward and Reverse Flow Directions (DCT #12):

Appendix C, Tables 38 through 47, list the original flow rate versus differential pressure data acquired on HPOF S/N 028 during DCT #12. The data were obtained after two additions of approximately 5 mg of synthetic contaminant in the forward flow direction and two additions in the reverse flow direction. These data were smoothed by the least squares technique to provide differential pressure data at discrete flow rates as listed in Tables XXVIII and XXIX. Table XXVIII lists the data obtained at a nominal inlet pressure of 29.177 Kg/cm^2 (415 psia) and Table XXIX lists similar data obtained at the nominal inlet pressure of 70.307 Kg/cm^2 (1,000 psia). Table XXX lists the high pressure GN_2 impact data observed during the DCT. The data indicates that the specimen was subjected to peak pneumatic impact pressures larger than 667.9 Kg/cm^2 (9,500 psia) as required by the test directive.

Plots of the smoothed contaminant tolerance data at specific flowrates are shown in Figures 18 and 19. The test sequence for this test did not provide for measurement of the pressure drop on the HPOF in the reverse flow direction following the addition of contaminant to the forward flow direction side of the HPOF.

The zero contaminant-added data points in the forward flow direction are probably higher than they should be because the HPOF was not subjected to high pressure impact cycles at this point in the test. Hence the phenomenon of reduced pressure drop following the impact cycles observed in earlier tests does not apply. The data in the last column in each figure is from a test that is described in paragraph 8.2. These figures indicate that the HPOF will provide reasonable flow capability even when the specimen is partially loaded with contaminant on both sides.

8.0 Results of Additional Tests Performed, Using the Final Version of the HPOF, Designed to Further Evaluate the Performance Characteristics of the HPOF:

8.1 Pressure Drop Characteristics of the HPOF in the Forward and Reverse Flow Directions:

Test specimen S/N 025 was subjected to the "Clean Condition - Flow Rate versus Differential Pressure" test (DCT #5) in the forward (HPOF S/N side upstream) and reverse flow directions. This test was conducted to verify that the pressure drop across the HPOF was the same in either flow direction. In the actual test the pressure drop was measured at the two nominal test specimen inlet pressure conditions of 29.177 Kg/cm^2 (415 psia) and 70.307 Kg/cm^2 (1,000 psia) in the forward direction. The specimen was then reversed (HPOF S/N side downstream) and the test repeated at the two same nominal inlet pressure. The specimen was then reversed again and evaluated at 70.307 Kg/cm^2 (1,000 psia) inlet pressure to verify the data was repeatable. The data observed for the forward tests are listed in Appendix C, Tables 10 through 12. Appendix C

Tables 48 and 49 list the data observed in the reverse flow directions. Appendix C, Table 50 lists the data obtained at 70.307 Kg/cm^2 (1,000 psia) inlet pressure during the repeat forward flow test.

Table XXXI lists the differential pressure at specific flow rates obtained from the least square equations of the data for each inlet pressure and flow direction. The data in the tables indicates that the repeat test conducted at 70.307 Kg/cm^2 (1,000 psia) inlet pressure satisfactorily reproduces the data initially obtained under the same test conditions.

Figure 20 clearly illustrates that the differential pressure across the HPOF is not the same in both flow directions and is significantly higher (approximately 30%) in the reverse flow direction.

A similar test to evaluate the pressure drop characteristics of the HPOF in both flow directions was also performed on S/N 028. Appendix C, Tables 51 and 52 list the data obtained during these flow rate versus differential pressure tests conducted under clean conditions. Table XXXII is a tabulation of S/N 028 pressure drop data calculated from least square equations of the original data for specific flow rates. These data are also shown in log-log plots in Figure 21. The data obtained on S/N 028 substantiates that observed on S/N 025.

It should be noted that during the acceptance test conducted by the Wintec Division, the HPOF specimens are subjected to the proof pressure test on the S/N side of the specimen.

Test Specimen S/N 023 presented a unique opportunity to evaluate the pressure drop characteristics of the HPOF under several conditions. At one time S/N 023 was received at WSTF before it was subjected to the acceptance test proof pressure test by the Wintec Division, thus allowing the specimen to be evaluated in an "as manufactured" (before proof test) condition.

Appendix C, Tables 53 and 54 list data obtained on S/N 023 before the proof pressure test and Tables 55 and 56 list similar data obtained after the proof test in the reverse flow direction. As a result of the test sequence, HPOF S/N 023 was also evaluated for pressure drop characteristics after having been subjected to 10 high pressure GN_2 impact cycles.

Appendix C, Tables 57 through 60 list the flow rate versus differential pressure data observed on S/N 023 after the 10 high pressure (703.07 Kg/cm^2 (10,000 psia) nominal) impact cycles in both flow directions.

Tables XXXIII through XXXIV are tabulations of the clean condition differential pressure data calculated from the least square equations of the data for the three general test conditions, (1) before proof test, (2) after proof test, and (3) after 10 high pressure impact cycles at inlet pressure of 29.177 Kg/cm^2 (415 psia) and 70.307 Kg/cm^2 (1,000 psia). Figures 22 and 23 show that both the proof pressure test and the high pressure impact cycles significantly influence the differential pressure characteristics of the HPOF. The data clearly indicates the influence of the proof pressure test on the differential pressure across the specimen in the forward flow direction. The reduction in differential pressure by the proof pressure test is very significant. It is unfortunate that the differential pressure in the reverse flow direction was not measured on the unproofed specimen. As indicated in the figures, the high pressure impact cycles applied in the forward direction of flow also significantly reduces the differential pressure in the forward flow direction. The figures also indicated that the differential pressure in the reverse direction after the high pressure impact cycles is similar to that observed after the proof test in the forward direction, thus indicating another path for reduction of the differential pressure.

As a result of this test, it may be concluded that both the proof pressure test and high pressure GN_2 impact cycles will reduce the differential pressure across the HPOF. Standard bubble point data obtained on the specimen, before and after the proof pressure test differs by less than 2.54 cm (1 inch) of water pressure and is considered to be insignificant.

HPOF specimen S/N 024, one of the final design HPOF specimens, due to program scheduling was received at WSTF along with S/N 023 without having been subjected to the proof test required by the Acceptance Test procedure.

HPOF S/N 023 was subsequently returned to the Wintec Division for proof test. HPOF S/N 024 was utilized to perform DCT #6 to evaluate the influence, under clean conditions, of the high pressure GN_2 impact cycles on the pressure drop characteristics of the HPOF. Appendix C, Tables 61 through 66 list the original flow rate versus differential pressure data obtained on the specimen before proof pressure testing and after the high pressure impact cycles. These data were subsequently smoothed to provide equations for the development of the data in Tables XXXV and XXXVI which lists the differential pressure observed at specific flow rates. The specimen was subjected to only 80 high pressure (703.07 Kg/cm^2 (10,000 psia) nominal) GN_2 impact cycles due to failure of the gas intensifier. Figures 24 through 26 are log-log plots of the data listed in the tables at inlet pressure 29.177

Kg/cm^2 (415 psia), 49.215 Kg/cm^2 (700 psia), and 70.307 Kg/cm^2 (1,000 psia). The data clearly indicates that the HPOF pressure drop is significantly reduced from the "as manufactured" (without proof test) condition by the high pressure impact cycles. This test indicates that the high pressure impact cycles applied to the HPOF specimens will reduce, in the forward direction of flow, the differential pressure of specimen even if they had not been proof tested.

These changes in the differential pressure of the HPOF as a result of either the proof test or the application of high pressure GN_2 impact cycles or both prompted WSTF to disassembly HPOF S/N 024. This was accomplished by machining off the mounting ring and removing the CHS material. Figures 27 through 29 are macro photographs of the surface of the CHS next to the wire mesh in the wire mesh/Dynalloy X3 assembly. Indentations of the wire mesh into the CHS can clearly be seen in both photographs of the CHS. The wire mesh appears to be undamaged. Electron microprobe electron back scatter images of the CHS material from the S/N sides of the specimen shown in Figures 30 through 32 do not indicate that the structure has been materially influenced (i.e., the pores at the indentations are not closed, but are slightly altered in shape). Figures 33 through 35 are electron microprobe electron back scatter images of the square weave mesh/Dynalloy X3 assembly in the center of the HPOF. Figures 36 through 38 are similar electron microprobe images of the surface of a sheet of new Dynalloy X3 material. Comparative examination of the figures suggests that the Dynalloy X3 material from HPOF S/N 024 may be slightly more open then the new material. A bubble point test was performed on a piece of the new Dynalloy X3 material and the square weave mesh/Dynalloy X3 assembly in the HPOF S/N 024. The standard bubble point of each was found to be within 2.54 cm (1 inch) of water pressure of each other. The new Dynalloy X3 was found to have a standard bubble point of 86.4 cm (34 inches) of water pressure.

In summary, the examination of HPOF S/N024 did not clearly reveal anything that could directly explain why or how the differential pressure characteristics are changed by the application of the high pressure GN_2 impact cycles.

8.2 <u>Effect of Operating Sequence on Contaminant Loading of the HPOF:</u>

During DCT #10, HPOF S/N 027 was loaded with synthetic contaminant and subjected to 20 GN_2 impact cycles. The specimen would not provide adequate flow at either 2.72 Kg/hr (6 lbs/hr) or 3.63 Kg/hr (8 lbs/hr) at the end of the test at either test speicmen inlet pressure. This situation would simulate a HPOF that was utilized extensively in one flow direction and presented the question of how would it perform in the reverse direction. To evaluate this situation the specimen was reversed in the test system, subjected to 10 high pressure GN_2 impact cycles and then evaluated for pressure drop characteristics. Appendix C, Tables 67 through 70 list the flow rate versus differential pressure data obtained on HPOF S/N 027 after the completion of DCT #10 and after the application of 10 high pressure impact cycles on the reverse side of the specimen. The data were obtained in both the forward and reverse flow directions at 29.177 Kg/cm^2 (415 psia) and 70.307 Kg/cm^2 (1,000 psia) test specimen inlet pressures. Table XXXVII is a tabulation of the differential pressure data for specific flow rates obtained through least square treatment of the original data. Figure 39 is a log-log plot of the data listed in Table XXXVII. The data clearly shows that the filter would flow satisfactorily at 2.72 Kg/hr (6 lbs/hr) and 3.63 Kg/hr (8 lbs/hr) under the conditions outlined above.

Examination of the sampler (F-2) mounted below the HPOF during the GN_2 impact cycles and the specimen did not indicate that significant amounts of contaminant were removed from the filter by the GN_2 impact cycles applied to the reverse side of the HPOF. Apparently the contaminant is simply re-arranged in the structure of the HPOF by the impact cycles and is not expelled from the structure.

Another question investigated was the influence of less than 10 impact cycles upon the differential pressure across the HPOF partially loaded with synthetic contaminant. This situation was examined during the formal performance of DCT #12 in the following manner. After the addition of 5.2 mg of synthetic contaminant the HPOF was subjected to only two high pressure GN_2 impact cycles and then examined for pressure drop values. The specimen was then subjected to eight more impact cycles to bring the total number up to the required 10 impact cycles and re-examined for pressure drop characteristics. Table XXVIII and XXXIX are tabular listings of the differential pressure at specific flow rates obtained during DCT #12. A portion of the data were extracted and are summarized in Tables XXXVIII and XXXIX to illustrate the influence of two versus ten impact cycles on the differential pressure at nominal test specimen inlet pressures of 29.177 Kg/cm^2 (415 psia) and 70.307 Kg/cm^2 (1,000 psia). The data in the tables indicate two impact cycles are not as influential in reducing the differential pressure across the HPOF as are 10 impact cycles. This is probably due to the fact that during the application of the impact cycles (1) the specimen itself is being reduced in differential pressure as observed during earlier tests and (2) the contaminant is being re-arranged in the HPOF.

The test, in summary, indicates the influence of the GN_2 impact cycles on the differential pressure is greater than the rearrangement of the contaminant during the initial use of the filter.

The other operation oriented question is also associated with DCT #12 which loaded HPOF S/N 028 on both sides. The question may be stated as, what is the pressure drop characteristics of the HPOF in the forward direction after having been loaded, at least partially, with contaminant in the forward and reverse directions. The data was obtained immediately following the normal DCT #12 test sequence. Appendix C, Tables 71 and 72 list the original test data. Tables XXVIII and XXIX list differential pressure values for specific flow rates derived from least square equations of the original data. The values listed in the last column of the tables are also shown in Figures 18 and 19 for ready comparison with the normal DCT #12 data. The data indicates that the differential pressure in the forward direction is greater than it was in either direction and that adequate flow can be obtained at 2.72 Kg/hr (6 lbs/hr) at either 29.177 Kg/cm^2 (415 psia) or 70.307 Kg/cm^2 (1,000 psia) inlet pressure. The data suggests that the HPOF will perform satisfactorily when partially loaded with contaminant in both directions of flow under the proper flow direction condition.

8.3 <u>Affect of Contaminant Composition on Pressure Drop Characteristics of the HPOF</u>:

As noted in paragraph 7.7, the contaminant tolerance of the HPOF using the synthetic contaminant is small. In DCT #10 less than 16 mg of the predominantly TFE Teflon synthetic contaminant was demonstrated to be sufficient to increase the pressure drop to a point where the unit would no longer permit satisfactory GN_2 flow. HPOF S/N 025 after the contaminant transmission test (DCT #8) was loaded with Fe_2O_3 and had been subjected to a total of 100 high pressure GN_2 impact cycles. This specimen was returned to the test system and subjected to the normal flow rate versus differential pressure test.

Appendix C, Table 73 lists the pressure drop data obtained on the specimen after the completion of DCT #8. Table XL is a tabulation of the differential pressure data at specific flow rates before and after DCT #8. Figure 40 illustrates the data listed in the table and shows that at 70.307 Kg/cm^2 (1,000 psia) this HPOF specimen will provide adequate flow even when it is loaded with 46 mg of Fe_2O_3. Consideration of this observation together with that from DCT #10 strongly suggests that the composition of the particulate to which the HPOF is subjected can make a meaningful difference in the observed contaminant tolerance. The

Fe_2O_3 particle size range distribution is similar to that of the synthetic contaminant, but the hardness of the materials is considerably different. Another consideration worthy of note is the effect of the transient high temperatures generated by the isentropic compression of the GN_2 on the HPOF surface during the impact sequences. Microscopic examination of the synthetic contaminant on the surface of the HPOF from DCT #10 suggests that some slight surface melting or softening of the TFE Teflon did occur as a result of the GN_2 impact cycles. Without doubt softening of the TFE Teflon would make it easier to extrude the contaminant into the HPOF structure thus further increasing the differential pressure observed on the specimens.

9.0 DESIGN CERTIFICATION TESTS PERFORMED ON DEVELOPMENT VERSIONS OF THE HPOF

Several DCT's were performed on early versions of the HPOF before it was determined that the original and an interim design would not perform satisfactorily under the high pressure GN_2 impact cycle test sequences. The data are presented below for easy reference and correlation with data obtained on the final design of the HPOF.

9.1 HPOF S/N 006:

This specimen was one of three (S/N 006, 003, and 020) received at WSTF that conformed to the original design detailed in Figures 41 and 42. The electron beam weld used to bond the filter to its mounting was subsequently found to be inadequate to withstand the high pressure (703.07 Kg/cm^2 (10,000 psia) nominal) impact cycles. HPOF specimen S/N 006 was subjected to DCT #5 "Clean Condition - Flow Rate Versus Differential Pressure Test." Appendix C, Tables 74 through 77 list the original test data obtained at test specimen inlet pressures of 29.177 Kg/cm^2 (415 psia) 49.215 Kg/cm^2 (700 psia), 70.307 Kg/cm^2 (1,000 psia) and 210.92 Kg/cm^2 (3,000 psia). The original data were least squared to provide smooth data for the development of Table XLI which tabulate the differential pressure across the specimen at specific flow rates. The data in the table are illustrated on log-log plots in Figure 43. The plot shows the relationship between differential pressure and flow rate for each of the four test specimen inlet pressures evaluated. The data indicates that the differential pressure across the HPOF drops rapidly as the test specimen inlet pressure is increased. This observation is a characteristic behavior of all gas filters evaluated at common flow rates. Table XLII is a tabulation of the cleanliness verification and bubble point test data acquired on S/N 006 before and after the test.

9.2 HPOF S/N 003:

HPOF specimen S/N 003 was also one of the original configuration specimens. The specimen, as reported in TD-121-025 "Failure Analysis Report, High Pressure Oxygen Filter (HPOF) Program, Wintec P/N 9-812 S/N 003," was evaluated for its clean condition - pressure drop characteristics and was subjected to DCT #6, "Clean Condition - Impact/Flow Rate Versus Differential Pressure." During DCT #6, the electron beam weld on the specimen failed. A full discussion of the data associated with S/N 003 is given in the failure analysis report.

9.3 HPOF S/N 020:

HPOF specimen S/N 020 was the result of an attempt to correct the electron beam (EB) weld thickness problem encountered in the original design of the HPOF. This particular specimen features an EB weld that is 0.635 mm (0.025 inch) thick in contrast to the 0.127 mm (0.005 inch) thick weld utilized on the original design. In order to accomplish the EB weld, the ring surrounding the HPOF filter stack was cut down to provide a "burn down" flange for the EB weld. This action left the specimen with a large, deep ring or annulus between the EB weld and the outer edge of the mounting ring. This annulus provides an excellent trap or collection area for contaminant. This manufacturing process was found to be marginally acceptable due to surface cracking of the CHS structure as a result of weld shrinkage. The specimen was, however, utilized in the performance of DCT #5 "Clean Condition - Flow Rate Versus Differential Pressure" and DCT #11 "Contaminated Condition - Flow Rate Versus Differential Pressure."

Appendix C, Tables 78 through 80 are tabulations of the original data obtained during the performance of DCT #5. Table XLIII is a tabulation of smooth values of differential pressure for specific flow rates obtained from least square equations of the original data. Figure 44 is a log-log plot of the pressure drop characteristics of the specimen expressed in SI and conventional units. Comparison of the Figure 44 with Figures 8 through 12 indicates that the original design exhibited much lower pressure drop characteristics than the final design.

Table XLIV lists cleanliness verification and standard bubble point data obtained on S/N 020 prior to DCT #5.

Appendix C, Tables 81 through 98 are tabulations of the DCT #11 data obtained on S/N 020 after each addition of contaminant. These data were smoothed by the least square technique to provide the tabulation of data listed in Tables XLV and XLVI. The tables list the differential pressure at specific flow rates for each of the 10 additions of synthetic contaminant. Figures 45 and 46 are contaminant tolerance plots of the data in the tables. The data suggests that this configuration of the HPOF exhibits a large contaminant tolerance in comparison to that observed on the final version of the HPOF as shown in Figure 17. At least part of this characteristic is due to the physical arrangement of the HPOF, as noted earlier, which allows for collection of some contaminant around the HPOF filter stack and not directly on the element.

10.0 CONCLUSIONS

The HPOF specimens of the final design performed satisfactorily during all of the Design Certification Tests. During this series of tests the HPOF passed the proof and burst pressure tests without any measurable change to the filter. The vibration test indicated that the HPOF was not materially affected by the environment and is not subject to media migration. The flow rate versus differential pressure tests conducted under clean conditions, in the forward flow direction, indicated that the pressure drop across the HPOF at a flow rate of 3.63 Kg/hr (8 lbs/hr) varied from approximately 12.02 Kg/cm^2 differential (171 psid) at an inlet pressure of 29.177 Kg/cm^2 (415 psia) to a lower value of 3.94 Kg/cm^2 differential (56 psid) at an inlet pressure of 70.307 Kg/cm^2 (1,000 psia). The HPOF was shown to exhibit much lower differential pressures as the inlet pressure is increased for fixed flow rate such as 2.72 Kg/cm^2 (6 lbs/hr) or 3.63 Kg/hr (8 lbs/hr). All six specimens examined exhibited pressure drop characteristics that were within $\pm$ 20% of each other, thus indicating reasonable performance repeatability. HPOF specimens examined under clean conditions for the effect of the high pressure (703.07 Kg/cm^2 (10,000 psia) nominal) GN_2 impact cycles on the pressure drop characteristics of the filter indicated that the impact cycles significantly reduced the differential pressure across the specimen by approximately 50%. Subsequent tests, not part of the formal DCT's, indicated that the pressure drop was reduced by being subjected to the proof pressure test as well as the application of GN_2 impact cycles. Other tests indicated that the pressure drop across the HPOF was not the same in both flow directions. Specifically the pressure drop was observed to be considerably higher (approximately 30%) in the reverse flow direction which is the side not subjected to either the proof pressure load or high pressure GN_2 impact cycles.

Comparison of the observed standard bubble point data with the pressure drop characteristics of the specimens failed to indicate any direct correlation between these two filter characteristics. The lack of correlation may be due to uncertainties associated with the bubble point determination.

The two contaminant transmission tests conducted using a new specimen and the specimen used for the vibration test both indicated that the largest identifiable particle transmitted by the HPOF is 10x10 microns. Numerous particles smaller than 3 microns were initially transmitted by the specimen and very few particles larger than 3 microns were observed during the tests. Based upon the contaminant transmission tests is may be stated that the maximum size particle rating of the HPOF is 10 microns. The three contaminant tolerance tests indicated that under simple gas flow conditions the HPOF would exhibit good contaminant tolerance performance. Specifically, over 100 mg of the predominantly TFE Teflon synthetic contaminant designed to simulate material found in the Apollo Oxygen Purge System (OPS) and Skylab Secondary Oxygen Pack (SOP) emergency oxygen systems would increase the differential pressure by less than 2.11 Kg/cm^2 differential (30 psid) at a flow rate of 3.63 Kg/hr (8 lbs/hr) at an inlet pressure of 70.307 Kg/cm^2 (1,000 psia). The second contaminant tolerance test employing the same synthetic contaminant and the application of high pressure GN_2 impact cycles indicated that less than 16 mg of contaminant would prohibit flow through the HPOF at 2.72 Kg/cm^2 (6 lbs/hr) at inlet pressures less than 70.307 Kg/cm^2 (1,000 psia). This observation is considered to be the only performance shortcoming of the HPOF. The affect is probably due to the extrudable nature of the synthetic contaminant.

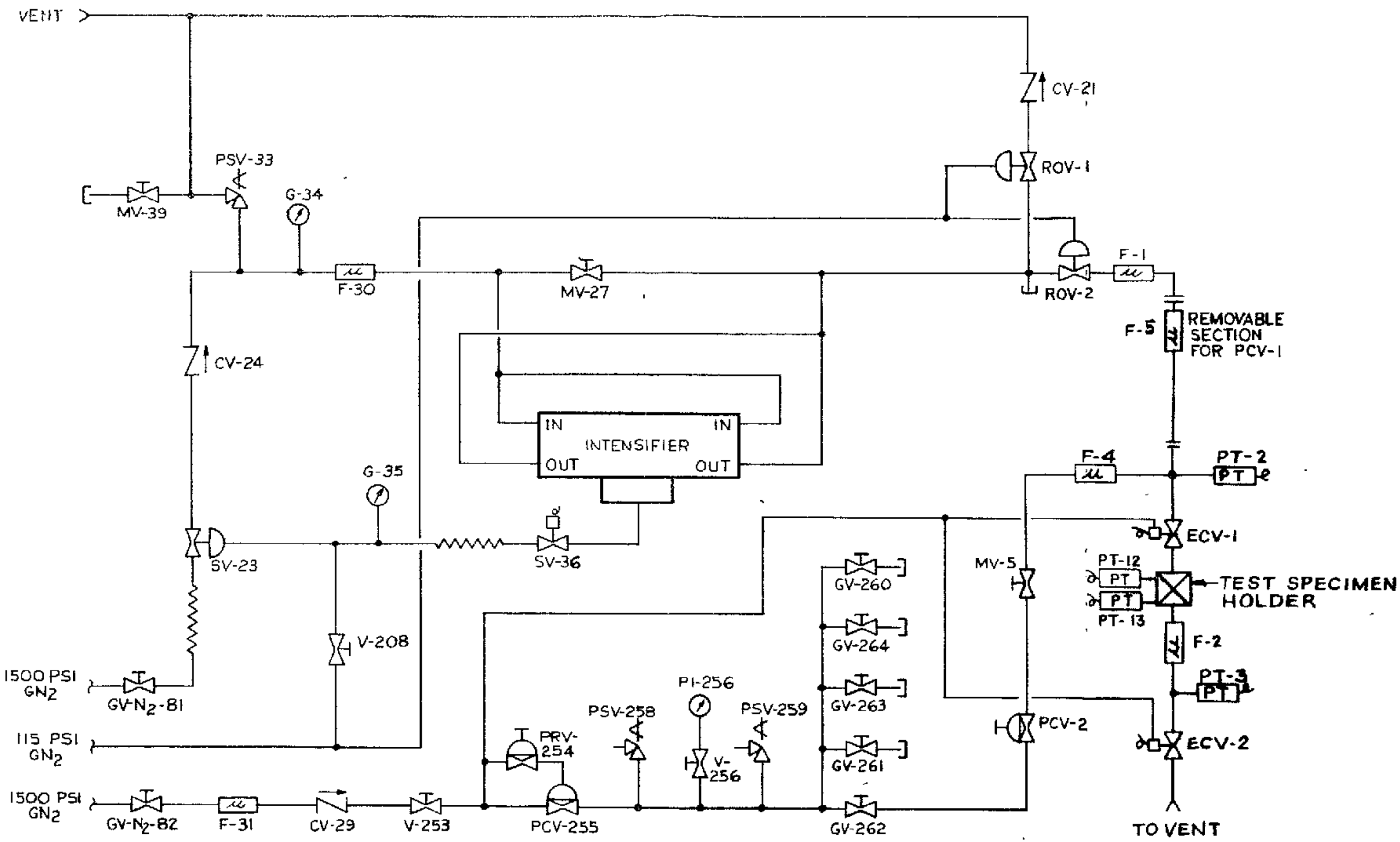
The third contaminant tolerance test performed in both flow directions indicated that the HPOF would perform satisfactorily at a flow rate of 3.63 Kg/hr (8 lbs/hr) at an inlet pressure of 29.177 Kg/cm^2 (415 psia).

Tests performed to further evaluate the performance characteristics of the HPOF indicated that a HPOF plugged with synthetic contaminant, would when reversed and subjected to 10 high pressure GN_2 impact cycles, provide adequate flow capability. Another test demonstrated that the number of high pressure GN_2 impact cycles applied to a filter partially loaded with synthetic contaminant influences the pressure drop significantly.

Specifically, it was observed that the pressure drop across a freshly loaded filter was not reduced significantly by two high pressure impact cycles; however, a total of 10 high pressure impact cycles were found to reduce the pressure drop to values close to those observed under clean conditions.

Examination of the pressure drop characteristics of the HPOF specimen S/N 025 at the completion of the contaminant transmission test indicated that satisfactory flow at 3.63 Kg/hr (8 lbs/hr) at an inlet pressure of 70.307 Kg/cm^2 (1,000 psia) could be obtained on this specimen loaded with 46 mg of Fe_2O_3. Consideration of this observation in comparison with the inability to obtain satisfactory flow when the HPOF was loaded with 15.8 mg of synthetic contaminant during DCT #10 clearly suggests that hard granular particulate will significantly alter the contaminant tolerance capability of the HPOF. Thus, the composition of the particulate in a real system employing the HPOF is important and every effort should be made to reduce the amount of soft contaminant such as TFE Teflon present in the system in order to prolong the useful life of the HPOF.

In summary, the HPOF performed satisfactorily during all of the design certification tests. It is limited in contaminant tolerance under high pressure impact conditions when the contaminant is the soft predominantly TFE Teflon synthetic contaminant resembling the material found in the OPS and SOP emergency oxygen systems. The pressure drop characteristics of the HPOF are not the same in both flow directions and are significantly reduced by the application of high pressure GN_2 impact cycles simulating conditions created by opening an isolation valve upstream of the filter.



HPOF TEST SYSTEM

IMPACT VERSION

FIGURE 1

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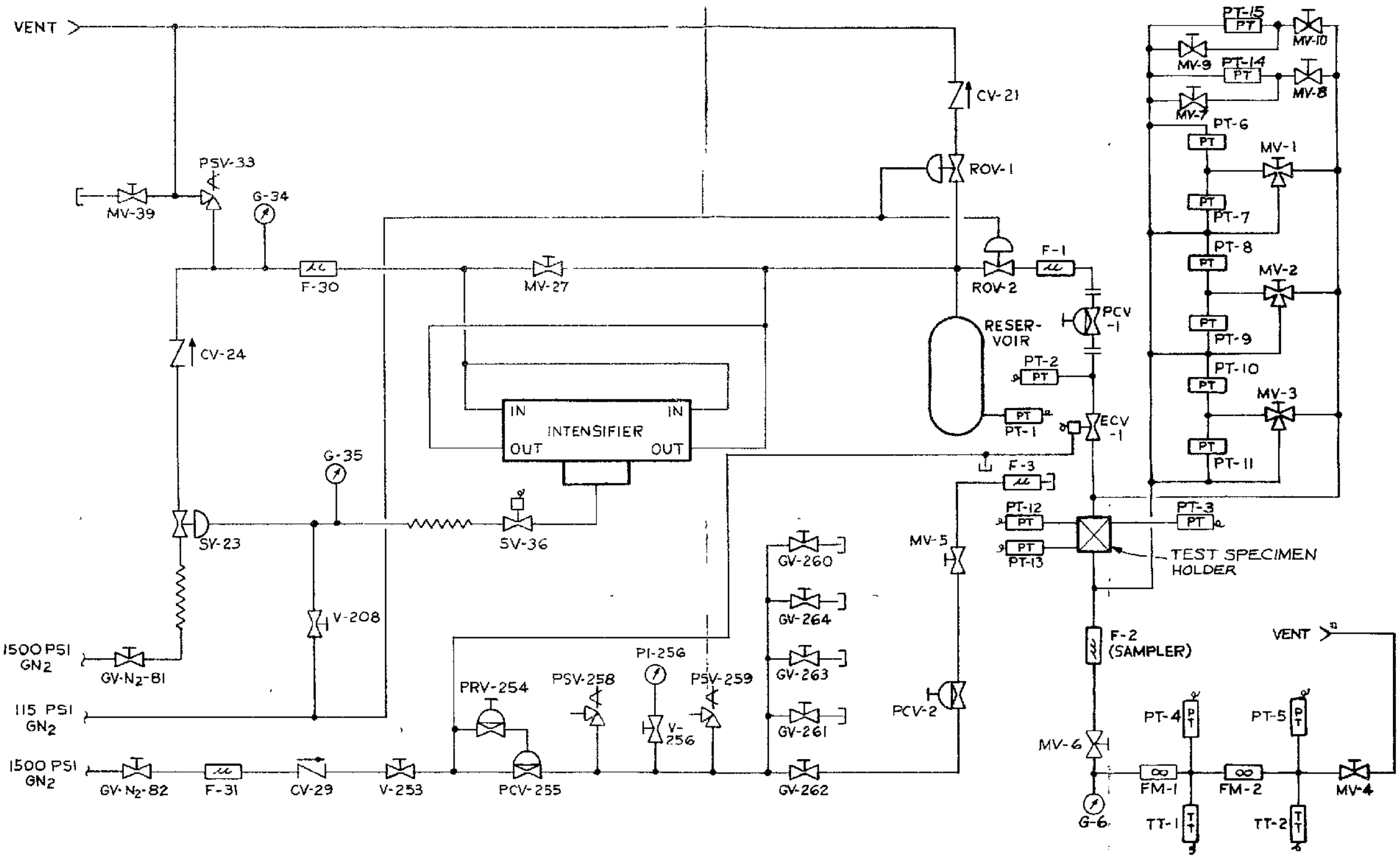
6-4-76

FOLDOUT FRAME 1

FOLDOUT FRAME 2



HPOF TEST SYSTEM

FLOW RATE VERSION

FIGURE 2

FOLDOUT FRAME 1

FOLDOUT FRAME 2

9-812

REVISIONS			
SYM	DESCRIPTION	DATE	APPROVAL
D	RE-DESIGNED & RE-DRAWN	6/15/76	[illegible]

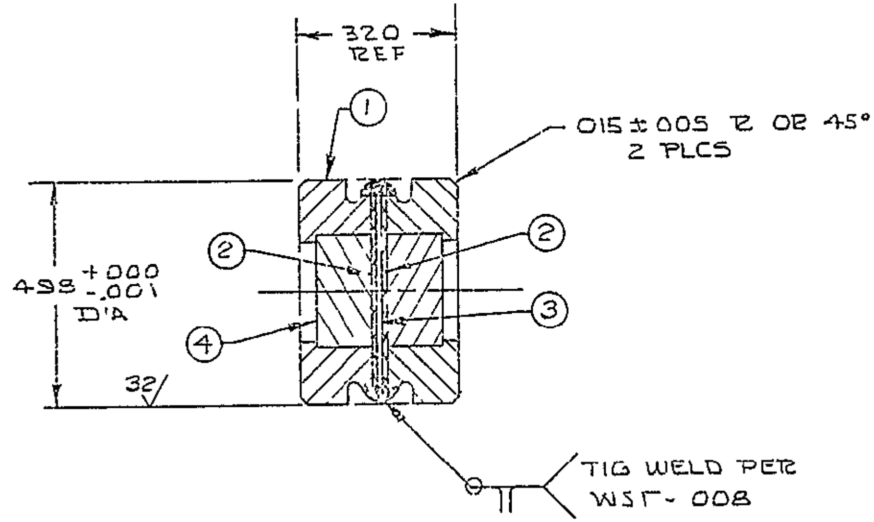


FIGURE 3

GENERAL NOTES UOS

1 FLUID 100% OXYGEN PER MIL-O-27210
2 FLOW RATE 2 TO 13 LBS/HR @ 8000 PSIG
3 FILTRATION 3 MICRONS ABS
4 ACCEPTANCE TEST PER TP259
5 BURR INSPECT PER WSI-001

ITEM NO	QTY	NAME	PART NO	MATERIAL
4	2	CHS	20-1232	304 CRES
3	1	FILTER	19-1612	304 CRES
2	2	SCREEN	19-1611	304L CRES
1	2	RING	20-1265	304L, 316L, 321 OR 347 CRES

LIST OF MATERIAL

UNLESS OTHERWISE SPECIFIED
ALL DIMENSIONS ARE IN INCHES
DO NOT SCALE DRAWING
PART TO BE FREE OF BURRS
BREAK SHARP EDGES .005—.015
ALL THREADS PER MIL S 7742

TOL .XX ± .03 .XXX ± .010 ANG ± 1/2

SURFACE ROUGHNESS PER ASA B46.1 125 MAX

MAT'L —

FINISH CLEAN PER WSP-010

HEAT TREAT

NEXT ASSY	USED ON
—	—
APPLICATION	

DRAWN	J D	6 14 76
CHECK	[illegible]	6/15/76
APPR		
APPR	[illegible]	6/15/76
APPR		

APPROVAL

APPROVAL

WINTEC DIVISION
BRUNSWICK CORPORATION
LOS ANGELES CALIFORNIA

CHS FILTER

CODE IDENT NO	SIZE	
21550	B	9-812
SCALE 4/1	WT —	SHEET 1 OF 1

UNCONTROLLED COPY
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WITHOUT NOTICE

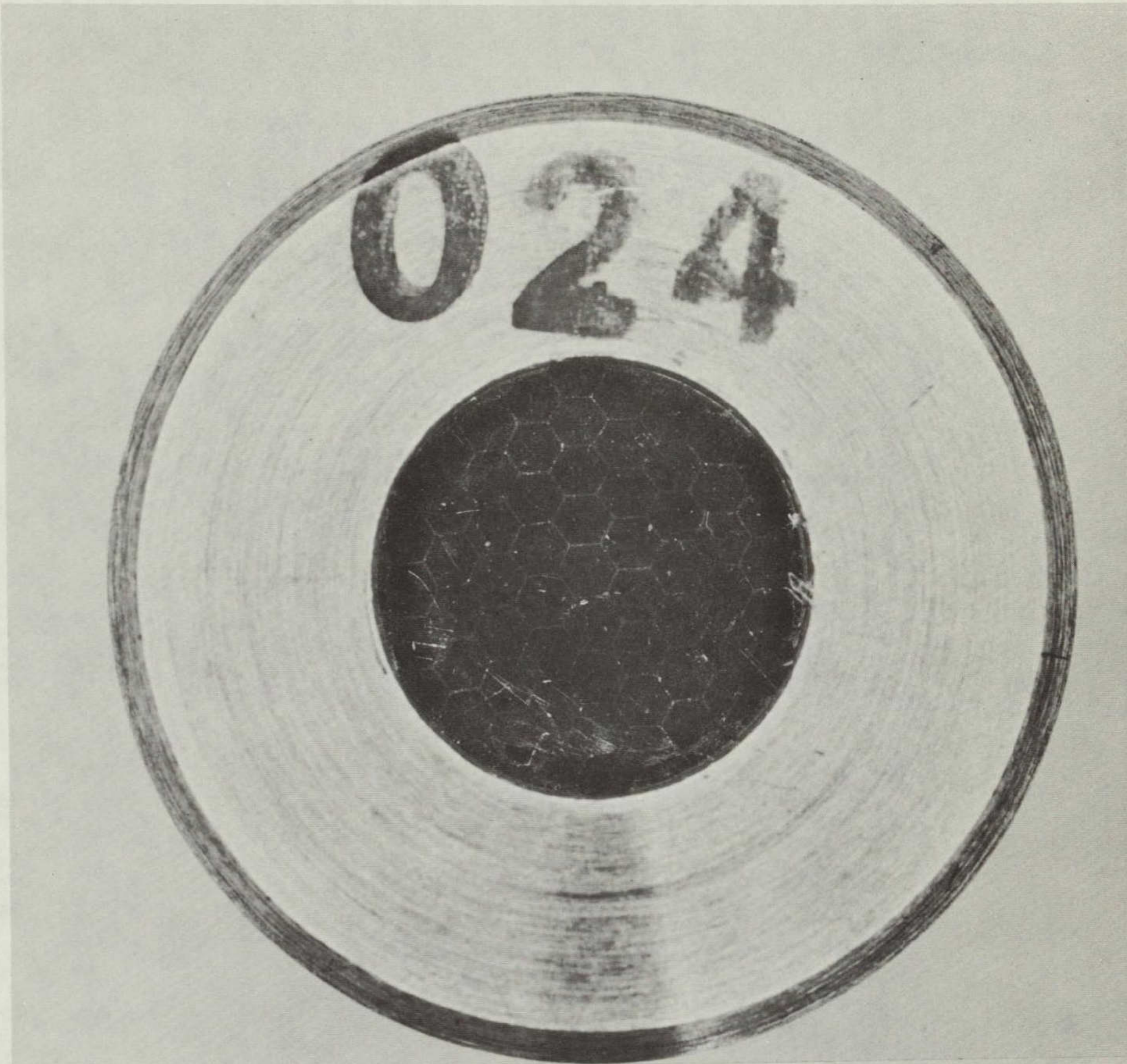


Figure 4: Photograph of
S/N Side of HPOF Specimen
S/N 024

Magnification: 10X

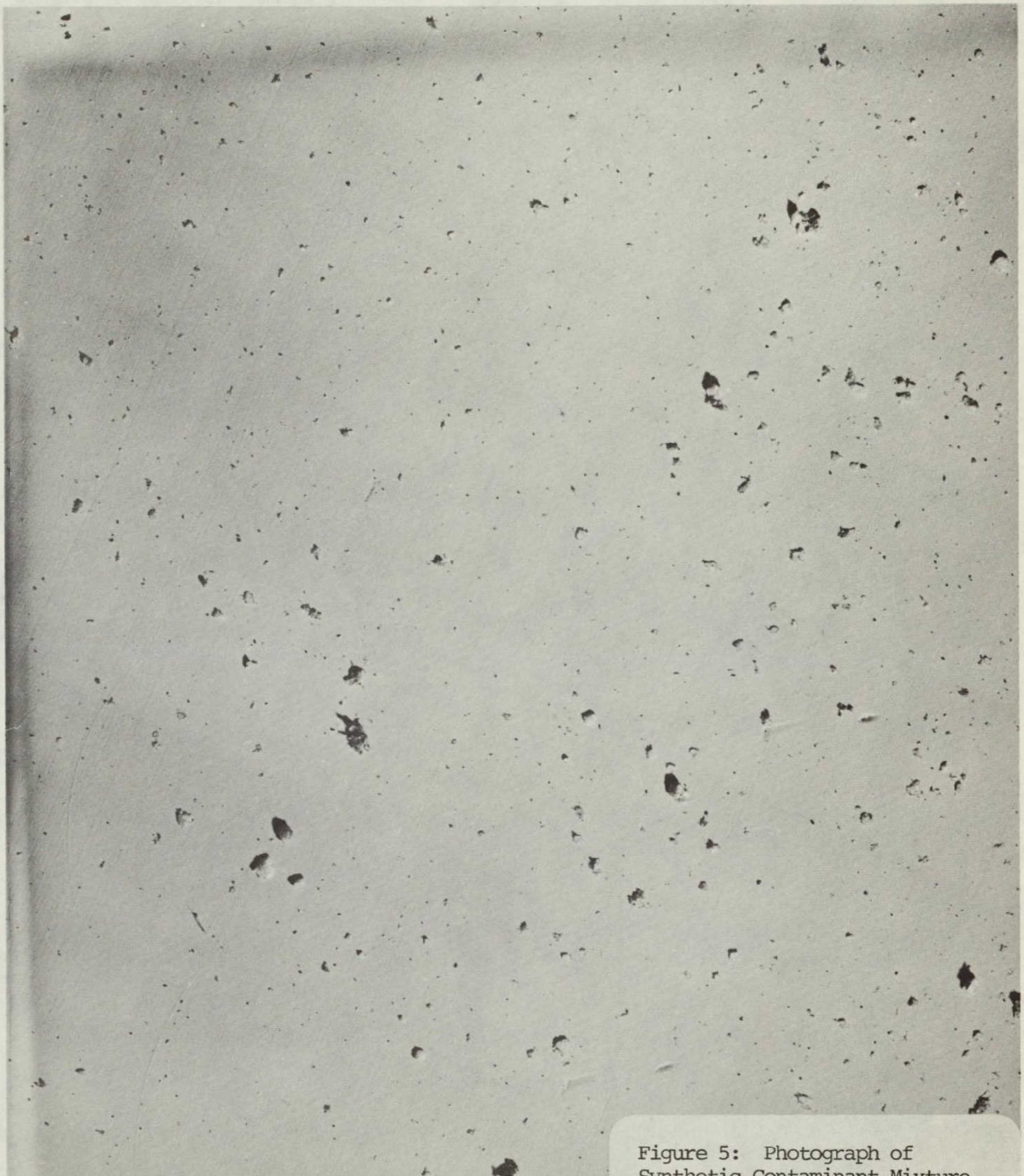


Figure 5: Photograph of Synthetic Contaminant Mixture Used for Contaminant Tolerance Tests.

Magnification: Approximately 5X

TEST NO. 5

TEST SPECIMEN S/N 022

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE

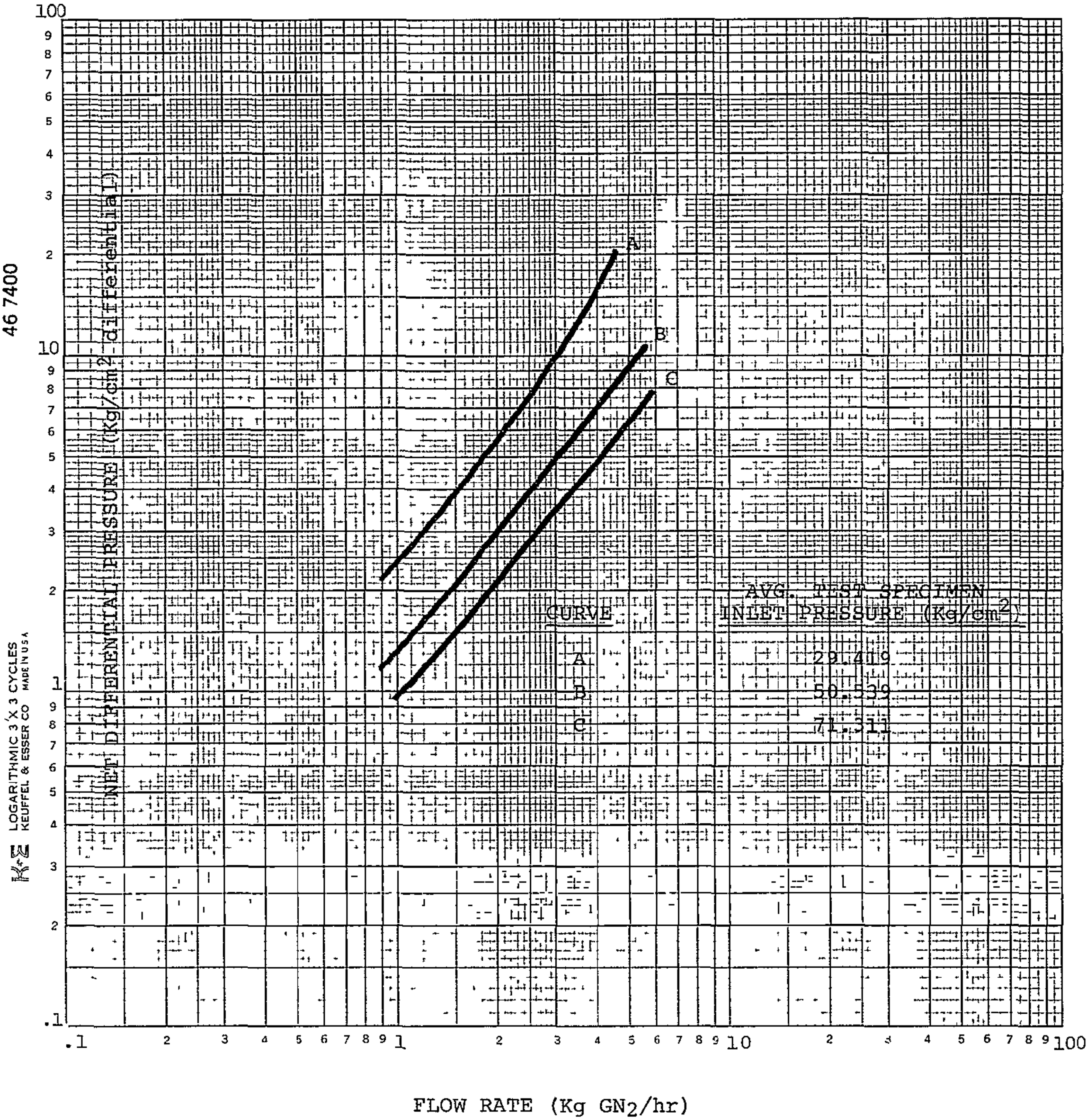
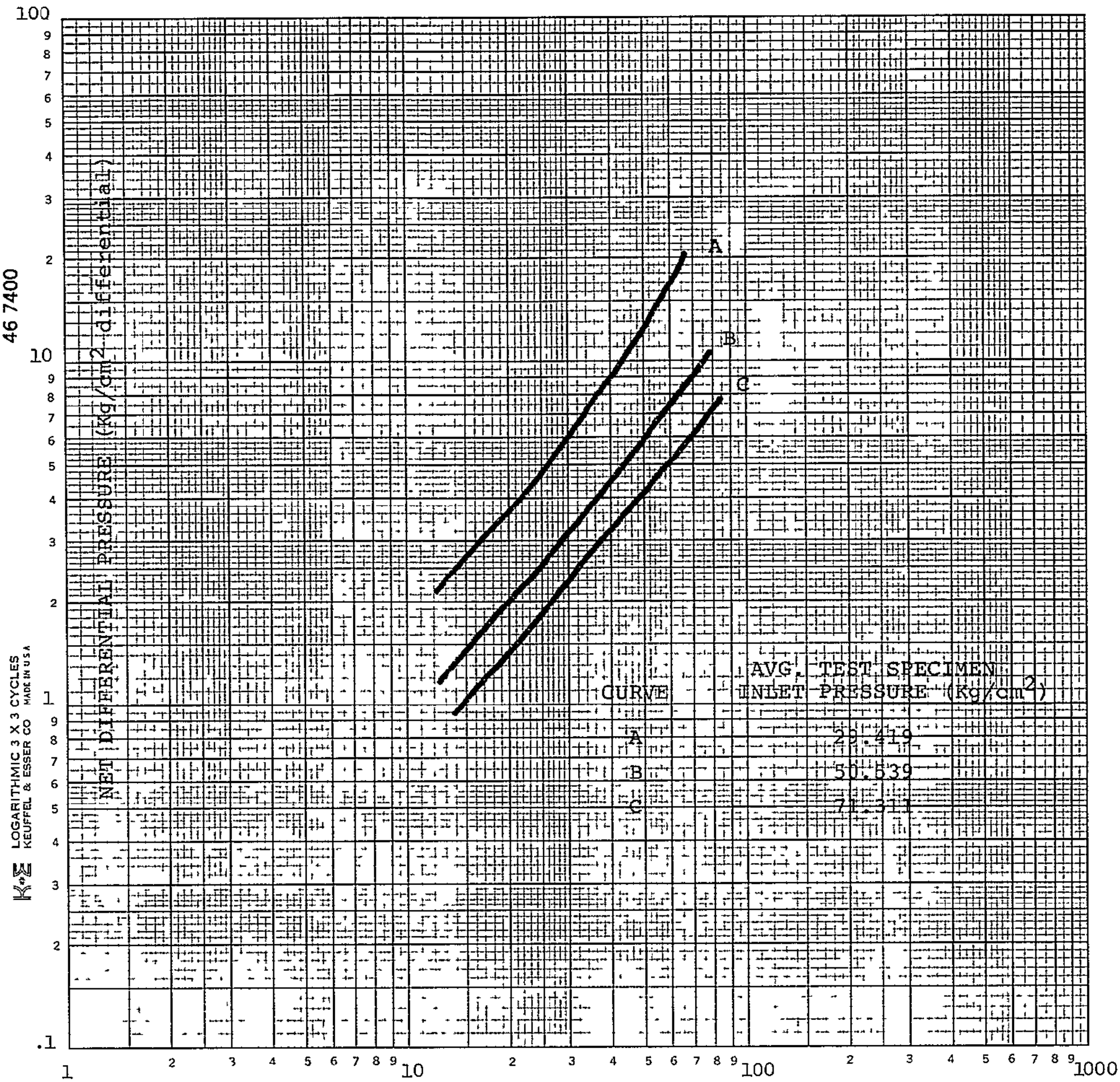


FIGURE 7 Part A

TEST NO. 5

TEST SPECIMEN S/N 022

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE



*At 21.1°C (70°F) and 1.033 Kg/cm^2 (14.7 psia)

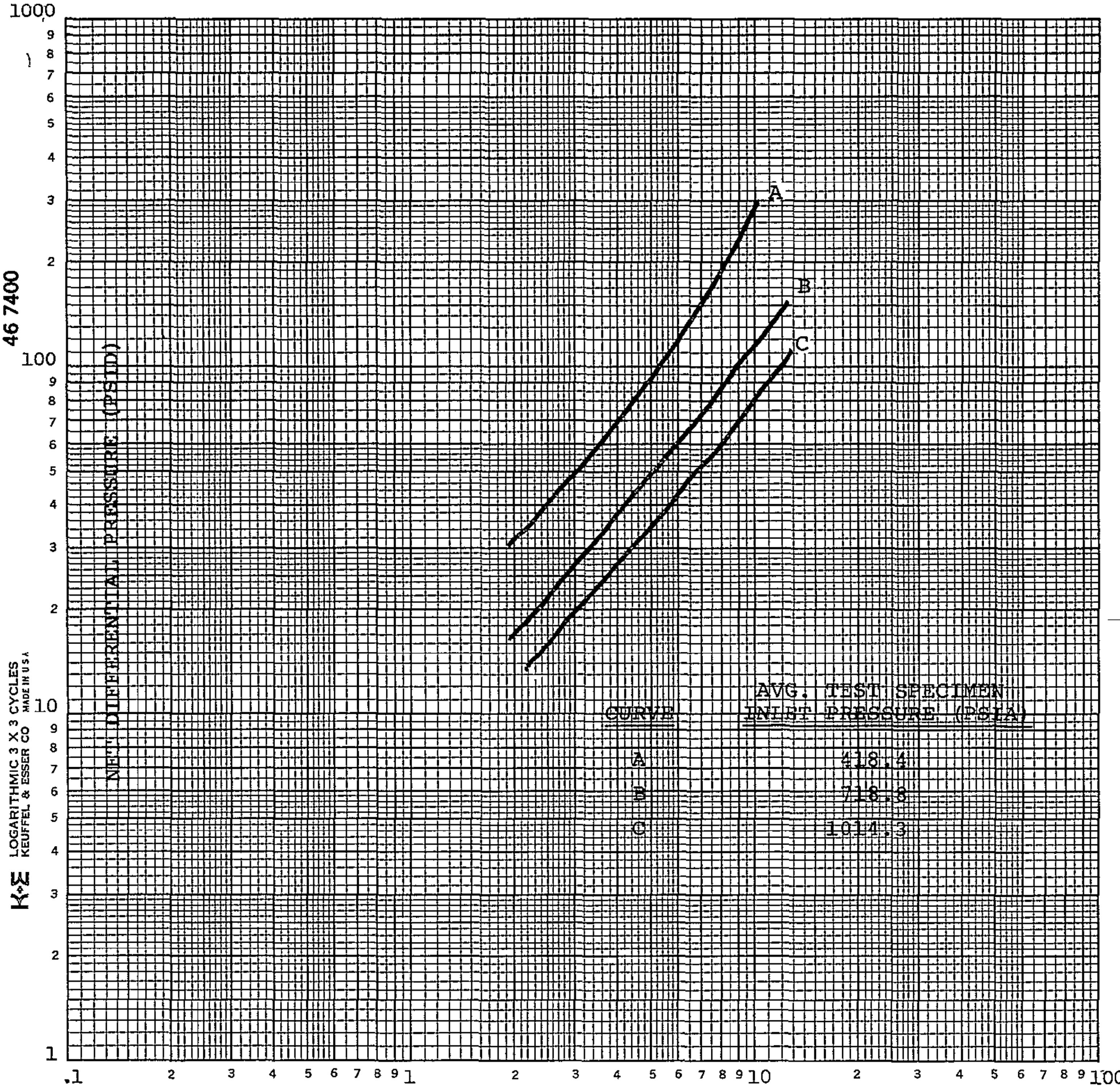
FIGURE 7 Part B

Revised 1-6-77

TEST NO. 5

TEST SPECIMEN S/N 022

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE



FLOW RATE (lbs GN_2/hr)

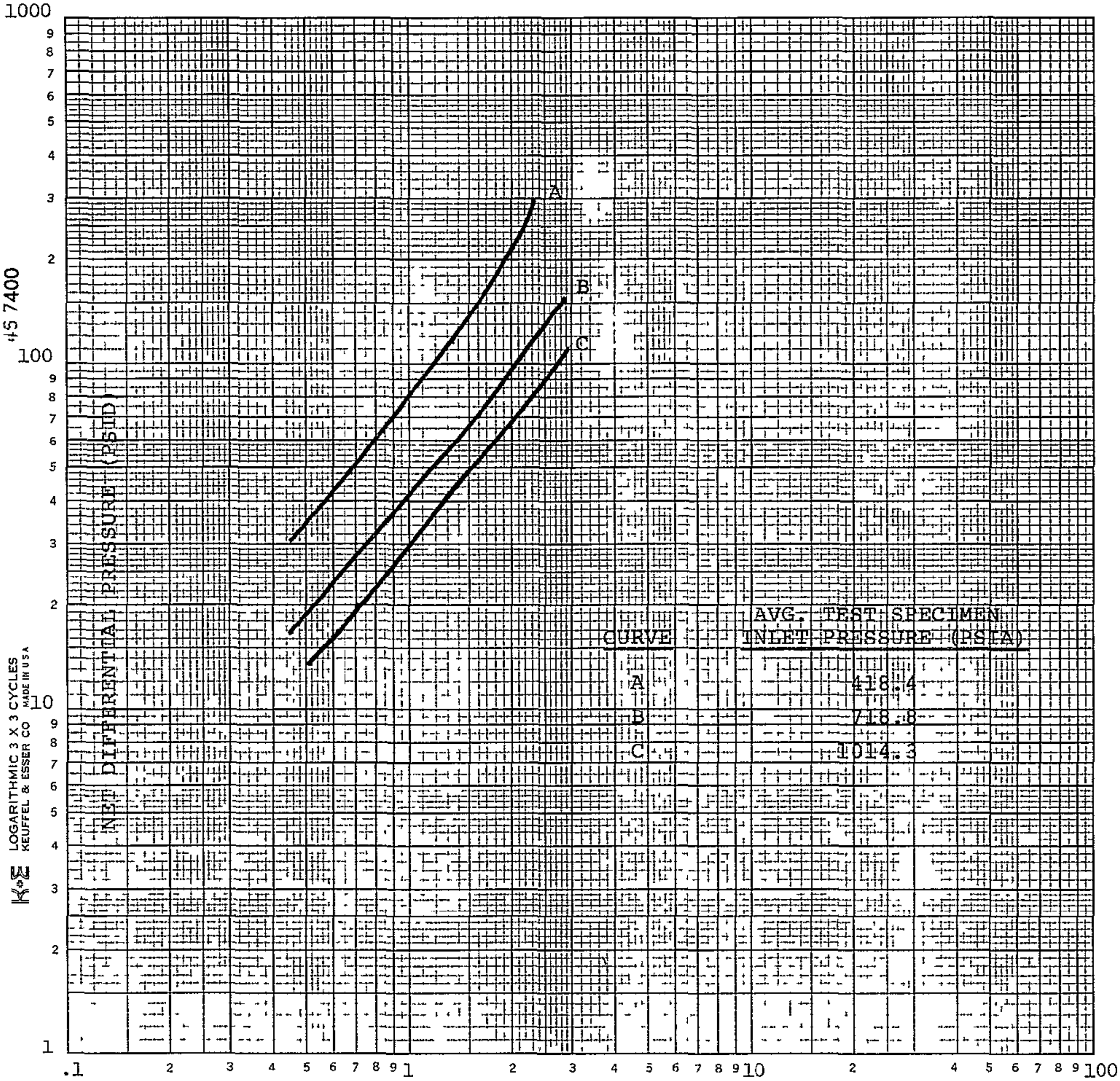
FIGURE 7 Part C

11

TEST NO. 5

TEST SPECIMEN S/N 022

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE



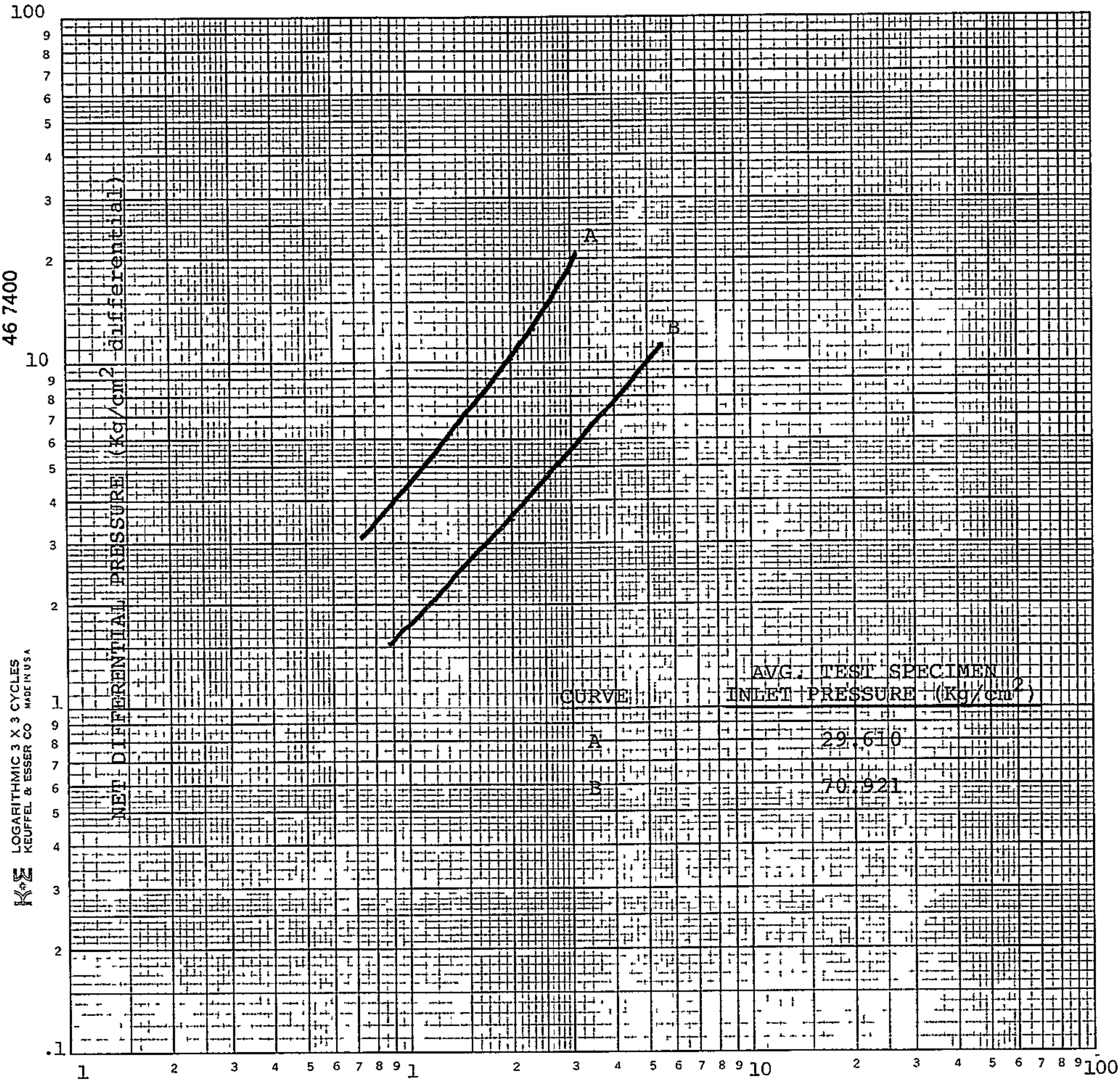
FLOW RATE (SCFM)

FIGURE 7 Part D

HPOF PROGRAM TEST NO. 5

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE

TEST SPECIMEN S/N 023



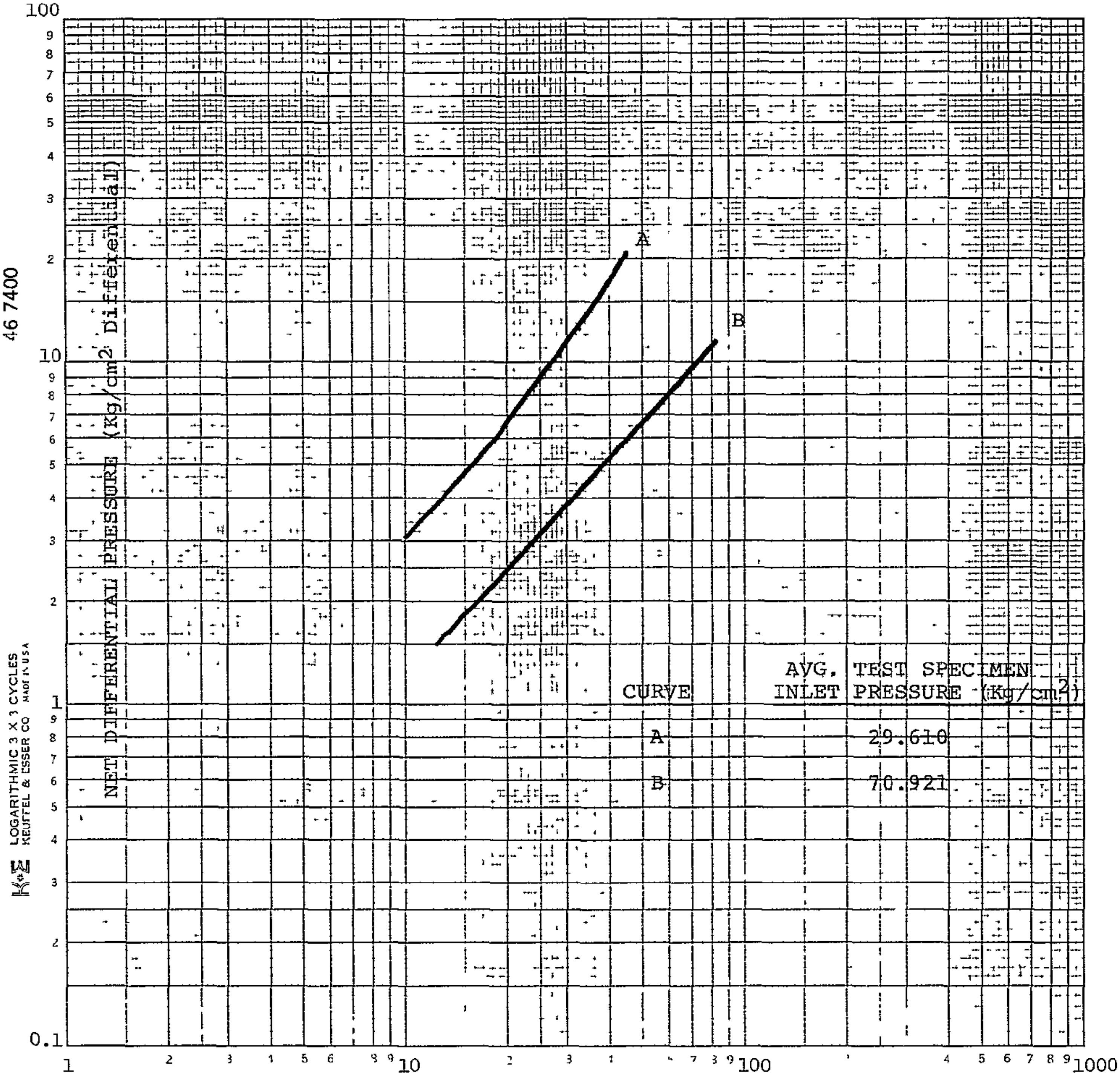
FLOW RATE (Kg GN_2/hr)

FIGURE 8 Part A

HPOF PROGRAM TEST NO. 5

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE

TEST SPECIMEN S/N 023



FLOW RATE (liters* GN_2/min)

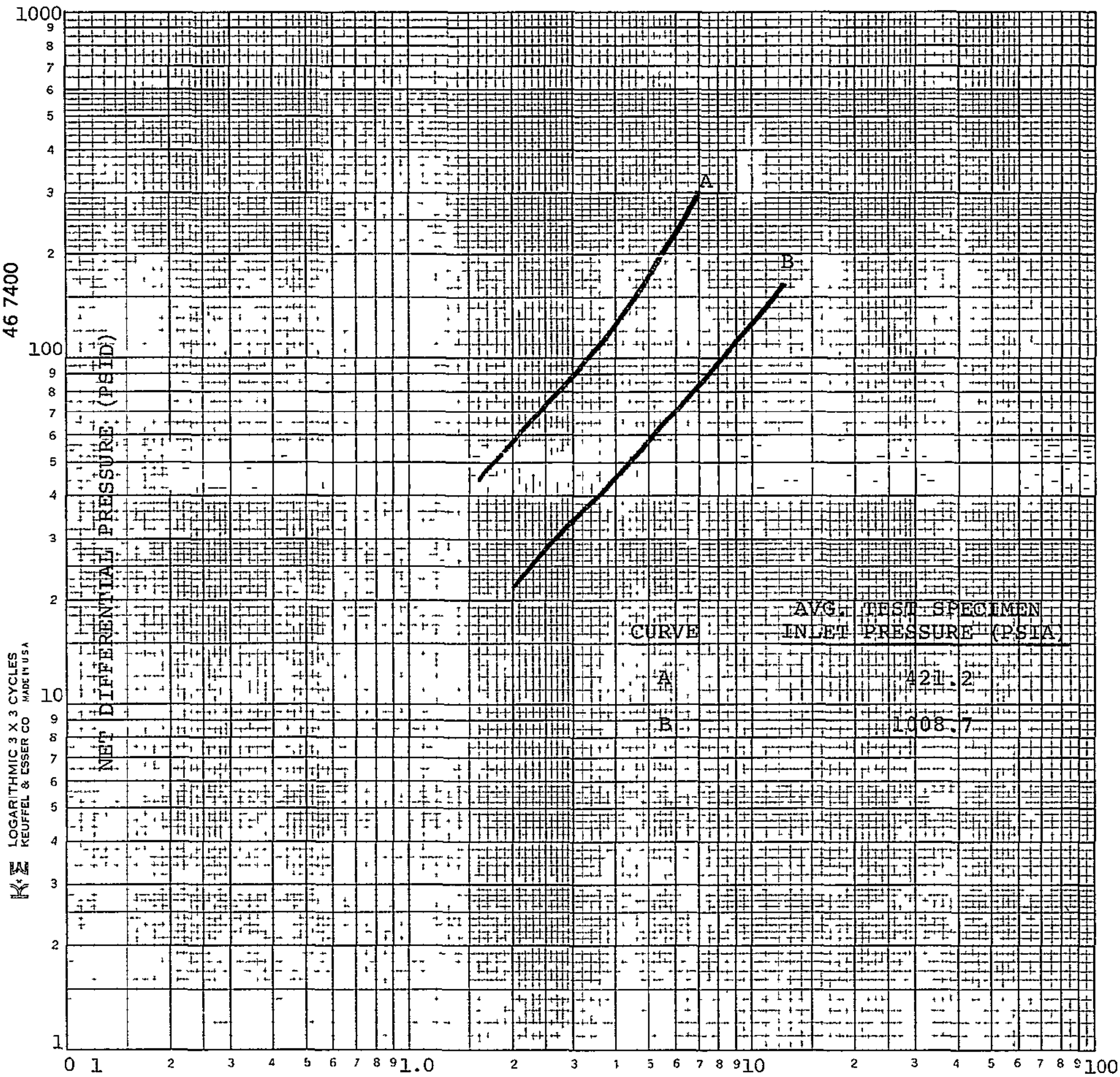
*At 21.1°C (70°F) and 1.033 Kg/cm^2 (14.7 psia)

FIGURE 8 Part B

HPOF PROGRAM TEST NO. 5

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE

TEST SPECIMEN S/N 023



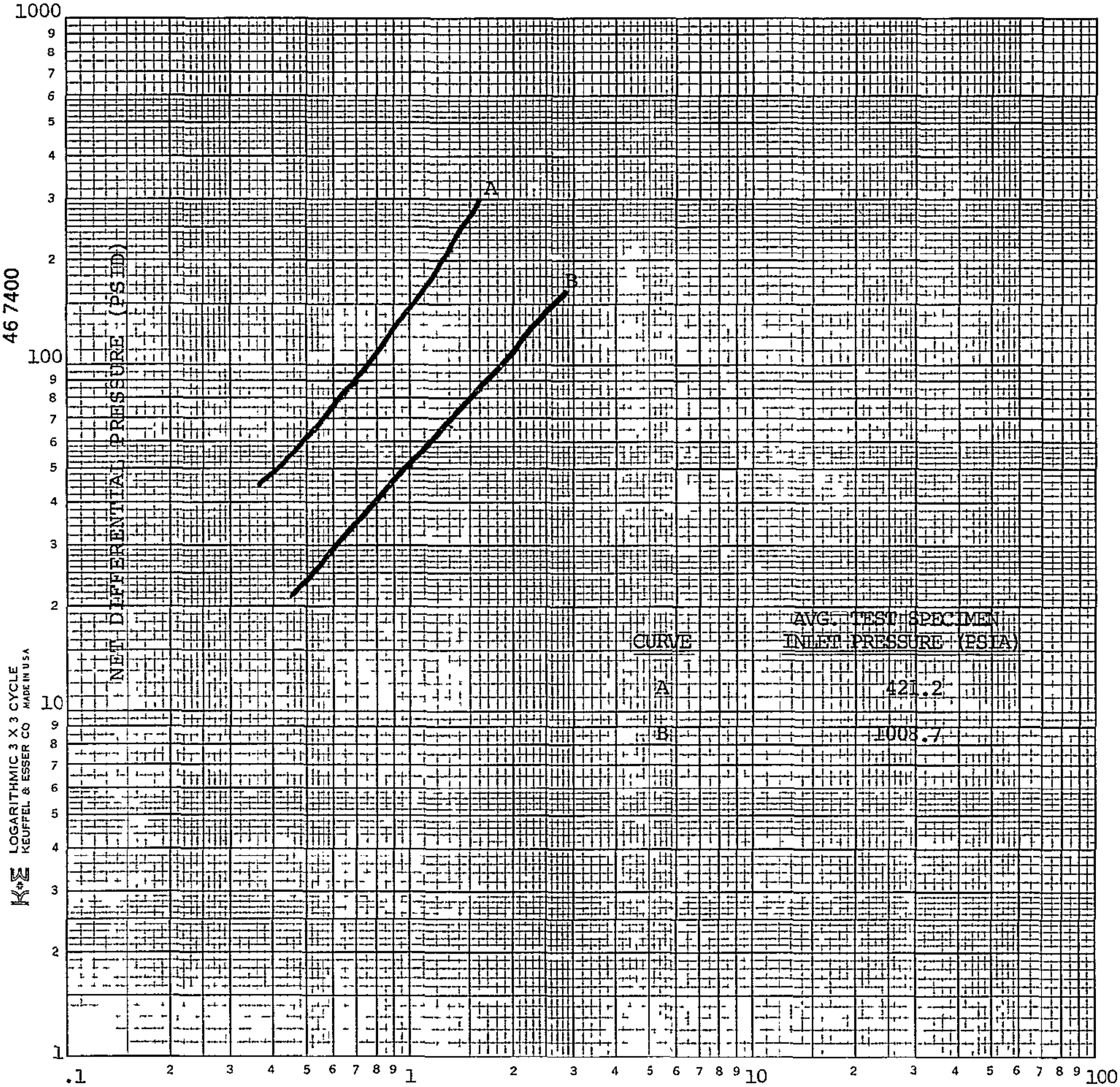
FLOW RATE (lbs GN_2/hr)

FIGURE 8 Part C

HPOF PROGRAM TEST NO. 5

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE

TEST SPECIMEN S/N 023



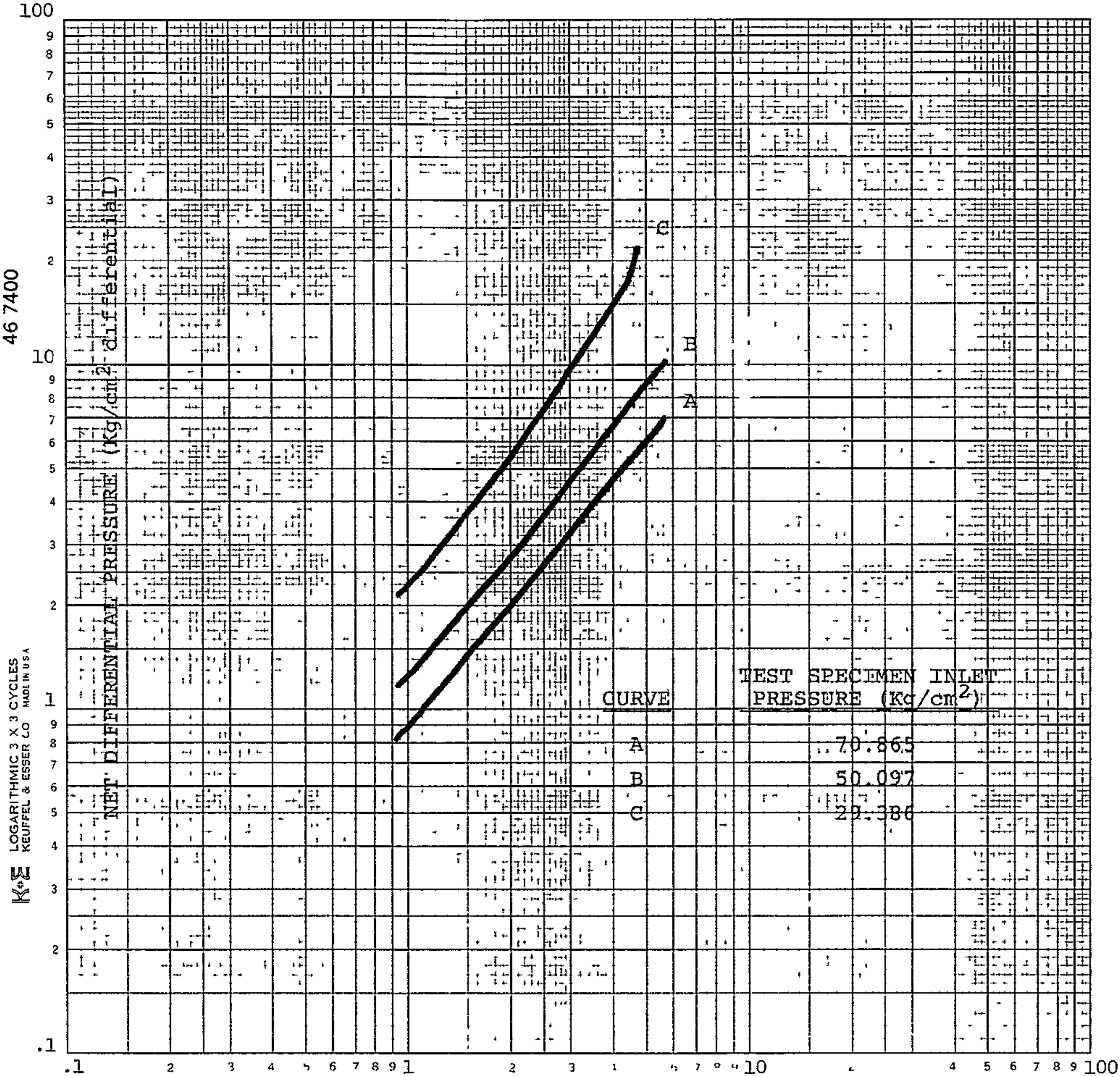
FLOW RATE (SCFM)

FIGURE 8 Part D

TEST NO. 5

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE

TEST SPECIMEN S/N 025



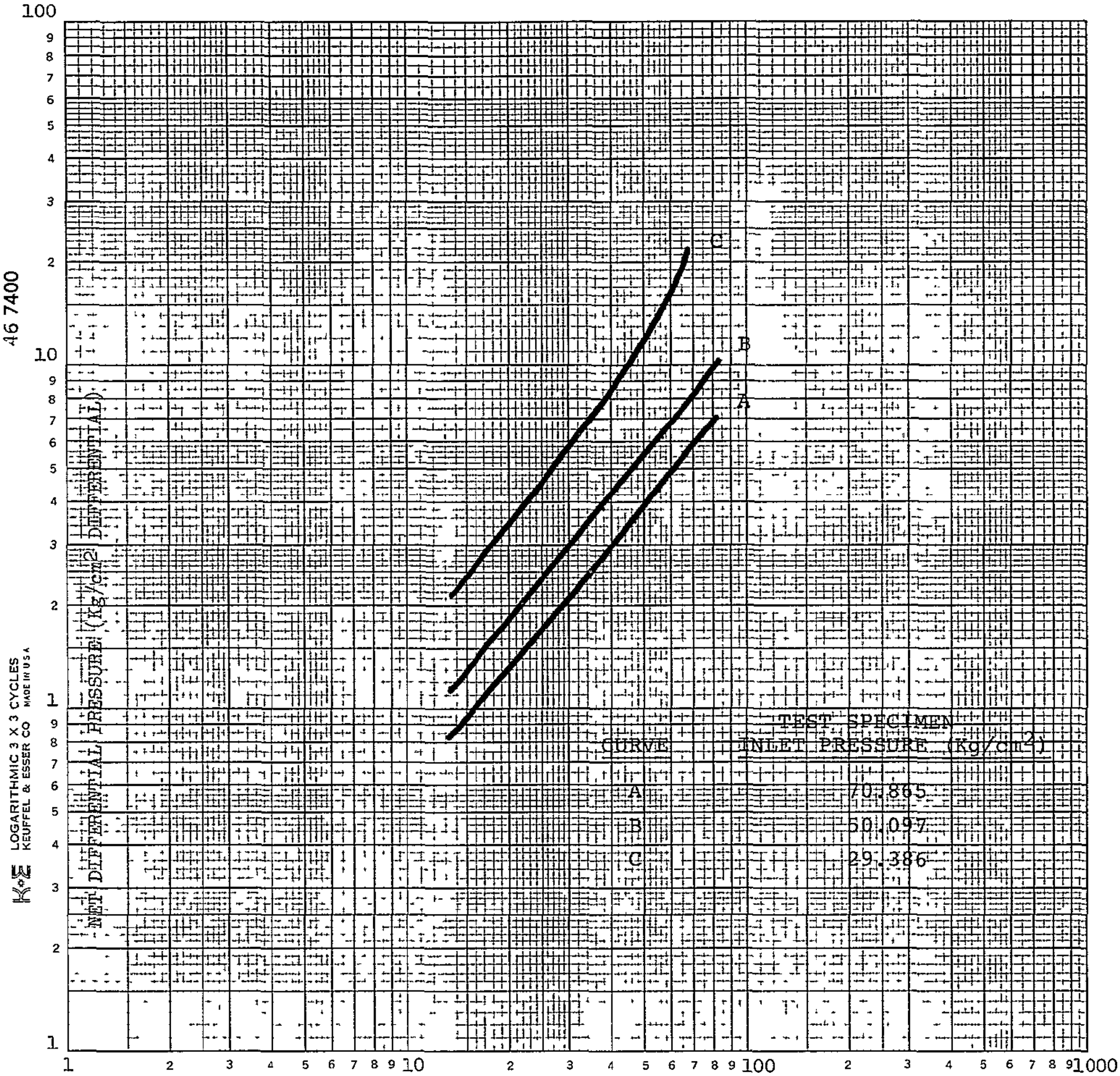
FLOW RATE (Kg GN_2/hr)

FIGURE 9 Part A

TEST NO. 5

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE

TEST SPECIMEN S/N 025



FLOW RATE (liters* GN_2/min)

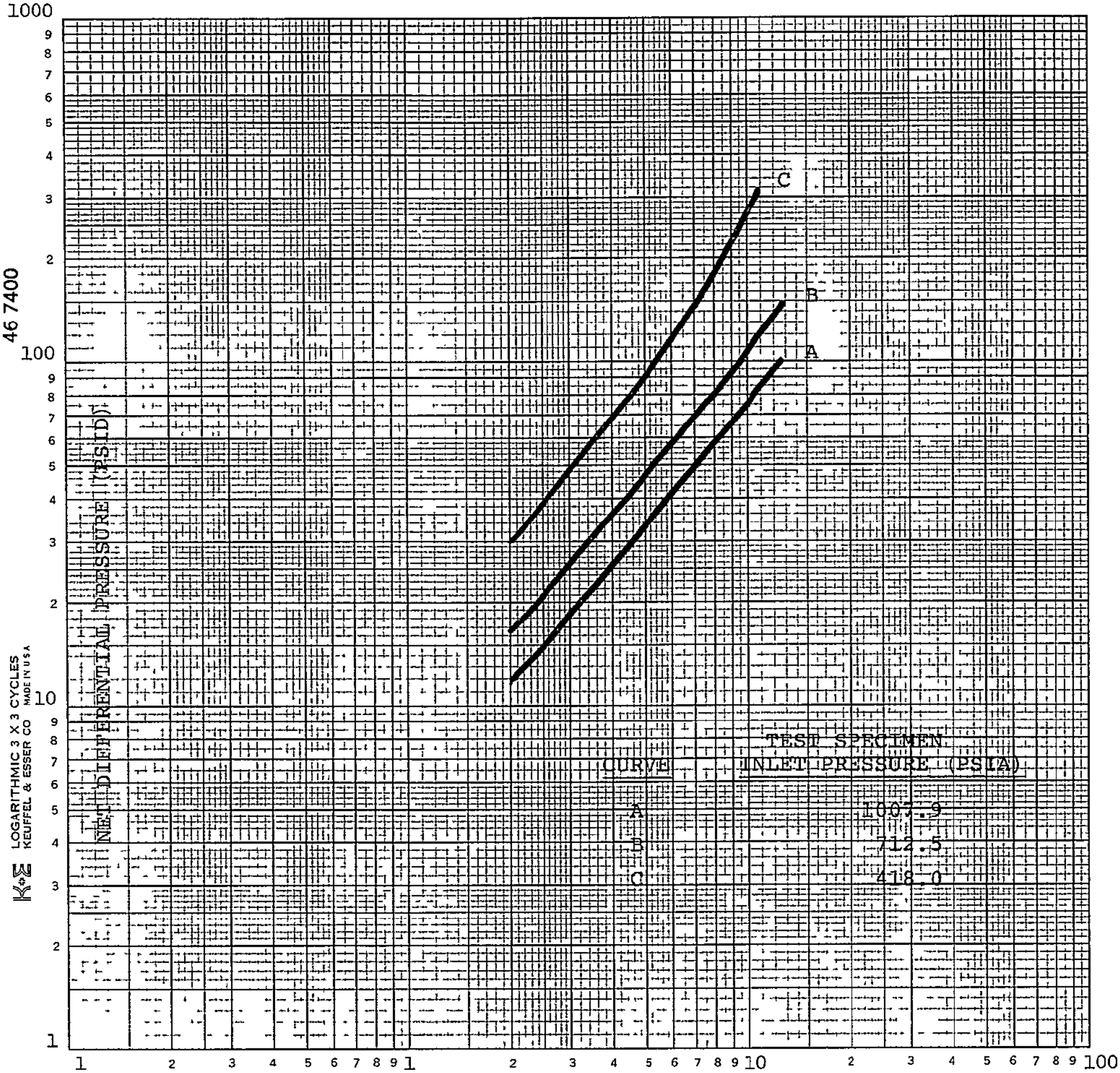
*At 21.1°C (70°F) and 1.033 Kg/cm^2 (14.7 psia)

FIGURE 9 Part B

TEST NO. 5

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE

TEST SPECIMEN S/N 025



FLOW RATE (lbs GN_2/hr)

FIGURE 9 Part C

TEST NO. 5

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE

TEST SPECIMEN S/N 025

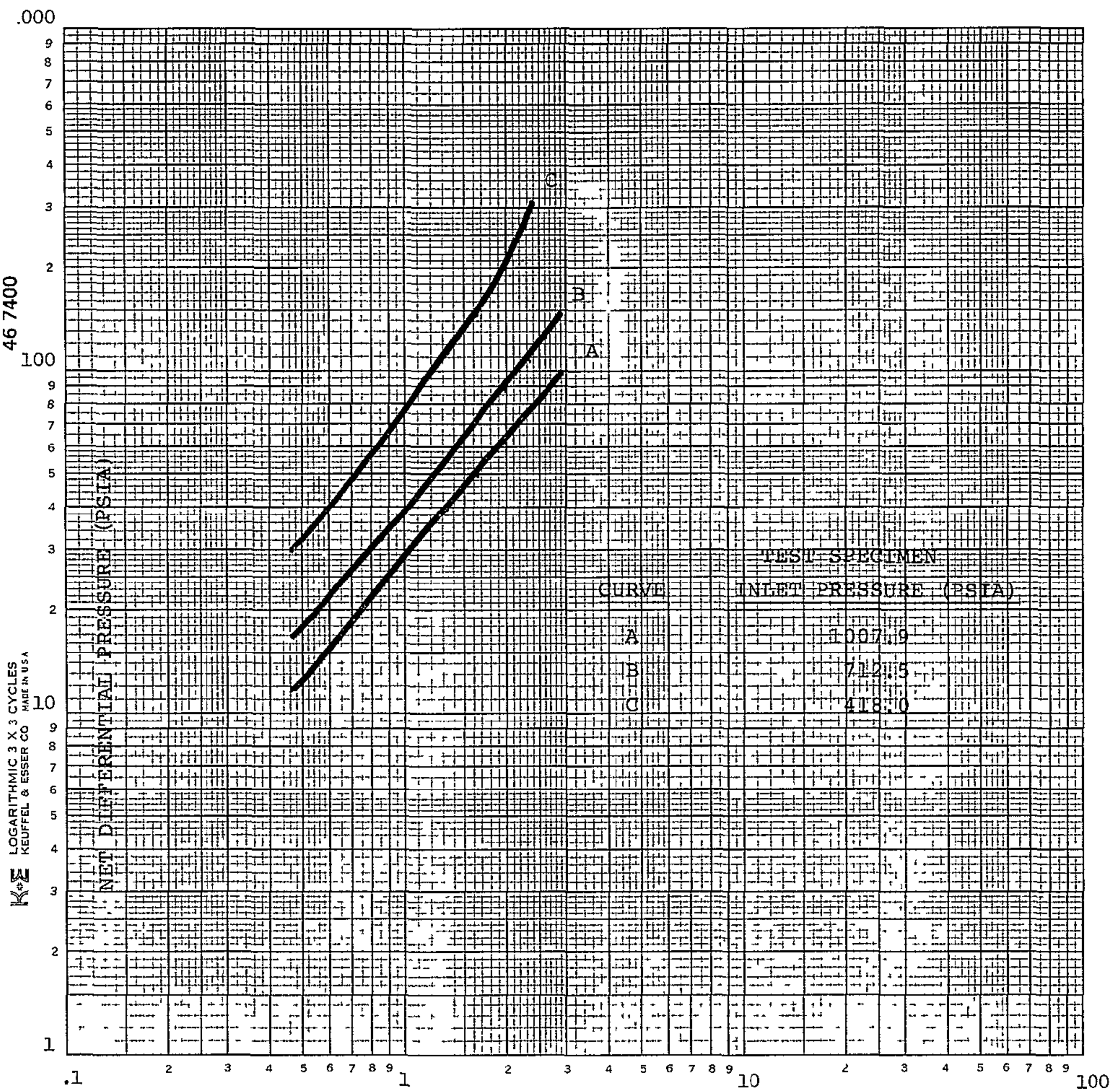
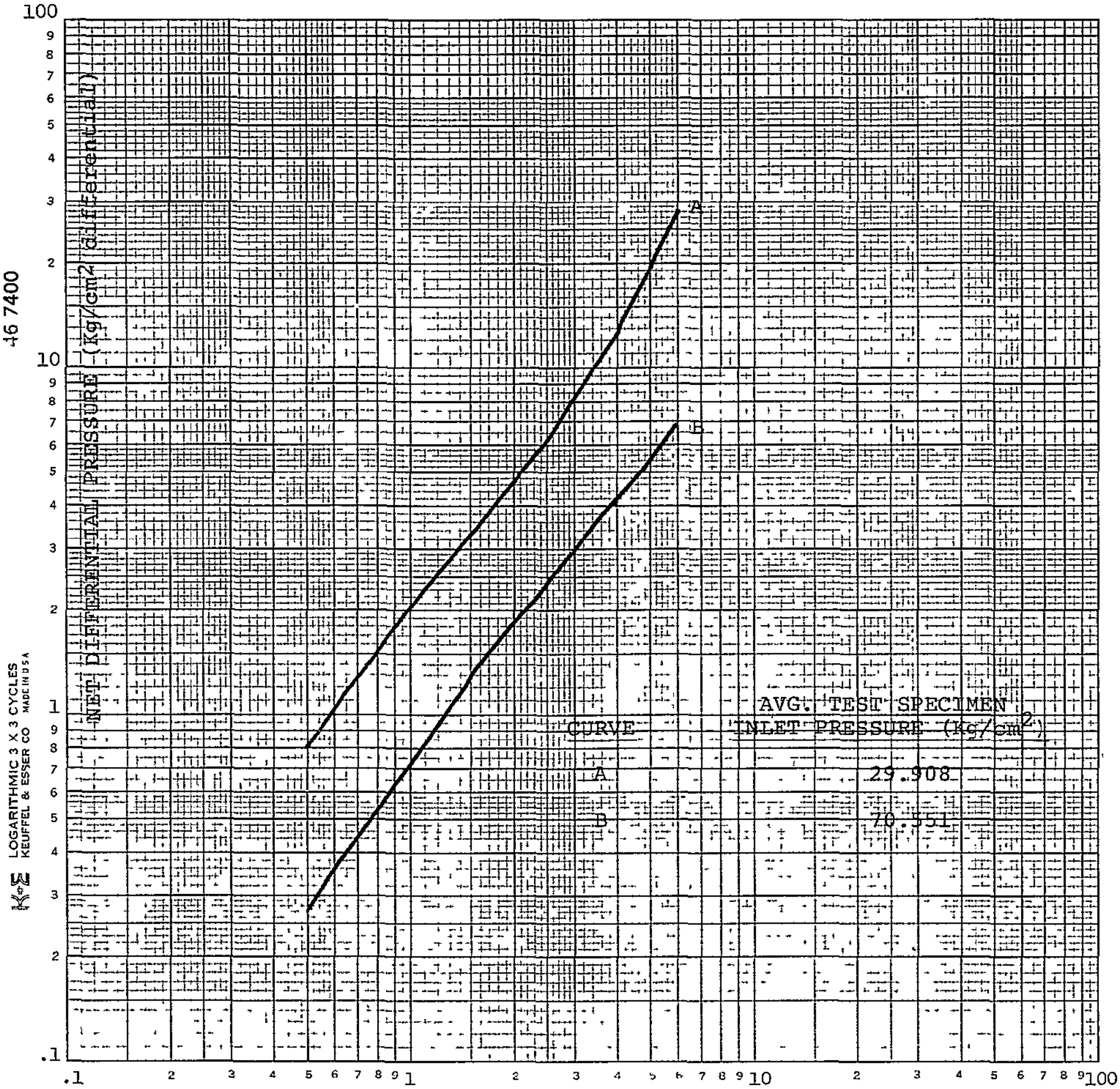


FIGURE 9 Part D

TEST NO. 5

TEST SPECIMEN S/N 027

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE



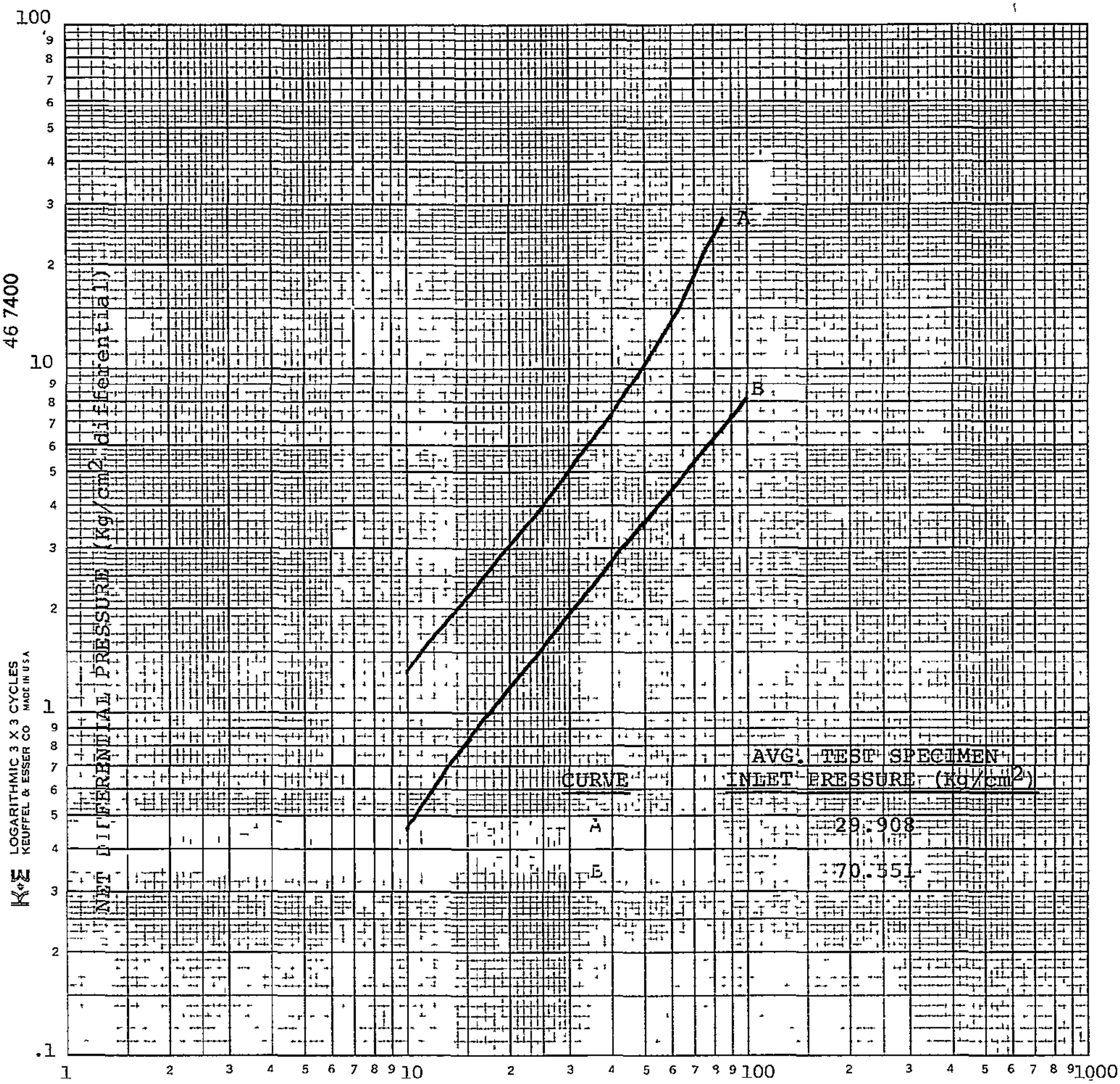
FLOW RATE (Kg GN_2/hr)

FIGURE 10 Part A

TEST NO. 5

TEST SPECIMEN S/N 027

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE



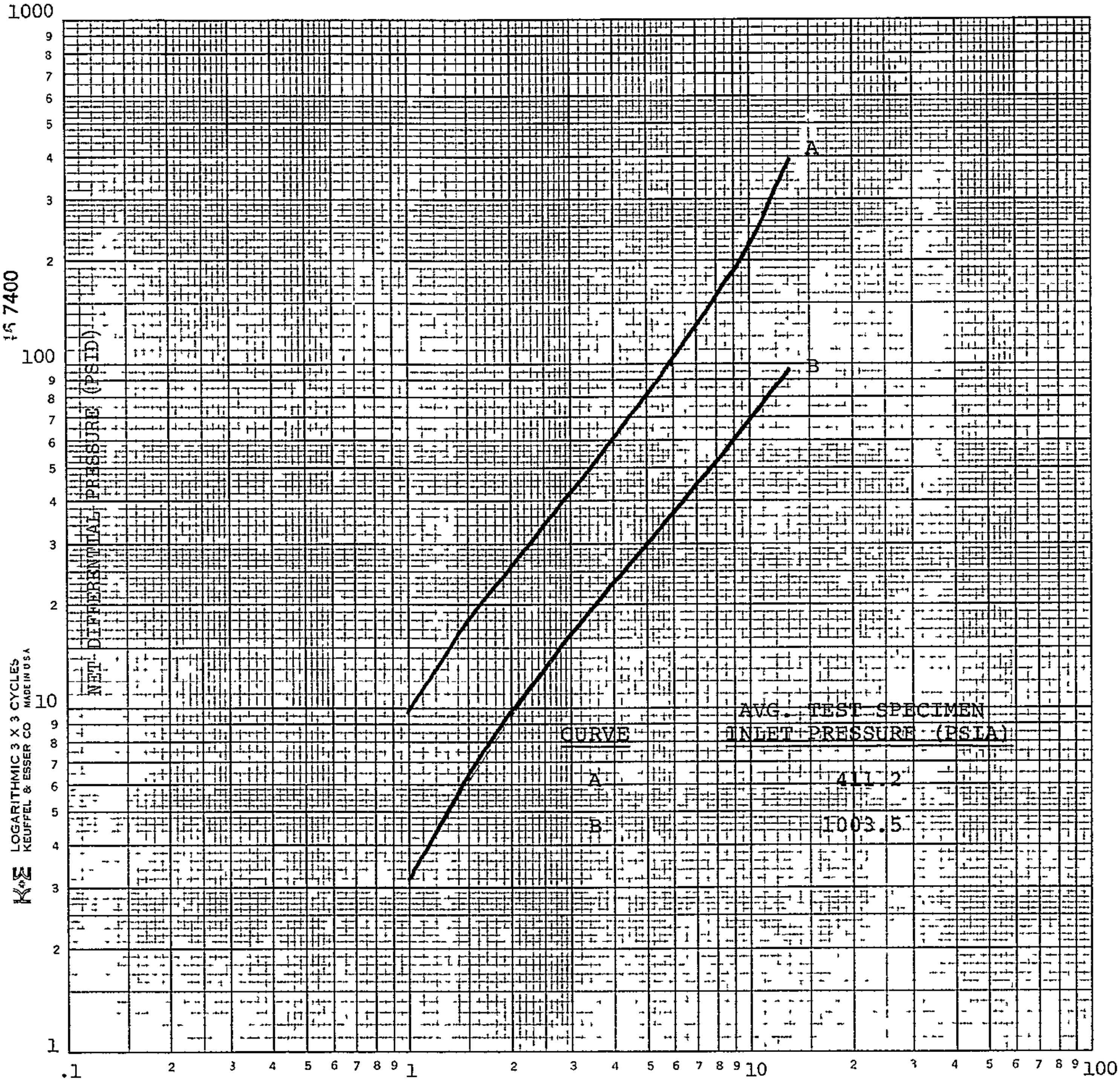
*At 21.1°C (70°F) and 1.033 Kg/cm^2 (14.7 psia)

FIGURE 10 Part B

TEST NO. 5

TEST SPECIMEN S/N 027

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE



FLOW RATE (lbs GN_2/hr)

FIGURE 10 Part C

TEST NO. 5

TEST SPECIMEN S/N 027

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE

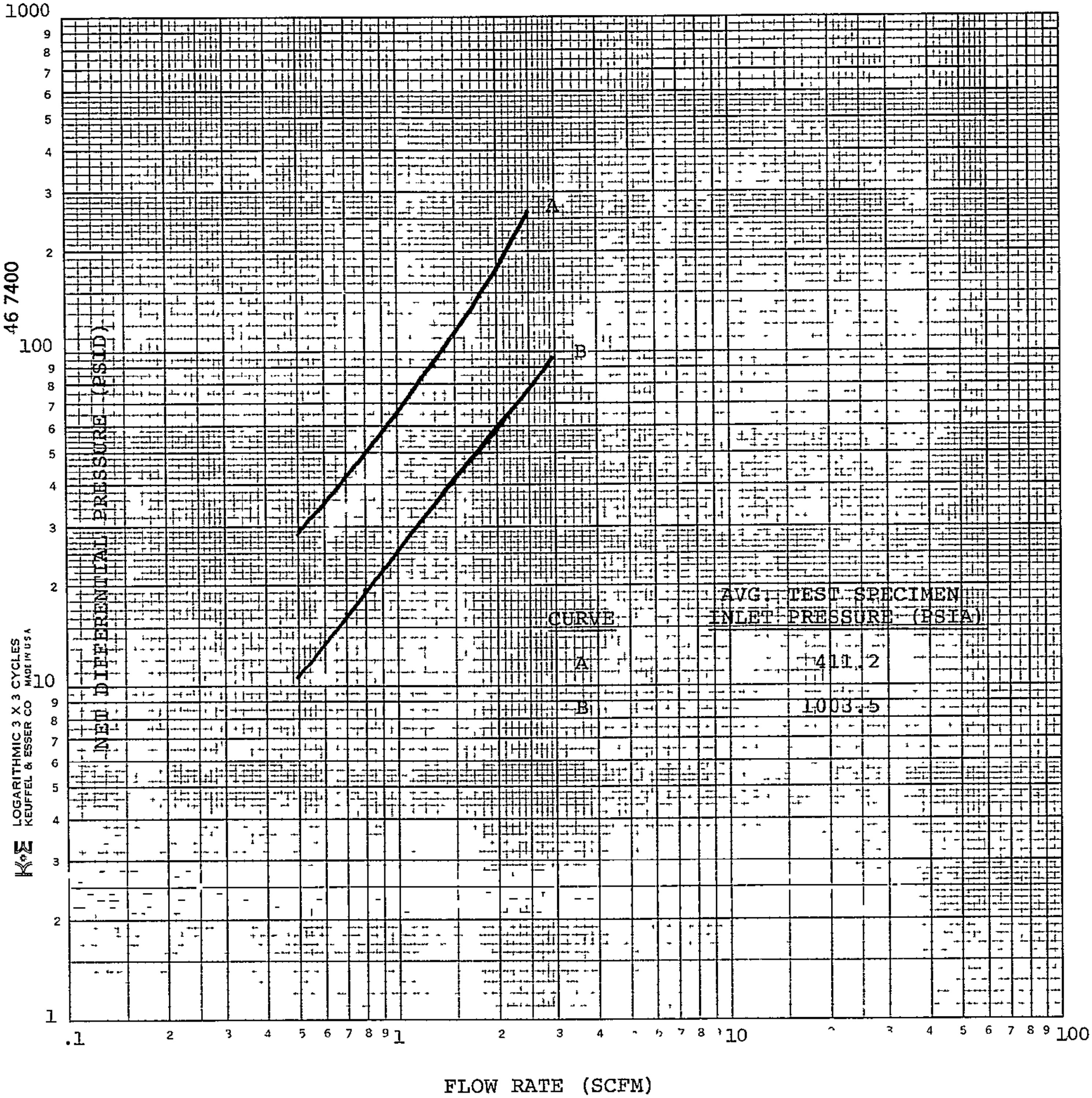


FIGURE 10 Part D

TEST NO. 5

TEST SPECIMEN S/N 028

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE

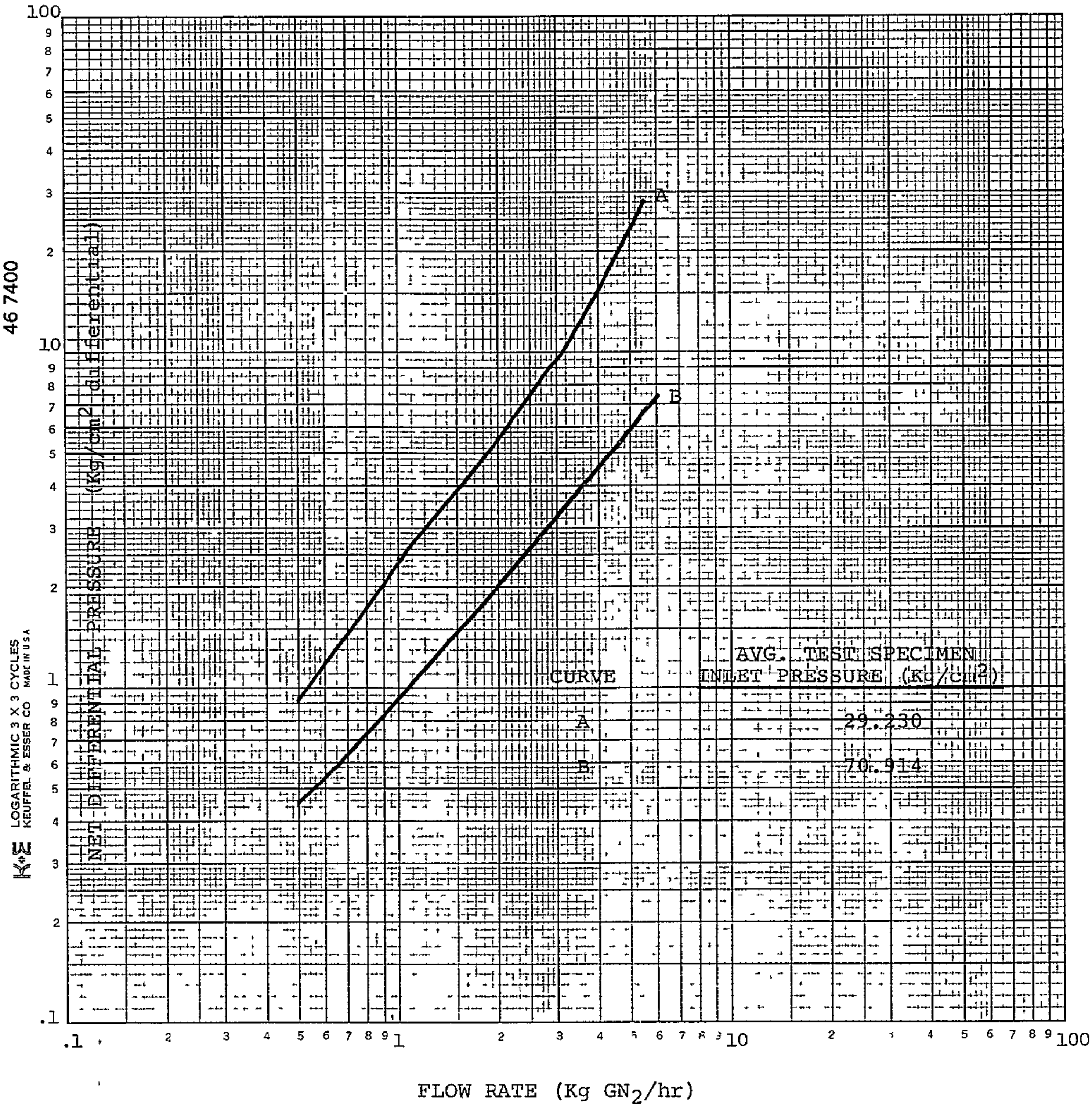
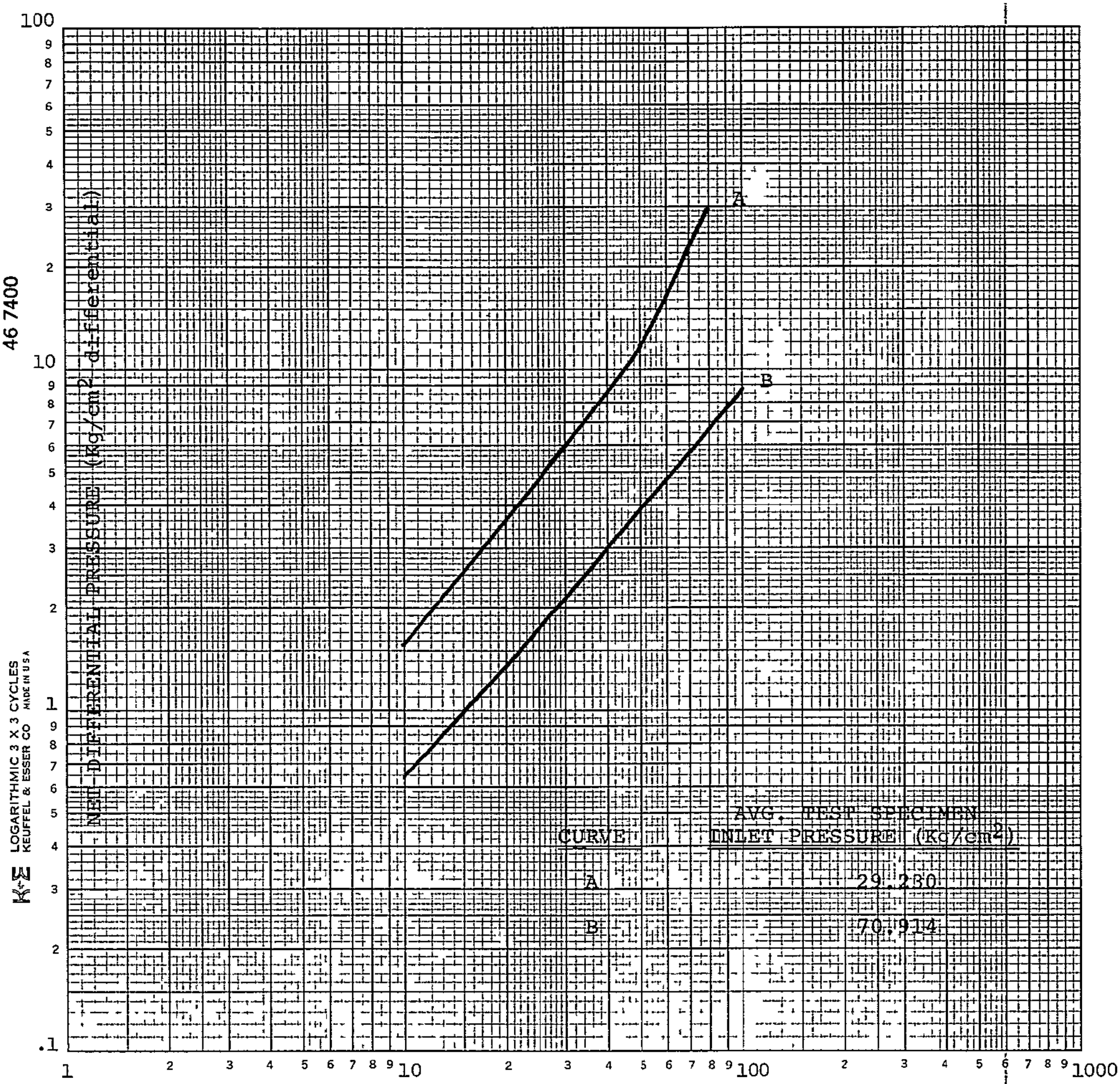


FIGURE 11 Part A

TEST NO. 5

TEST SPECIMEN S/N 028

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE



*At 21.1°C (70°F) and 1.033 Kg/cm^2 (14.7 psia)

FIGURE 11 Part B

TEST NO. 5

TEST SPECIMEN S/N 028

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE

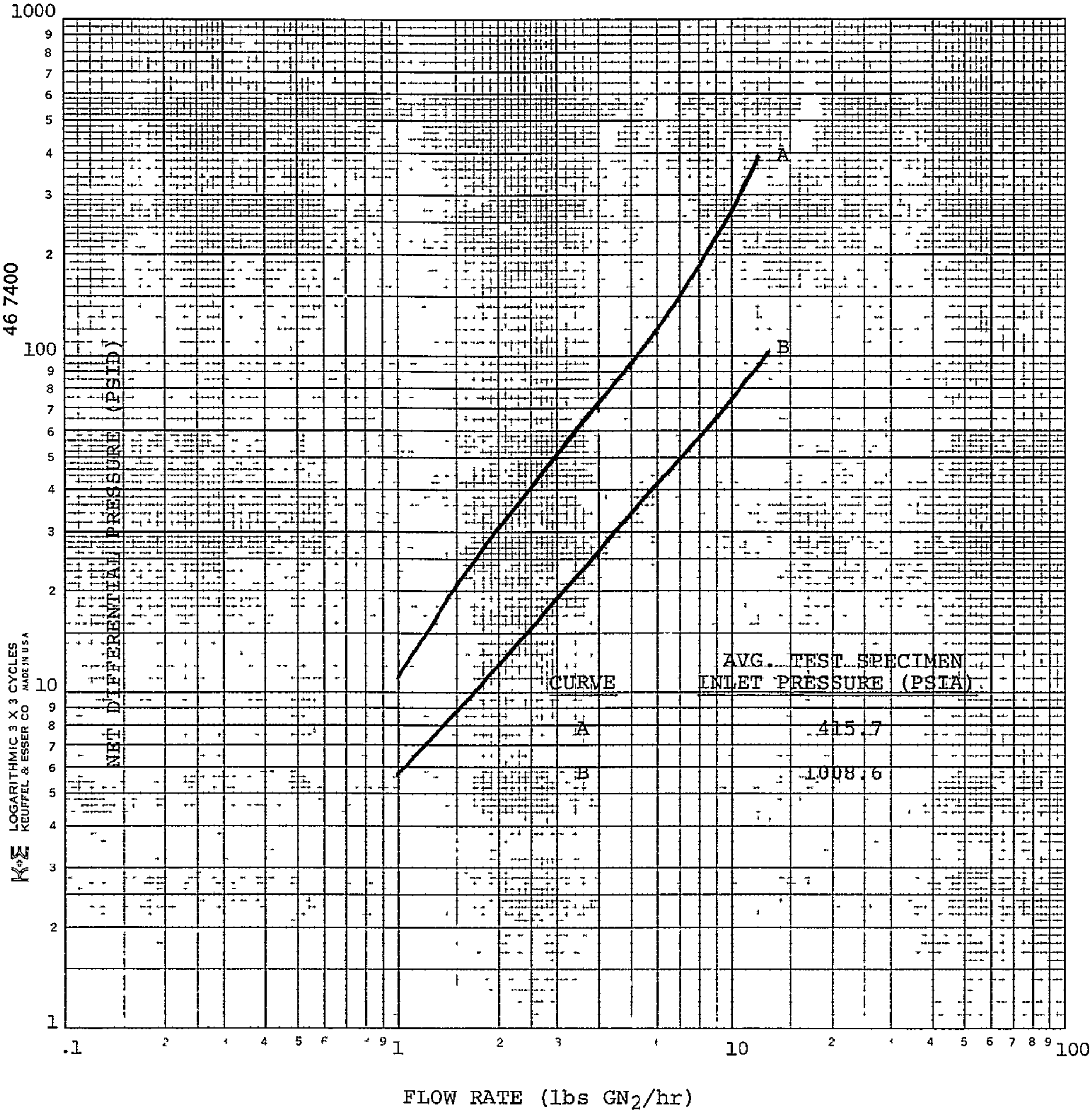
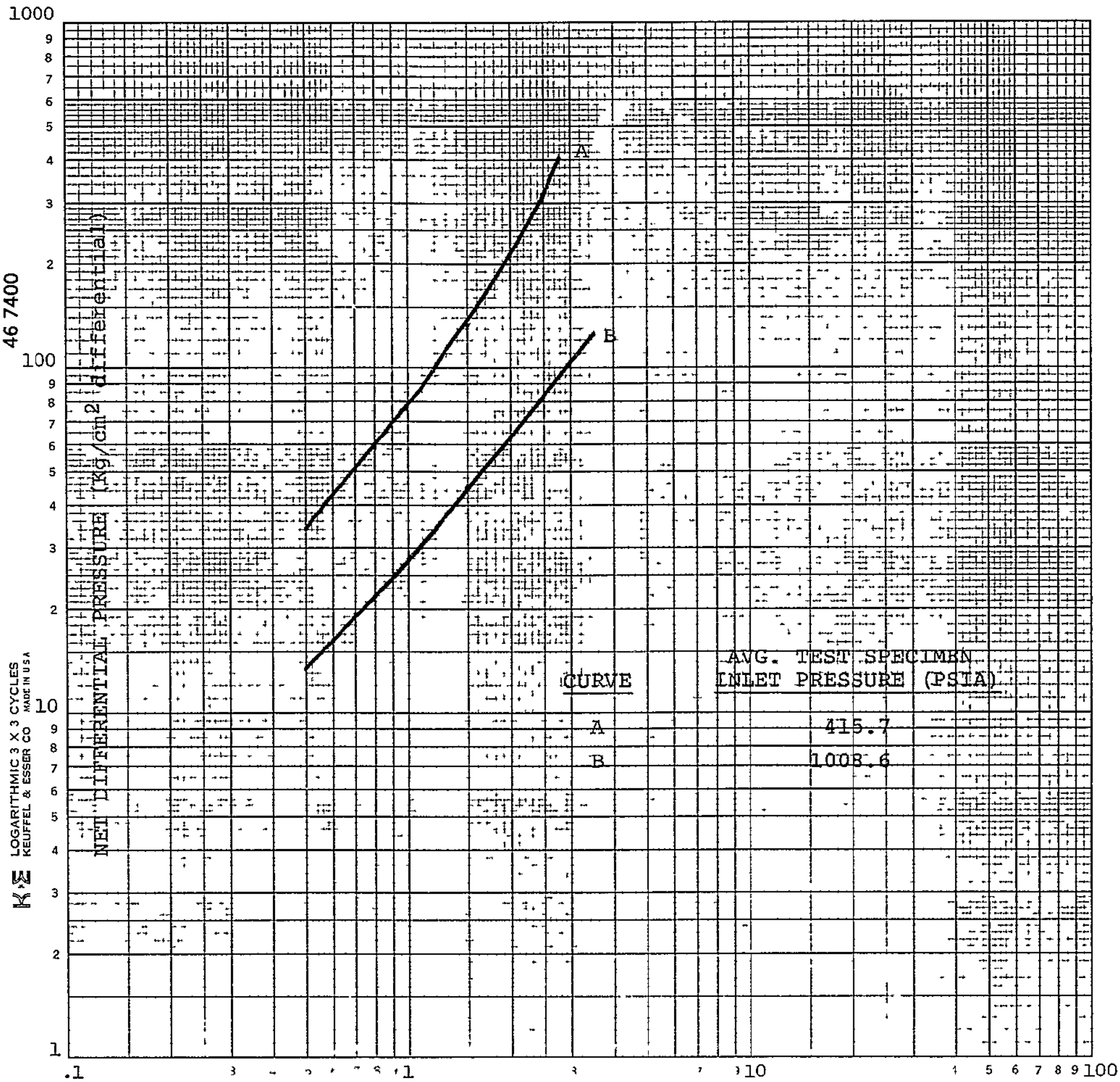


FIGURE 11 Part C

TEST NO. 5

TEST SPECIMEN S/N 028

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE



FLOW RATE (SCFM)

FIGURE 11 Part D

TEST NO. 5

TEST SPECIMEN S/N 021

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE

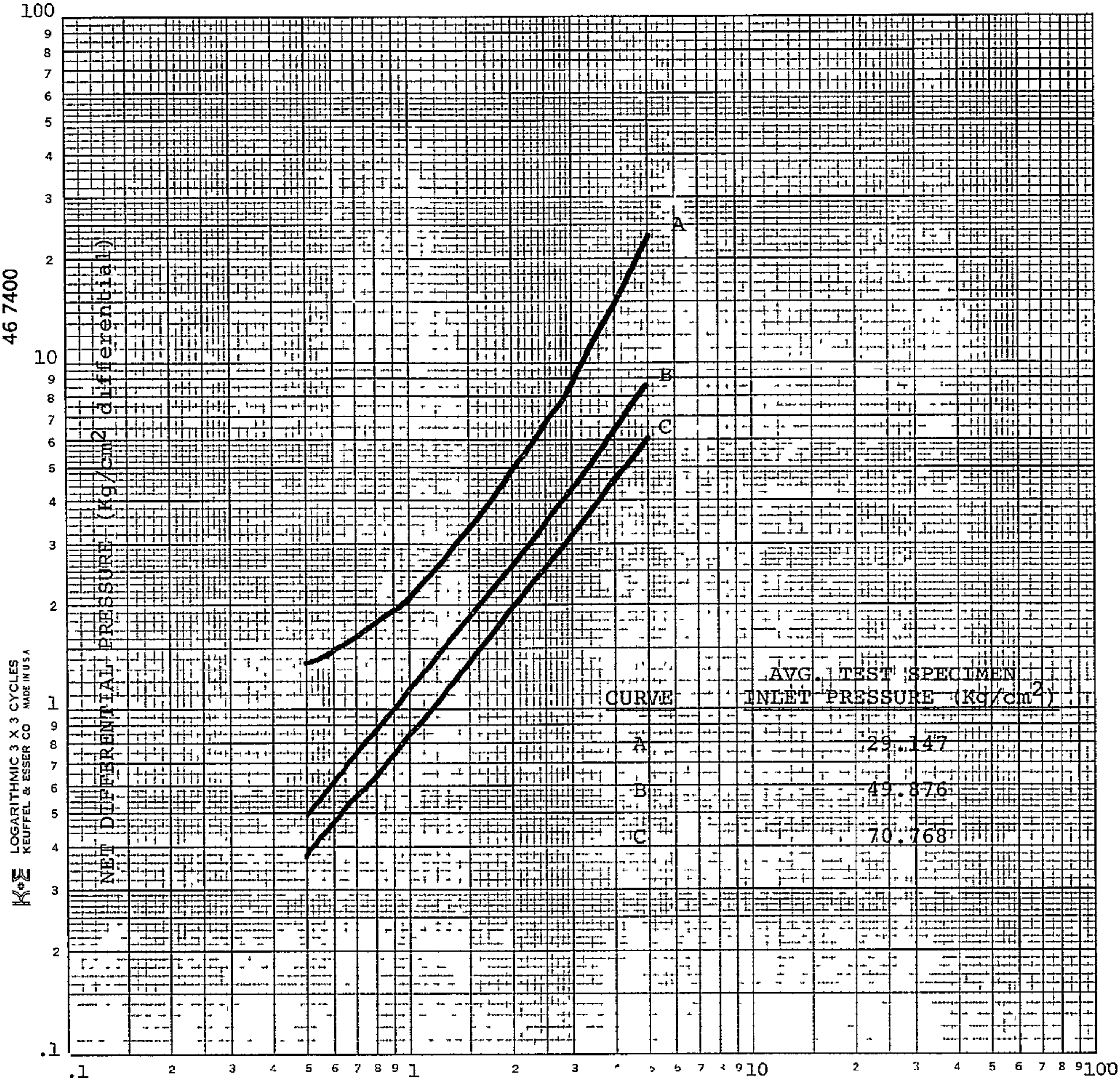
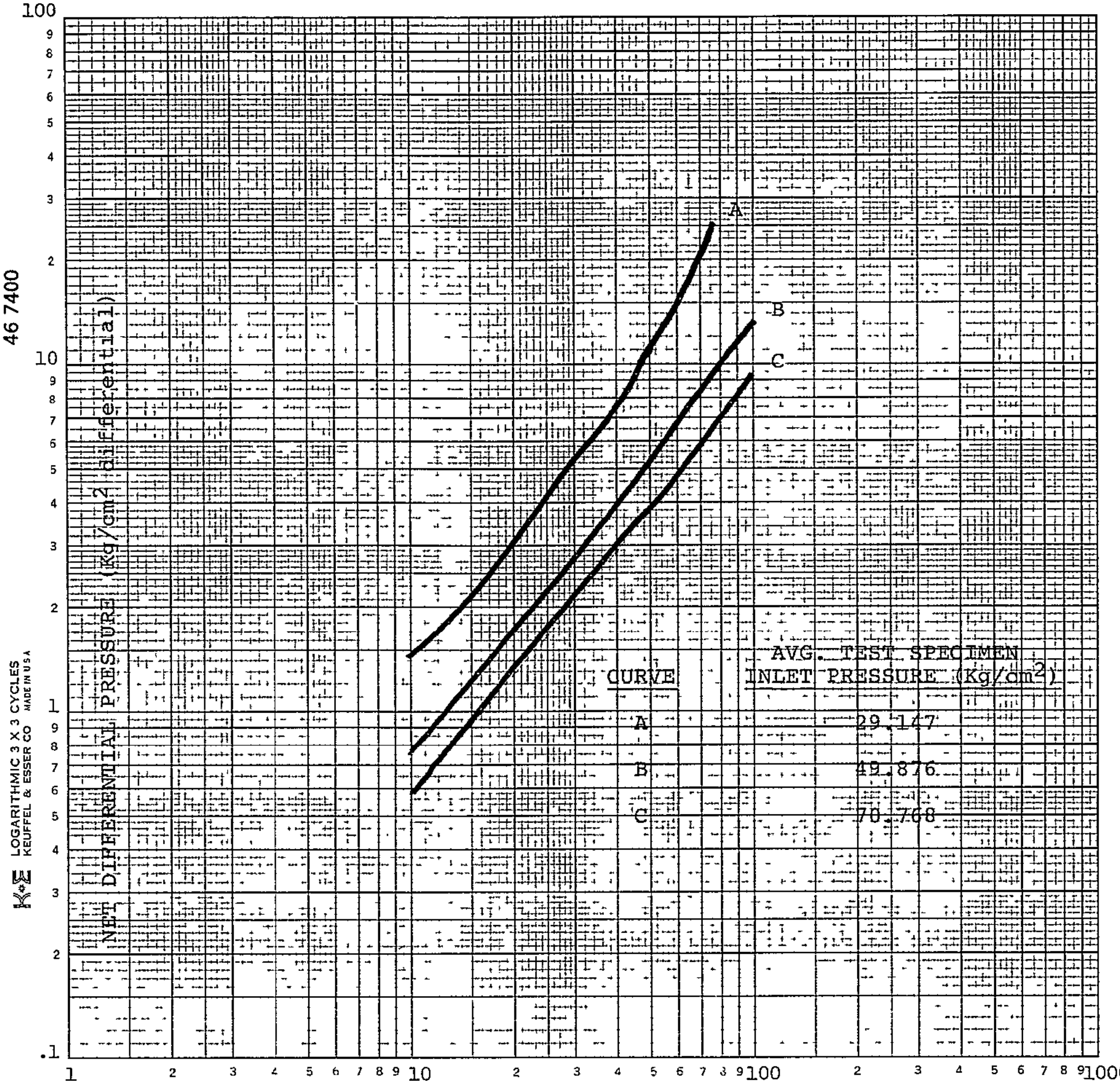


FIGURE 12 Part A

TEST NO. 5

TEST SPECIMEN S/N 021

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE



FLOW RATE (liters* GN_2/min)

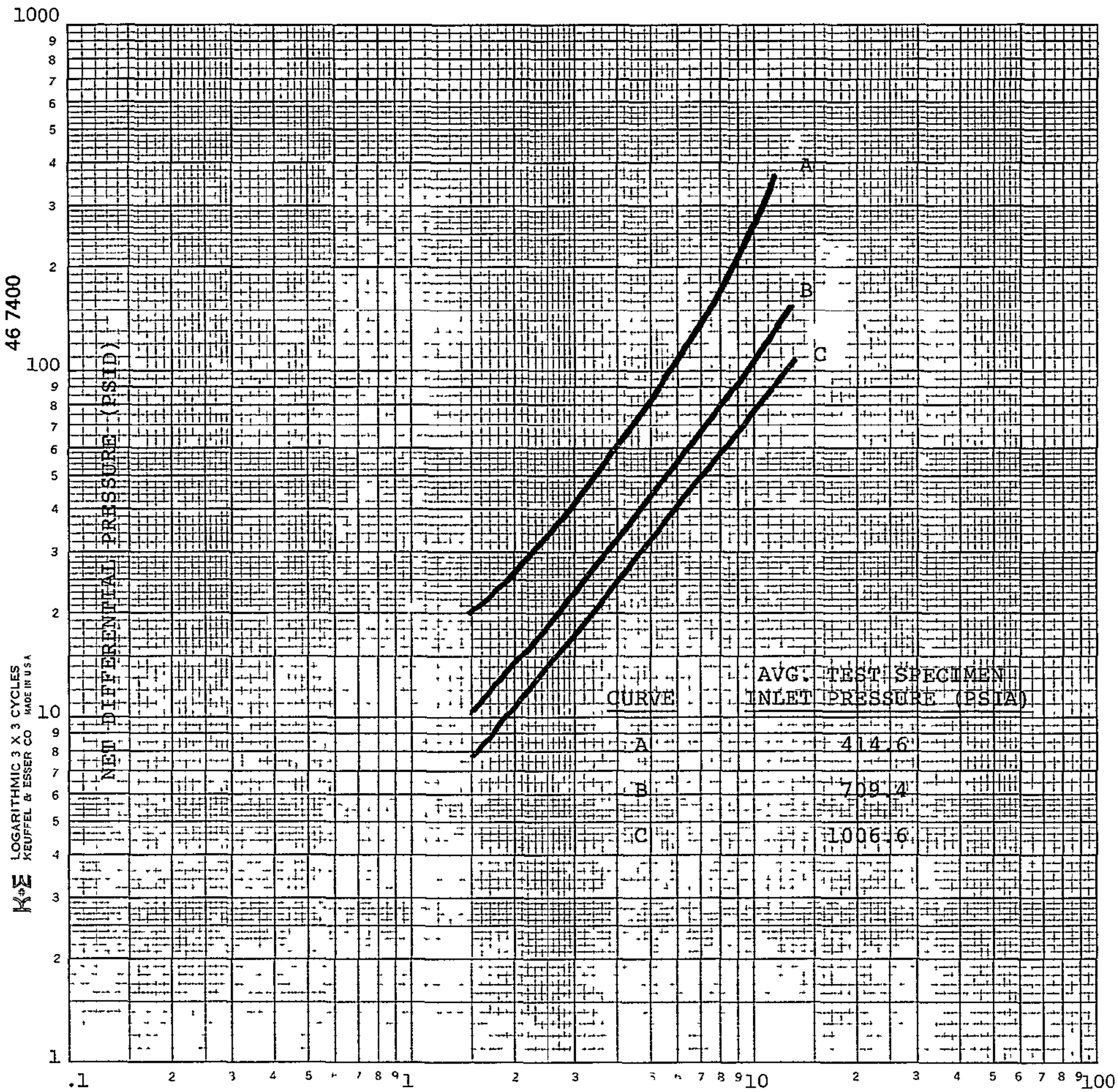
*At 21.1°C (70°F) and 1.033 Kg/cm^2 (14.7 psia)

FIGURE 12 Part B

TEST NO. 5

TEST SPECIMEN S/N 021

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE



FLOW RATE (lbs GN_2/hr)

FIGURE 12 Part C

TEST NO. 5

TEST SPECIMEN S/N 021

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE

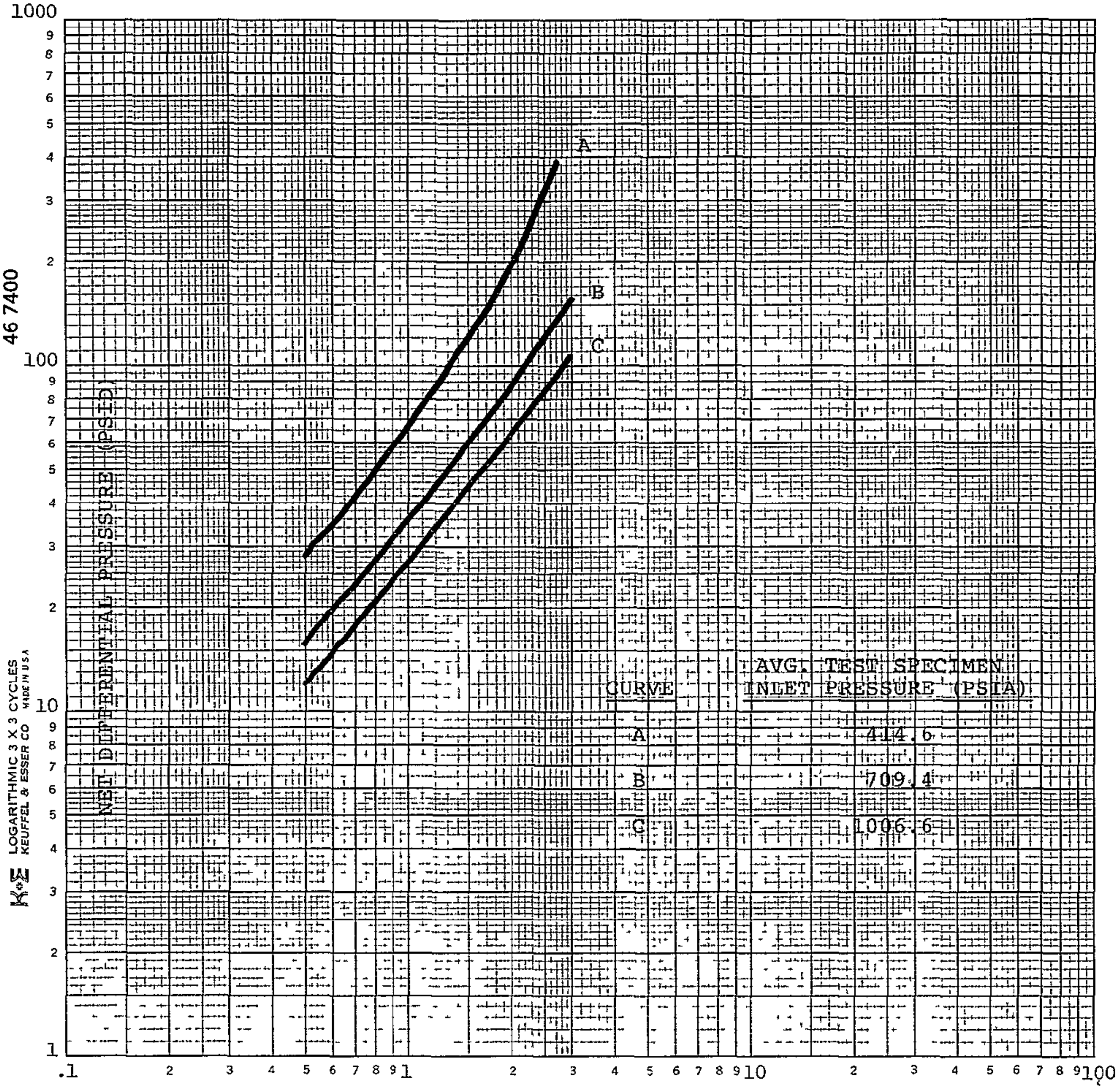
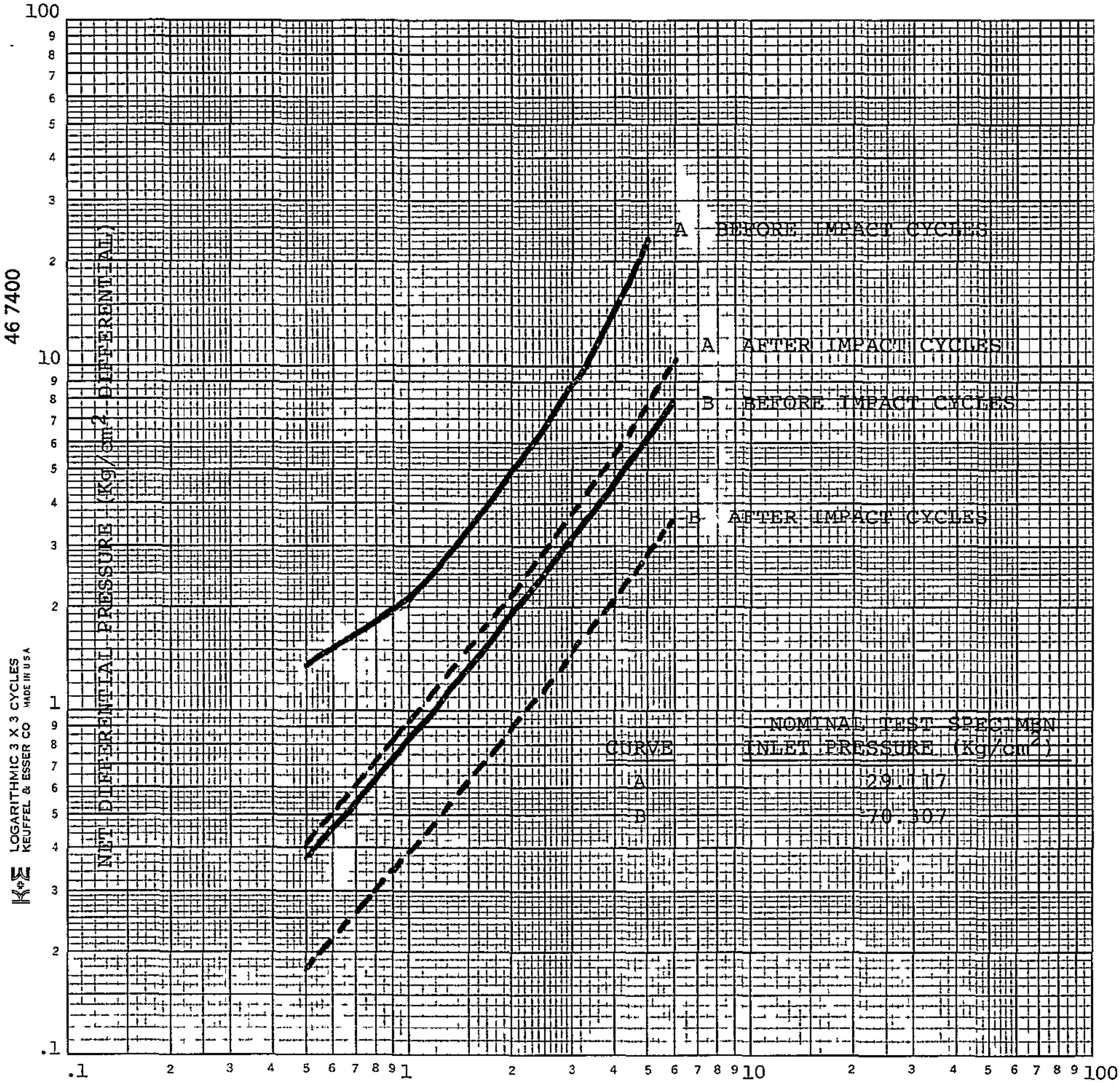


FIGURE 12 Part D

TEST NO. 5

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE

PRESSURE DROP CHARACTERISTICS OF TEST SPECIMEN S/N 021 BEFORE AND AFTER 100 (703.07 Kg/cm^2 NOMINAL) GN_2 IMPACT CYCLES



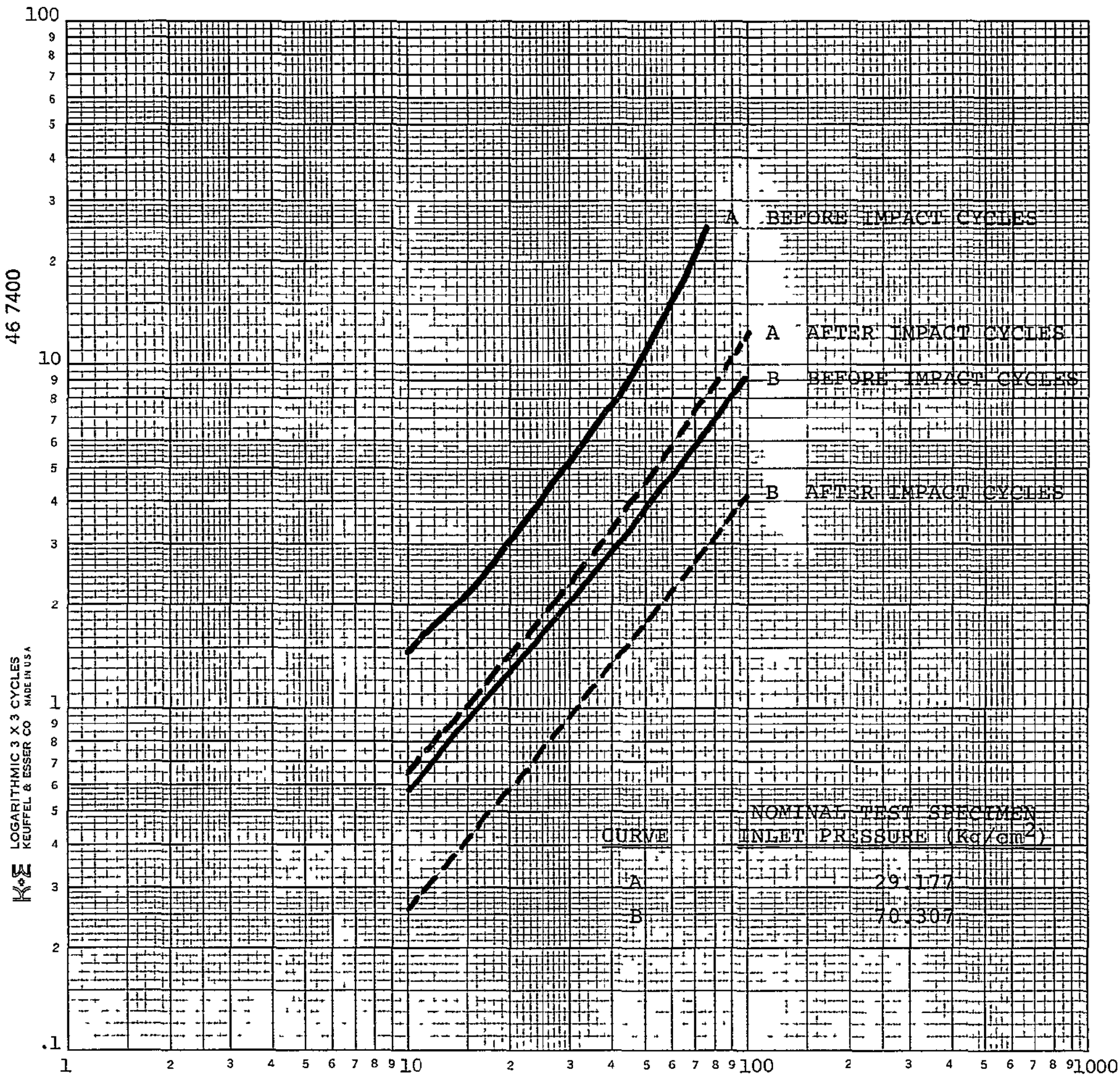
FLOW RATE (Kg GN_2/hr)

FIGURE 13 Part A

TEST NO. 5

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE

PRESSURE DROP CHARACTERISTICS OF TEST SPECIMEN S/N 021 BEFORE AND AFTER 100 (703.07 Kg/cm^2 NOMINAL) GN_2 IMPACT CYCLES



FLOW RATE (liters* GN_2/min)

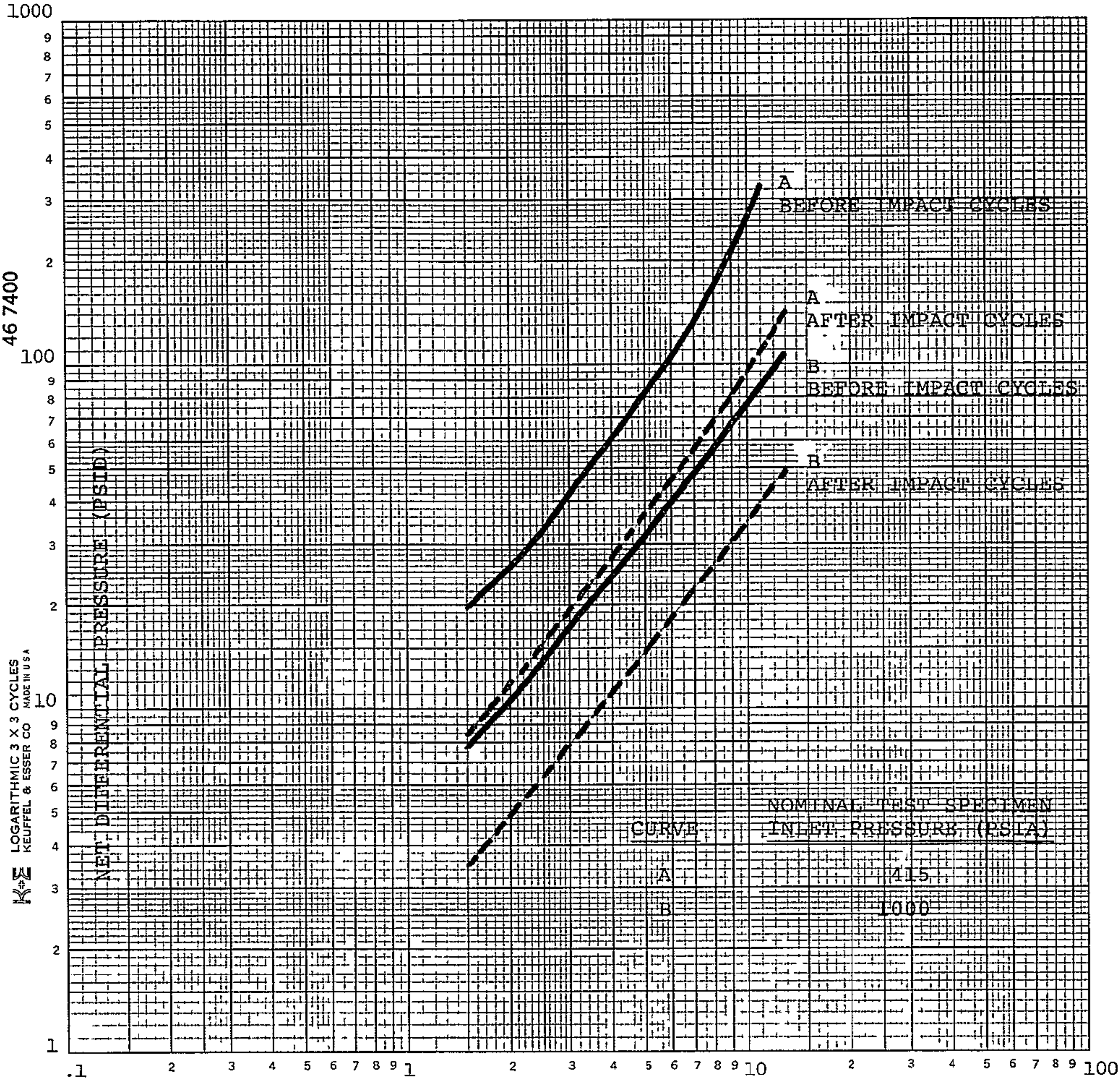
*At 21.1°C (70°F) and 1.033 Kg/cm^2 (14.7 psia)

FIGURE 13 Part B

TEST NO. 5

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE

PRESSURE DROP CHARACTERISTICS OF TEST SPECIMEN S/N 021 BEFORE AND AFTER 100 (10,000 PSIA NOMINAL) GN_2 IMPACT CYCLES



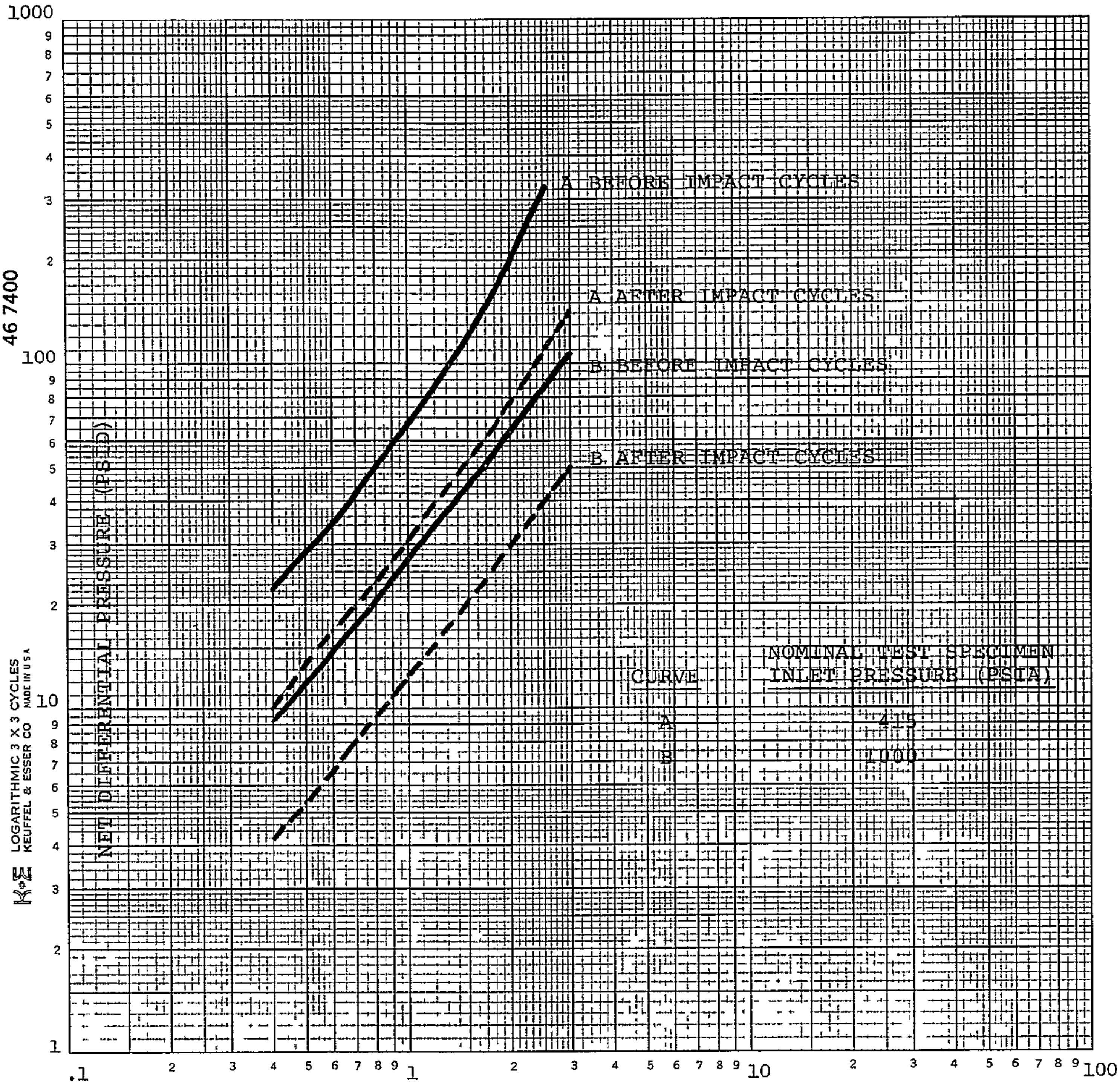
FLOW RATE (lbs GN_2/hr)

FIGURE 13 Part C

TEST NO. 5

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE

PRESSURE DROP CHARACTERISTICS OF TEST SPECIMEN S/N 021 BEFORE AND AFTER 100 (10,000 PSIA NOMINAL) GN_2 IMPACT CYCLES



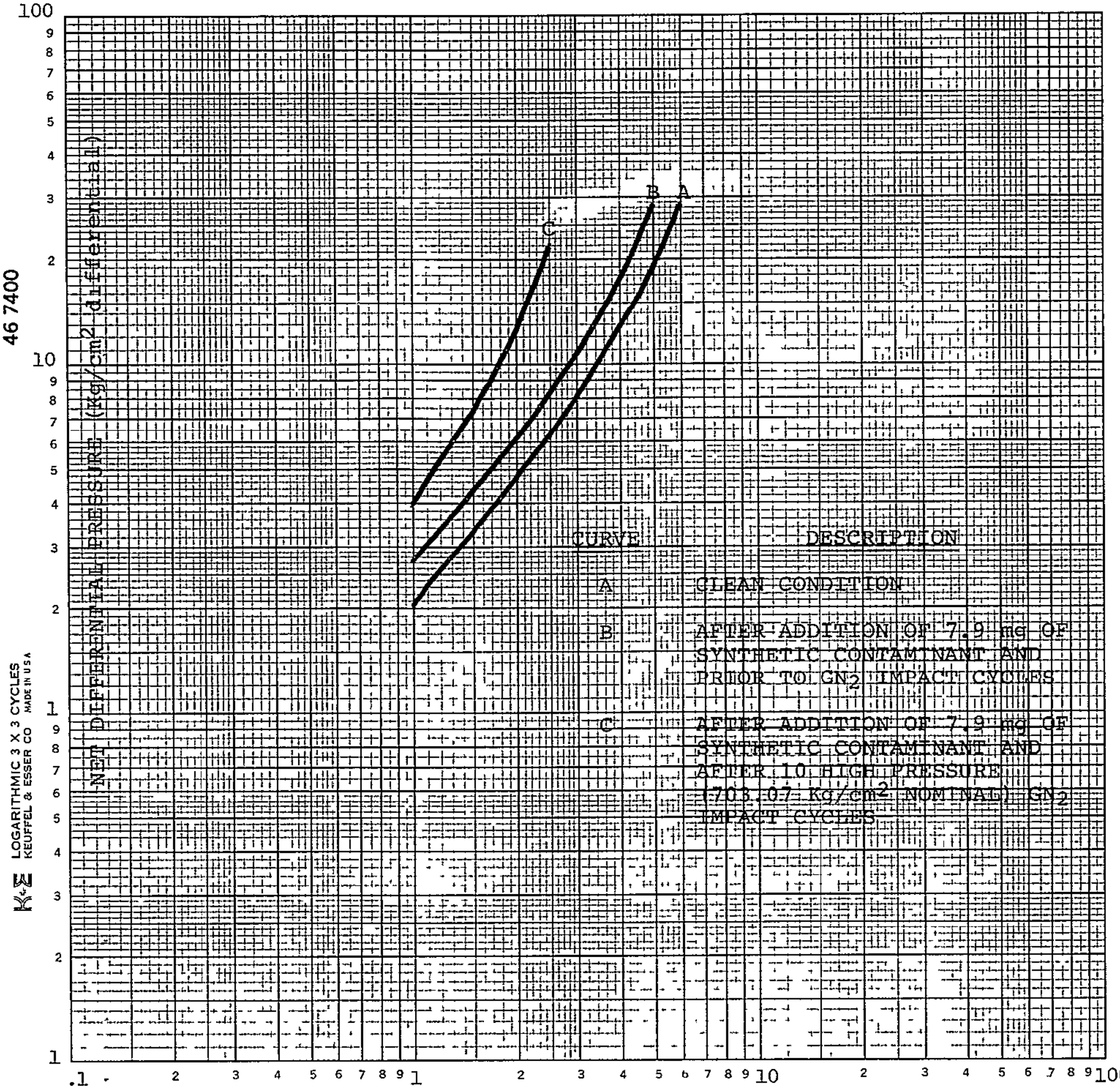
FLOW RATE (SCFM)

FIGURE 13 Part D

TEST NO. 10

TEST SPECIMEN S/N 027

FLOW RATE VERSUS DIFFERENTIAL PRESSURE DATA
AT A NOMINAL TEST SPECIMEN INLET PRESSURE
OF 29.177 Kg/cm²



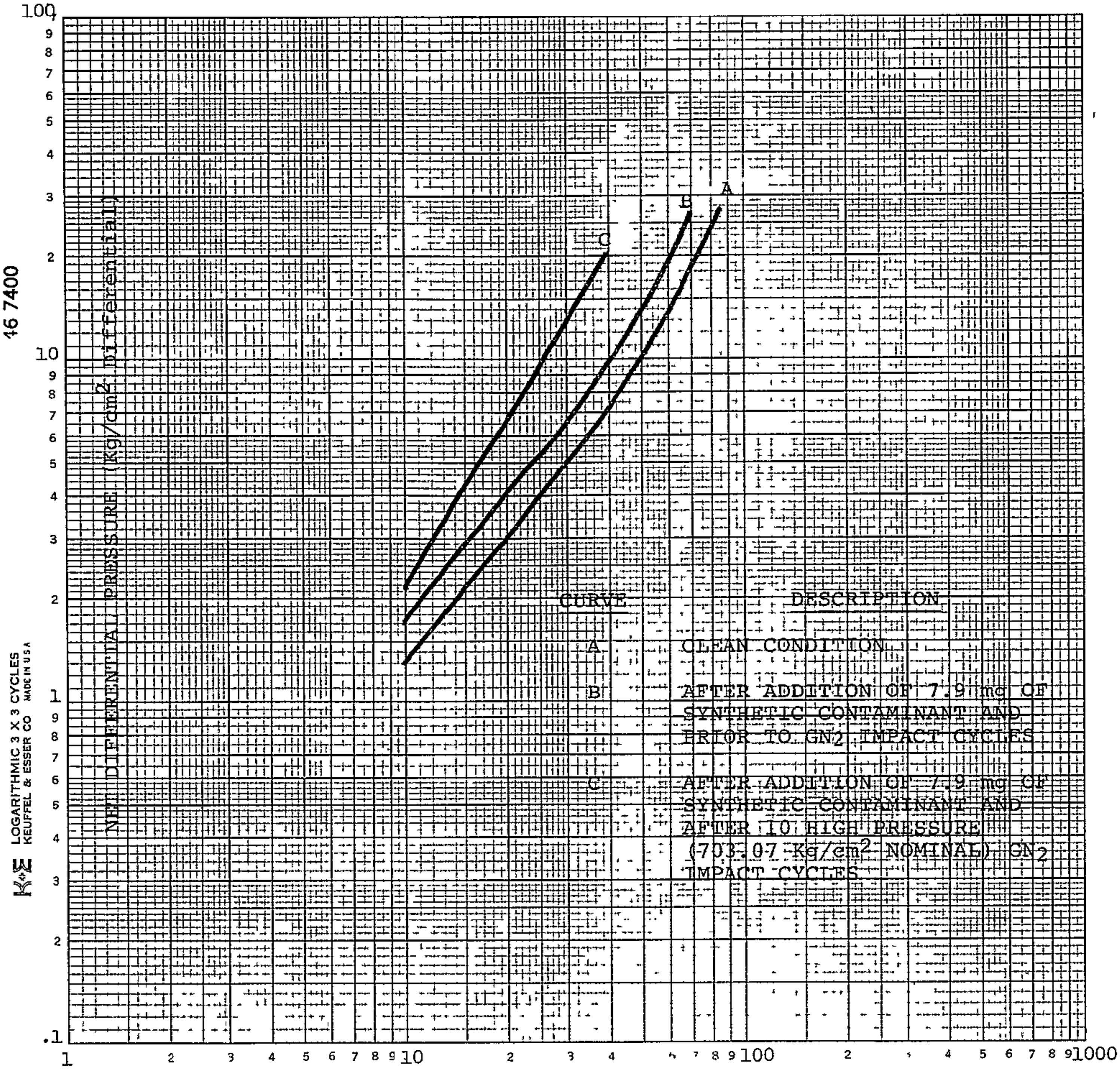
FLOW RATE (Kg GN_2/hr)

FIGURE 14 Part A

TEST NO. 10

TEST SPECIMEN S/N 027

FLOW RATE VERSUS DIFFERENTIAL PRESSURE DATA AT A NOMINAL TEST SPECIMEN INLET PRESSURE OF 29.177 Kg/cm^2



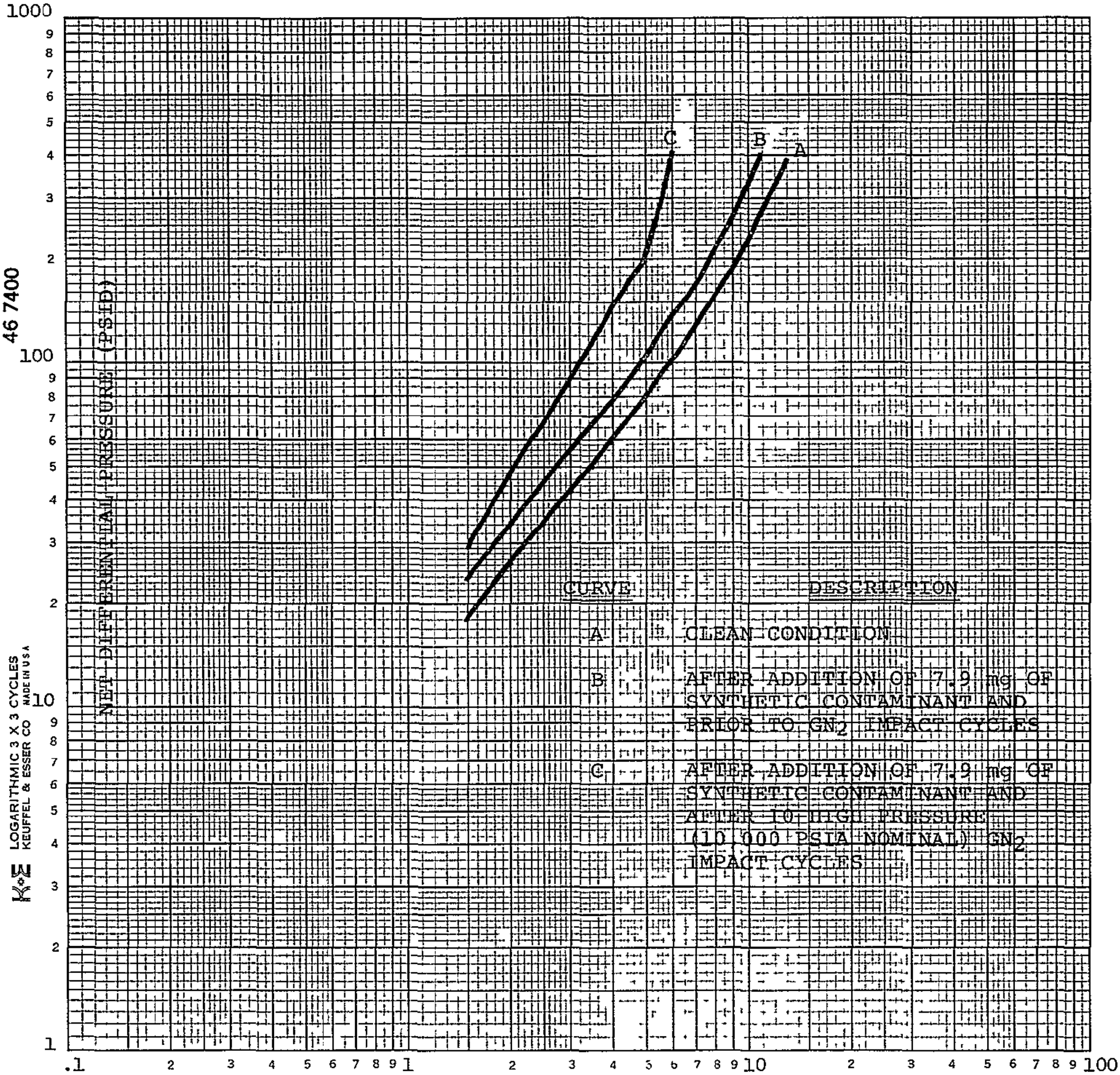
*At 21.1°C (70°F) and 1.033 Kg/cm^2 (14.7 psia)

FIGURE 14 Part B

TEST NO. 10

TEST SPECIMEN S/N 027

FLOW RATE VERSUS DIFFERENTIAL PRESSURE DATA
AT A NOMINAL TEST SPECIMEN INLET PRESSURE
OF 415 PSIA



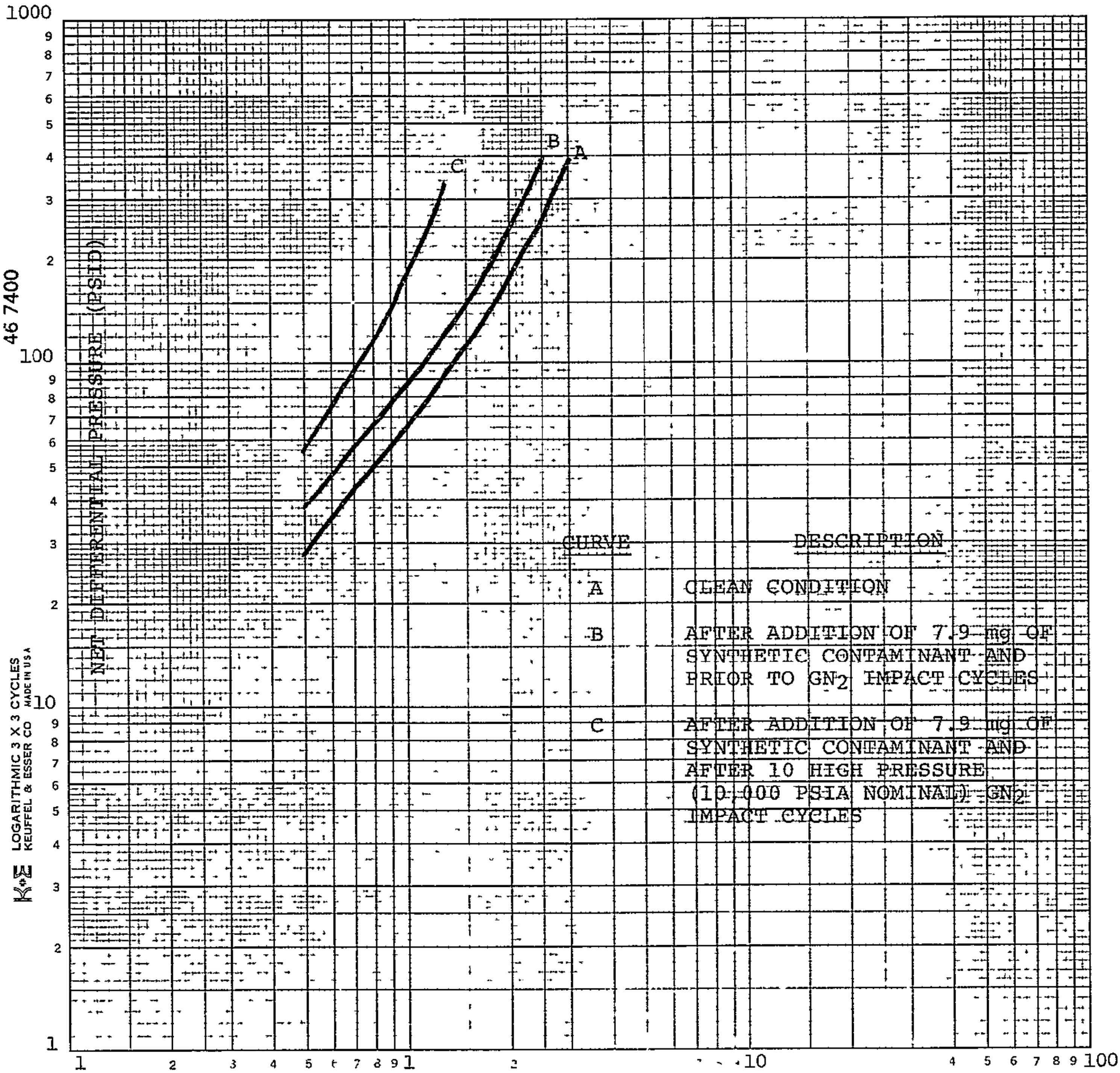
FLOW RATE (lbs GN_2/hr)

FIGURE 14 Part C

TEST NO. 10

TEST SPECIMEN S/N 027

FLOW RATE VERSUS DIFFERENTIAL PRESSURE DATA
AT A NOMINAL TEST SPECIMEN INLET PRESSURE
OF 415 PSIA



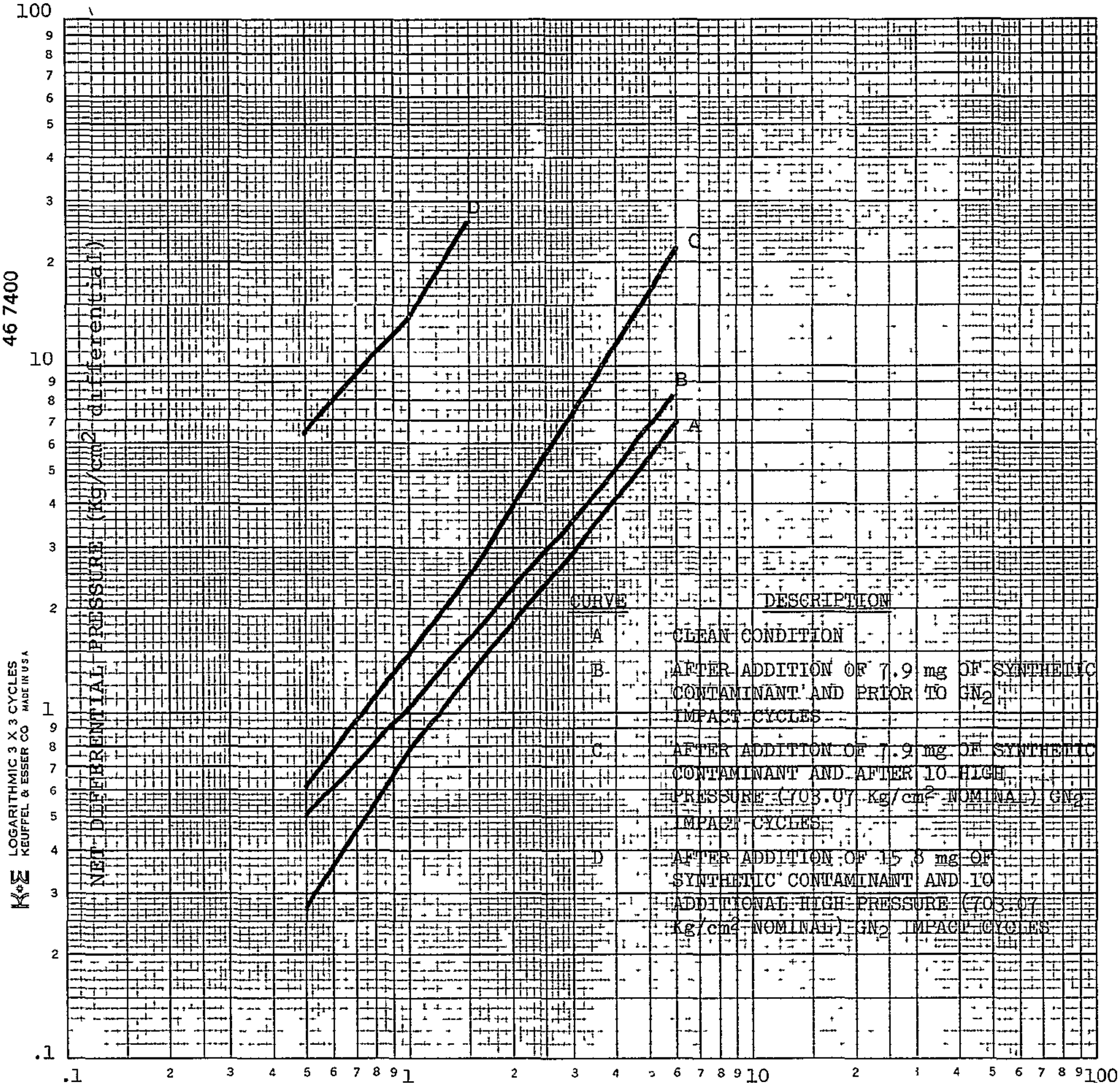
FLOW RATE (SCFM)

FIGURE 14 Part D

TEST NO. 10

TEST SPECIMEN S/N 027

FLOW RATE VERSUS DIFFERENTIAL PRESSURE DATA
AT A NOMINAL TEST SPECIMEN INLET PRESSURE
OF 70.307 Kg/cm^2



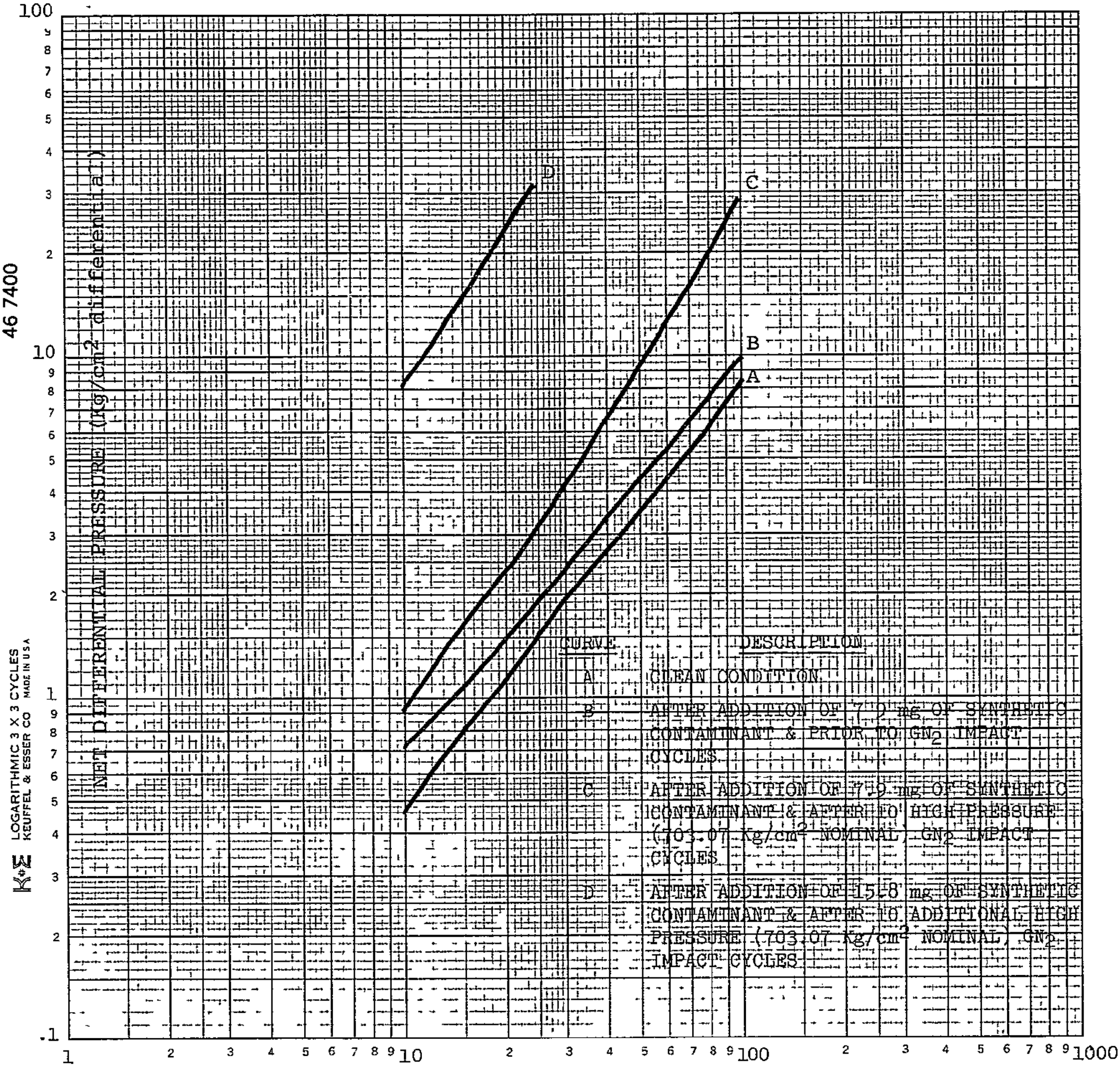
FLOW RATE (Kg GN_2/hr)

FIGURE 15 Part A

TEST NO. 10

TEST SPECIMEN S/N 027

FLOW RATE VERSUS DIFFERENTIAL PRESSURE DATA
AT A NOMINAL TEST SPECIMEN INLET PRESSURE
OF 70.307 Kg/cm^2



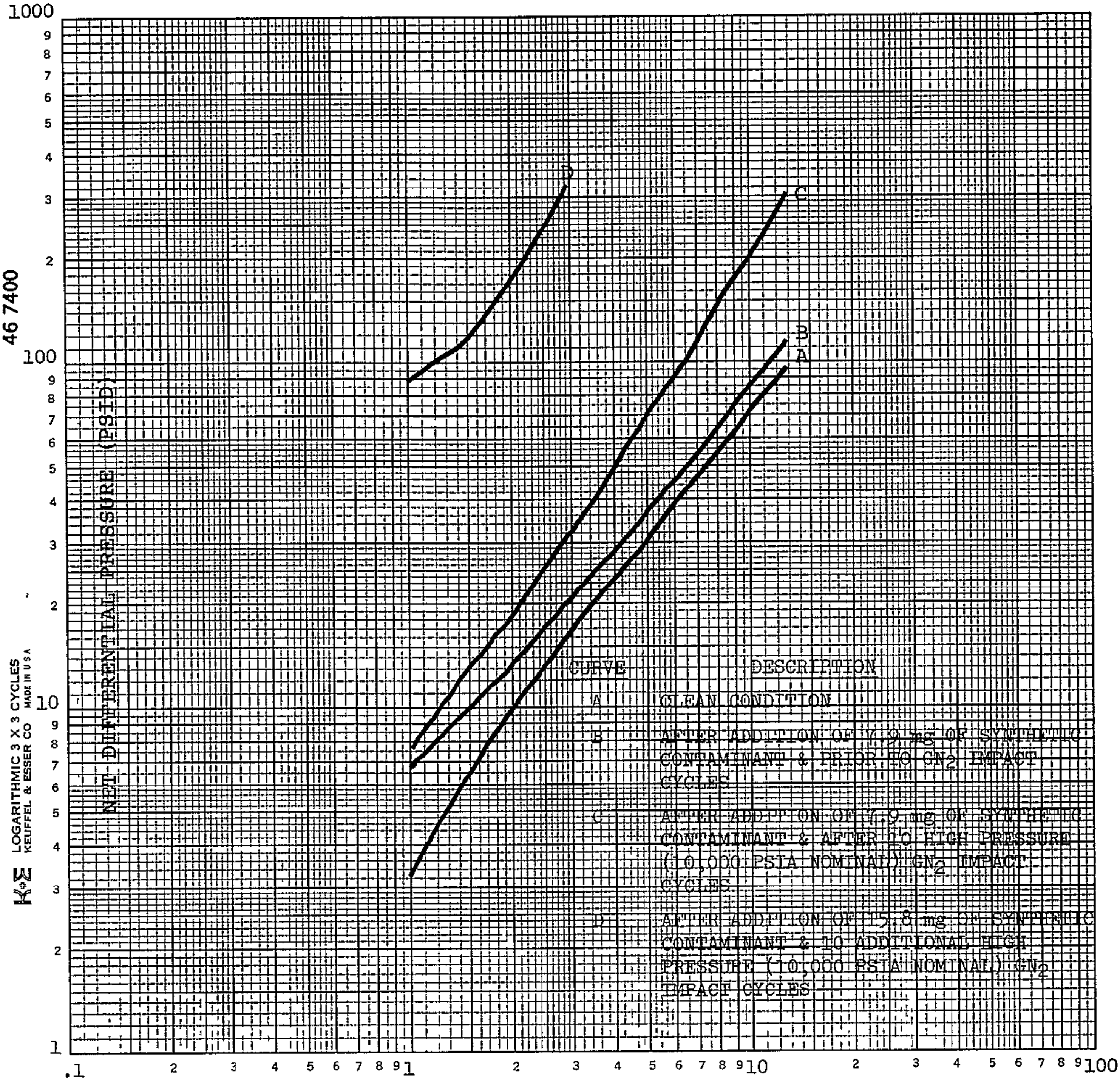
*At 21.1°C (70°F) and 1.033 Kg/cm^2 (14.7 psia)

FIGURE 15 Part B

TEST NO. 10

TEST SPECIMEN S/N 027

FLOW RATE VERSUS DIFFERENTIAL PRESSURE DATA
AT A NOMINAL TEST SPECIMEN INLET PRESSURE
OF 1,000 PSIA



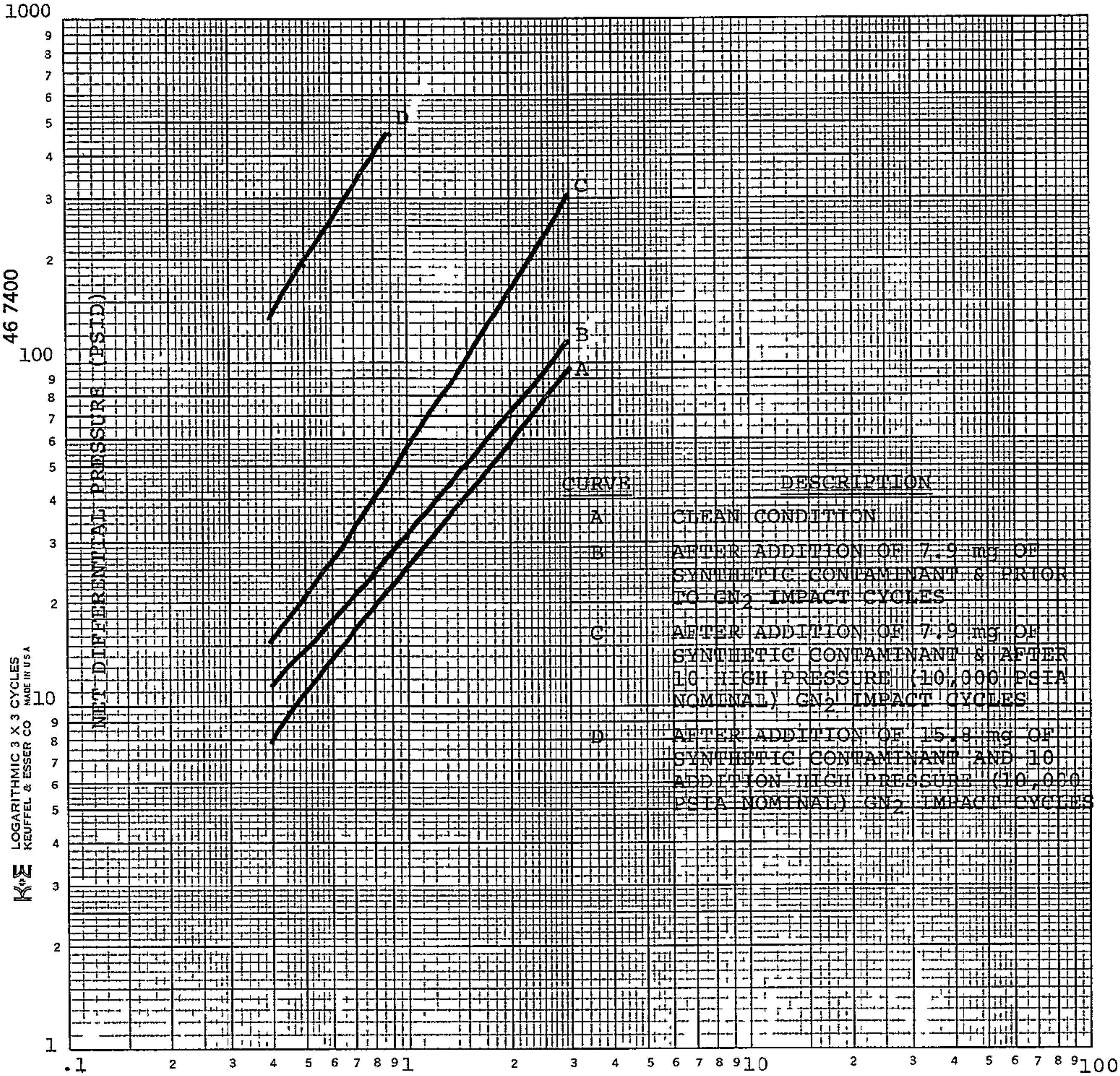
FLOW RATE (lbs GN_2/hr)

FIGURE 15 Part C

TEST NO. 10

TEST SPECIMEN S/N 027

FLOW RATE VERSUS DIFFERENTIAL PRESSURE DATA
AT A NOMINAL TEST SPECIMEN INLET PRESSURE
OF 1,000 PSIA



FLOW RATE (SCFM)

FIGURE 15 Part D

CONTAMINATED CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE

TEST SPECIMEN S/N 022

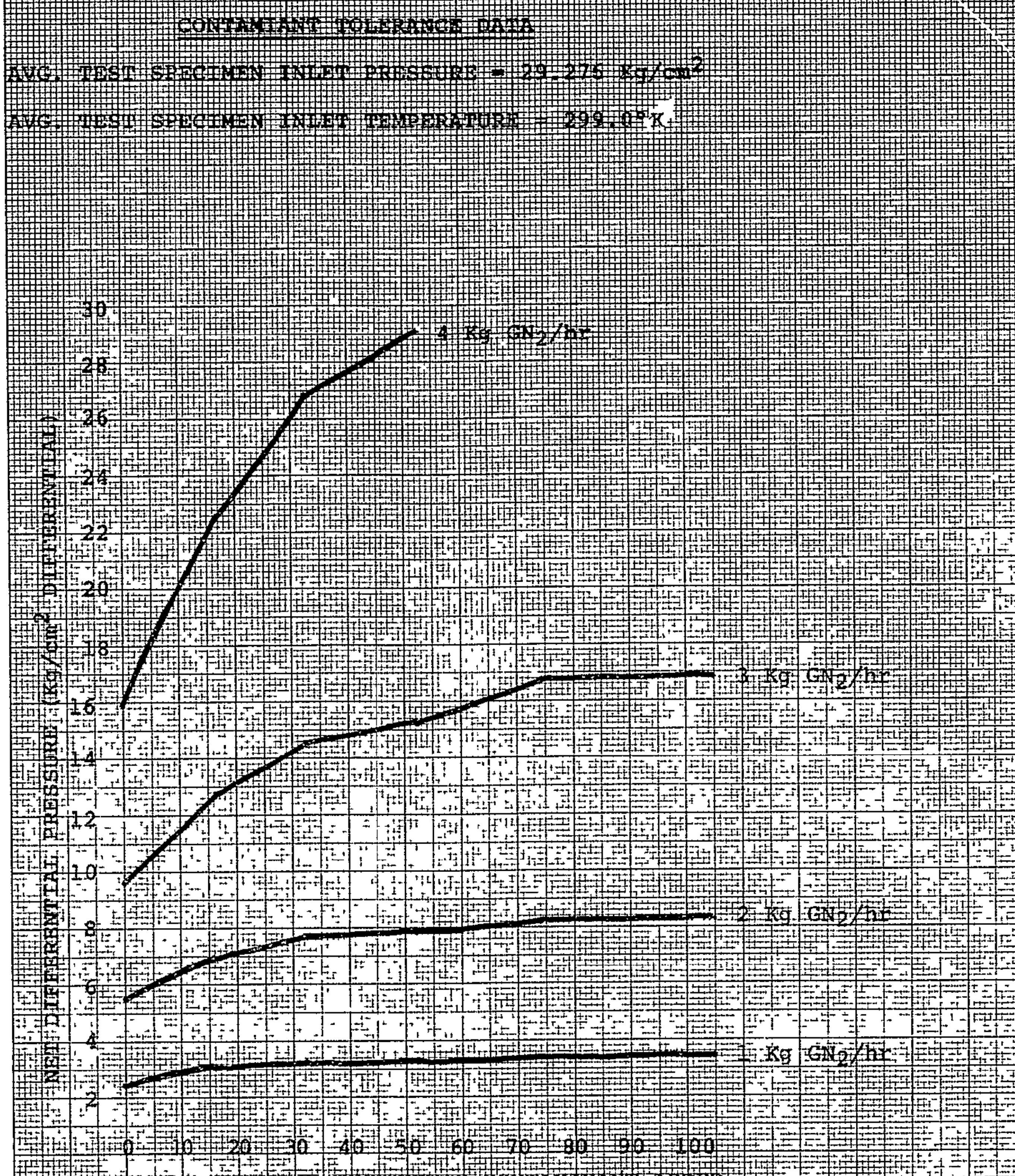


FIGURE 16 Part A

TEST NO. 11

CONTAMINATED CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE

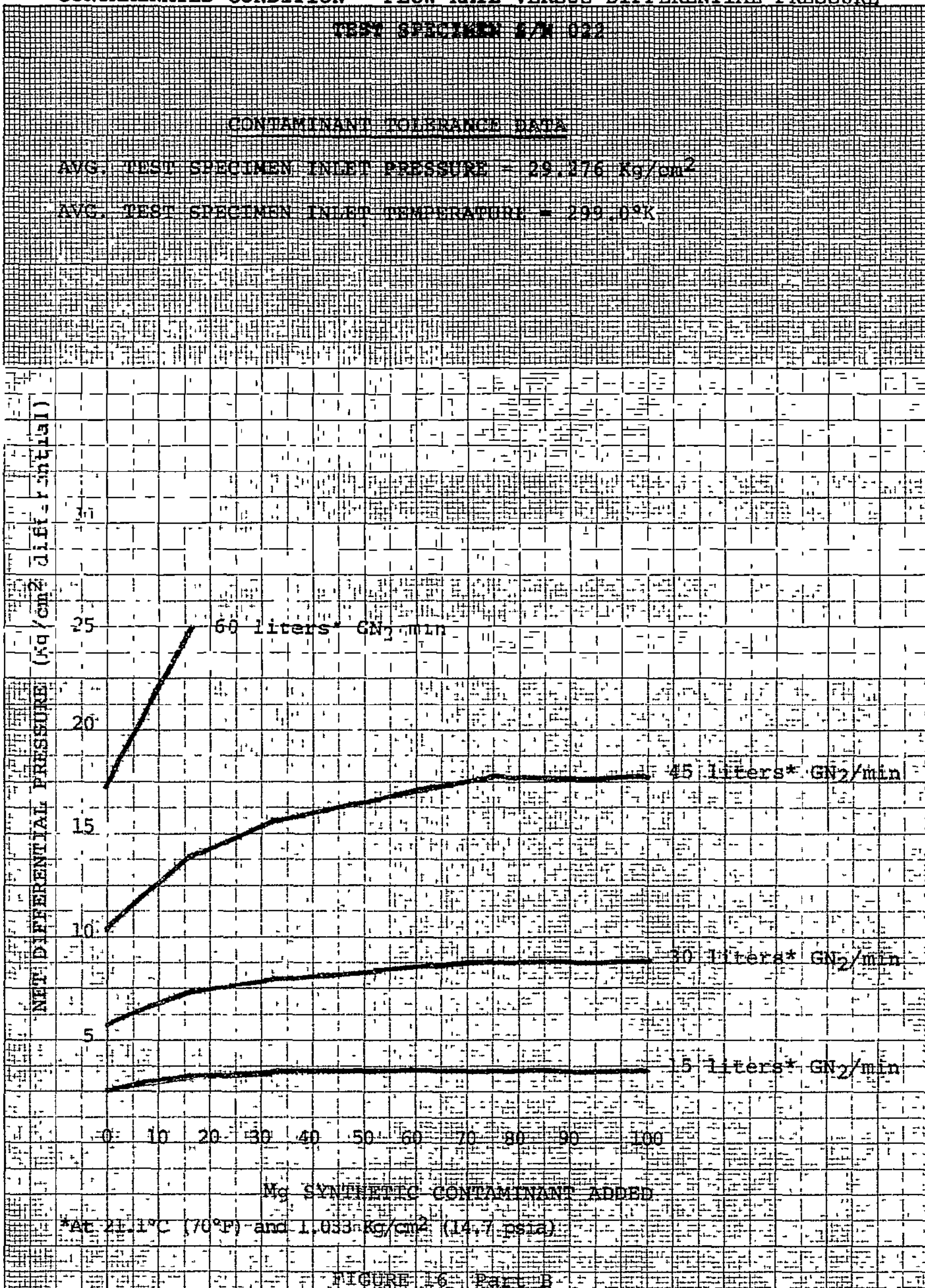


FIGURE 16 Part B

FIGURE 16 Part C

TEST NO. 11

CONTAMINATED CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE

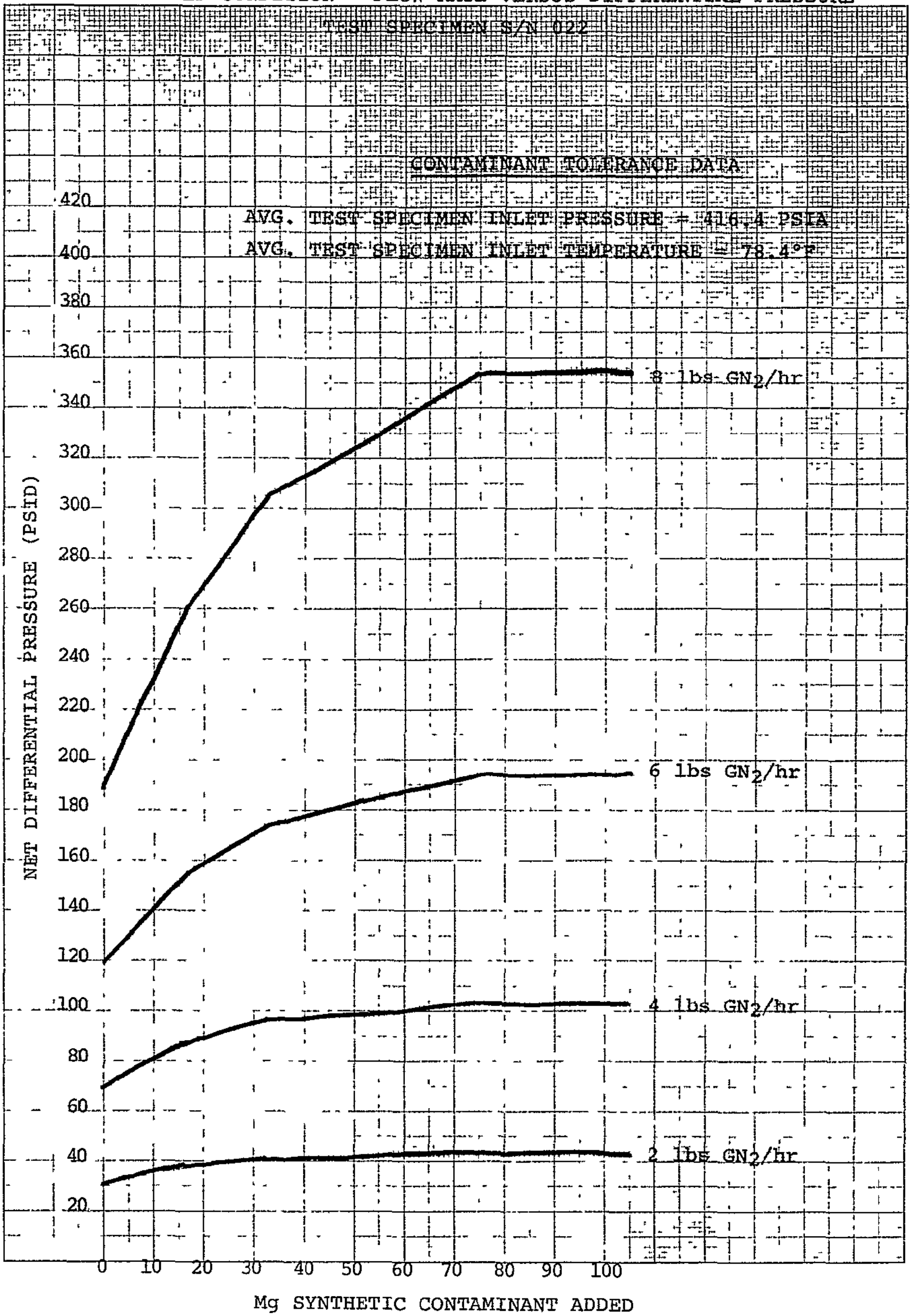
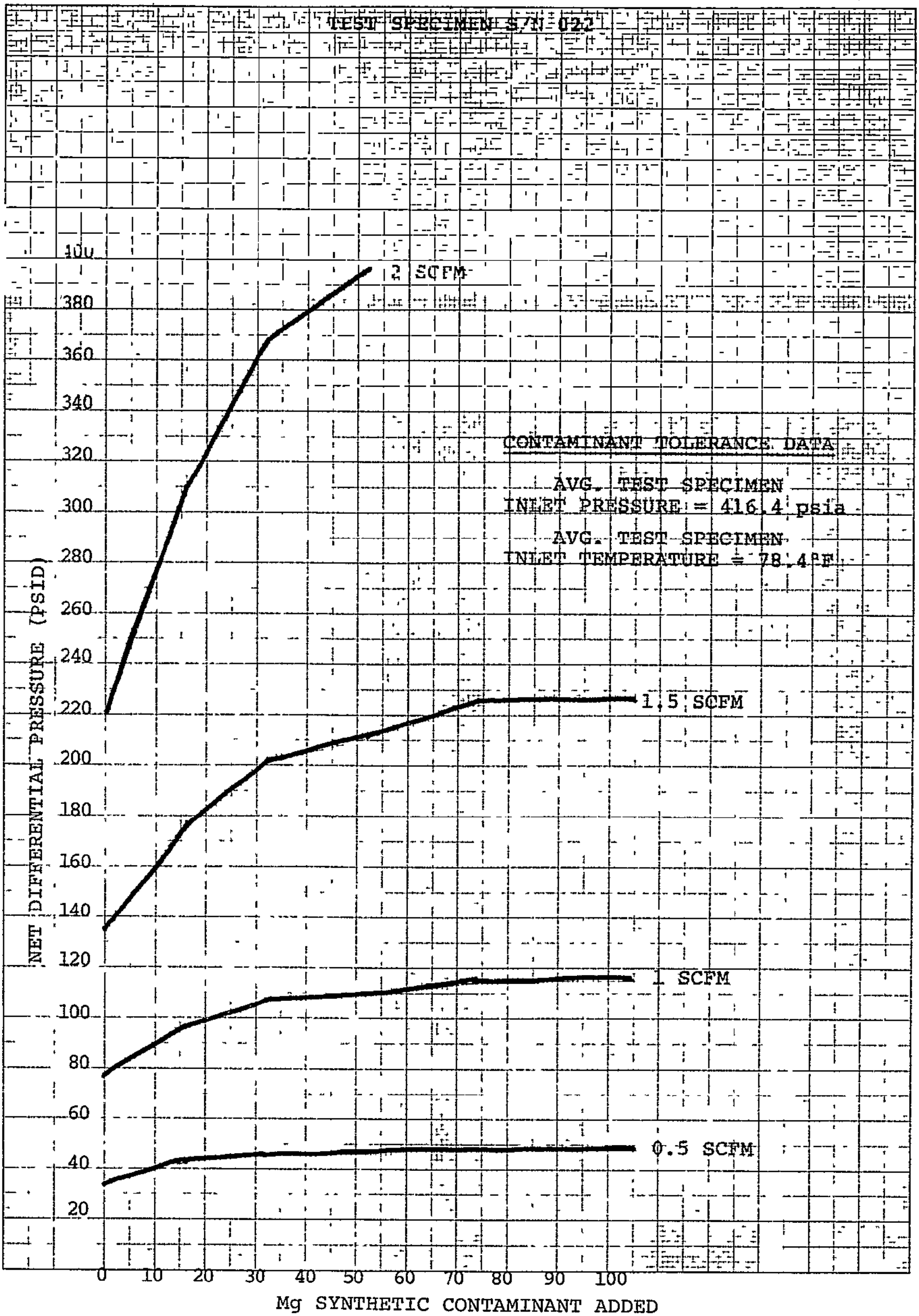


FIGURE 16 Part D
TEST NO. 11
CONTAMINATED CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE



TEST NO. 11

CONTAMINATED CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE

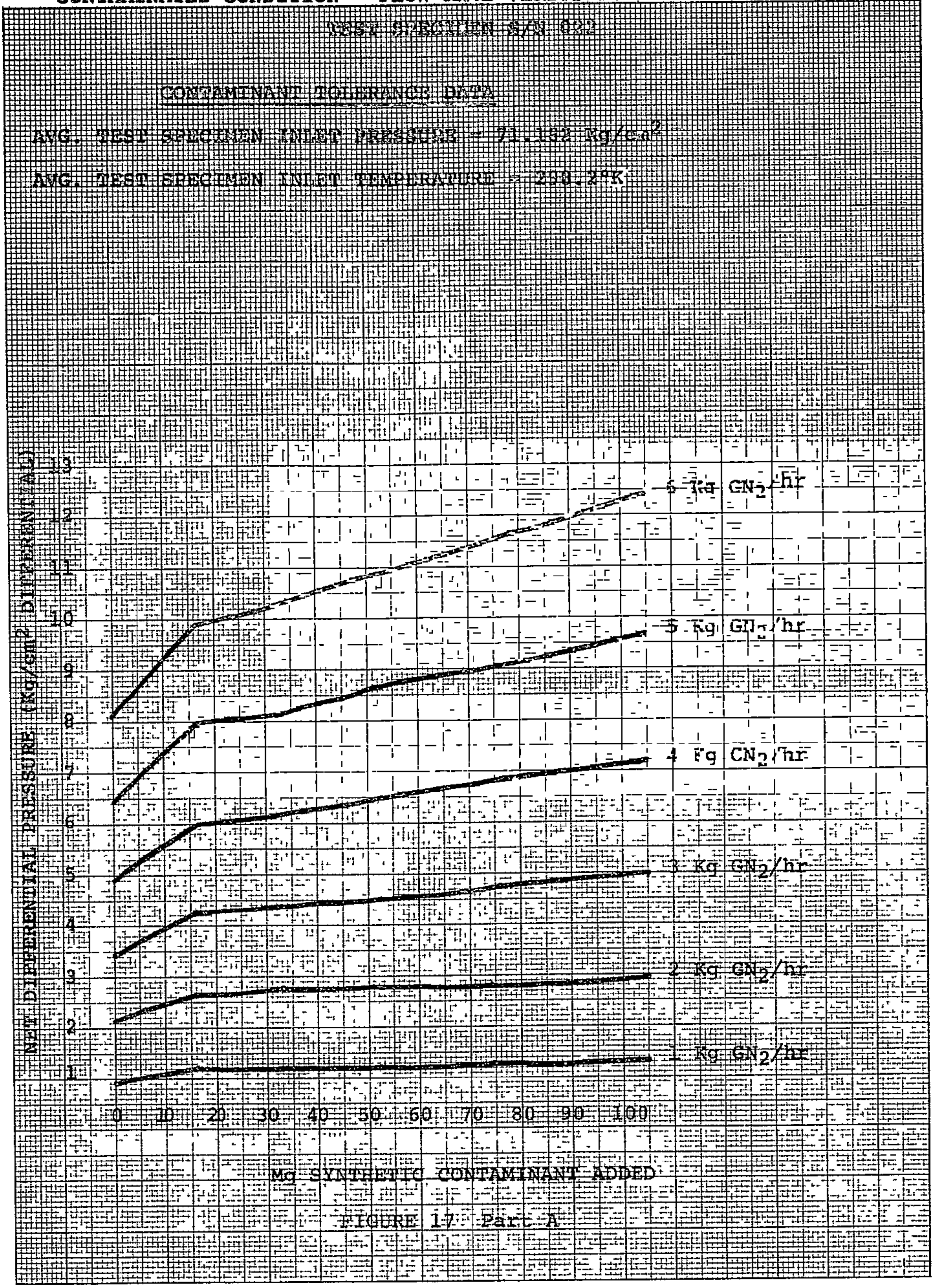


FIGURE 17 Part A

TEST NO. 11 Revised 1-6-77

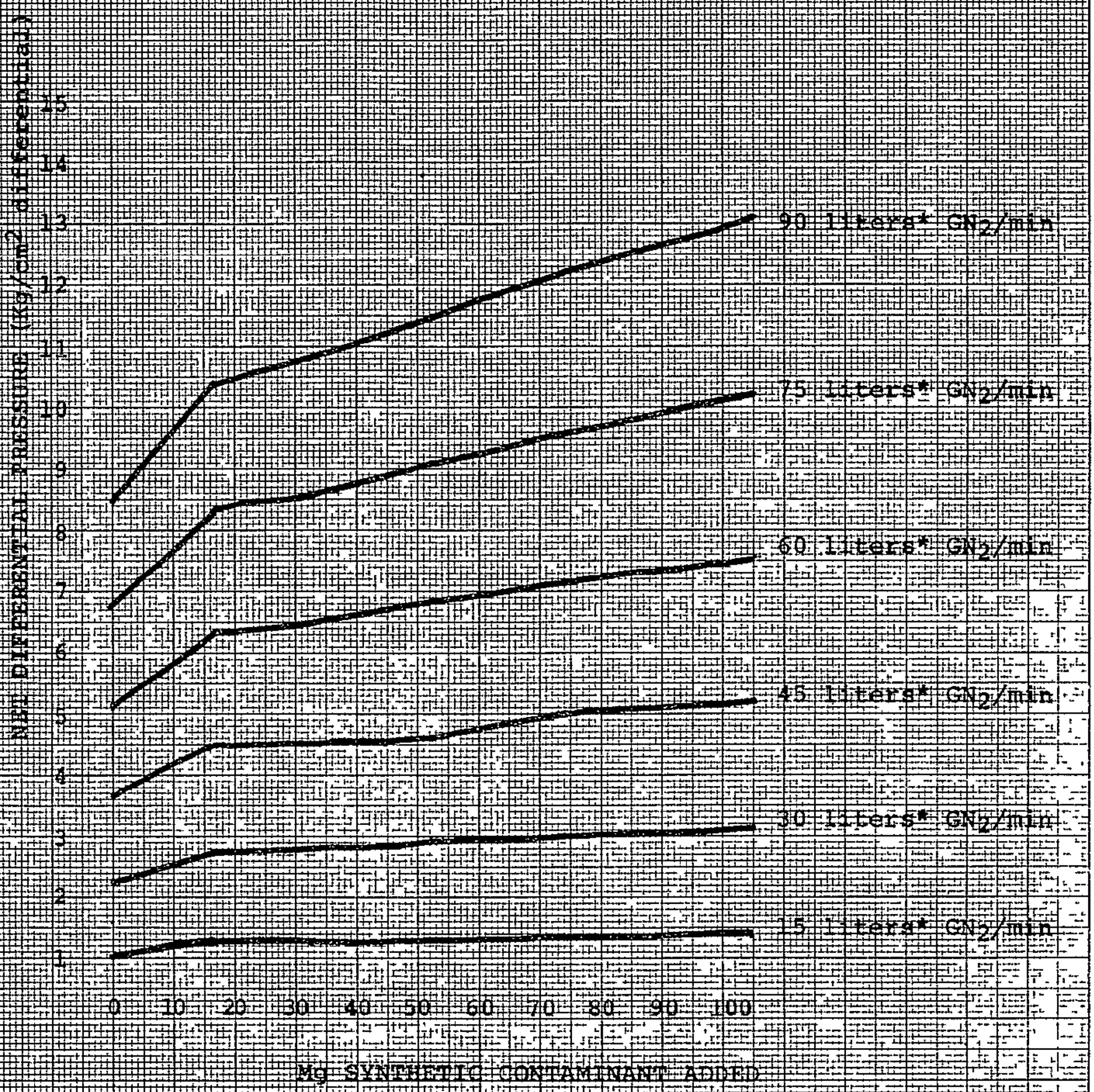
CONTAMINATED CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE

TEST SPECIMEN S/N 022

CONTAMINANT TOLERANCE DATA

AVG. TEST SPECIMEN INLET PRESSURE = 71.182 Kg/cm^2

AVG. TEST SPECIMEN INLET TEMPERATURE = 298.2°K



*At 21.1°C (70°F) and 1.033 Kg/cm^2 (14.7 PSIA)

FIGURE 17 Part B

TEST NO. 11

CONTAMINATED CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE

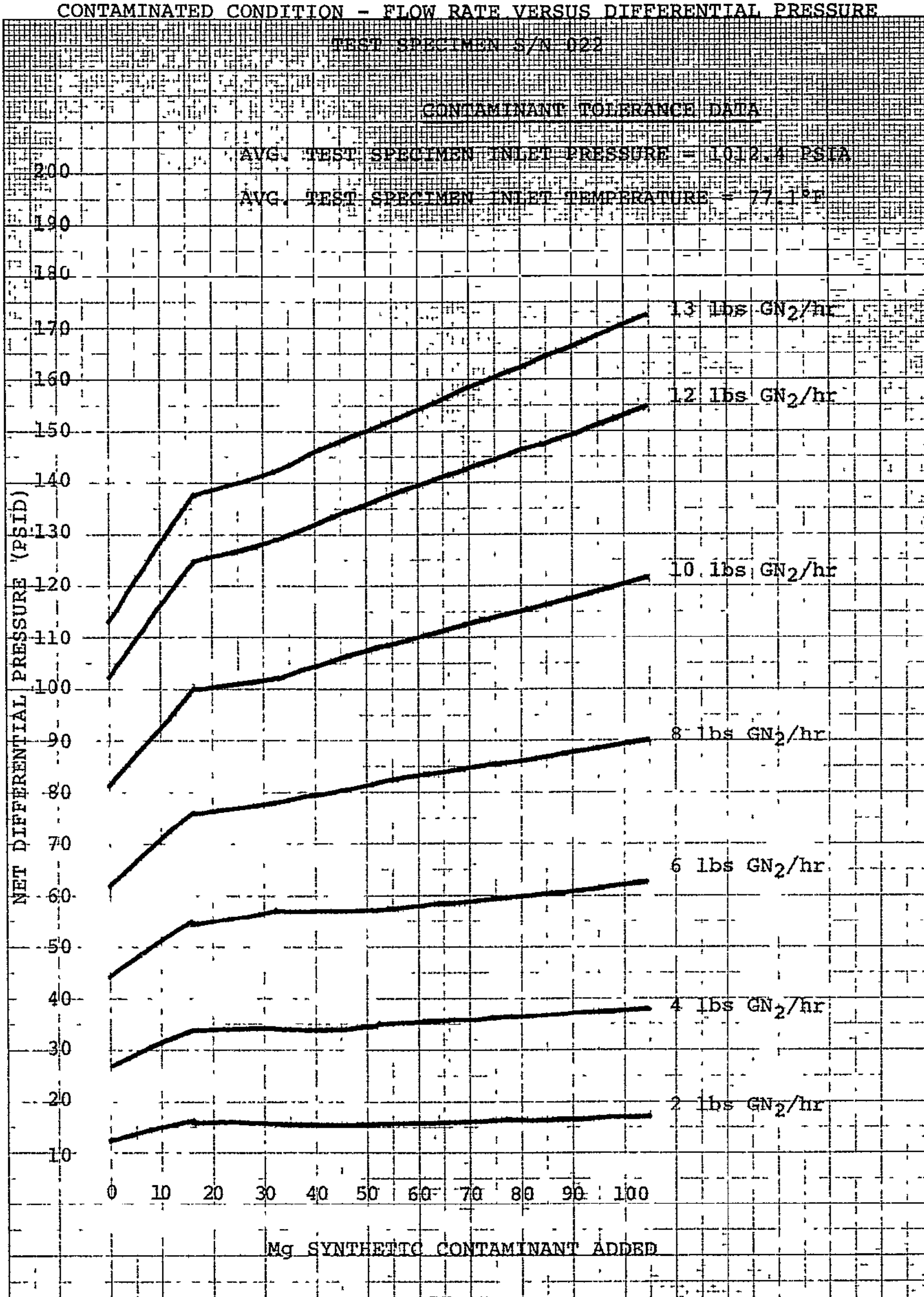


FIGURE 17 Part C

TEST NO. 11

CONTAMINATED CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE

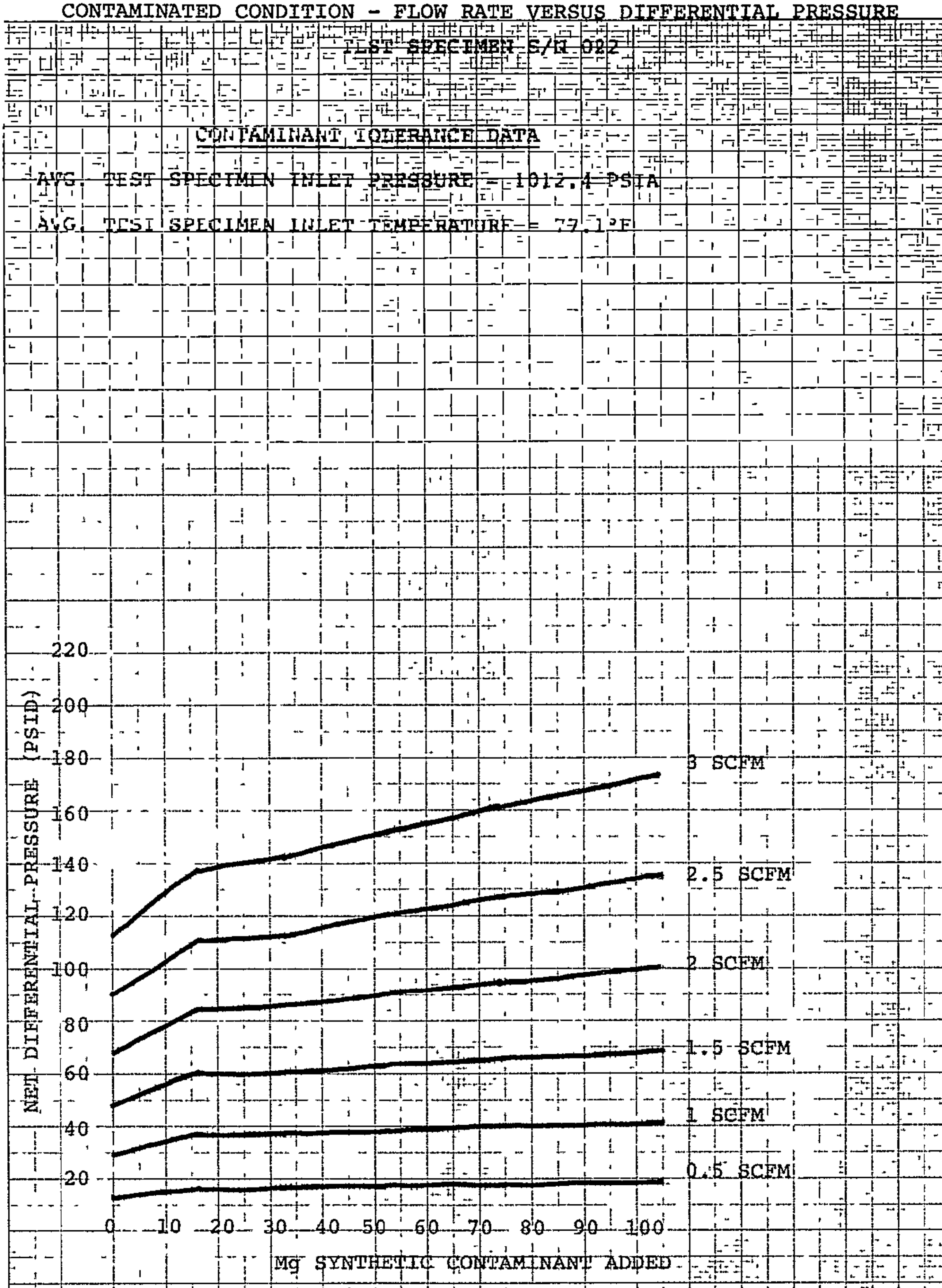


FIGURE 17, Part D

FIGURE 18 Part A

TEST NO. 12

TEST SPECIMEN S/N 028
CONTAMINANT TOLERANCE DATA

CONTAMINATED CONDITION - IMPACT/FLOW RATE VERSUS DIFFERENTIAL PRESSURE

NOMINAL TEST SPECIMEN INLET PRESSURE = 29.177 Kg/cm^2

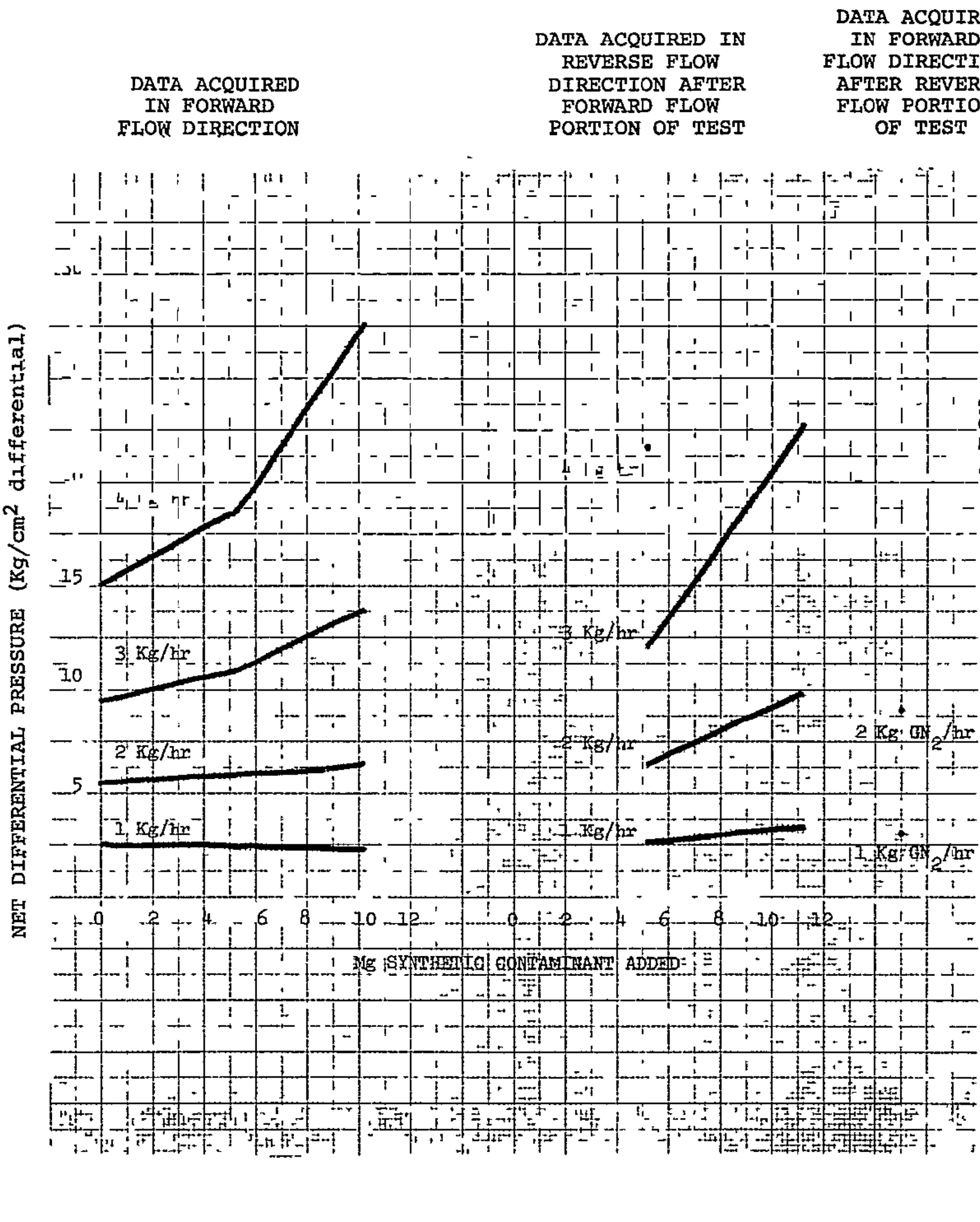


FIGURE 18 Part B

TEST NO. 12

TEST SPECIMEN S/N 028
CONTAMINANT TOLERANCE DATA

CONTAMINATED CONDITION - IMPACT/FLOW RATE VERSUS DIFFERENTIAL PRESSURE

NOMINAL TEST SPECIMEN INLET PRESSURE = 29.177 Kg/cm^2

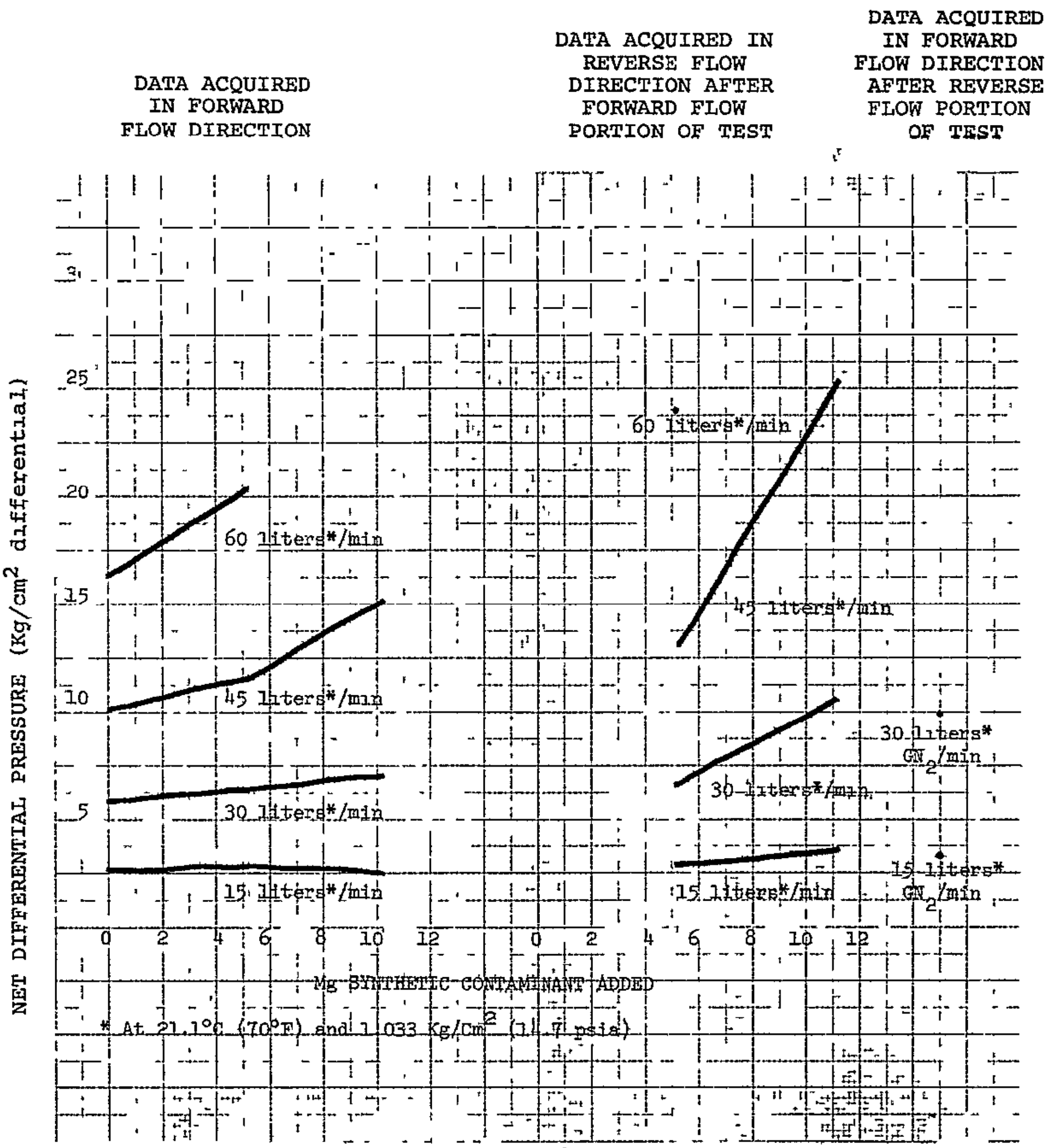


FIGURE 18 Part C

TEST NO. 12

TEST SPECIMEN S/N 028
CONTAMINANT TOLERANCE DATA

CONTAMINATED CONDITION - IMPACT/FLOW RATE VERSUS DIFFERENTIAL PRESSURE

NOMINAL TEST SPECIMEN INLET PRESSURE = 415 PSIA

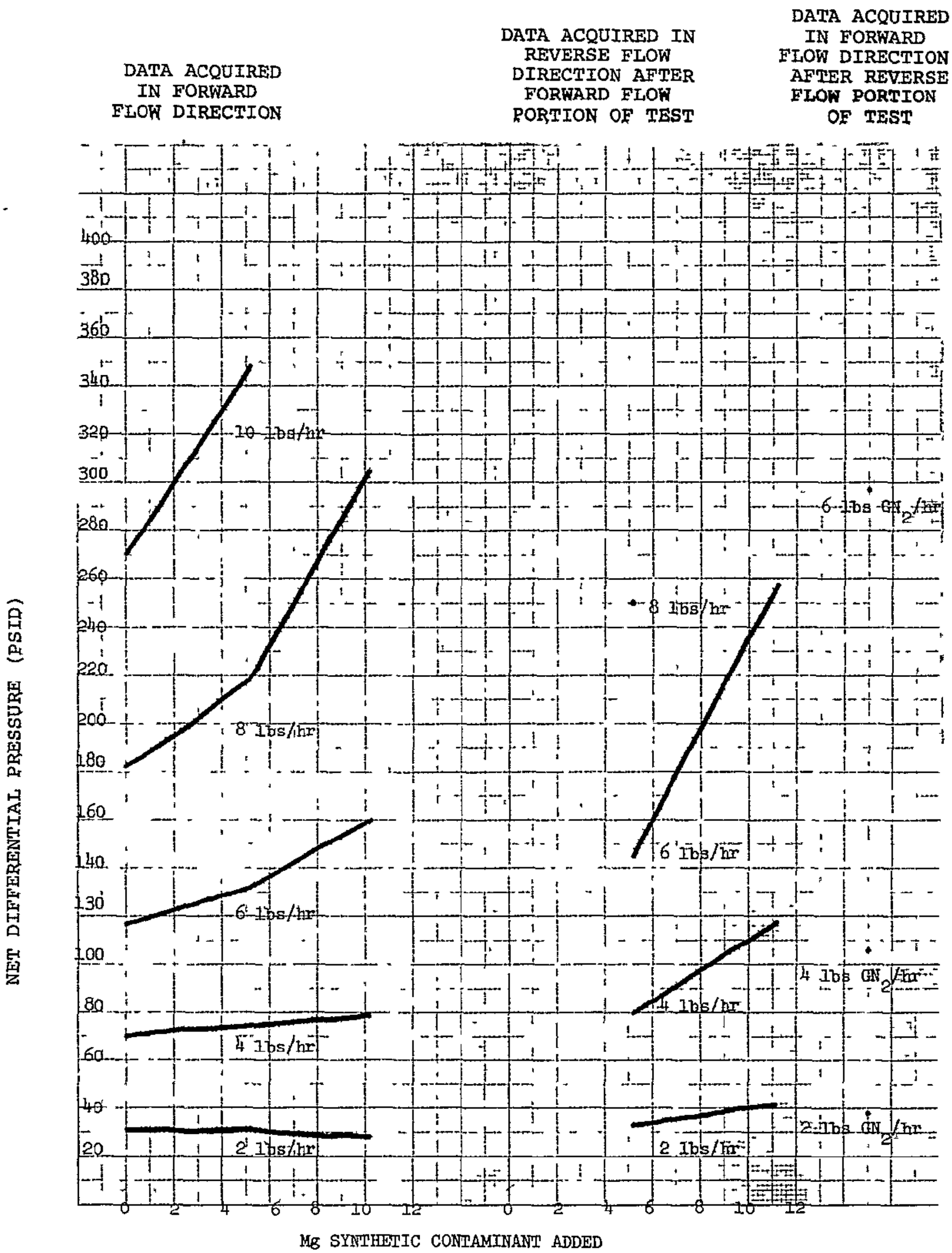


FIGURE 18 Part D
TEST NO. 12

TEST SPECIMEN S/N 028
CONTAMINANT TOLERANCE DATA

CONTAMINATED CONDITION - IMPACT/FLOW RATE VERSUS DIFFERENTIAL PRESSURE

NOMINAL TEST SPECIMEN INLET PRESSURE = 415 PSIA

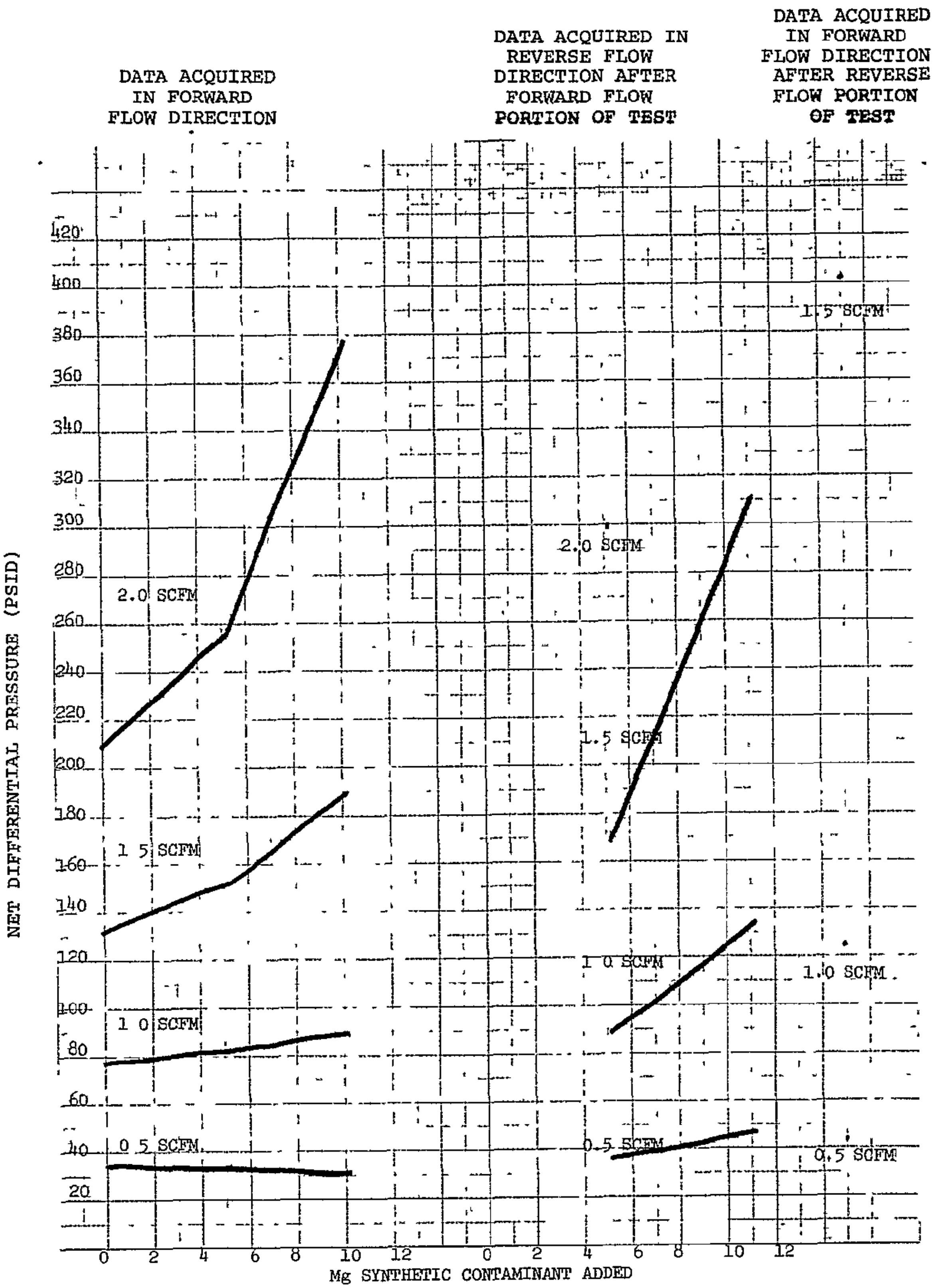


FIGURE 19 Part A

TEST NO. 12

TEST SPECIMEN S/N 028
CONTAMINANT TOLERANCE DATA

CONTAMINATED CONDITION - IMPACT/FLOW RATE VERSUS DIFFERENTIAL PRESSURE

NOMINAL TEST SPECIMEN INLET PRESSURE = 70.307 Kg/cm^2

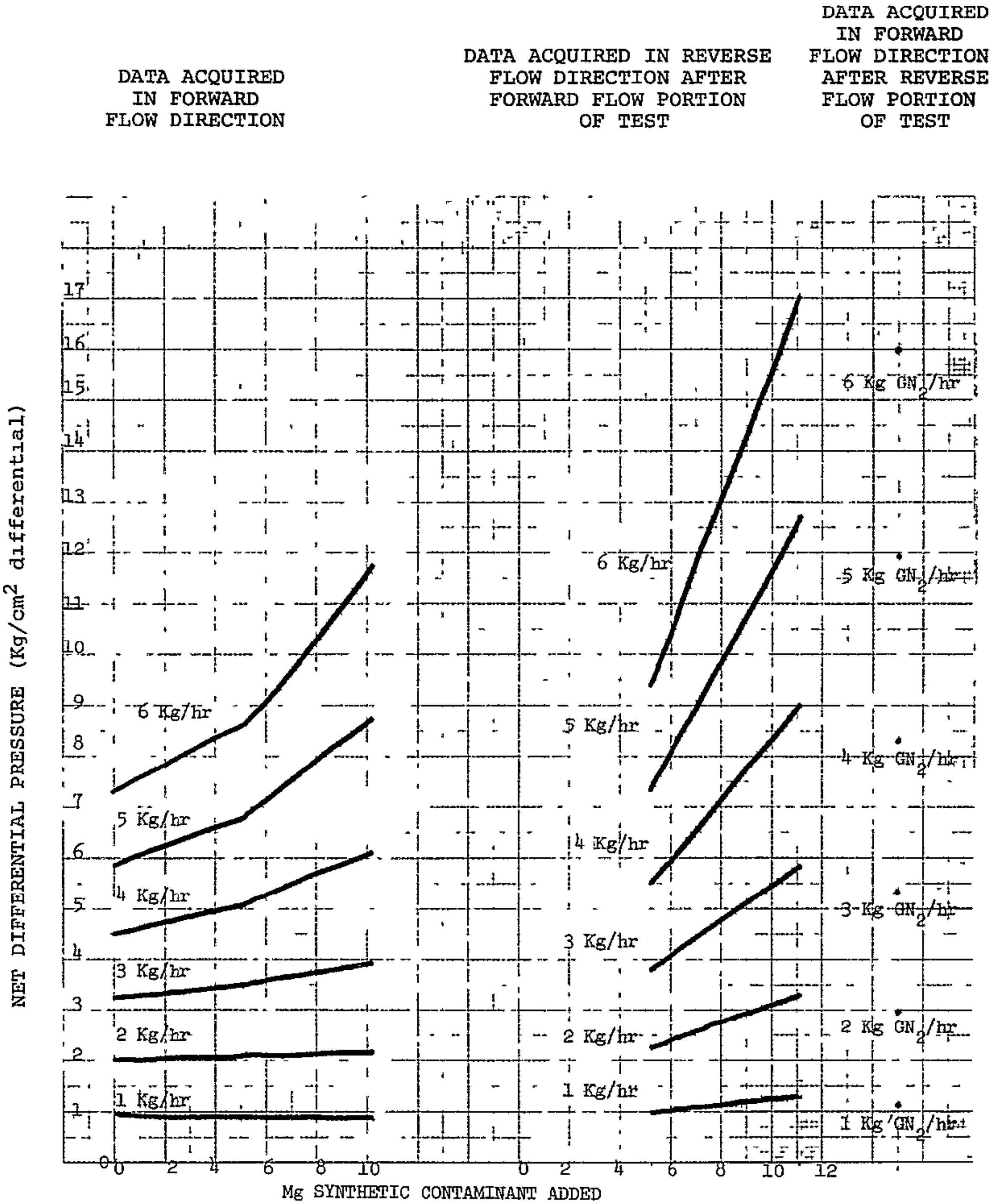
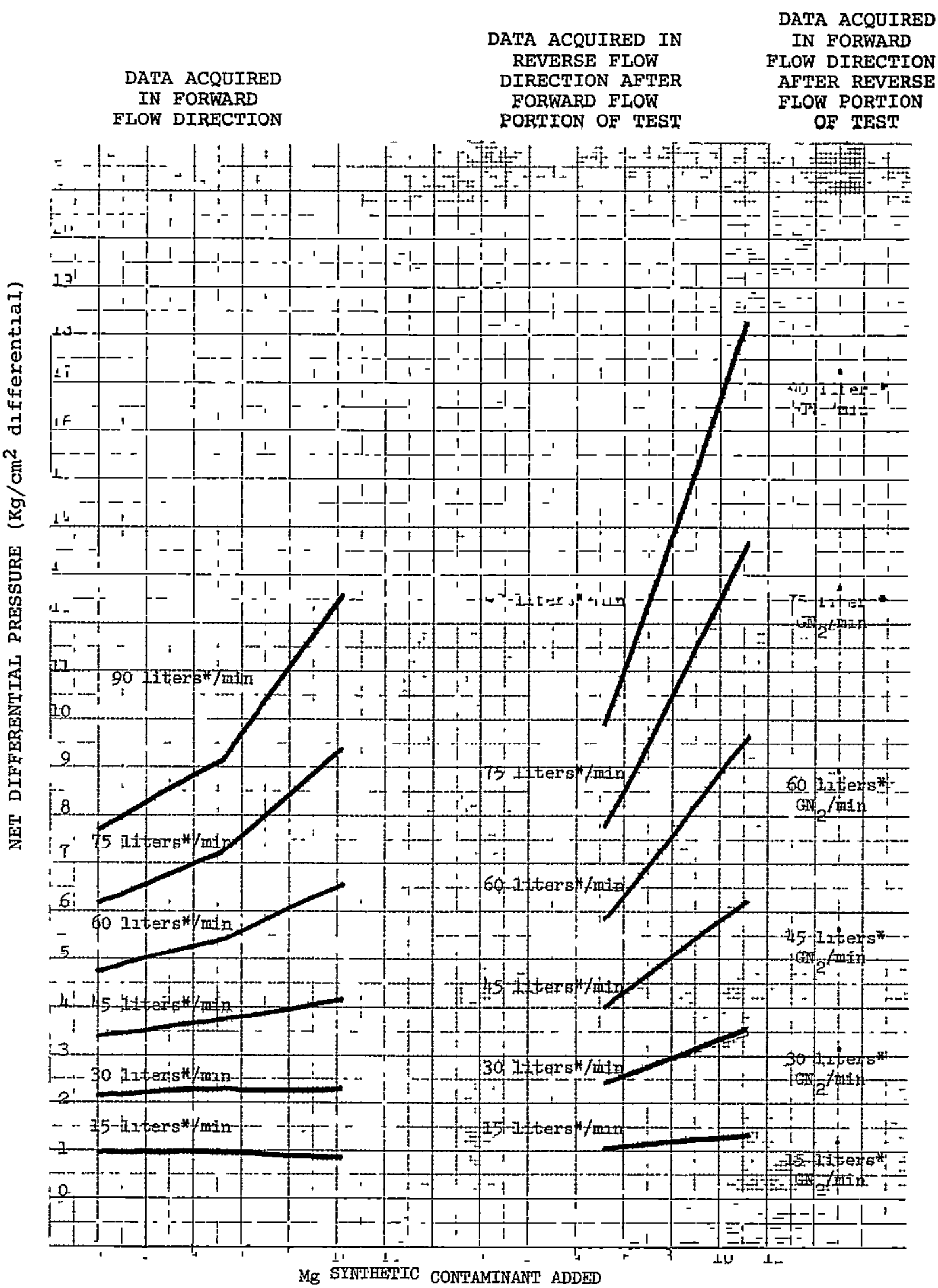


FIGURE 19 Part B
TEST NO. 12

TEST SPECIMEN S/N 028
CONTAMINANT TOLERANCE DATA

CONTAMINATED CONDITION - IMPACT/FLOW RATE VERSUS DIFFERENTIAL PRESSURE

NOMINAL TEST SPECIMEN INLET PRESSURE = 70.307 Kg/cm²



*At 21.1°C (70°F) and 1.033 Kg/cm² (14.7 psia)

FIGURE 19 Part C

TEST NO. 12

TEST SPECIMEN S/N 028
CONTAMINANT TOLERANCE DATA

CONTAMINATED CONDITION - IMPACT/FLOW RATE VERSUS DIFFERENTIAL PRESSURE

NOMINAL TEST SPECIMEN INLET PRESSURE = 1,000 PSIA

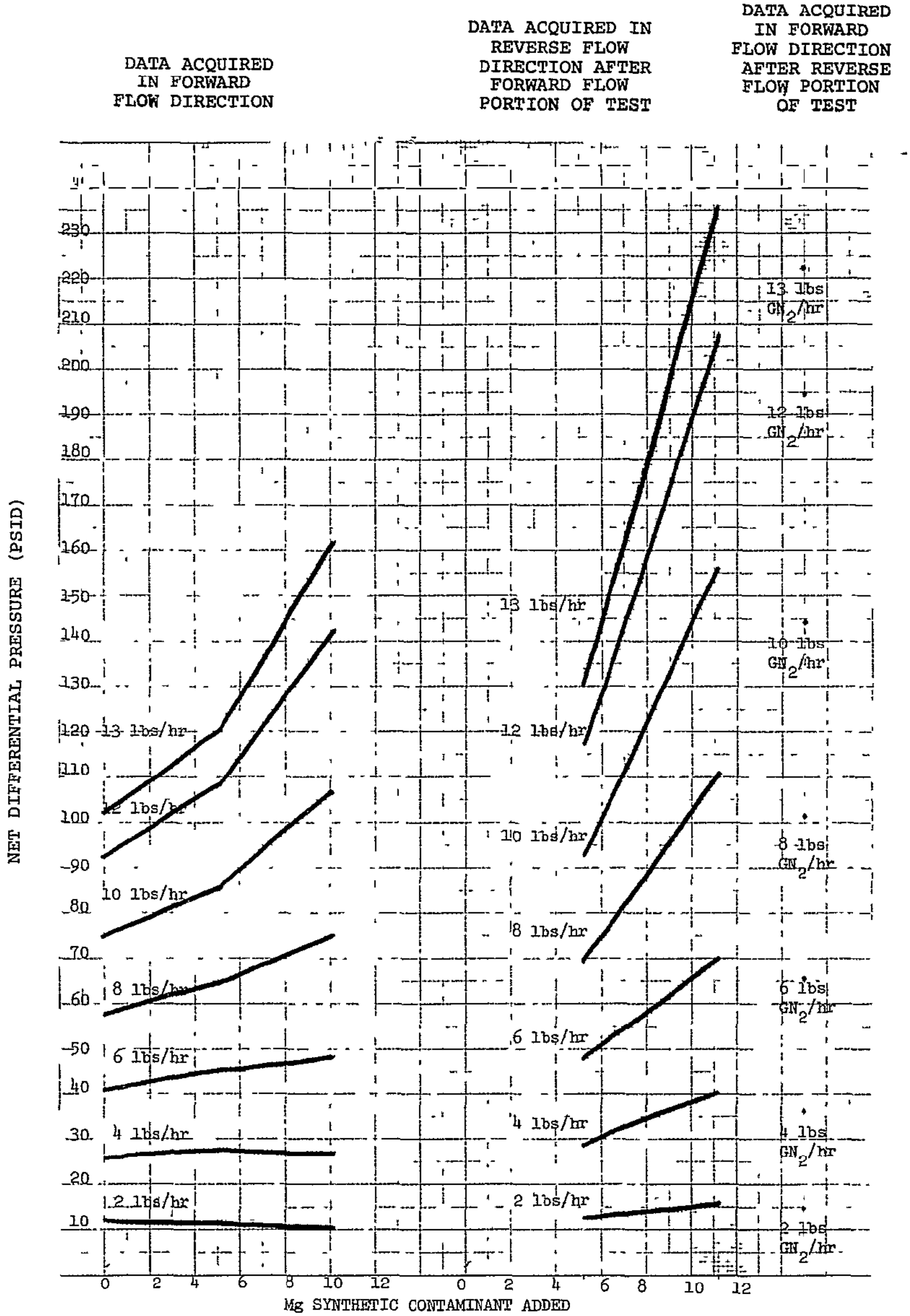
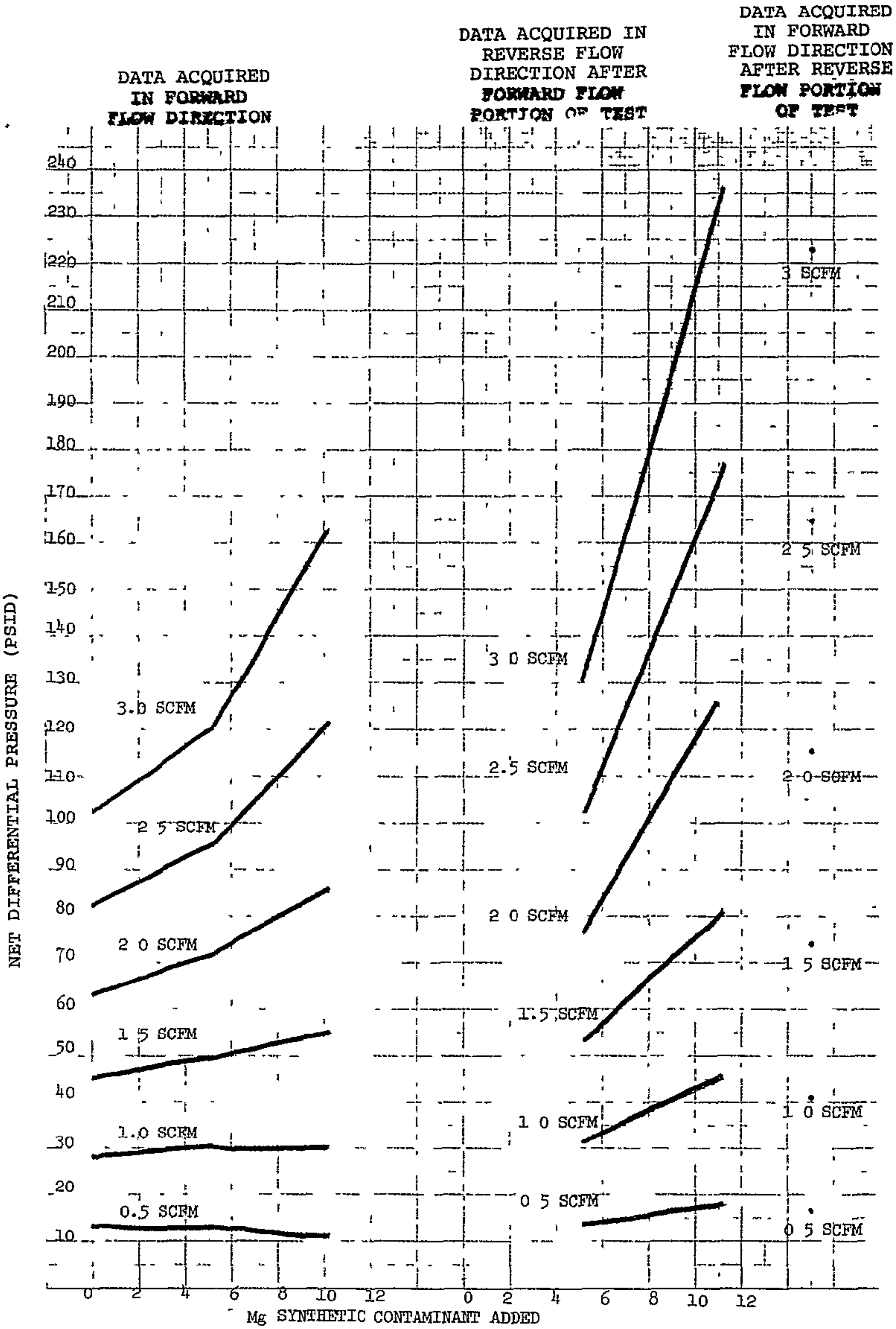


FIGURE 19 Part D
TEST NO. 12

TEST SPECIMEN S/N 028
CONTAMINANT TOLERANCE DATA

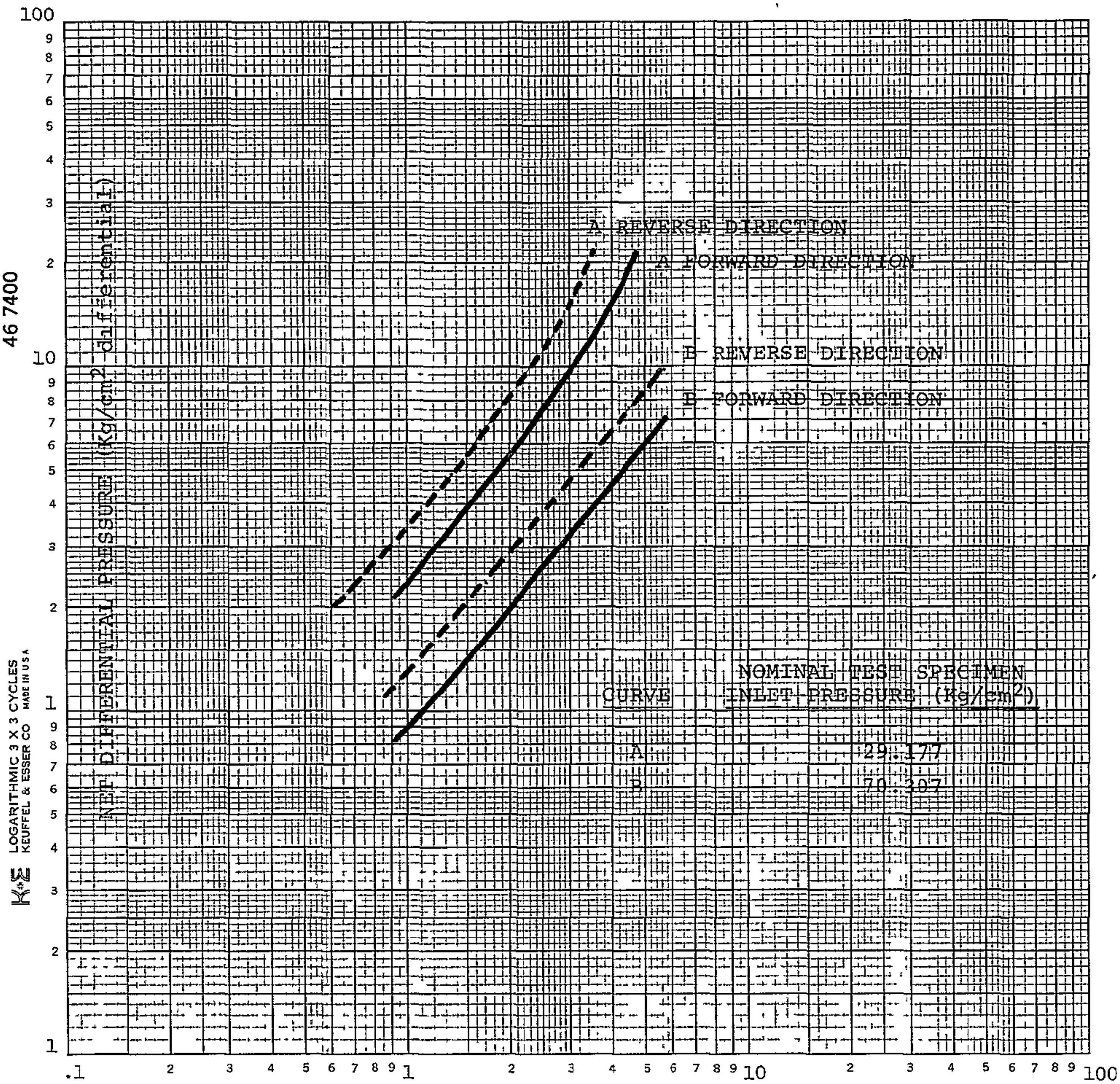
CONTAMINATED CONDITION - IMPACT/FLOW RATE VERSUS DIFFERENTIAL PRESSURE

NOMINAL TEST SPECIMEN INLET PRESSURE = 1,000 PSIA



TEST NO. 5

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE
DATA OBTAINED USING TEST SPECIMEN S/N 025 WITH FLOWS IN THE
FORWARD (S/N SIDE FACING UPSTREAM) AND REVERSED DIRECTIONS

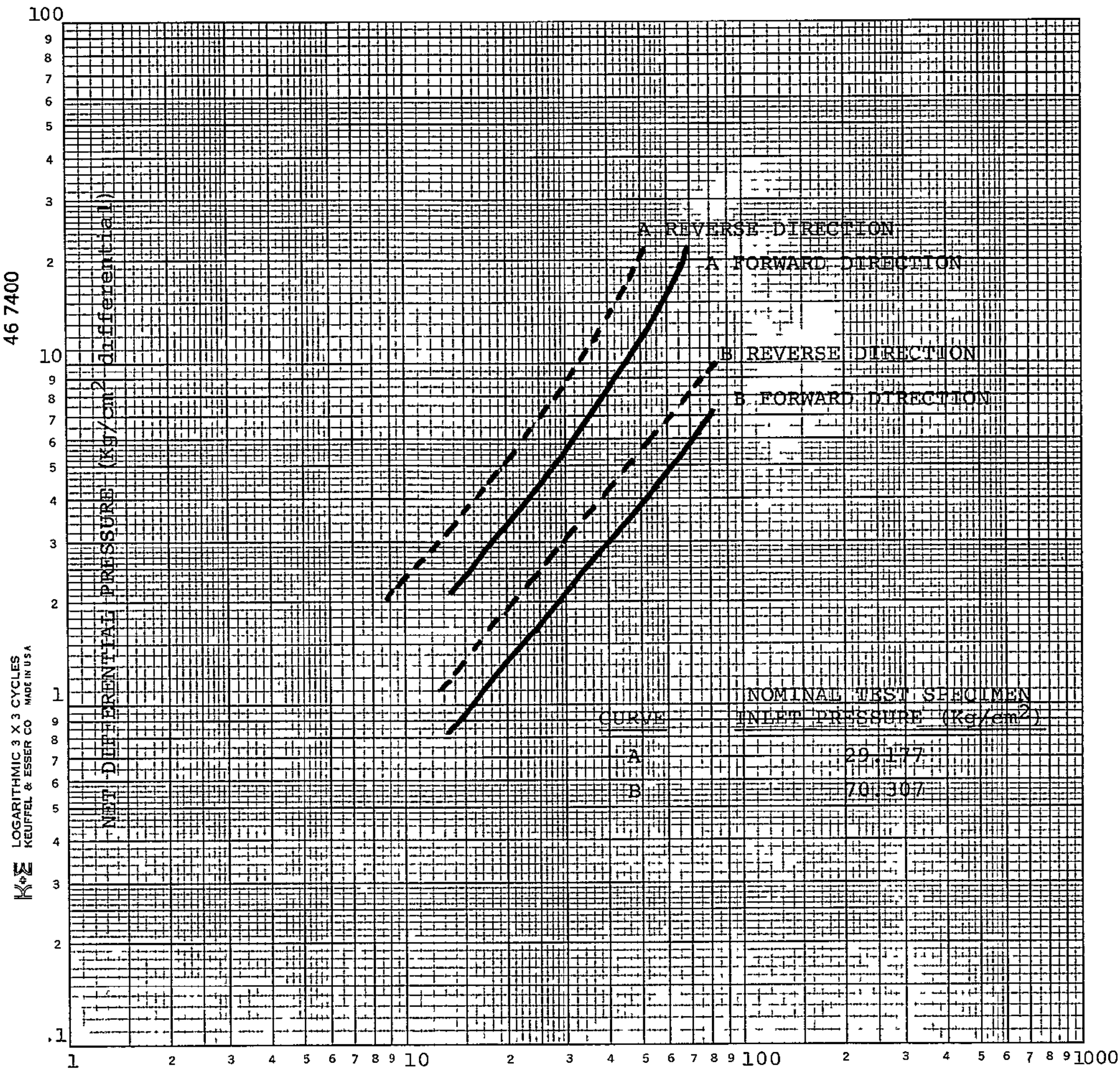


FLOW RATE (Kg GN_2/hr)

FIGURE 20 Part A

TEST NO. 5

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE
DATA OBTAINED USING TEST SPECIMEN S/N 025 WITH FLOWS IN THE
FORWARD (S/N SIDE FACING UPSTREAM) AND REVERSED DIRECTIONS



*At 21.1°C (70.0°F) and 1.033 Kg/cm^2 (14.7 psia)

FIGURE 20 Part B

TEST NO. 5

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE
DATA OBTAINED USING TEST SPECIMEN S/N 025 WITH FLOWS IN THE
FORWARD (S/N SIDE FACING UPSTREAM) AND REVERSED DIRECTIONS

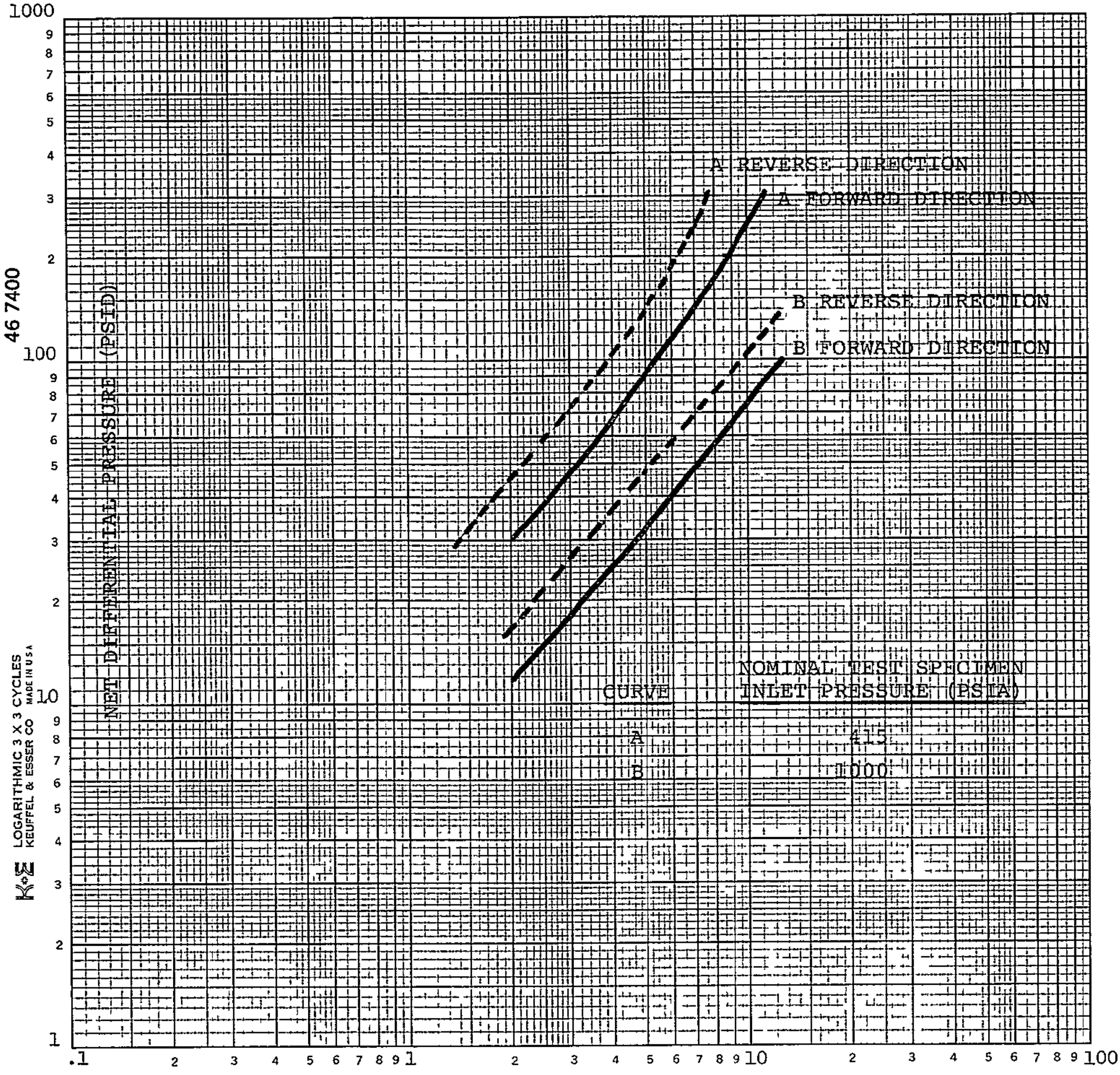


FIGURE 20 Part C

C-92

TEST NO. 5

CLEAN CONDITION - FLOW RATE VERSUS IDFFERENTIAL PRESSURE
DATA OBTAINED USING TEST SPECIMEN S/N 025 WITH FLOWS IN THE
FORWARD (S/N SIDE FACING UPSTREAM) AND REVERSED DIRECTIONS

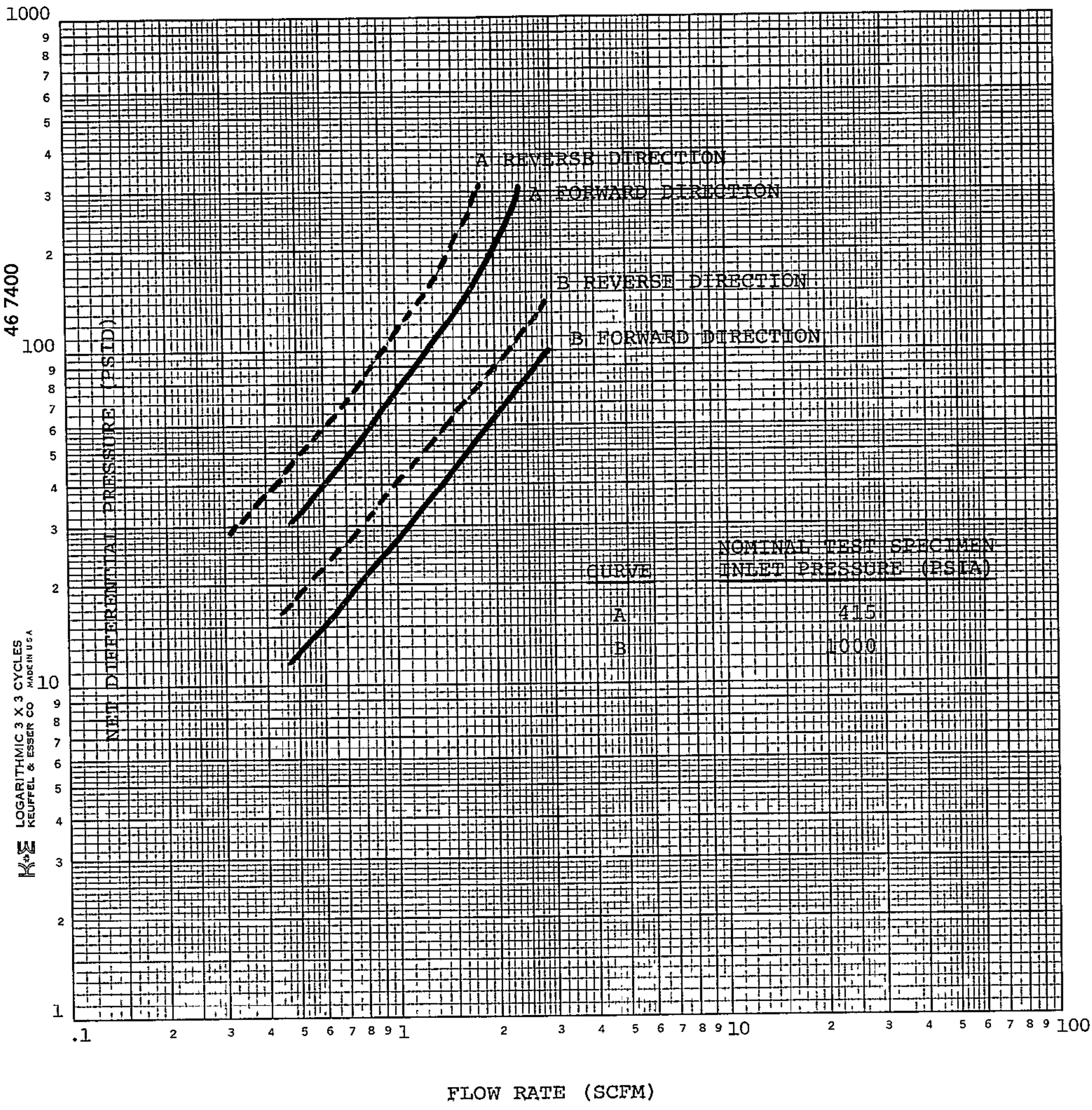
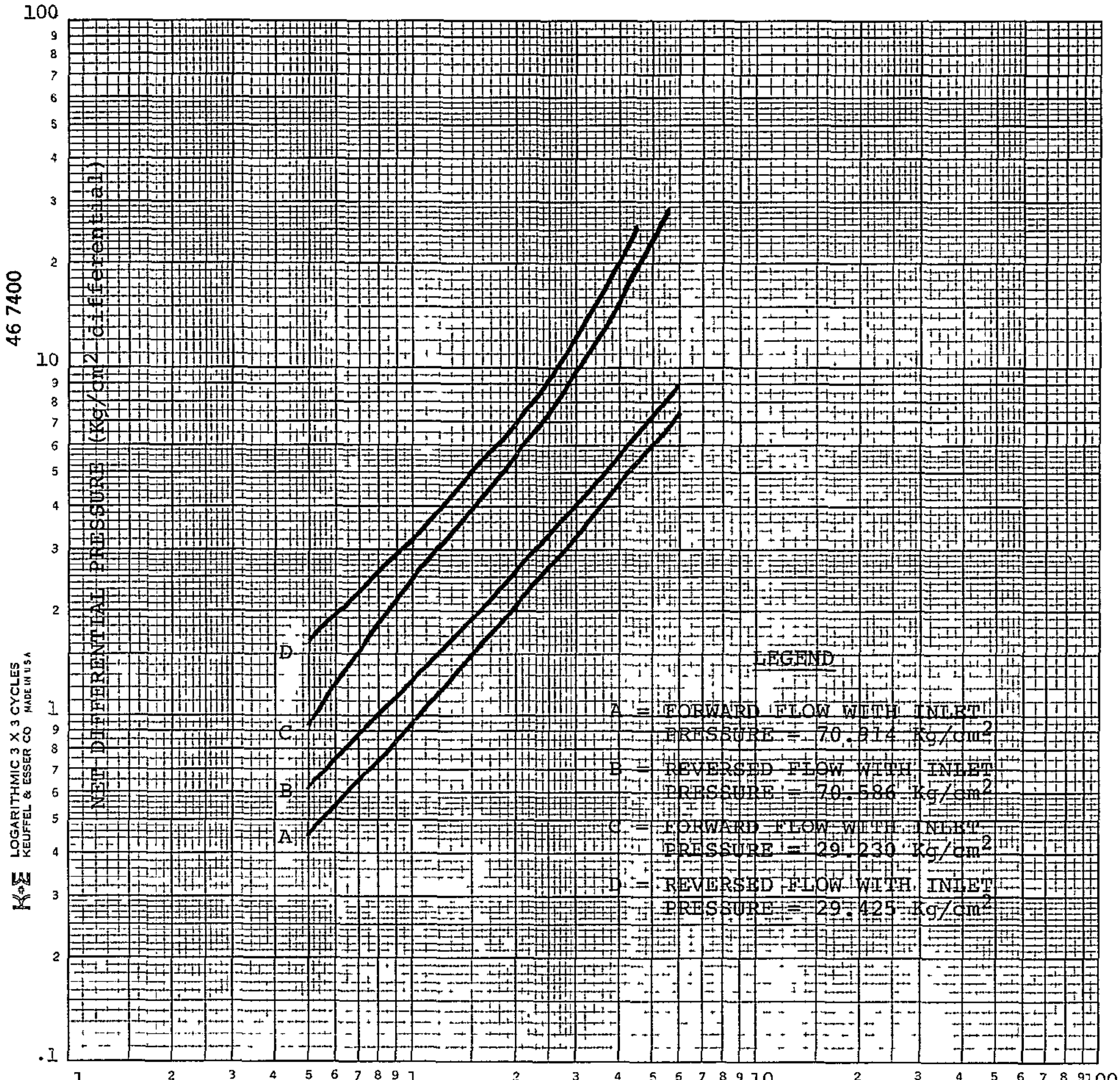


FIGURE 20 Part D

TEST NO. 5

TEST SPECIMEN S/N 028

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE WITH FLOW IN BOTH THE FORWARD (S/N SIDE UPSTREAM) AND REVERSED FLOW DIRECTIONS



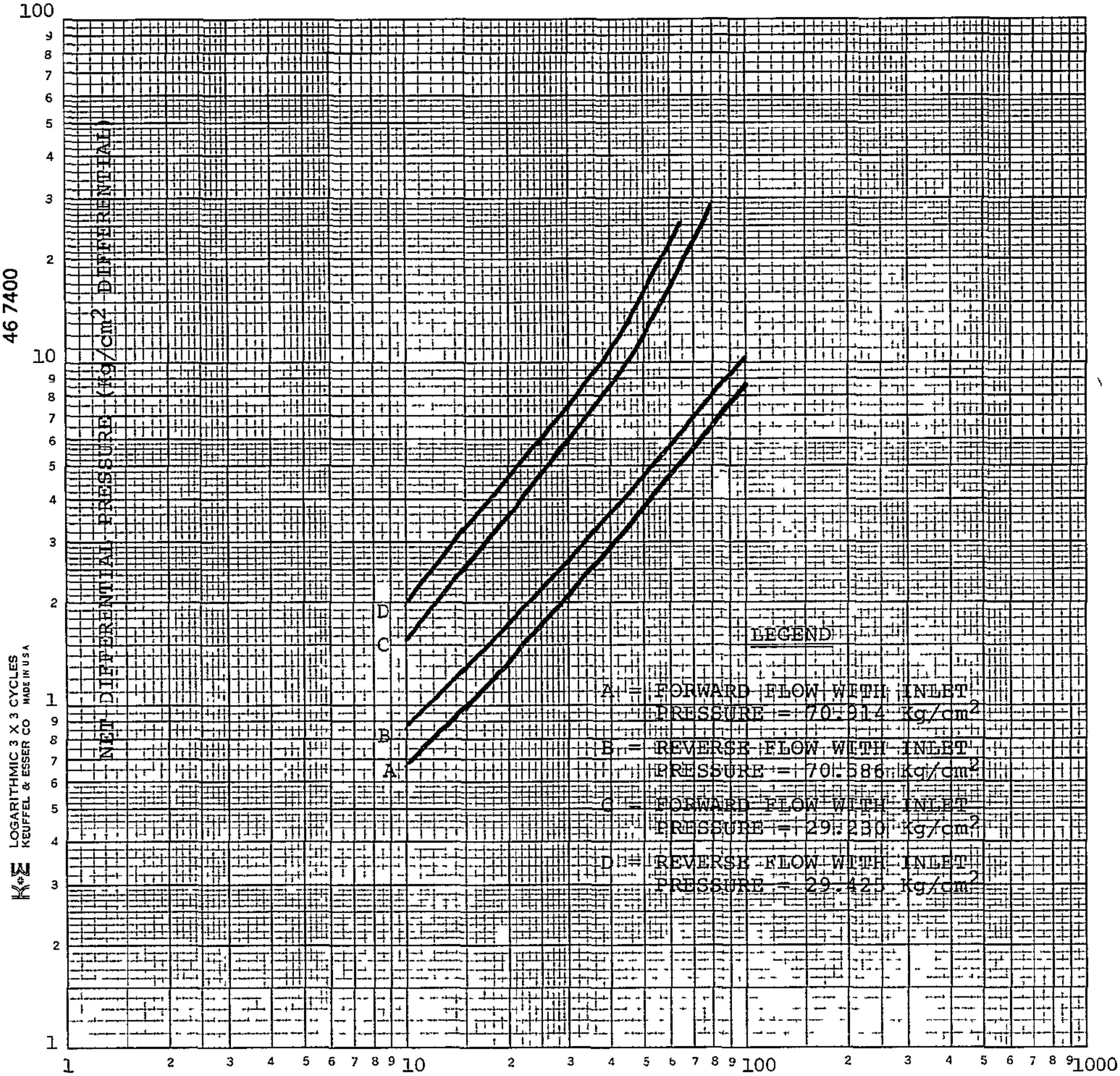
FLOW RATE (Kg GN_2/hr)

FIGURE 21 Part A

TEST NO. 5

TEST SPECIMEN S/N 028

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE WITH FLOW IN BOTH THE FORWARD (S/N SIDE UPSTREAM) AND REVERSED FLOW DIRECTIONS



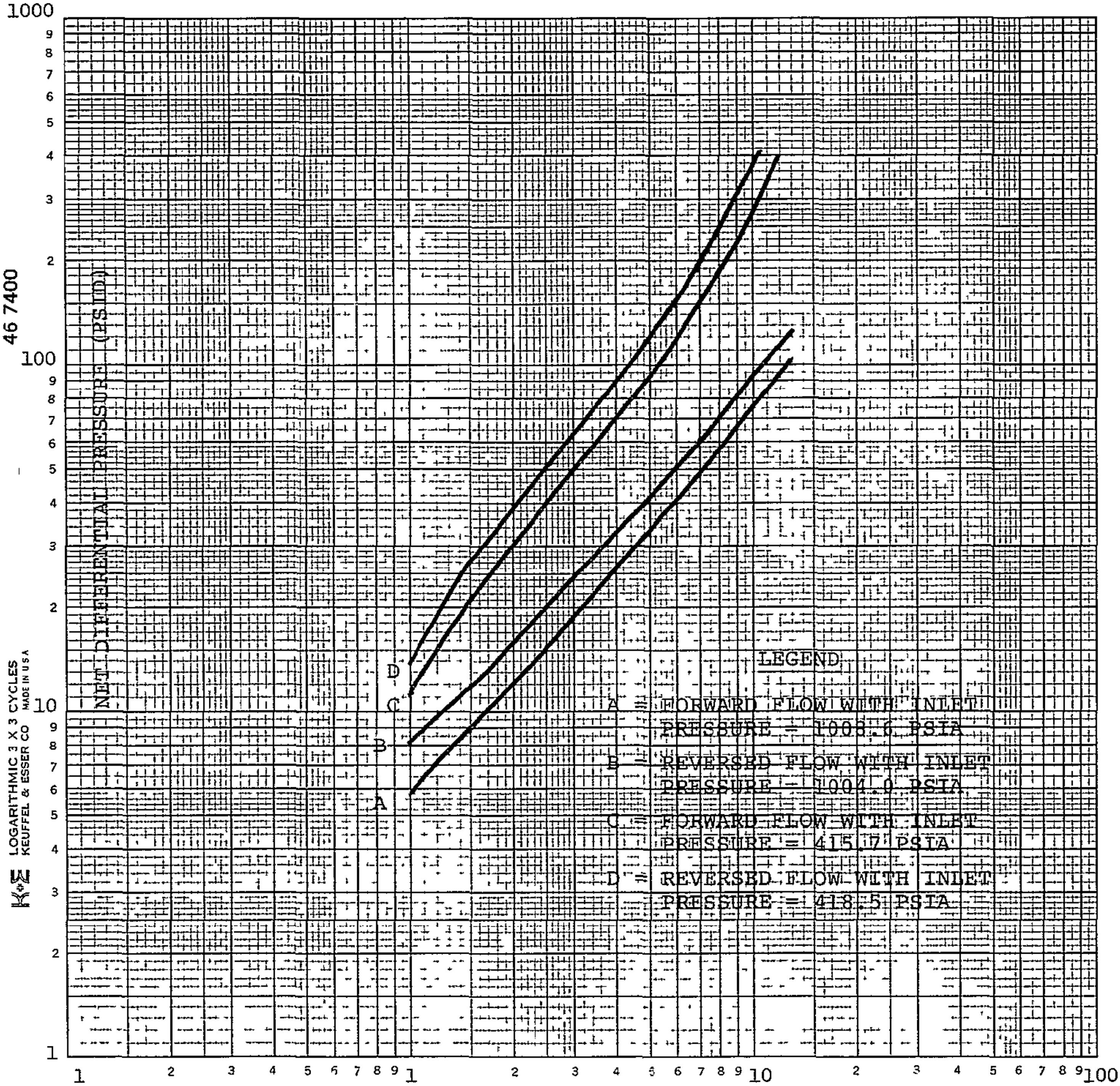
*At 21.1°C (70°F) and 1.033 Kg/cm^2 (14.7 psia)

FIGURE 21 Part B

TEST NO. 5

TEST SPECIMEN S/N 028

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE WITH FLOW IN BOTH THE FORWARD (S/N SIDE UPSTREAM) AND REVERSED FLOW DIRECTIONS



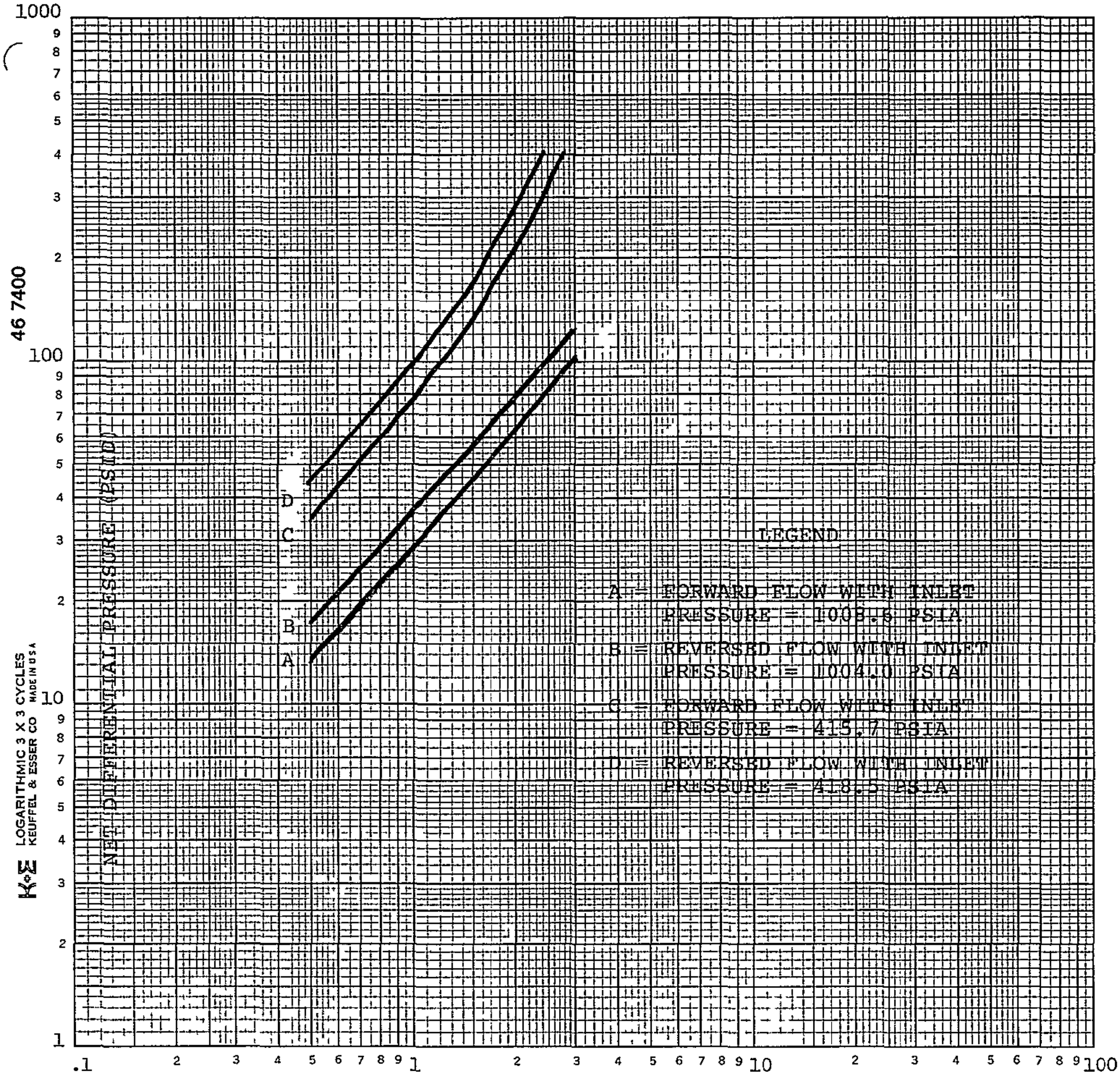
FLOW RATE (lbs GN_2/hr)

FIGURE 21 Part C

TEST NO. 5

TEST SPECIMEN S/N 028

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE WITH FLOW IN BOTH THE FORWARD (S/N SIDE UPSTREAM) AND REVERSED FLOW DIRECTIONS



FLOW RATE (SCFM)

FIGURE 21 Part D

TEST NO. 5

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE CHARACTERISTICS
OF TEST SPECIMEN S/N 023 UNDER VARIOUS CONDITIONS
AT A NOMINAL INLET PRESSURE OF 29.177 Kg/cm^2

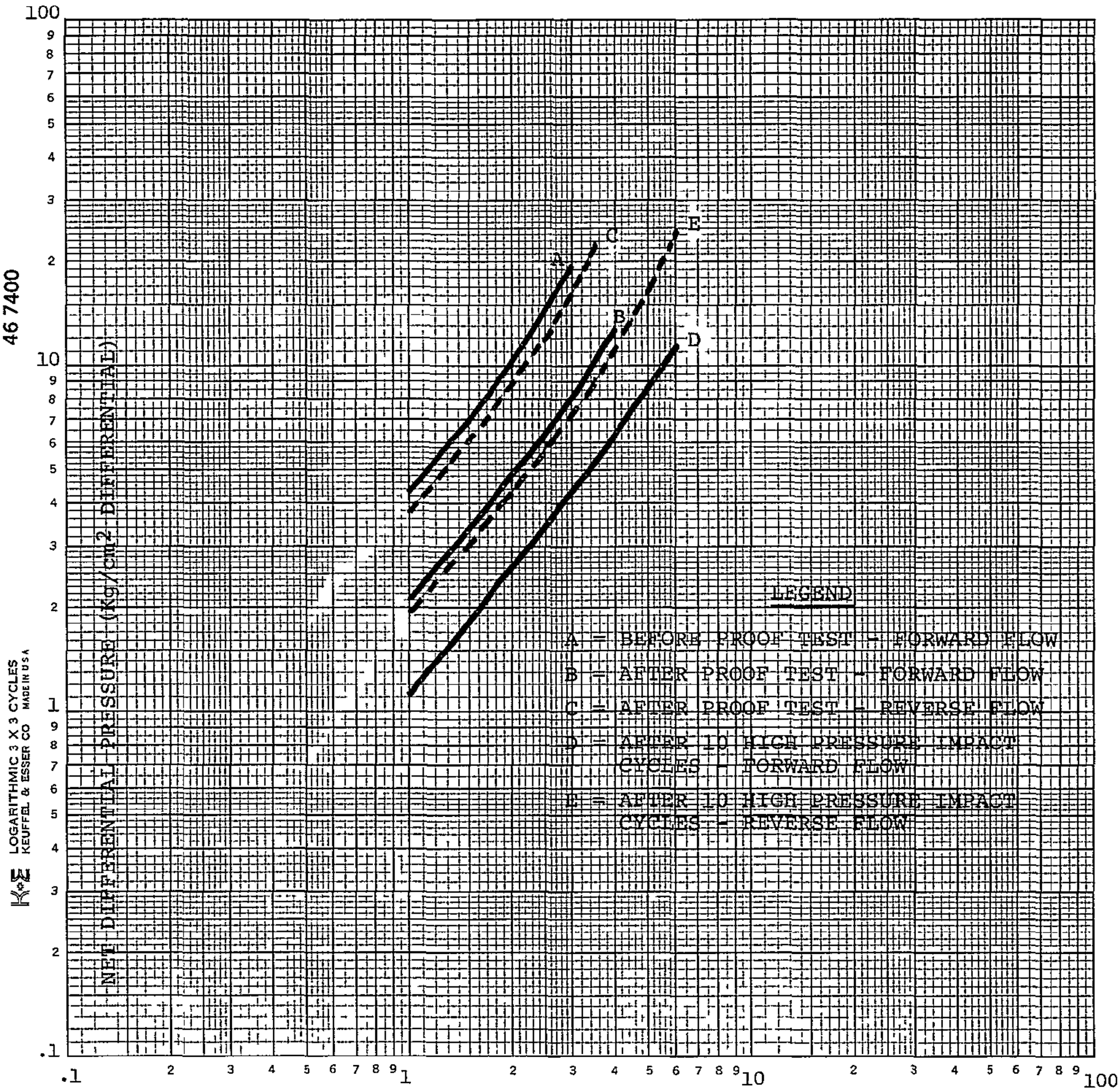
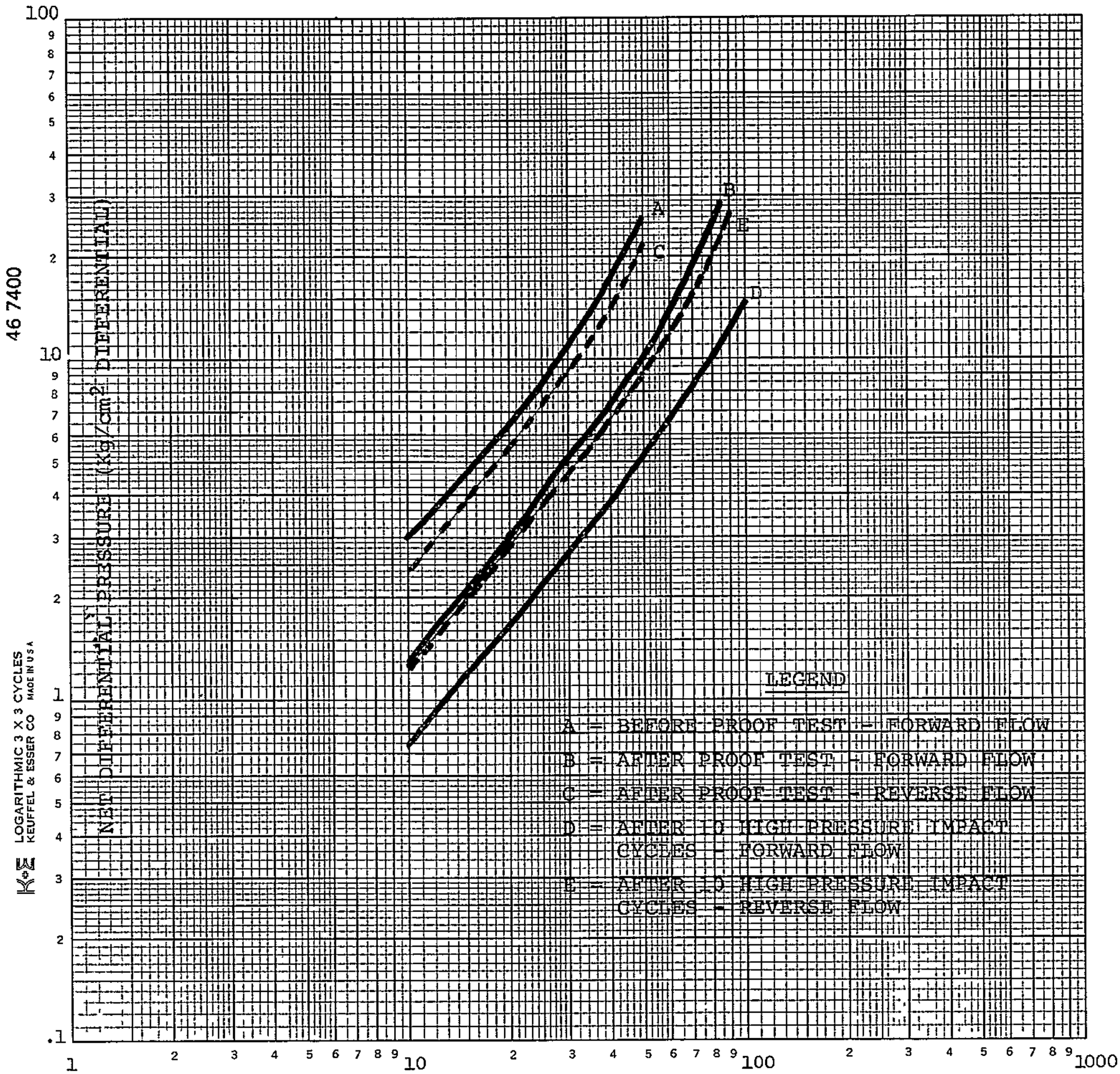


FIGURE 22 Part A

TEST NO. 5

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE CHARACTERISTICS OF TEST SPECIMEN S/N 023 UNDER VARIOUS CONDITIONS AT A NOMINAL INLET PRESSURE OF 29.177 Kg/cm^2



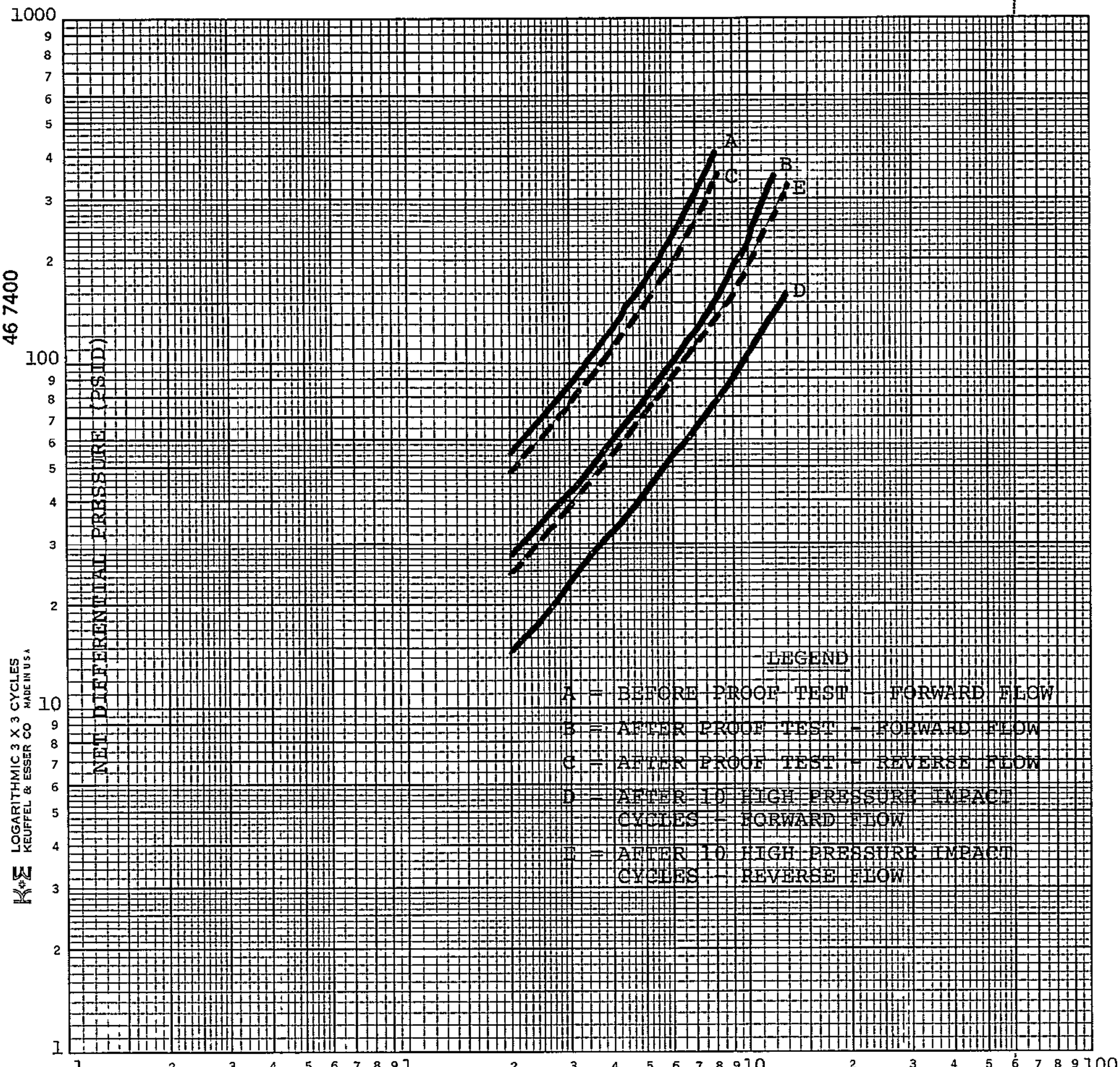
FLOW RATE (liters* GN_2/min)

*At 21.1°C (70°F) and 1.033 Kg/cm^2 (14.7 psia)

FIGURE 22 Part B

TEST NO. 5

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE CHARACTERISTICS
OF TEST SPECIMEN S/N 023 UNDER VARIOUS CONDITIONS
AT A NOMINAL INLET PRESSURE OF 415 PSIA



FLOW RATE (lbs GN_2/hr)

FIGURE 22 Part C

TEST NO. 5

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE CHARACTERISTICS
OF TEST SPECIMEN S/N 023 UNDER VARIOUS CONDITIONS
AT A NOMINAL INLET PRESSURE OF 415 PSIA

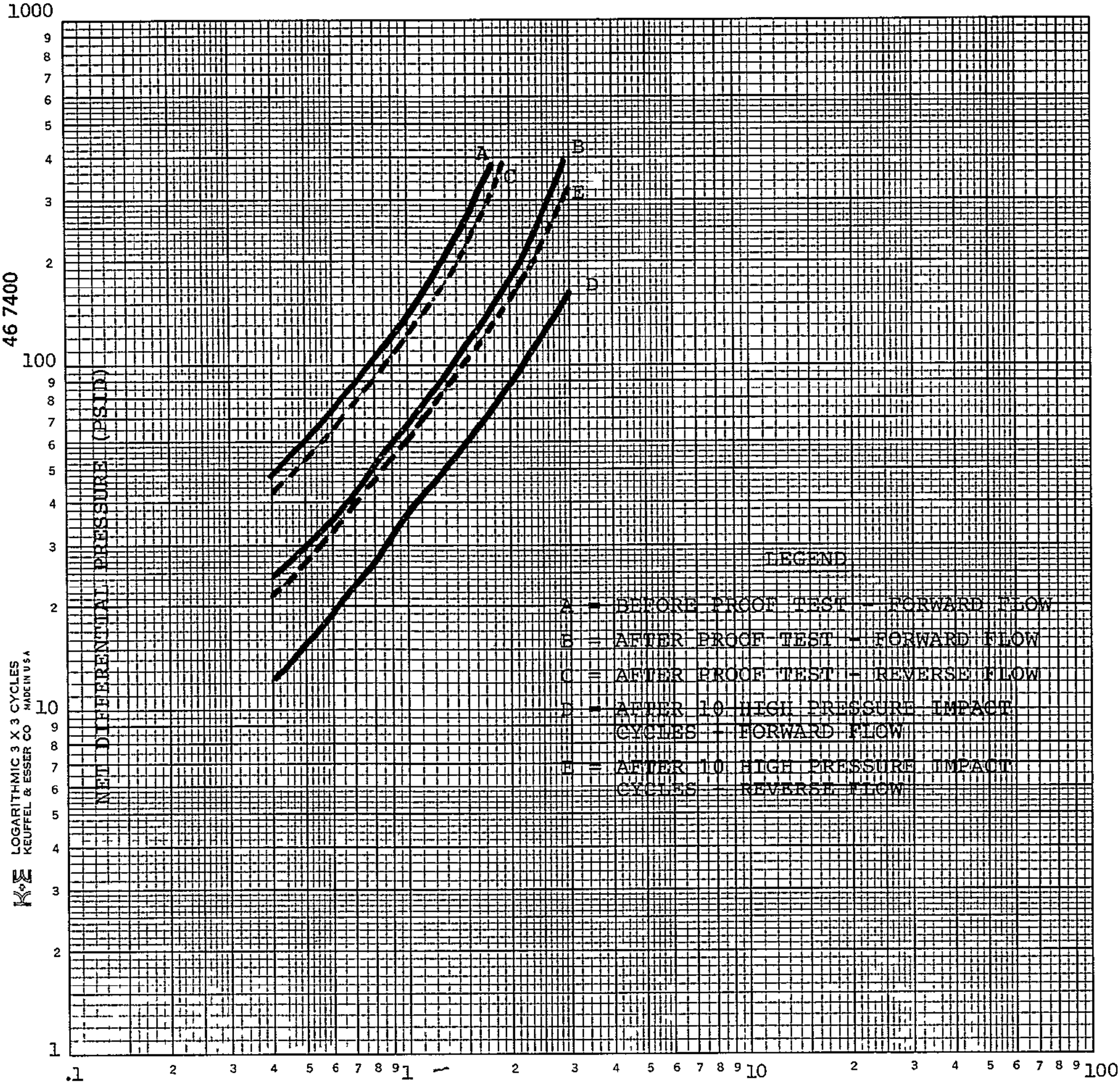
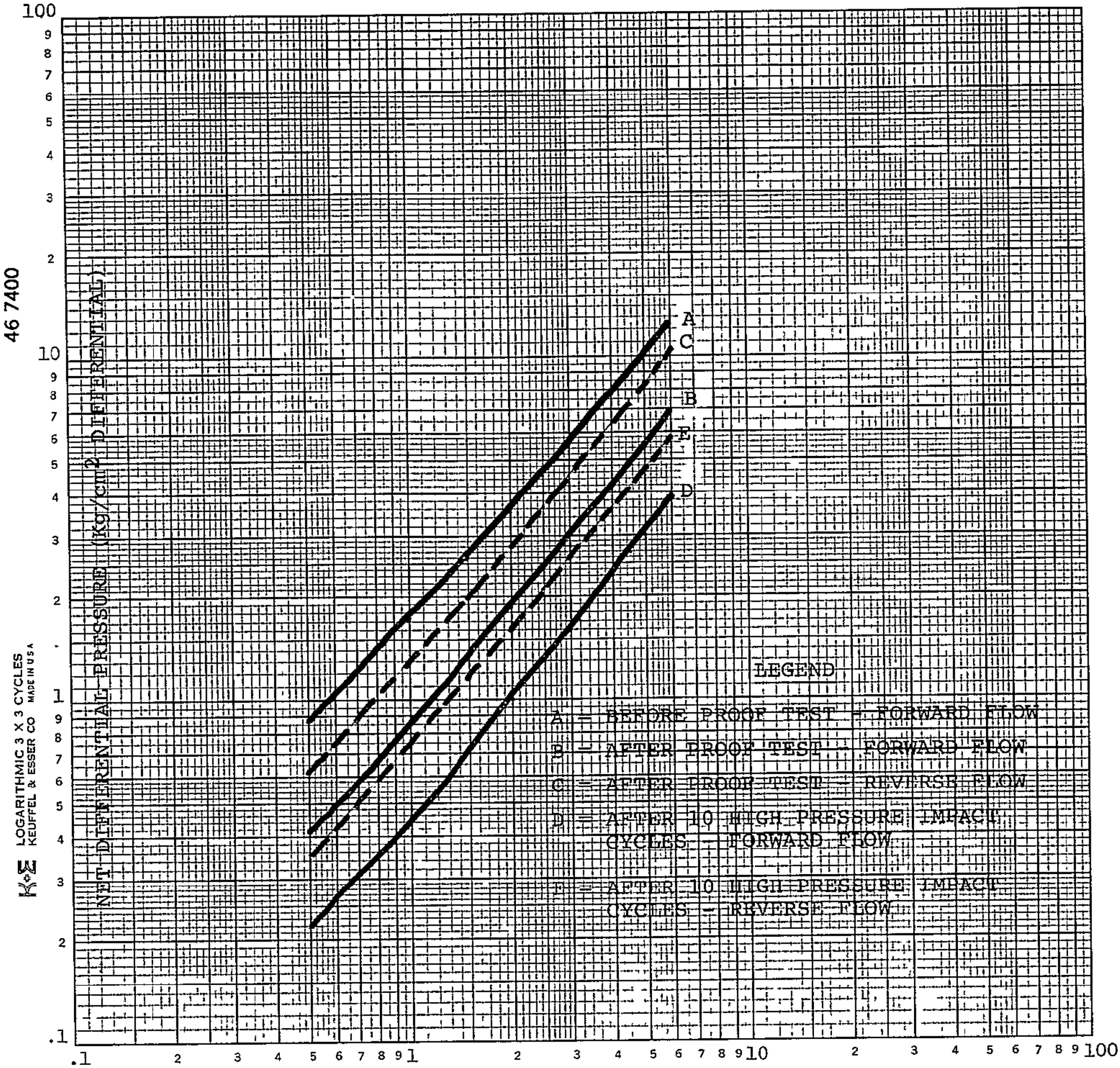


FIGURE 22 Part D

TEST NO. 5

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE CHARACTERISTICS OF TEST SPECIMEN S/N 023 UNDER VARIOUS CONDITIONS AT A NOMINAL INLET PRESSURE OF 70.307 Kg/cm^2

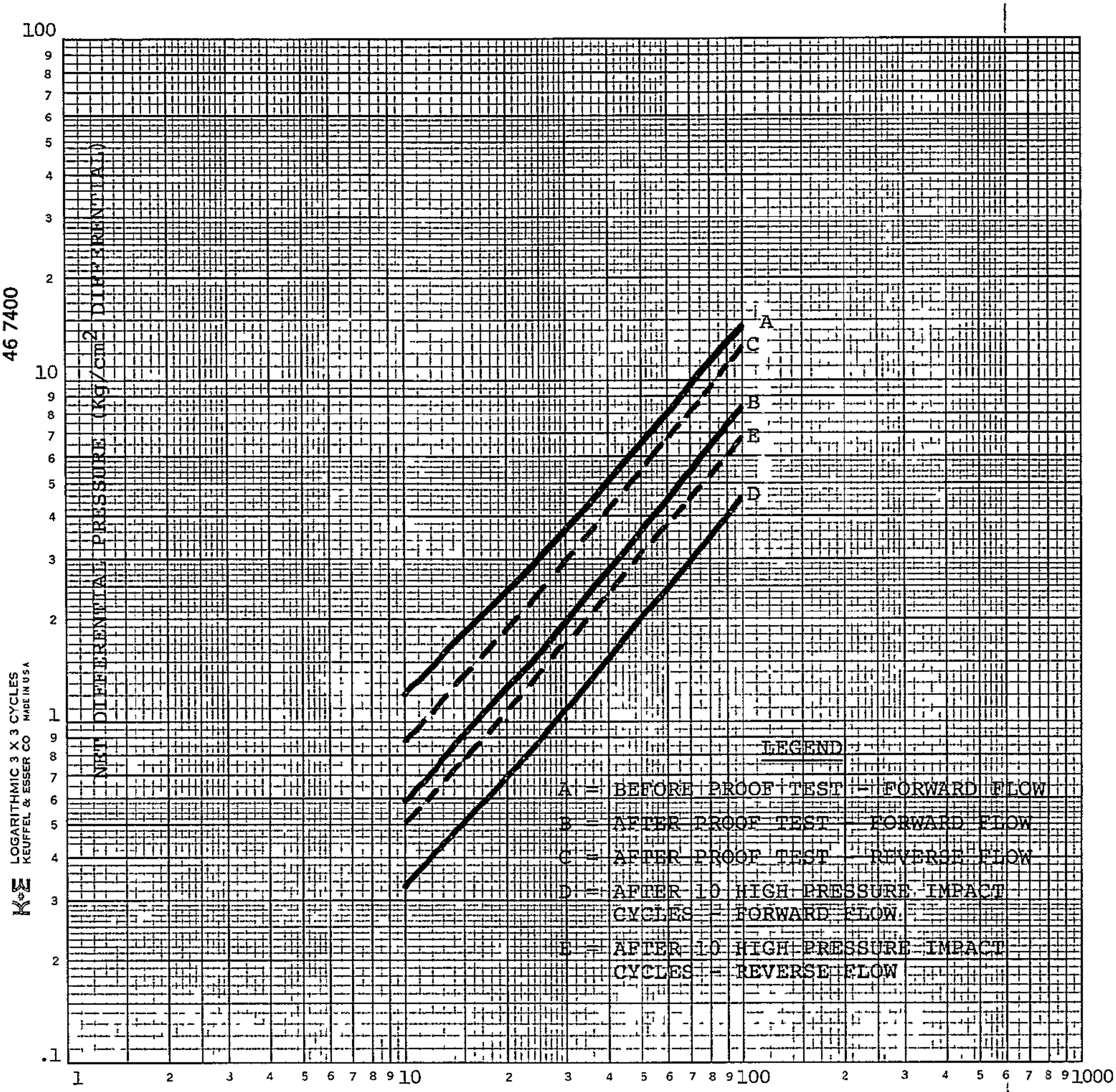


FLOW RATE (Kg GN_2/hr)

FIGURE 23 Part A

TEST NO. 5

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE CHARACTERISTICS
OF TEST SPECIMEN S/N 023 UNDER VARIOUS CONDITIONS
AT A NOMINAL INLET PRESSURE OF 70.307 Kg/cm^2



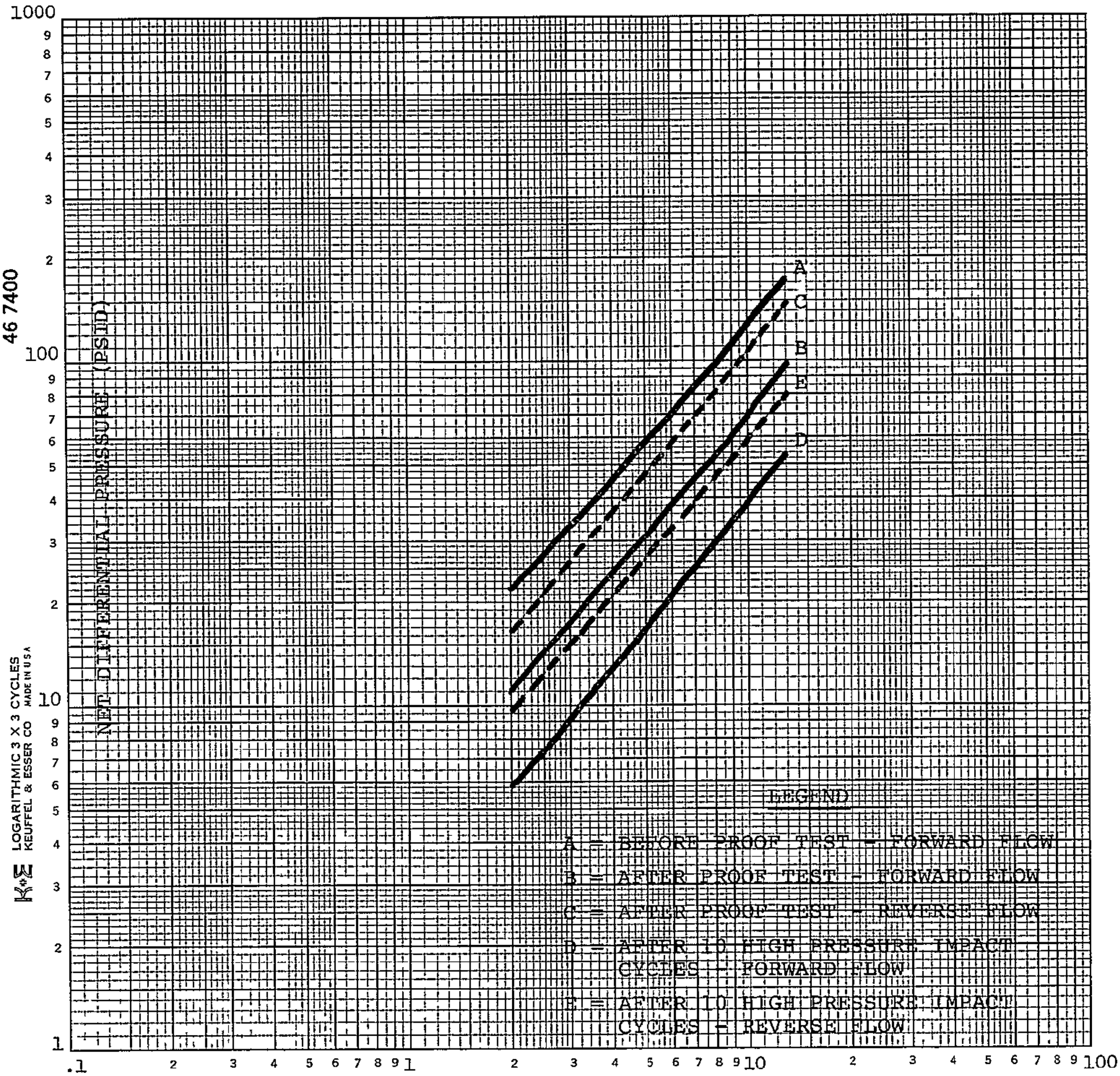
FLOW RATE (liters* GN_2/min)

*At 21.1°C (70°F) and 1.033 Kg/cm^2 (14.7 psia)

FIGURE 23 Part B

TEST NO. 5

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE CHARACTERISTICS
OF TEST SPECIMEN S/N 023 UNDER VARIOUS CONDITIONS
AT A NOMINAL INLET PRESSURE OF 1000 PSIA

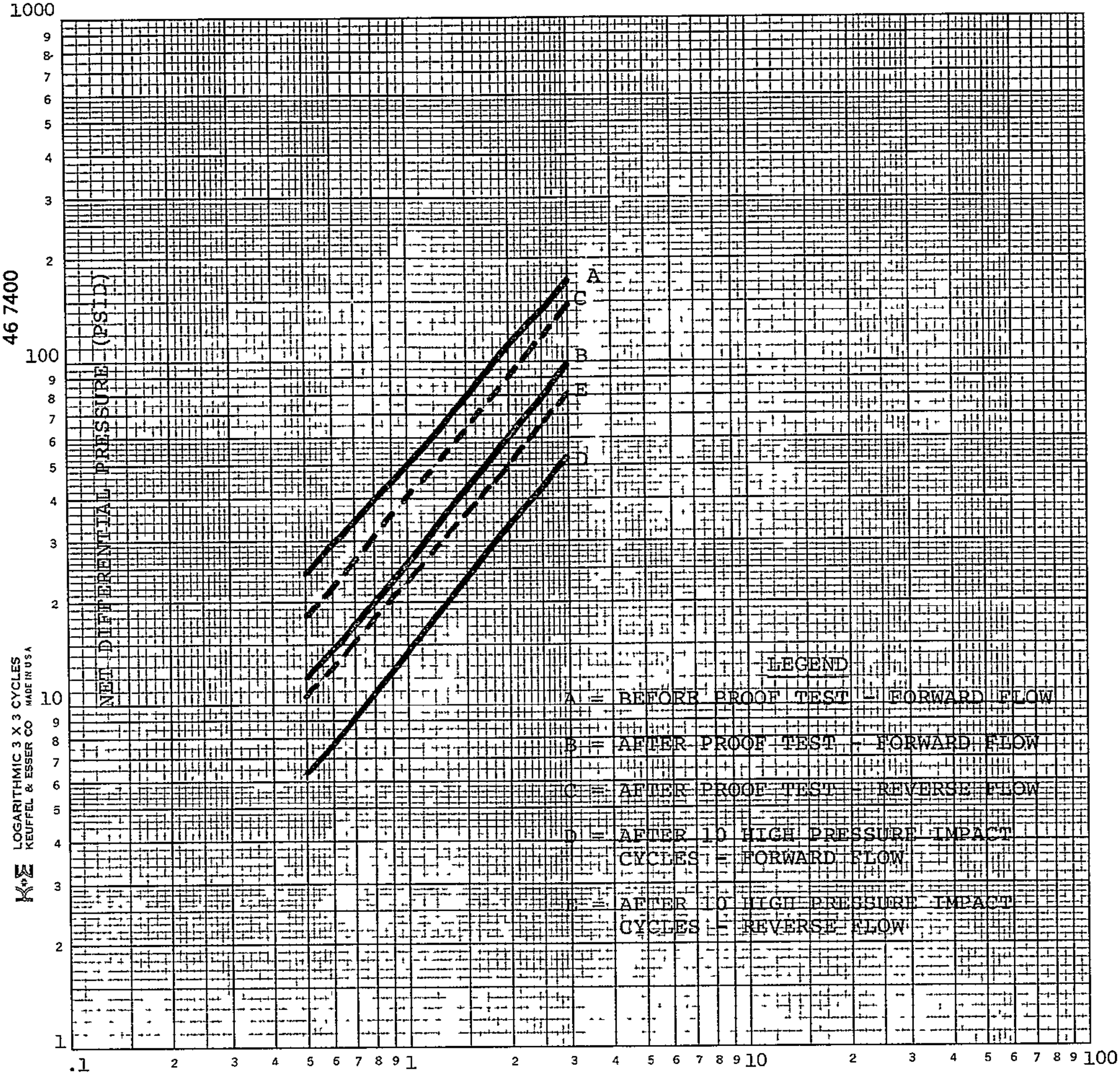


FLOW RATE (lbs GN_2/hr)

FIGURE 23 Part C

TEST NO. 5

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE CHARACTERISTICS
OF TEST SPECIMEN S/N 023 UNDER VARIOUS CONDITIONS
AT A NOMINAL INLET PRESSURE OF 1000 PSIA



FLOW RATE (SCFM)

FIGURE 23 Part D

TEST NO. 5

CLEAN CONDITION - IMPACT/FLOW RATE VERSUS DIFFERENTIAL PRESSURE

USING SPECIMEN S/N 024 WHICH WAS NOT PROOF-PRESSURE-TESTED

INFLUENCE OF 80 HIGH PRESSURE (10,000 PSIA [703.07 Kg/cm^2] NOMINAL GN_2 IMPACT CYCLES ON THE FLOW RATE VERSUS DIFFERENTIAL PRESSURE CHARACTERISTICS OF THE TEST SPECIMEN

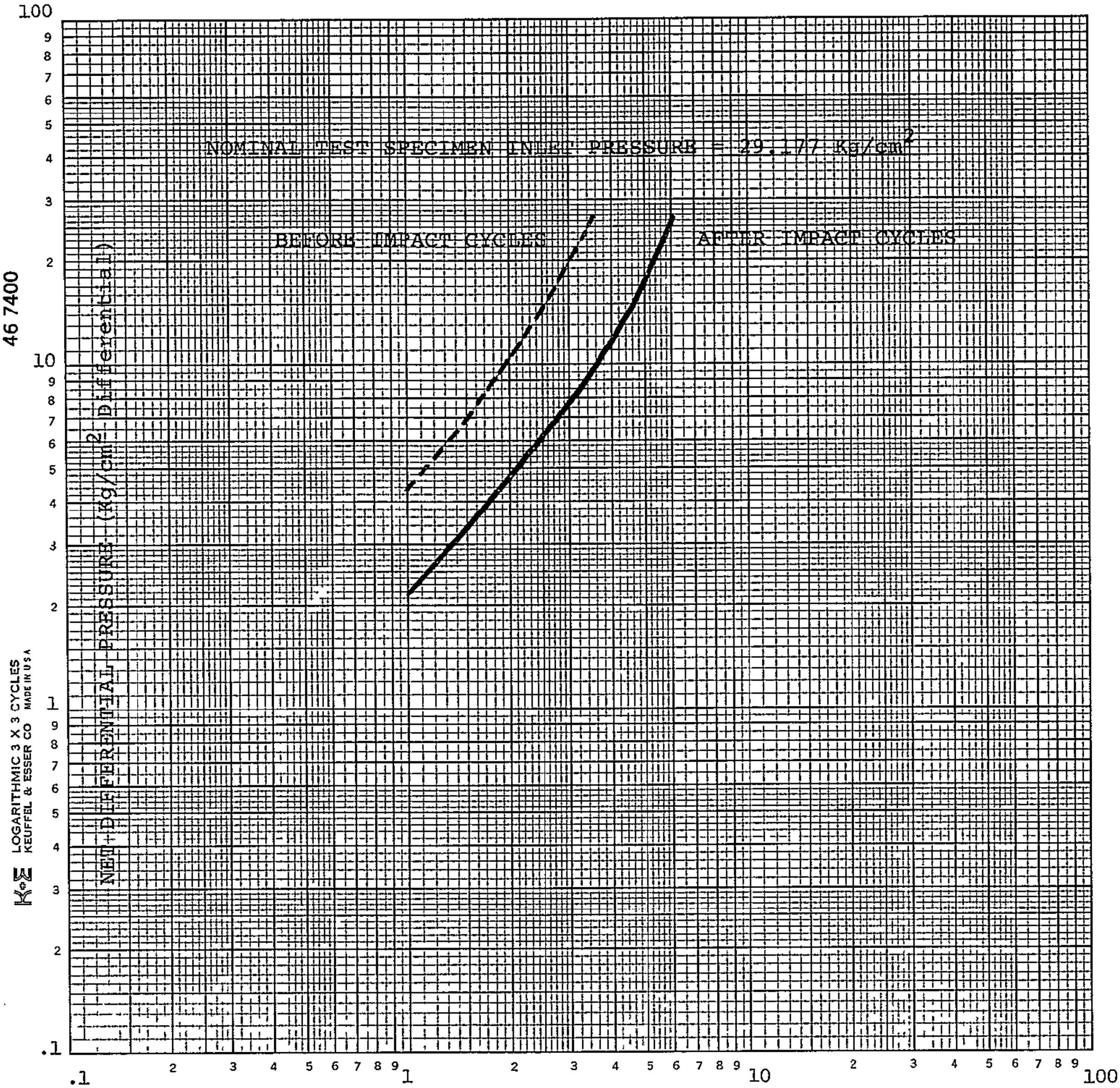


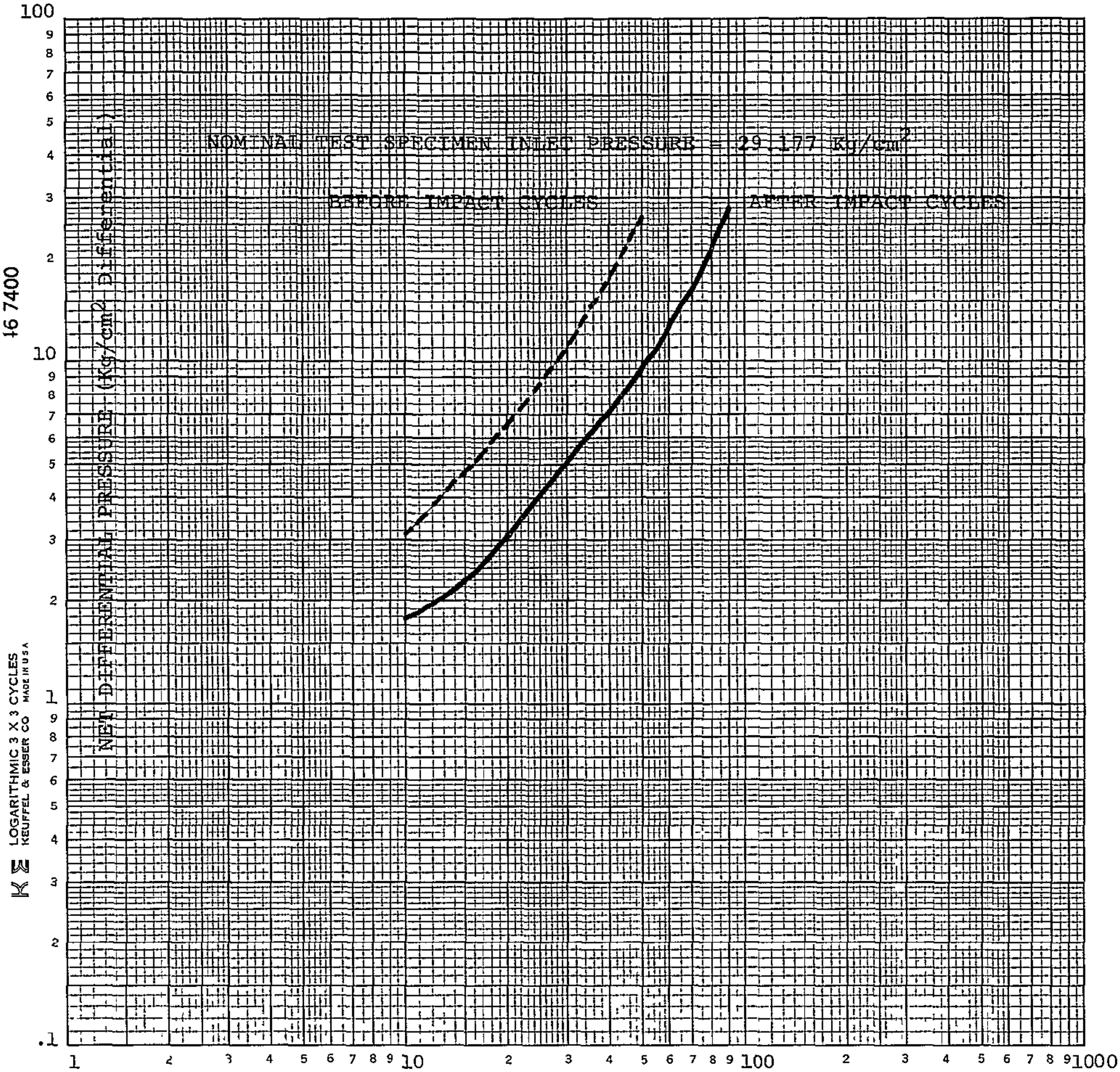
FIGURE 24 Part A

TEST NO. 5

CLEAN CONDITION - IMPACT/FLOW RATE VERSUS DIFFERENTIAL PRESSURE

USING SPECIMEN S/N 024 WHICH WAS NOT PROOF-PRESSURE-TESTED

INFLUENCE OF 80 HIGH PRESSURE (10,000 PSIA [703.07 Kg/cm^2] NOMINAL GN_2 IMPACT CYCLES ON THE FLOW RATE VERSUS DIFFERENTIAL PRESSURE CHARACTERISTICS OF THE TEST SPECIMEN



FLOW RATE (liters* GN_2/min)

*At 21.1°C (70°F) and 1.033 Kg/cm^2 (14.7 psia)

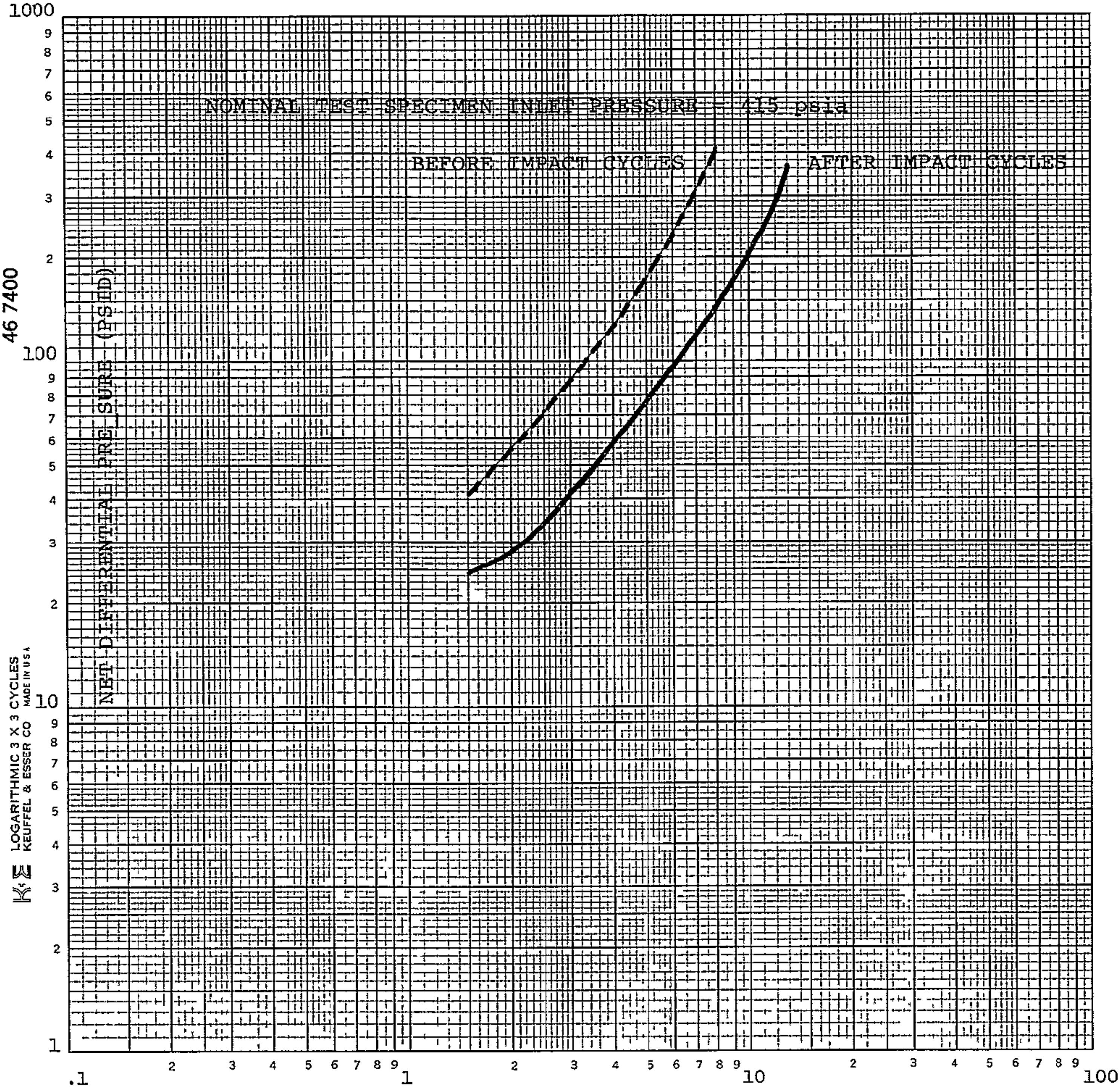
FIGURE 24 Part B

TEST NO. 5

CLEAN CONDITION - IMPACT/FLOW RATE VERSUS DIFFERENTIAL PRESSURE

USING SPECIMEN S/N 024 WHICH WAS NOT PROOF-PRESSURE-TESTED

INFLUENCE OF 80 HIGH PRESSURE (10,000 PSIA [703.07 Kg/cm^2] NOMINAL GN_2 IMPACT CYCLES ON THE FLOW RATE VERSUS DIFFERENTIAL PRESSURE CHARACTERISTICS OF THE TEST SPECIMEN



FLOW RATE (lbs GN_2/hr)

FIGURE 24 Part C

TEST NO. 5

CLEAN CONDITION - IMPACT/FLOW RATE VERSUS DIFFERENTIAL PRESSURE

USING SPECIMEN S/N 024 WHICH WAS NOT PROOF-PRESSURE-TESTED

INFLUENCE OF 80 HIGH PRESSURE (10,000 PSIA [703.07 Kg/cm^2] NOMINAL GN_2 IMPACT CYCLES ON THE FLOW RATE VERSUS DIFFERENTIAL PRESSURE CHARACTERISTICS OF THE TEST SPECIMEN

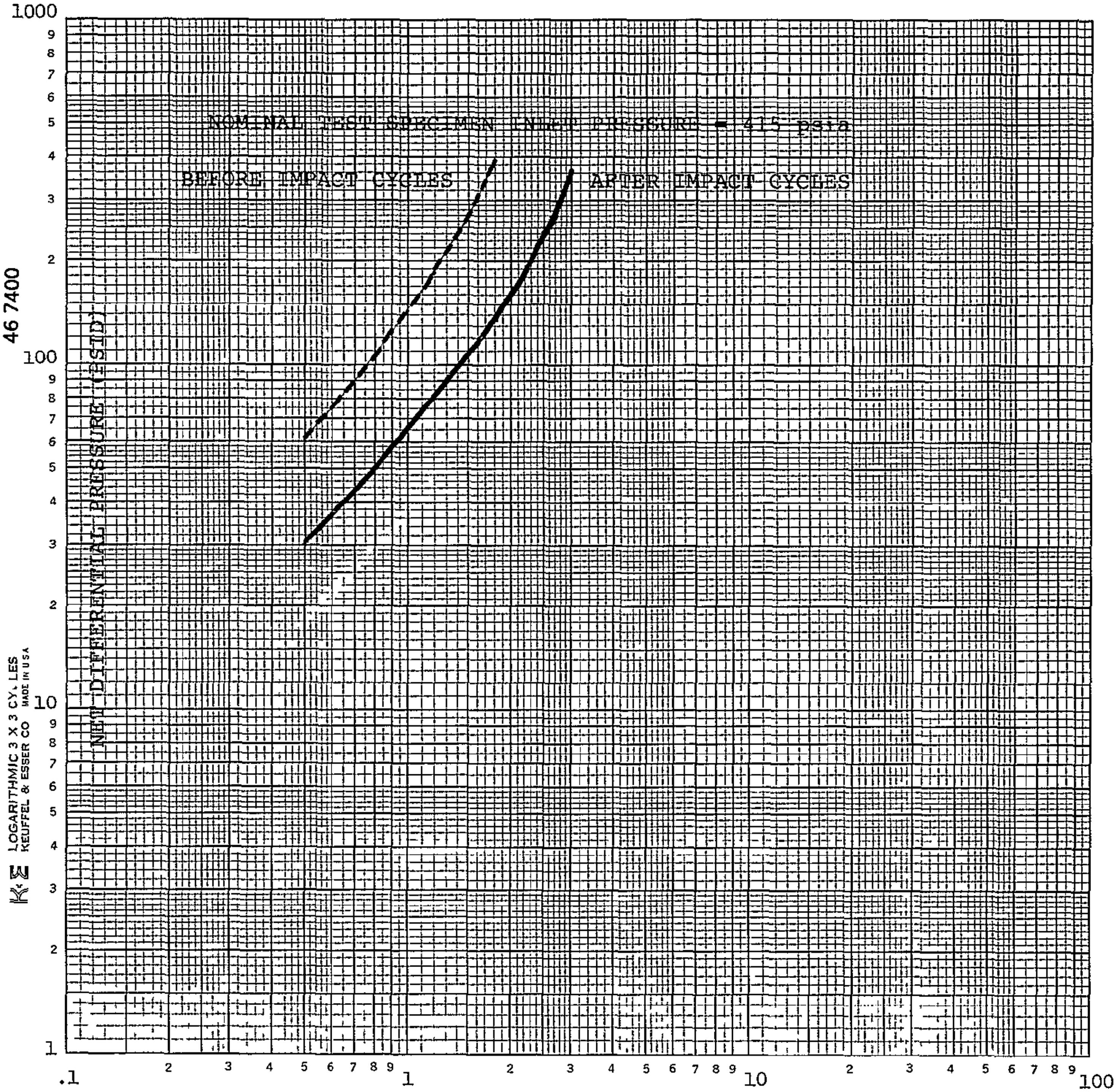


FIGURE 24 Part D

TEST NO. 5

CLEAN CONDITION - IMPACT/FLOW RATE VERSUS DIFFERENTIAL PRESSURE

USING SPECIMEN S/N 024 WHICH WAS NOT PROOF-PRESSURE-TESTED

INFLUENCE OF 80 HIGH PRESSURE (10,000 PSIA [703.07 Kg/cm^2] NOMINAL GN_2 IMPACT CYCLES ON THE FLOW RATE VERSUS DIFFERENTIAL PRESSURE CHARACTERISTICS OF THE TEST SPECIMEN

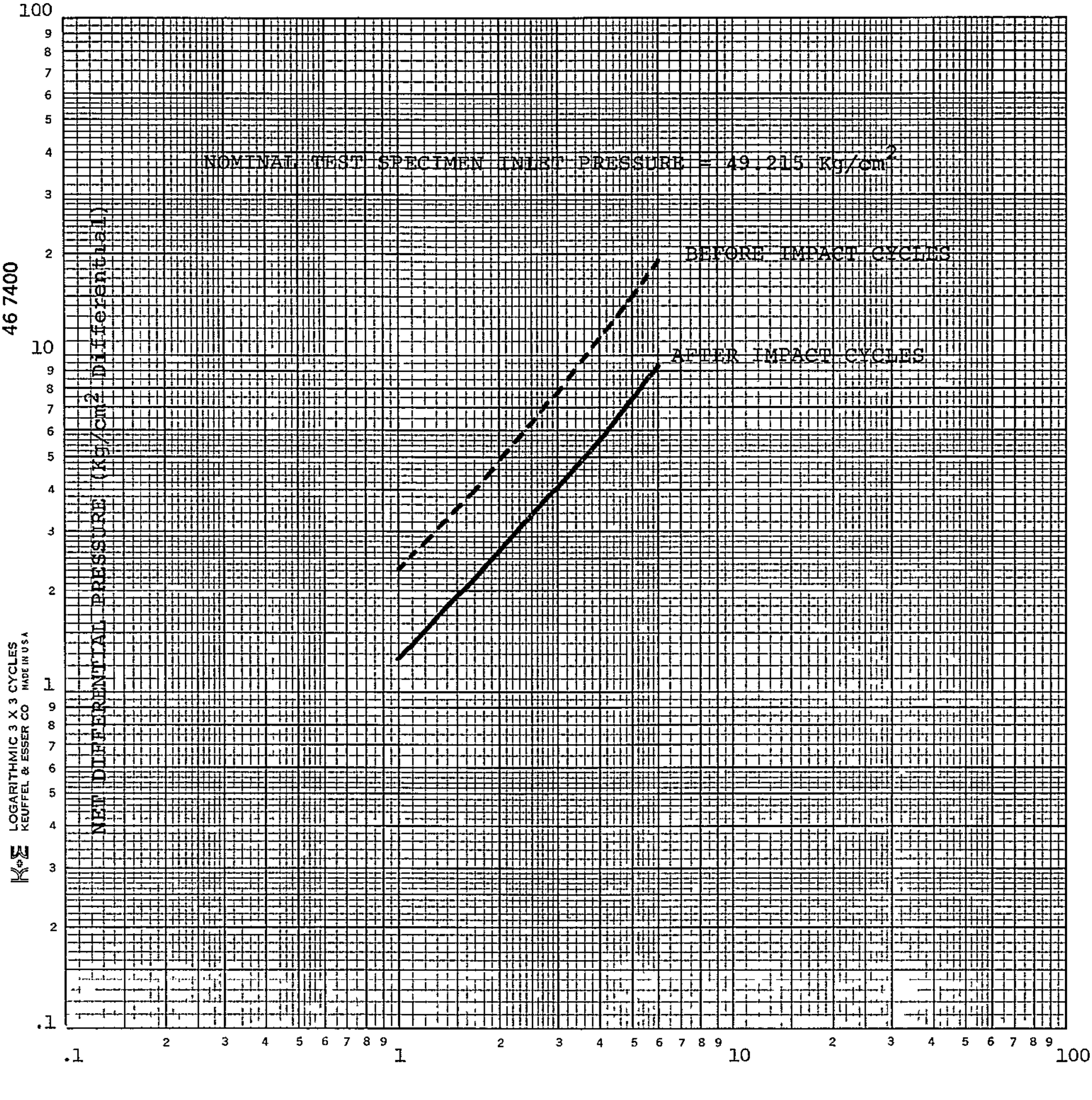


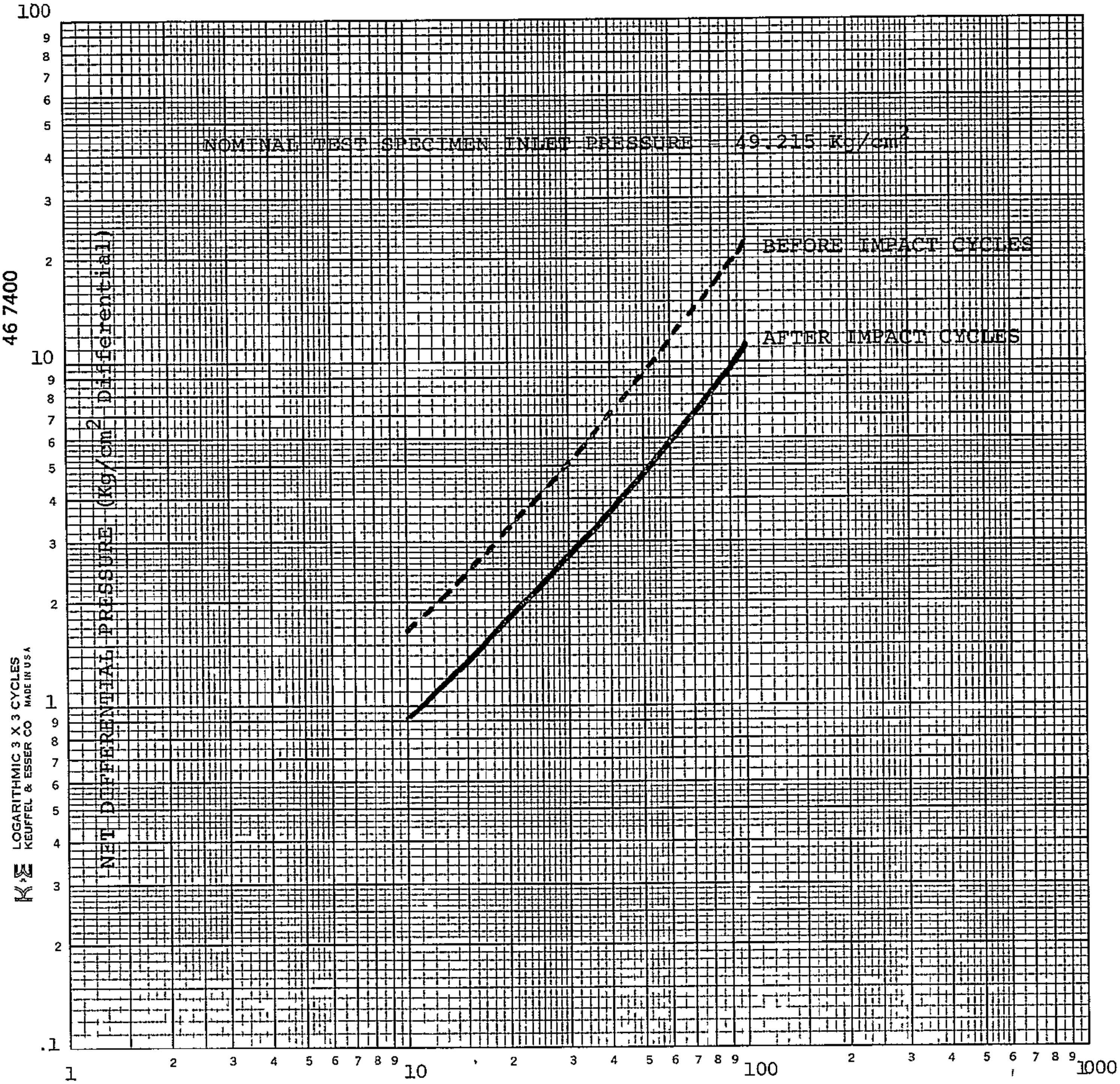
FIGURE 25 Part A

TEST NO. 5

CLEAN CONDITION - IMPACT/FLOW RATE VERSUS DIFFERENTIAL PRESSURE

USING SPECIMEN S/N 024 WHICH WAS NOT PROOF-PRESSURE-TESTED

INFLUENCE OF 80 HIGH PRESSURE (10,000 PSIA [703.07 Kg/cm^2] NOMINAL GN_2 IMPACT CYCLES ON THE FLOW RATE VERSUS DIFFERENTIAL PRESSURE CHARACTERISTICS OF THE TEST SPECIMEN



*At 21.1°C (70°F) and 1.033 Kg/cm^2 (14.7 psia)

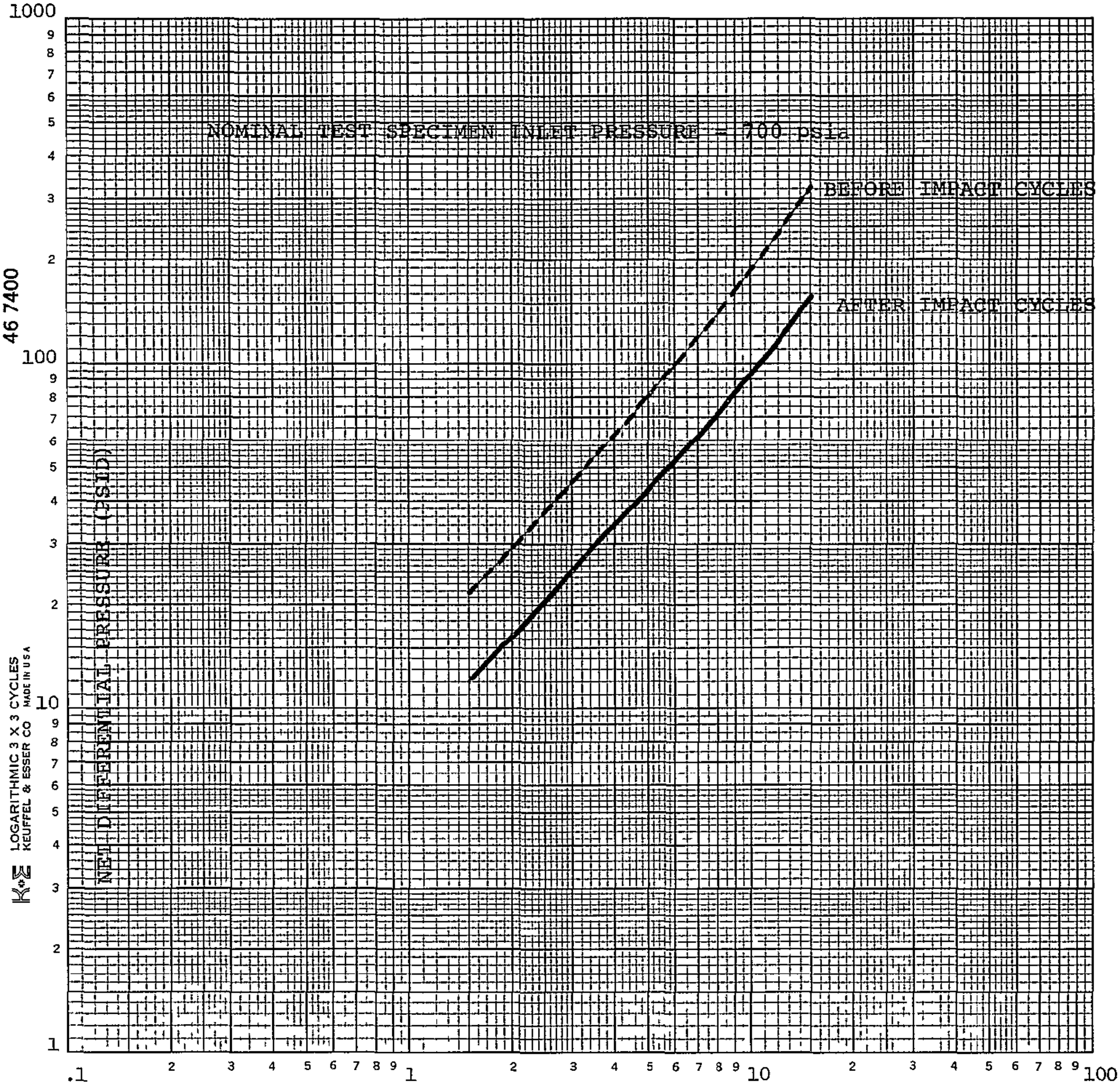
FIGURE 25 Part B

TEST NO. 5

CLEAN CONDITION - IMPACT/FLOW RATE VERSUS DIFFERENTIAL PRESSURE

USING SPECIMEN S/N 024 WHICH WAS NOT PROOF-PRESSURE-TESTED

INFLUENCE OF 80 HIGH PRESSURE (10,000 PSIA [703.07 Kg/cm^2] NOMINAL GN_2 IMPACT CYCLES ON THE FLOW RATE VERSUS DIFFERENTIAL PRESSURE CHARACTERISTICS OF THE TEST SPECIMEN



FLOW RATE (lbs GN_2/hr)

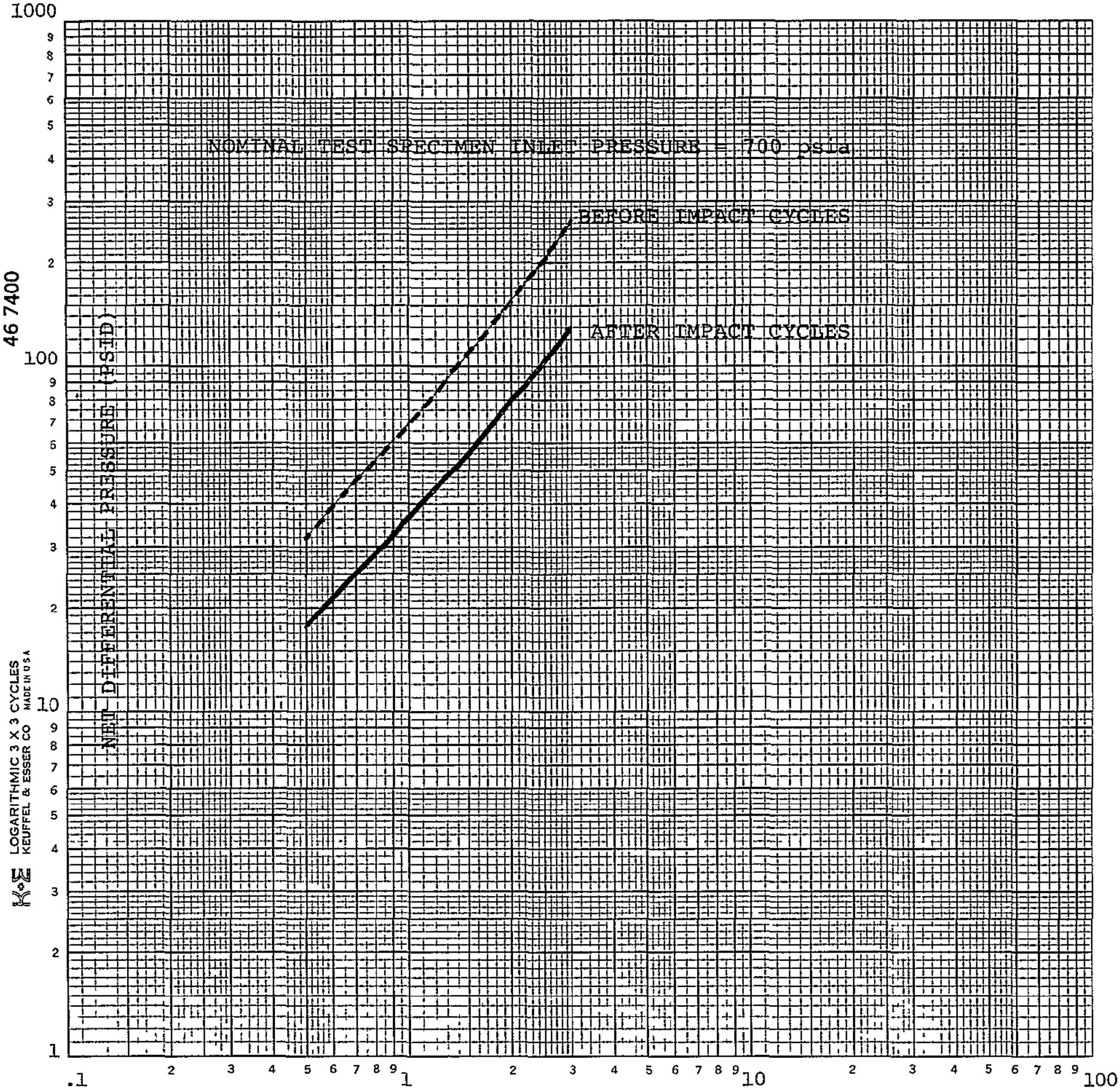
FIGURE 25 Part C

TEST NO. 5

CLEAN CONDITION - IMPACT/FLOW RATE VERSUS DIFFERENTIAL PRESSURE

USING SPECIMEN S/N 024 WHICH WAS NOT PROOF-PRESSURE-TESTED

INFLUENCE OF 80 HIGH PRESSURE (10,000 PSIA [703.07 Kg/cm^2] NOMINAL GN_2 IMPACT CYCLES ON THE FLOW RATE VERSUS DIFFERENTIAL PRESSURE CHARACTERISTICS OF THE TEST SPECIMEN



FLOW RATE (SCFM)

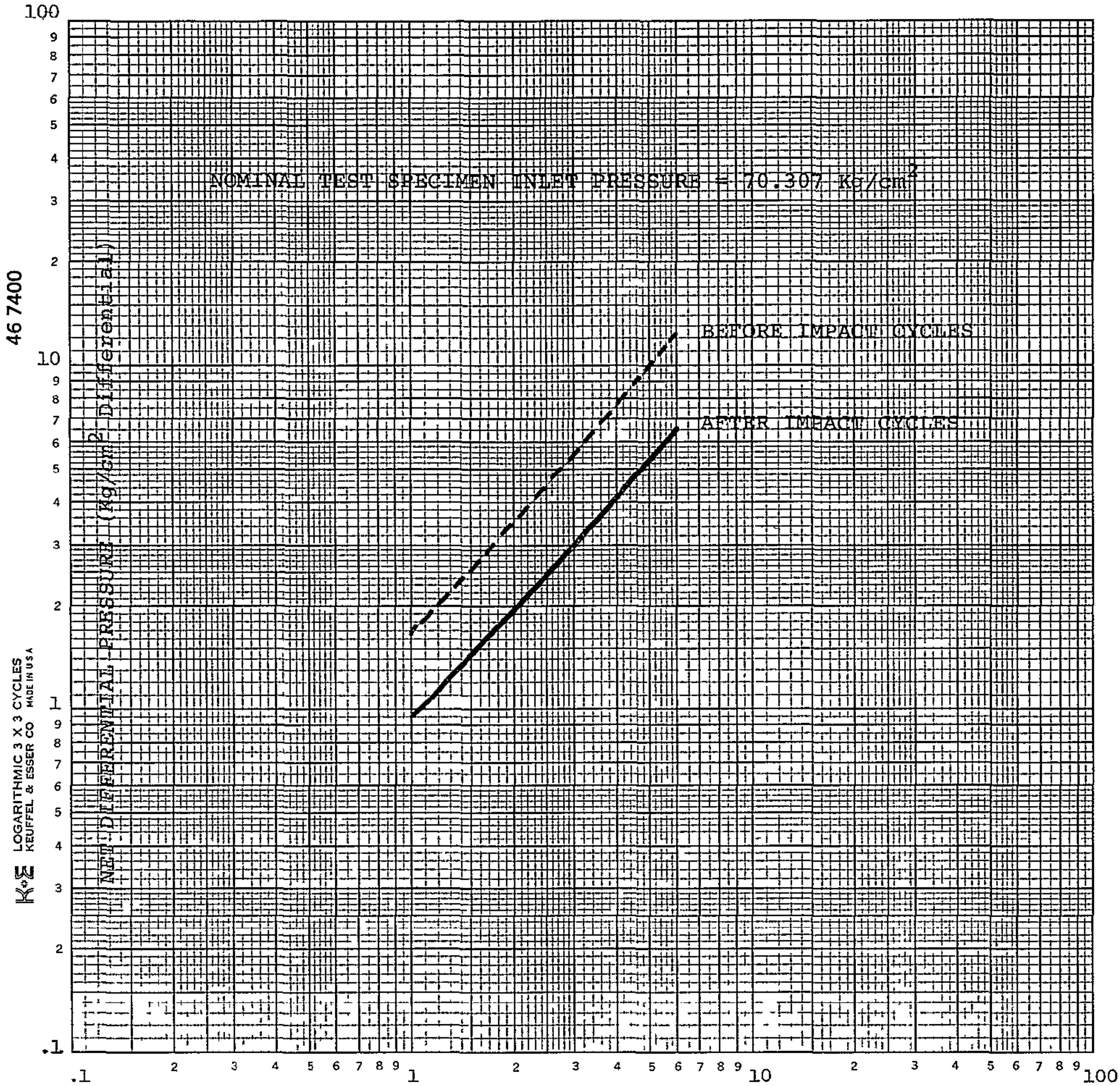
FIGURE 25 Part D

TEST NO. 5

CLEAN CONDITION - IMPACT/FLOW RATE VERSUS DIFFERENTIAL PRESSURE

USING SPECIMEN S/N 024 WHICH WAS NOT PROOF-PRESSURE-TESTED

INFLUENCE OF 80 HIGH PRESSURE (10,000 PSIA [703.07 Kg/cm^2] NOMINAL GN_2 IMPACT CYCLES ON THE FLOW RATE VERSUS DIFFERENTIAL PRESSURE CHARACTERISTICS OF THE TEST SPECIMEN



FLOW RATE (Kg GN_2/hr)

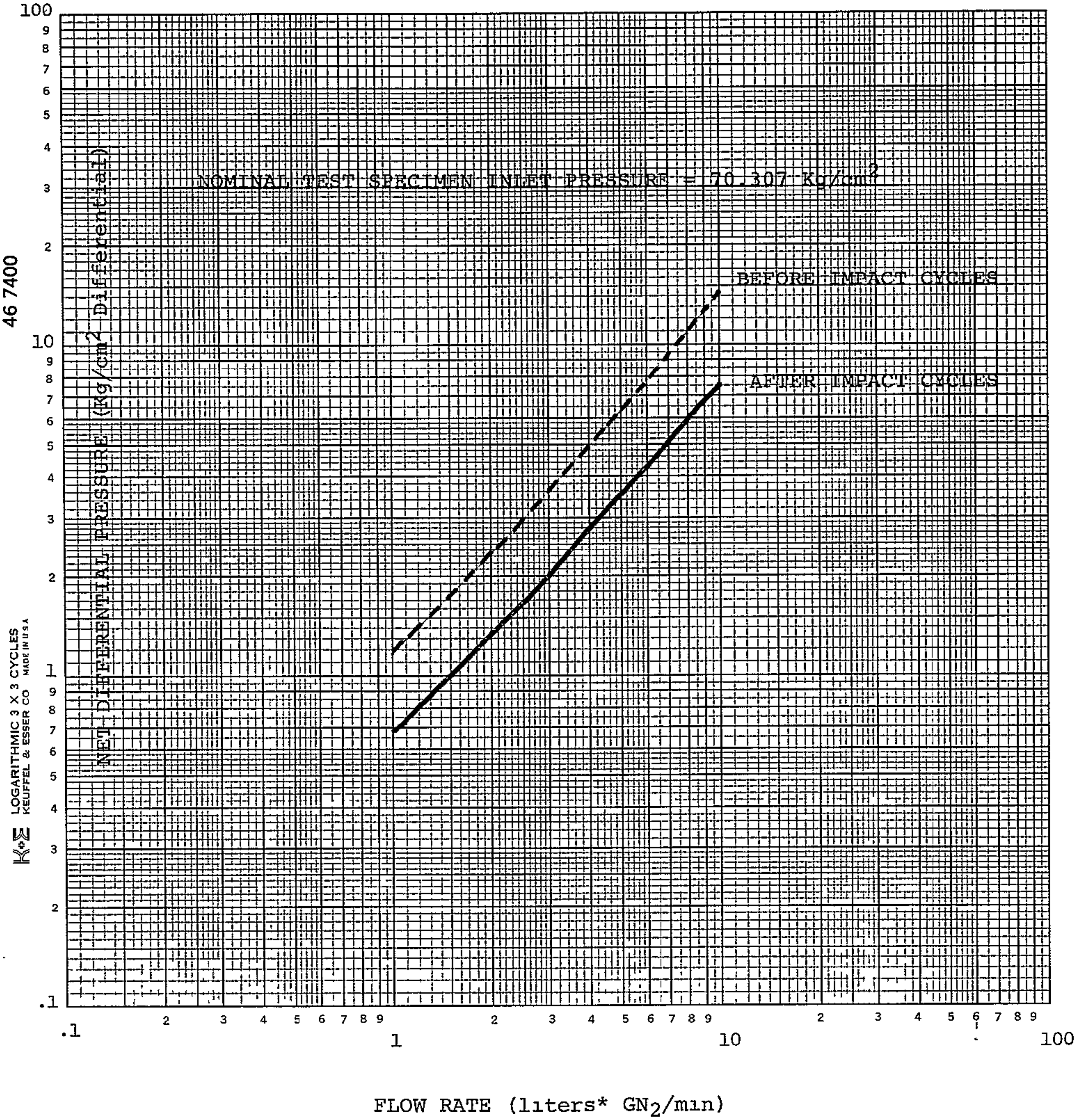
FIGURE 26 Part A

TEST NO. 5

CLEAN CONDITION - IMPACT/FLOW RATE VERSUS DIFFERENTIAL PRESSURE

USING SPECIMEN S/N 024 WHICH WAS NOT PROOF-PRESSURE-TESTED

INFLUENCE OF 80 HIGH PRESSURE (10,000 PSIA [703.07 Kg/cm^2] NOMINAL GN$_2$ IMPACT CYCLES ON THE FLOW RATE VERSUS DIFFERENTIAL PRESSURE CHARACTERISTICS OF THE TEST SPECIMEN



*At 21.1°C (70°F) and 1.033 Kg/cm^2 (14.7 psia)

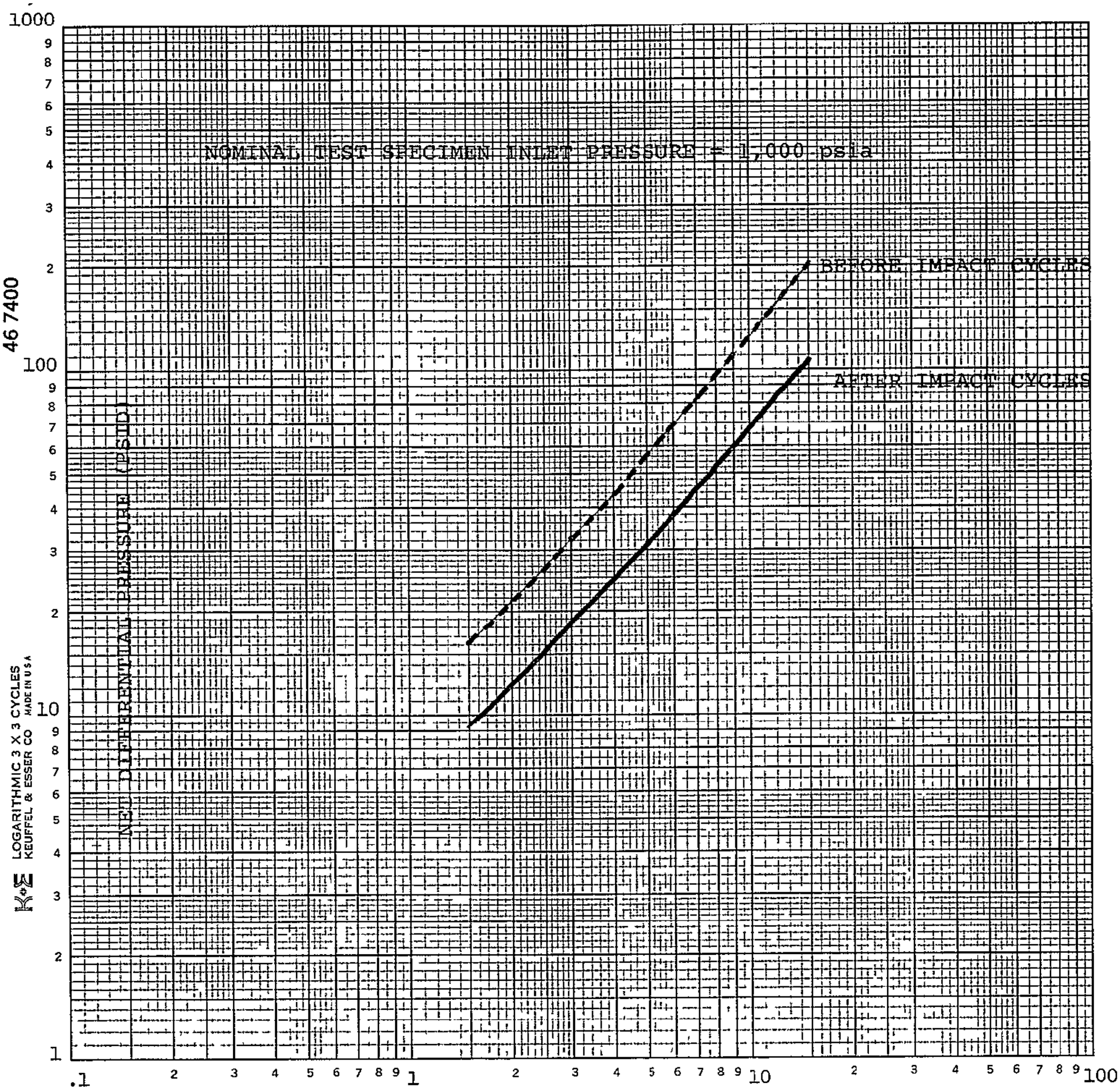
FIGURE 26 Part B

TEST NO. 5

CLEAN CONDITION - IMPACT/FLOW RATE VERSUS DIFFERENTIAL PRESSURE

USING SPECIMEN S/N 024 WHICH WAS NOT PROOF-PRESSURE-TESTED

INFLUENCE OF 80 HIGH PRESSURE (10,000 PSIA [703.07 Kg/cm^2] NOMINAL GN_2 IMPACT CYCLES ON THE FLOW RATE VERSUS DIFFERENTIAL PRESSURE CHARACTERISTICS OF THE TEST SPECIMEN



FLOW RATE (lbs GN_2/hr)

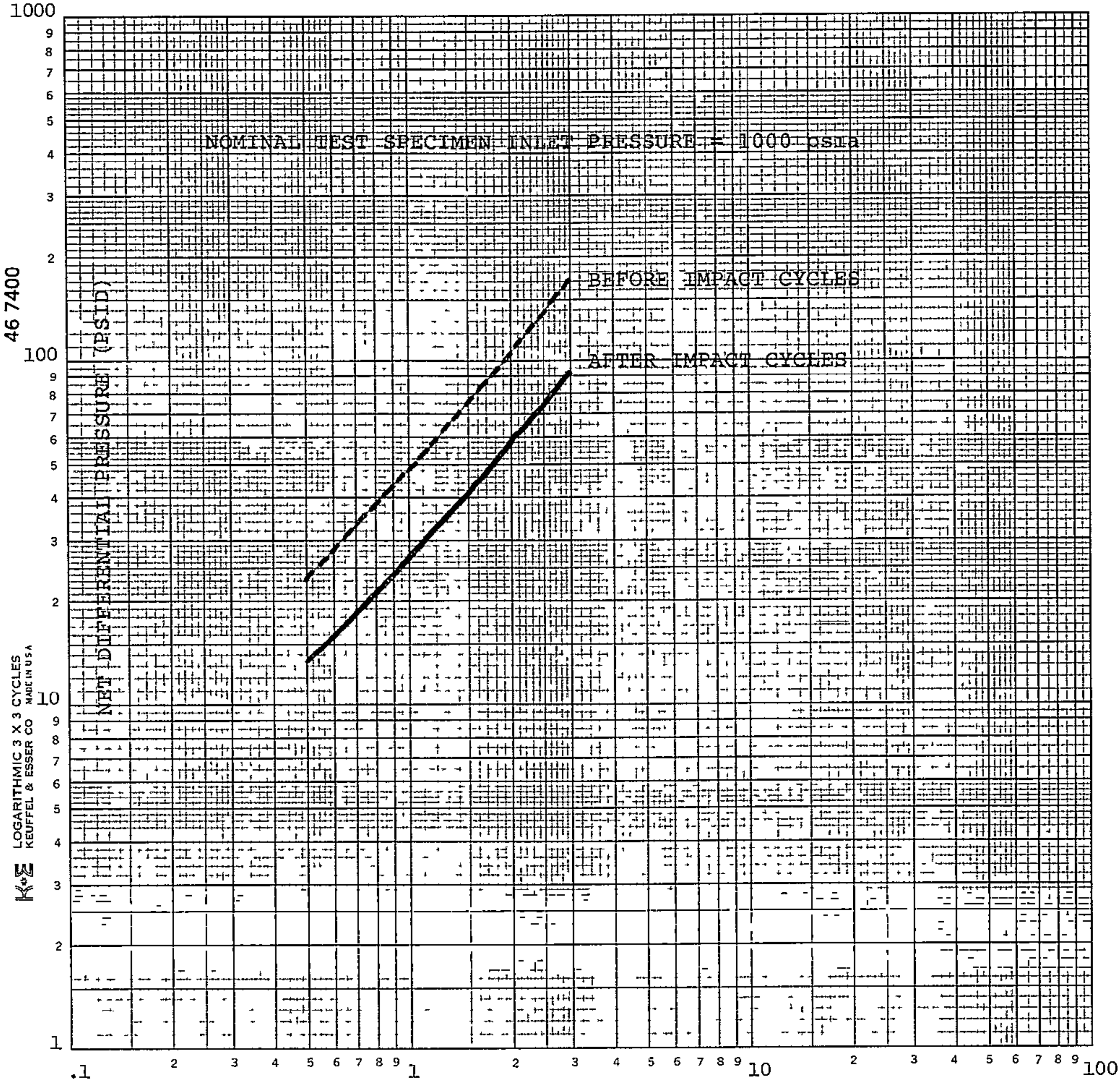
FIGURE 26 Part C

TEST NO. 5

CLEAN CONDITION - IMPACT/FLOW RATE VERSUS DIFFERENTIAL PRESSURE

USING SPECIMEN S/N 024 WHICH WAS NOT PROOF-PRESSURE-TESTED

INFLUENCE OF 80 HIGH PRESSURE (10,000 PSIA [703.07 Kg/cm^2] NOMINAL GN_2 IMPACT CYCLES ON THE FLOW RATE VERSUS DIFFERENTIAL PRESSURE CHARACTERISTICS OF THE TEST SPECIMEN



FLOW RATE (SCFM)

FIGURE 26 Part D

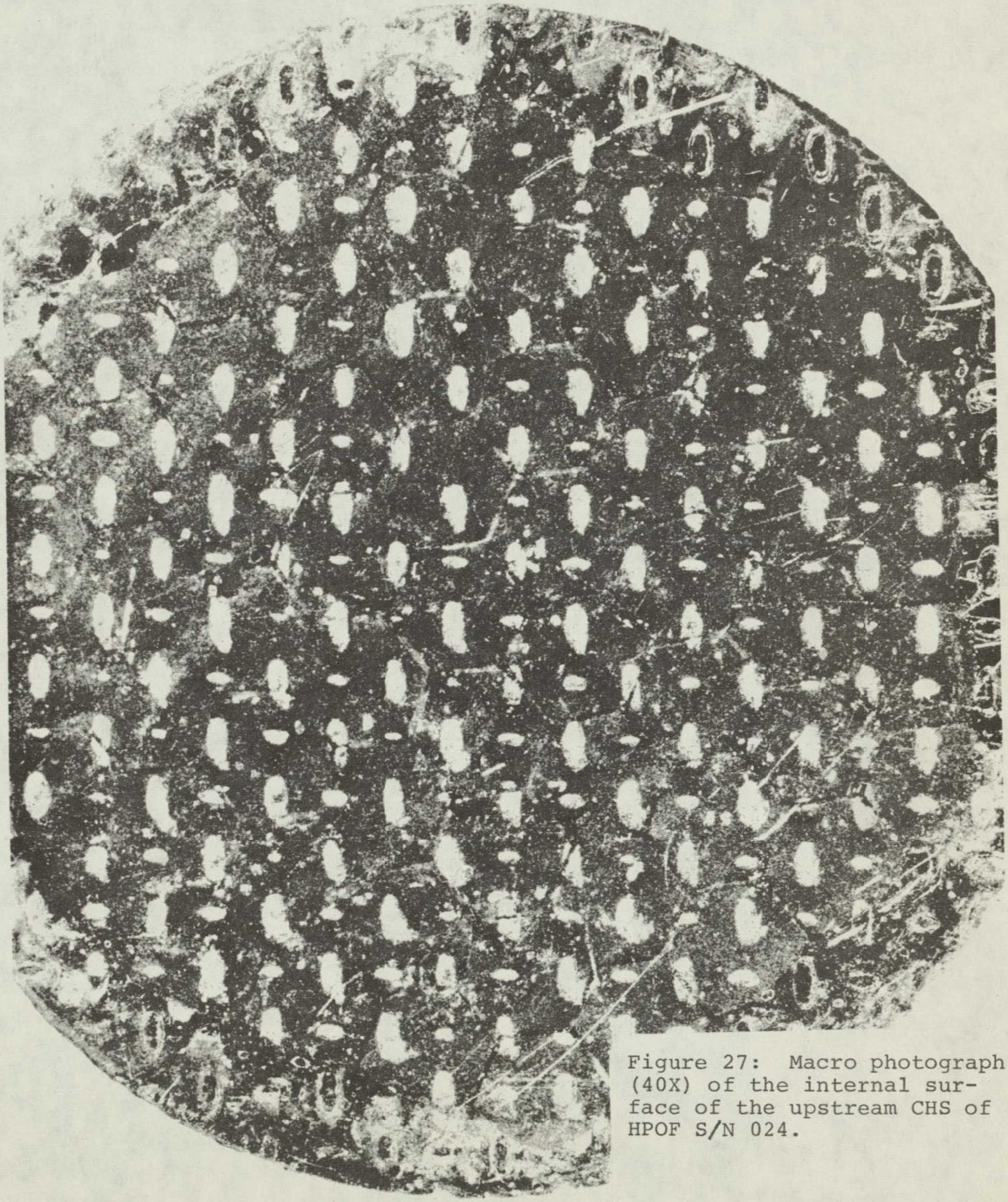


Figure 27: Macro photograph (40X) of the internal surface of the upstream CHS of HPOF S/N 024.

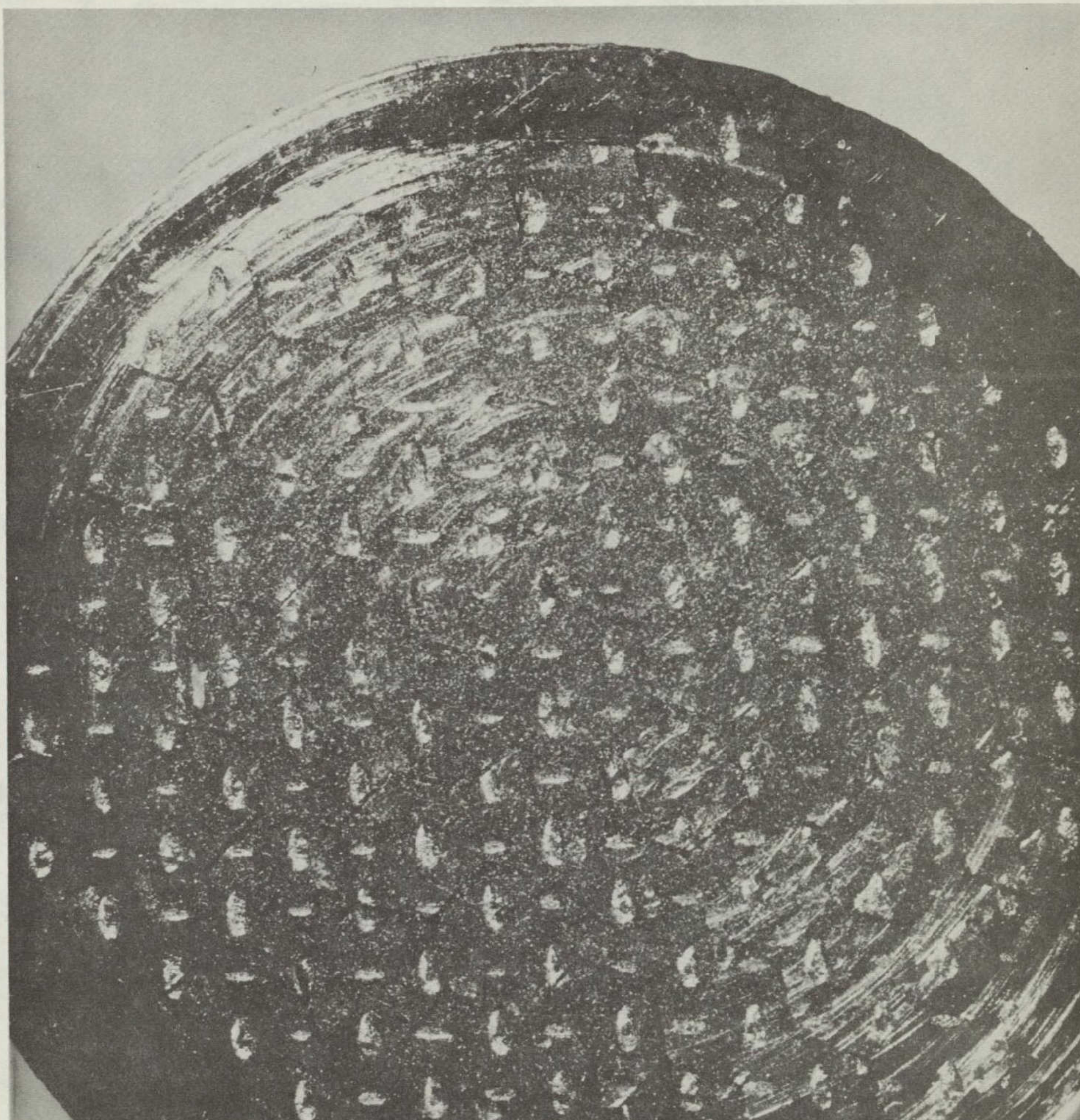


Figure 28: Macro Photograph (40X) of the Internal Surface of the Downstream CHS of HPOF S/N 024

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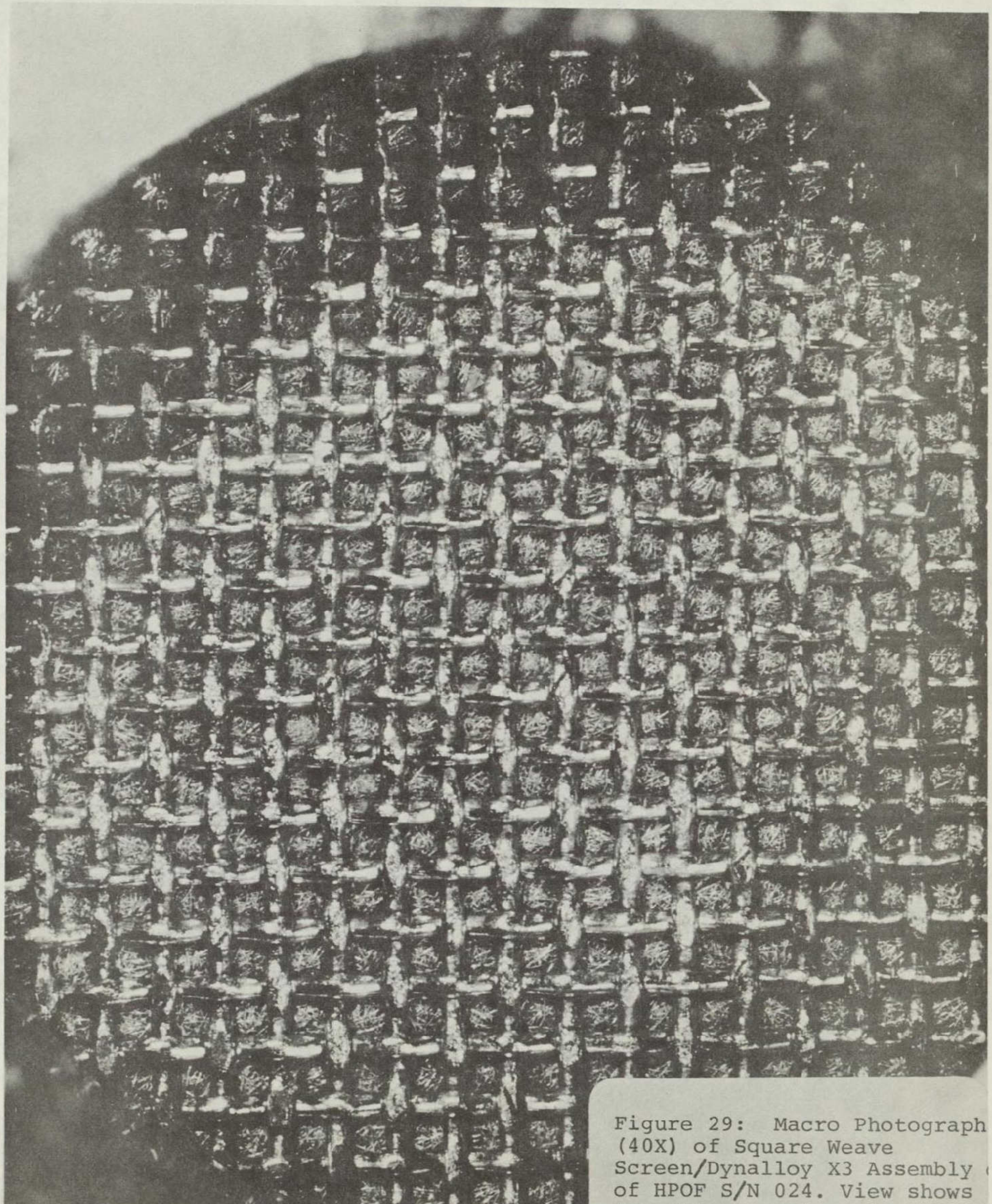

Figure 29: Macro Photograph (40X) of Square Weave Screen/Dynalloy X3 Assembly of HPOF S/N 024. View shows Assembly from Downstream side of HPOF

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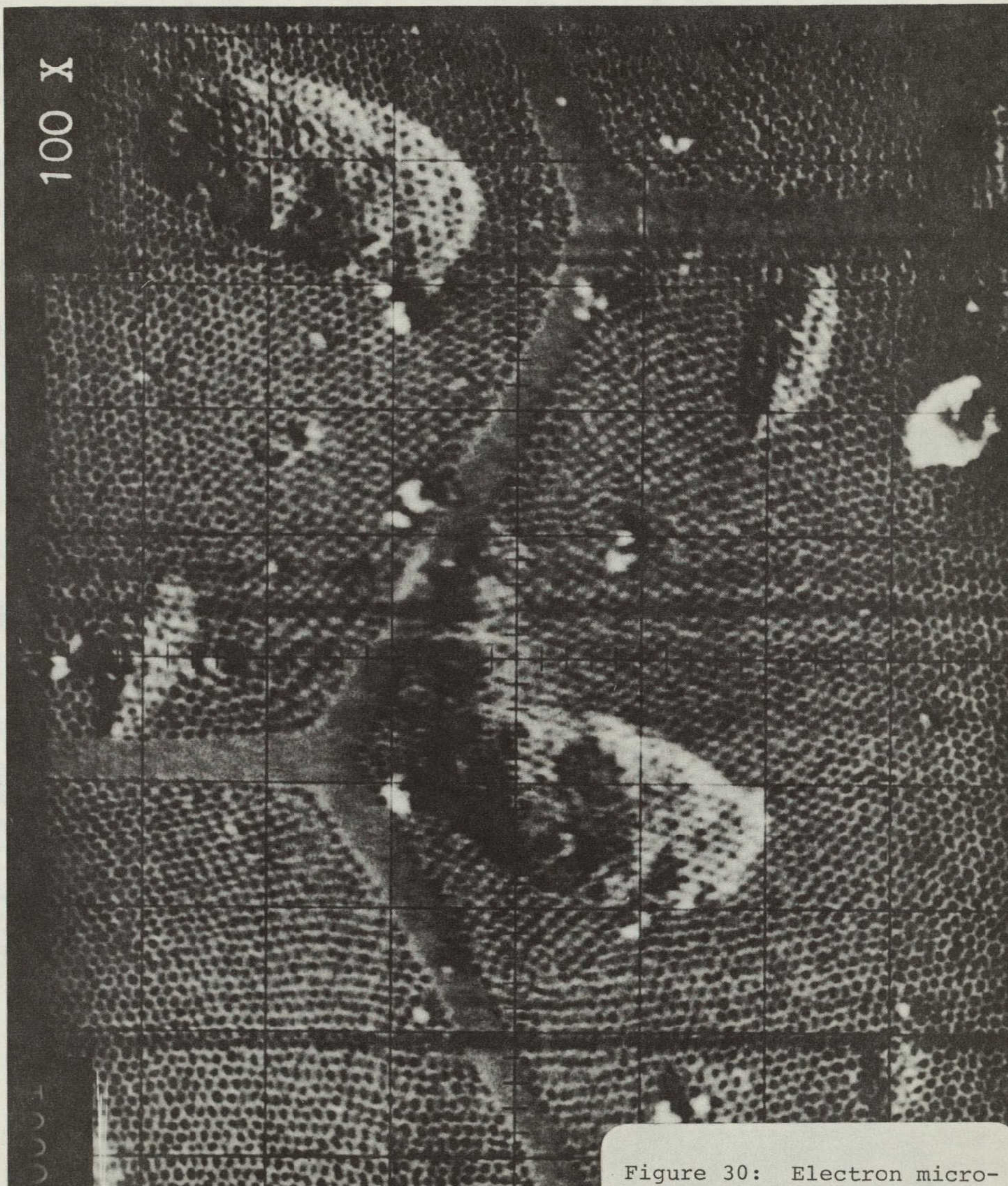

Figure 30: Electron microprobe electron back-scatter image of inlet (S/N side) CHS piece showing surface next to square weave screen.

Magnification: 100X

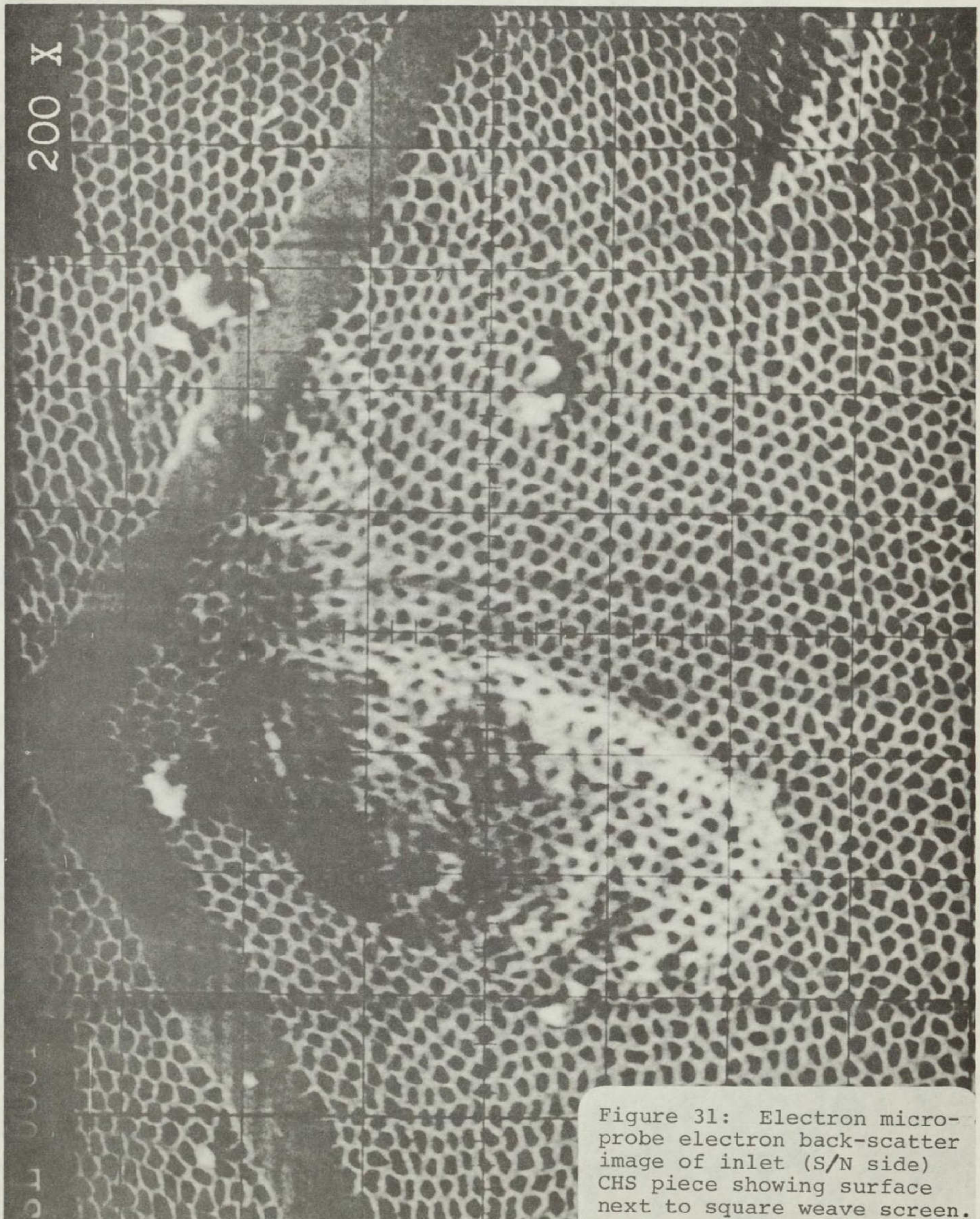

Figure 31: Electron micro-probe electron back-scatter image of inlet (S/N side) CHS piece showing surface next to square weave screen.

Magnification: 200X

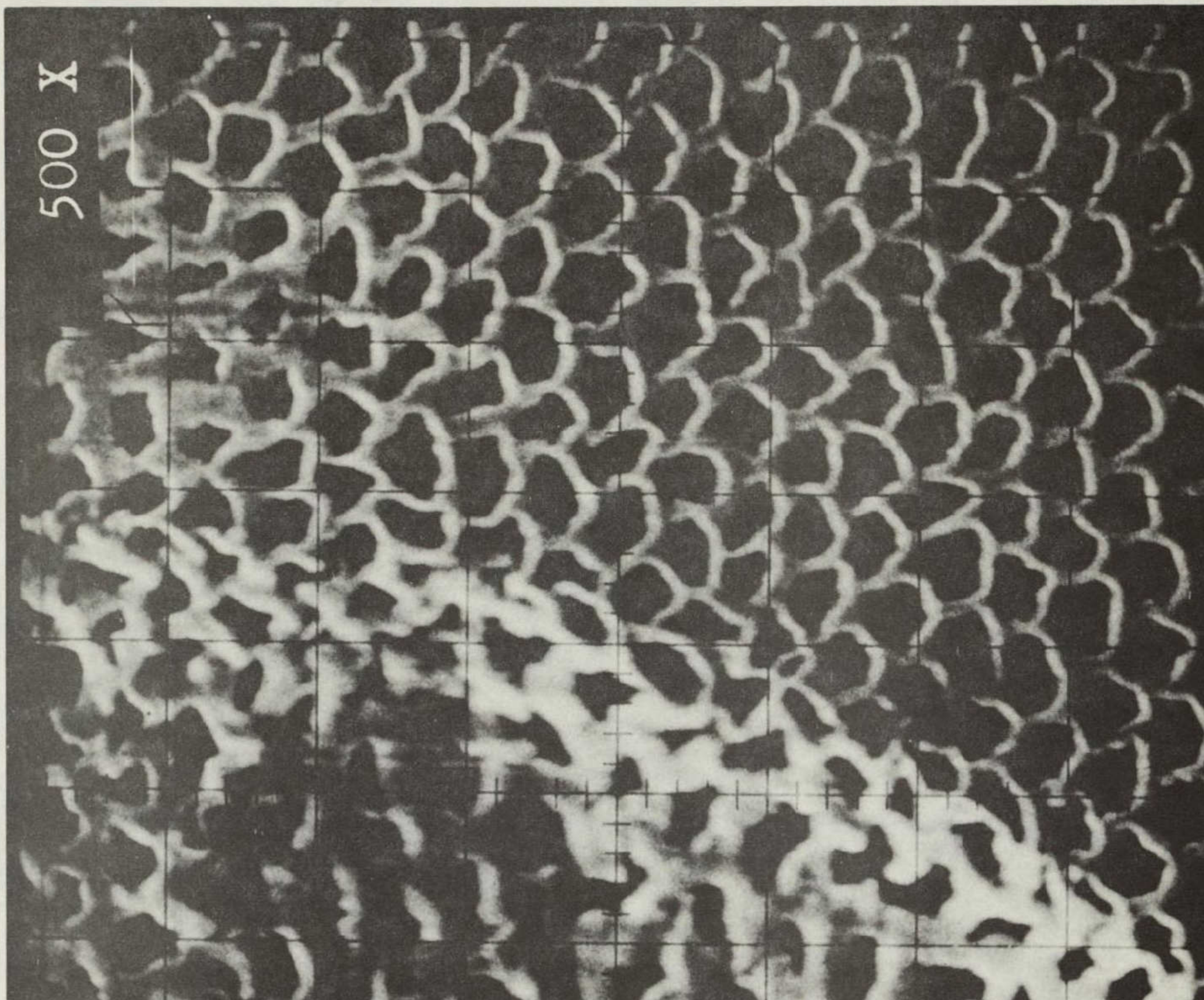

Figure 32: Electron microprobe electron back-scatter image of inlet (S/N side) CHS piece showing surface next to square weave screen.

Magnification: 500X

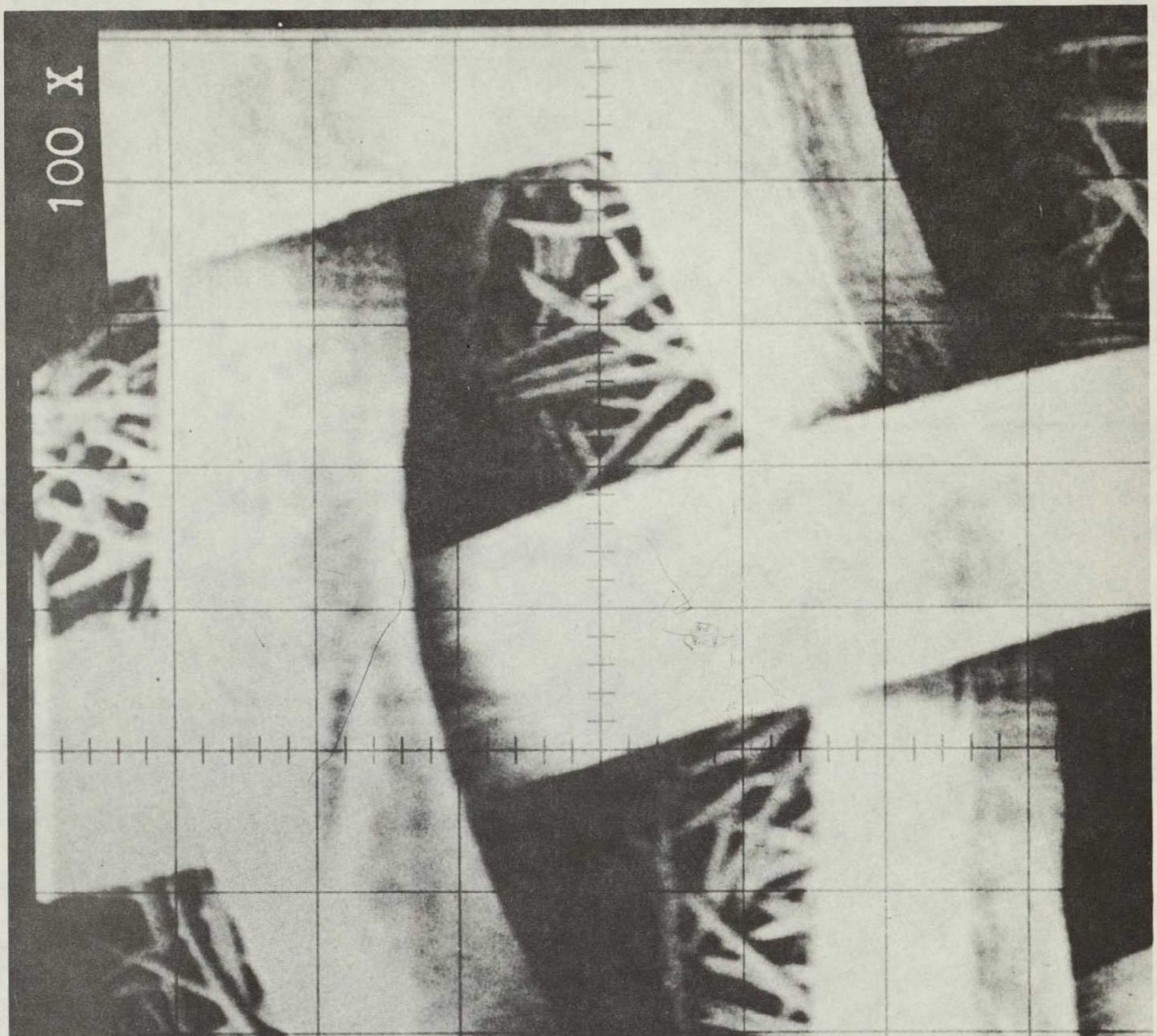

Figure 33: Electron micro-probe electron back-scatter image of inlet (S/N) side of square weave mesh/Dynalloy X3 assembly inside HPOF S/N 024

Magnification: 100X

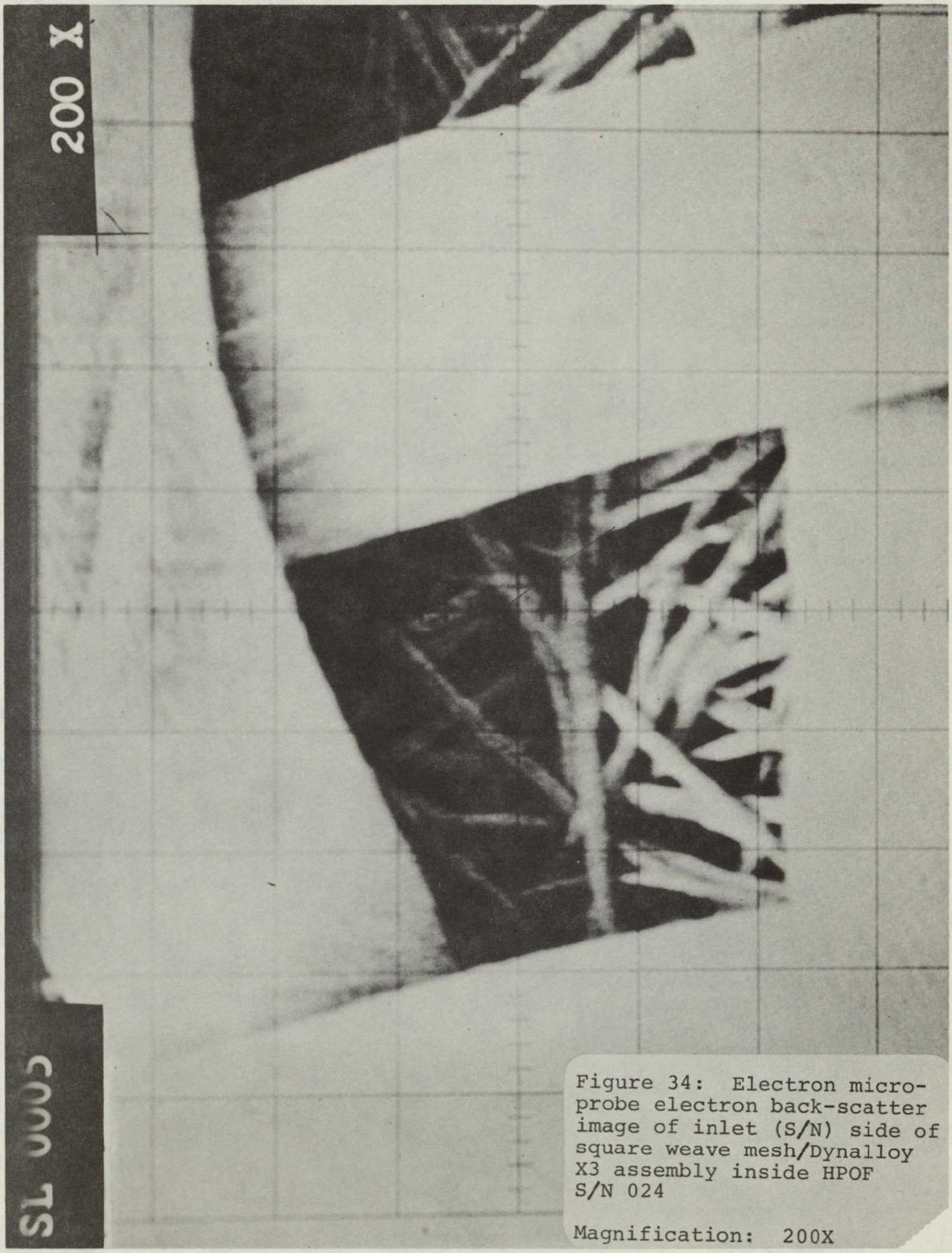

Figure 34: Electron microprobe electron back-scatter image of inlet (S/N) side of square weave mesh/Dynalloy X3 assembly inside HPOF S/N 024

Magnification: 200X

Figure 35: Electron microprobe electron back-scatter image of inlet (S/N) side of square weave mesh/Dynalloy X3 assembly inside HPOF S/N 024

Magnification: 500X

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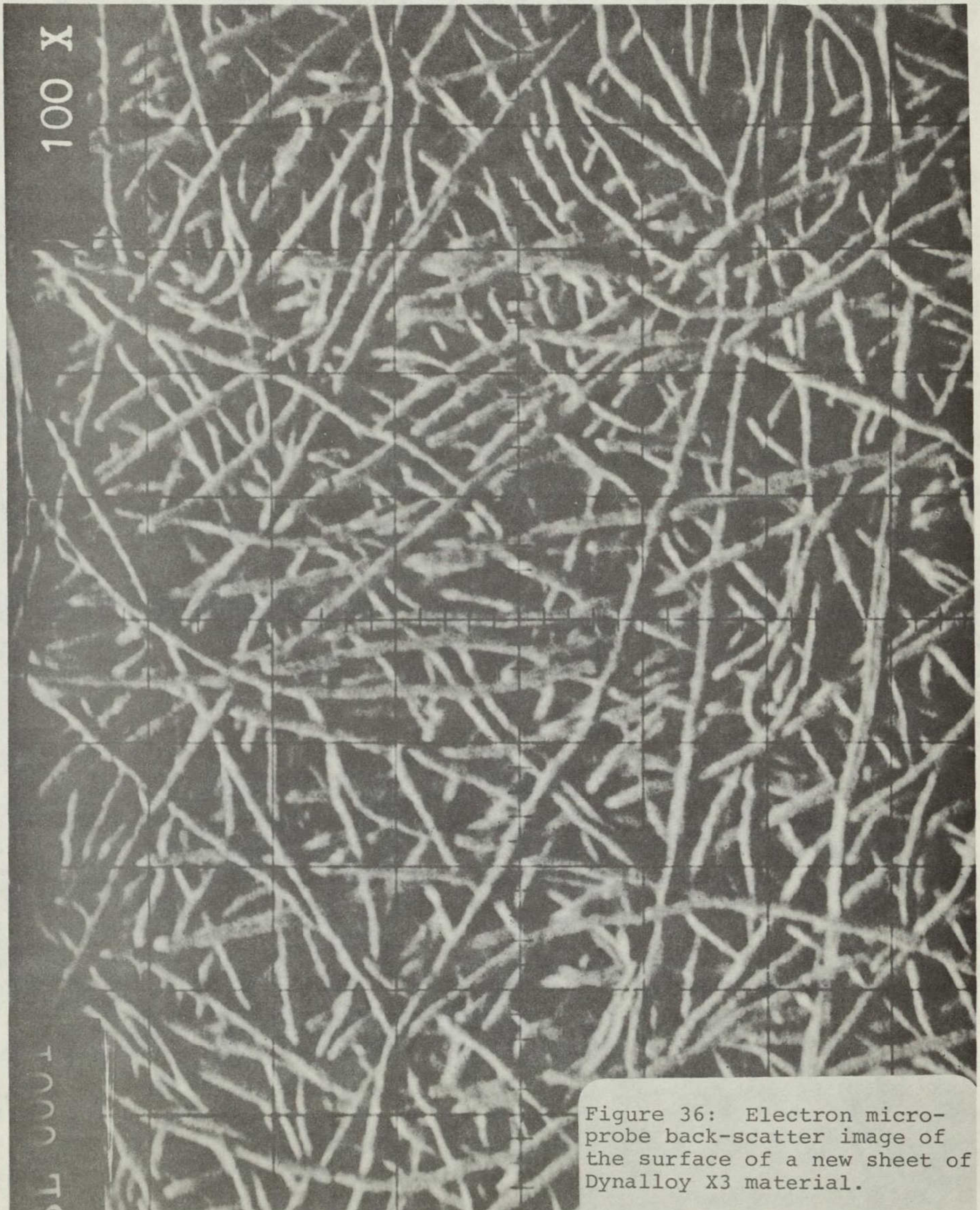


Figure 36: Electron micro-probe back-scatter image of the surface of a new sheet of Dynalloy X3 material.

Magnification: 100X

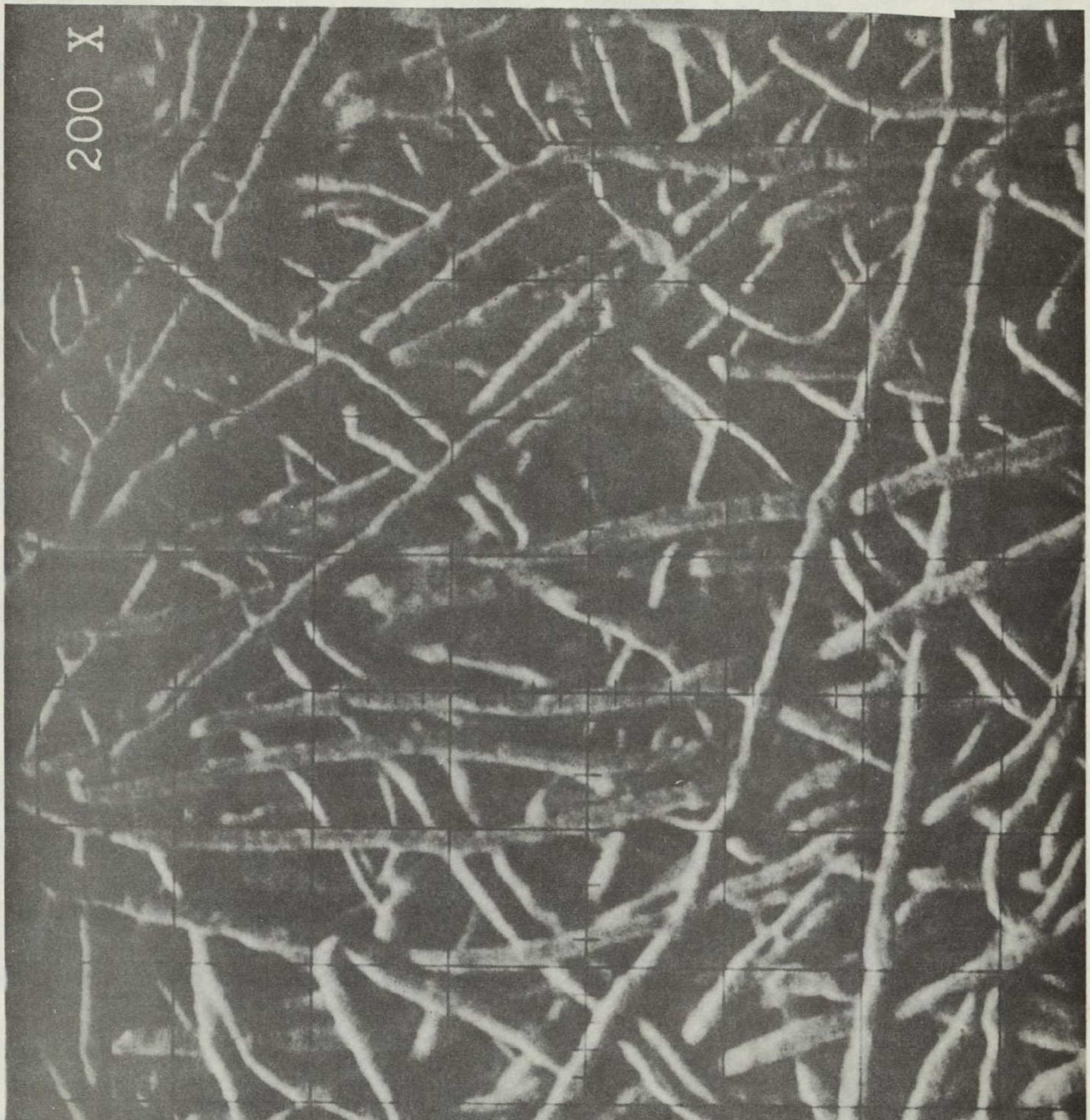


Figure 37: Electron micro-probe electron back-scatter image of the surface of a new sheet of Dynalloy X3 material

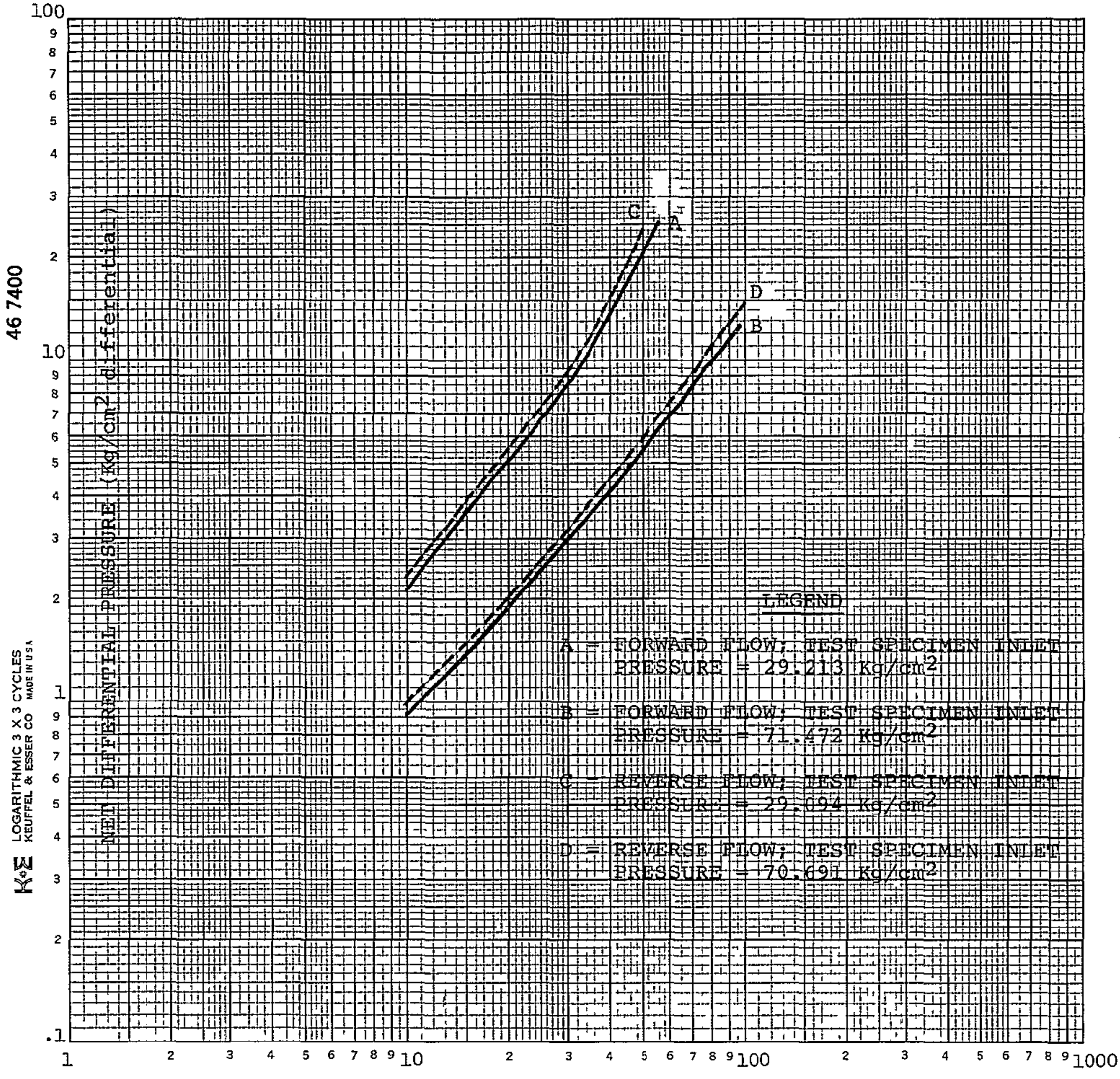
Magnification: 200X

Figure 38: Electron microprobe electron back-scatter image of the surface of a new sheet of Dynalloy X3 material.

Magnification: 500X

TEST NO. 5

FLOW RATE VERSUS DIFFERENTIAL PRESSURE CHARACTERISTICS OF TEST SPECIMEN S/N 027 AT THE COMPLETION OF TEST 10 AND AFTER THE APPLICATION OF 10 HIGH PRESSURE (703.07 Kg/cm^2 NOMINAL) GN_2 IMPACT CYCLES TO THE REVERSE SIDE (HPOF SPECIMEN S/N SIDE DOWNSTREAM) OF THE SPECIMEN

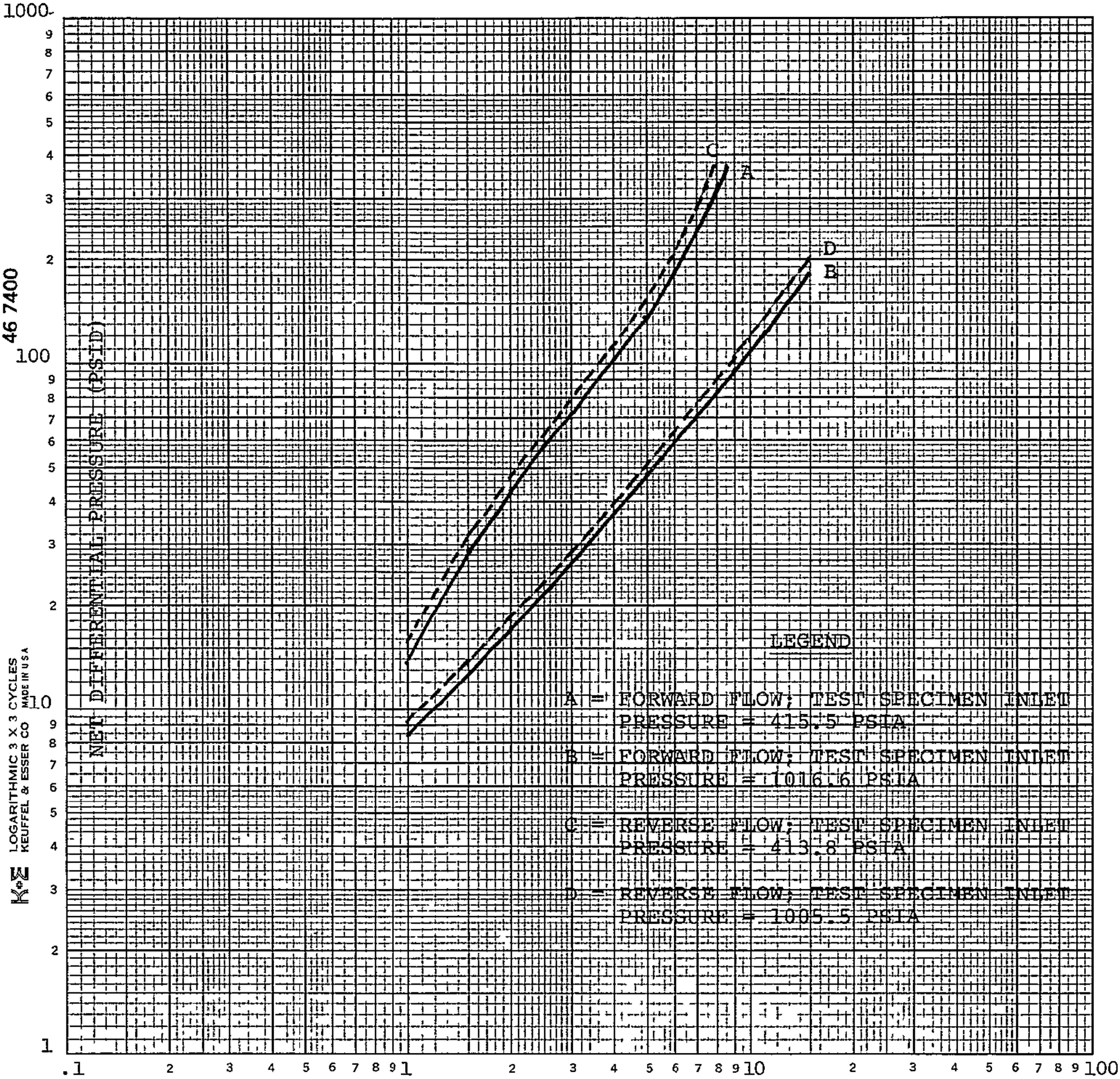


*At 21.1°C (70°F) and 1.033 Kg/cm^2 (14.7 psia)

FIGURE 39 Part B

TEST NO. 5

FLOW RATE VERSUS DIFFERENTIAL PRESSURE CHARACTERISTICS OF TEST SPECIMEN S/N 027 AT THE COMPLETION OF TEST 10 AND AFTER THE APPLICATION OF 10 HIGH PRESSURE (10,000 PSIA NOMINAL) GN_2 IMPACT CYCLES TO THE REVERSE SIDE (HPOF SPECIMEN S/N SIDE DOWNSTREAM OF THE SPECIMEN

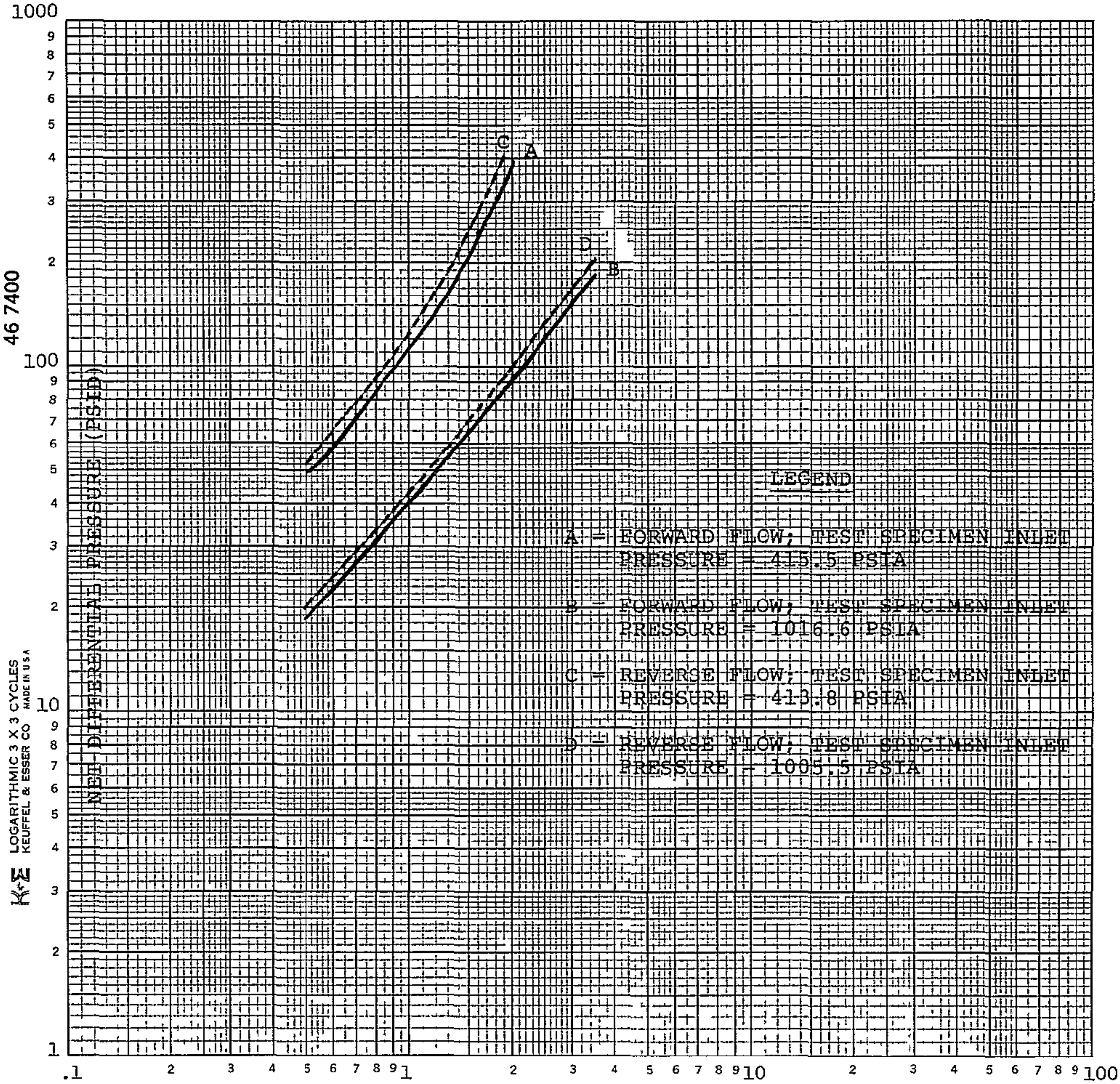


FLOW RATE (lbs GN_2/hr)

FIGURE 39 Part C

TEST NO. 5

FLOW RATE VERSUS DIFFERENTIAL PRESSURE CHARACTERISTICS OF TEST SPECIMEN S/N 027 AT THE COMPLETION OF TEST 10 AND AFTER THE APPLICATION OF 10 HIGH PRESSURE (10,000 PSIA NOMINAL) GN_2 IMPACT CYCLES TO THE REVERSE SIDE (HPOF SPECIMEN S/N SIDE DOWNSTREAM) OF THE SPECIMEN



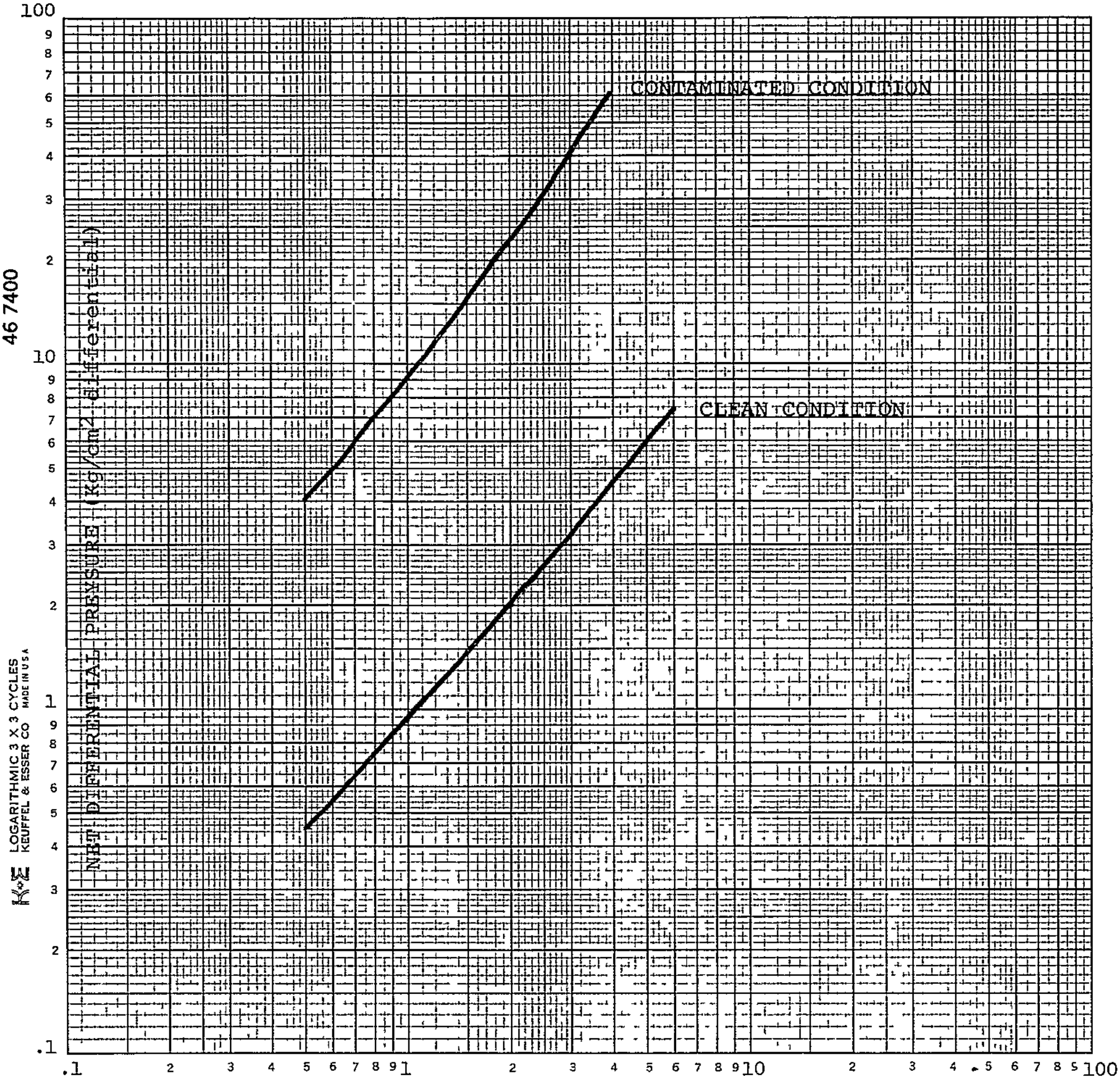
FLOW RATE (SCFM)

FIGURE 39 Part D

TEST NO. 5
TEST SPECIMEN S/N 025

FLOW RATE VERSUS DIFFERENTIAL PRESSURE DATA. DATA ACQUIRED IN THE FORWARD FLOW DIRECTION (S/N SIDE UPSTREAM) BEFORE AND AFTER SPECIMEN CONTAMINATED WITH 46 mg OF Fe_2O_3 AND SUBJECTED TO 100 HIGH PRESSURE (703.07 Kg/cm^2 NOMINAL) GN_2 IMPACT CYCLES.

TEST SPECIMEN INLET PRESSURE = 70.307 Kg/cm^2 (NOMINAL)



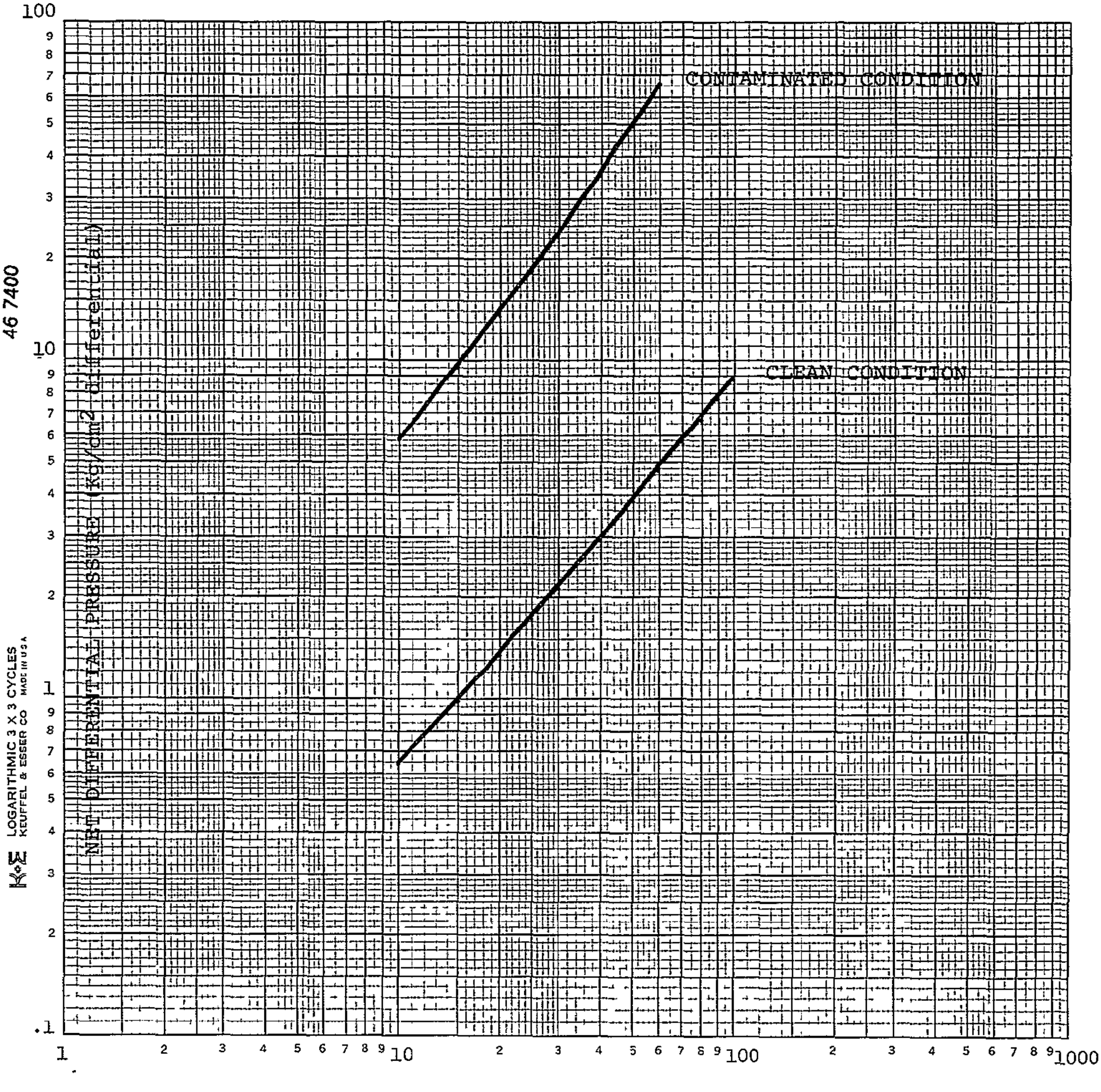
FLOW RATE (Kg GN_2/hr)

FIGURE 40 Part A

TEST NO. 5
TEST SPECIMEN S/N 025

FLOW RATE VERSUS DIFFERENTIAL PRESSURE DATA. DATA ACQUIRED IN THE FORWARD FLOW DIRECTION (S/N SIDE UPSTREAM) BEFORE AND AFTER SPECIMEN CONTAMINATED WITH 46 mg OF Fe_2O_3 AND SUBJECTED TO 100 HIGH PRESSURE (703.07 Kg/cm^2 NOMINAL) GN_2 IMPACT CYCLES.

TEST SPECIMEN INLET PRESSURE = 70.307 Kg/cm^2 (NOMINAL)



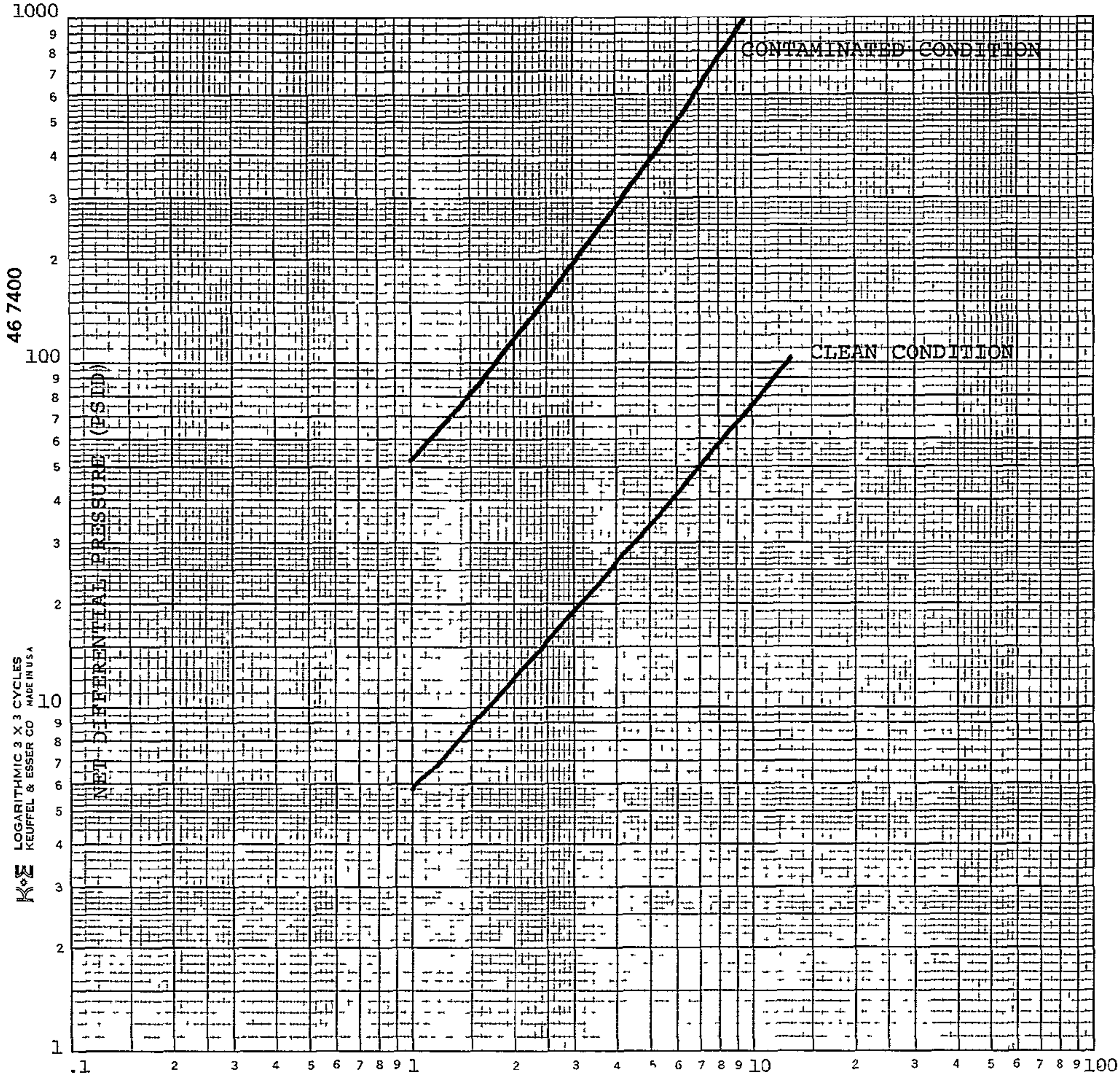
*At 21.1°C (70°F) and 1.033 Kg/cm^2 (14.7 psia)

FIGURE 40 Part B

TEST NO. 5
TEST SPECIMEN S/N 025

FLOW RATE VERSUS DIFFERENTIAL PRESSURE DATA. DATA ACQUIRED IN THE FORWARD FLOW DIRECTION (S/N SIDE UPSTREAM) BEFORE AND AFTER SPECIMEN CONTAMINATED WITH 46 mg OF Fe_2O_3 AND SUBJECTED TO 100 HIGH PRESSURE (10,000 PSIA NOMINAL) GN_2 IMPACT CYCLES.

TEST SPECIMEN INLET PRESSURE = 1,000 PSIA (NOMINAL)



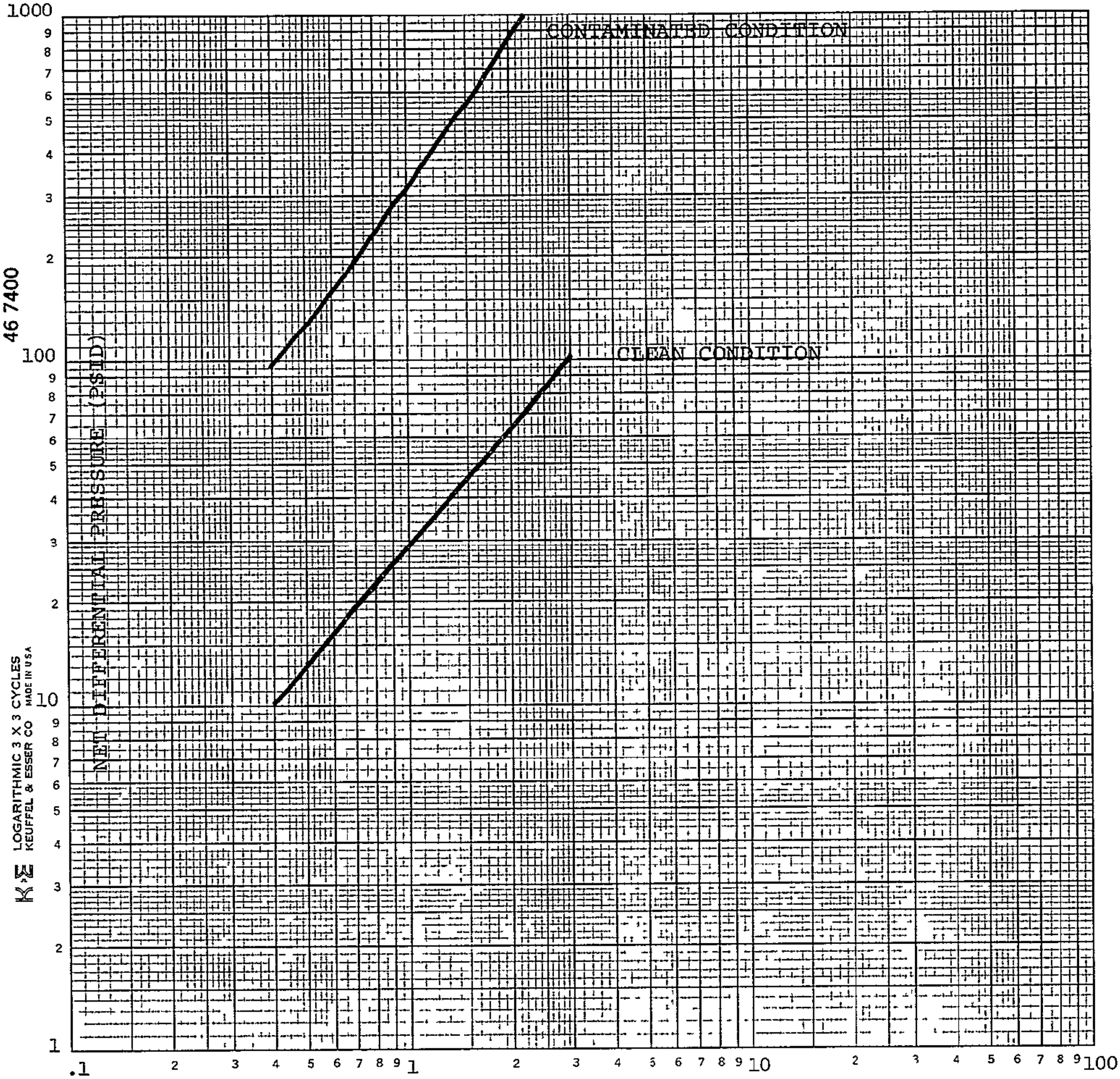
FLOW RATE (lbs GN_2/hr)

FIGURE 40 Part C

TEST NO. 5
TEST SPECIMEN S/N 025

FLOW RATE VERSUS DIFFERENTIAL PRESSURE DATA. DATA ACQUIRED IN THE FORWARD FLOW DIRECTION (S/N SIDE UPSTREAM) BEFORE AND AFTER SPECIMEN CONTAMINATED WITH 46 mg OF Fe_2O_3 AND SUBJECTED TO 100 HIGH PRESSURE (10,000 PSIA NOMINAL) GN_2 IMPACT CYCLES.

TEST SPECIMEN INLET PRESSURE = 1,000 PSIA (NOMINAL)



FLOW RATE (SCFM)

FIGURE 40 Part D

REVISIONS			
SYM	DESCRIPTION	DATE	APPROVAL
NC	[illegible] PRODUCTION	2/11/76	TMC

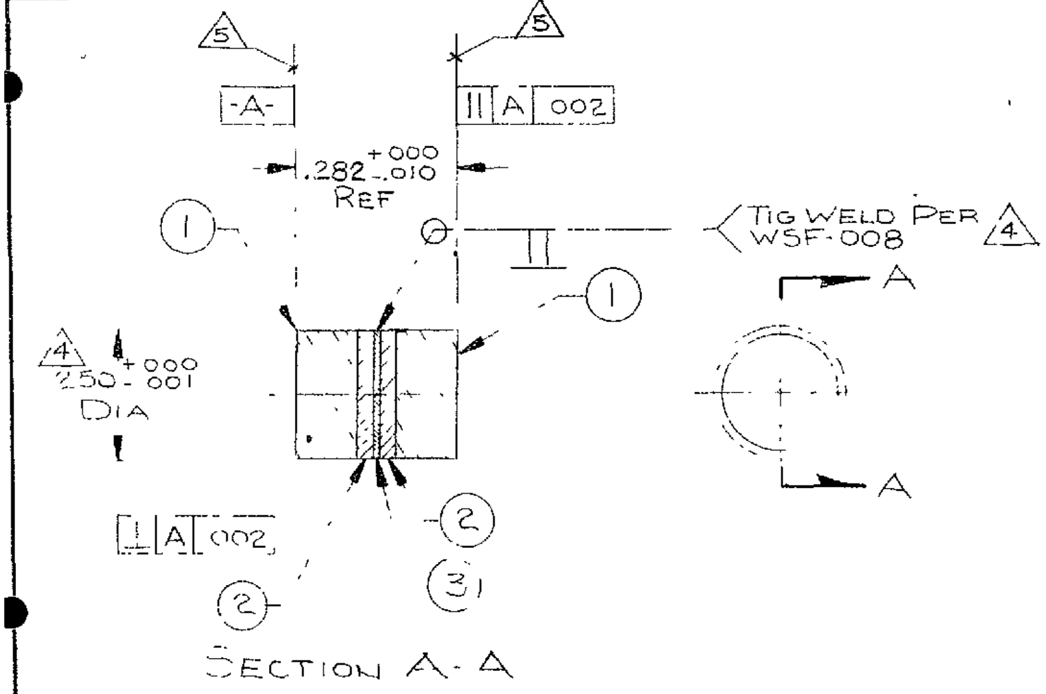


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FIGURE 41

ITEM NO	QTY	NAME	PART NO	MATERIAL
3	1	FILTER	19-1612	304 CRES
2	2	SCREEN	19-1611	304L CRES
1	2	CHS	20-1232	304L CRES

LIST OF MATERIAL

5 DO NOT MACHINE SURFACES INDICATED
4 BRUSH PASSIVATE MACHINED & WELD AREAS ONLY PER WSP-005
3 ACCEPTANCE TEST PER TP-259
A EXAMINATION OF PRODUCT
B BUBBLE POINT TBD IN H_2O MIN IN IPA
C CLEANLINESS JSC SN-C-0005 TABLE I LEVEL 25
2 PERFORMANCE DATA
A FLUID 100% OXYGEN PER MIL-O-27210
B FLOW RATE 2 TO 13 LBS/HR @ 8000 PSIG
C FILTRATION 3 MICRONS ABS
1 BURR INSPECT PER WSI-001

GENERAL NOTES:
UNLESS OTHERWISE SPECIFIED

NEXT ASSY	USED ON
9-812-2	132790
9-812-1	132790
9-812	9-812
APPLICATION	

UNLESS OTHERWISE SPECIFIED
ALL DIMENSIONS ARE IN INCHES
DO NOT SCALE DRAWING
PART TO BE FREE OF BURRS
BREAK SHARP EDGES .005—.015
ALL THREADS PER MIL S 7742

TOL .XX ± .03 .XXX ± .010 ANG ± 1/2°
SURFACE ROUGHNESS PER ASA B46.1 125 MAX
MATL NOTED
FINISH 4
HEAT TREAT

DRAWN	RBI	1/28/76
CHECK	T. Clancy	2/11/76
APPR		
APPR	T.M. Clancy	2/11/76
APPR		
APPROVAL		
APPROVAL		

WINTEC DIVISION
BRUNSWICK CORPORATION
LOS ANGELES, CALIFORNIA

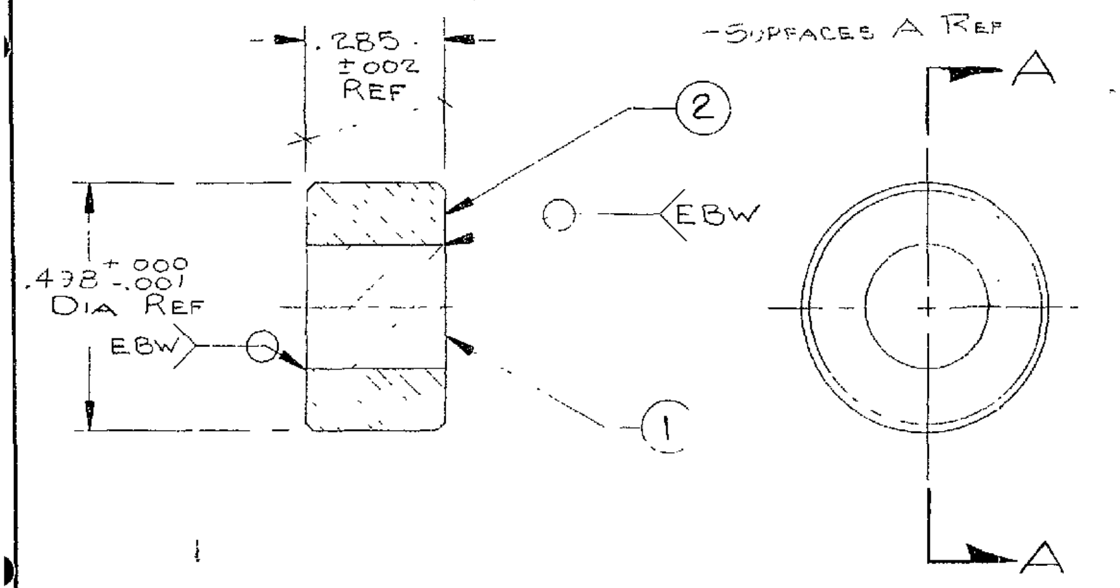
FILTER

CODE IDENT NO	SIZE	
21550	B	101-1258
SCALE 4/1	WT.	SHEET 1 OF 1

FOLDOUT FRAME 1

FOLDOUT FRAME 2

REVISIONS			
SYM	DESCRIPTION	DATE	APPROVAL
NC	RELEASE FOR PRODUCTION	2/11/76	TMC
A	ADDED SURFACES "A" REF NOTATION	2/26/76	RBI



SECTION A A

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FIGURE 42

ITEM NO	QTY	NAME	PART NO	MATERIAL
2	1	RING	20-1237	304L CRES
1	1	FILTER	101-1258	304 & 304L CRES

LIST OF MATERIAL

3. ACCEPTANCE TEST PER TP-53
   - A. EXAMINATION OF PRODUCT
   - B. BUBBLE POINT [illegible] IN H_2O MIN IN IPA
   - C. CLEANLINESS JSC-SN-C-0005 TABLE I LEVEL 25
   - D. PROOF TEST
   - E. FLOW TEST
2. PERFORMANCE DATA
   - A. FLUID 100% OXYGEN PER MIL-O-27210
   - B. FLOW RATE: 2 TO 13 LBS/HR @ 8000 PSIG
   - C. FILTRATION: 3 MICRONS ABS
1. BURR INSPECT PER WSI-001

GENERAL NOTES:
UNLESS OTHERWISE SPECIFIED

NEXT ASSY	USED ON
—	—
APPLICATION	

UNLESS OTHERWISE SPECIFIED
ALL DIMENSIONS ARE IN INCHES
DO NOT SCALE DRAWING
PART TO BE FREE OF BURRS
BREAK SHARP EDGES .005—.015
ALL THREADS PER MIL S 7742

TOL .XX ±.03 .XXX ±.010 ANG ±½°

SURFACE ROUGHNESS PER ASA B46.1 √ MAX

MATL NOTED

FINISH CLEAN PER WSP-010

HEAT TREAT

DRAWN	RBI	2/2/76
CHECK	T. Clancy	2/11/76
APPR		
APPR	T.M. Clancy	2/11/76
APPR		
APPROVAL		
APPROVAL		

WINTEC DIVISION
BRUNSWICK CORPORATION
LOS ANGELES, CALIFORNIA

CHS FILTER

CODE IDENT NO	SIZE	
21550	B	9-812
SCALE: 4/1	WT.	SHEET 1 OF 1

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HPOF PROGRAM TEST NO. 5

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE

TEST SPECIMEN S/N 6

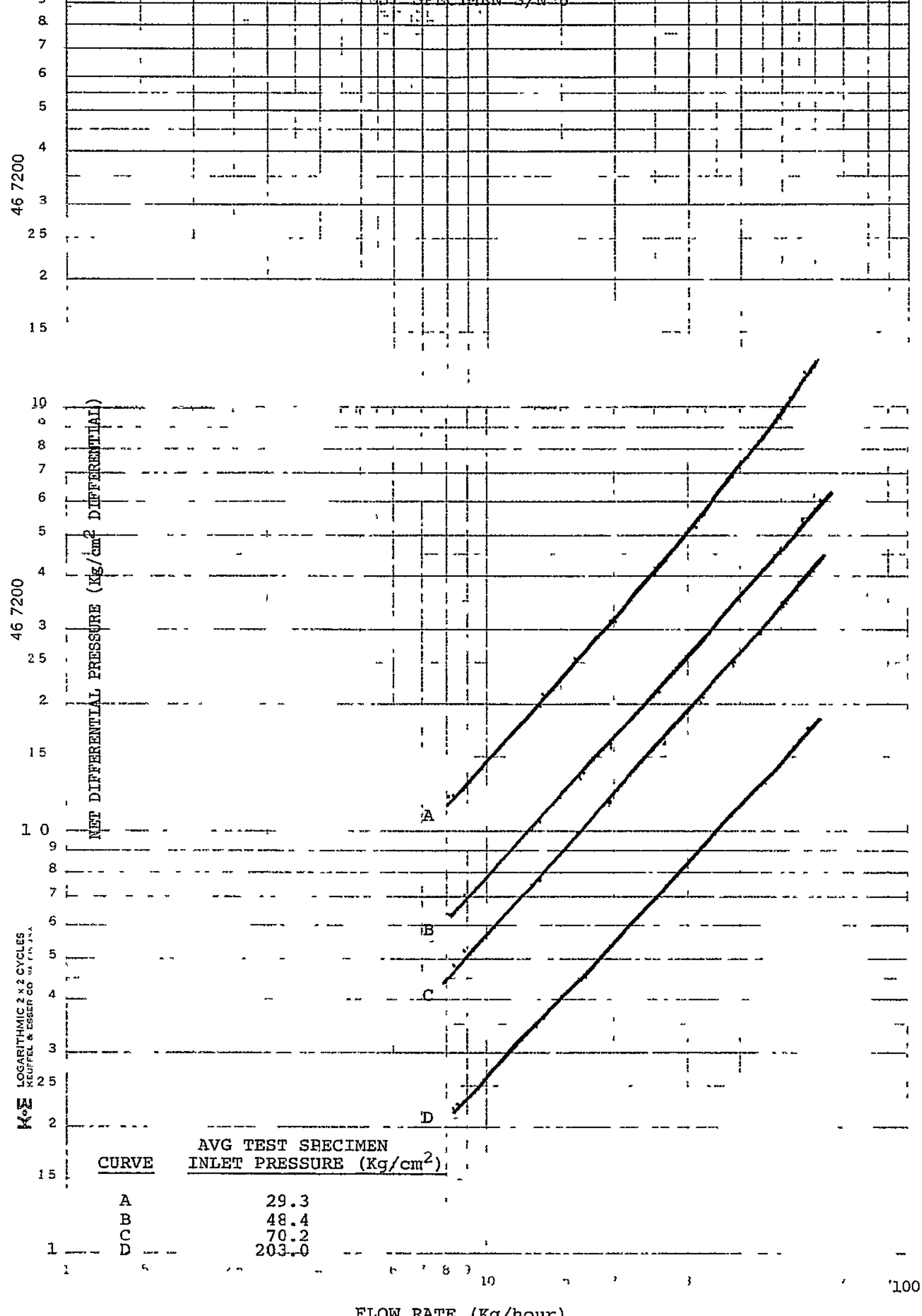
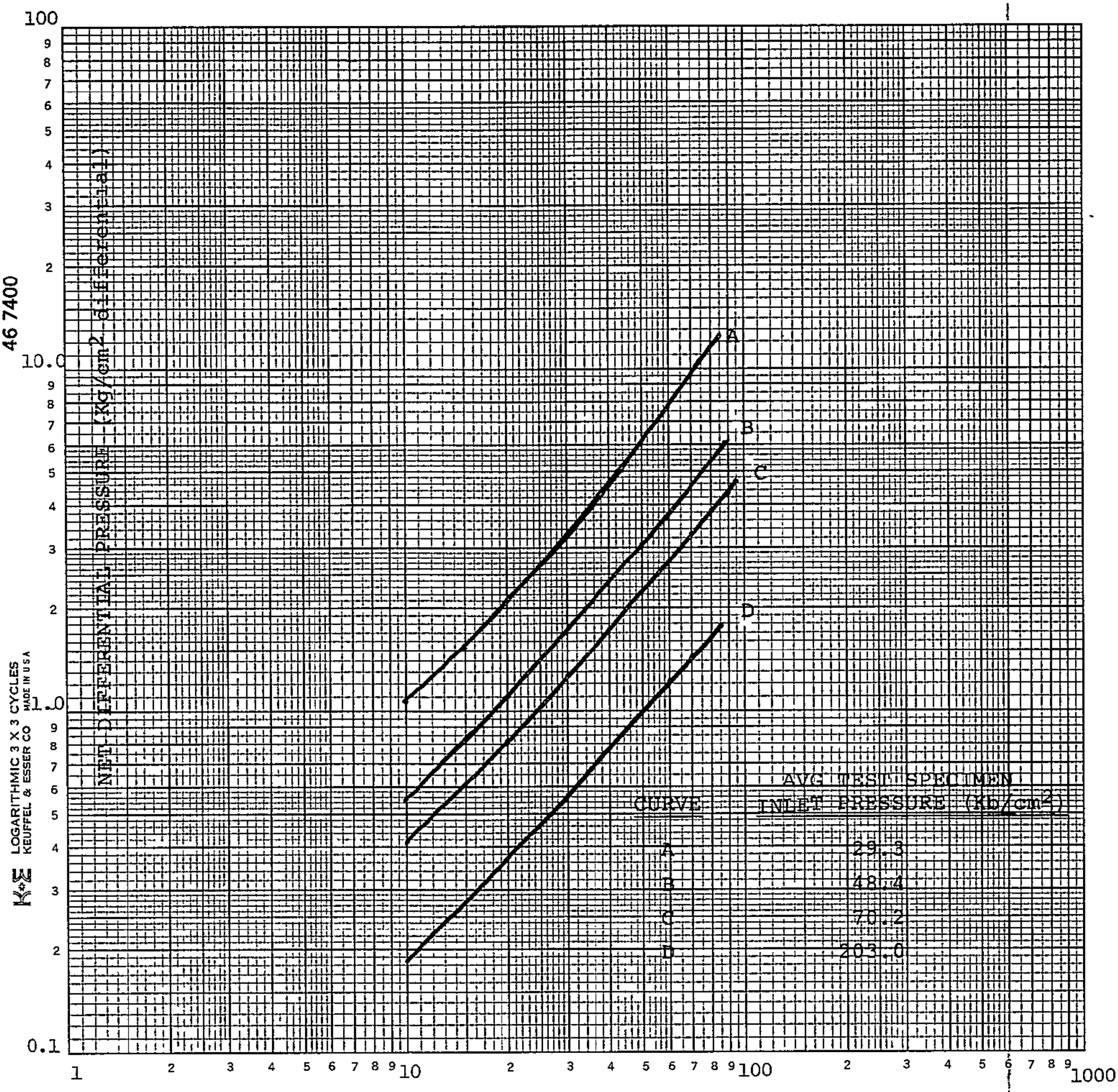


FIGURE 43 Part A

HPOF PROGRAM TEST NO. 5

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE

TEST SPECIMEN S/N 6

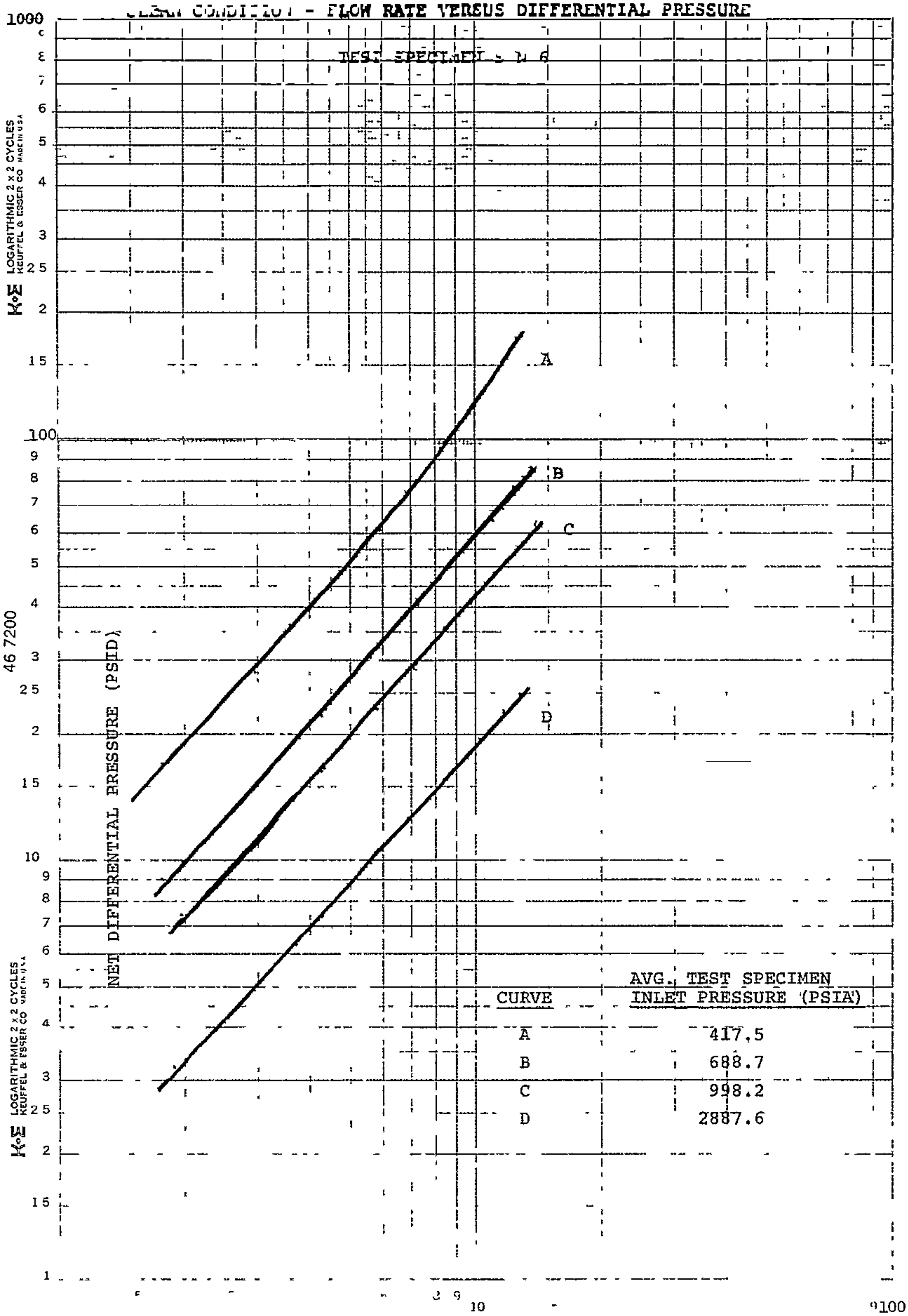


FLOW RATE (LITERS [AT 21.1°C (70°F) AND 1.033 Kg/cm^2 (14.7 psia)/MINUTE]

FIGURE 43 Part B

HPOF PROGRAM TEST NO. 5

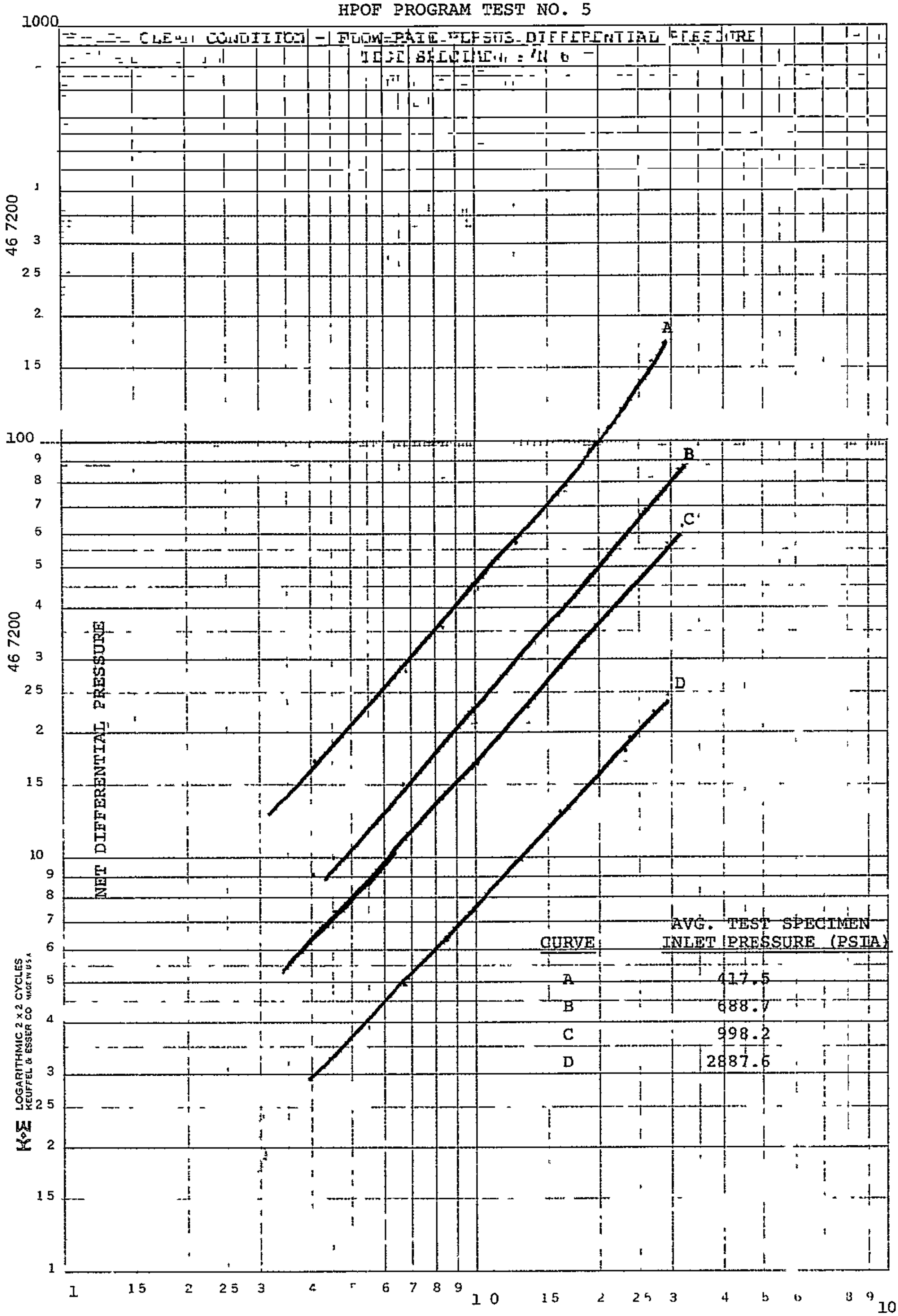
CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE



FLOW RATE (lbs GN_2/Hour)

FIGURE 43 Part C

HPOF PROGRAM TEST NO. 5



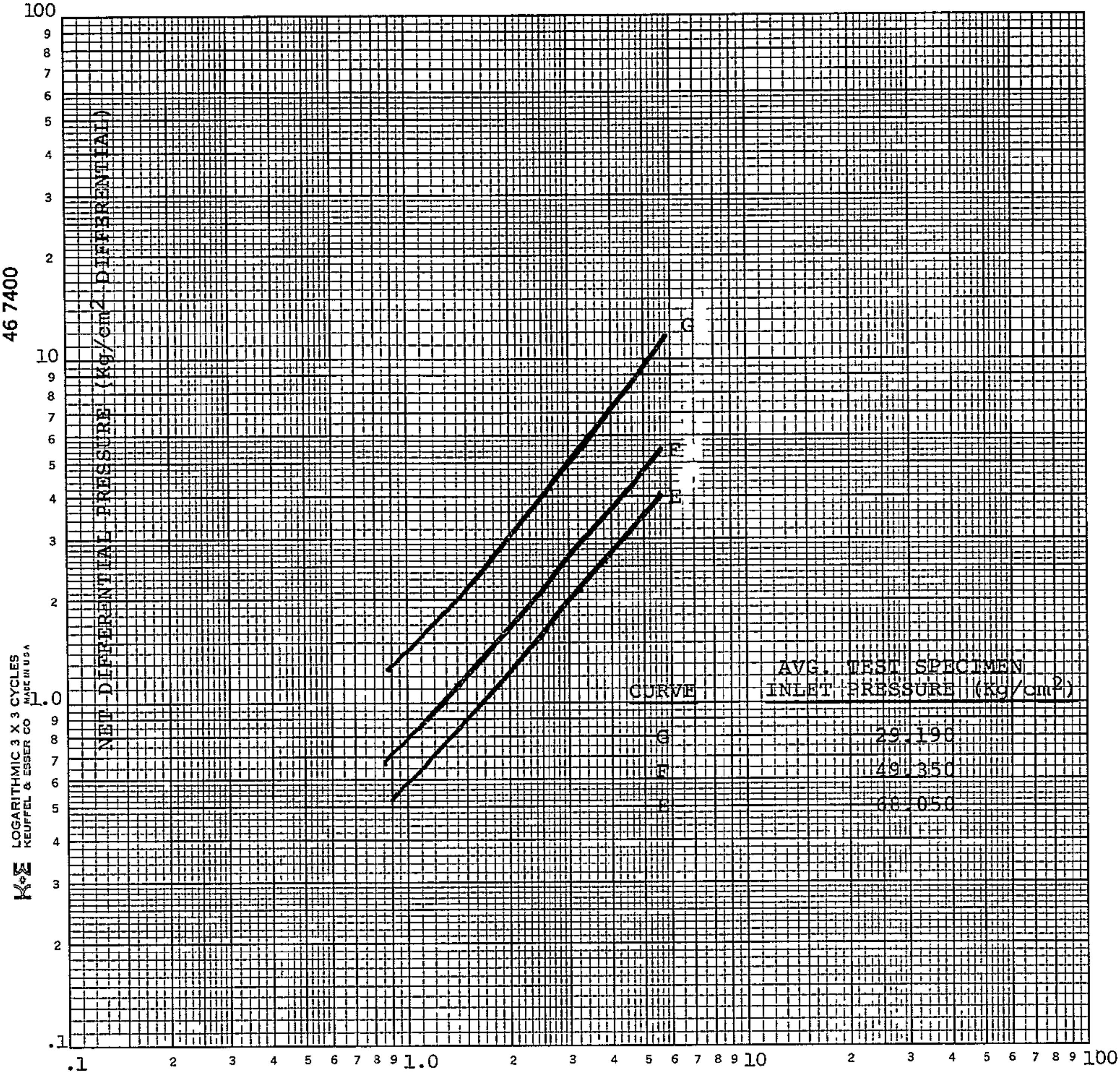
FLOW RATE (SCFM)

FIGURE 43 Part D

HPOF PROGRAM TEST NO. 5

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE

TEST SPECIMEN S/N 020



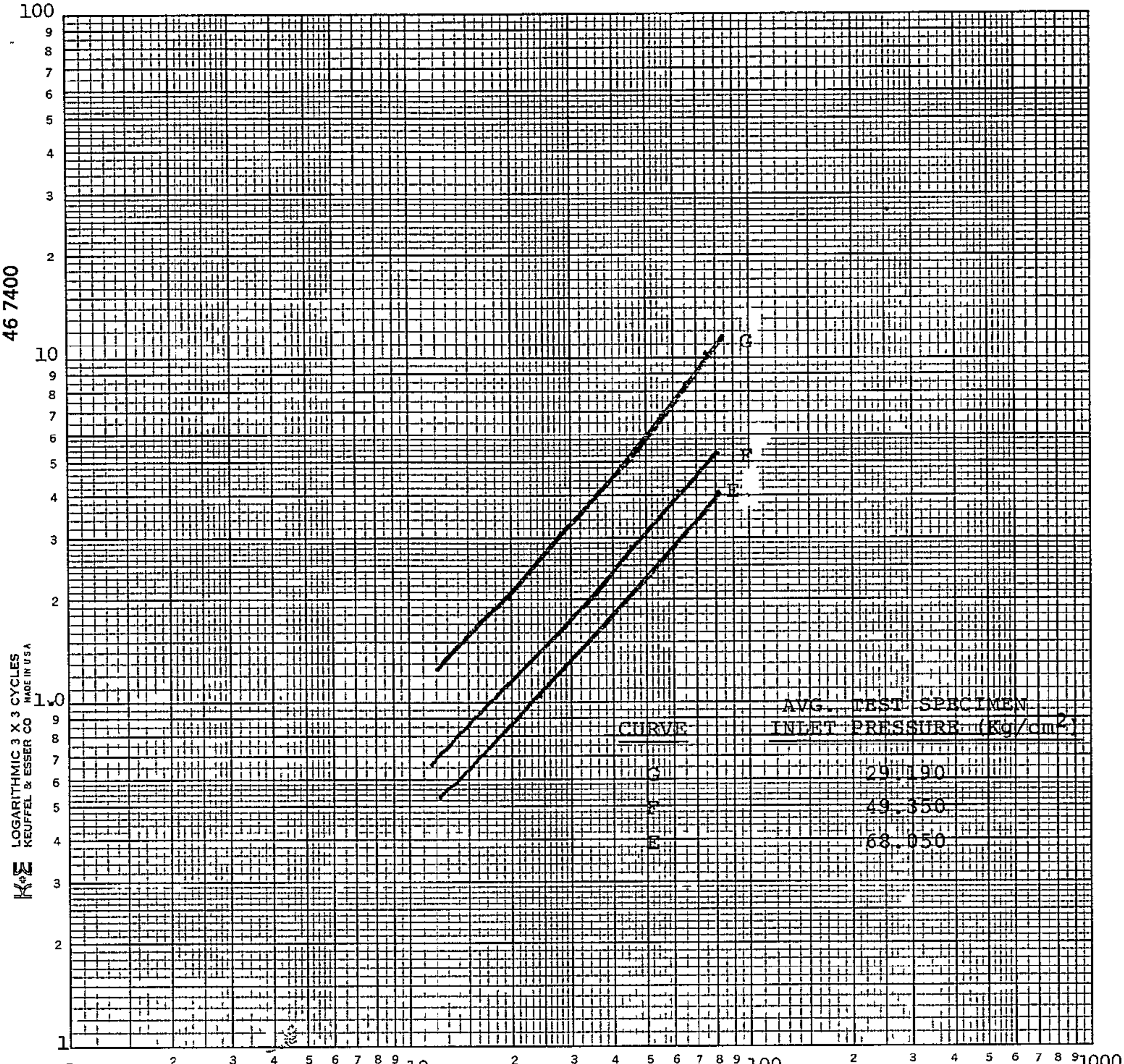
FLOW RATE (Kg/hour)

FIGURE 44 Part A

HPOF PROGRAM TEST NO. 5

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE

TEST SPECIMEN S/N 020



FLOW RATE (liters*/min)

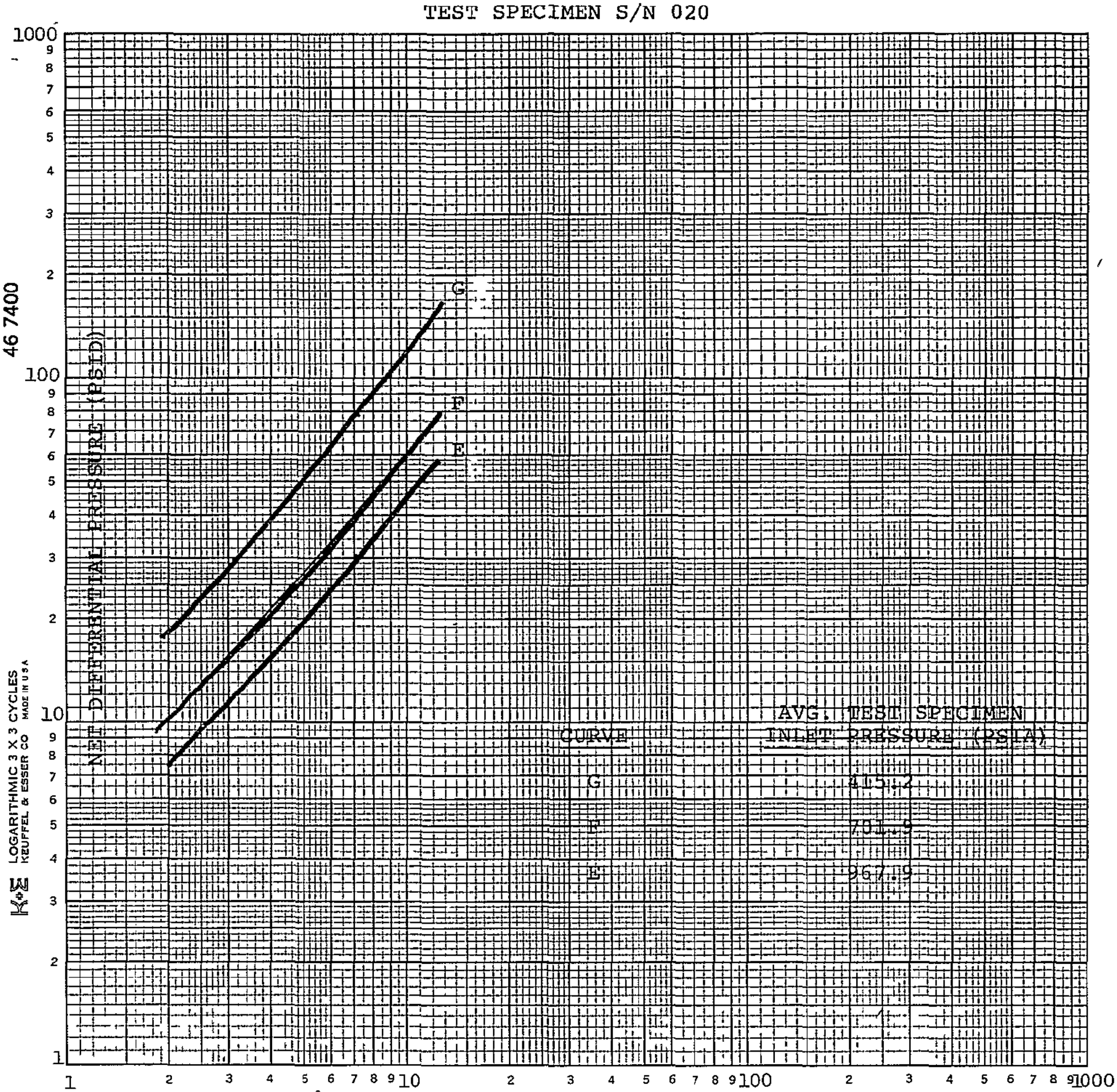
*At 21.1°C (70°F) and 1.033 Kg/cm^2 (14.7 psia)

FIGURE 44 Part B

HPOF PROGRAM TEST NO. 5

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE

TEST SPECIMEN S/N 020



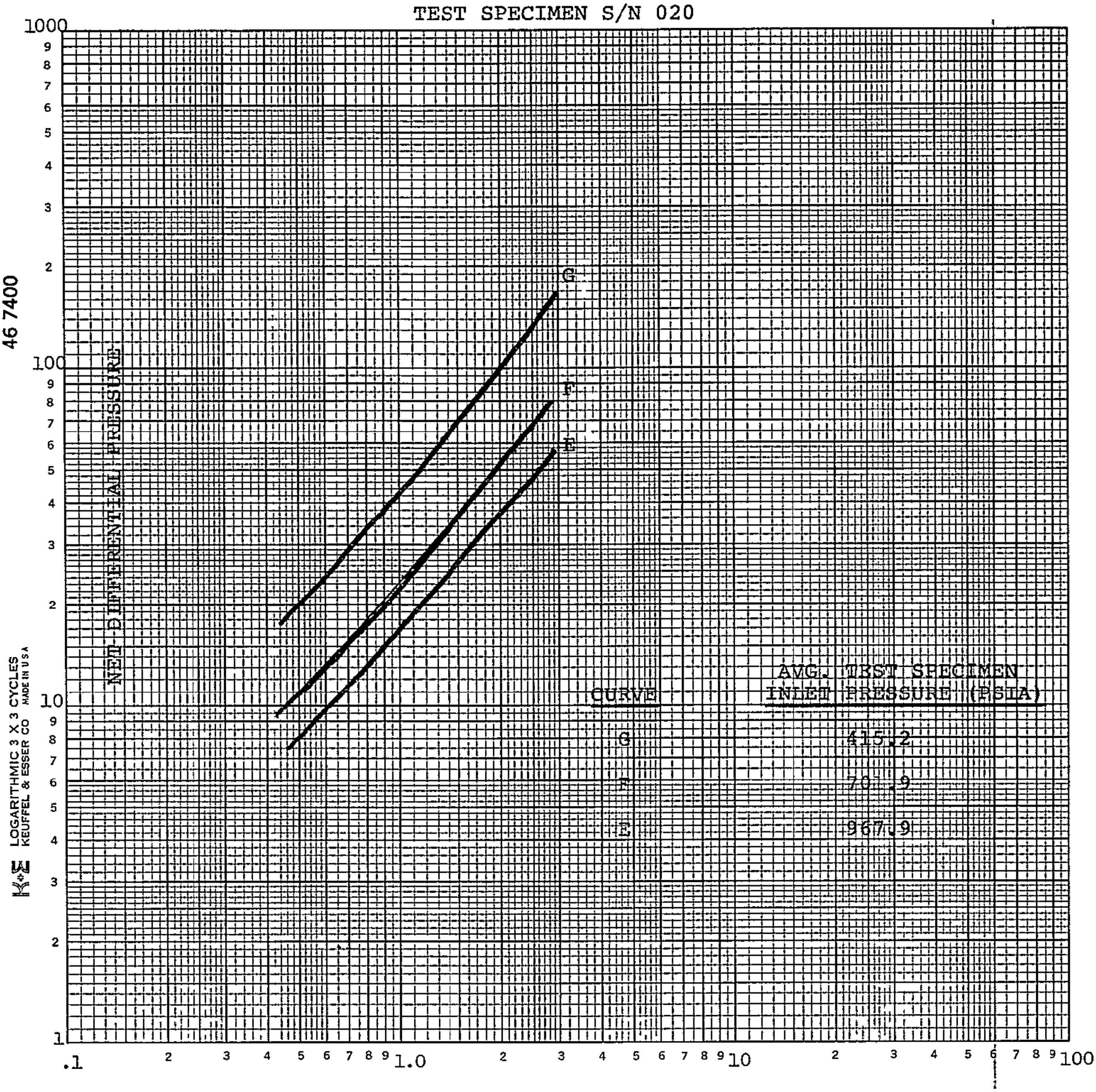
FLOW RATE (lbs GN_2/Hour)

FIGURE 44 Part C

HPOF PROGRAM TEST NO. 5

CLEAN CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE

TEST SPECIMEN S/N 020



FLOW RATE (SCFM)

FIGURE 44 Part D

TEST NO. 11
CONTAMINATED CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE
TEST SPECIMEN S/N 020

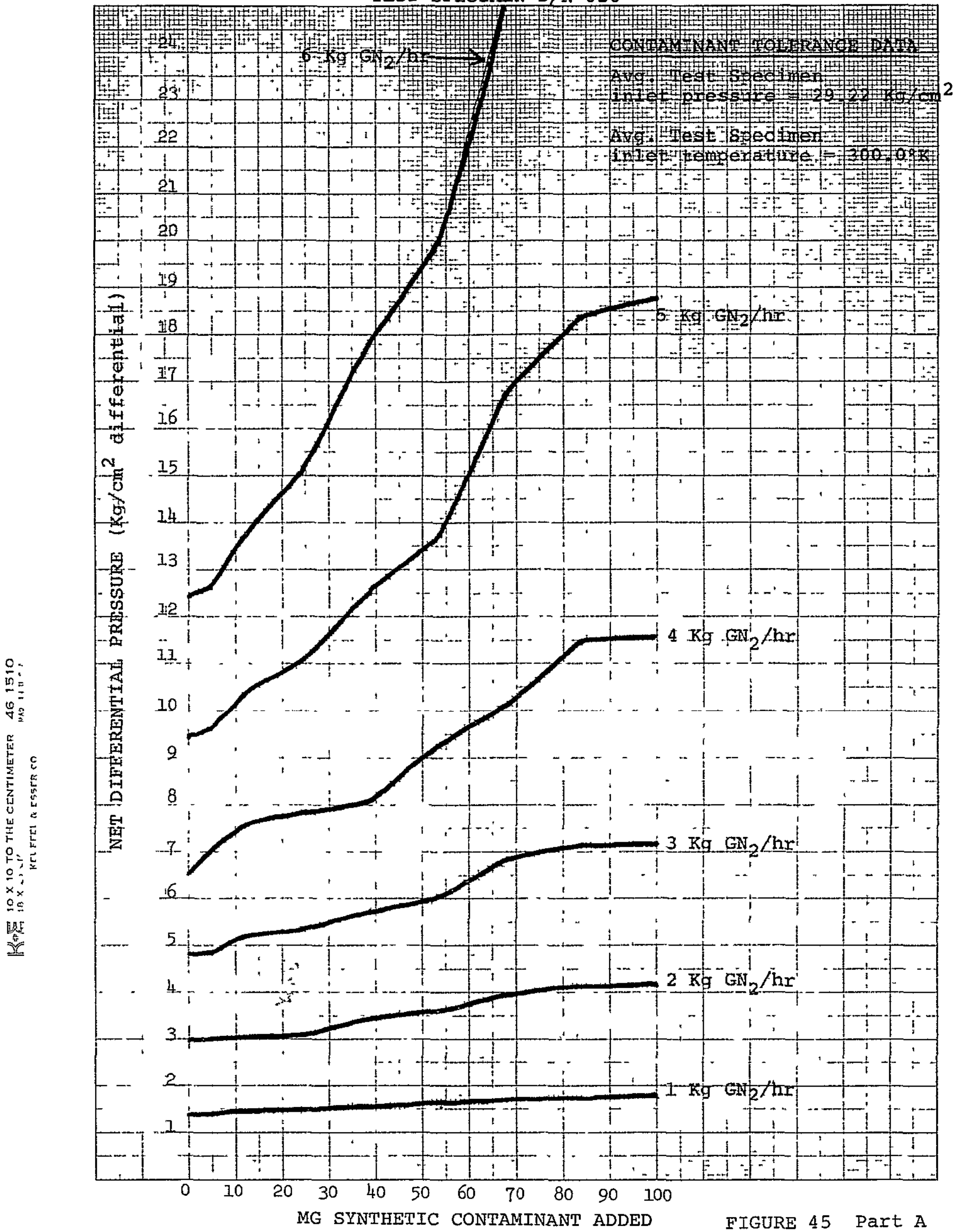


FIGURE 45 Part A

TEST NO. 11

CONTAMINATED CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE

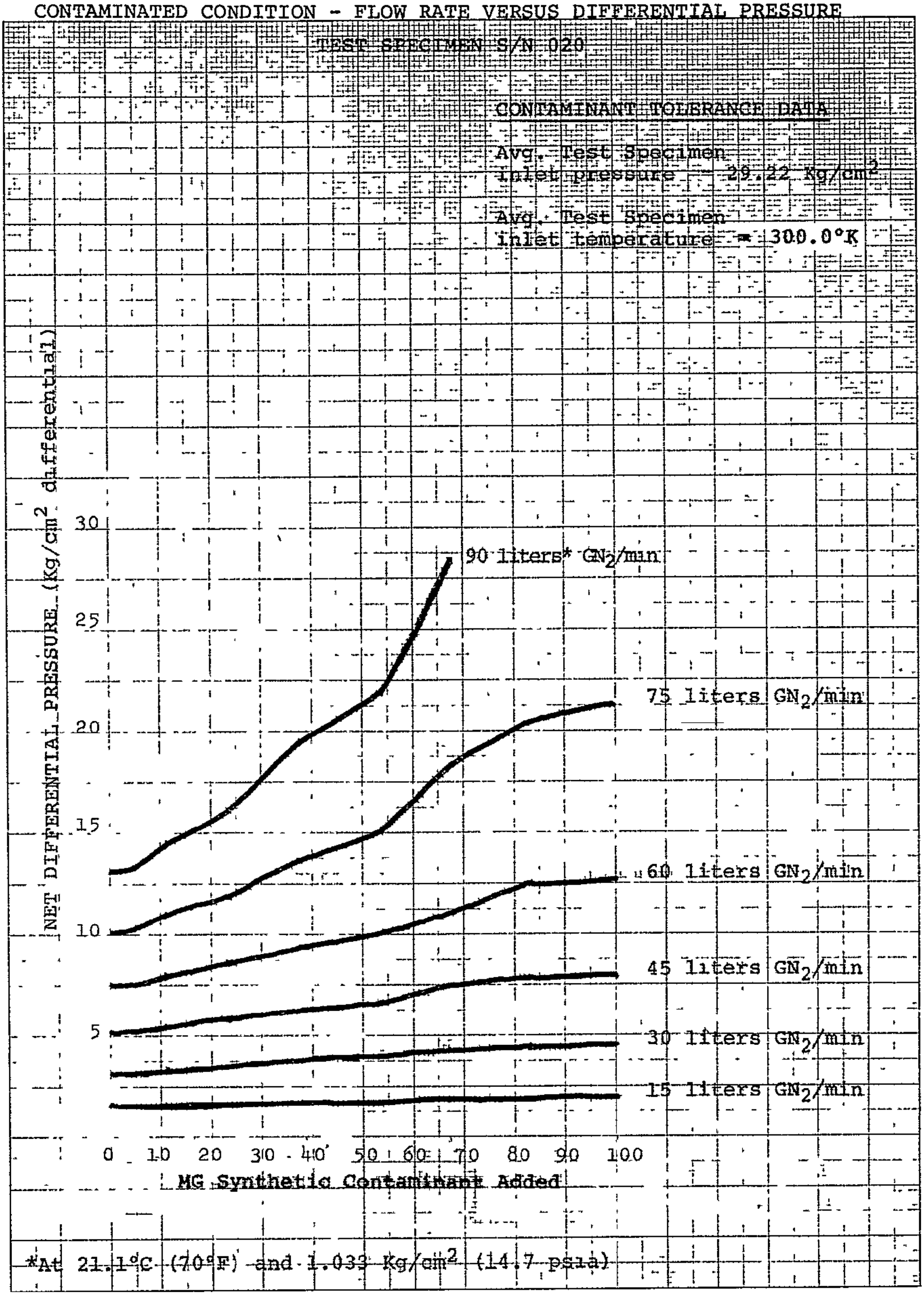
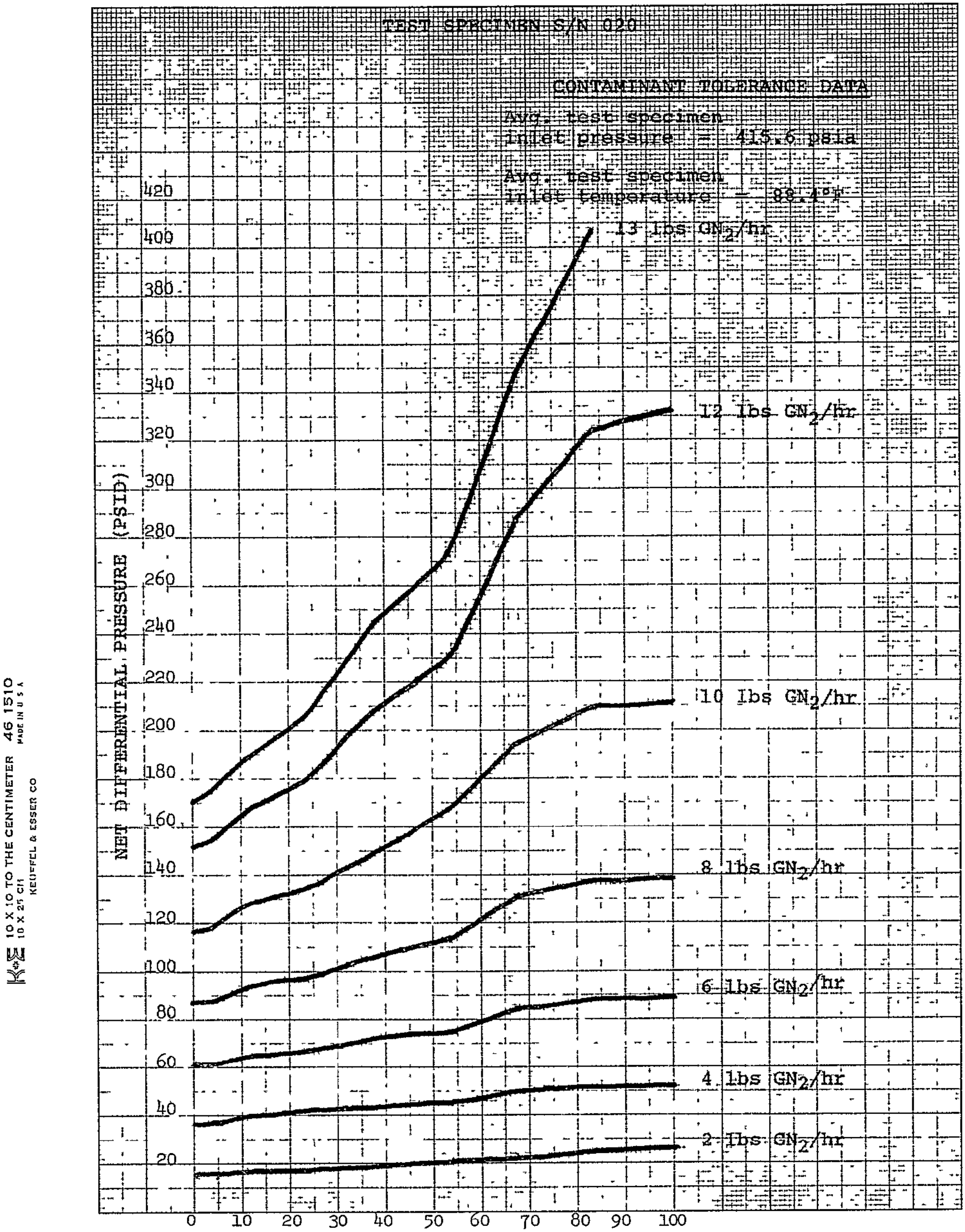


FIGURE 45 Part B

TEST NO. 11

CONTAMINATED CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE



MG Synthetic Contaminant Added

FIGURE 45 Part C

TEST NO. 11

CONTAMINATED CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE

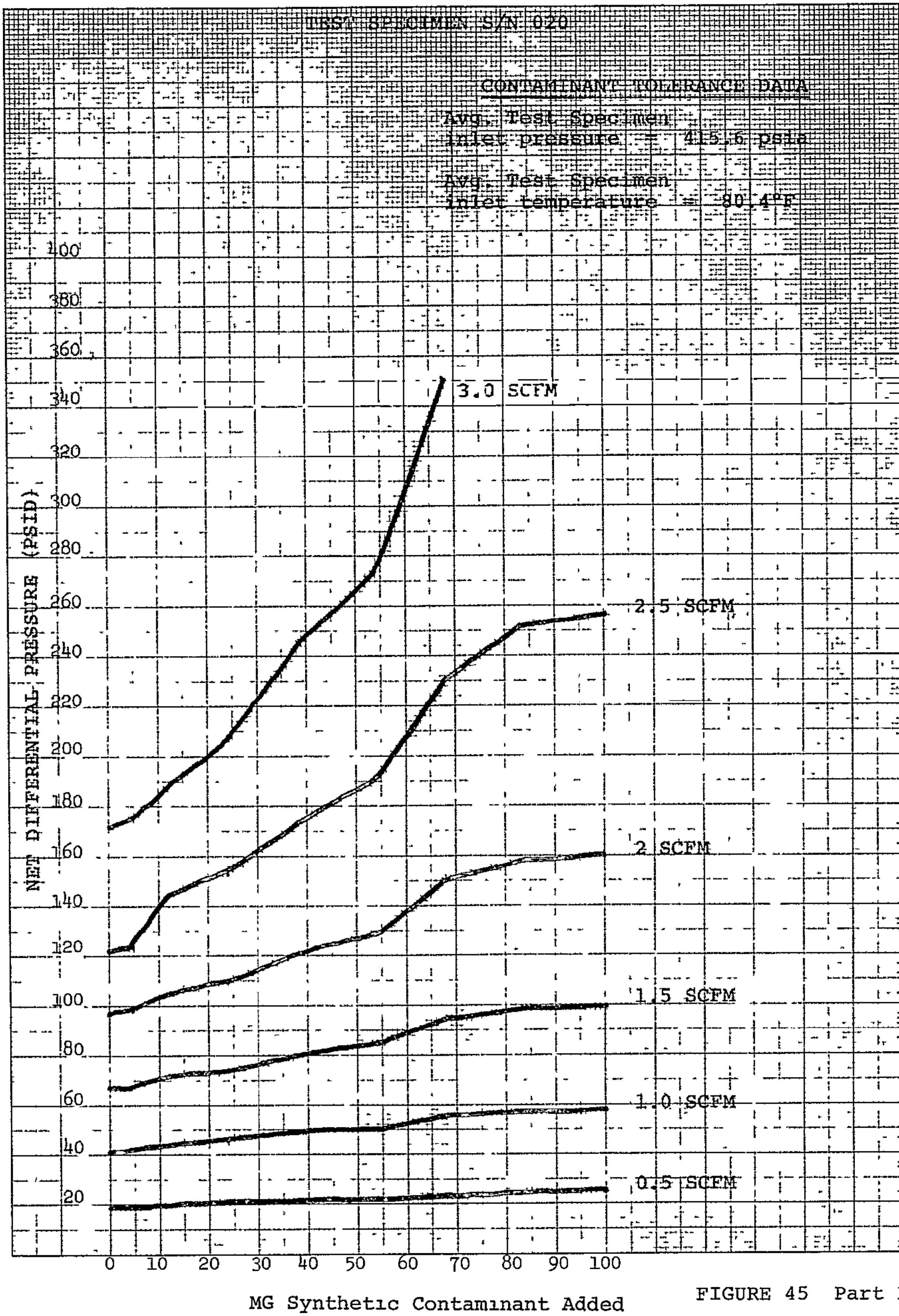


FIGURE 45 Part D

TEST NO. 11

CONTAMINATED CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE

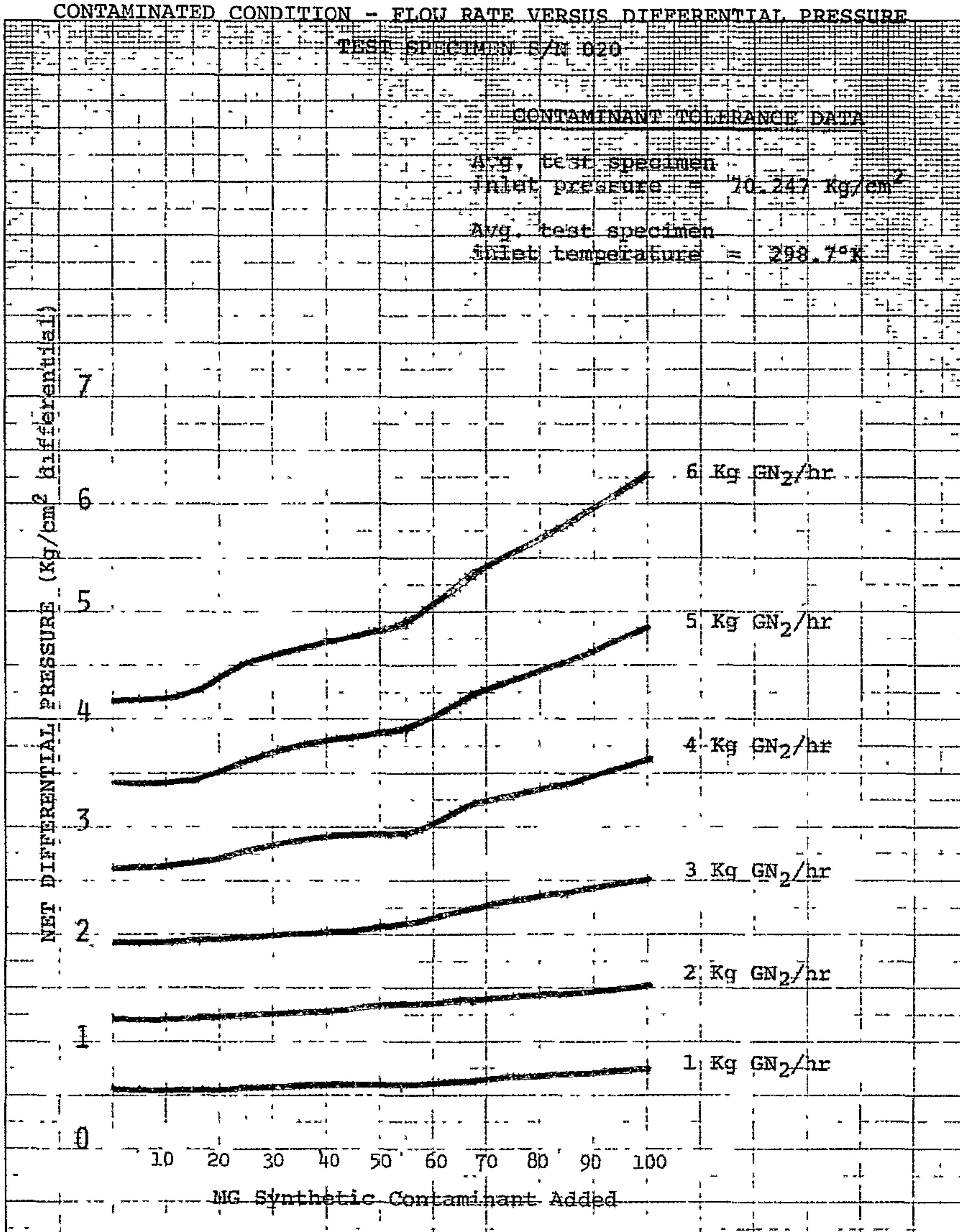


FIGURE 46 Part A

TEST NO. 11

CONTAMINATED CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE

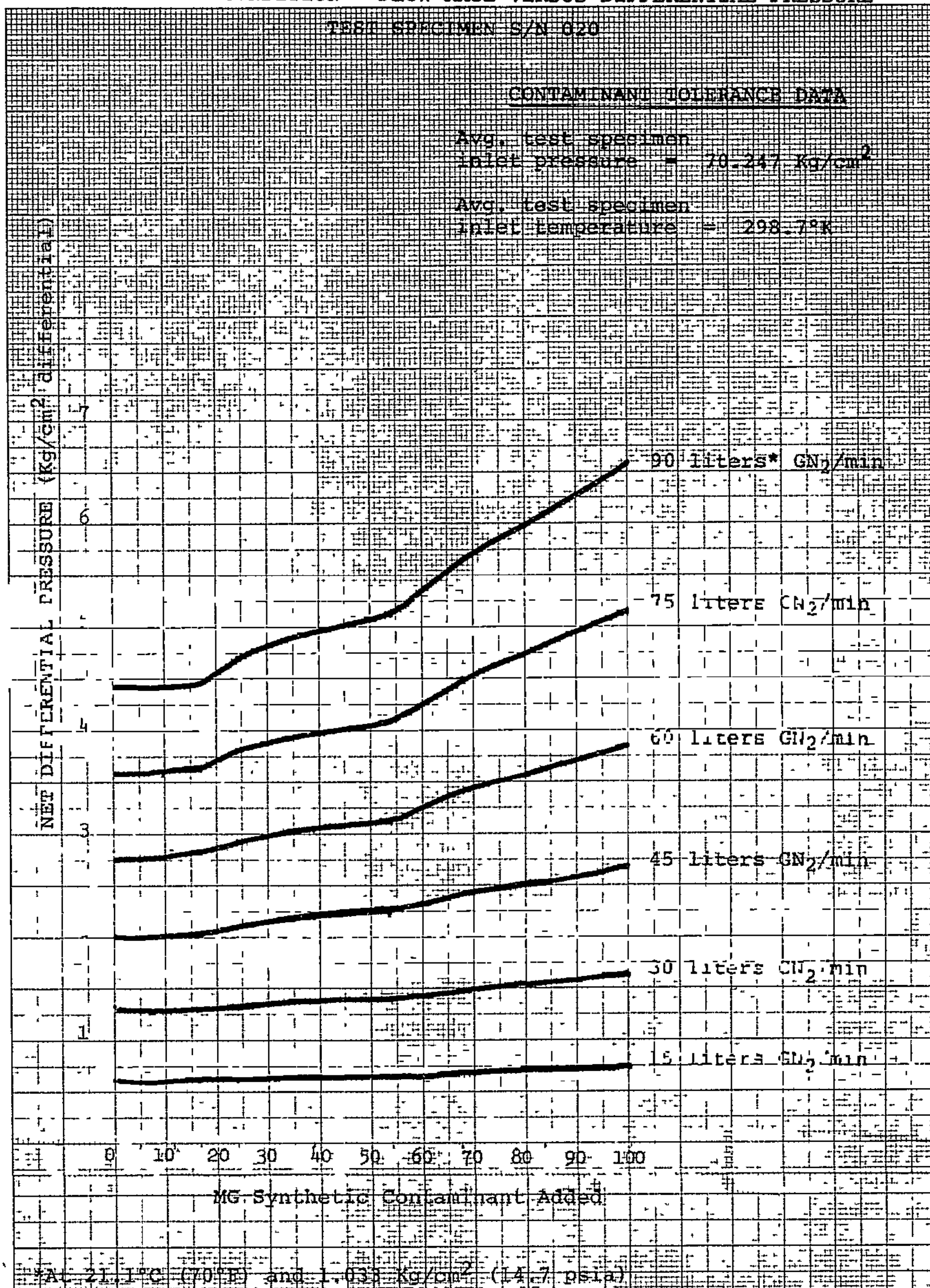


FIGURE 46 Part B

TEST NO. 11

CONTAMINATED CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE

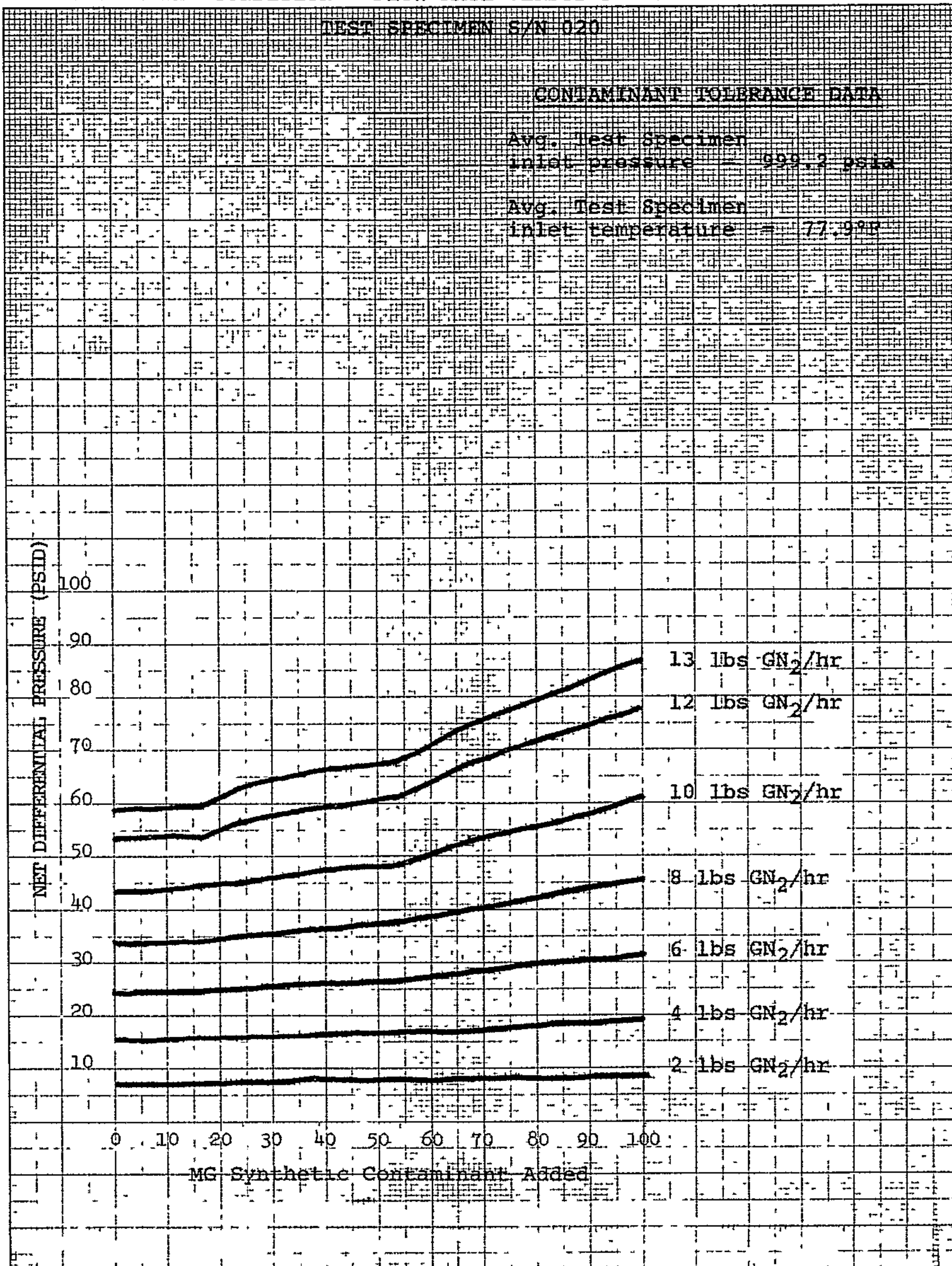
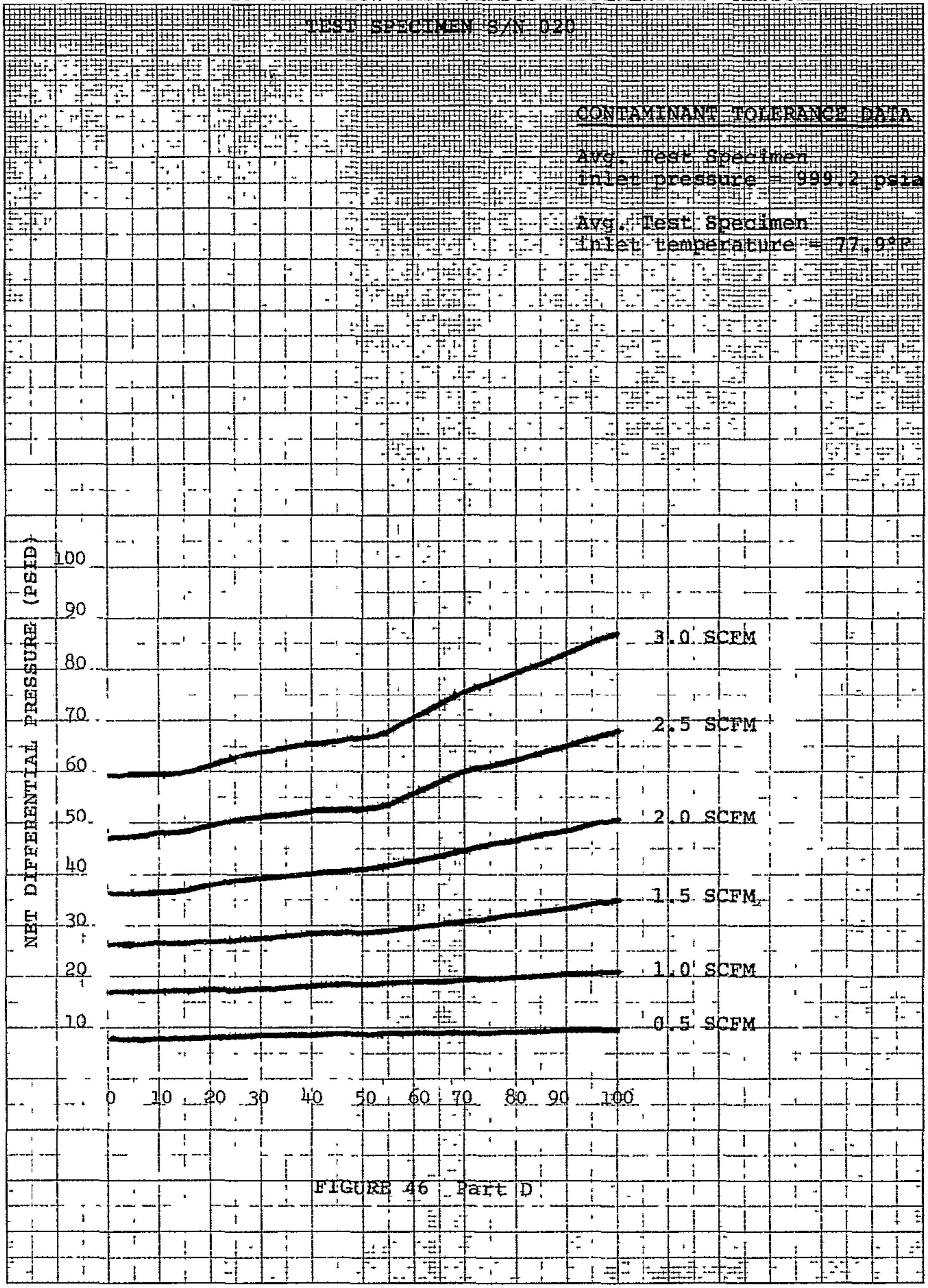


FIGURE 46 Part G

TEST NO. 11

CONTAMINATED CONDITION - FLOW RATE VERSUS DIFFERENTIAL PRESSURE



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