Contrails

AFAPL-TR-69-44
PART II

PROPULSION SYSTEM INTEGRATION AND TEST PROGRAM (STEADY STATE)

PART II. SHARED EXIT EJECTOR NOZZLE STATIC TESTS

D. L. Alfano

*** Export controls have been removed ***

This document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of the Air Force Aero Propulsion Laboratory (APTA), Air Force Systems Command, Wright-Patterson Air Force Base, Ohio.

Approved for Public Release

Contrails

FOREWORD

The effort described in this part of the report was conducted under Phase II, Task IIA of Air Force Contract F33615-67-C-1829, "Propulsion System Integration and Test Program (Steady State)." The static thrust tests described herein were conducted from 23 July 1968 through 5 September 1968 at the Rocketdyne Rocket Nozzle Test Facility under the supervision of C. L. Brown of the Rocketdyne Division of North American Rockwell Corporation.

Some additional testing was done under Internal Research and Development funds, and a portion of these results are included.

The program was sponsored by the Air Force Aero Propulsion Laboratory, Wright-Patterson Air Force Base, Ohio. Squadron Leader Brian Brimelow (RAF), Air Force Aero Propulsion Laboratory , was the program monitor. This report was submitted by the author 15 January 1968.

This Technical Report consists of six parts. The titles of the six parts, along with the portion of the Phase II effort to which each is addressed, are shown below.

Part I.	Thrust Diverter/Vectoring System Flow Tests (Allison)	Task I
Part II.	Shared Exit Ejector Nozzle Static Tests	Task IIA
Part III.	Nozzle Interaction Drag Tests	Task IIB
Part IV.	Inlet Drag Tests	Task IIIA
Part V.	Low Speed Auxiliary Inlet Tests	Task IIIB
Part VI.	YTF-33 Turbofan Engine Tests	Task IIIC

Part II of the report has also been published as Los Angeles Division of North American Rockwell Corporation report number NA-68-939, Part II, dated February 1969.

Publication of this report does not constitute Air Force approval of the report's findings or conclusions. It is published only for the exchange and stimulation of ideas.

Ernest C. Simpson
Ernest C. Simpson
Chief, Turbine Engine Division

Approved for Public Release

Contrails

ABSTRACT

A program for designing and conducting tests on a shared exit ejector nozzle was formulated to provide experimental verification of available analytic techniques, where applicable, and to provide data at those conditions where analytic techniques were not applicable so that this nozzle concept could be evaluated. The test plan was formulated around the complete spectrum of engine cycle data for an Integrated Propulsion System Tactical Fighter. Results from this test program indicate that the reliability of the available analytic techniques for predicting nozzle performance is dependent on an accurate estimate of the internal losses and aerodynamic flow areas involved. The model performance was generally better than predicted. Where analytic techniques are not available, model performance has been observed to be generally greater than 97 percent of ideal thrust.

(The reverse of this page is blank)

Approved for Public Release

Contrails

Approved for Public Release

Contrails

TABLE OF CONTENTS

Section		Page
I	INTRODUCTION	1
II	SUMMARY	3
III	APPARATUS AND PROCEDURES	5
	Test Facility	5
	Model Description	5
	Test Setup	6
	Instrumentation	7
	Procedure	7
IV	DISCUSSION OF RESULTS	9
	Satellite Mode	9
	Comparison of Predicted and Experimental Thrust Performance	9
	Comparison of Predicted and Experimental Pumping Characteristics	10
	Fan Mode	11
	Comparison of Predicted and Experimental Thrust Performance	11
	Fan Mode Pumping Characteristics	12
V	CONCLUSIONS	13
	REFERENCES	15
	APPENDIX I RUN HISTORY	133
	APPENDIX II SECONDARY NOZZLE STATIC PRESSURE DISTRIBUTIONS	143
	APPENDIX III ACCURACY	271
	APPENDIX IV THRUST PERFORMANCE	275
	APPENDIX V PUMPING CHARACTERISTICS	309
	APPENDIX VI SCHLIEREN PHOTOGRAPHS	333

Approved for Public Release

Contrails

LIST OF FIGURES

Figure No.	Title	Page
1	Model Assembly and Installation - IPS Shared Exit Ejector Nozzle - R.N.T.F.	17/18
2	Details Model - IPS Shared Exit Ejector Nozzle - R.N.T.F.	19/20
3	Support Equipment - IPS Shared Exit Ejector Nozzle - R.N.T.F.	21/22
4	Pertinent Areas Used to Define Shared Exit Ejector Nozzle Configuration	23
5-34	Shared Exit Ejector Nozzle - Model Configurations Tested	24-53
35	Shared Exit Ejector Nozzle Model and Balance Assembly Installed in R.N.T.F. - Front View	54
36	Shared Exit Ejector Nozzle Model and Balance Assembly Installed in R.N.T.F. - Rear View	55
37	Shared Exit Ejector Nozzle Model and Balance Assembly - Typical Satellite Mode Configuration	56
38	Shared Exit Ejector Nozzle Model and Balance Assembly - Typical Fan Mode Configuration	57
39	Shared Exit Ejector Nozzle Model Installed in R.N.T.F. - Front View with Windshield Installed	58
40	Shared Exit Ejector Nozzle Model Installed in R.N.T.F. - Side View with Windshield Installed	59
41	Shared Exit Ejector Nozzle Installed in R.N.T.F. - Side View, Primary Nozzle Only	60
42-64	Shared Exit Ejector Nozzle Static Tests - Satellite Mode Performance (Carpet Plots)	61-105
65-66	Shared Exit Ejector Nozzle Static Tests - Satellite Mode Pumping Characteristics	107-109
67	Shared Exit Ejector Nozzle Static Tests - Satellite Mode - Primary Nozzle Flow Coefficients	111

Approved for Public Release

Contrails

Figure No.	Title	Page
68	Shared Exit Ejector Nozzle Static Tests - Typical Primary Nozzle Contour	112
69-71	Shared Exit Ejector Nozzle Static Tests - Fan Mode Performance (vs. Nozzle Pressure Ratio)	113-115
72-84	Shared Exit Ejector Nozzle Static Tests - Fan Mode Performance (Carpet Plots)	116-128
85-87	Shared Exit Ejector Nozzle Static Tests - Fan Mode Pumping Characteristics	129-131
APPENDIX II		
88-147	Shared Exit Ejector Nozzle Static Tests - Satellite Mode - Secondary Nozzle Static Pressure Distributions	146-205
148-212	Shared Exit Ejector Nozzle Static Tests - Fan Mode - Secondary Nozzle Static Pressure Distributions	206-270
APPENDIX IV		
213-230	Shared Exit Ejector Nozzle Static Tests - Satellite Mode Performance (vs. Nozzle Pressure Ratio)	278-295
231-242	Shared Exit Ejector Nozzle Static Tests - Fan Mode Performance (vs. Nozzle Pressure Ratio)	296-307
APPENDIX V		
243-251	Shared Exit Ejector Nozzle Static Tests - Satellite Mode Pumping Characteristics	312-320
252-263	Shared Exit Ejector Nozzle Static Tests - Fan Mode Pumping Characteristics	321-332
APPENDIX VI		
264-317	Shared Exit Ejector Nozzle Static Tests - Satellite Mode - Schlieren Photographs	336-389

Approved for Public Release

Contrails

LIST OF ABBREVIATIONS AND SYMBOLS

A	Area
A_{MIN}	Area in the secondary nozzle (defined in figure 4)
C_V	Thrust Coefficient
IPS	Integrated Propulsion System
P	Pressure, psi
T	Temperature, ^{o}R
W	Airflow, lb_m/sec
X	Linear distance from the exit of the secondary nozzle
γ	Ratio of specific heat at constant pressure to the specific heat at constant volume

SUBSCRIPTS

A,∞	Ambient conditions
T	Total or stagnation conditions
P	Primary flow system
F	Fan flow system
W	Secondary nozzle wall properties
8	Primary nozzle exit station
9	Secondary nozzle exit station

SUPERSCRIPTS

*	Sonic conditions

Approved for Public Release

Contrails

Section I

INTRODUCTION

The analytic effort performed in Phase I of this program included consideration of a wide variety of missions, vehicles, and propulsion system installations. One of the promising turbofan derivative propulsion systems used in the vehicle studies placed some unique requirements on the nozzle system. To satisfy the requirements, a number of nozzle concepts were evaluated in Phase I. Among the most promising were two nozzle designs of the ejector type; a blown flap ejector and a shared exit ejector. An experimental investigation of the blown flap technique was performed in Phase I with Contractor funds. The results indicated that this concept would not be satisfactory for certain critical engine cycle operating points. Therefore, further nozzle evaluation was directed toward the shared exit ejector concept.

The particular engine cycle of concern involves two distinct modes of operation. The first, denoted satellite mode, requires a conventional ejector with a convergent-divergent secondary shroud. In this mode the nozzle must operate as an aircraft type ejector at ratios of primary total pressure to ambient static pressure approaching 20, and secondary to primary airflow ratios approaching two percent. However, unlike ordinary ejector operation, it must also be able to handle large quantities of secondary airflow (secondary to primary temperature corrected airflow ratios approaching 200 percent) at total pressures near those of the primary stream.

The second, or fan mode of operation, requires an ejector nozzle with a convergent shroud. In this mode, the primary stream assumes a secondary role with a small but unknown quantity of airflow through the central part of the nozzle. The level of total pressure in the primary stream is much lower than in the satellite mode. Most of the air goes through the annular opening around the primary stream.

Computer programs and other techniques developed for analyzing ejector nozzles are generally directed toward conventional aircraft ejectors. The range of operating conditions in the satellite mode greatly exceeds this normal area of application. Analytic results are therefore uncertain outside the range of conditions for which these techniques were developed. For fan mode operating conditions, rigorous analytic techniques are non-existent. Therefore, a model test program was designed to meet the following primary objectives:

1. Verify analytic predictions with experimental results in the areas where analytic techniques are applicable.

2. Provide experimental data where there are no analytic techniques available.

(The reverse of this page is blank)

Approved for Public Release

Contrails

Approved for Public Release

Contrails

Section II

SUMMARY

A comprehensive test program was conducted to substantiate the concept of an ejector nozzle designed to match the requirements of a particular integrated propulsion system cycle. The test plan was formulated around the complete spectrum of cycle data for an IPS Tactical Fighter. Various engine power settings, mach numbers and altitudes were considered. Thirty nozzle configurations of 1/10 scale size were tested to provide parametric data covering the range of geometries currently anticipated for the airplane. Such an ejector nozzle must be able to operate efficiently in two distinct cycle modes. The satellite mode configurations, incorporating a convergent-divergent secondary shroud, must handle a range of secondary to primary-temperature-corrected-airflow ratios from two percent to 200 percent. Nozzle pressure ratio in this mode, defined as the ratio of primary total pressure to ambient static pressure, varies over an approximate range of 1.5 to 20. Fan mode configurations are characterized by a convergent secondary shroud. Total pressure and airflow in the primary stream are much lower than in the satellite mode. Most of the air passes through the annular opening around the primary stream and the nozzle pressure ratio, based on the total pressure in the annular stream, ranges between 1.1 and 3.5.

This report presents all of the results from the tests. Comparisons of data and analytic predictions are made and discussed.

The results presented include the nozzle gross thrust coefficient, ejector pumping characteristics, static pressure distributions along the inside of the secondary nozzle wall, and schlieren photographs of the exhaust flow pattern. Nozzle thrust performance is presented in carpet plot form and discussed in Section IV. The tests were conducted in a variable back pressure vacuum chamber. Unheated air was supplied from a storage system to the primary and secondary flow systems. Nozzle thrust was measured on a force balance.

The conclusions reached were that analytic techniques available for predicting nozzle performance in the satellite mode are generally satisfactory if the nozzle aerodynamic flow areas and internal losses can be accurately estimated. Comparisons of experimental and analytic nozzle performance are shown in the satellite mode carpet plots. These analytic predictions were made with the Pratt & Whitney Aircraft GODD computer program with an assigned internal loss factor of 1-1/2 percent. Test results indicate that the assumption was pessimistic. Satellite mode pumping characteristics, as predicted by the GODD program, agreed better with experimental values when the aerodynamic nozzle exit flow areas were used rather than the geometric areas.

In the case of fan mode nozzle configurations, where only crude estimates of thrust coefficient were possible for a limited number of conditions,

Approved for Public Release

Contrails

test results indicated that predicted internal losses were greatly exaggerated. Additionally, fan mode performance level was relatively insensitive to pressure ratio or the amount of flow in the primary stream. The test program also provided data over the entire range of fan mode cycle conditions where analytic techniques were not available. The level of fan mode internal performance was generally greater than 97 percent of ideal gross thrust.

The shared exit ejector nozzle appears to be a workable concept.

Approved for Public Release

Contrails

Section III

APPARATUS AND PROCEDURE

TEST FACILITY

All testing was conducted at the Rocketdyne Rocket Nozzle Test Facility (RNTF), an intermittent blown-down vacuum chamber test facility located at the Los Angeles Division of North American Rockwell Corporation (reference 1). The test chamber is a reinforced steel cylinder approximately 16 feet long and five feet in diameter. Both primary and secondary air flow systems were supplied from a group of 12 high pressure cylinders with a pressure rating of 3100 psig. A series of precision regulators delivers the working fluid to the model at the desired pressure level. The exhaust from the test chamber enters a 36,000 cu ft vacuum sphere via a removable diffuser section attached to the downstream tunnel door. Supersonic flow in the diffuser section isolates the test chamber from rising pressure in the sphere.

Two data recording systems were used during the test. The main system consists of Bristol analog recorders in conjunction with a Datex encoder. The latter converts the analog signals to digital form every 0.6 second. Output of this system is in the form of punched cards for direct input into data reduction computer programs. A second recording system, utilizing high precision face gages and digital voltmeters, was read directly during each test run to monitor and control test conditions. Information from this system also provided a check on the validity of the main Datex system data.

The test facility is equipped with a schlieren photographic system. Schlieren photos, both regular and Polaroid, were taken during high pressure ratio test runs with excellent results.

MODEL DESCRIPTION

The three design drawings used in fabricating the model and support equipment hardware are shown in figures 1, 2 and 3. The model scale was one-tenth full size. Figure 1 is the model assembly and installation drawing which shows the complete model/balance system and instrumentation. Details of the model are shown in figure 2, including all part dimensions. Figure 3 shows the support equipment.

Figure 4 is a sketch illustrating the geometric areas used to define each configuration. Sketches of the model configurations tested are shown, full size, in figures 5 through 34. These configurations were obtained through various combinations of six primary and ten secondary nozzles. Satellite mode configurations are characterized by a divergent secondary nozzle ($A_{MIN} < A_9$). The value of A_{MIN} for all satellite mode nozzles is approximately four square inches. Fan mode configurations have convergent

Approved for Public Release

Contrails

secondary nozzles ($A_{MIN} > A_9$) and a constant value of A_{MIN} equal to 7.73 square inches.

Flow straightening screens were installed in both the primary and fan plenum chambers to insure uniform flow parallel to the model centerline. Additionally, the plenum chambers were sized to produce low flow velocities ($M < 0.1$).

Figures 35 through 41 are photographs of the model/balance assembly as installed in the test chamber. Figure 35 is a view from the downstream tunnel door. Fan mode configuration number 28 is shown installed on the model. Air is delivered from a non-metric fitting to the metric model by way of trombone fittings designed to minimize balance interference. Figure 36 is a rear view of the assembly. The sonic flowmeter used to measure secondary airflow is shown in this view. The primary flowmeter was external to the test chamber. Figure 37 is a close-up of the model with a satellite mode divergent secondary nozzle installed. Configuration changes were facilitated with a coupling block to connect the secondary nozzle static pressure taps with permanent instrumentation lines. Figure 38 is similar to figure 37 with the exception that a convergent fan mode secondary nozzle has been installed.

Figure 39 is a view from the downstream tunnel door just prior to testing. Covers have been taken off the schlieren windows and a windshield has been installed to prevent any recirculating air from affecting the force balance readings. Figure 40 is a side view with the windshield installed. Figure 41 is also a side view with the secondary nozzle removed.

TEST SETUP

The model and single component force balance assembly was mounted on a pedestal in the test chamber as shown in figure 35. Both primary and fan streams enter the model plenum chambers at right angles to the model centerline. Six trombone-shaped fittings isolate the force balance from any influence of the entering flows.

Primary and fan flow rates were measured with sonic venturi flowmeters. Throat size was dictated by the magnitude of the flow rate being measured. Several meter changes were made during the test program in order to provide choked flow at these venturis.

Model testing was separated into three basic phases; satellite mode high pressure ratio, satellite mode low pressure ratio, and fan mode testing. A chronological run history showing the actual model geometries and test conditions is presented in Appendix I.

The primary flow system was leak checked to a pressure of 25 psia following each primary nozzle change. Similarly, the secondary system was leak checked subsequent to a secondary nozzle change. Also, the static pressure taps along the inner wall of the secondary nozzle were sequence checked.

Approved for Public Release

Contrails

Pressure transducer calibrations were made prior to initiating the testing and after any instrumentation changes or suspected transducer overloadings. Also, several calibration curves were obtained for the 250 pound single component force balance system.

INSTRUMENTATION

Model instrumentation was essentially the same as described in the pretest report (reference 2). However, three additional static pressure taps were installed in the fan duct at equal circumferential positions between the total pressure rakes as a result of concern over the proximity of the total pressure probes to the static taps at the rake positions.

Ideal thrust calculations were based on total pressure measurements in the primary plenum chamber and the fan duct. Total and static pressure measurements were also taken in the fan plenum chamber for the purpose of calculating possible tare forces between the fan plenum and the fan duct. A static tap was placed on the external tip of the secondary nozzle to record this pressure and determine a tare force, if appropriate. This pressure was always equal to ambient, thus the tare force was zero.

A row of seventeen static pressure taps were placed along the inner wall of the secondary nozzle. The pressure distributions provided by this instrumentation appears in Appendix II.

A thermocouple in each plenum chamber measured the temperature in the primary and fan gas streams through the model.

In addition to model instrumentation, pressure and temperature measurements were made in each sonic flowmeter for each test.

Forces were measured on a 250 pound Revere dual bridge single component balance.

All data was recorded automatically for each test case on the Bristol analog system. Pressure signals were measured on differential pressure transducers. Reference pressure levels were either recorded automatically or read immediately before each test. Critical pressures, such as the total pressures in the fan duct and the primary plenum chamber and the ambient static pressure were read fifteen times during each test case.

System accuracy is discussed in Appendix III.

PROCEDURE

For satellite mode testing, total pressure in the primary plenum chamber was set at a nominal value of 25 psia by establishing the primary flow rate in the sonic flowmeter upstream of the model. Secondary flow rates were based on the weight flow ratios specified in the pretest report (reference 2). Having established these flow rates, they were held constant throughout each test run. Nozzle pressure ratio was varied during a run by

Approved for Public Release

Contrails

varying the ambient static pressure. This was accomplished with a hydraulically actuated translating plug in the diffuser section of the test facility. Calibrations were made to provide nozzle pressure ratio as a function of diffuser plug position.

A similar procedure was followed during fan mode testing except that the fan plenum chamber pressure was set first at 15 psia. Primary airflow rate was then established based on the desired primary to fan weight flow ratio.

Data was taken at an average of six values of pressure ratio during each test. Plots of thrust performance and pumping characteristics versus pressure ratio are presented in Appendices IV and V, respectively. Each curve appearing in these appendices represents the data gathered during a specific test run. All data was recorded automatically by the Bristol/Datex recording system. Critical pressures were also monitored on gages during each test and used as an immediate check on the validity of each test run.

Schlieren photographs of the exhaust plume and shock pattern were taken only for the high pressure ratio satellite mode tests, and are presented in Appendix VI.

Approved for Public Release

Contrails

Section IV

DISCUSSION OF RESULTS

SATELLITE MODE

COMPARISON OF PREDICTED AND EXPERIMENTAL THRUST PERFORMANCE

Figures 42 through 64 present carpet plots of thrust performance for the satellite mode nozzle configuration. Each carpet plot pertains to a constant value of A_{MIN}/A_8 and temperature corrected fan to primary weight flow ratio. Thrust coefficient, C_V, is defined as the actual or measured thrust divided by the sum of the ideal thrusts of both the fan and primary streams. The symbols on each figure represent the experimental performance measured during the test. Actual thrust was based on the single component force balance reading only. Investigation into the possibility of tare forces on the model resulted in the conclusion that these forces were negligible during all testing. The thrust coefficient was evaluated as shown below:

$$C_V = \frac{F_{MEASURED}}{(F_{IDEAL})_{PRIMARY} + (F_{IDEAL})_{SECONDARY}}$$

$$F_{IDEAL} = C_{F_{OPT}} \frac{W\sqrt{T_T}}{K_t}$$

where: $$C_{F_{OPT}} = \left\{ \frac{2\gamma^2}{\gamma-1} \left(\frac{2}{\gamma+1}\right)^{\frac{\gamma+1}{\gamma-1}} \left[1 - \left(\frac{P_\infty}{P_T}\right)^{\frac{\gamma-1}{\gamma}}\right] \right\}^{1/2} = \frac{F_{IDEAL}}{A^* P_T}$$

$$K_t = \left[\frac{\gamma}{R} \left(\frac{2}{\gamma+1}\right)^{\frac{\gamma+1}{\gamma-1}}\right]^{1/2} = \frac{W\sqrt{T_T}}{A^* P_T} \qquad \text{(reference 4)}$$

and for $\gamma = 1.4$, $R = 53.3$; $K_t = 0.532$ and $C_{F_{OPT}} = f\left(\frac{P_\infty}{P_T}\right)$

For several cases, during low pressure ratio satellite mode testing, the total pressure in the fan duct dropped to a level less than the ambient static pressure. Calculation of the ideal thrust of the fan stream could not be handled correctly by the data reduction computer program for these cases. Manual calculations were made which showed that the ideal thrust of the fan stream was negligible in comparison to the ideal thrust of the primary stream. Therefore, thrust coefficient was based only on the ideal thrust of the primary stream for these few cases.

Solid lines (constant area ratio, A_9/A_8), and dashed lines (constant pressure ratio, P_{T_P}/P_∞) illustrate the performance as predicted by the

Approved for Public Release

Contrails

Pratt & Whitney Aircraft GODD computer program (reference 3). This computer program is a simplified one-dimensional analysis, accounting for over- or under- expansion and internal losses via an arbitrary friction loss factor. Secondary to primary weight flow ratios from 0.1 percent to 200 percent were run successfully in this computer deck, although some difficulty was encountered at the high weight flow ratios. All cases run on the GODD deck were input with a friction loss factor of 1.5 percent, limiting the maximum thrust coefficient to 0.985.

Investigation of the carpet plots shows that static thrust coefficients as computed from test results are generally higher than the available estimates. Peak test performance ranges from 1/2 percent to 1-1/2 percent higher than GODD program predictions, indicating that the assigned internal loss penalty may have been pessimistic.

In order to minimize scaling effects on internal losses, the model primary plenum chamber was run at as high a pressure as practical. A value of 25 psia was used for the tests. Full-size engine Reynolds numbers will vary significantly, depending on flight conditions. The full-size Reynolds number per foot, for a typical supersonic flight condition with maximum afterburner, is about one-third of the model Reynolds number per foot. The Reynolds numbers were based on flow conditions at the primary nozzle exit. Referring to plots in reference 5 of estimated boundary layer thrust correction as a function of pressure, temperature and size, it appears that any scaling effects for the model tested are of second order importance and are most likely lost in the uncertainty band of the data.

COMPARISON OF PREDICTED AND EXPERIMENTAL PUMPING CHARACTERISTICS

Figure 65 presents the pumping characteristics of the shared exit ejector nozzle in the satellite mode. The solid lines are the characteristic curves predicted by the GODD deck. Symbols represent test point data. The satellite mode pumping characteristic is defined as the ratio of total pressure in the fan duct to the total pressure in the primary plenum chamber, P_{T_F}/P_{T_P}. As calculated by the GODD deck, pumping characteristic versus temperature-corrected weight-flow ratio for choked ejector nozzles is solely dependent on the area ratio A_{MIN}/A_8. However, the test data points plotted on figure 65 indicate a slight effect of nozzle area ratio, A_9/A_8. This effect becomes less significant with increasing weight flow ratio. The points that have been plotted represent the maximum (flagged symbols) and minimum (plain symbols) values of A_9/A_8 corresponding to each value of A_{MIN}/A_8. Intermediate configurations were omitted for clarity. Also, only one configuration with a ratio of $A_{MIN}/A_8 = 1.354$ was tested.

Agreement between test data and estimated pumping characteristic is best at an area ratio $A_{MIN}/A_8 = 1.074$. This agreement deteriorates as the ratio of A_{MIN}/A_8 increases. This lack of agreement between predicted and experimental pumping characteristics at higher values of A_{MIN}/A_8 is due to the fact that the actual measured model areas were used as input to the GODD computer program, rather than the effective flow areas.

Approved for Public Release

Contrails

Primary nozzle flow coefficient data (figure 67) show the effective flow area to be significantly less than A_8, particularly for the smaller primary exit areas. Flow coefficient is defined as the ratio of aerodynamic throat area, A^*_P, to the physical area, A_8, measured on the model. A^*_P was calculated with the following equation:

$$A^*_P = \frac{W_P \sqrt{T_{TP}}}{P_{T_P} K_{t_p}}$$

$$K_{t_p} = 0.532 \quad (\gamma = 1.4,\ R = 53.3)$$

All calculations of flow coefficient plotted in figure 67 were made for temperature-corrected airflow ratios of 0.0. In other words, there was no flow present to influence the flow discharging from the primary nozzle. Several check cases were re-run on the GODD program with area ratios based on A^*_P rather than A_8. The results indicate closer agreement between these calculations and the test data, as indicated in figure 66.

The low discharge coefficients were the result of the sharp radius turn on the inside contour of the primary nozzle as shown on figure 68. Test run number 22 (Appendix I) was conducted with no secondary nozzle installed and designated configuration number 140. This was done to check the possibility that the secondary nozzle might have influenced the discharge coefficient of the primary nozzle. No influence was evident.

FAN MODE

COMPARISON OF PREDICTED AND EXPERIMENTAL THRUST PERFORMANCE

Analytical techniques for estimating performance for the fan mode configuration was limited to manual calculation since no applicable computer solution was known to be available. These estimates accounted for friction losses, underexpansion and a dumping or sudden expansion loss in passing from the fan duct to the secondary nozzle. No attempt was made to calculate the effect of flow through the primary system on the dumping loss. All fan mode secondary nozzle configurations were convergent. That is, the minimum area occurred at the exit, A_9. The parameter A_{MIN}/A_8 is retained from satellite mode configurations for continuity. A_{MIN}, although not the minimum area in the secondary shroud, is measured at the same station as for the satellite mode configuration and is constant for all fan mode nozzles (figures 24 through 34).

Figures 69 through 71 show comparisons of calculated thrust performance with test results. Only those tests specifying zero flow in the primary system are shown. Three values of the parameter A_{MIN}/A_8 correspond to the three primary nozzles tested.

The pressure ratio range over which these nozzle configurations were tested was approximately 1.3 to 2.5. Dumping loss estimates indicated a

Approved for Public Release

Contrails

maximum loss occurring with the largest primary nozzle (A_{MIN}/A_8 = 2.077). Test data for these configurations (figures 69 through 71) indicate that this estimated dumping loss was greatly exaggerated. As primary nozzle size decreases and the estimated dumping loss is diminished, the test data agrees more closely with calculated performance for pressure ratios above 2.0. Lower performance at low (unchoked) pressure ratios is due to the sensitivity of thrust coefficient to total pressure losses in this region.

Figures 72 through 84 present carpet plots of nozzle performance for all fan mode configurations and conditions tested. Performance levels are generally greater than 97 percent of ideal thrust. Variation in the amount of flow through the primary system has little effect on nozzle performance providing further evidence that the dumping loss is quite negligible.

FAN MODE PUMPING CHARACTERISTICS

Figures 85 through 87 present the pumping characteristic curves for all fan mode configurations. Analytic predictions were not attempted in this area. Fan mode pumping characteristic is defined as the ratio of total pressure in the primary plenum chamber to the total pressure in the fan duct, P_{T_P}/P_{T_F}. An interesting fact evident from these curves is that for a given primary nozzle size (constant value of A_{MIN}/A_8), the pumping characteristic equals 1.0 at a unique value of primary/fan temperature-corrected weight flow ratio. This value is independent of secondary nozzle exit area, A_9.

Approved for Public Release

Contrails

Section V

CONCLUSIONS

The following conclusions are drawn from the results of the test program for the shared exit ejector nozzle:

1. Thrust performance for satellite mode configurations was generally better than the estimates made with the Pratt & Whitney Aircraft GODD computer program using an internal loss factor of 1-1/2 percent.

2. Peak performance of satellite mode configurations was 1/2 percent to 1-1/2 percent higher than the maximum performance predicted by the GODD program indicating that the internal losses (skin friction, mixing, etc.) were overestimated.

3. The GODD computer program is capable of analyzing the performance of ejector nozzles with secondary to primary airflow ratios up to 200 percent.

4. Disagreement of the pumping characteristic curves predicted by the GODD computer program for satellite mode configurations with experimental results was due to the relatively poor discharge coefficients of the primary nozzles tested.

5. The Pratt & Whitney GODD computer program is a satisfactory tool for predicting ejector nozzle thrust performance and pumping characteristics only when the aerodynamic flow areas and nozzle internal losses can be accurately estimated by other methods.

6. The internal performance of the shared exit ejector model in the convergent fan mode is generally greater than 97 percent of ideal thrust.

7. Estimates of a loss in total pressure when the fan flow is dumped into the secondary nozzle from the annular fan duct were greatly exaggerated.

8. There was no significant variation in fan mode performance level with the amount of flow in the primary system.

(The reverse of this page is blank)

Approved for Public Release

Contrails

Approved for Public Release

Contrails

REFERENCES

1. Reyes, C. A., "Description of the Cold Flow Rocket Nozzle Test Facility," LAP-67-291 (RC), Rocketdyne Division of North American Rockwell Corporation, 5 July 1967.

2. Alfano, D. L., Pretest Report for Static Tests of the Shared Exit Ejector Nozzle Concept, NA-68-548, Los Angeles Division of North American Rockwell Corporation, 3 July 1968

3. "Overall Ejector Performance Calculation Deck," PWA-2888, Supplement A, Pratt & Whitney Aircraft, East Hartford, Connecticut

4. Shapiro, A. H., The Dynamics and Thermodynamics of Compressible Fluid Flow, Volume I, The Ronald Press Company, New York, 1953

5. Bonner, E., and Nixon, J. A., Wind Tunnel Testing Techniques for Integrated Airframe-Exhaust Nozzle Systems, AFFDL-TR-68-94, Air Force Flight Dynamics Laboratory, Wright-Patterson Air Force Base, Ohio, July 1968

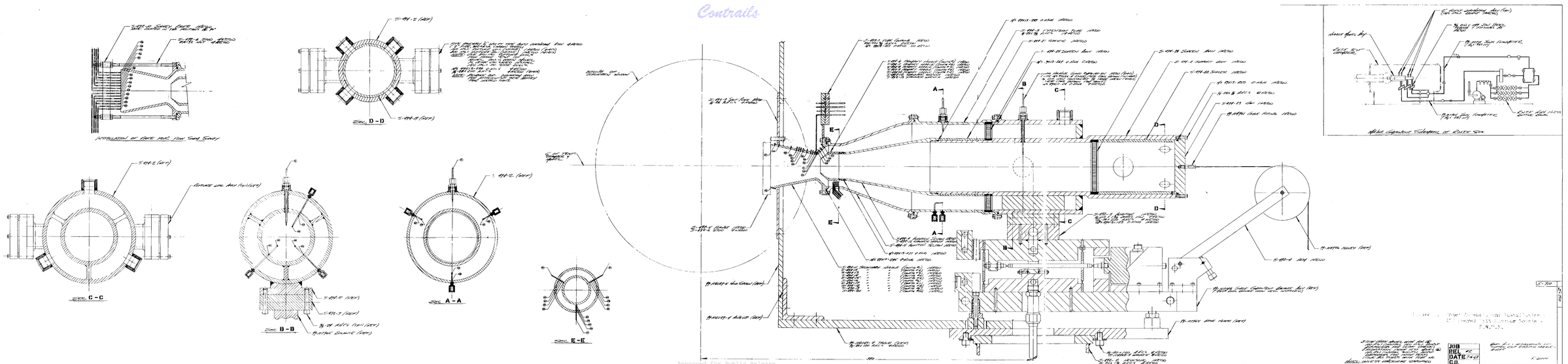
(The reverse of this page is blank)

Approved for Public Release

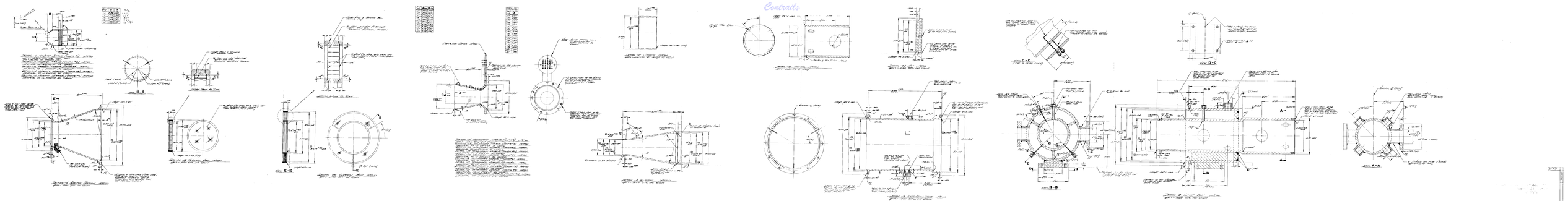
Contrails

Approved for Public Release

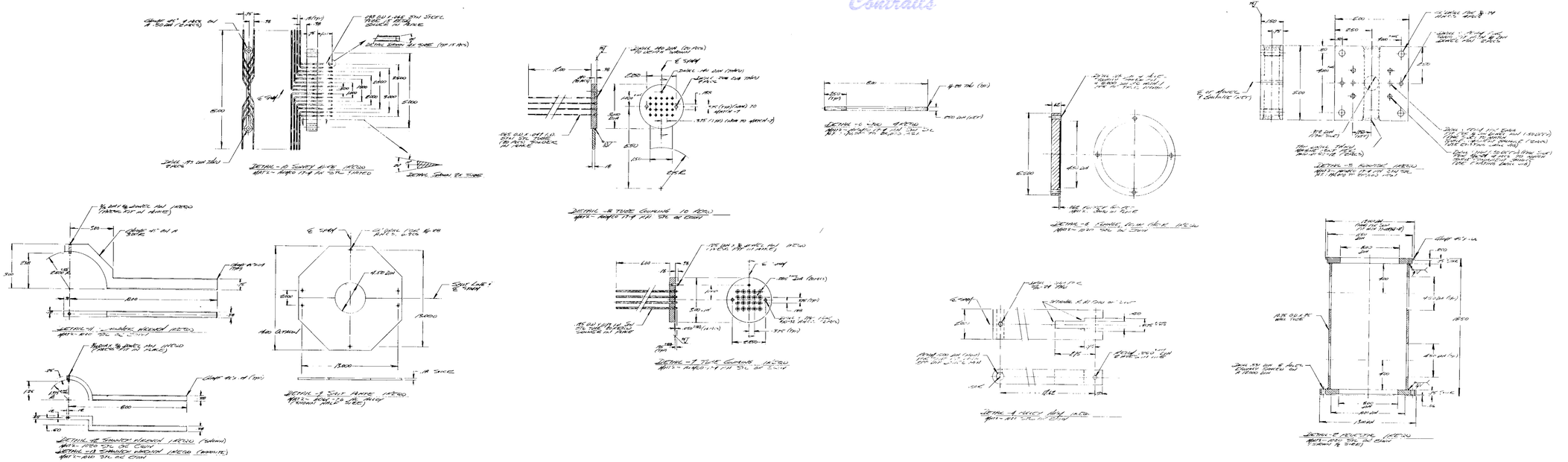
Contrails


INSTALLATION OF PARTS FOR FLOW SHAPE SCHEDULE
SEC D-D
SEC C-C
SEC B-B
SEC A-A
SEC E-E
Approved For Public Release

Contrails

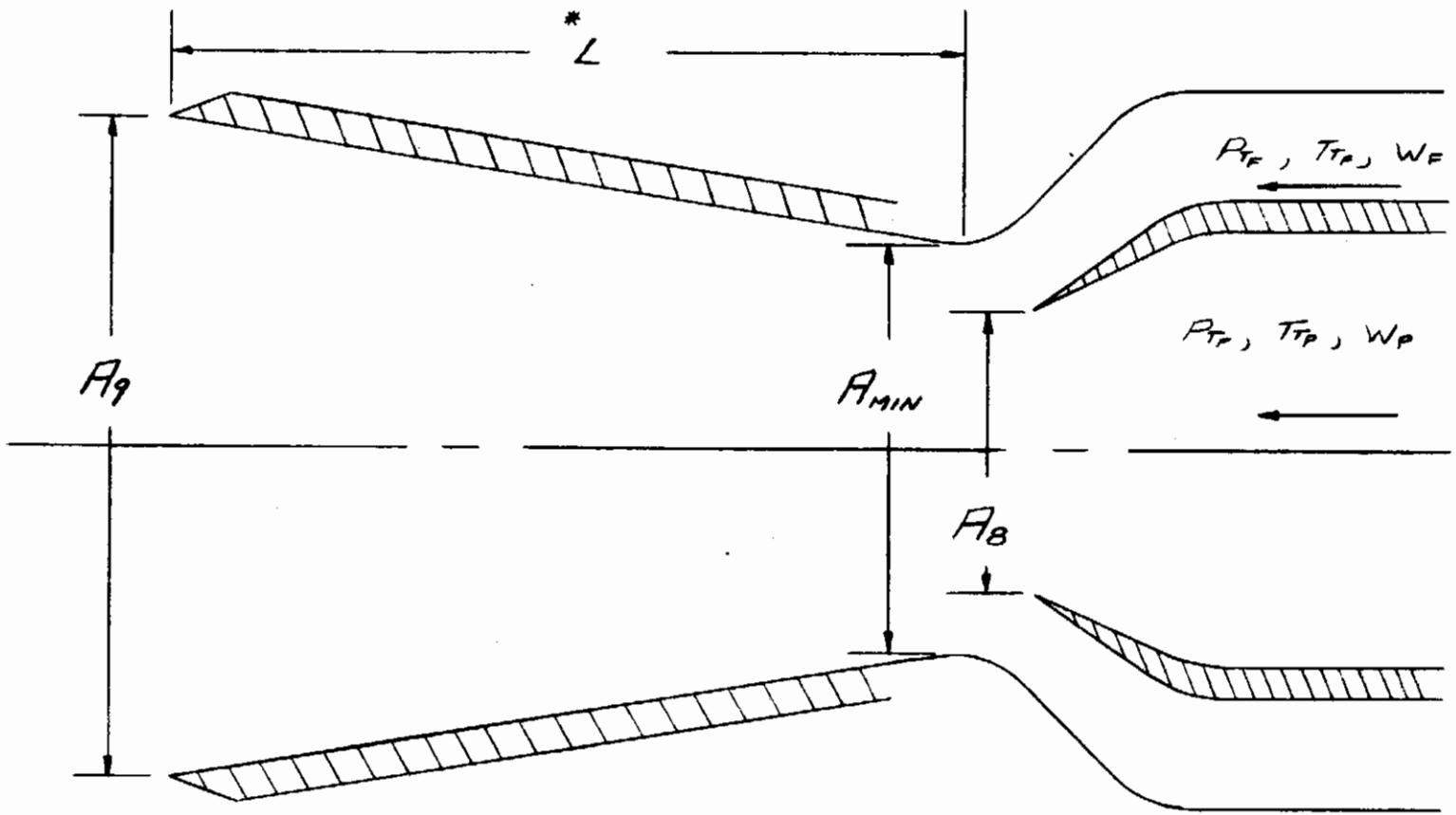

SECTION E-E
SECTION E-E
SECTION B-B
SECTION A-A
SECTION C-C
SECTION D-D
SECTION A-A
SECTION B-B
SECTION E-E
SECTION E-E
SECTION E-E

Contrails



Approved for Public Release

Contrails



* L = DISTANCE FROM PLANE OF A_{MIN} TO PLANE OF A_9.
= 4.35" FOR ALL CONFIGURATIONS

Figure 4. Pertinent Areas Used To Define Shared Exit Ejector Nozzle Configuration

Approved for Public Release

Contrails

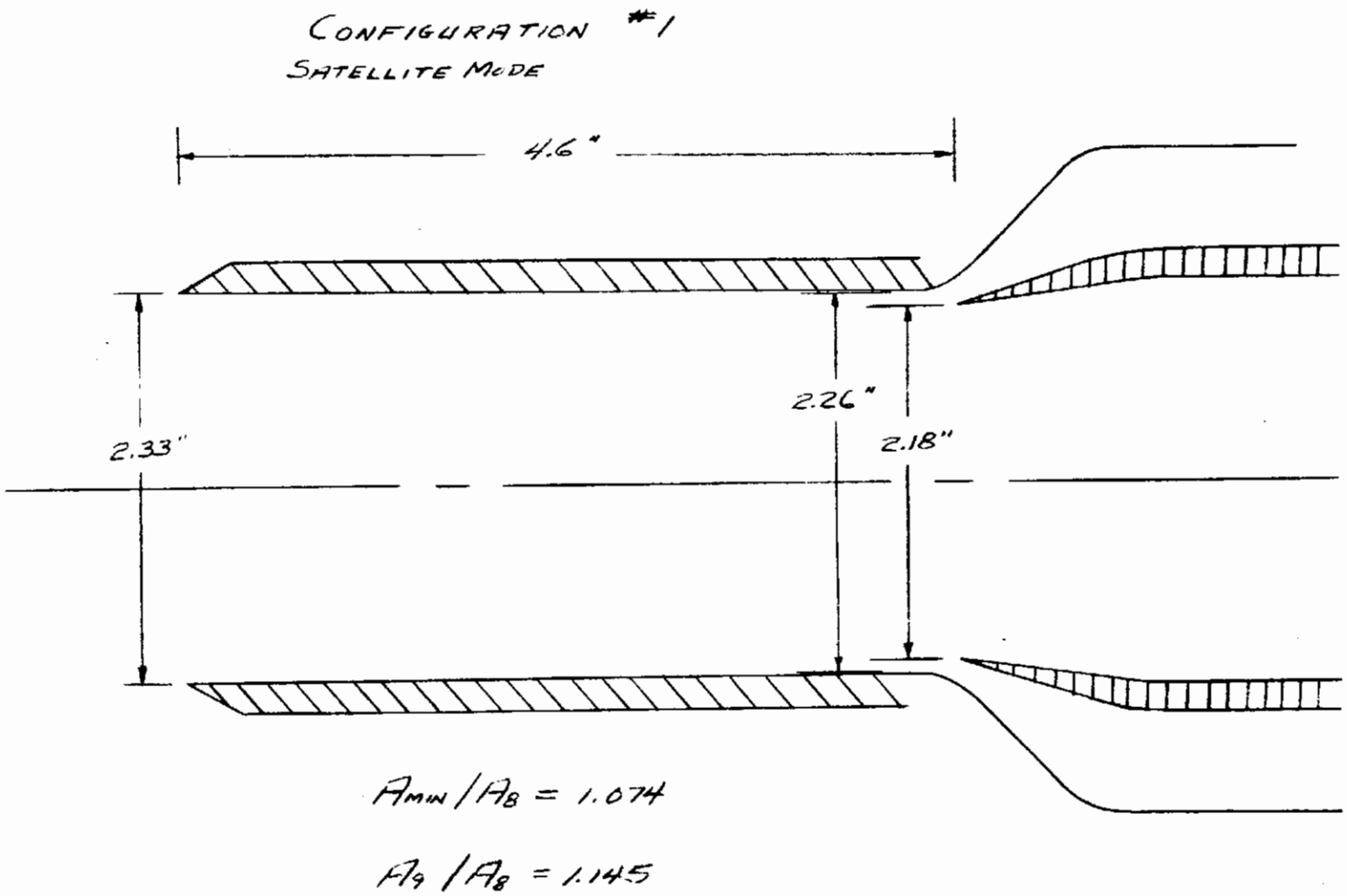


Figure 5. Shared Exit Ejector Nozzle - Model Configuration Tested, Satellite Mode

Approved for Public Release

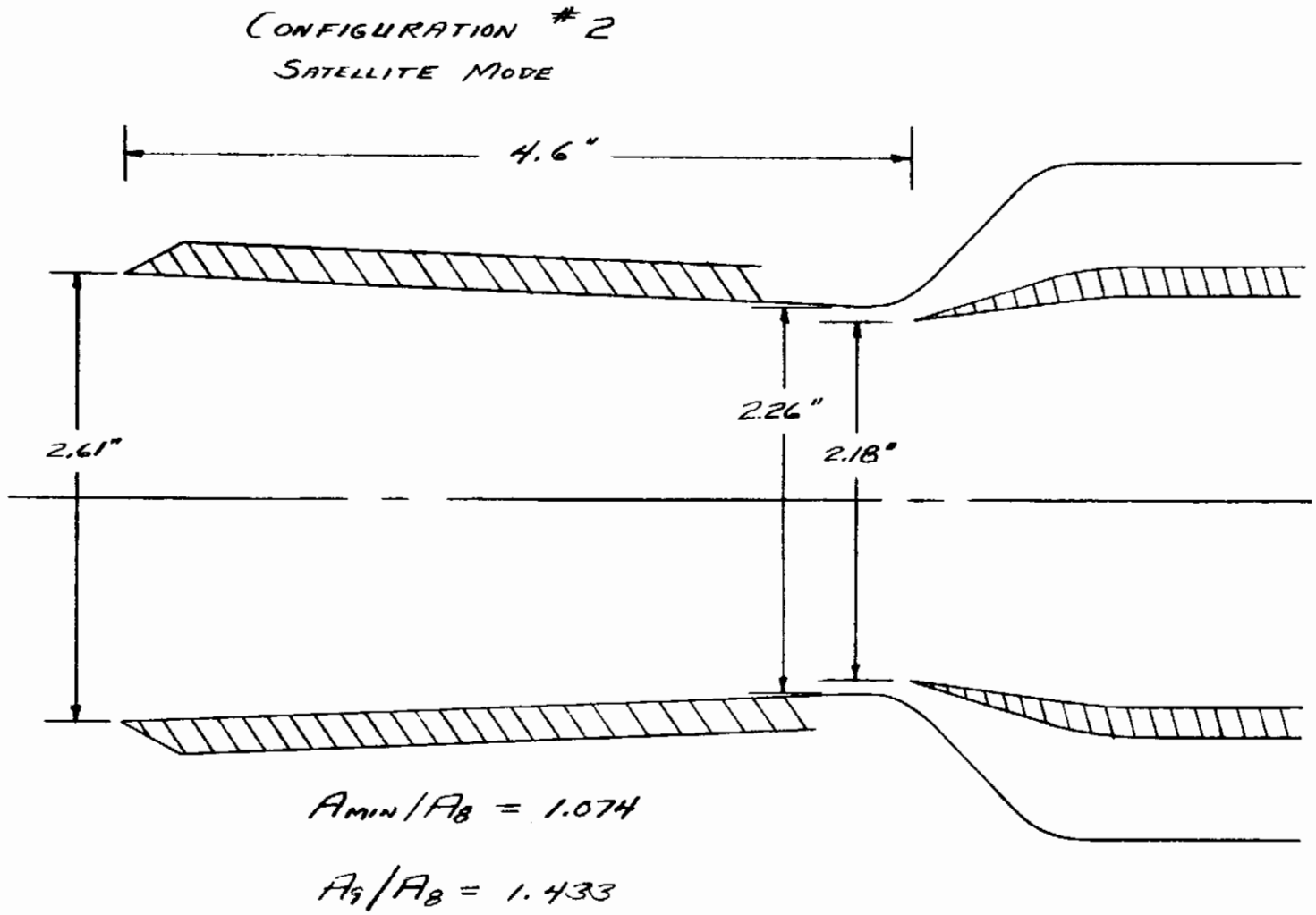


Figure 6. Shared Exit Ejector Nozzle - Model Configuration Tested, Satellite Mode

Approved for Public Release

Contrails

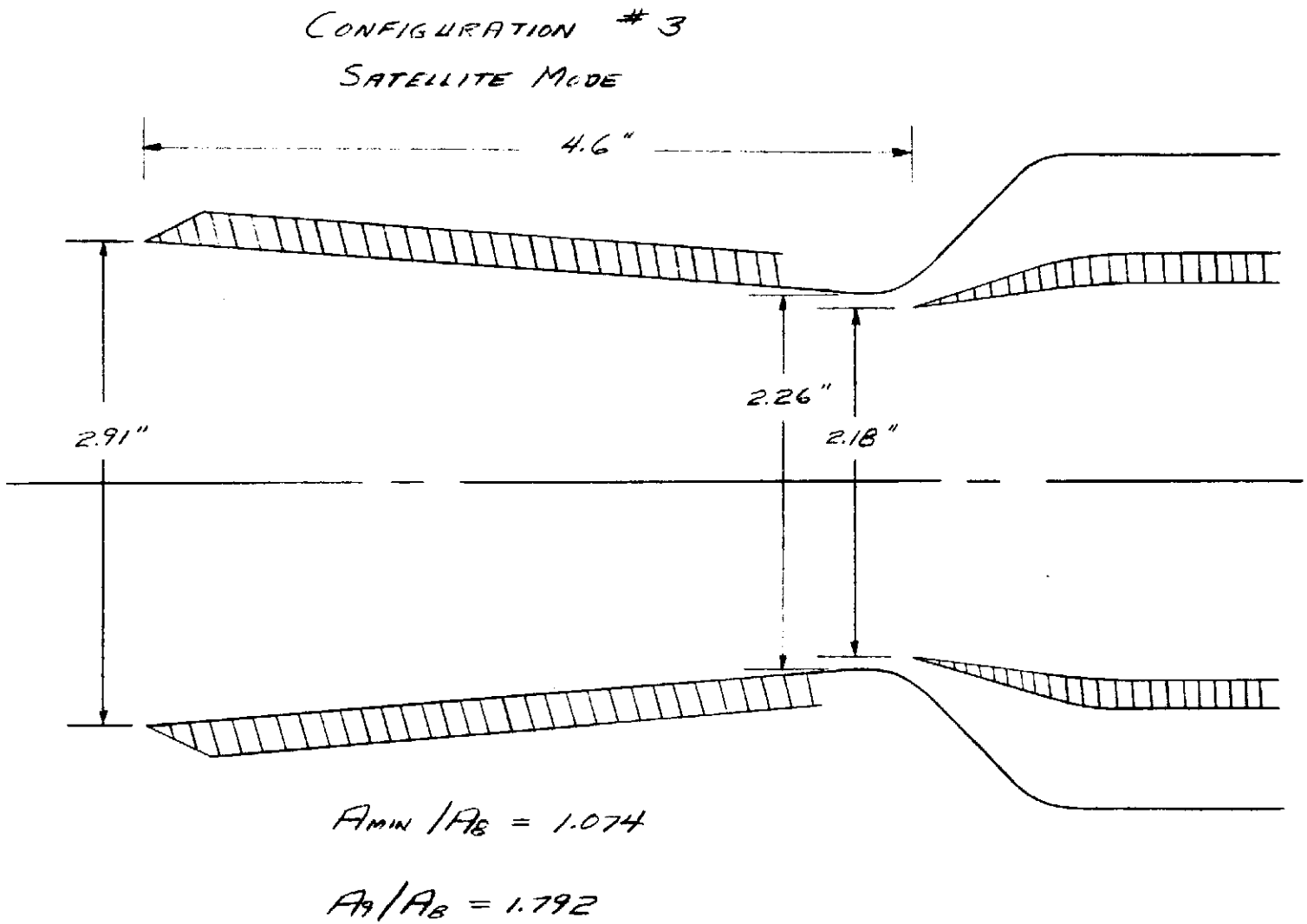


Figure 7. Shared Exit Ejector Nozzle - Model Configuration Tested, Satellite Mode

Approved for Public Release

Contrails

Contrails

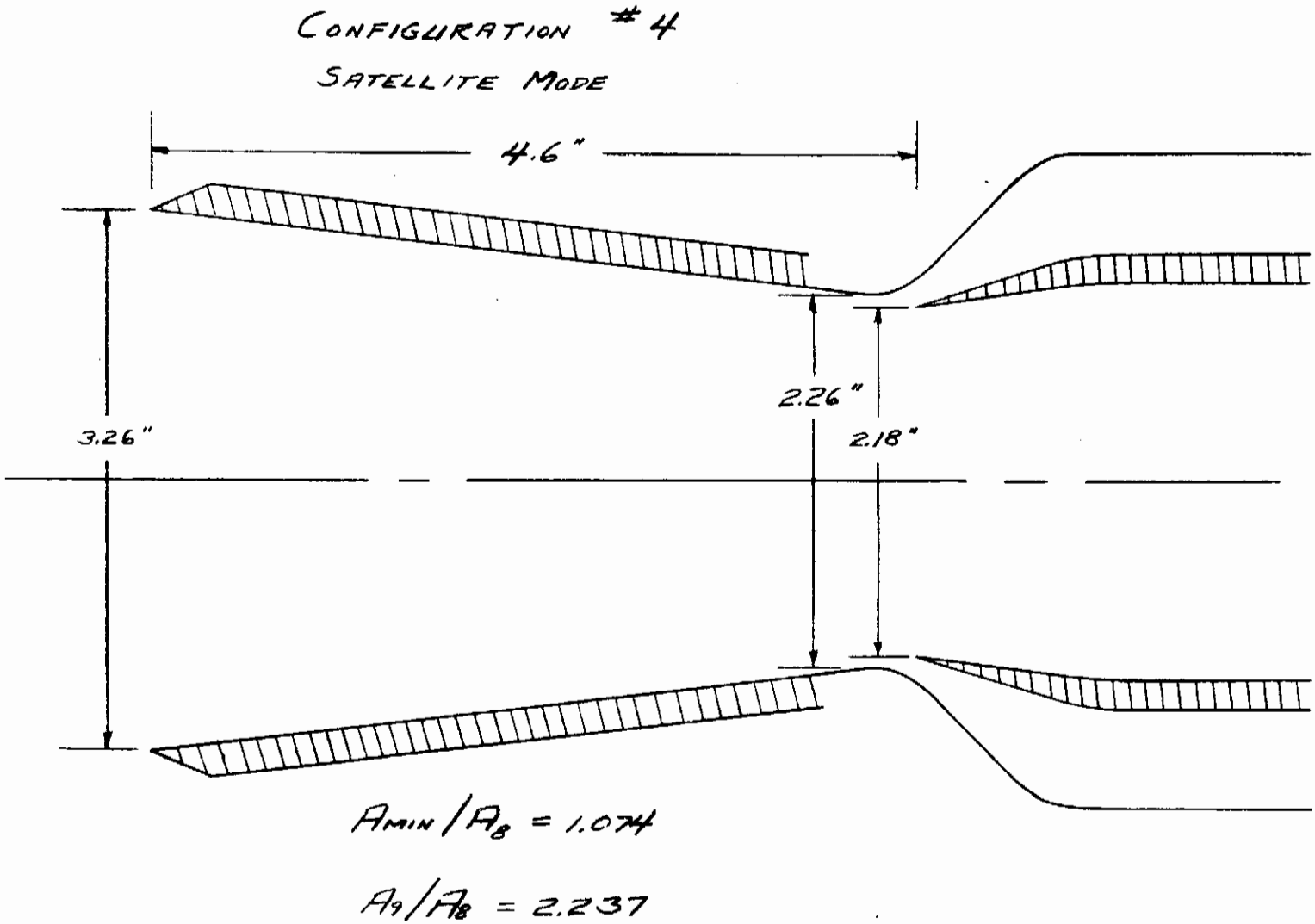


Figure 8. Shared Exit Ejector Nozzle - Model Configuration Tested, Satellite Mode

Approved for Public Release

Contrails

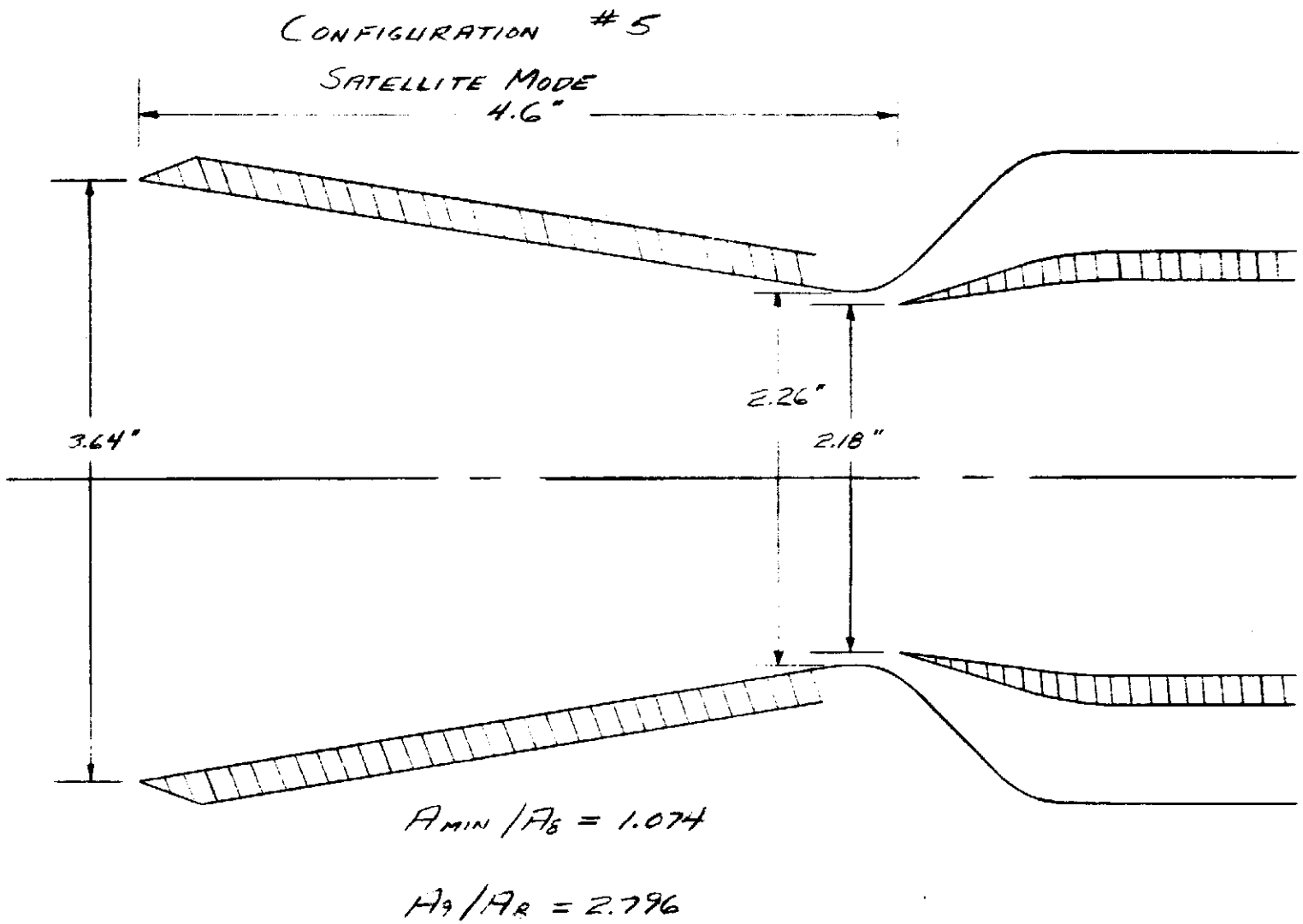


Figure 9. Shared Exit Ejector Nozzle - Model Configuration Tested, Satellite Mode

Approved for Public Release

Contrails

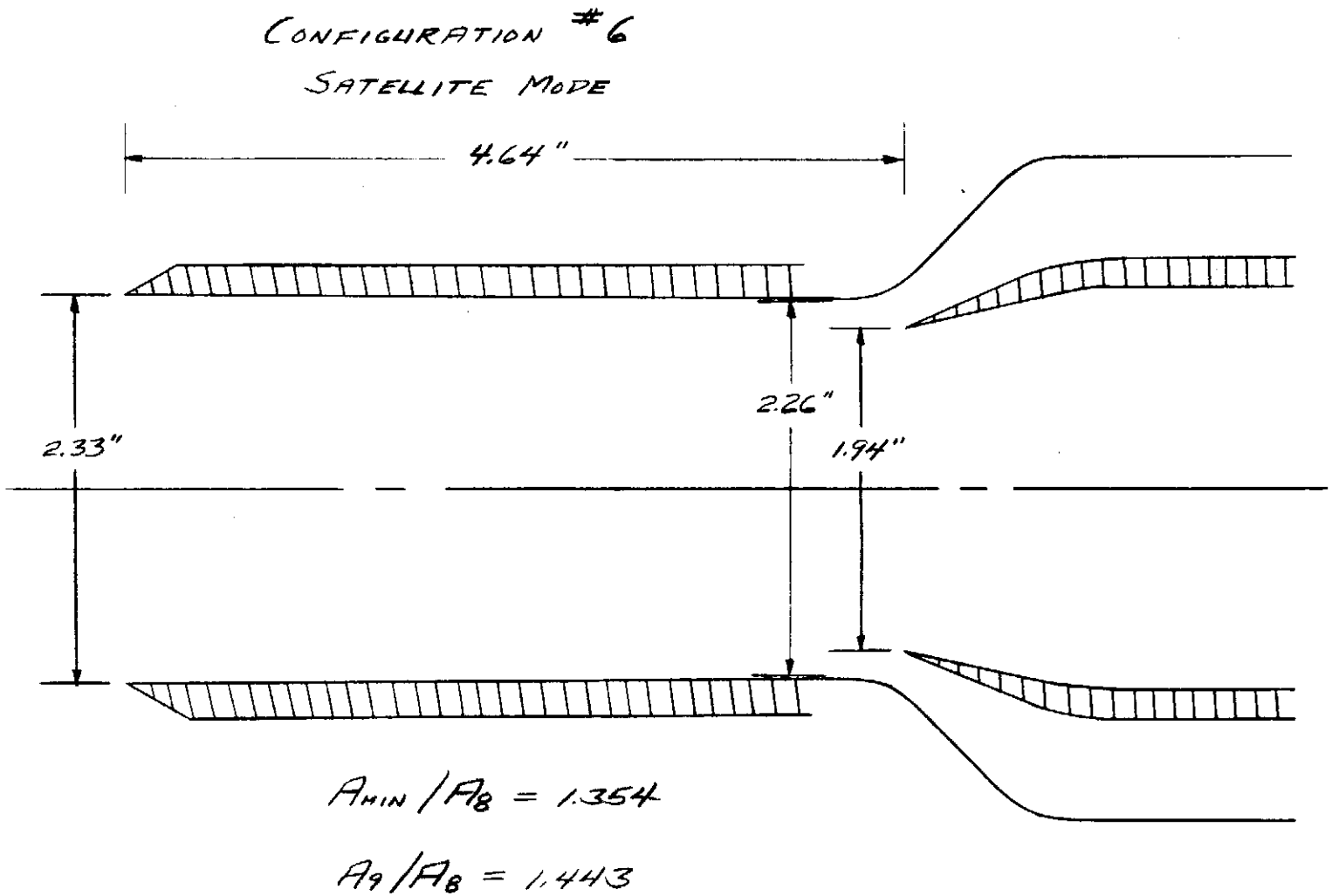


Figure 10. Shared Exit Ejector Nozzle - Model Configuration Tested, Satellite Mode

Approved for Public Release

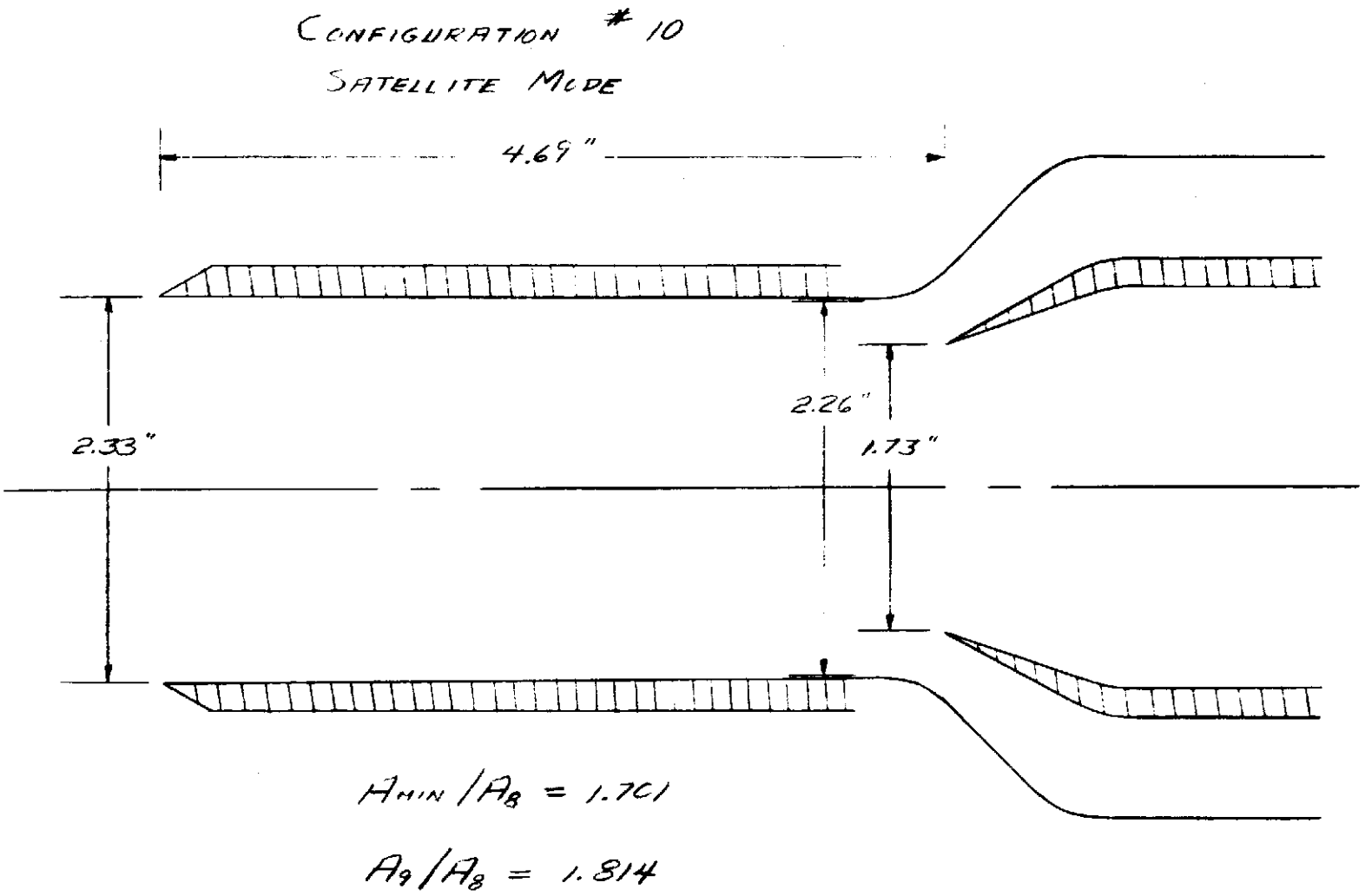


Figure 11. Shared Exit Ejector Nozzle - Model Configuration Tested, Satellite Mode

Approved for Public Release

Contrails

Contrails

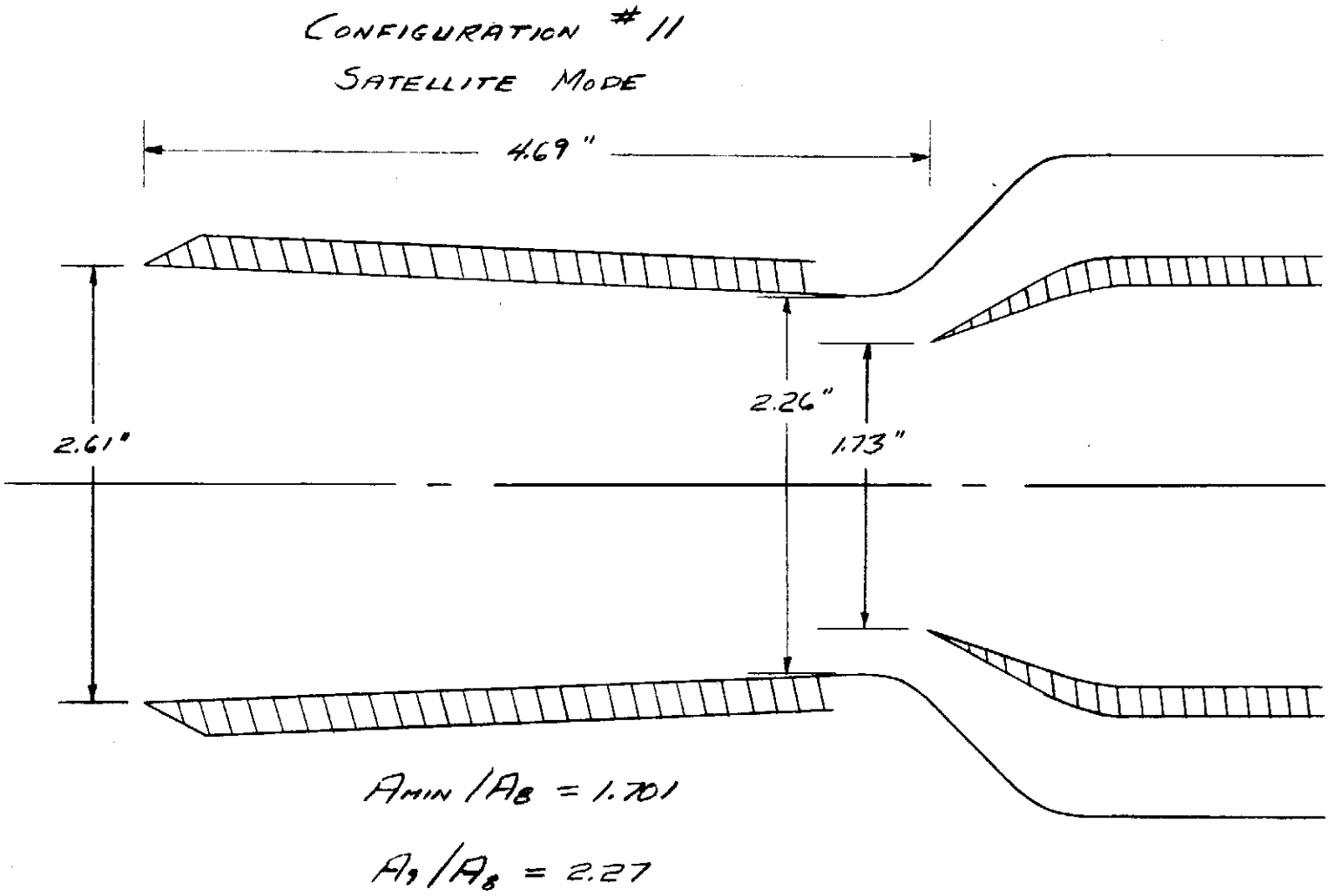


Figure 12. Shared Exit Ejector Nozzle - Model Configuration Tested, Satellite Mode

Approved for Public Release

Contrails

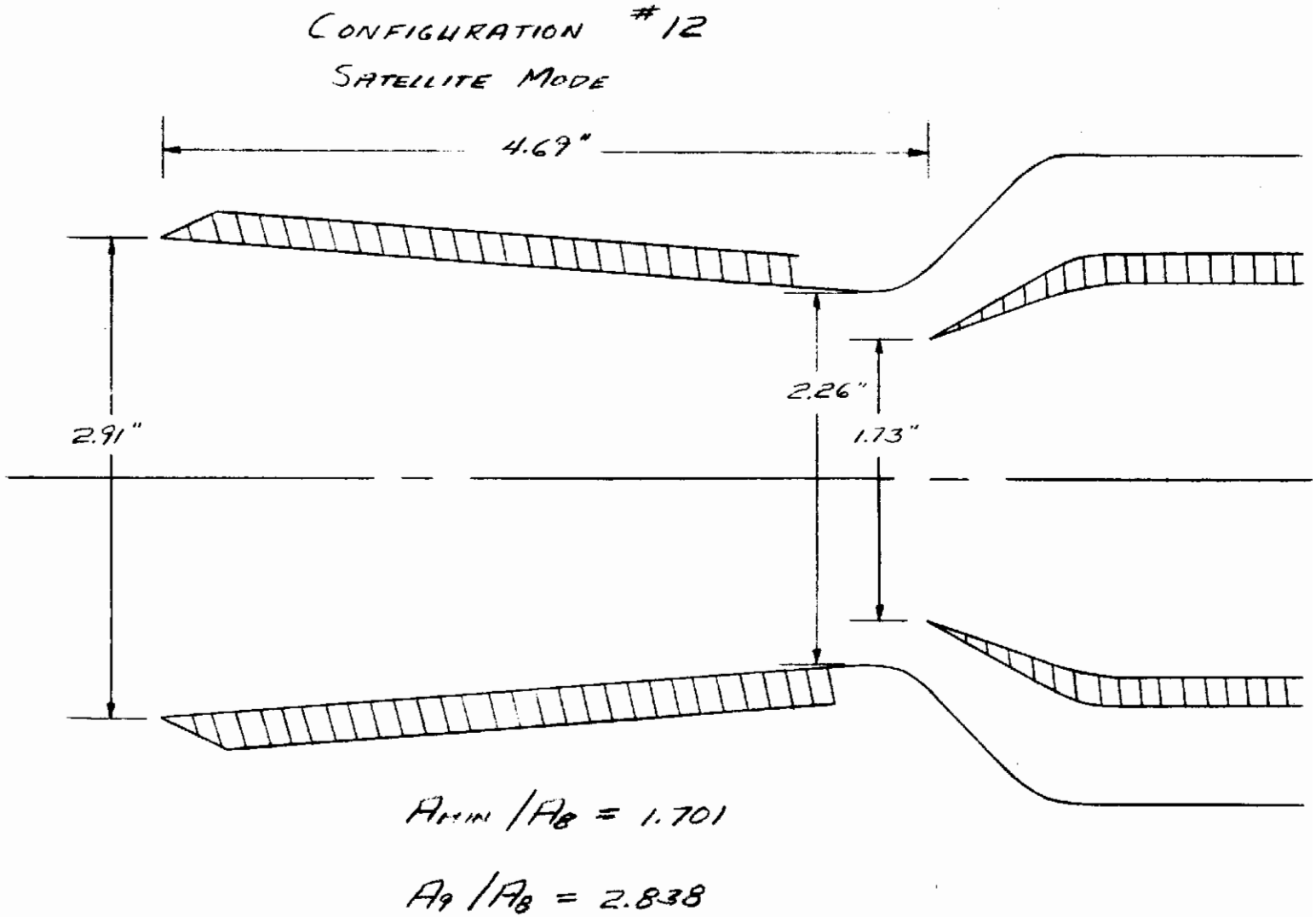


Figure 13. Shared Exit Ejector Nozzle - Model Configuration Tested, Satellite Mode

Approved for Public Release

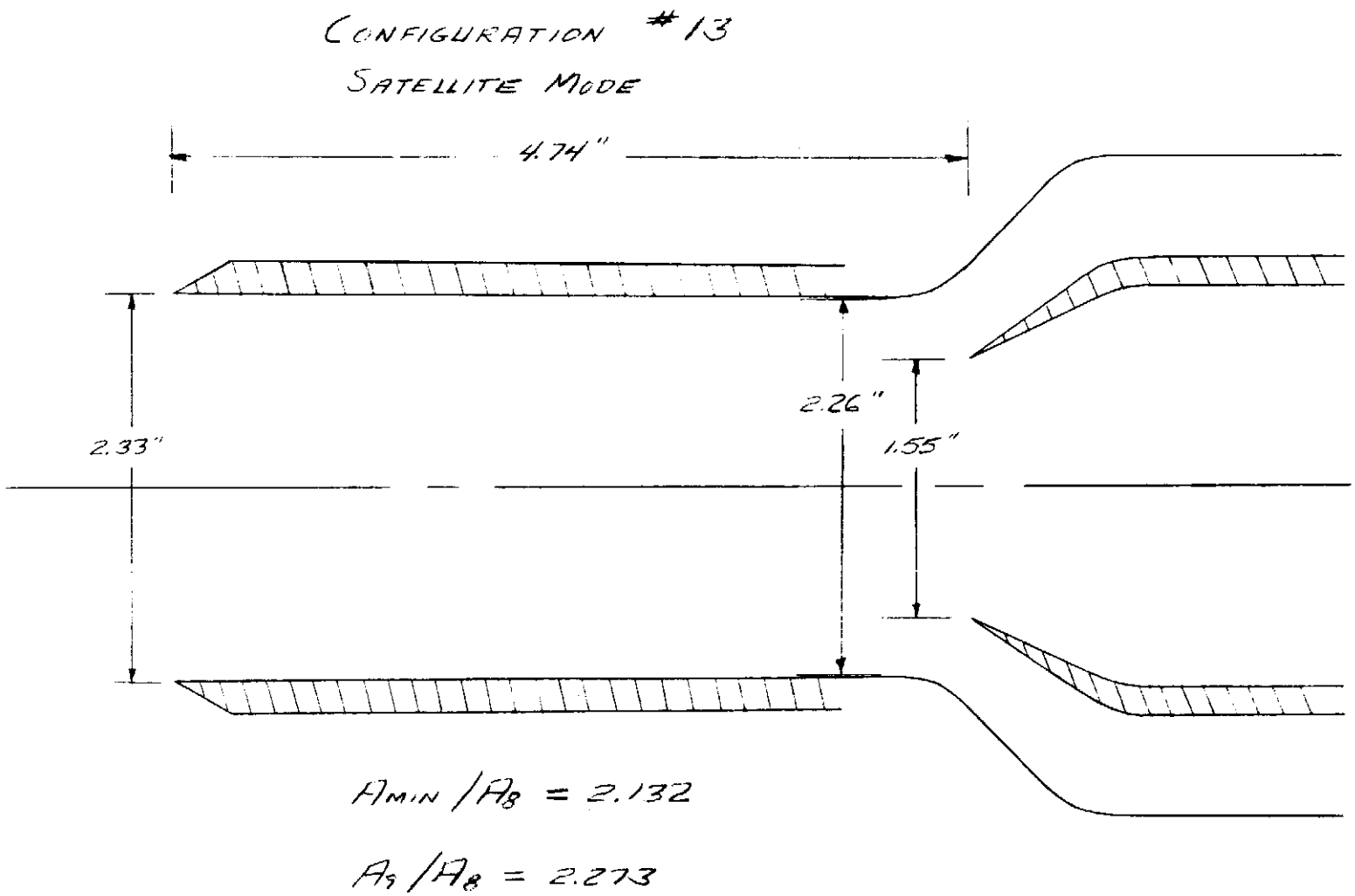


Figure 14. Shared Exit Ejector Nozzle - Model Configuration Tested, Satellite Mode

Approved for Public Release

Contrails

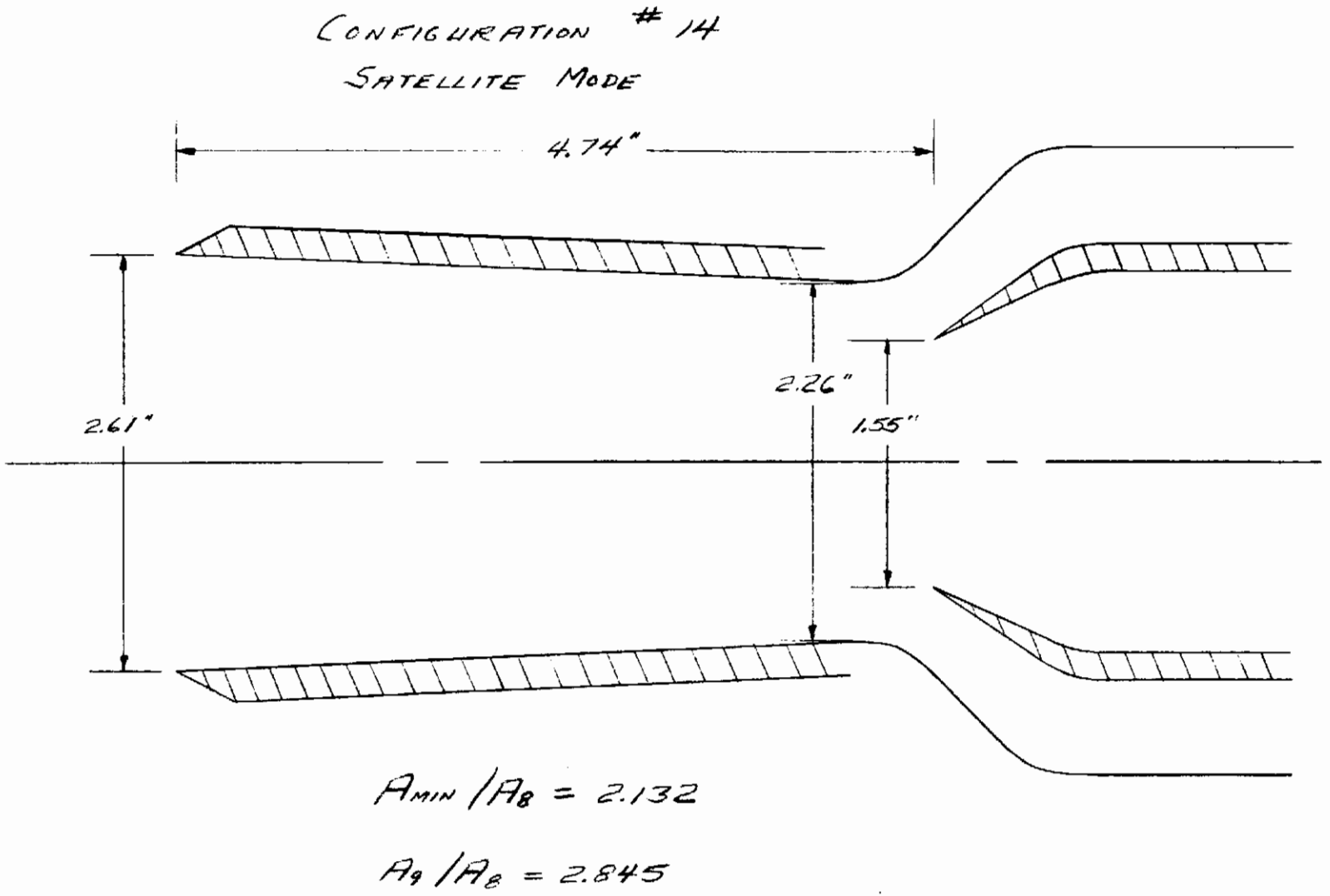


Figure 15. Shared Exit Ejector Nozzle - Model Configuration Tested, Satellite Mode

Approved for Public Release

Contrails

Contrails

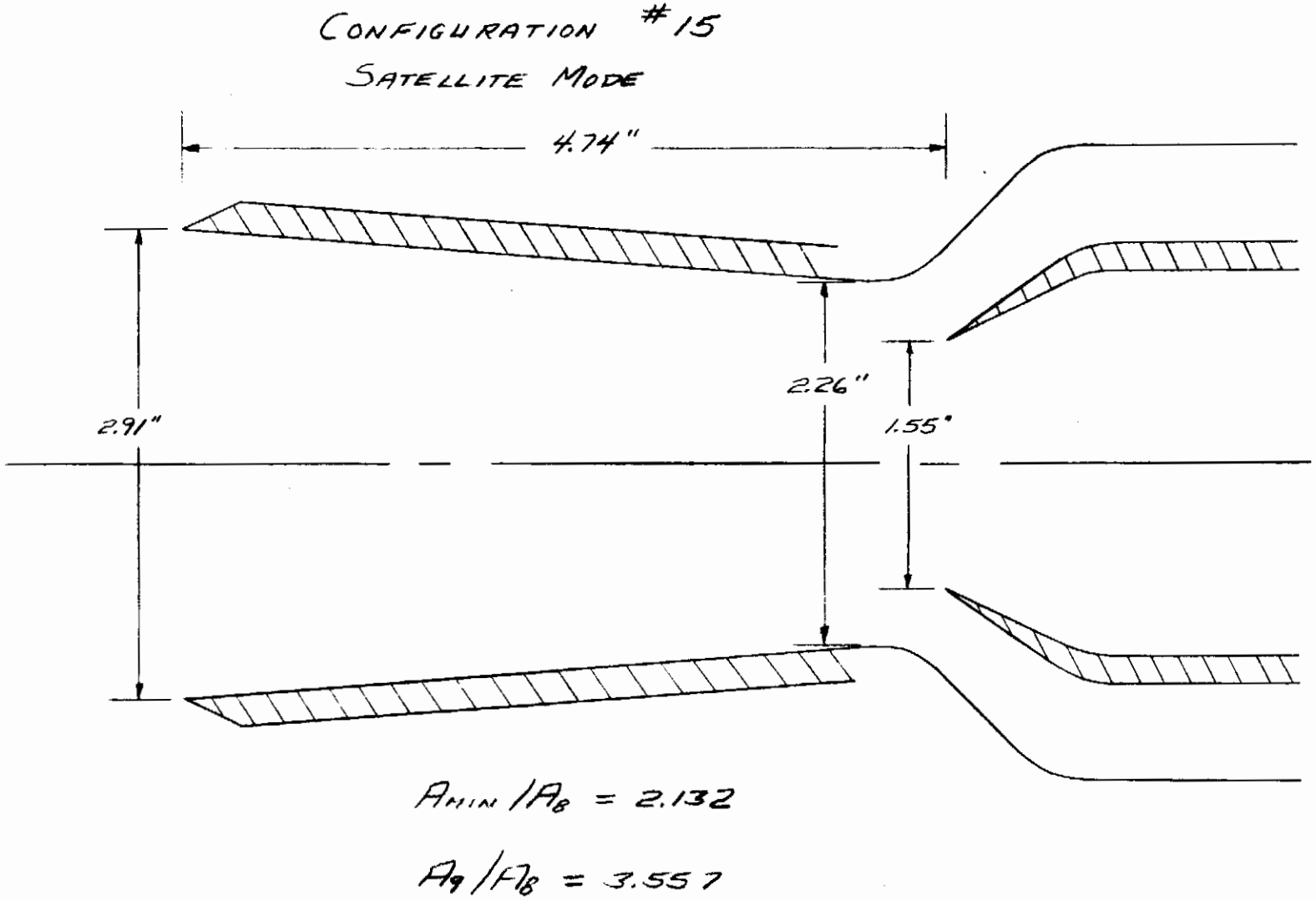


Figure 16. Shared Exit Ejector Nozzle - Model Configuration Tested, Satellite Mode

Approved for Public Release

Contrails

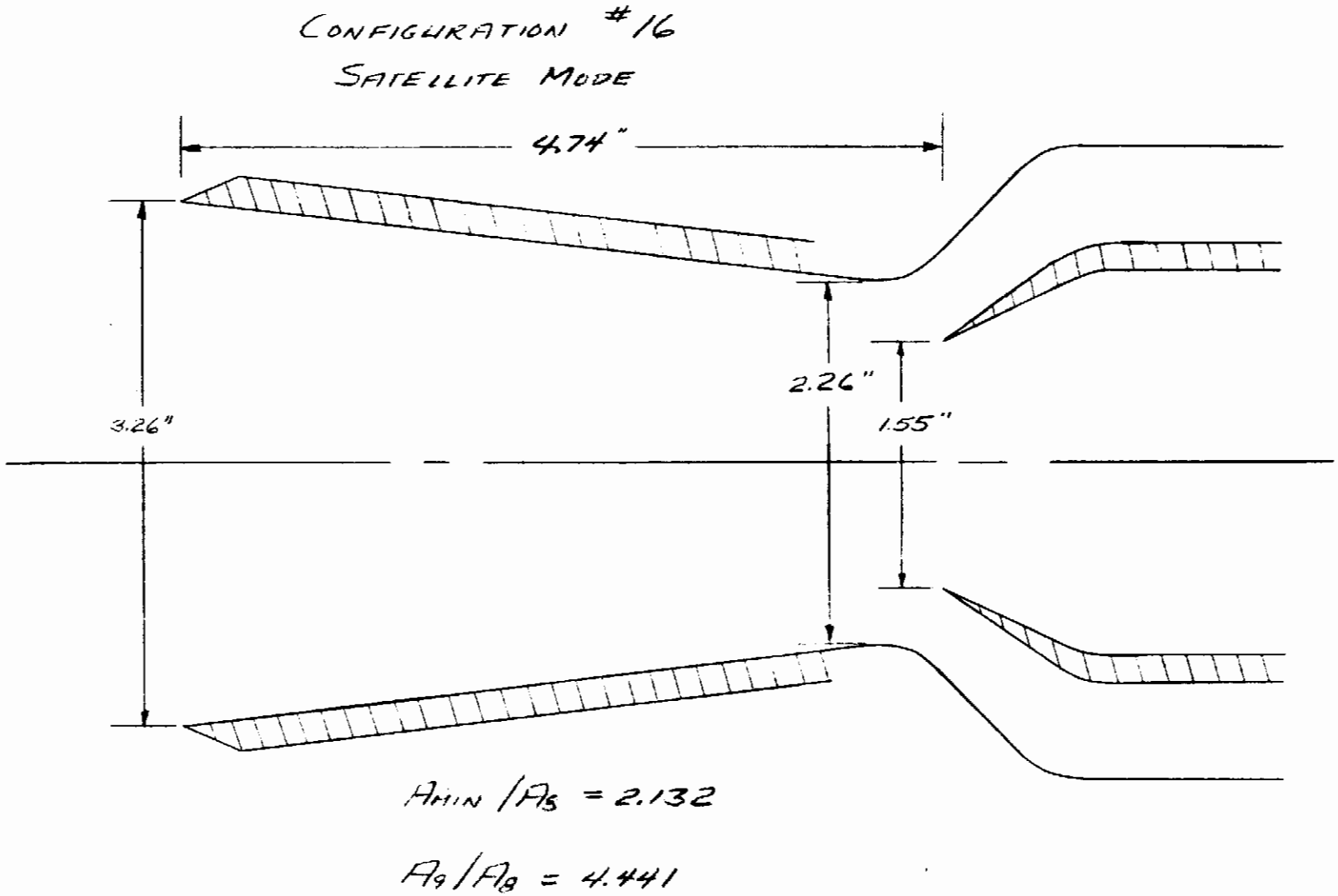
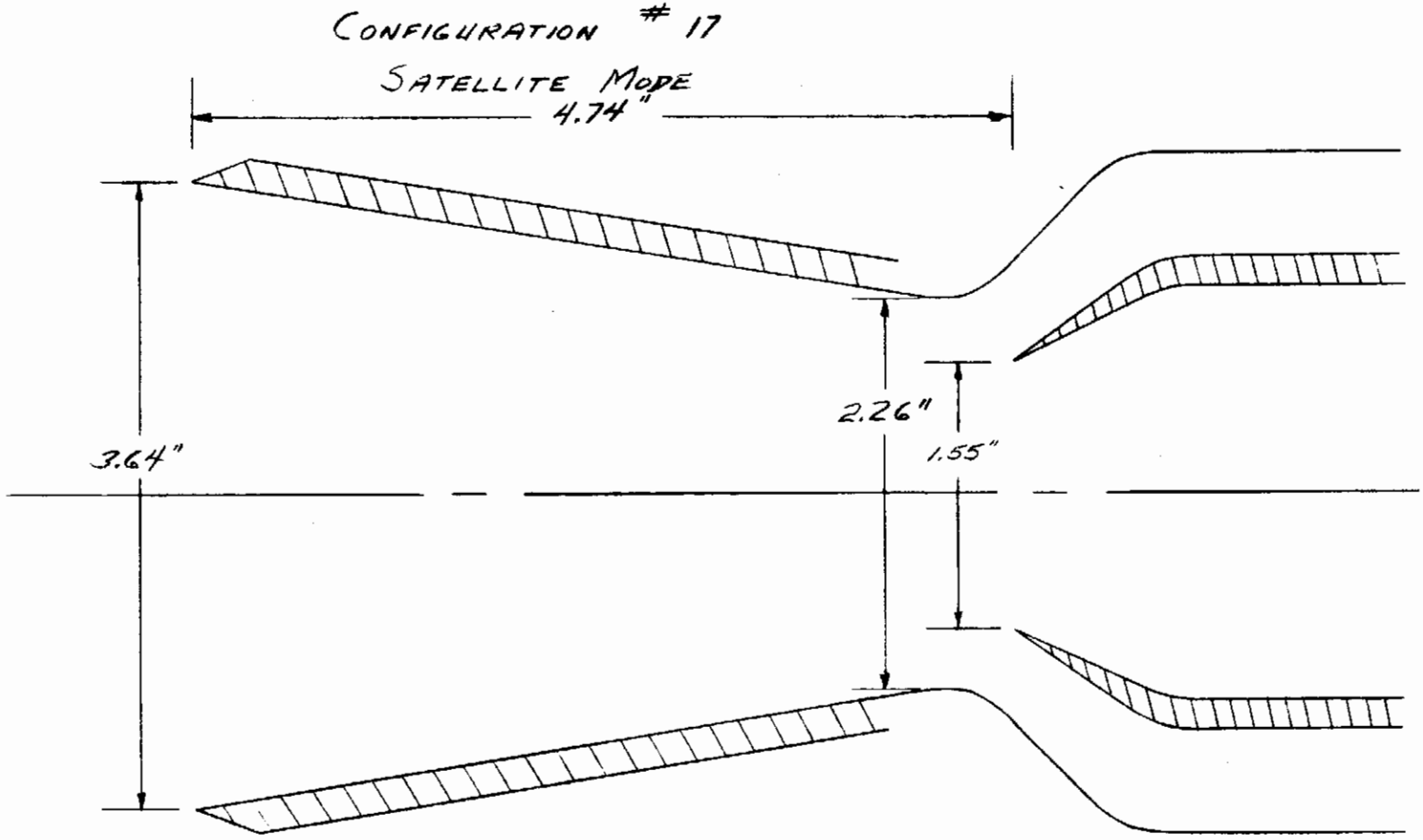


Figure 17. Shared Exit Ejector Nozzle - Model Configuration Tested, Satellite Mode

Approved for Public Release

Contrails



$A_{MIN}/A_8 = 2.132$

$A_9/A_8 = 5.551$

Figure 18. Shared Exit Ejector Nozzle - Model Configuration Tested, Satellite Mode

Approved for Public Release

Contrails

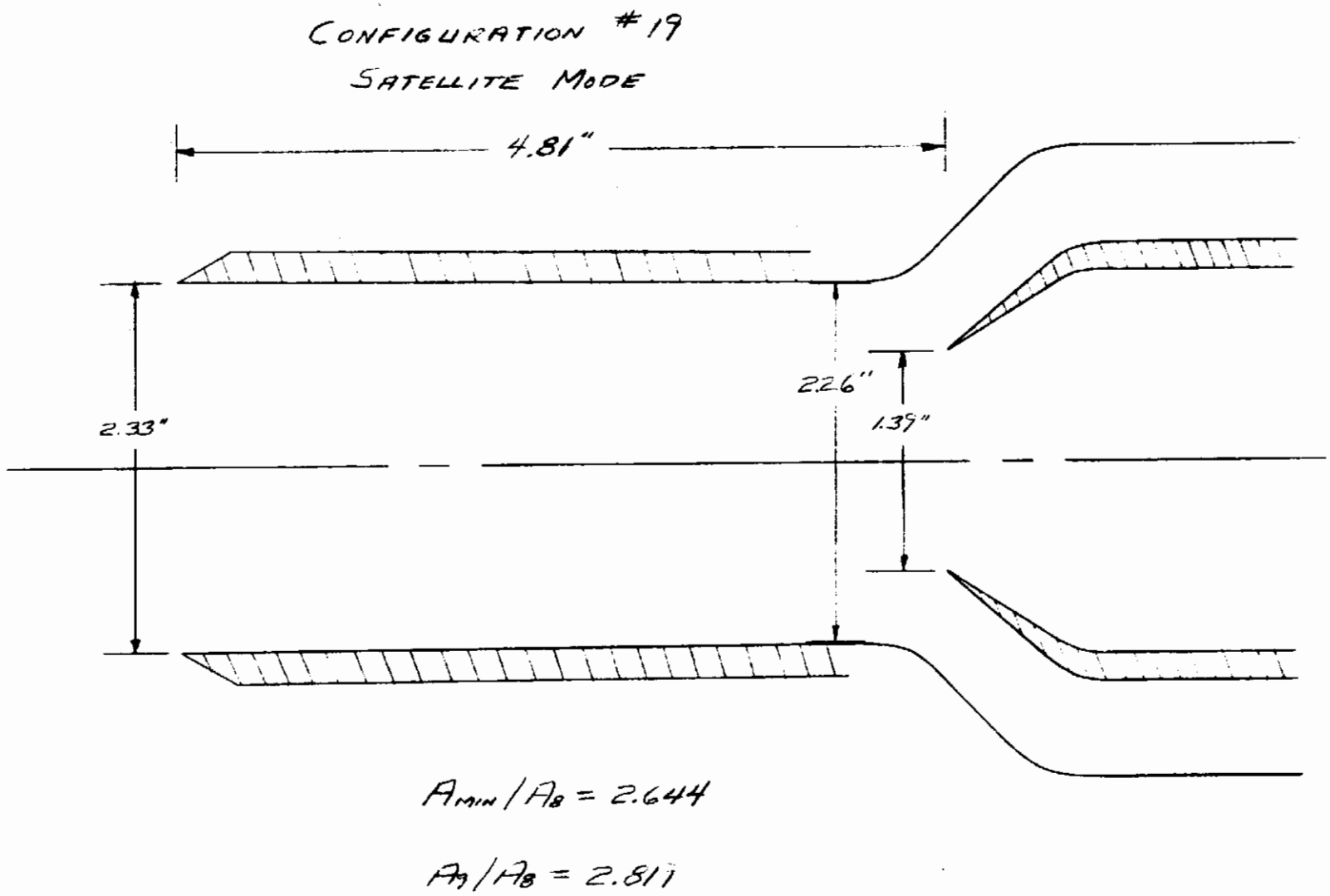


Figure 19. Shared Exit Ejector Nozzle - Model Configuration Tested, Satellite Mode

Approved for Public Release

Contrails

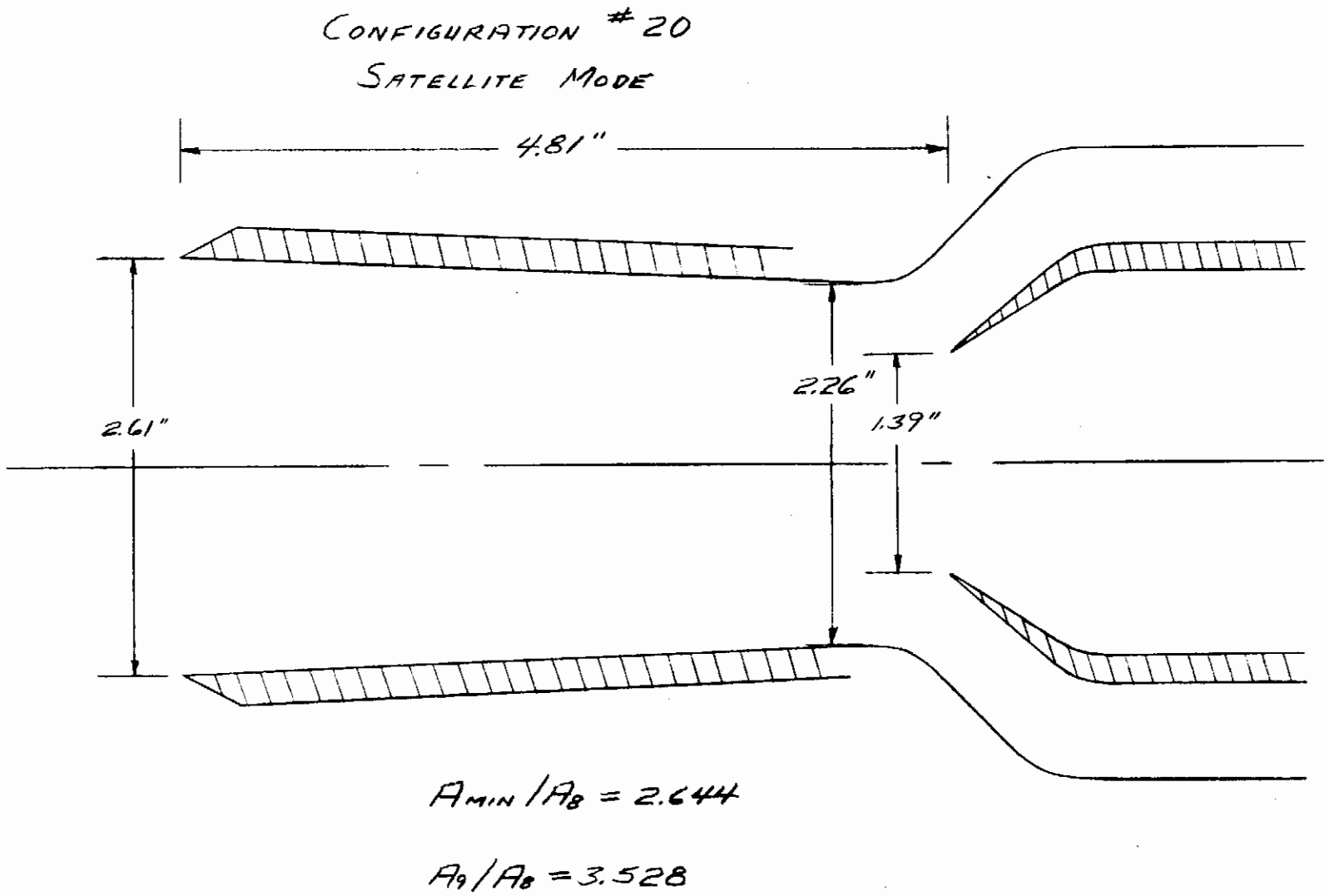


Figure 20. Shared Exit Ejector Nozzle - Model Configuration Tested, Satellite Mode

Approved for Public Release

Contrails

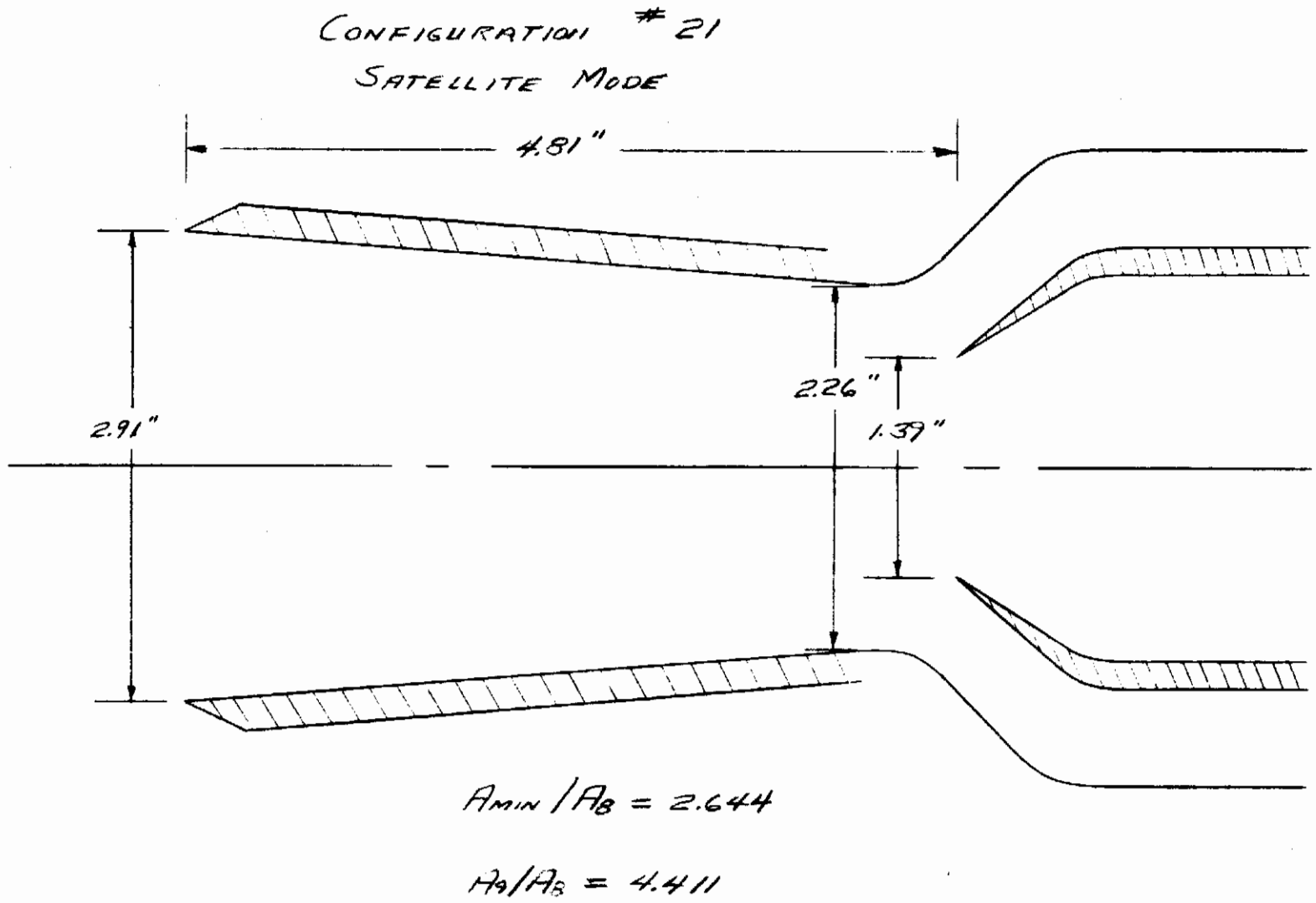


Figure 21. Shared Exit Ejector Nozzle - Model Configuration Tested, Satellite Mode

Approved for Public Release

Contrails

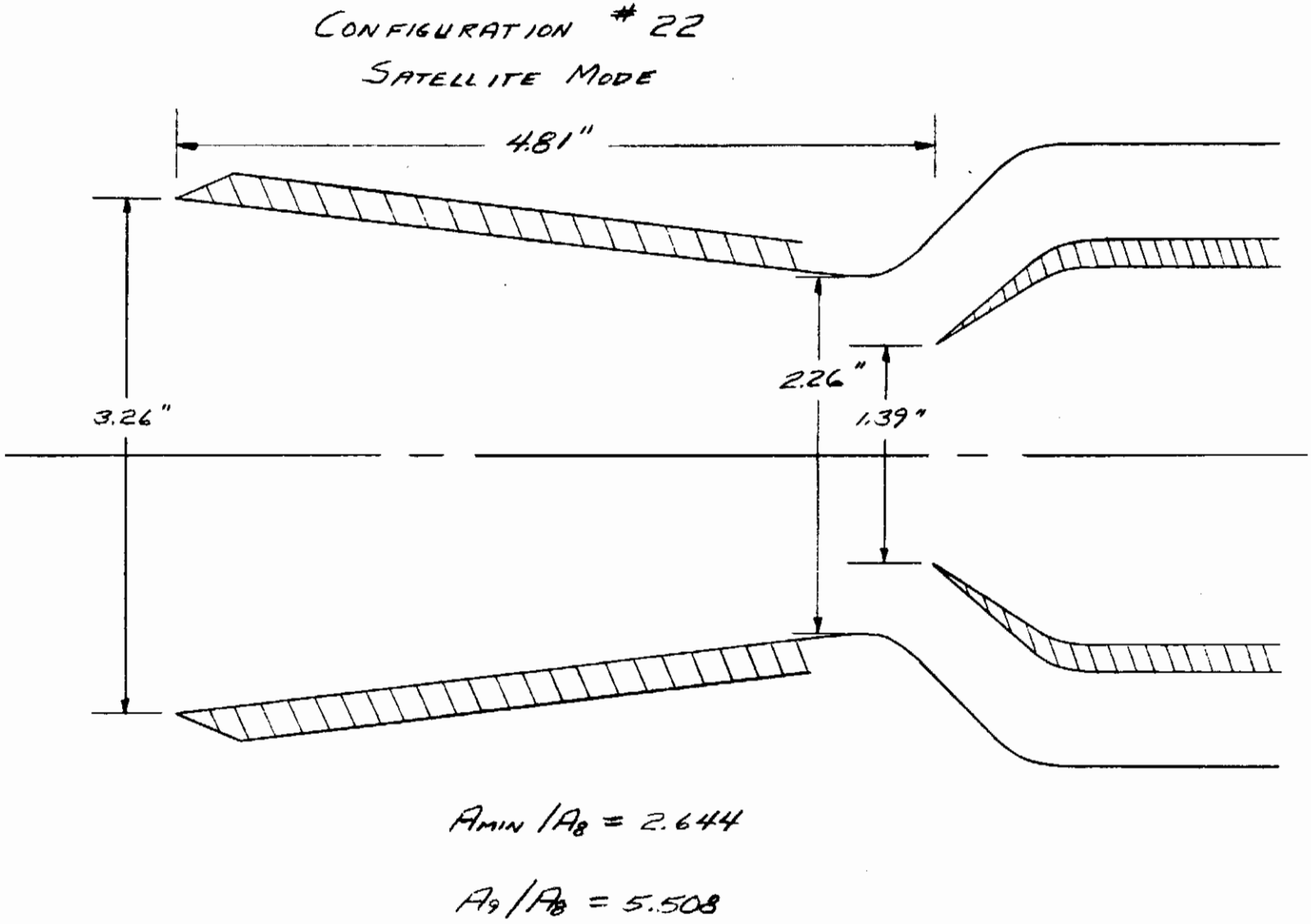


Figure 22. Shared Exit Ejector Nozzle - Model Configuration Tested, Satellite Mode

Approved for Public Release

Contrails

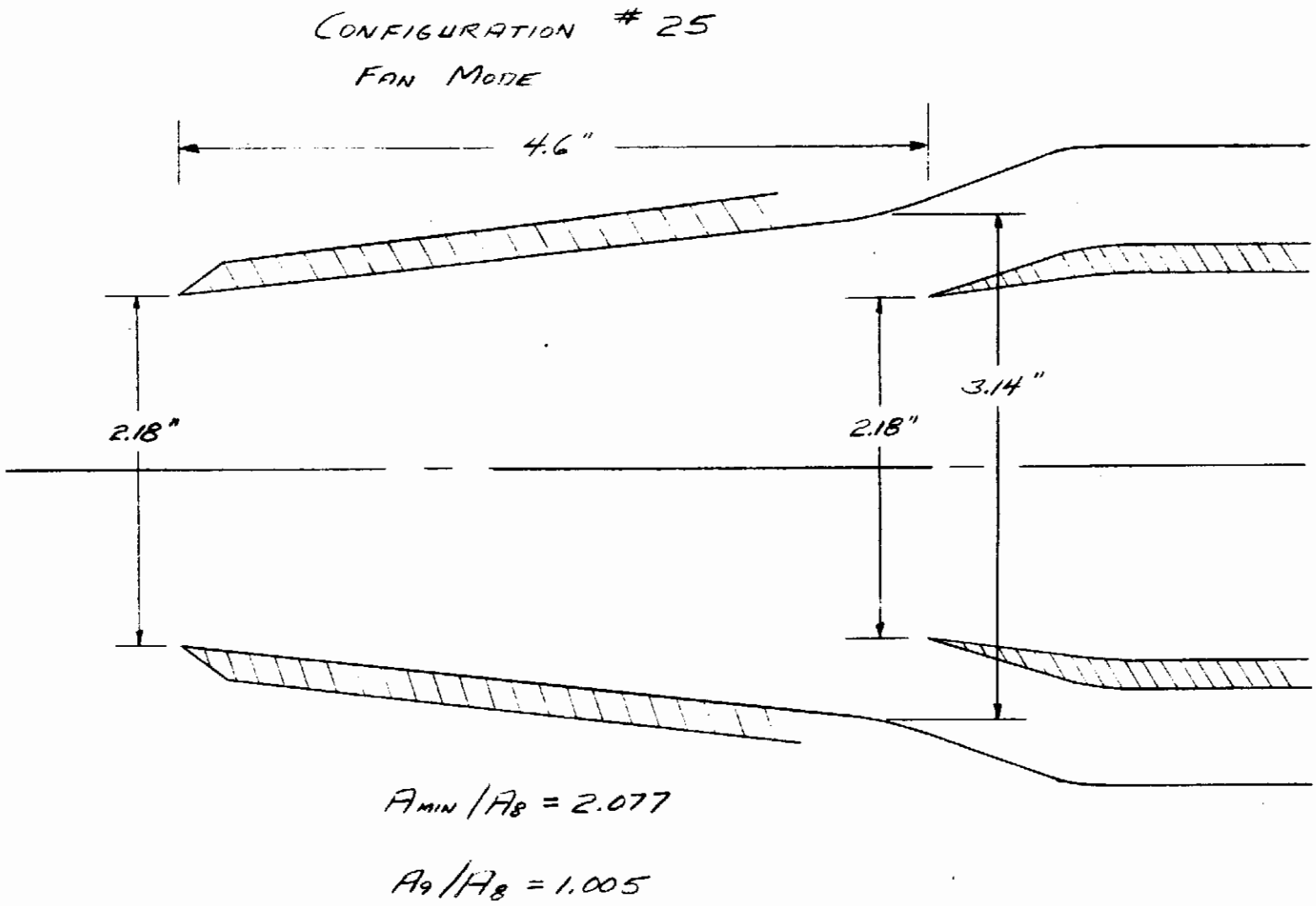


Figure 23. Shared Exit Ejector Nozzle - Model Configuration Tested, Fan Mode

Approved for Public Release

Contrails

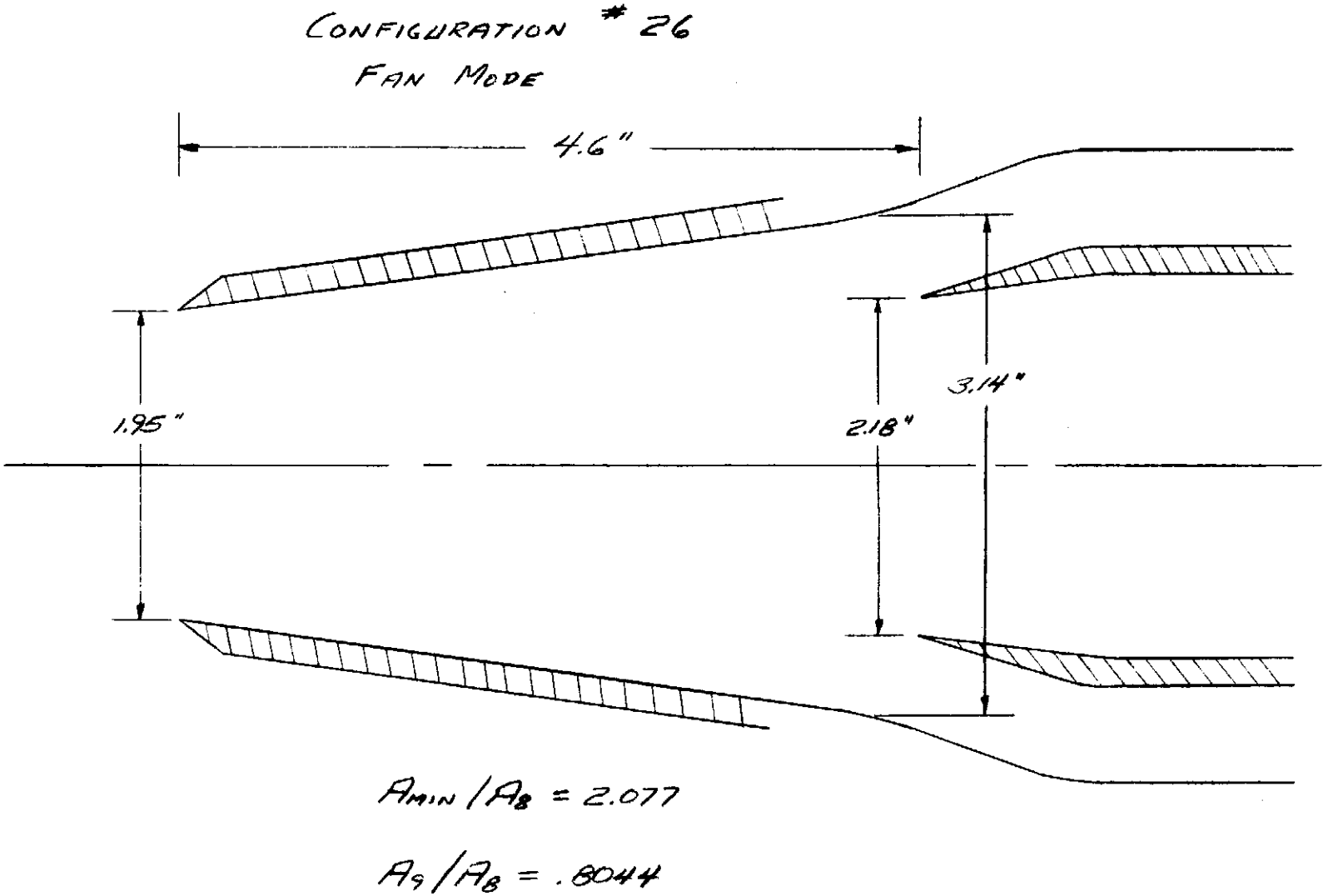


Figure 24. Shared Exit Ejector Nozzle - Model Configuration Tested, Fan Mode

Approved for Public Release

Contrails

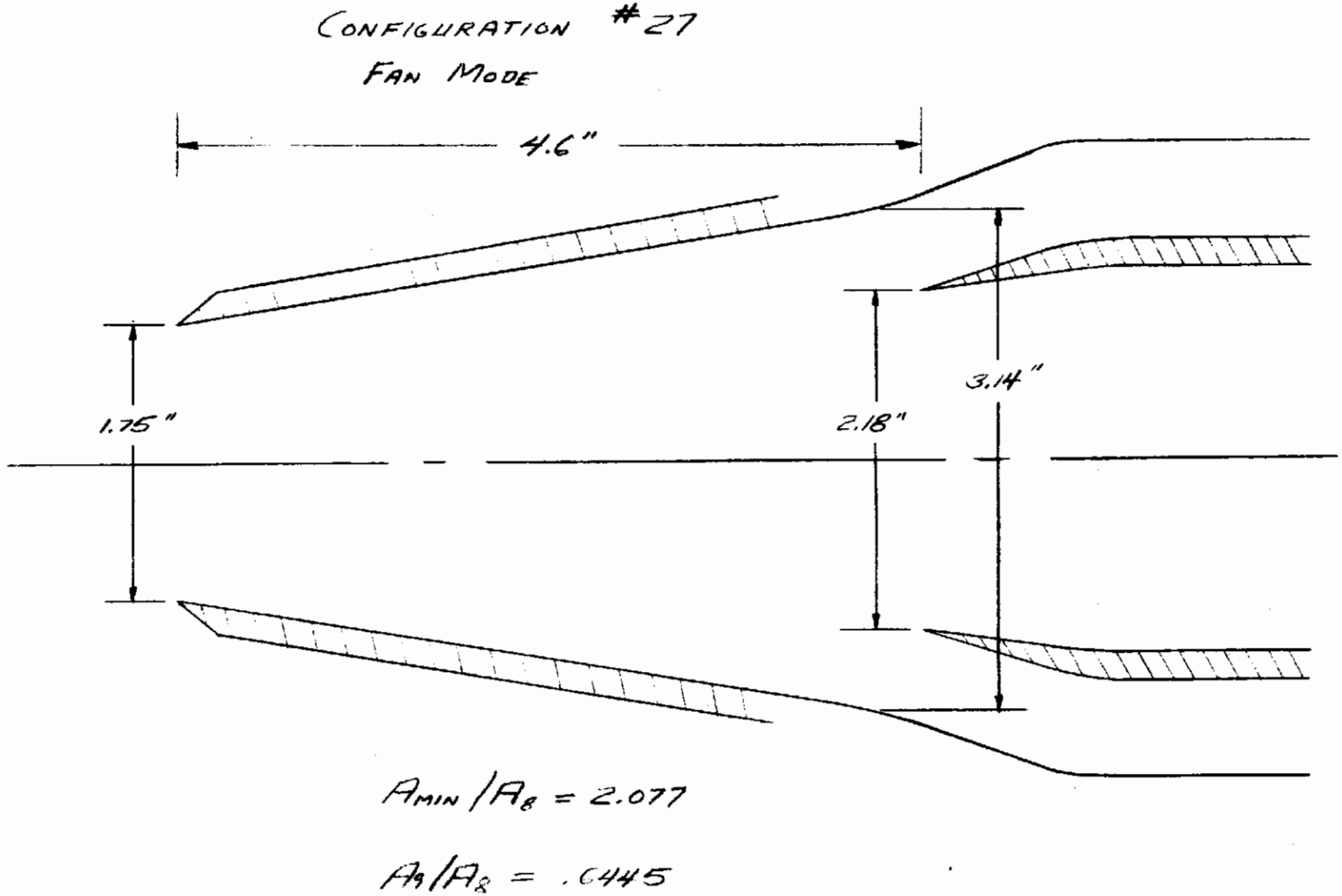


Figure 25. Shared Exit Ejector Nozzle - Model Configuration Tested, Fan Mode

Approved for Public Release

Contrails

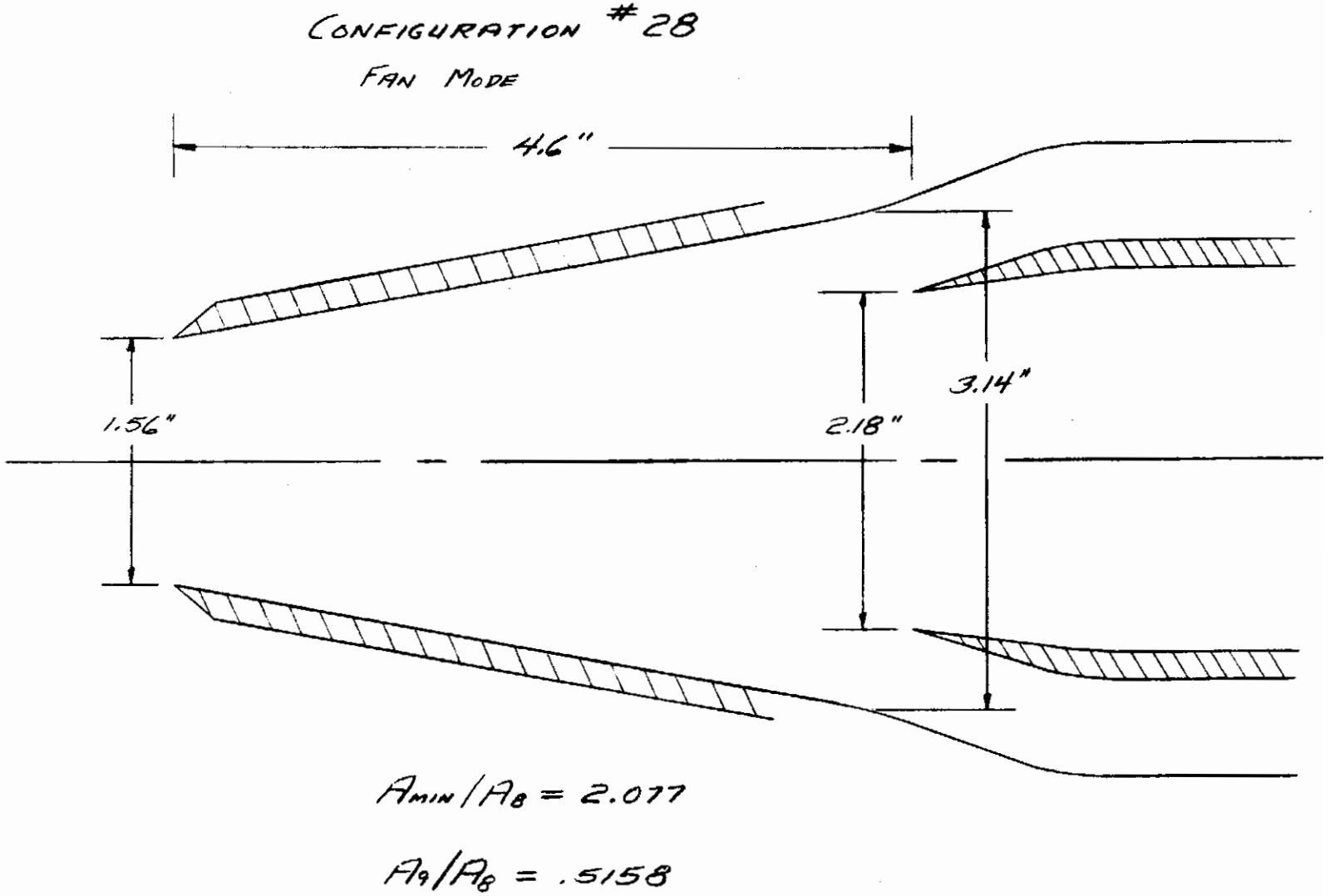


Figure 26. Shared Exit Ejector Nozzle - Model Configuration Tested, Fan Mode

Approved for Public Release

Contrails

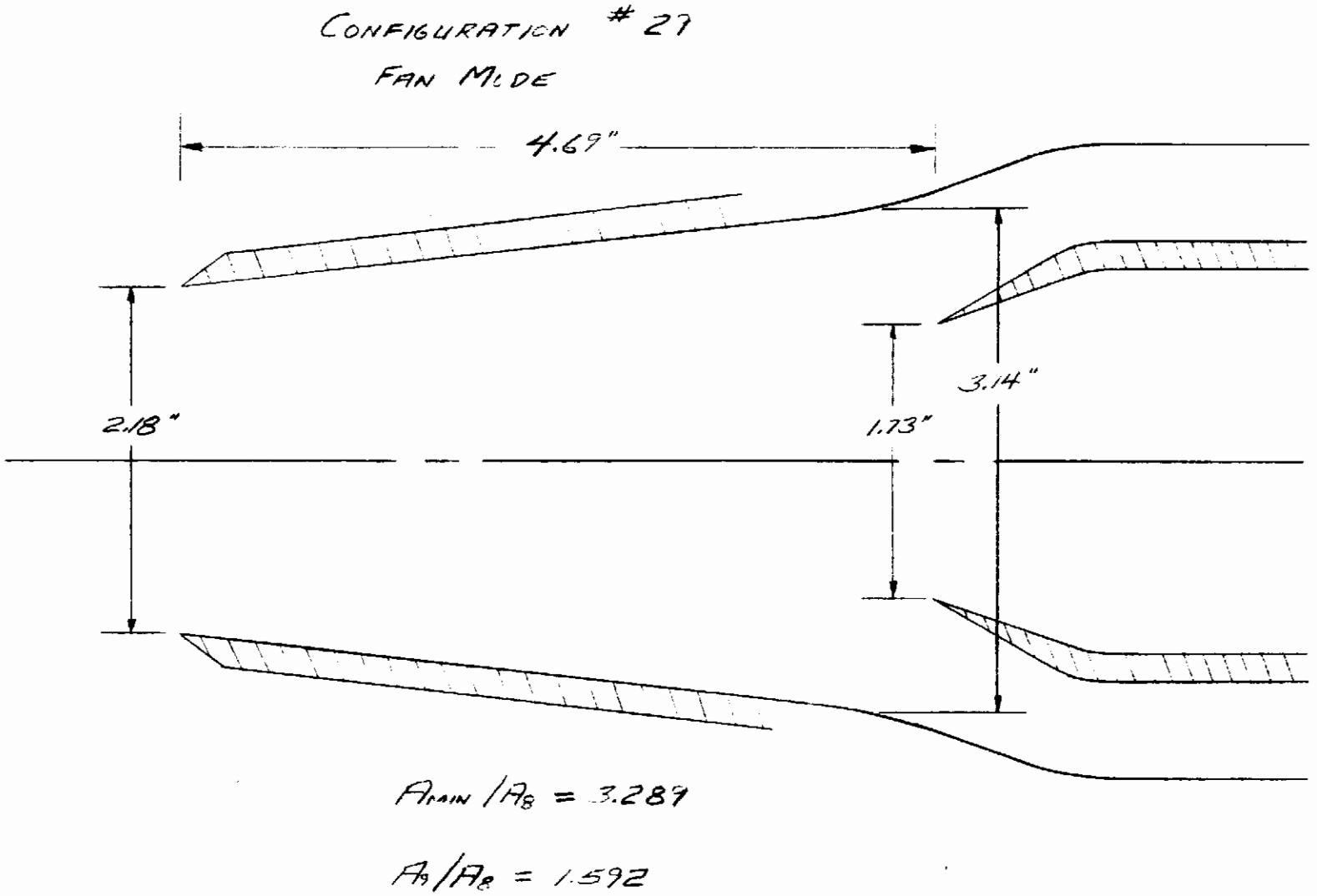


Figure 27. Shared Exit Ejector Nozzle - Model Configuration Tested, Fan Mode

Approved for Public Release

Contrails

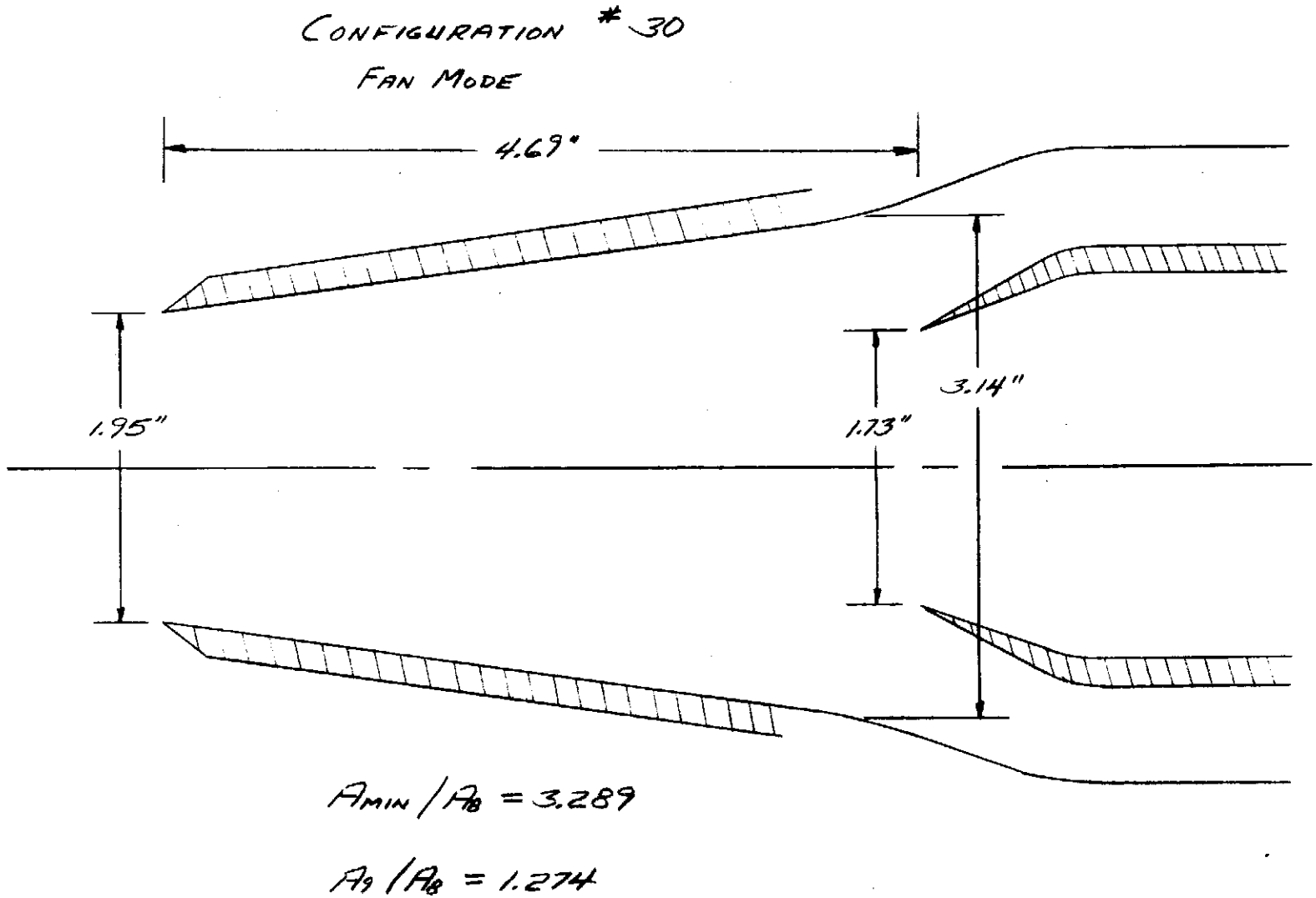


Figure 28. Shared Exit Ejector Nozzle - Model Configuration Tested, Fan Mode

Approved for Public Release

Contrails

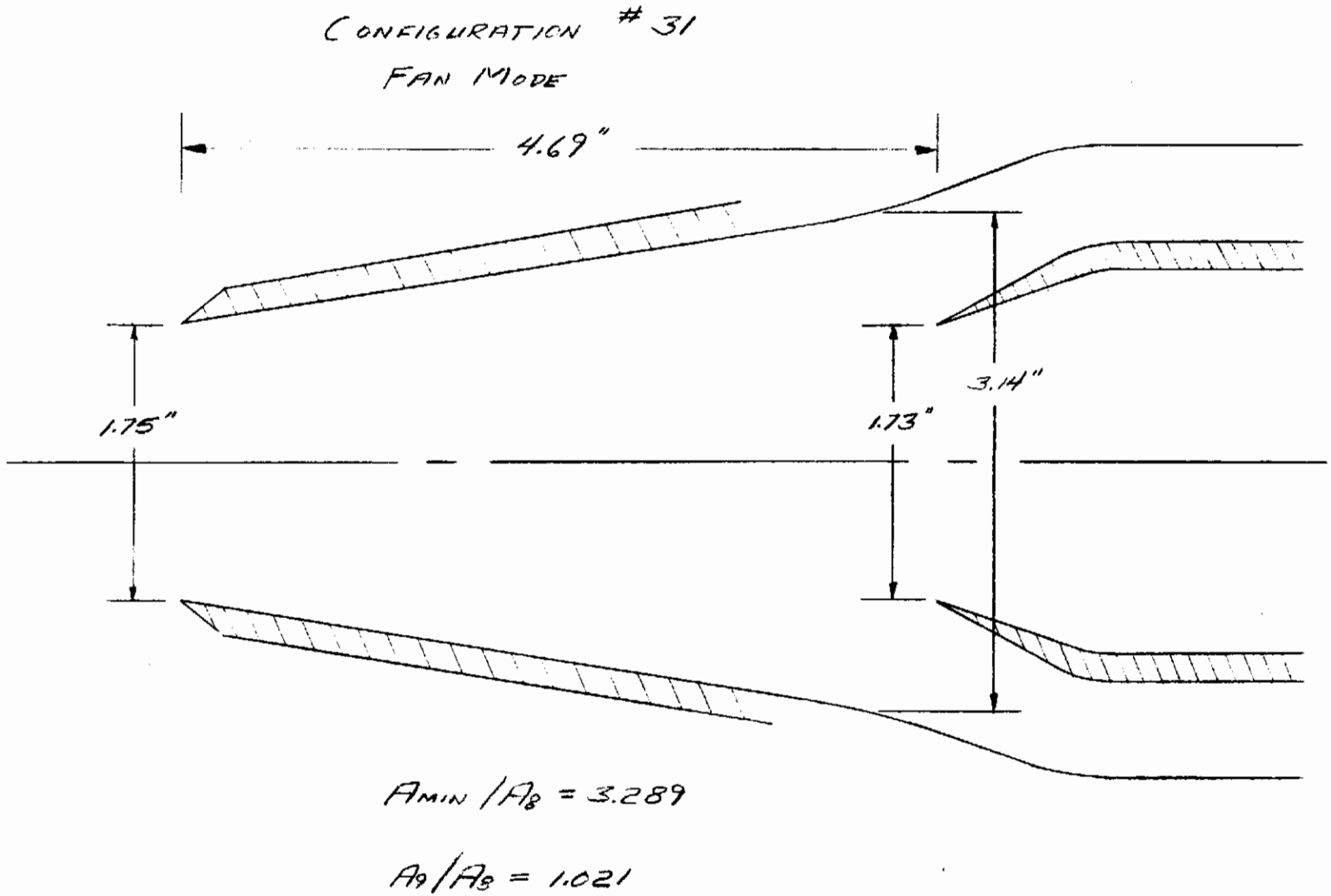


Figure 29. Shared Exit Ejector Nozzle - Model Configuration Tested, Fan Mode

Approved for Public Release

Contrails

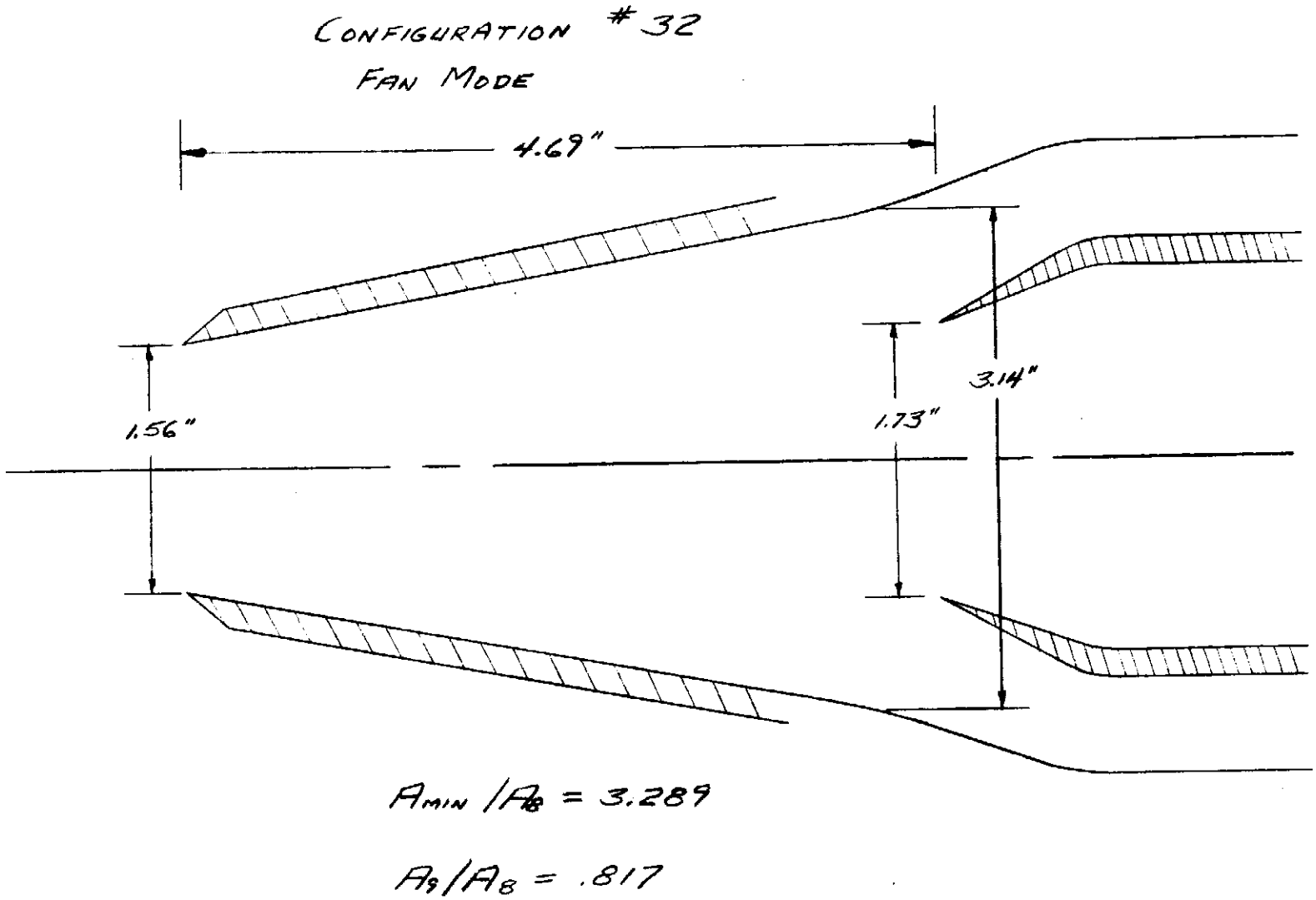


Figure 30. Shared Exit Ejector Nozzle - Model Configuration Tested, Fan Mode

Approved for Public Release

Contrails

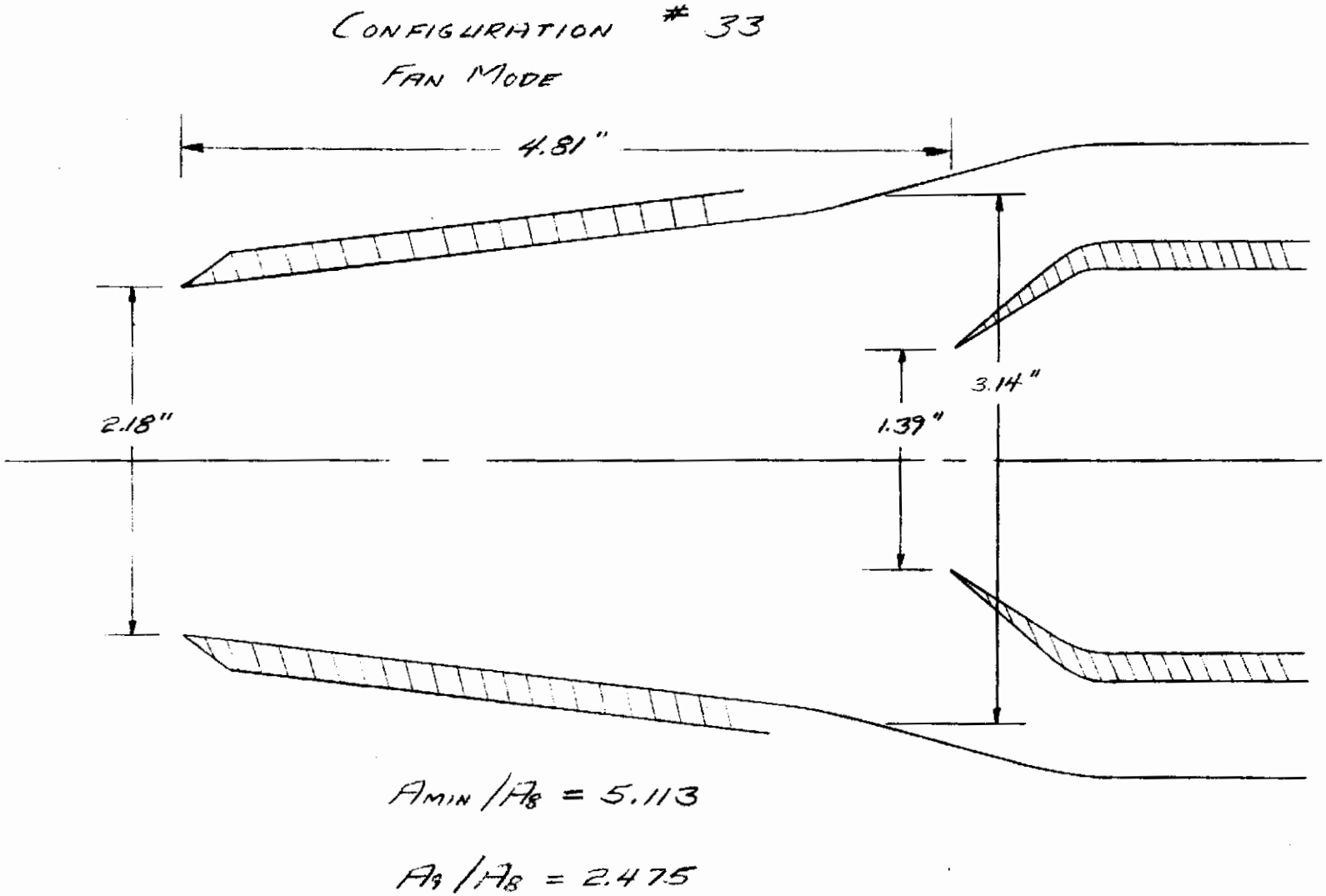


Figure 31. Shared Exit Ejector Nozzle - Model Configuration Tested, Fan Mode

Approved for Public Release

Contrails

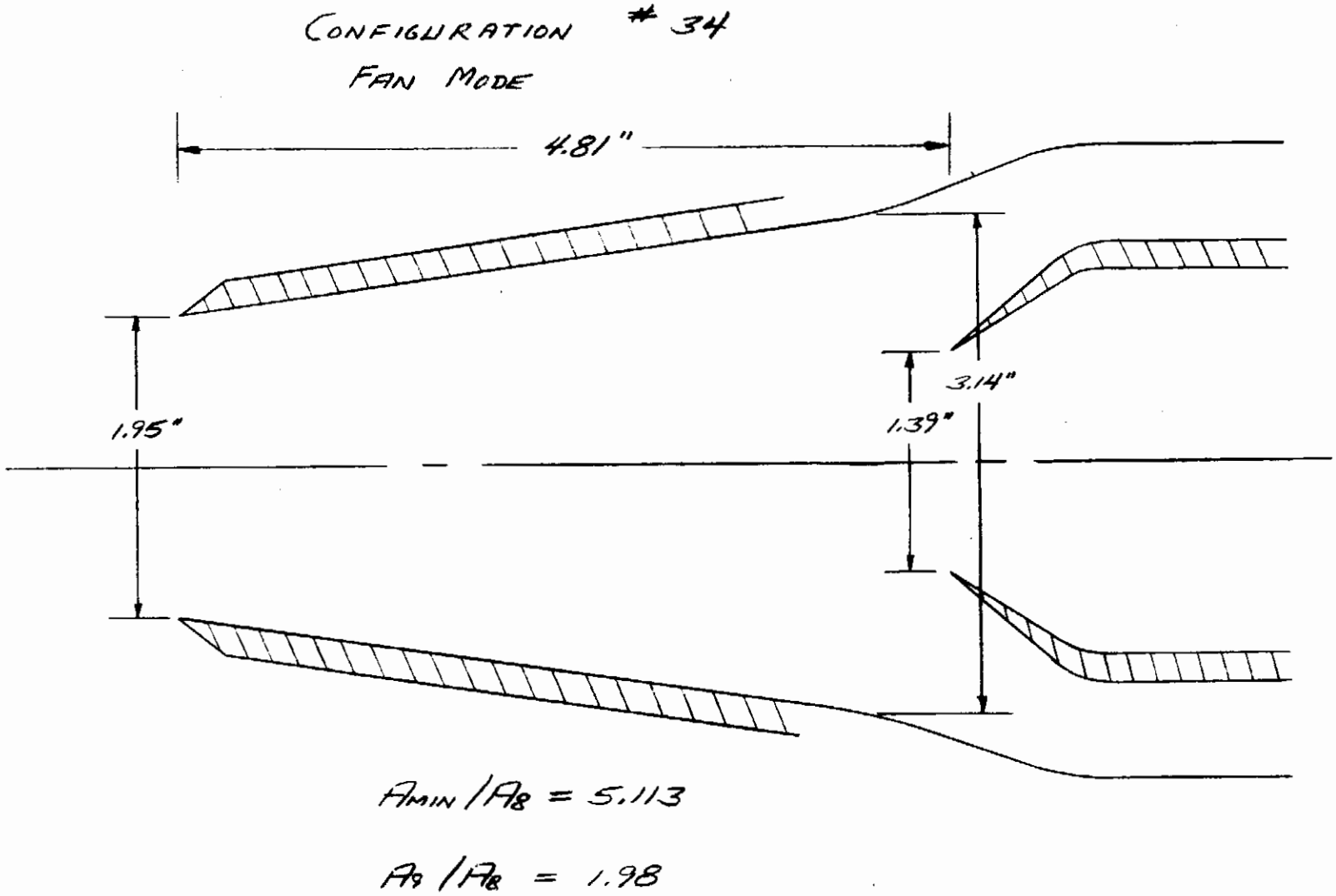


Figure 32. Shared Exit Ejector Nozzle - Model Configuration Tested, Fan Mode

Approved for Public Release

Contrails

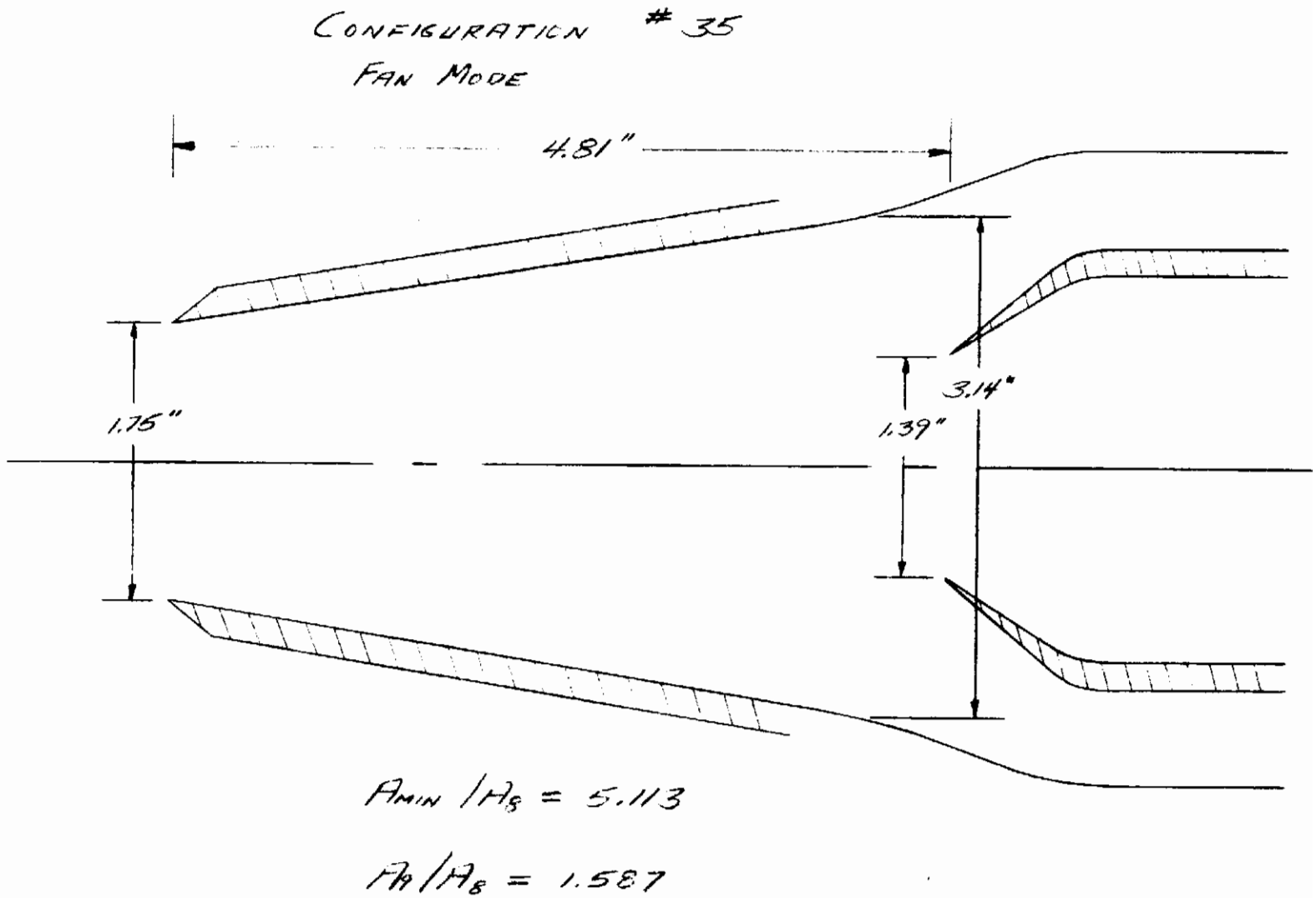


Figure 33. Shared Exit Ejector Nozzle - Model Configuration Tested, Fan Mode

Approved for Public Release

Contrails

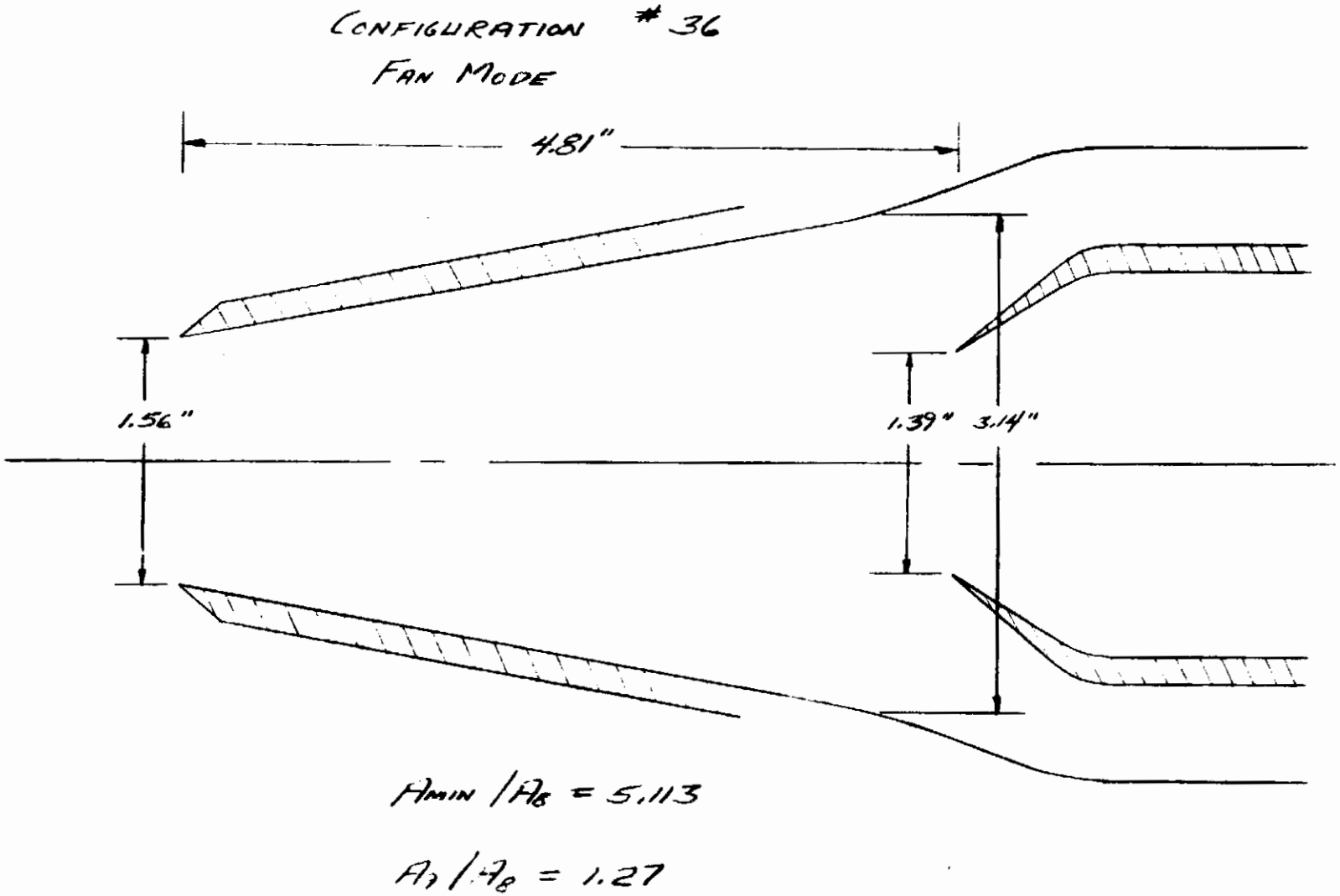


Figure 34. Shared Exit Ejector Nozzle - Model Configuration Tested, Fan Mode

Approved for Public Release

Contrails

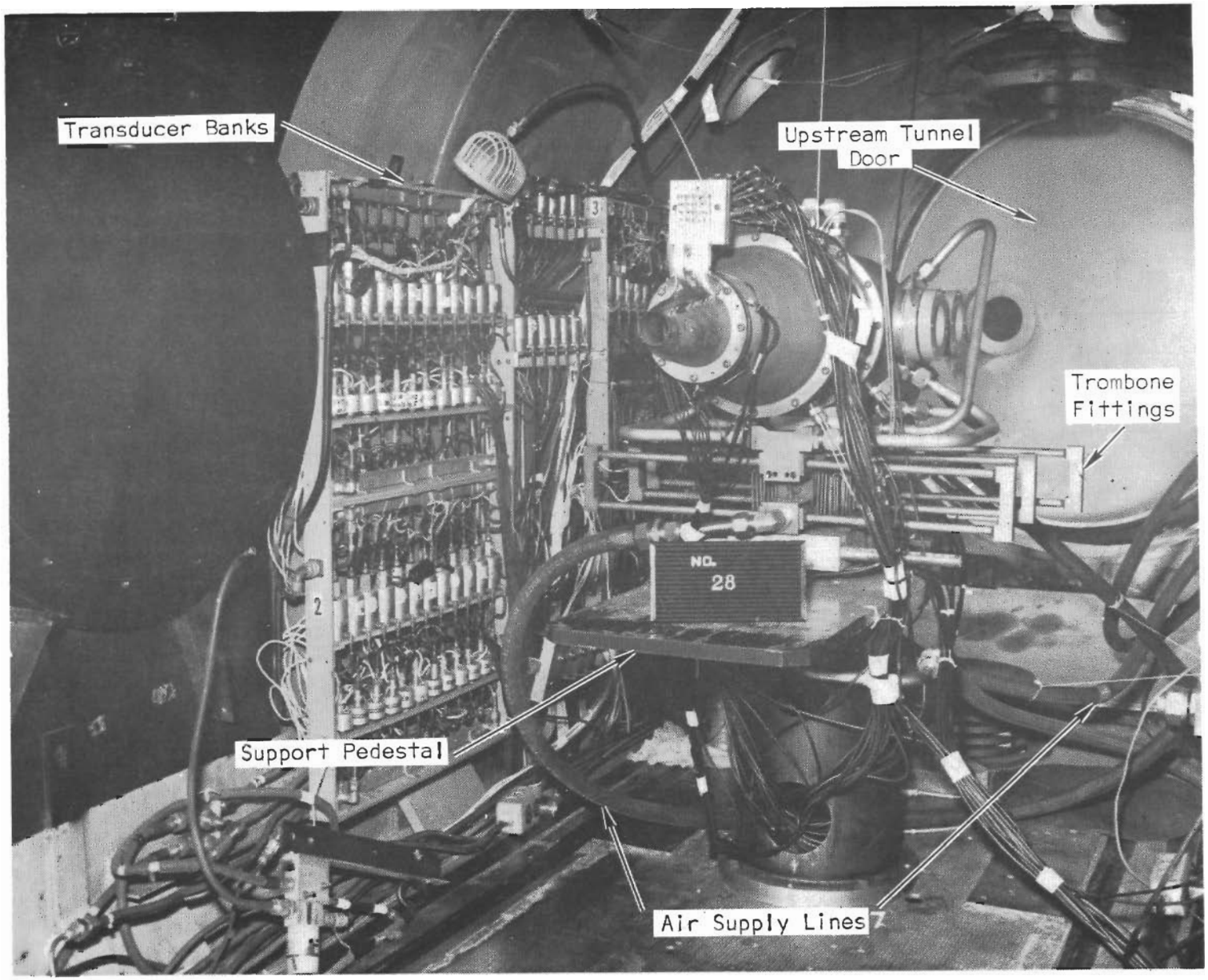


Figure 35. Shared Exit Ejector Nozzle Model and Balance Assembly Installed in RNTF - Front View

Approved for Public Release

Contrails

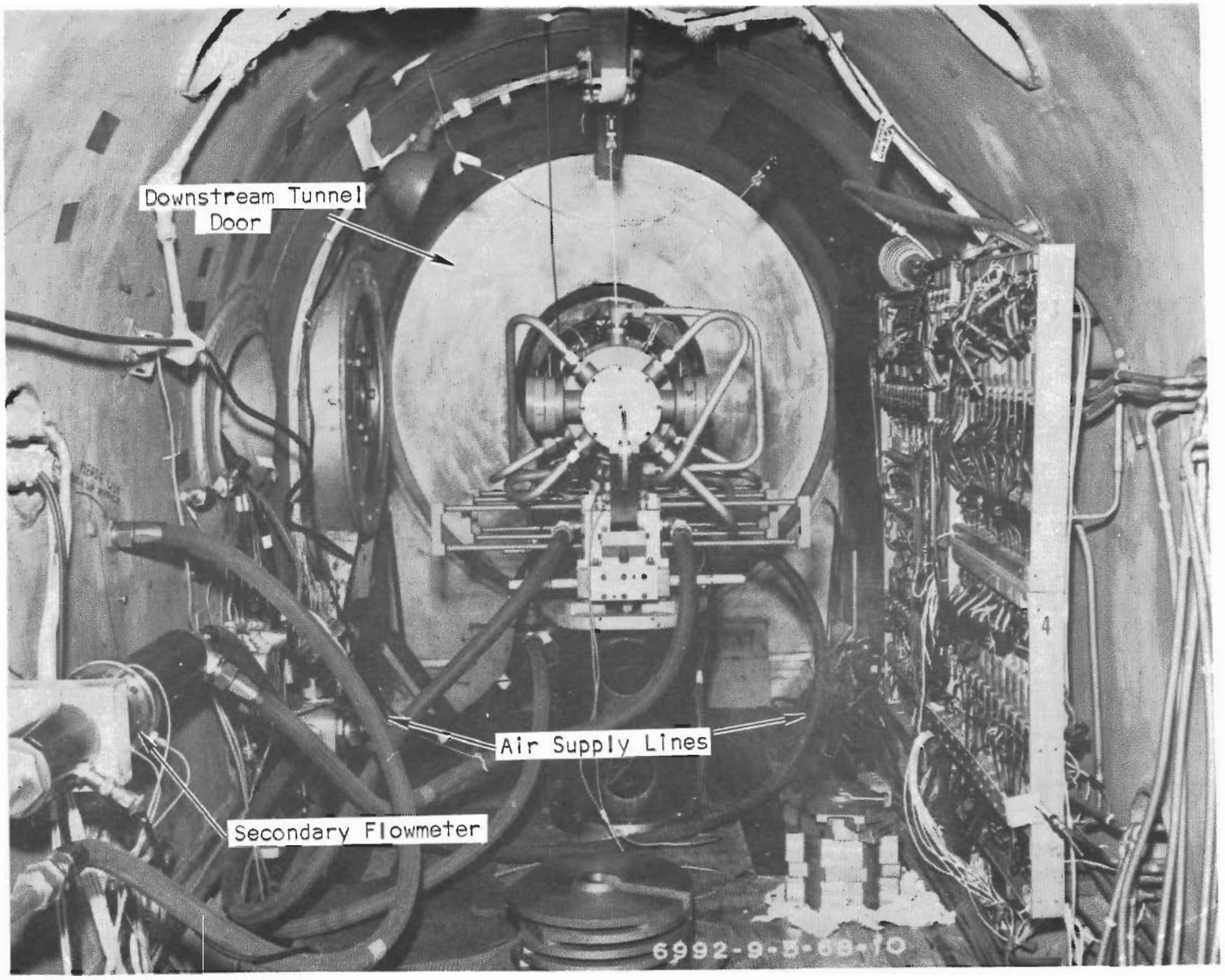


Figure 36. Shared Exit Ejector Nozzle Model and Balance Assembly Installed in R.N.T.F. - Rear View

Approved for Public Release

Contrails

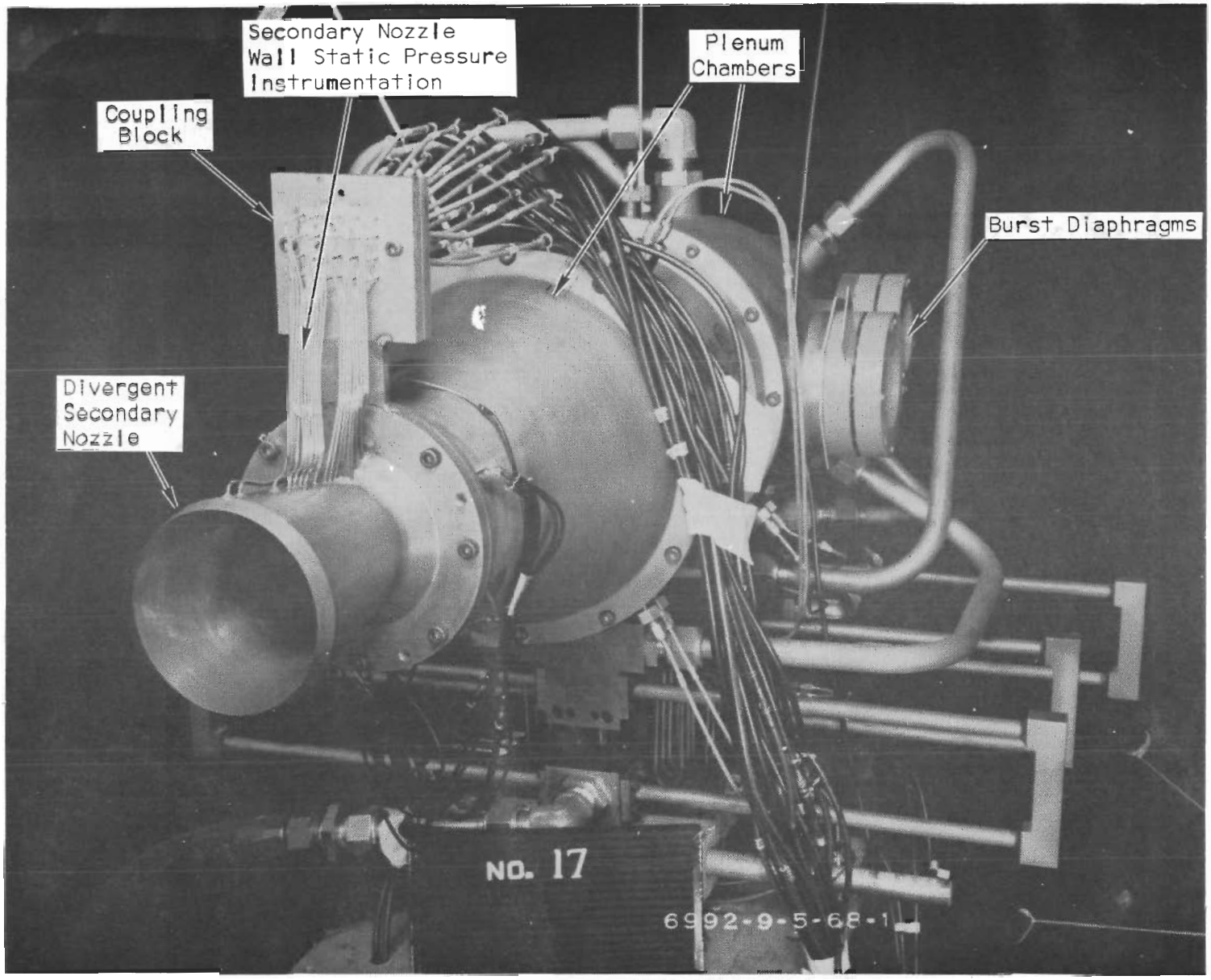


Figure 37. Shared Exit Ejector Nozzle Model and Balance Assembly - Typical Satellite Mode Configuration

Approved for Public Release

Contrails

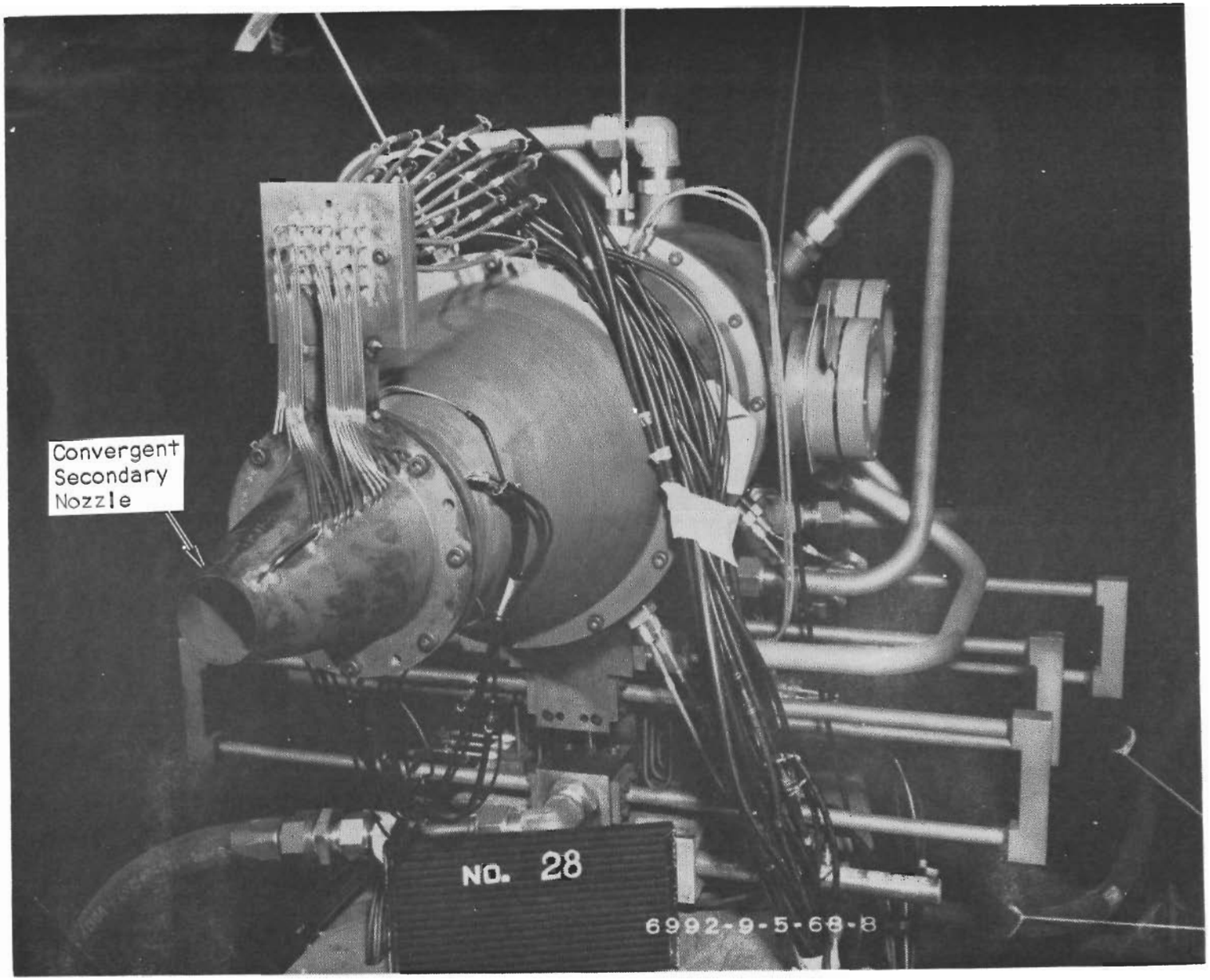


Figure 38. Shared Exit Ejector Nozzle Model and Balance Assembly - Typical Fan Mode Configuration

Approved for Public Release

Contrails

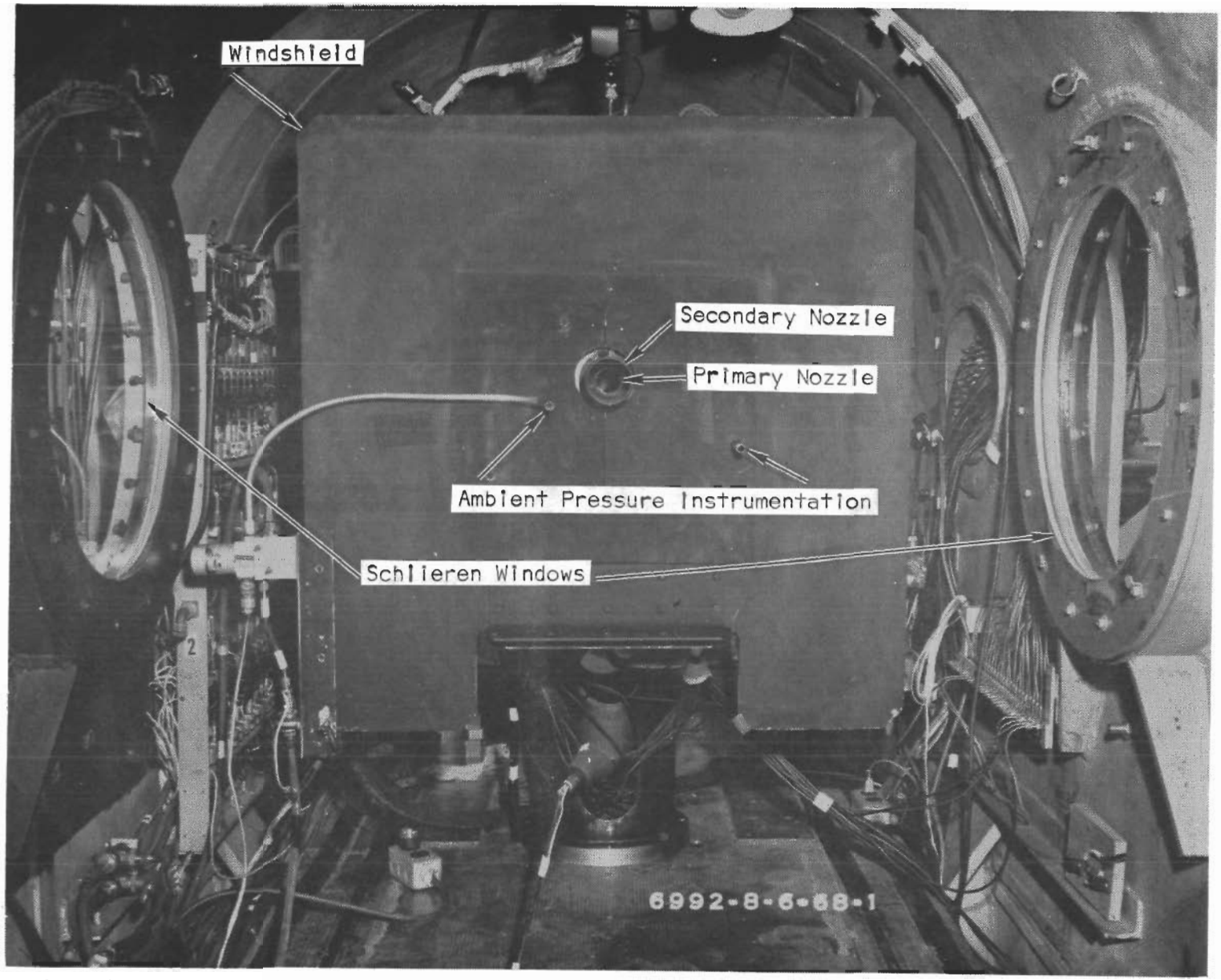


Figure 39. Shared Exit Ejector Nozzle Model Installed in R.N.T.F. - Front View with Windshield Installed

Approved for Public Release

Contrails

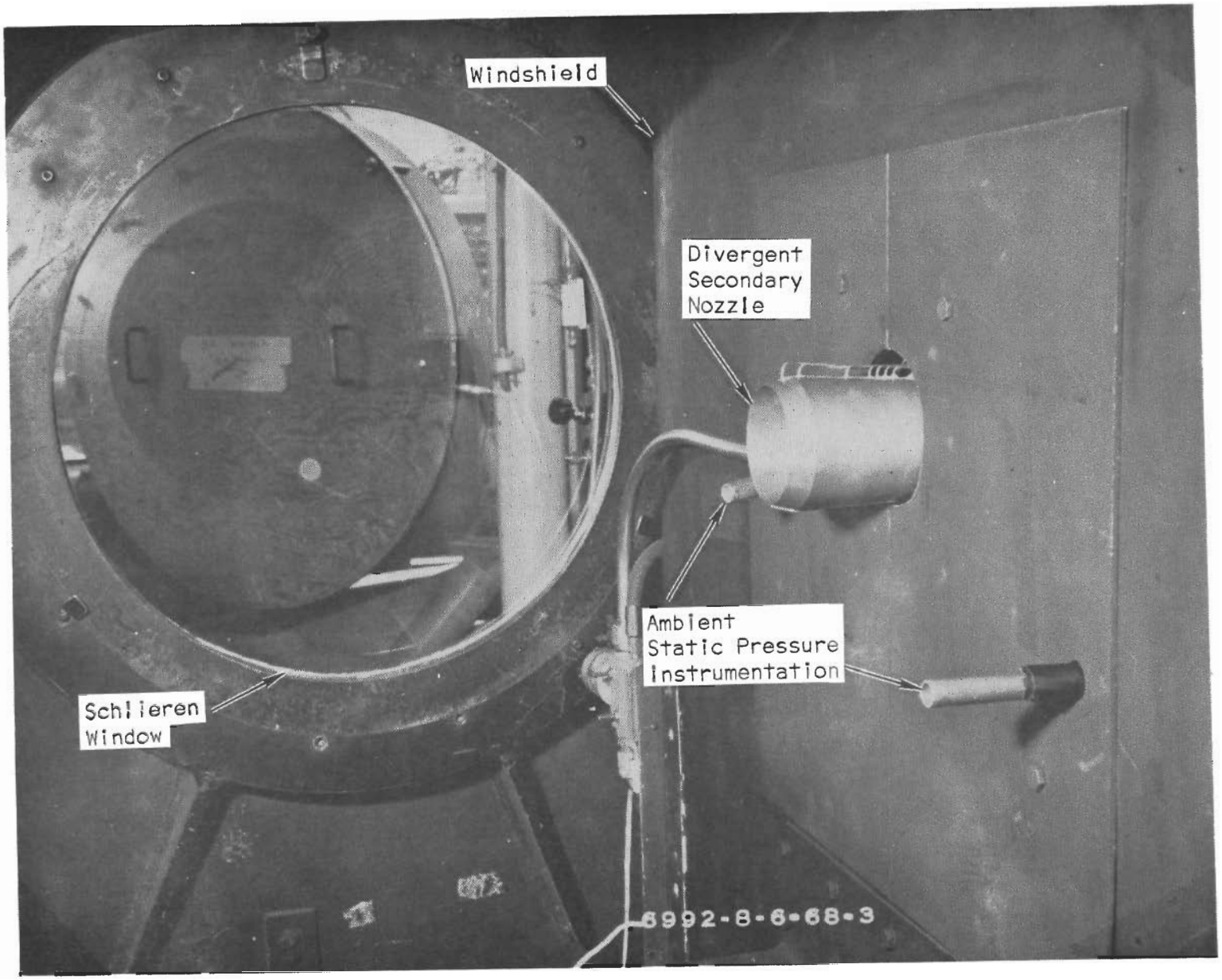


Figure 40. Shared Exit Ejector Nozzle Model Installed in RNTF - Side View with Windshield Installed

Approved for Public Release

Contrails

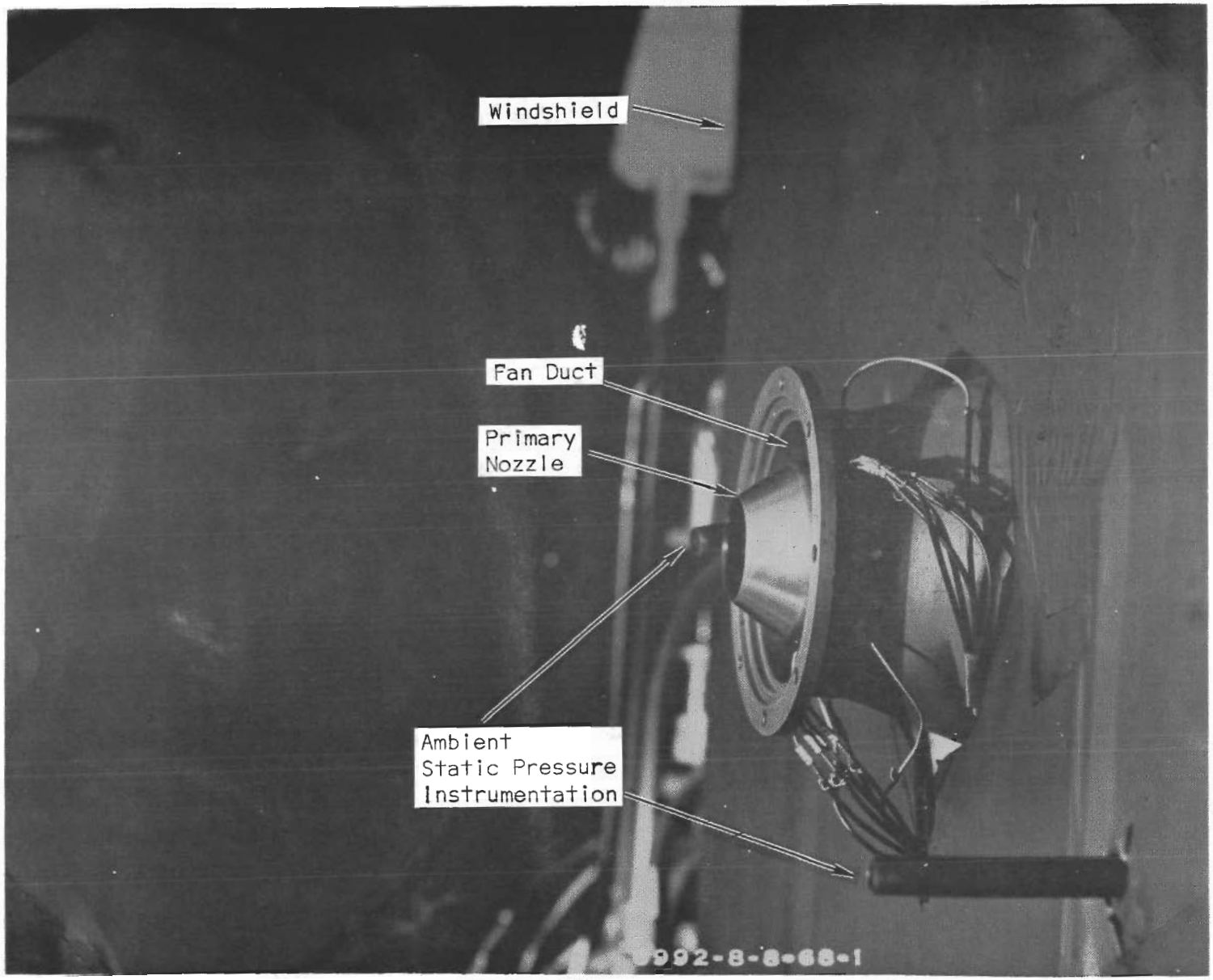
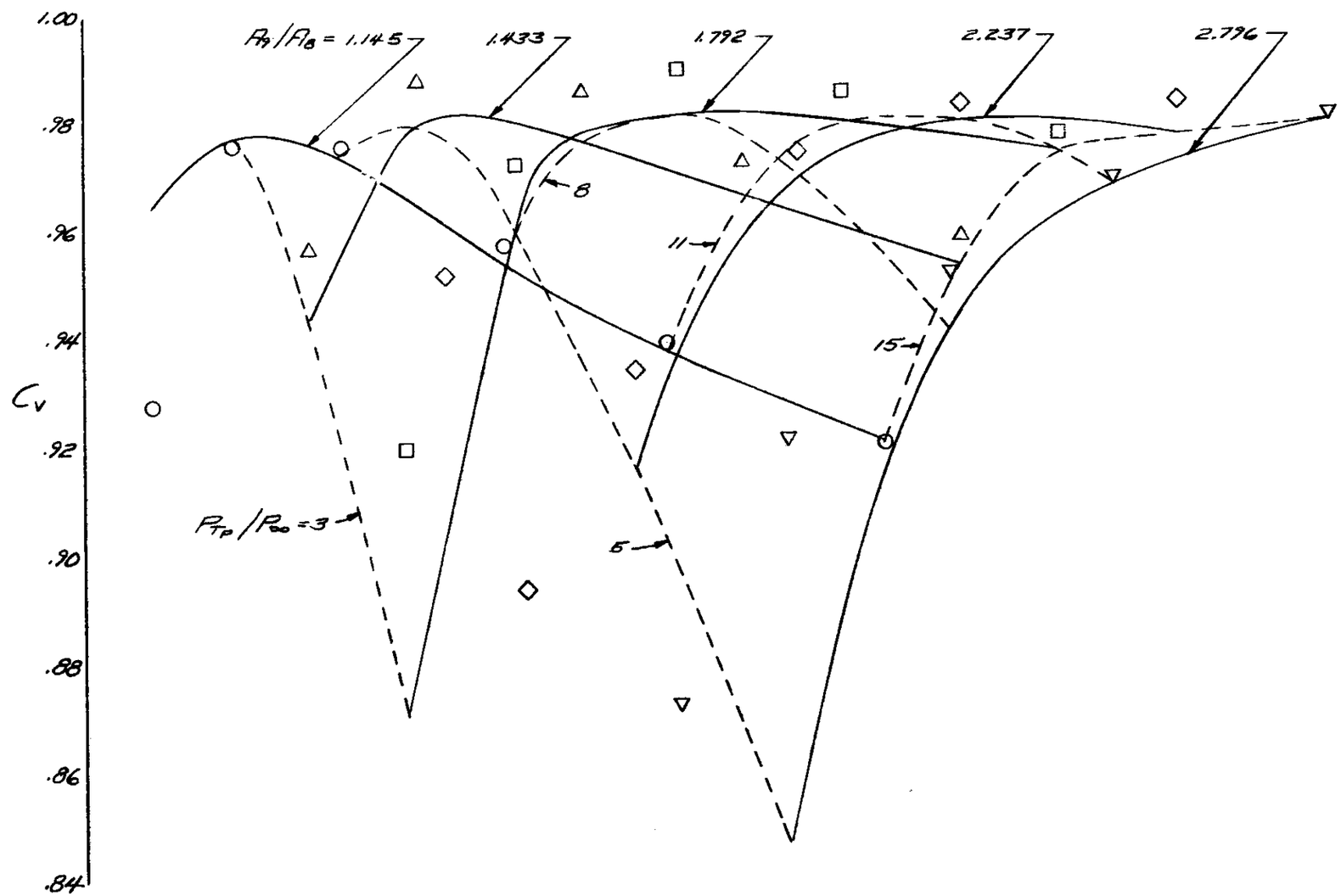


Figure 41. Shared Exit Ejector Nozzle Model Installed in R.N.T.F. - Side View, Primary Nozzle Only

Approved for Public Release

Contrails



SYMBOL	A_9/A_8
○	1.145
△	1.433
□	1.792
◇	2.237
▽	2.796

——— } ESTIMATED PERFORMANCE

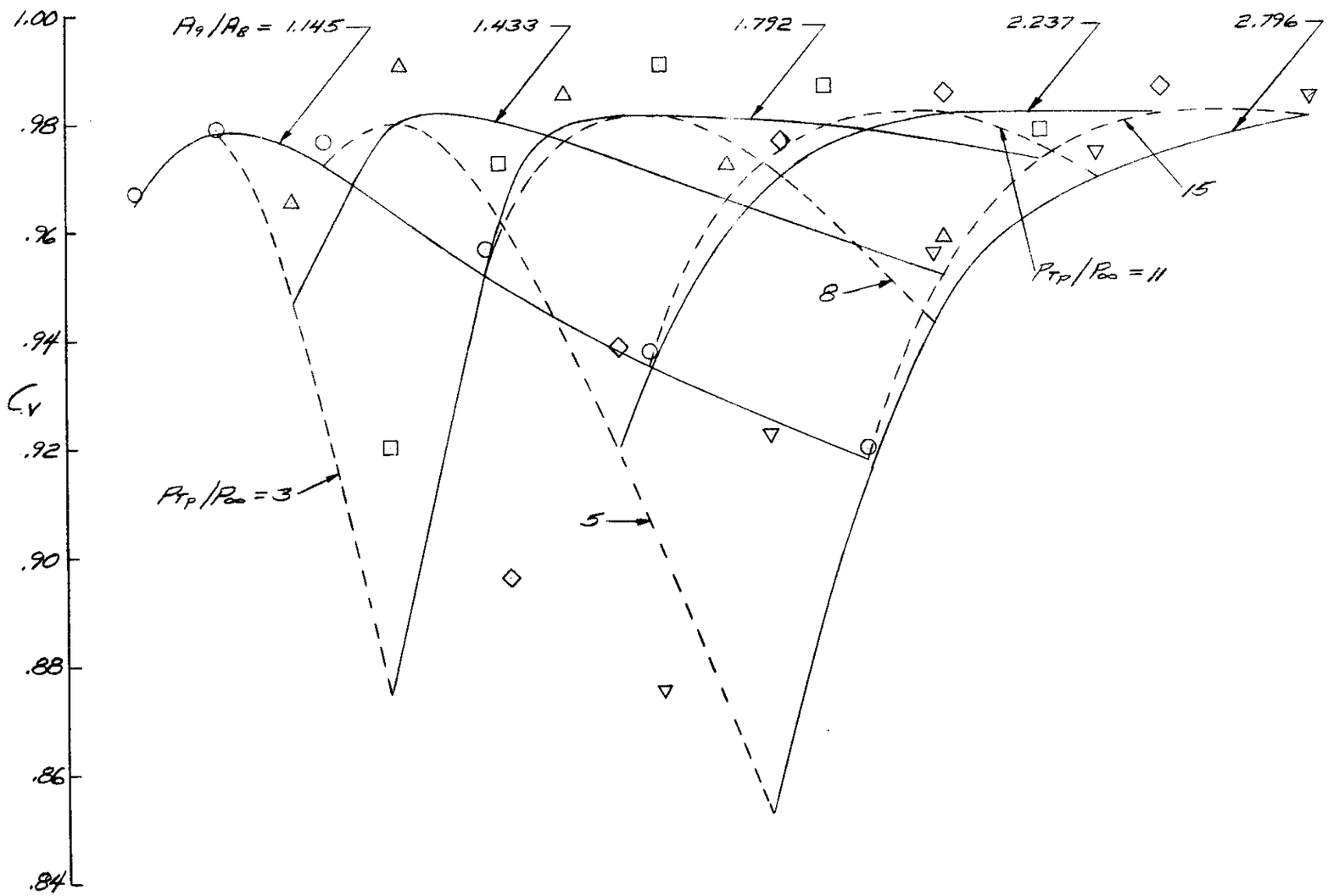
$A_{MIN}/A_8 = 1.074$

$W_F\sqrt{T_{T_F}}/W_P\sqrt{T_{T_P}} = 0.001$

Figure 42. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Performance

Approved for Public Release

Contrails



SYMBOL	A_9/A_8
○	1.145
△	1.433
□	1.792
◇	2.237
▽	2.796

——— } ESTIMATED PERFORMANCE
- - - -

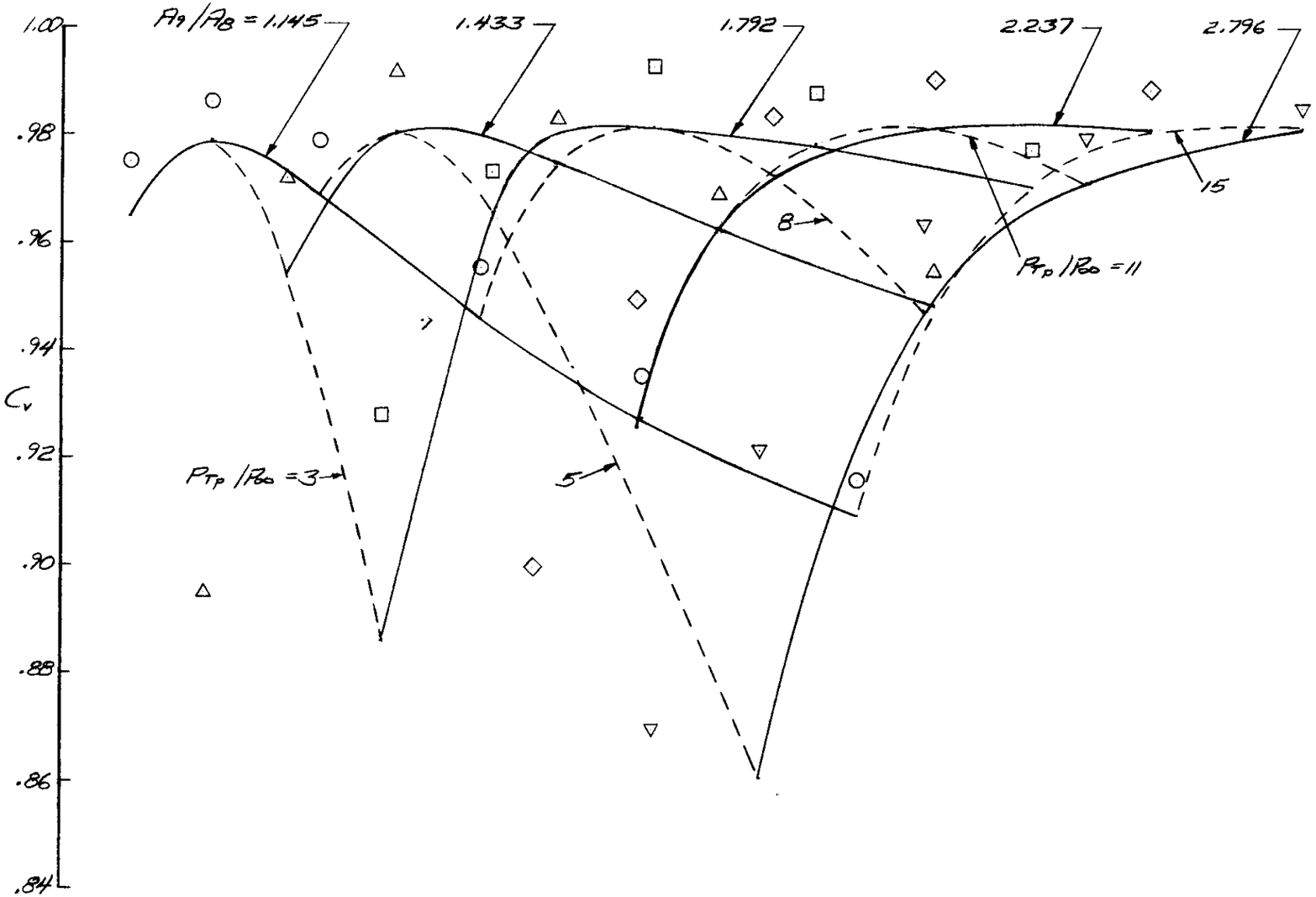
A_{MIN}/A_8 = 1.074

$W_F\sqrt{T_{T_F}}/W_P\sqrt{T_{T_P}}$ = 0.01

Figure 43. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Performance

Approved for Public Release

Contrails



SYMBOL	A_9/A_8
○	1.145
△	1.433
□	1.792
◇	2.237
▽	2.796

——— } ESTIMATED PERFORMANCE
- - - -

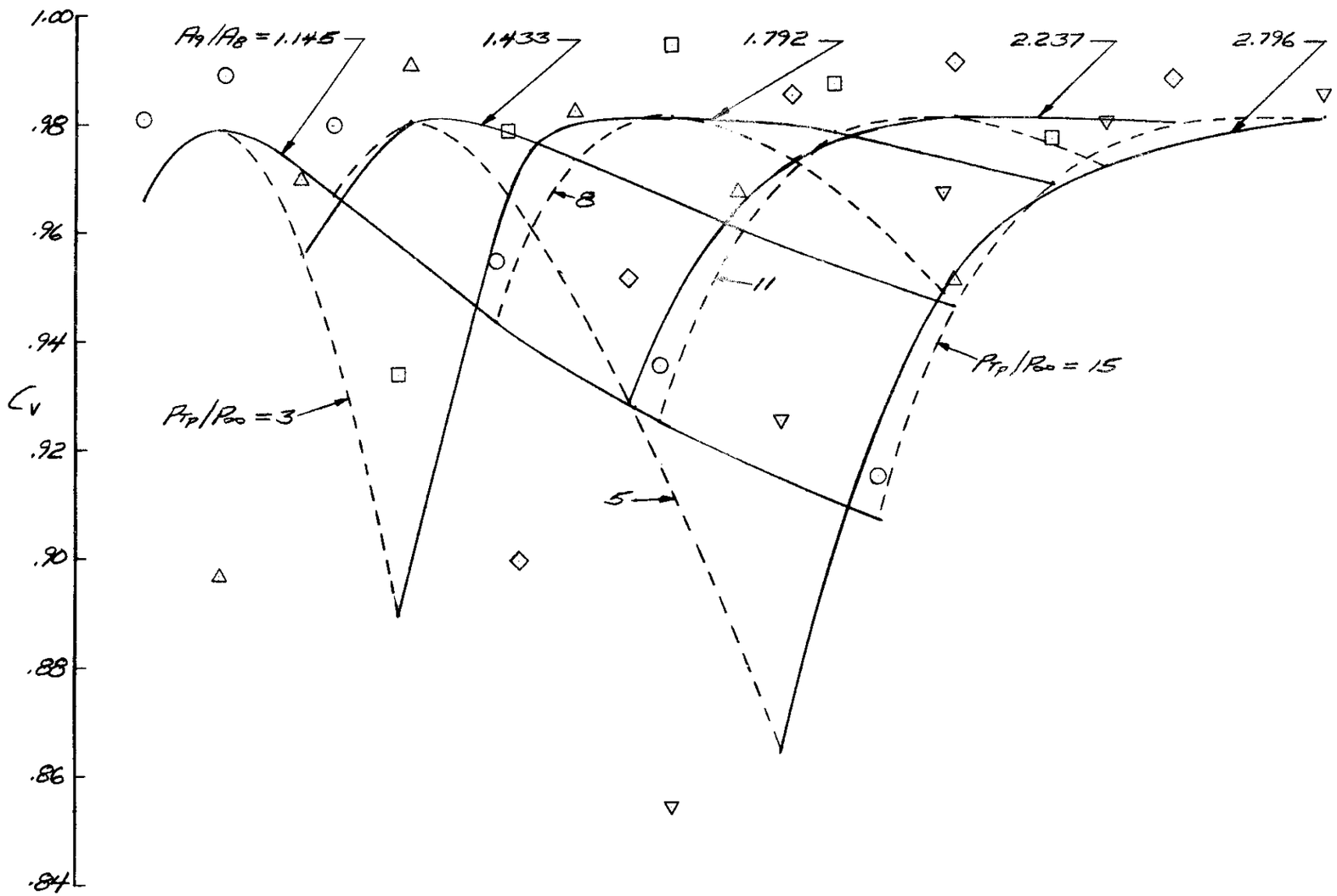
A_{MIN}/A_8 = 1.074

$W_F\sqrt{T_{T_F}}/W_P\sqrt{T_{T_P}}$ = 0.05

Figure 44. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Performance

Approved for Public Release

Contrails



SYMBOL	A_9/A_8
○	1.145
△	1.433
□	1.792
◇	2.237
▽	2.796

——— } ESTIMATED PERFORMANCE
- - - -

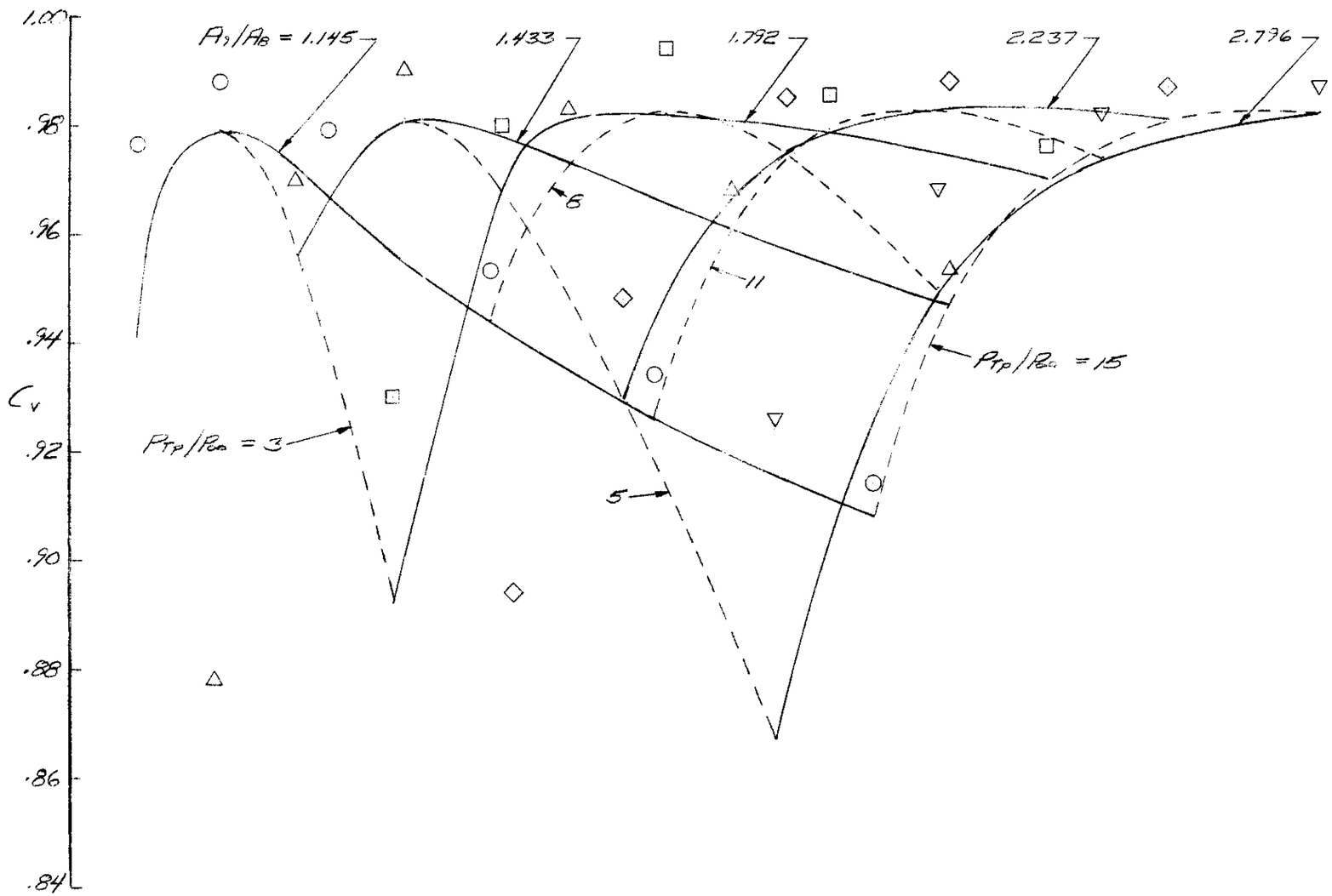
$A_{MIN}/A_8 = 1.074$

$W_F\sqrt{T_{TF}}/W_P\sqrt{T_{TP}} = 0.1$

Figure 45. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Performance

Approved for Public Release

Contrails



SYMBOL	A_9/A_B
○	1.145
△	1.433
□	1.792
◇	2.237
▽	2.796

——— } ESTIMATED PERFORMANCE
- - - -

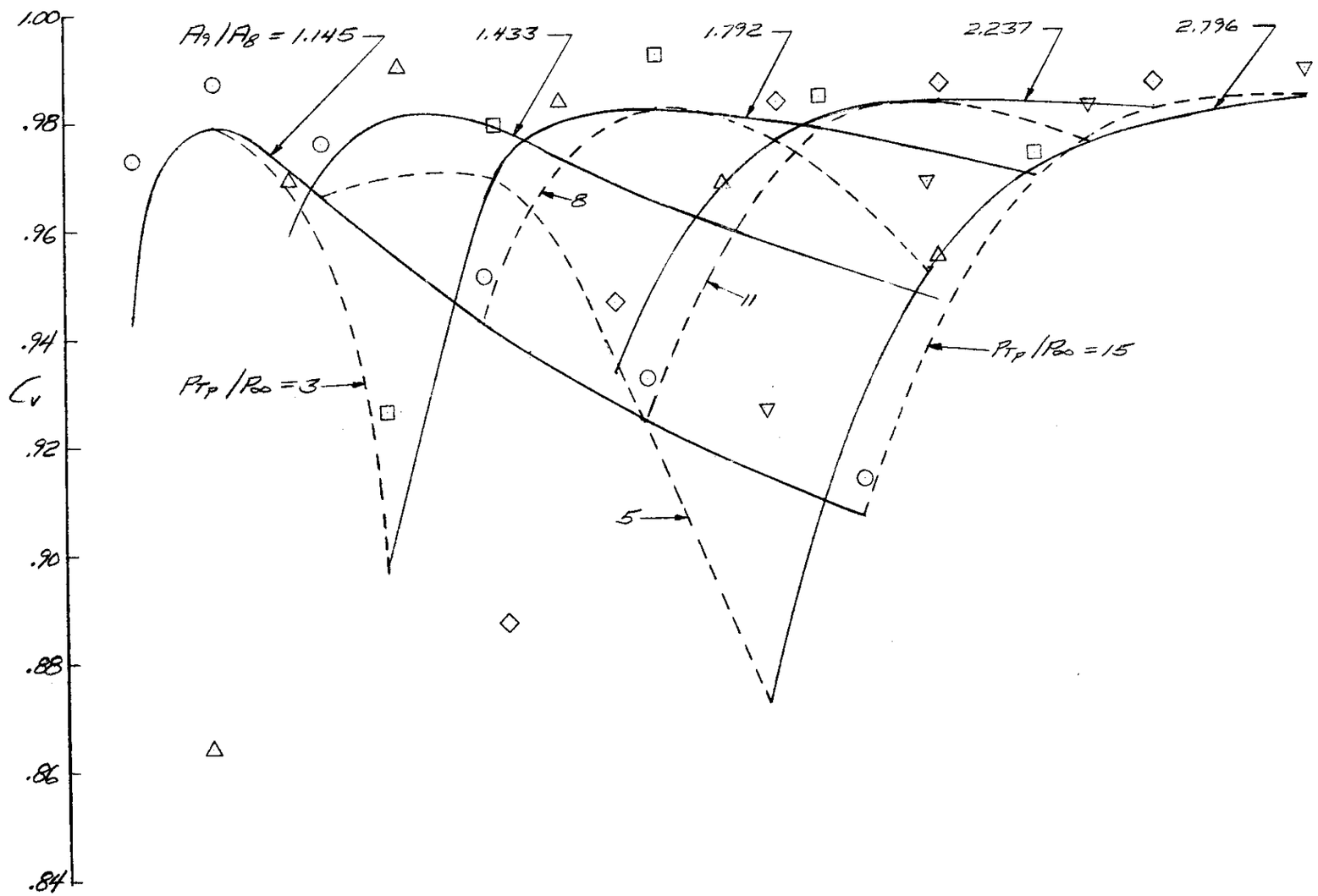
A_{MIN}/A_B = 1.074

$W_F\sqrt{T_{T_F}}/W_P\sqrt{T_{T_P}}$ = 0.05

Figure 46. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Performance

Approved for Public Release

Contrails



SYMBOL	A_9/A_8
○	1.145
△	1.433
□	1.792
◇	2.237
▽	2.796

——— } ESTIMATED PERFORMANCE
- - - -

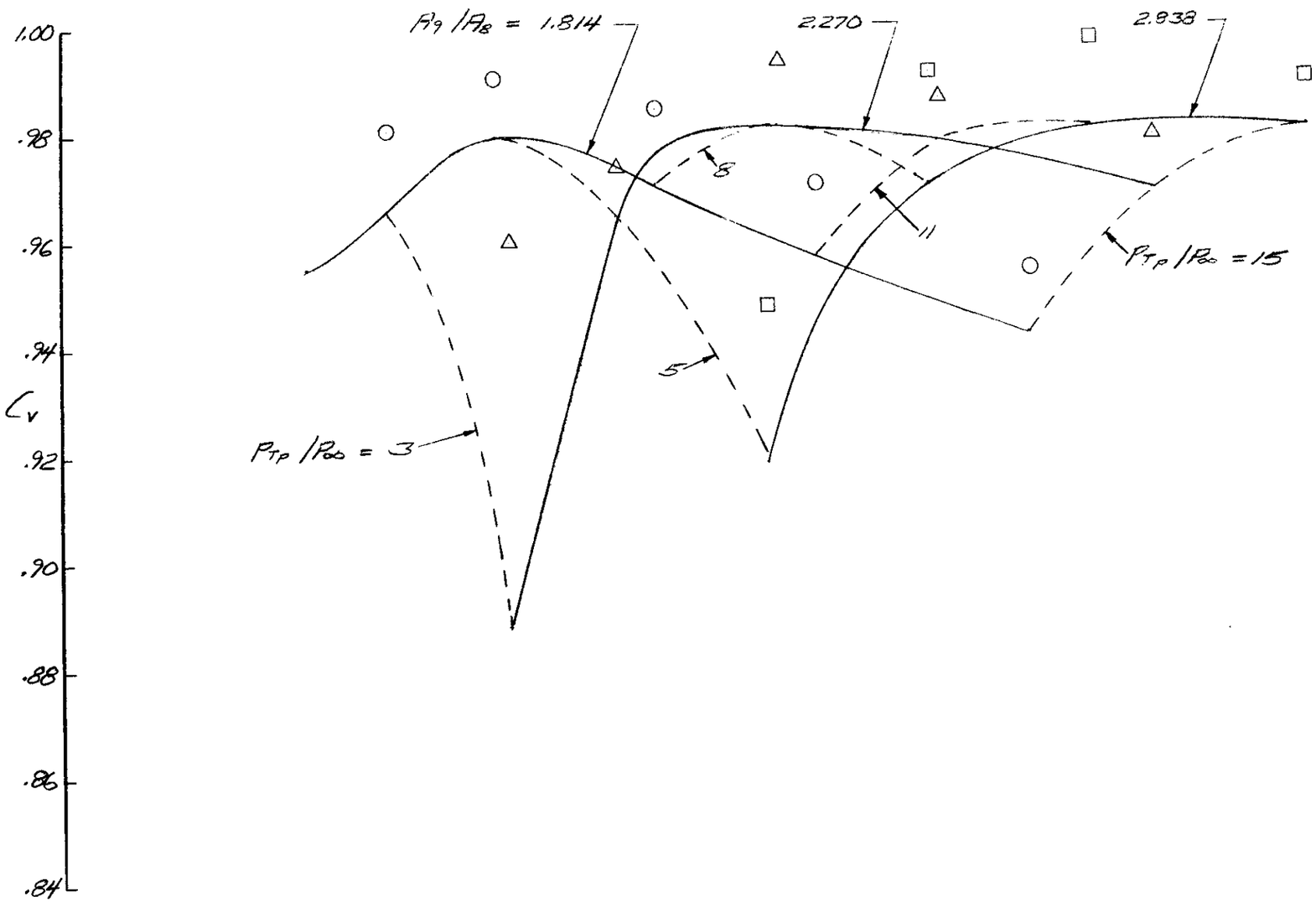
$A_{MIN}/A_8 = 1.074$

$W_F\sqrt{T_{T_F}}/W_P\sqrt{T_{T_P}} = 0.125$

Figure 47. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Performance

Approved for Public Release

Contrails



SYMBOL	A_9/A_8
○	1.814
△	2.270
□	2.838

——— } ESTIMATED PERFORMANCE

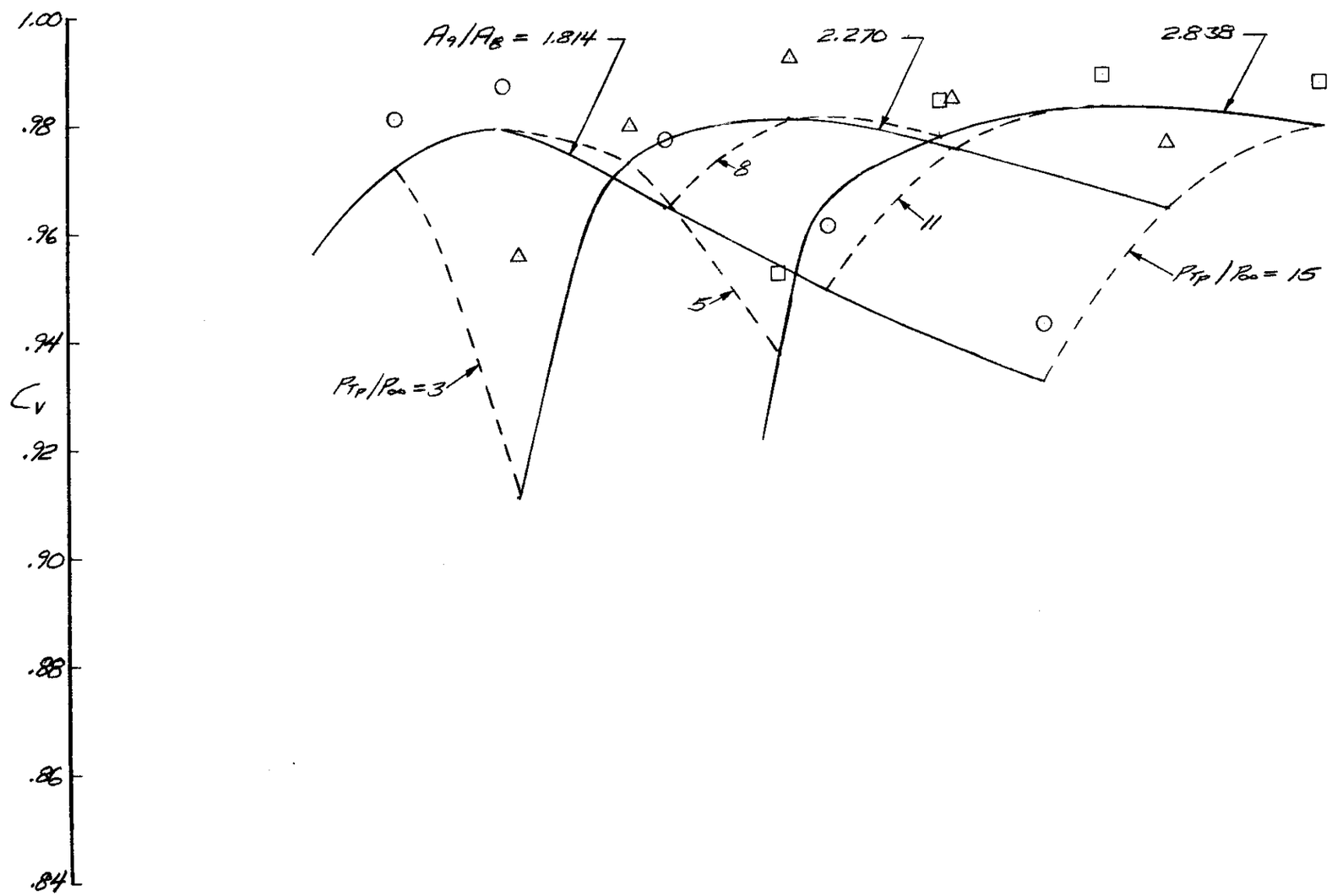
A_{MIN}/A_8 = 1.701

$W_F\sqrt{T_{TF}}/W_P\sqrt{T_{TP}}$ = 0.2

Figure 48. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Performance

Approved for Public Release

Contrails



SYMBOL	A_9/A_8
○	1.814
△	2.270
□	2.838

——— } ESTIMATED PERFORMANCE

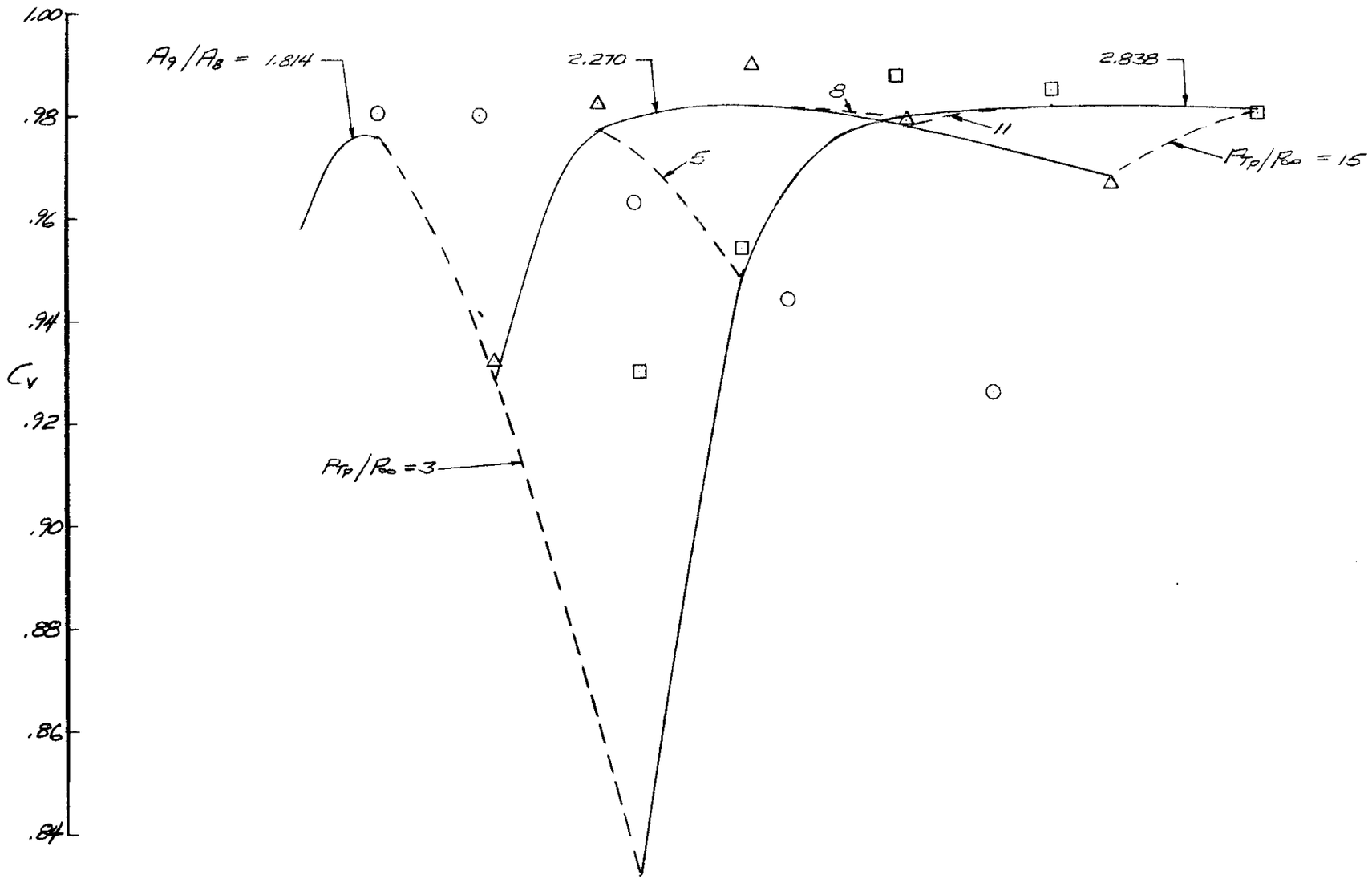
A_{MIN}/A_8 = 1.701

$W_F\sqrt{T_{TF}}/W_P\sqrt{T_{TP}}$ = 0.3

Figure 49. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Performance

Approved for Public Release

Contrails



SYMBOL	A_9/A_8
○	1.814
△	2.270
□	2.838

——— } ESTIMATED PERFORMANCE
- - - -

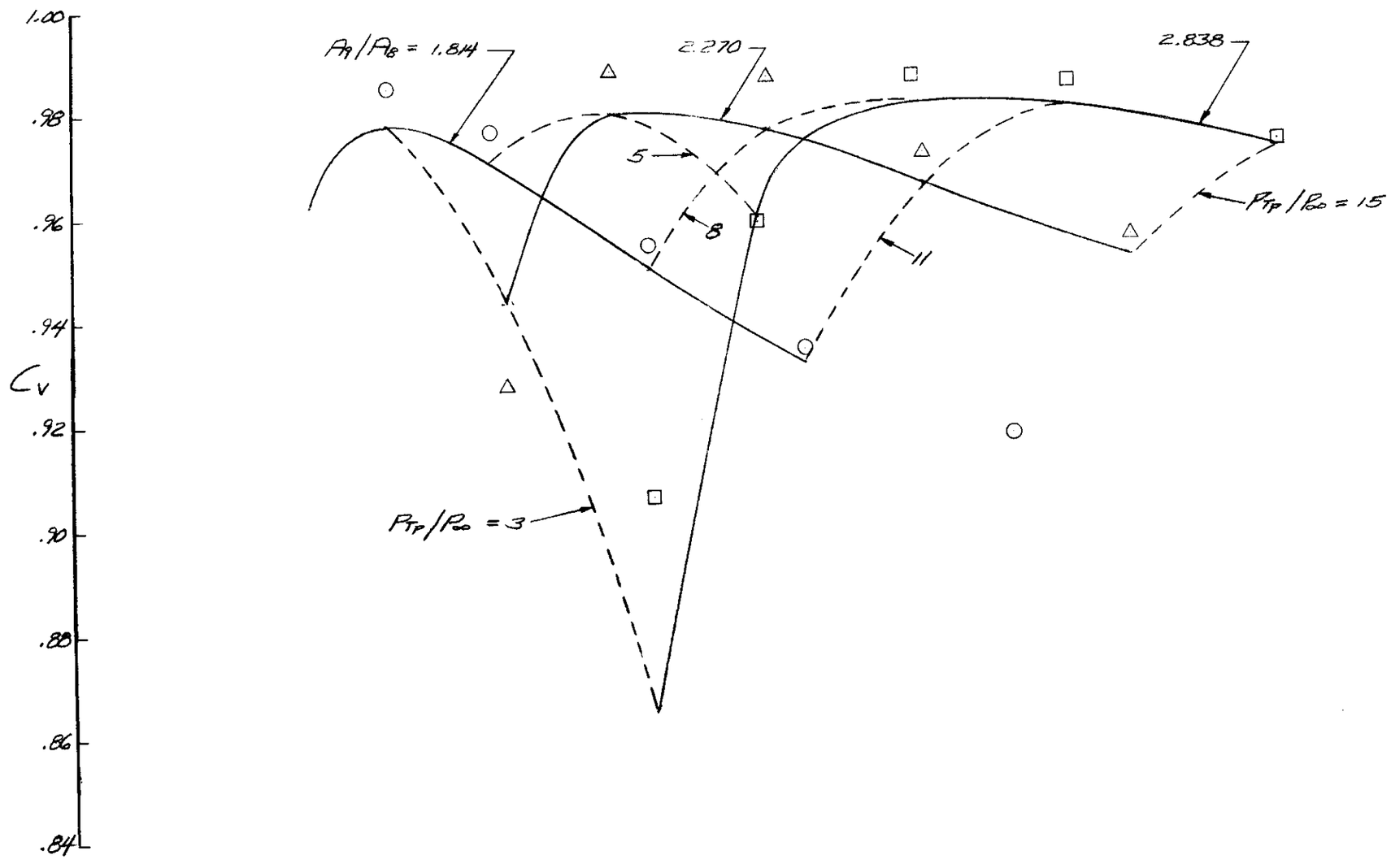
A_{MIN}/A_8 = 1.701

$W_F\sqrt{T_{T_F}}/W_P\sqrt{T_{T_P}}$ = 0.4

Figure 50. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Performance

Approved for Public Release

Contrails



SYMBOL	A_9/A_8
○	1.814
△	2.270
□	2.838

——— } ESTIMATED PERFORMANCE
- - - -

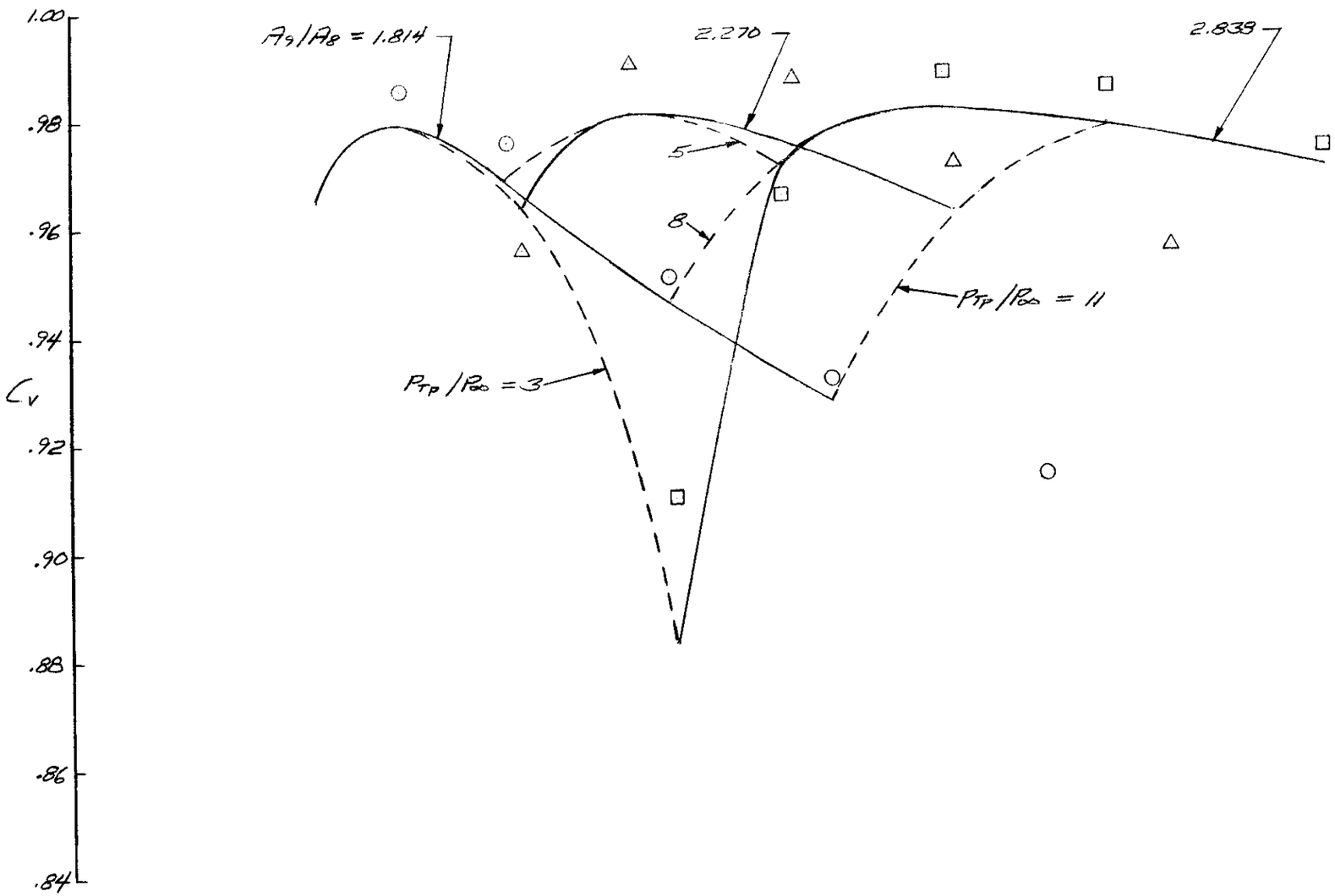
A_{MIN}/A_8 = 1.701

$W_F\sqrt{T_{TF}}/W_P\sqrt{T_{TP}}$ = 0.6

Figure 51. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Performance

Approved for Public Release

Contrails



SYMBOL	A_9/A_8
○	1.814
△	2.270
□	2.838

——— } ESTIMATED PERFORMANCE

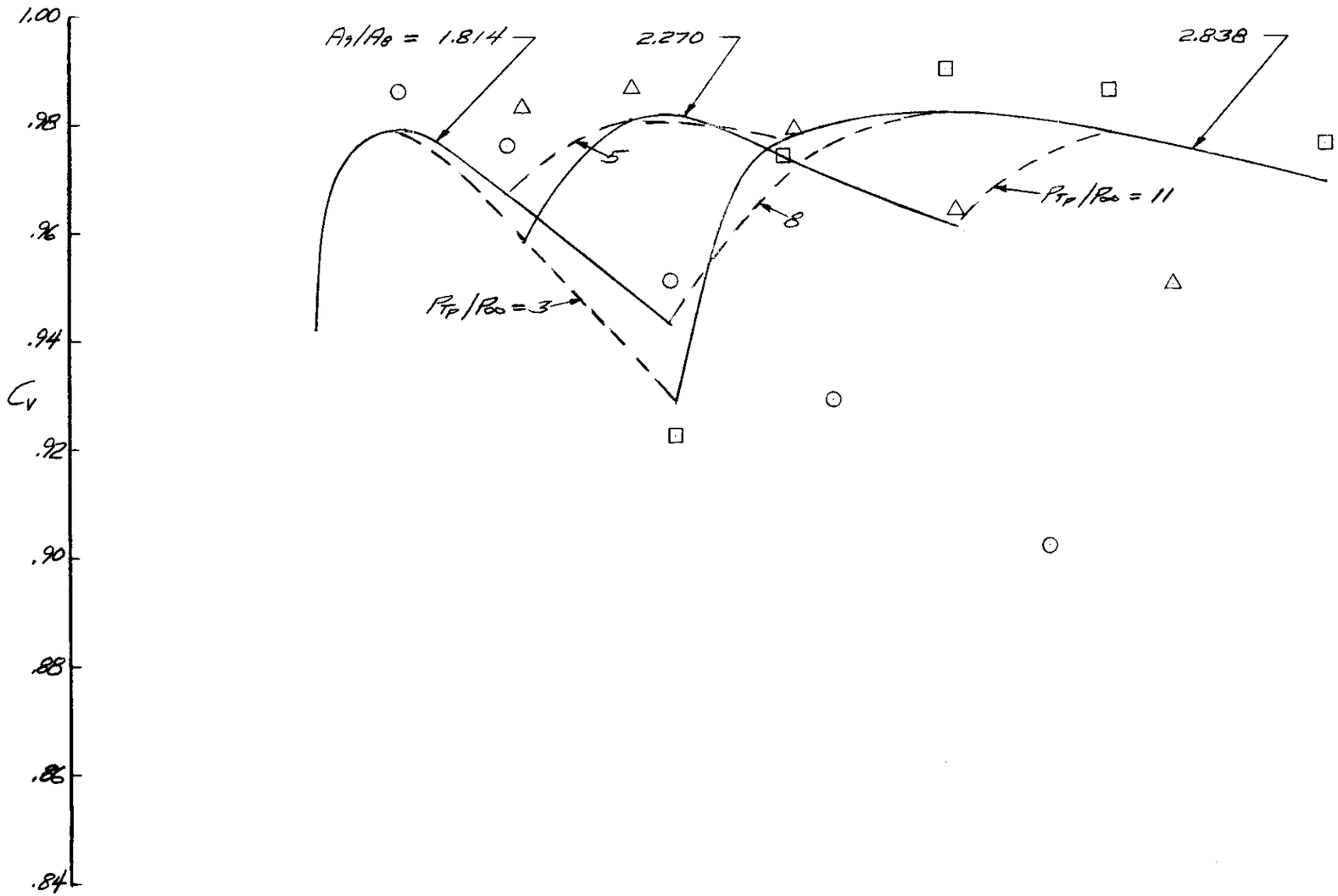
$A_{MIN}/A_8 = 1.701$

$W_F\sqrt{T_{TF}}/W_P\sqrt{T_{TP}} = 0.8$

Figure 52. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Performance

Approved for Public Release

Contrails



SYMBOL	A_9/A_8
○	1.814
△	2.270
□	2.838

——— } ESTIMATED PERFORMANCE
- - - -

A_{min}/A_8 = 1.701

$W_F\sqrt{T_{T_F}}/W_P\sqrt{T_{T_P}}$ = 1.0

Figure 53. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Performance

Approved for Public Release

Contrails

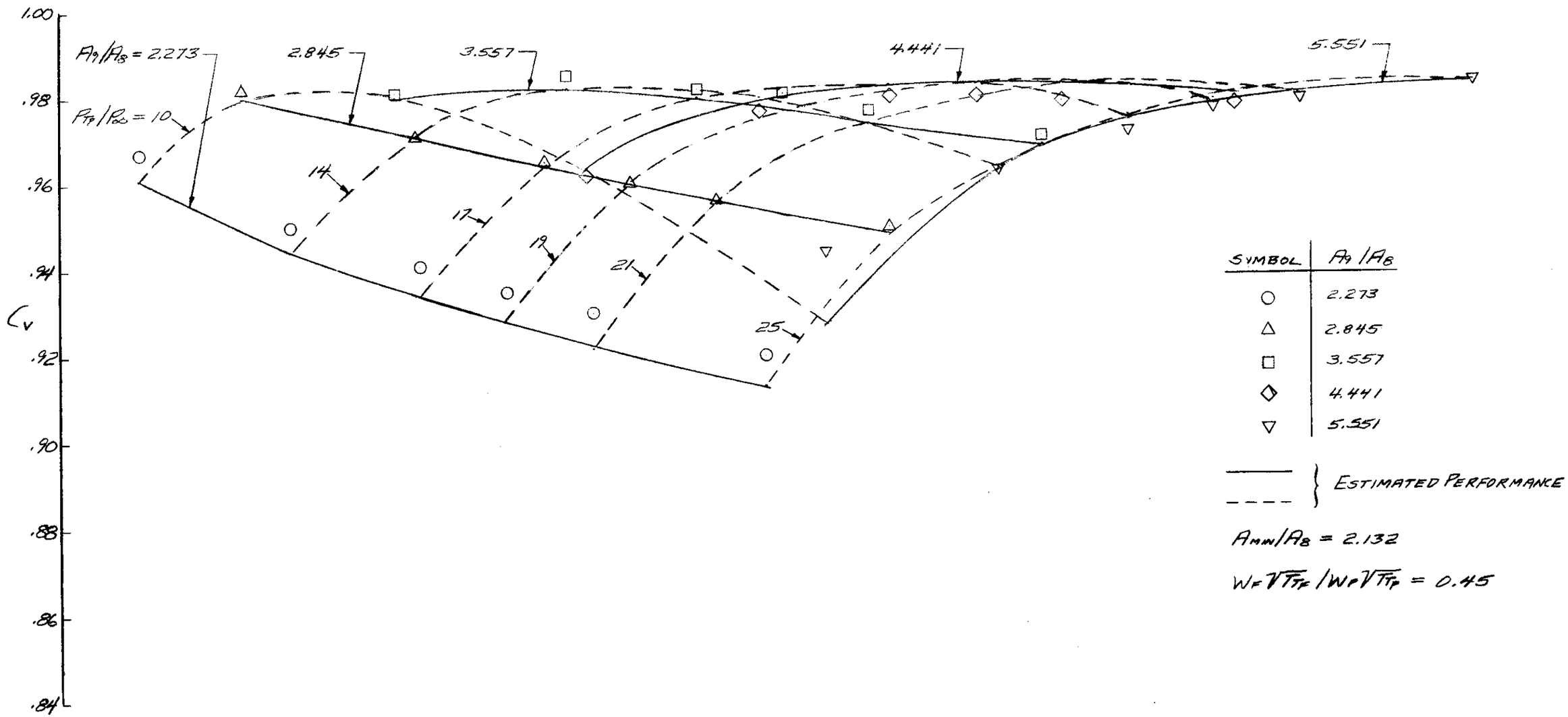


Figure 54. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Performance

Approved for Public Release

Contrails

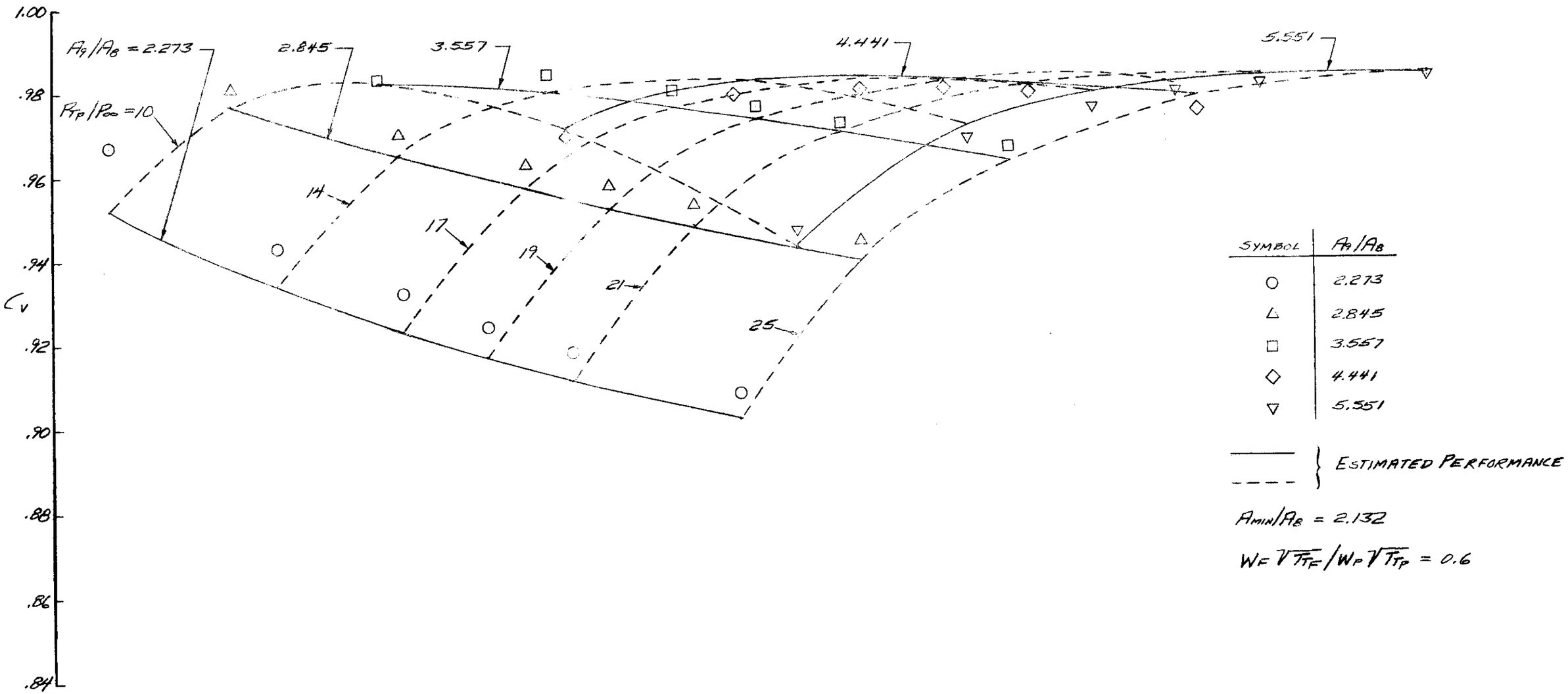


Figure 55. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Performance

Approved for Public Release

Contrails

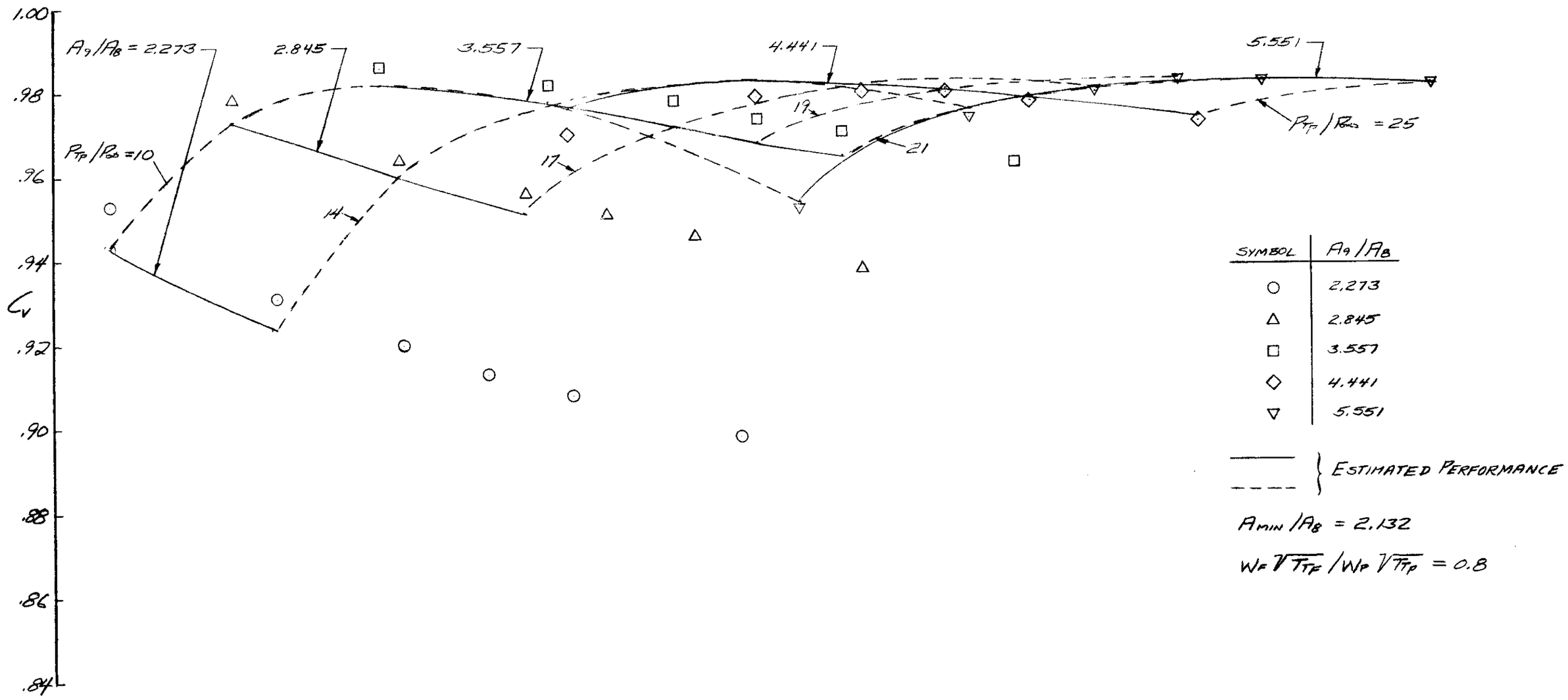


Figure 56. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Performance

Approved for Public Release

Contrails

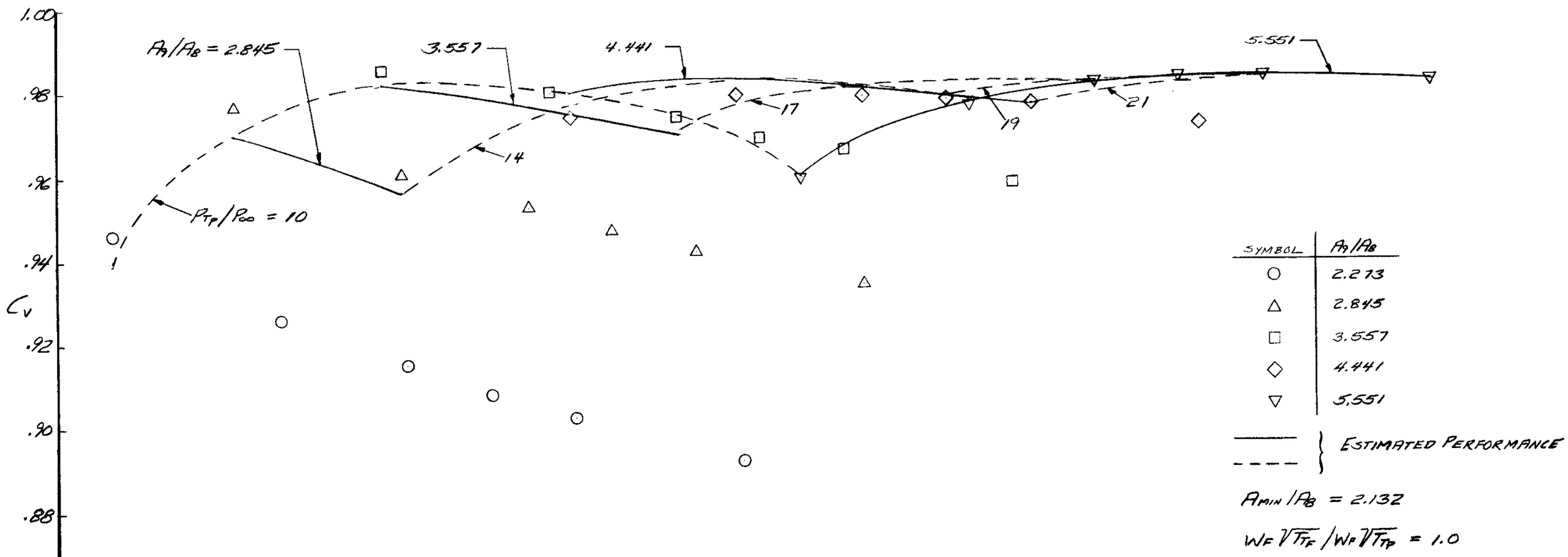


Figure 57. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Performance

Approved for Public Release

Contrails

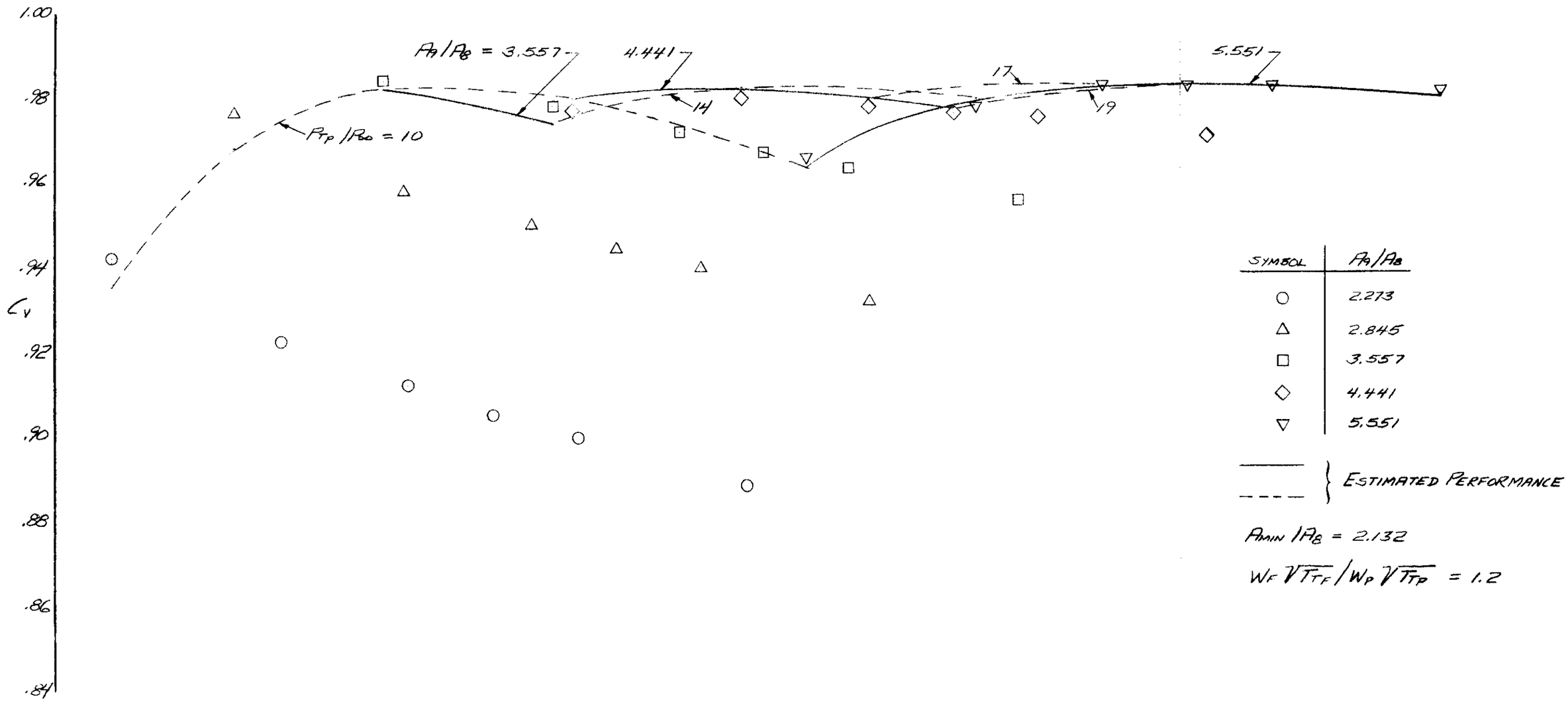


Figure 58. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Performance

Approved for Public Release

Contrails

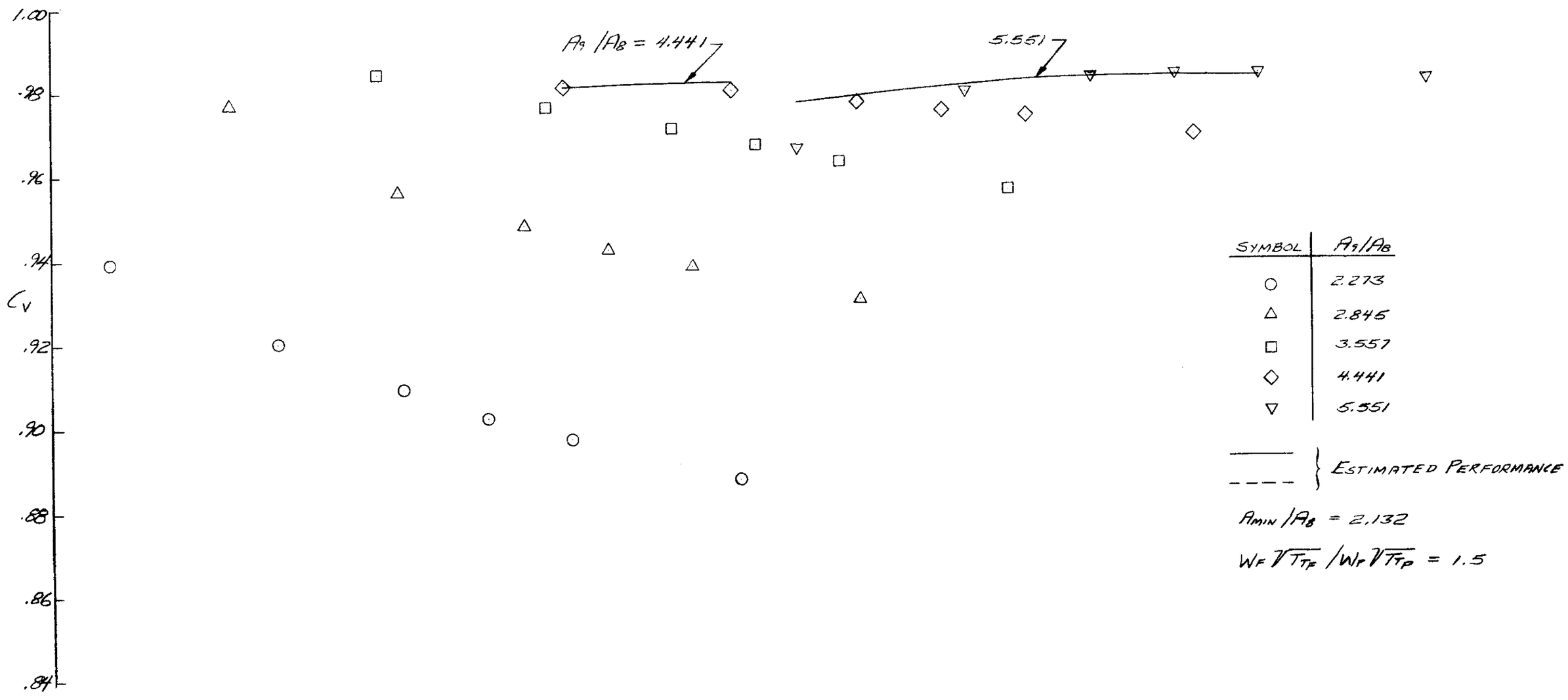


Figure 59. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Performance

Approved for Public Release

Contrails

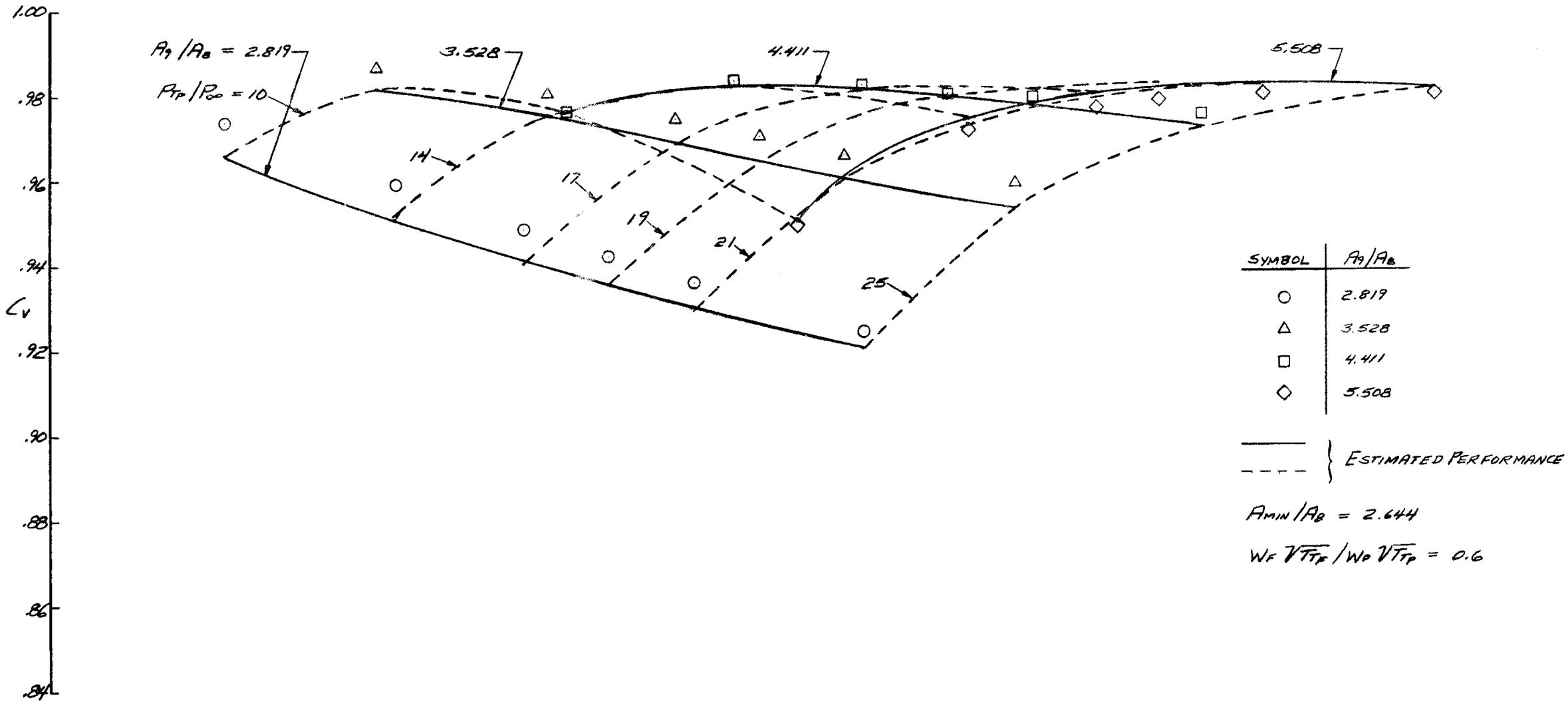


Figure 60. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Performance

Approved for Public Release

Contrails

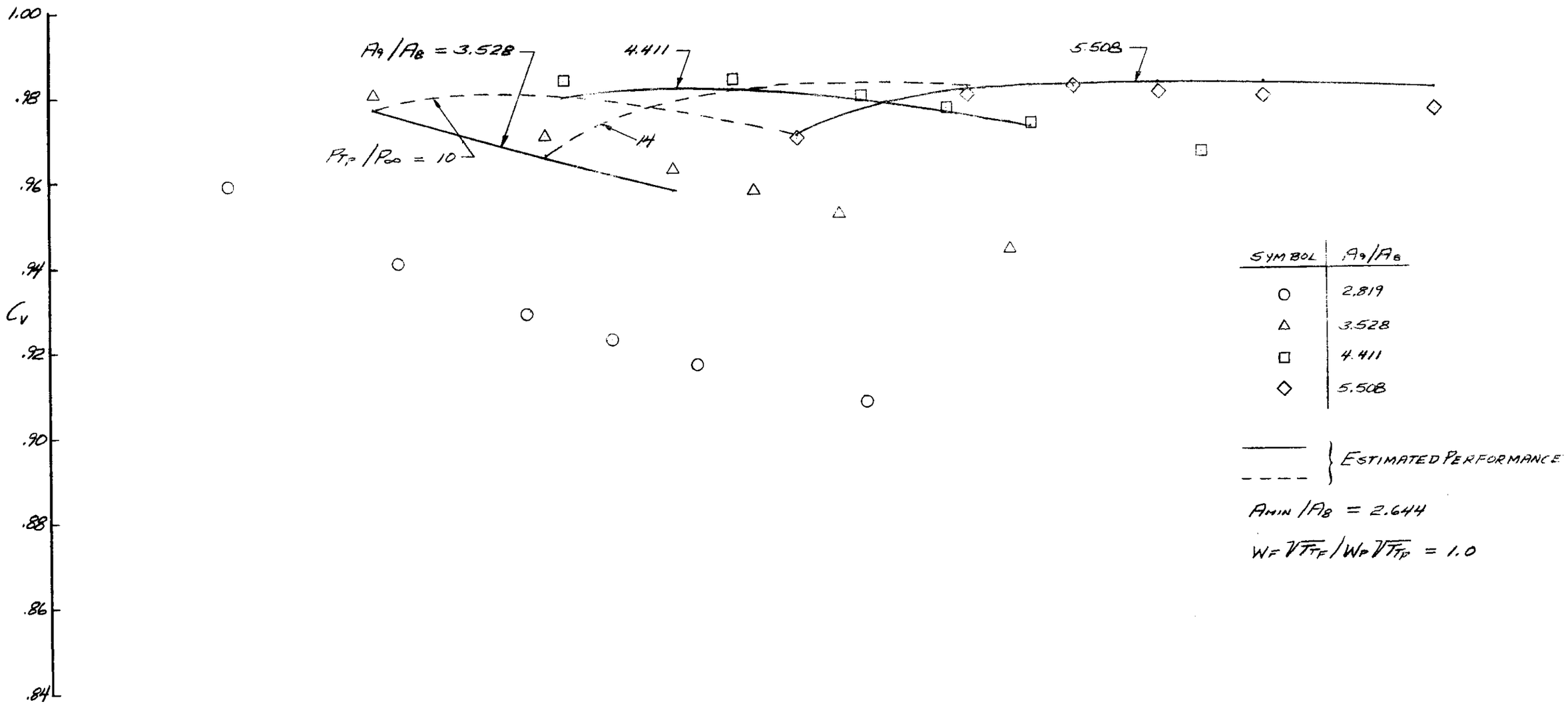


Figure 61. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Performance

Approved for Public Release

Contrails

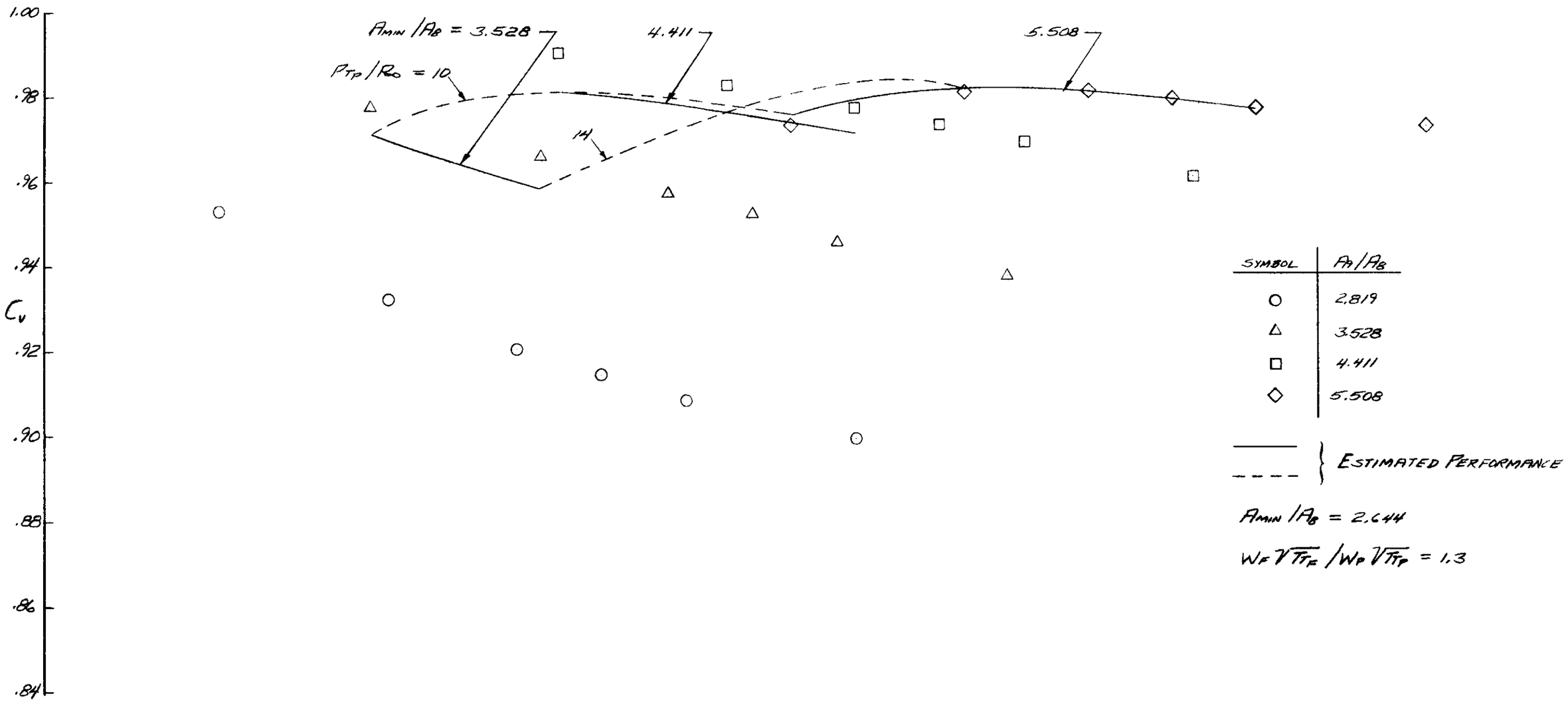


Figure 62. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Performance

Approved for Public Release

Contrails

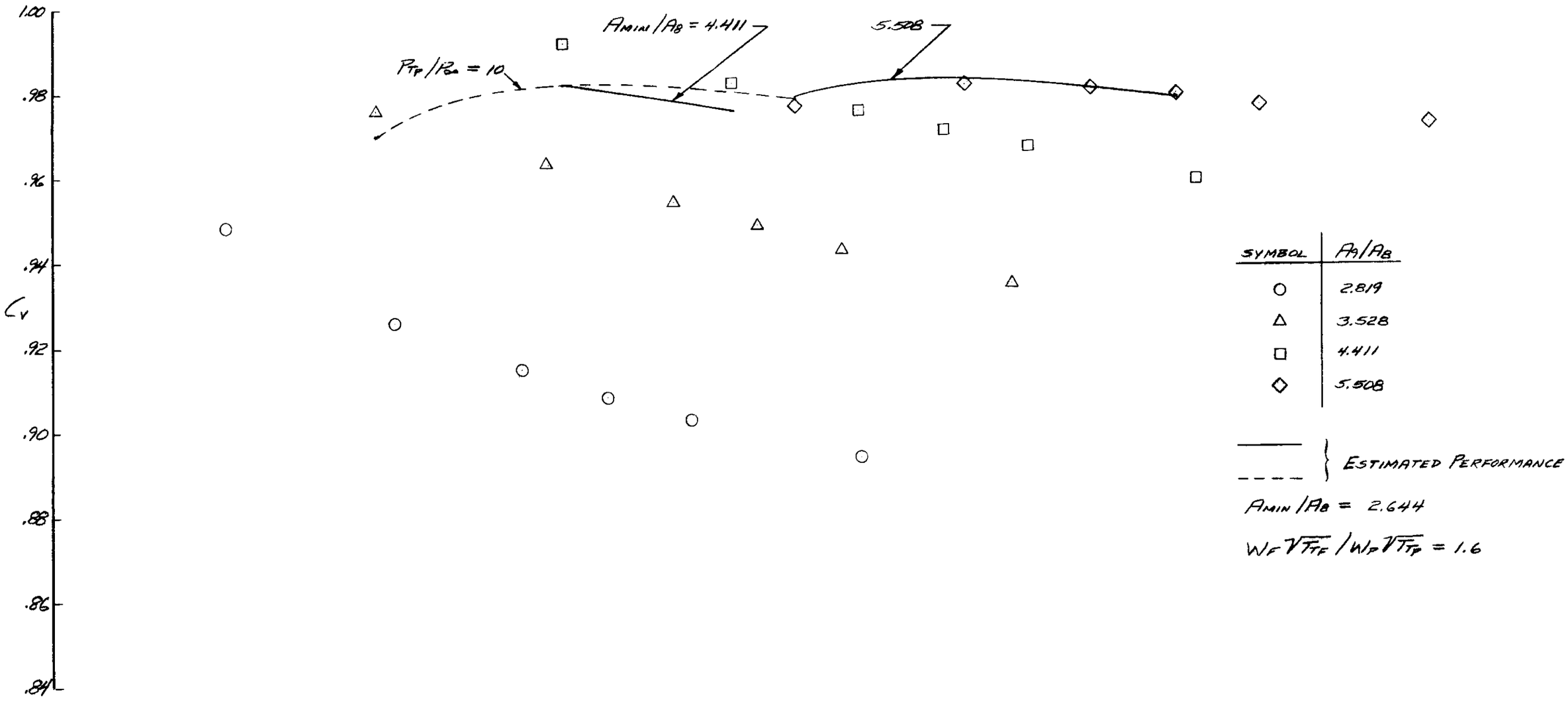


Figure 63. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Performance

Approved for Public Release

Contrails

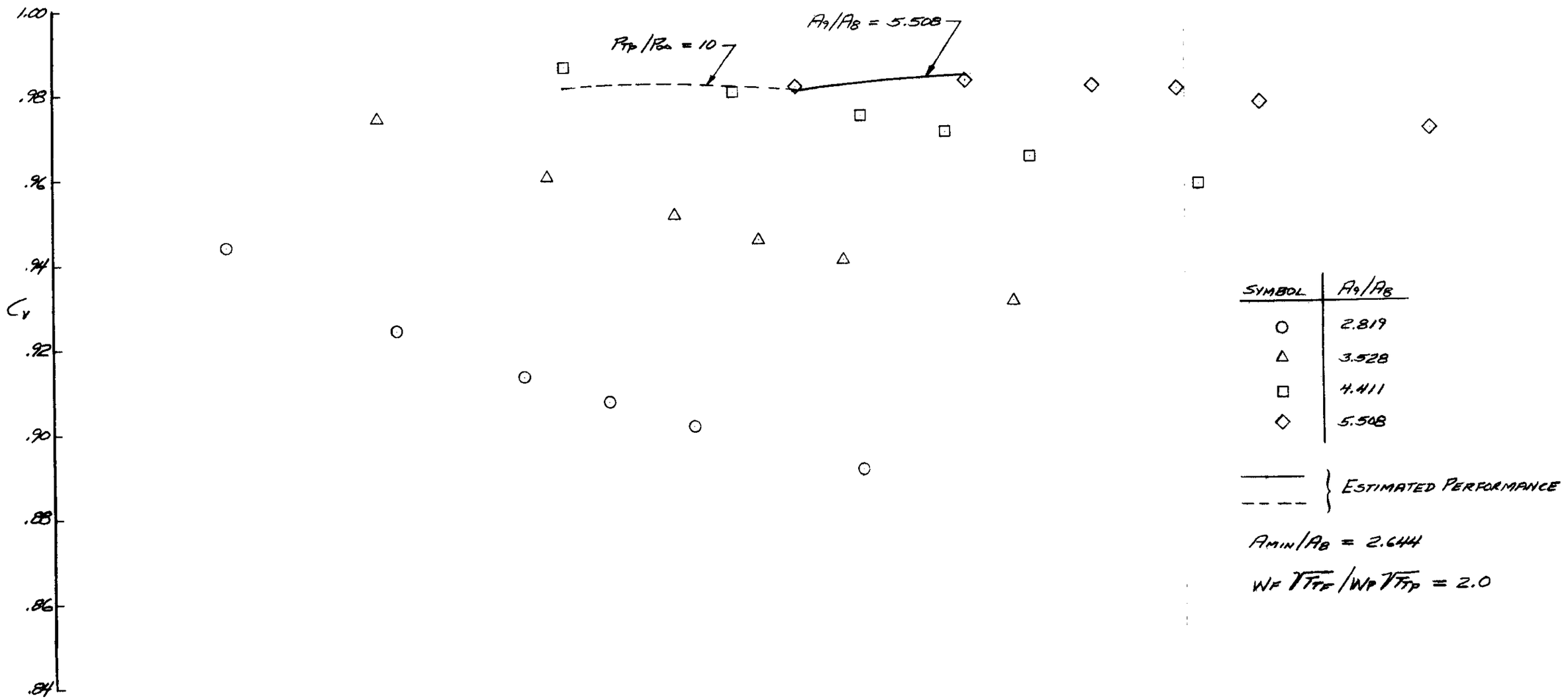
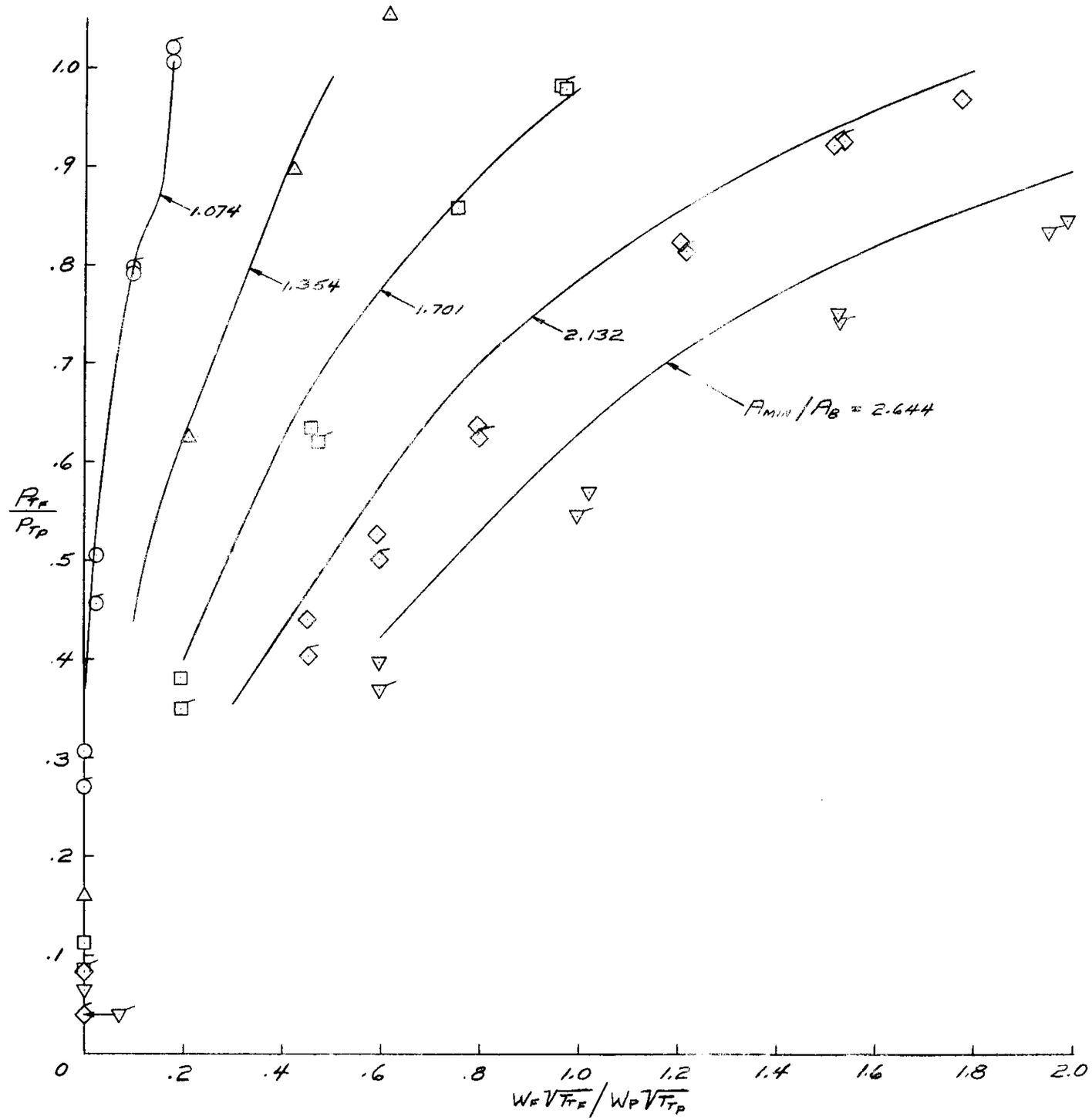


Figure 64. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Performance

Approved for Public Release

Contrails

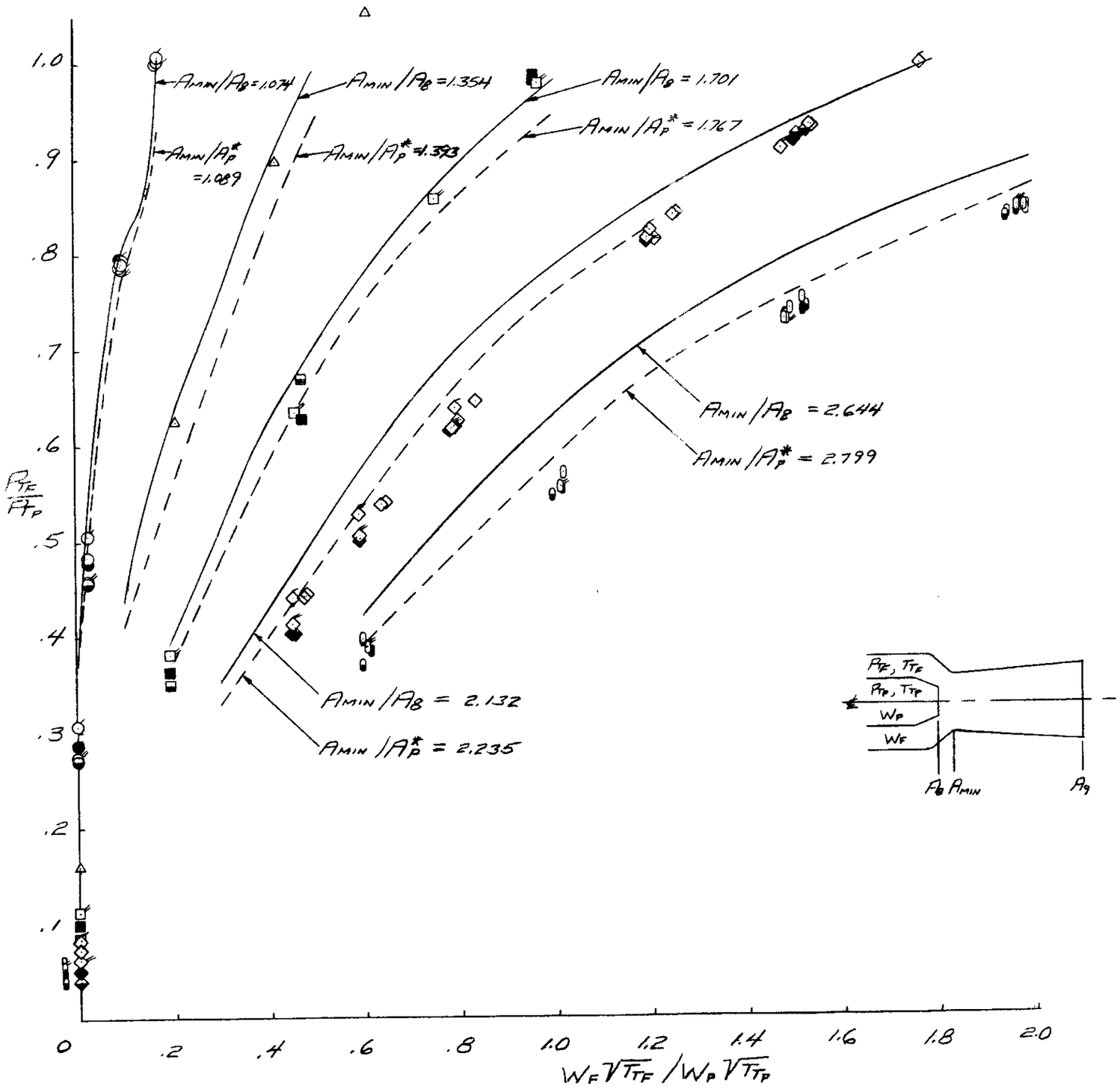


SYMBOL	A_{MIN}/A_B	A_9/A_8 PLAIN	A_9/A_8 FLAGGED
○	1.074	1.145	2.796
△	1.354	1.443	NOT TESTED
□	1.701	1.814	2.838
◇	2.132	1.796	5.551
▽	2.644	2.227	5.508

Figure 65. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Pumping Characteristics

Approved for Public Release

Contrails



SYMBOL	A_{MIN}/A_B	A_9/A_B	CONFIGURATION
	1.074	1.145	1
	"	1.433	2
	"	1.792	3
	"	2.237	4
	"	2.796	5
	1.354	1.443	6
	1.701	1.814	10
	"	2.270	11
	"	2.838	12
	2.132	2.273	13
	"	2.845	14
	"	3.557	15
	"	4.441	16
	"	5.551	17
	2.644	2.819	19
	"	3.528	20
	"	4.411	21
	"	5.508	22

A_{MIN}/A_B ——— } P&WA GØDD COMPUTER
A_{MIN}/A_P^* - - - - - } PROGRAM PREDICTIONS

Figure 66. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Pumping Characteristics

Approved for Public Release

Contrails

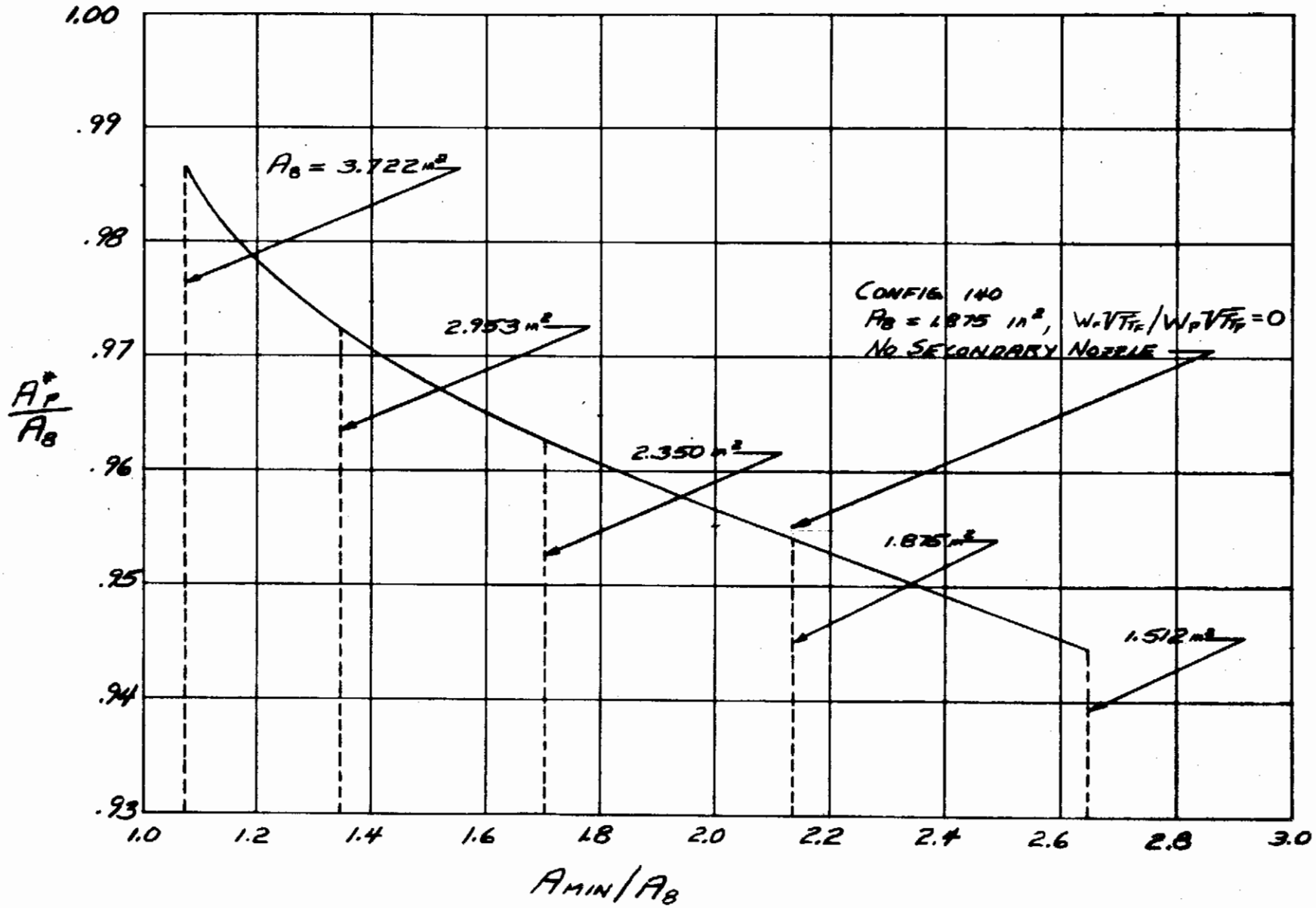


Figure 67. Shared Exit Ejector Nozzle Static Tests - Satellite Mode - Primary Nozzle Flow Coefficients

Approved for Public Release

Contrails

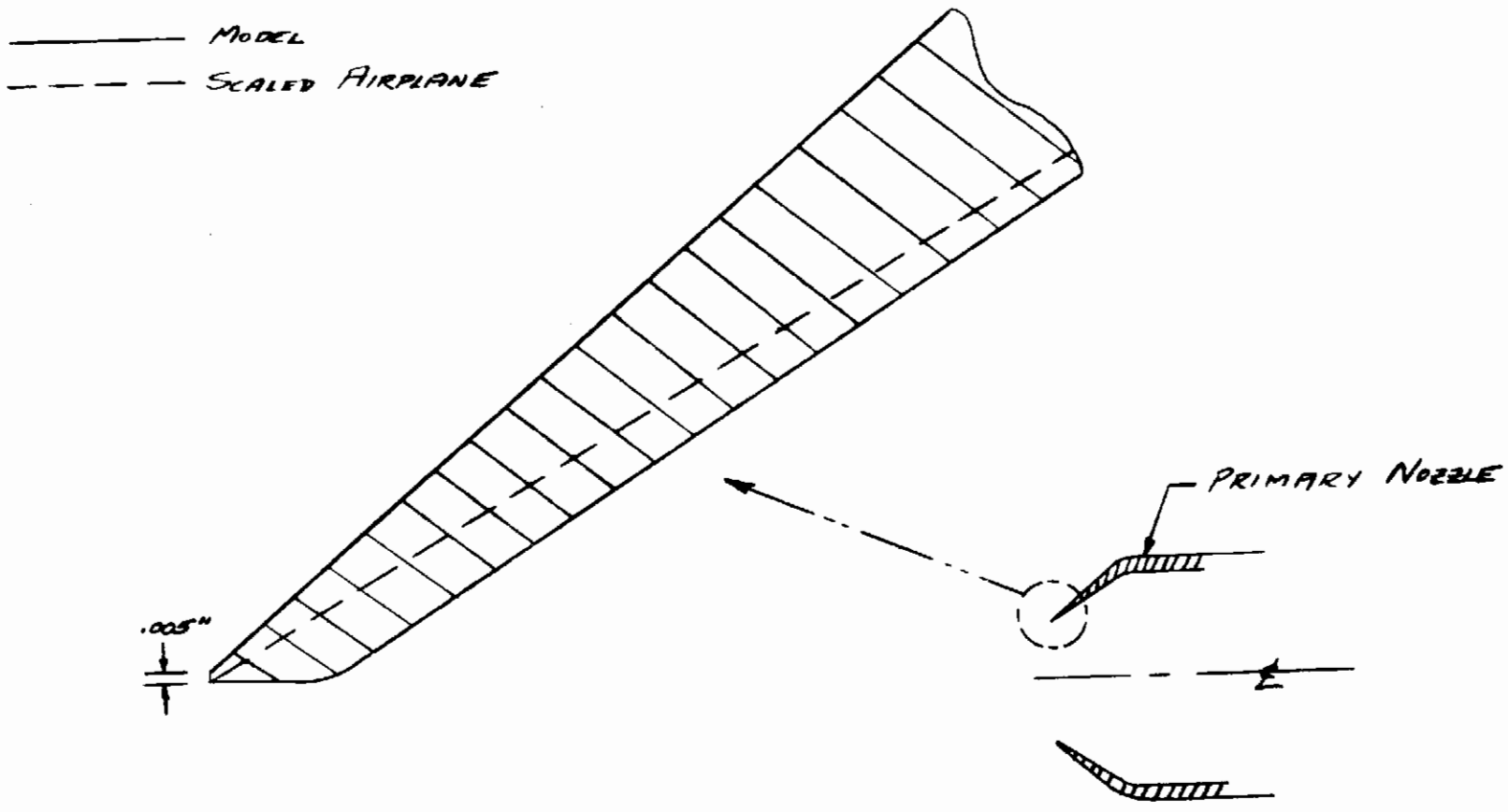


Figure 68. Shared Exit Ejector Nozzle Static Tests - Typical Primary Nozzle Contour

Approved for Public Release

Contrails

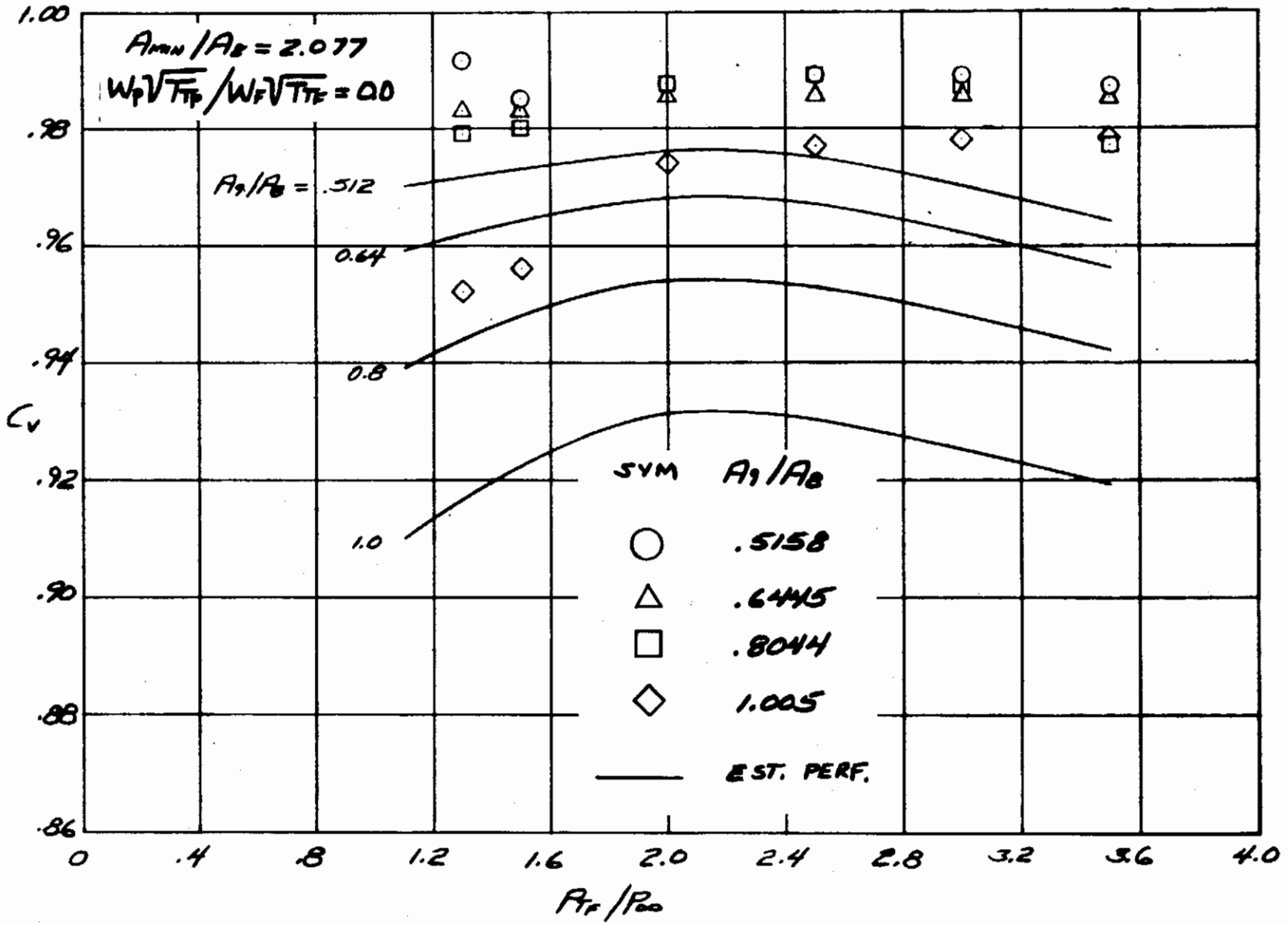


Figure 69. Shared Exit Ejector Nozzle Static Tests - Fan Mode Performance (versus Nozzle Pressure Ratio)

Approved for Public Release

Contrails

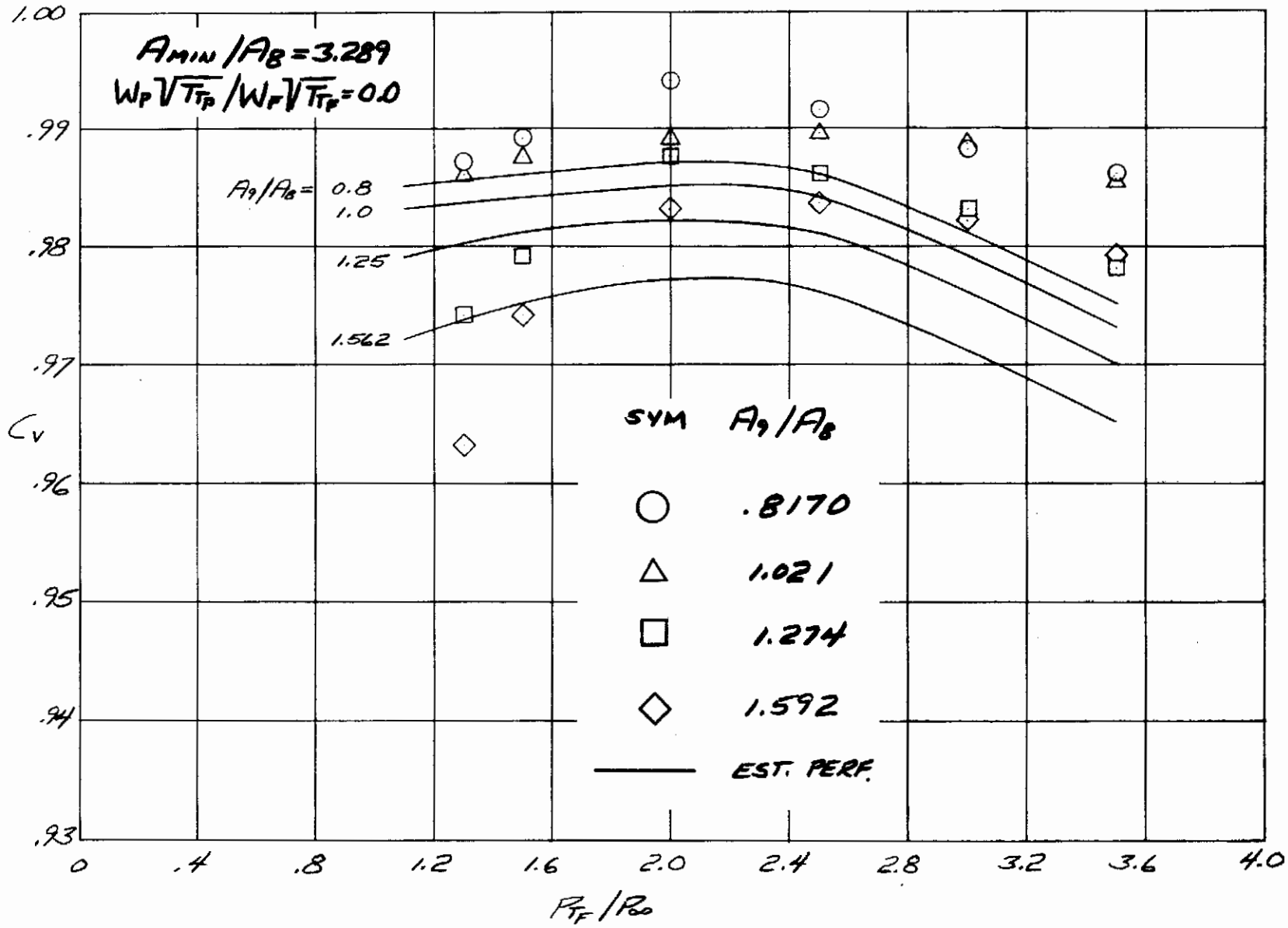


Figure 70. Shared Exit Ejector Nozzle Static Tests - Fan Mode Performance (versus Nozzle Pressure Ratio)

Approved for Public Release

Contrails

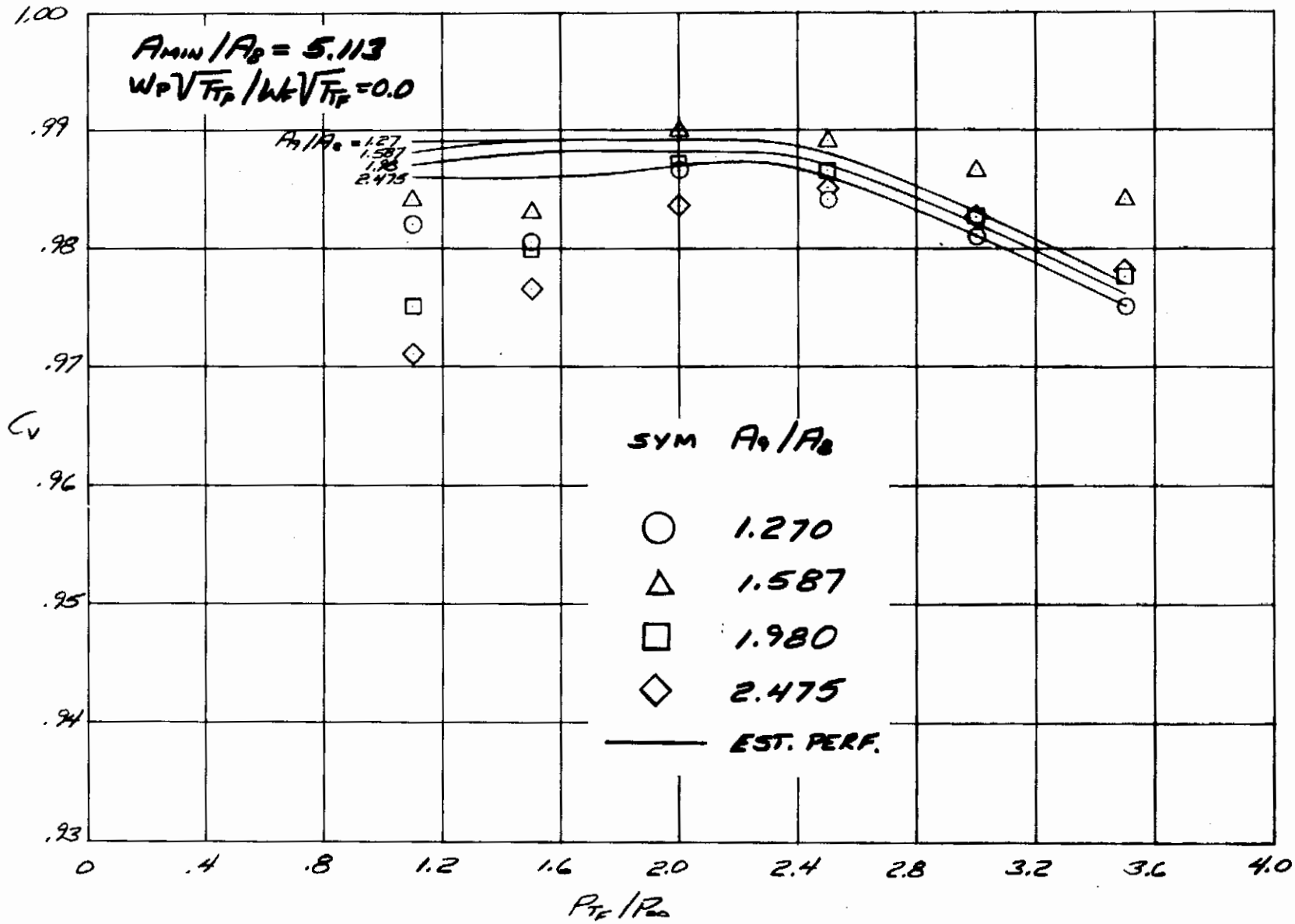


Figure 71. Shared Exit Ejector Nozzle Static Tests - Fan Mode Performance (versus Nozzle Pressure Ratio)

Approved for Public Release

Contrails

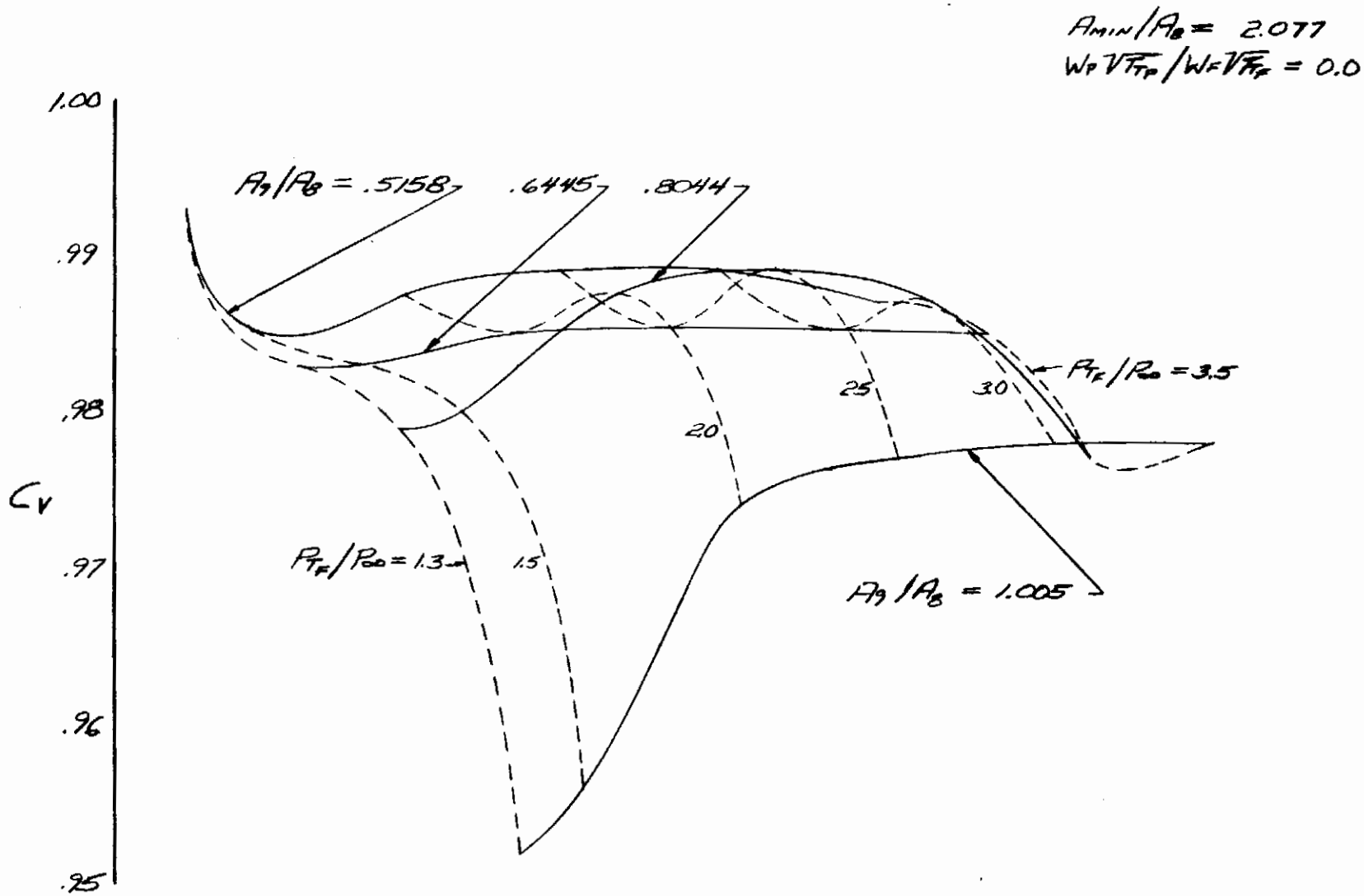


Figure 72. Shared Exit Ejector Nozzle Static Tests - Fan Mode Pumping Characteristics

Approved for Public Release

Contrails

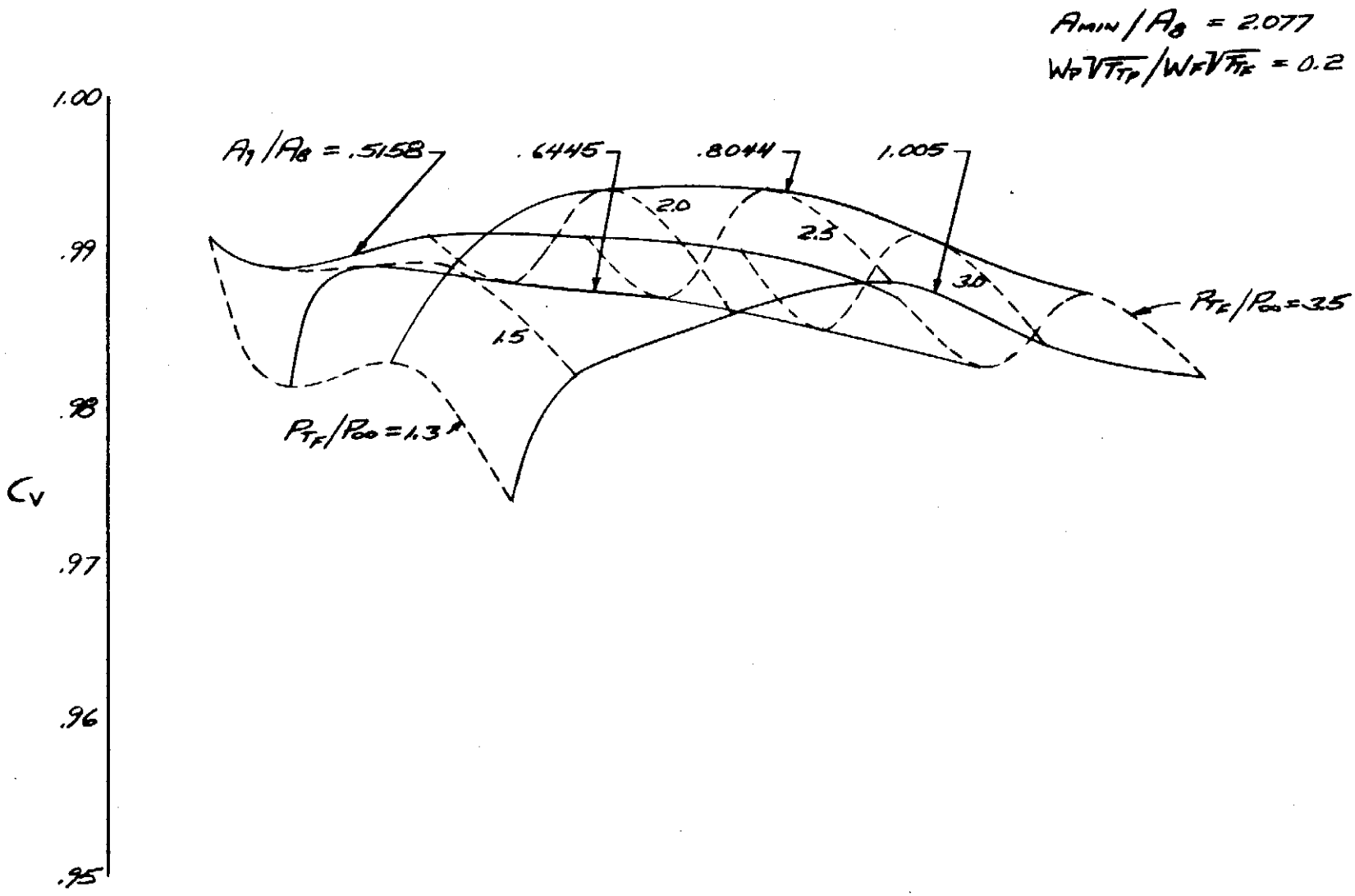


Figure 73. Shared Exit Ejector Nozzle Static Tests - Fan Mode Pumping Characteristics

Approved for Public Release

Contrails

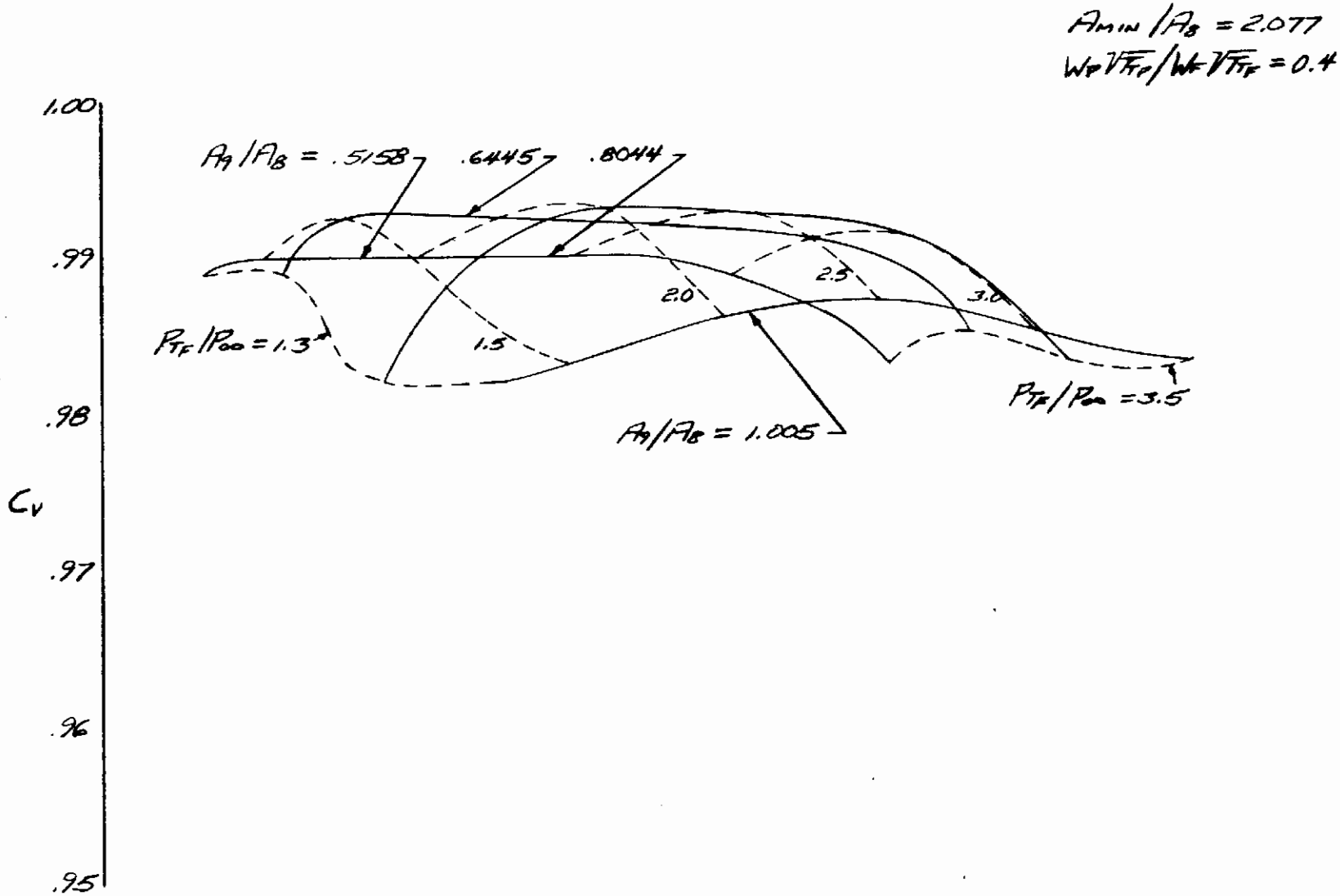


Figure 74. Shared Exit Ejector Nozzle Static Tests - Fan Mode Pumping Characteristics

Approved for Public Release

Contrails

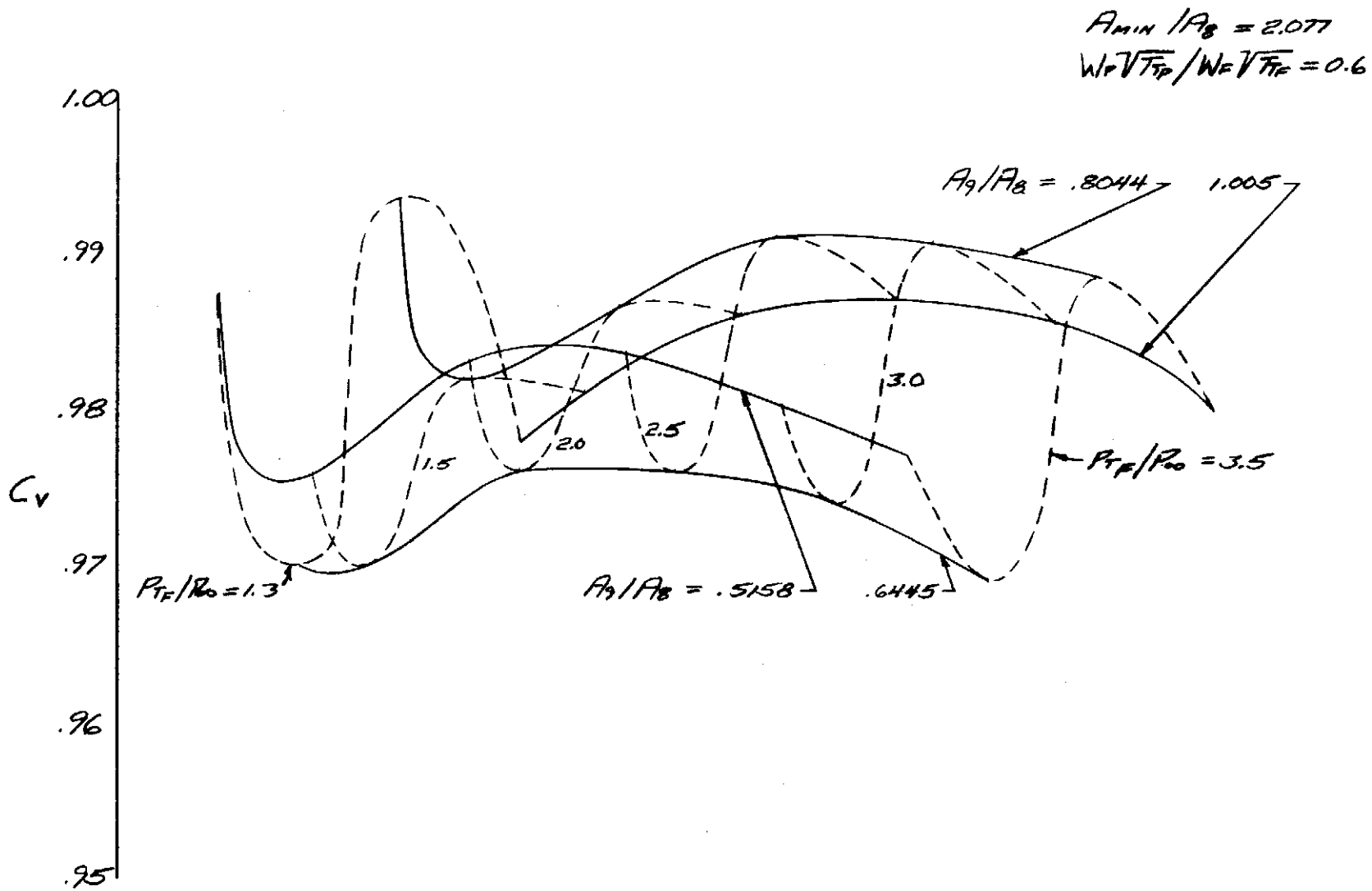


Figure 75. Shared Exit Ejector Nozzle Static Tests - Fan Mode Pumping Characteristics

Approved for Public Release

Contrails

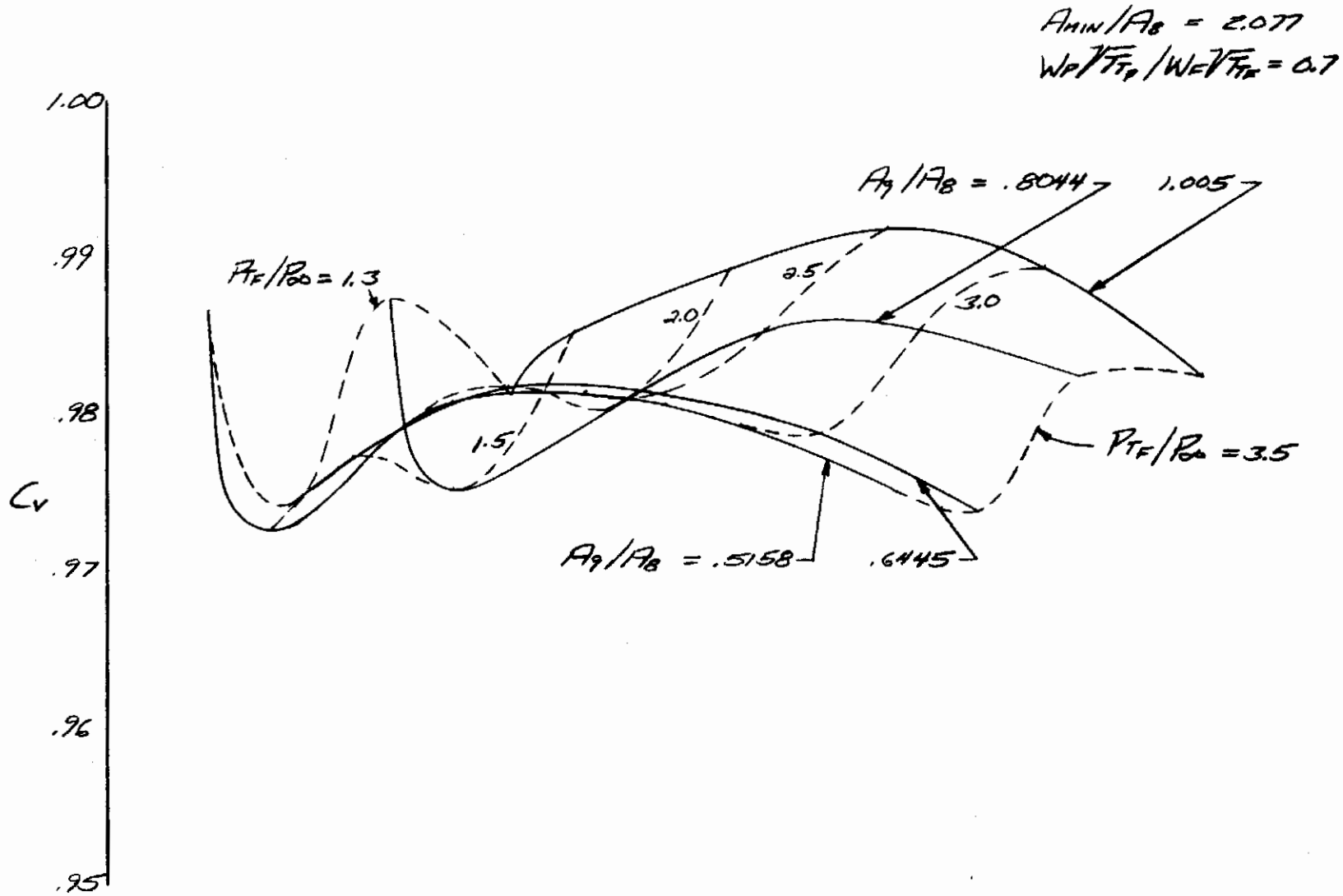


Figure 76. Shared Exit Ejector Nozzle Static Tests - Fan Mode Pumping Characteristics

Approved for Public Release

Contrails

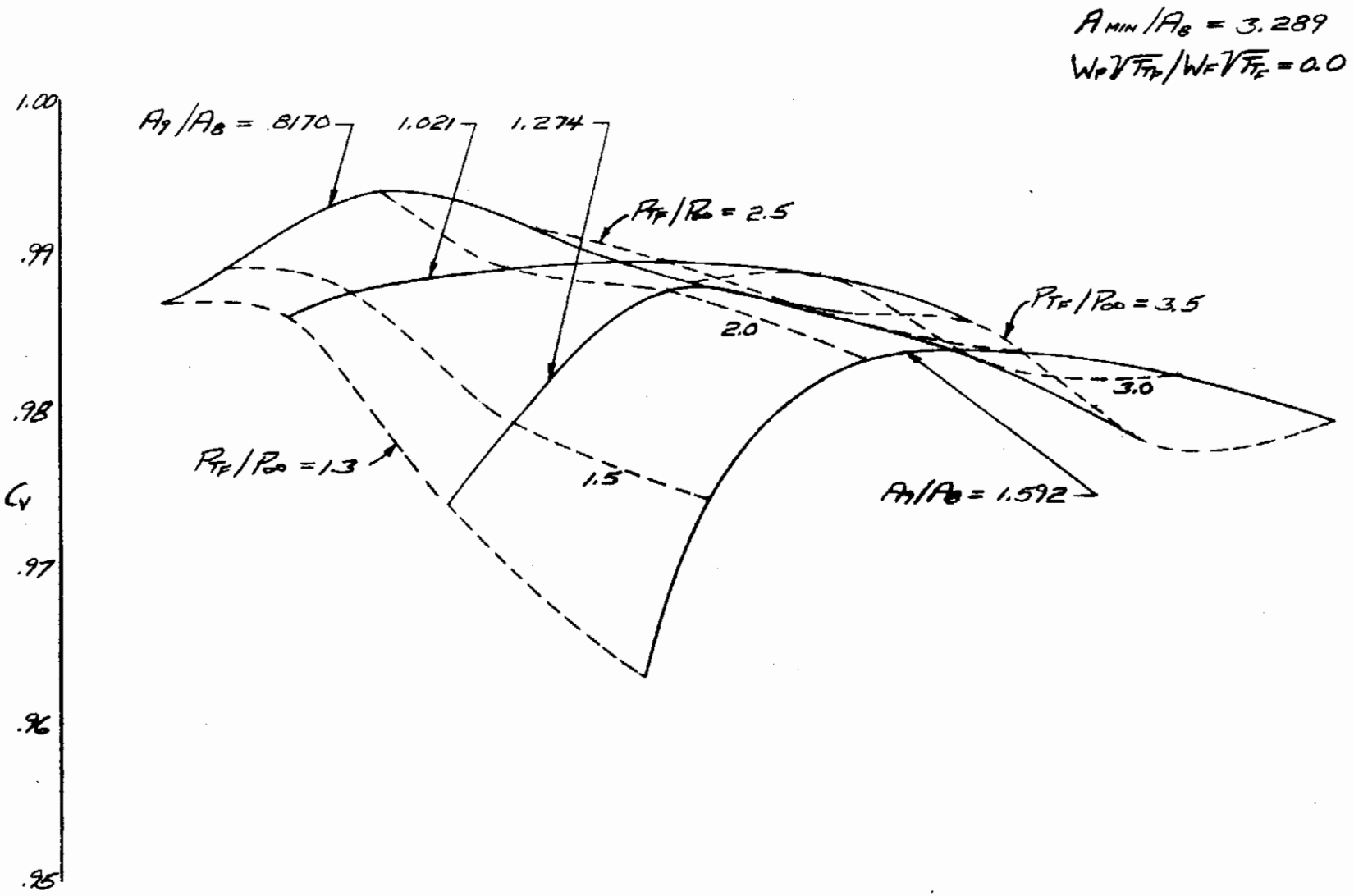


Figure 77. Shared Exit Ejector Nozzle Static Tests - Fan Mode Pumping Characteristics

Approved for Public Release

Contrails

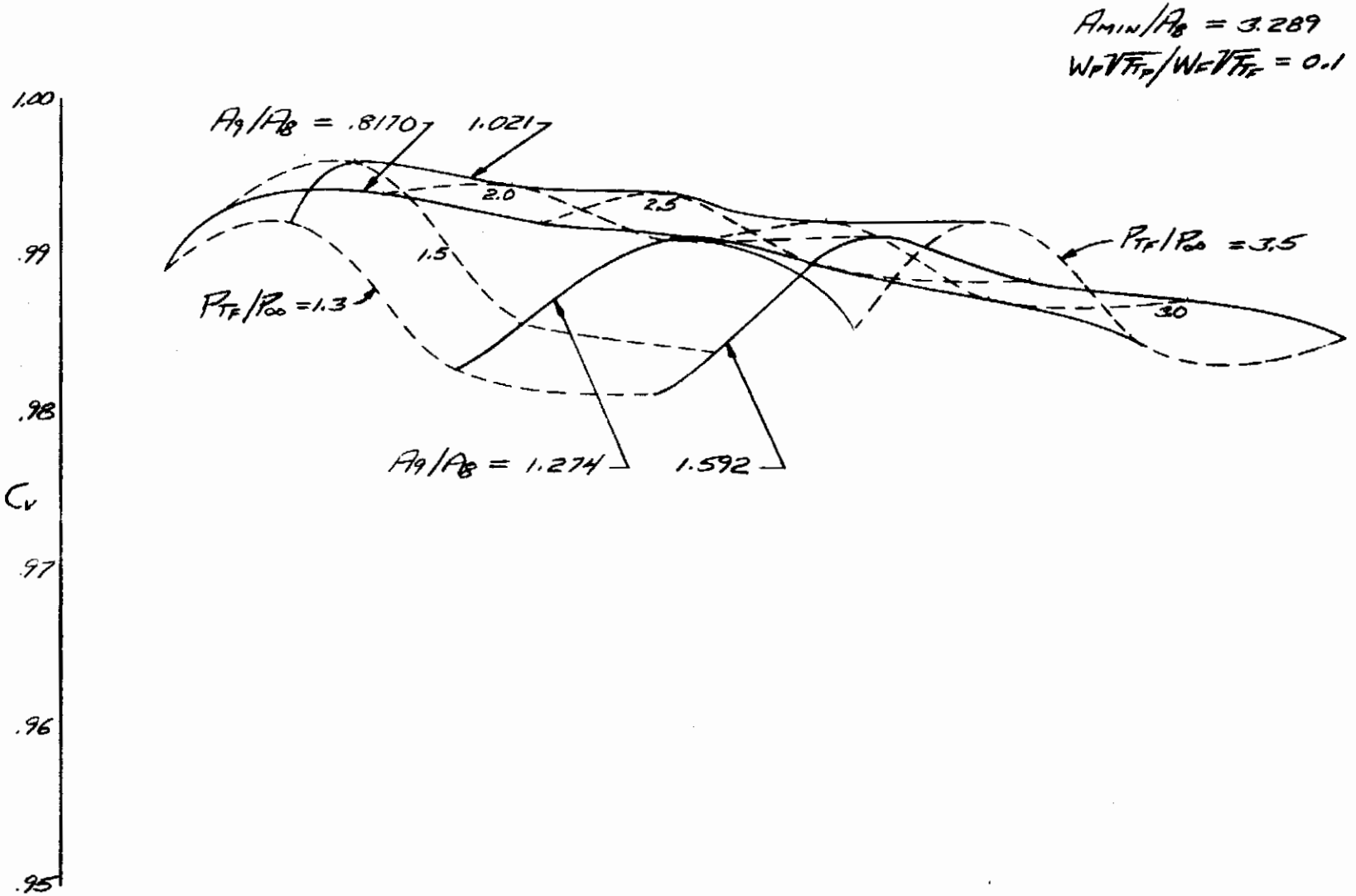


Figure 78. Shared Exit Ejector Nozzle Static Tests - Fan Mode Pumping Characteristics

Approved for Public Release

Contrails

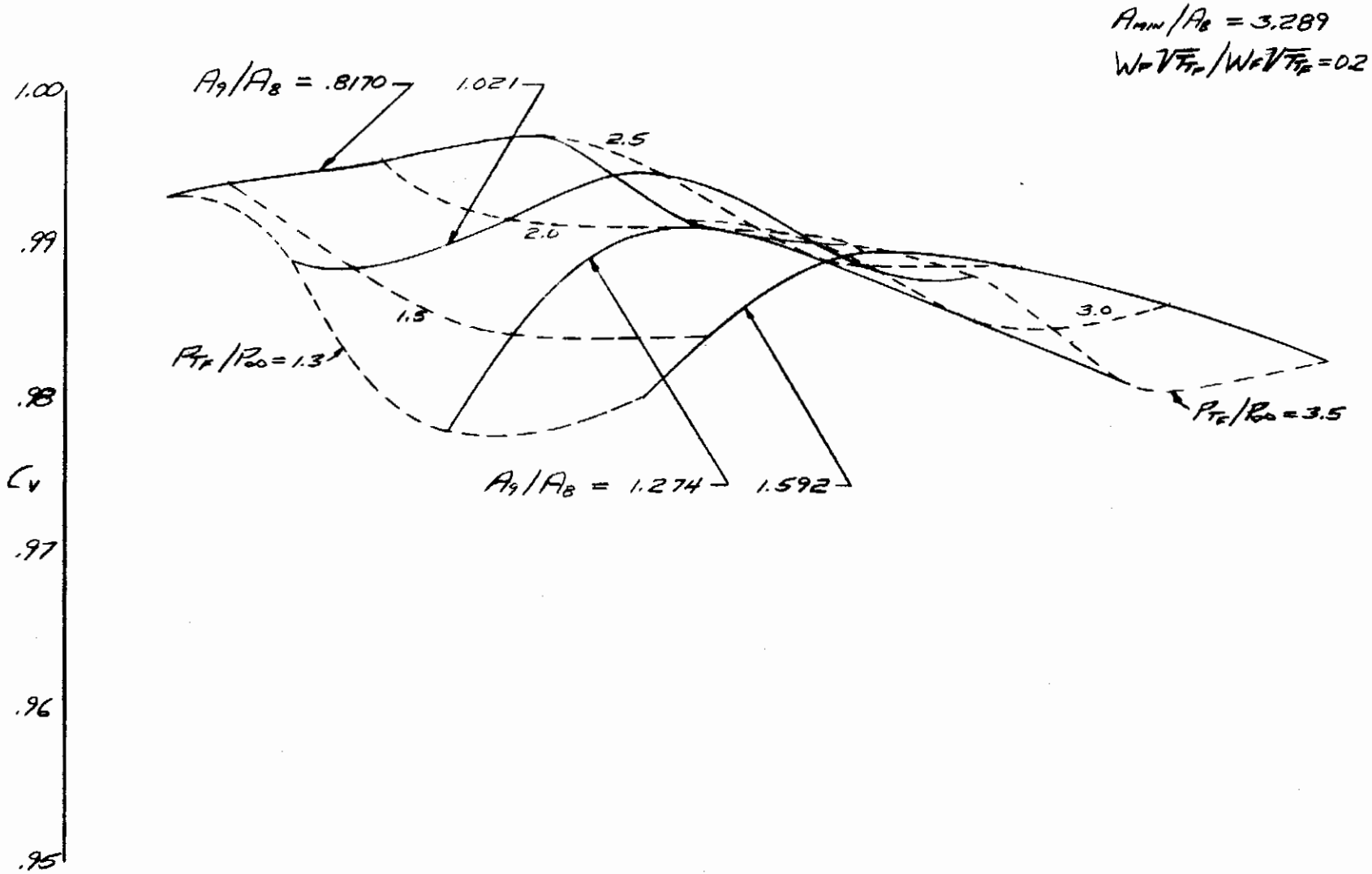


Figure 79. Shared Exit Ejector Nozzle Static Tests - Fan Mode Pumping Characteristics

Approved for Public Release

Contrails

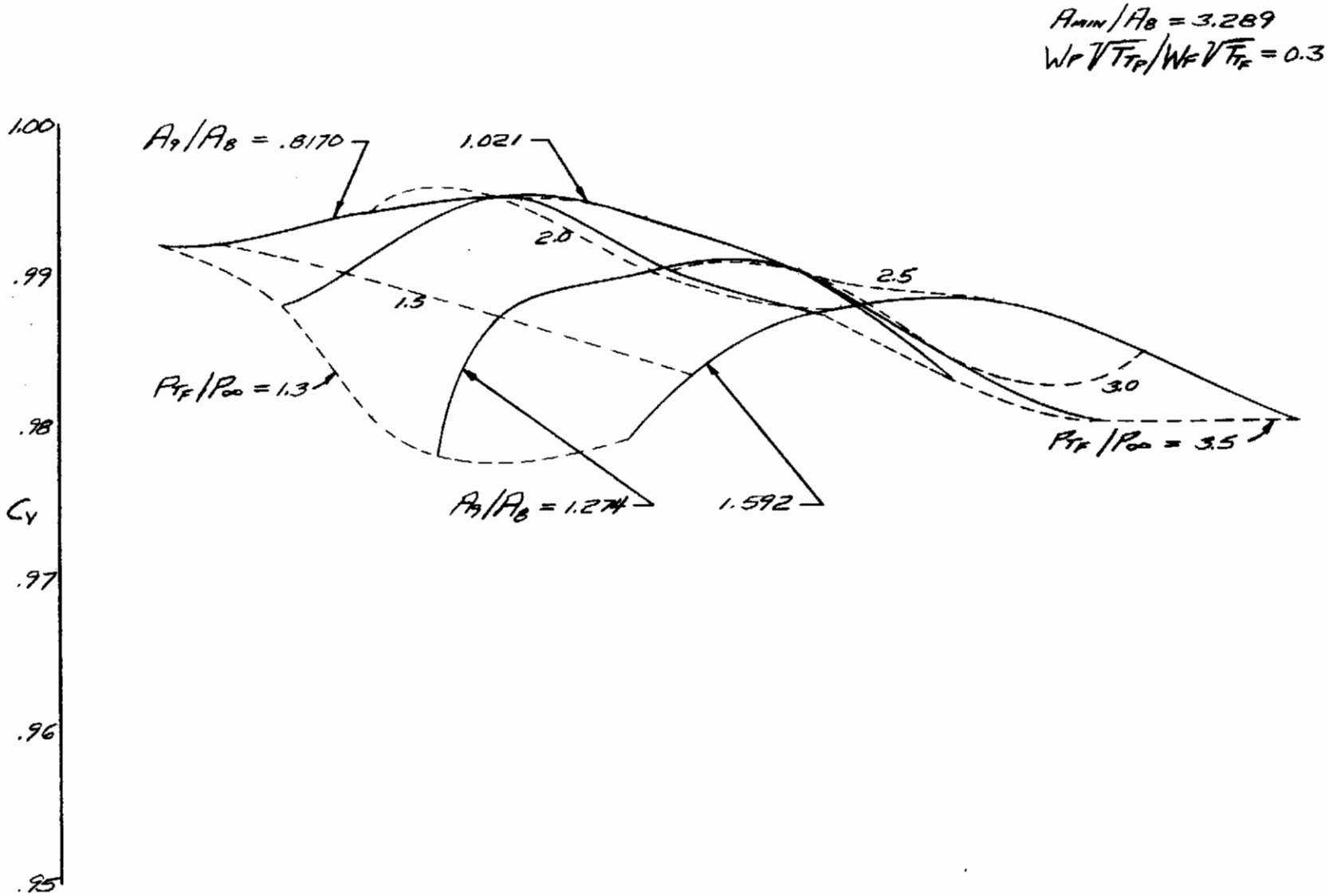


Figure 80. Shared Exit Ejector Nozzle Static Tests - Fan Mode Pumping Characteristics

Approved for Public Release

Contrails

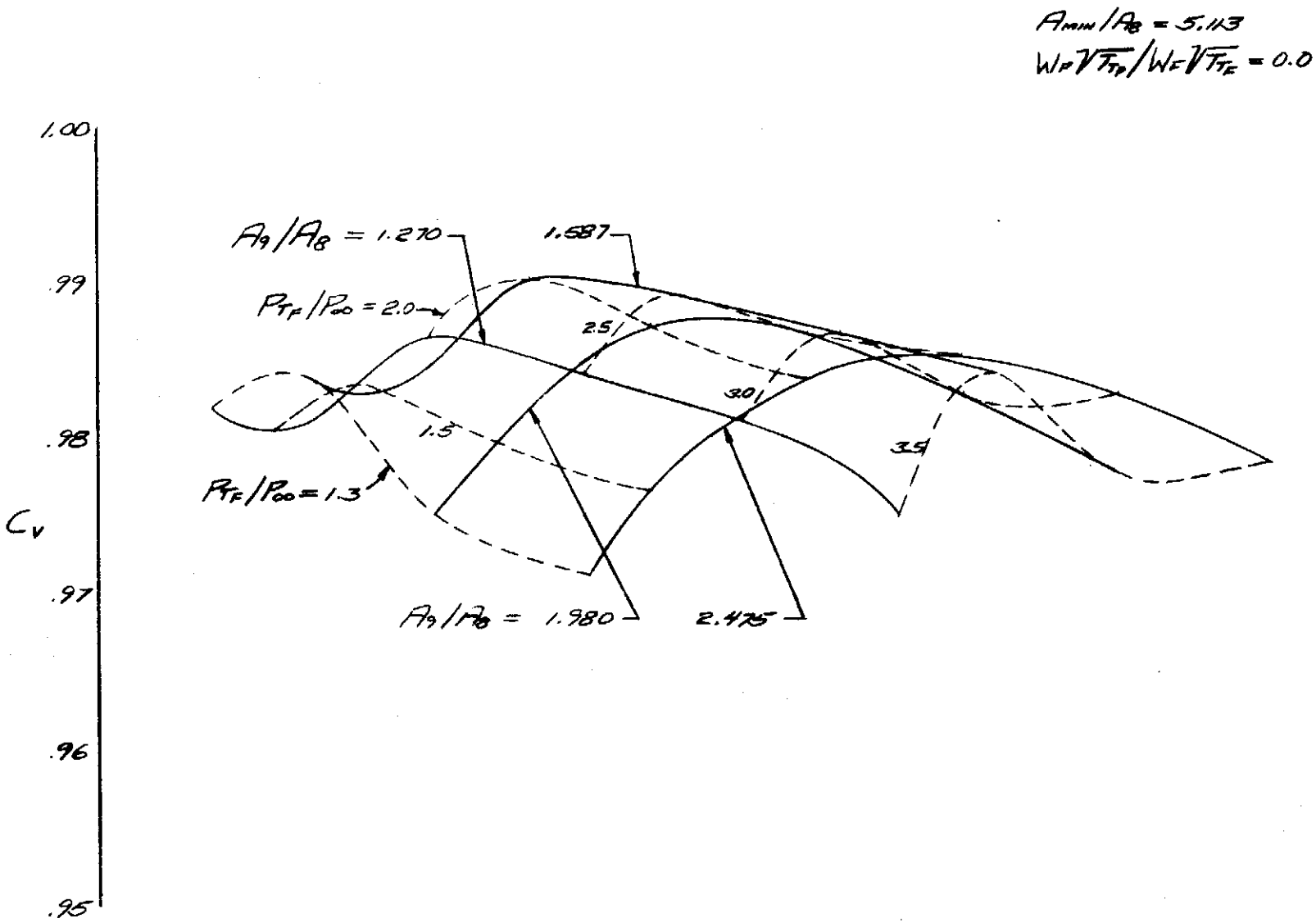


Figure 81. Shared Exit Ejector Nozzle Static Tests - Fan Mode Pumping Characteristics

Approved for Public Release

Contrails

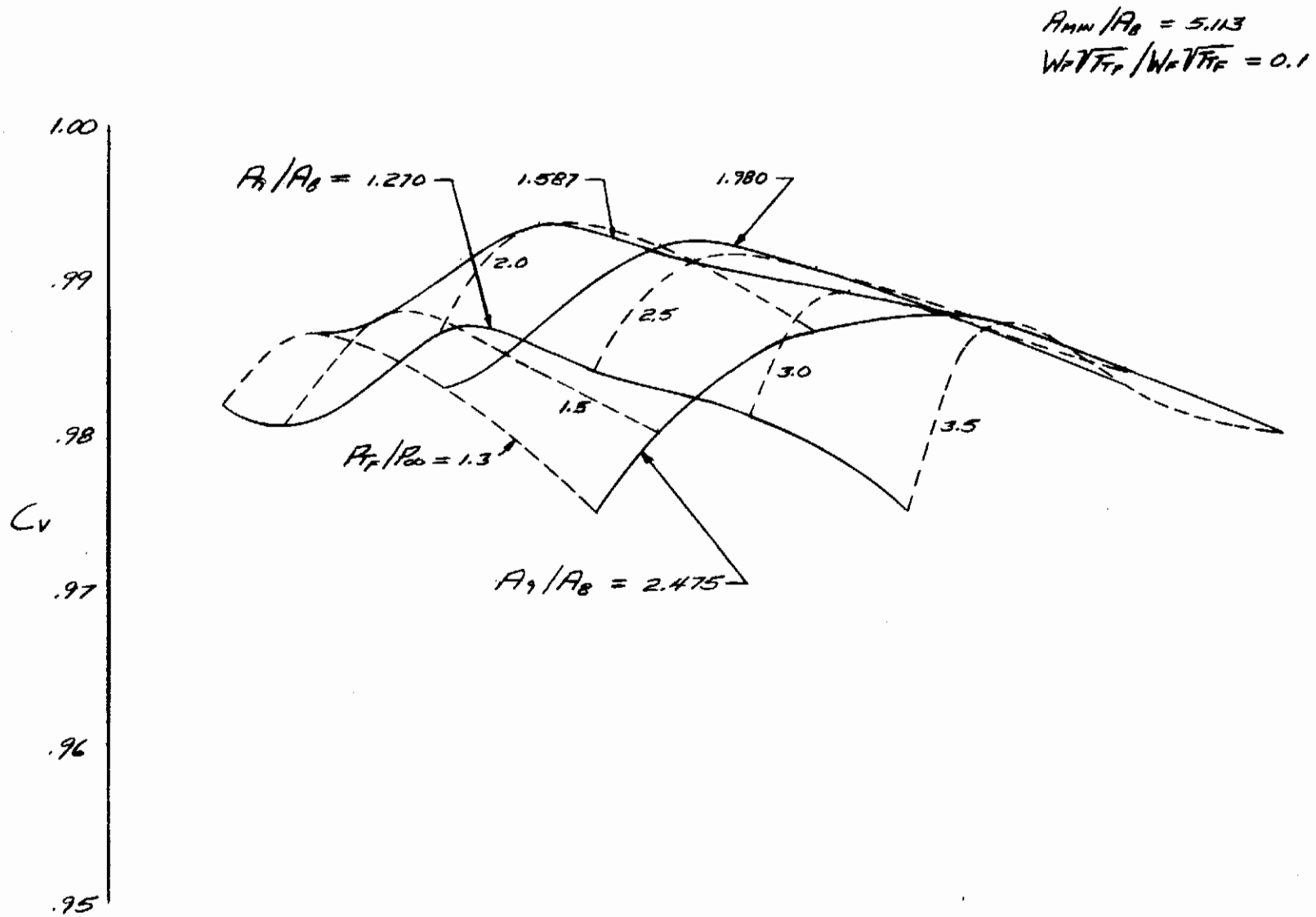


Figure 82. Shared Exit Ejector Nozzle Static Tests - Fan Mode Pumping Characteristics

Approved for Public Release

Contrails

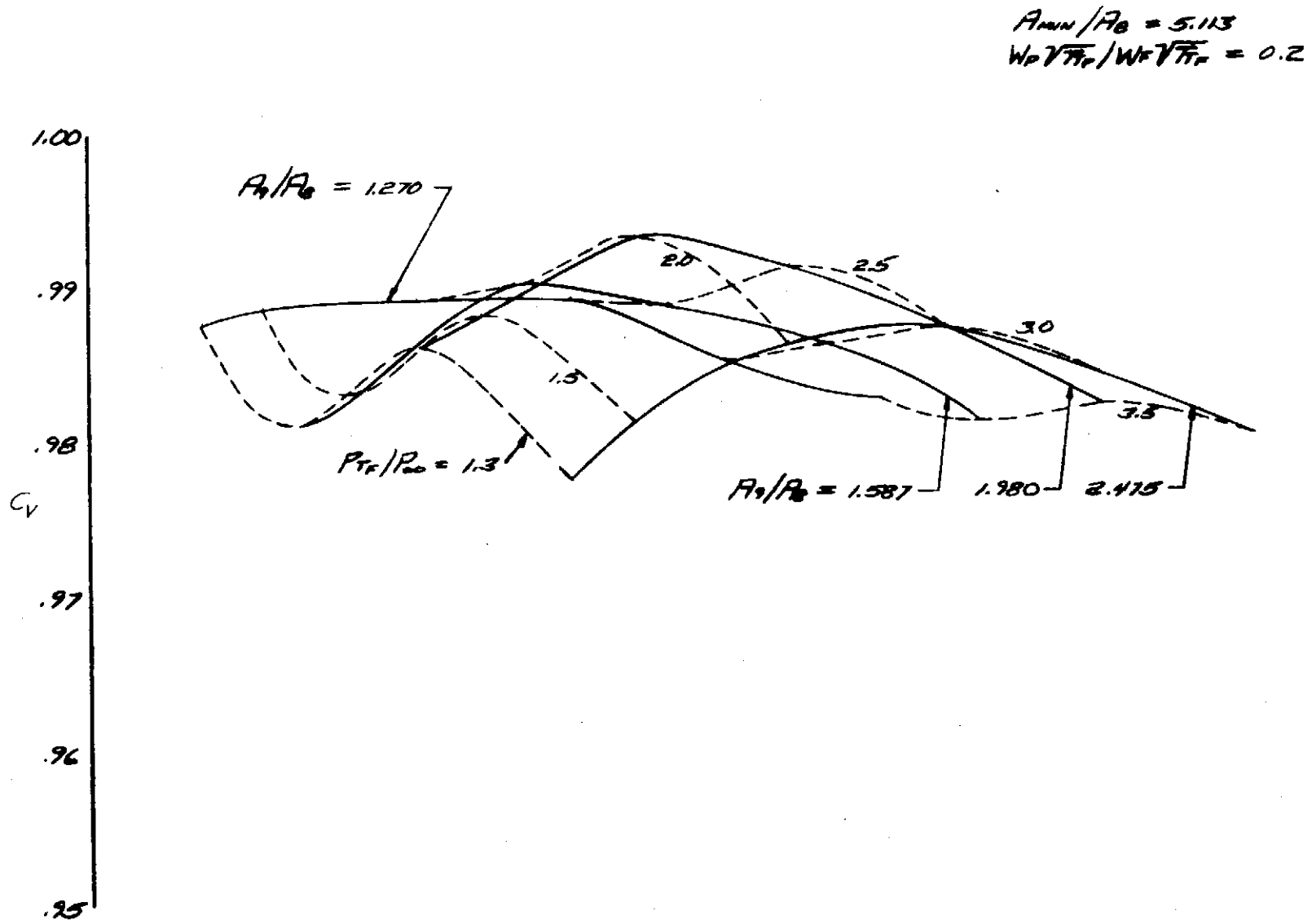


Figure 83. Shared Exit Ejector Nozzle Static Tests - Fan Mode Pumping Characteristics

Approved for Public Release

Contrails

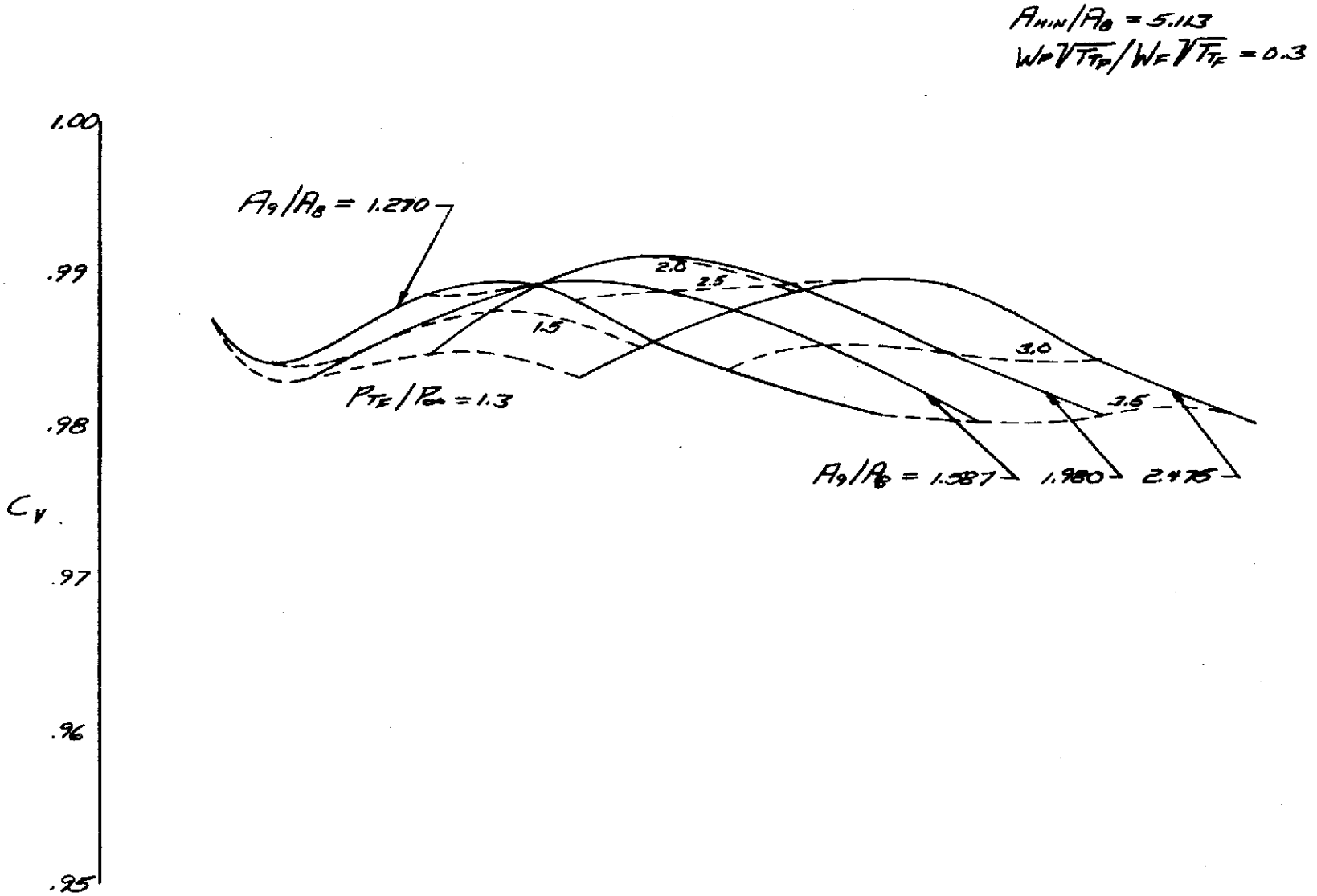


Figure 84. Shared Exit Ejector Nozzle Static Tests - Fan Mode Pumping Characteristics

Approved for Public Release

Contrails

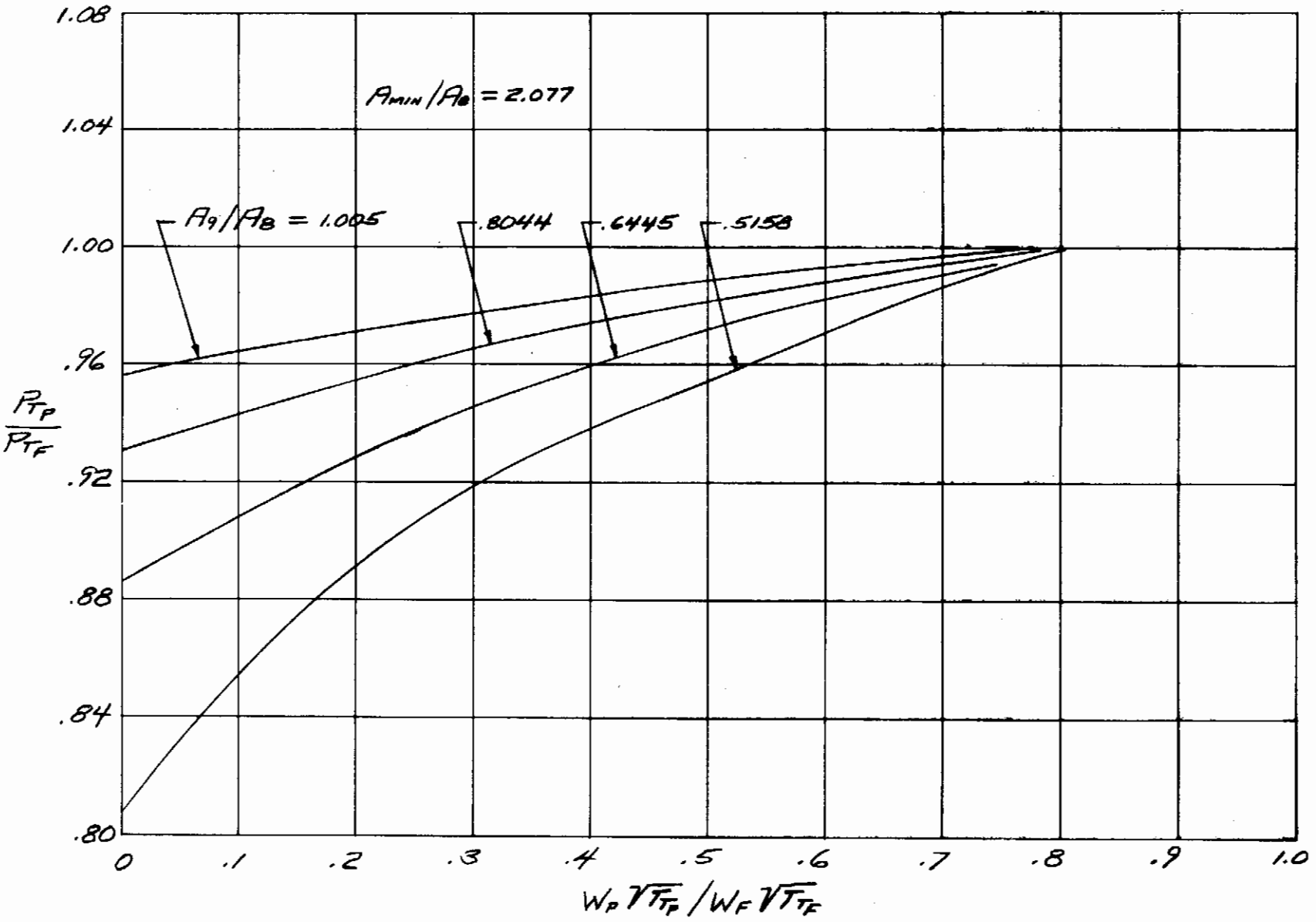


Figure 85. Shared Exit Ejector Static Tests - Fan Mode Pumping Characteristics

Approved for Public Release

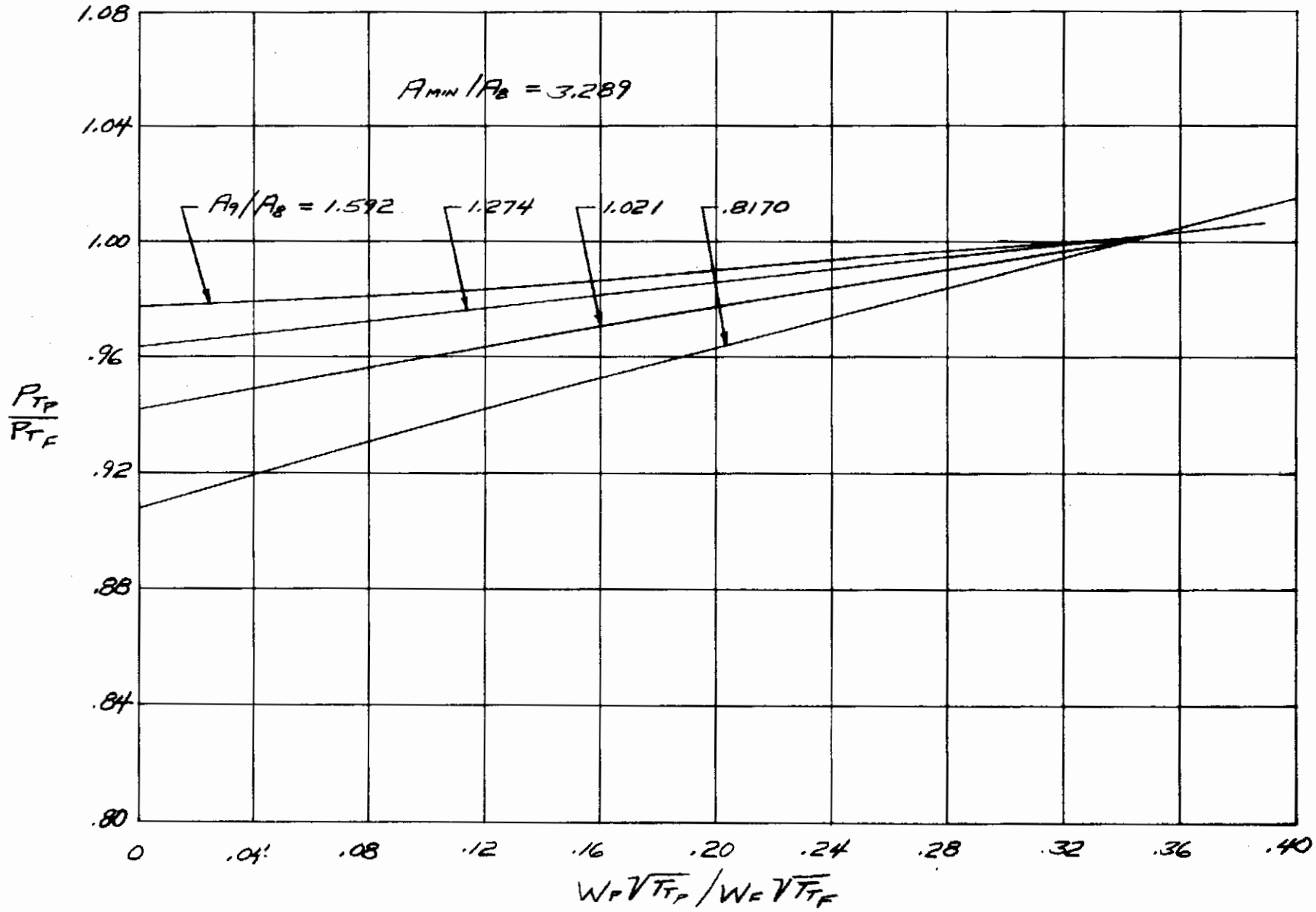


Figure 86. Shared Exit Ejector Static Tests - Fan Mode Pumping Characteristics

Approved for Public Release

Contrails

Contrails

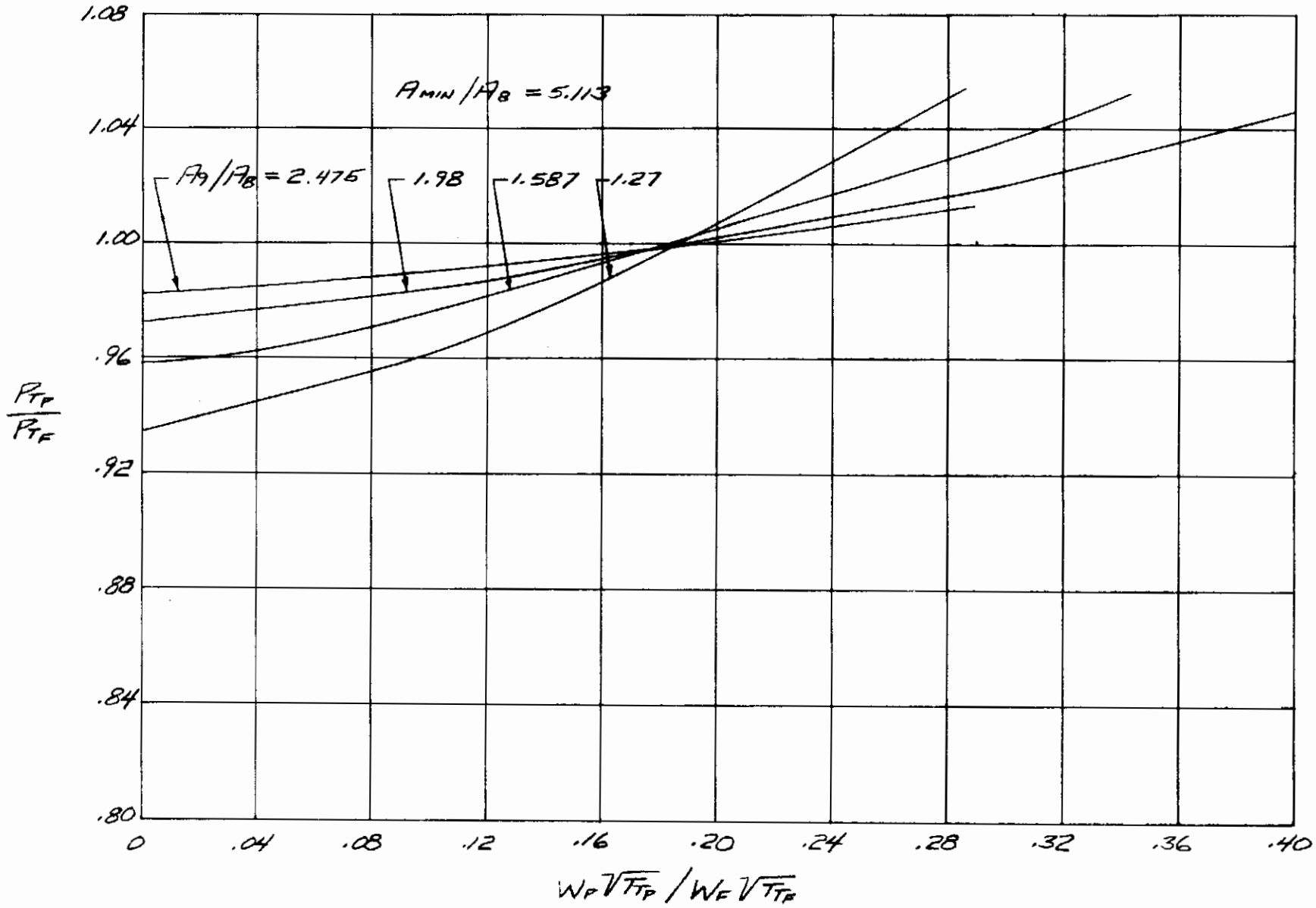


Figure 87. Shared Exit Ejector Static Tests - Fan Mode Pumping Characteristics

(The reverse of this page is blank)

Approved for Public Release

Contrails

Approved for Public Release

Contrails

APPENDIX I

RUN HISTORY

(The reverse of this page is blank)

Approved for Public Release

Contrails

Approved for Public Release

Contrails

APPENDIX I

RUN HISTORY

This appendix presents, in tabular form, a chronological run history of all configurations of the shared exit ejector nozzle model tested in the R.N.T.F. Tests 1 through 79 are high pressure ratio satellite mode configurations. The nominal pressure ratio range for these tests was $10 < \frac{P_{T_P}}{P} < 25$. Test runs 81 through 126 are low pressure ratio satellite mode configurations, with a pressure ratio range of $1.5 < \frac{P_{T_P}}{P} < 15$.

Fan mode configurations were tested in runs 127 through 201. Nominal pressure ratio range was $1.1 < \frac{P_{T_F}}{P} < 3.5$.

Test runs 202 through 223 were conducted under NR internal research and development funds. These tests produced nozzle performance data for arrangements of fan duct air passages that use the satellite afterburner as part of the duct area.

Approved for Public Release

Contrails

SHARED EXIT EJECTOR NOZZLE STATIC TESTS - R.N.T.F.

RUN HISTORY

TEST RUN #	MODEL CONFIG. #	A_{MIN}/A_8	A_9/A_8	$W_P\sqrt{T_{T_P}}/W_P\sqrt{T_{T_P}}$	P_{T_P}/P_0 MAX	P_{T_P}/P_0 MIN
		SATELLITE MODE				
1	14	2.132	2.845	OBSERVATION		
2				"		
3				"		
4				"		
5				NO DATA		
6				" "		
7				" "		
8				" "		
9				" "		
10				" "		
11				0.0	25.43	9.865
12				.48	25.59	21.56
13				.48	17.21	9.776
14				.646	25.53	9.509
15				.655	25.52	9.919
16				NO DATA		
17				.838	26.1	10.4
18				1.267	29.32	11.16
19				1.269	20.66	12.04
20				1.556	21.53	12.44
21				1.562	32.78	10.98
22	140	∞	∞	0.0	26.24	9.764
23	13	2.132	2.273	0.0	25.55	9.99
24				.451	25.58	9.756
25				NO DATA		
26				.596	26.94	10.05
27				.804	27.15	10.2
28				1.216	29.82	11.28
29				1.784	33.7	12.66
30	CALIBRATION					
31	15	2.132	3.557	0.0	25.68	9.755
32				NO DATA		
33				1.493	32.9	11.89
34				1.213	29.33	10.42
35				.795	27.56	10.61
36				.600	26.38	10.01

Approved for Public Release

Contrails

SHARED EXIT EJECTOR NOZZLE TESTS - R.N.T.F.

RUN HISTORY

TEST RUN #	MODEL CONFIG. #	A_{MIN}/A_8	A_9/A_8	$W_F\sqrt{T_{T_F}}/W_P\sqrt{T_{T_P}}$	P_{T_P}/P_∞ MAX	P_{T_P}/P_∞ MIN
37	15	2.132	3.557	.452	26.36	9.853
38	16	2.132	4.441	0.0	25.29	9.84
39				.453	26.02	9.843
40				.601	26.17	10.05
41				.795	26.82	16.93
42				.792	27.3	9.973
43				1.21	28.56	10.87
44				1.538	36.93	11.19
45	17	2.132	5.551	1.546	34.6	19.98
46				1.529	28.75	11.5
47				1.226	23.89	11.04
48				.807	27.29	10.37
49				.601	27.2	9.975
50				.454	25.79	9.638
51				0.0	26.93	9.723
52	19	2.644	2.227	0.0	26.32	9.71
53				NO DATA		
54				0.0	30.26	9.734
55				1.033	28.64	9.715
56				1.539	29.04	8.875
57				OBSERVATION		
58				1.543	28.98	10.46
59				2.005	23.51	16.53
60				2.006	31.73	20.33
61				2.005	19.28	10.93
62	20	2.644	3.528	2.005	31.65	11.89
63				1.501	29.4	10.63
64				2.029	34.05	11.18
65				1.511	31.07	10.33
66				1.025	29.78	10.07
67				.612	28.74	9.313
68				0.0	27.54	9.894
69	21	2.644	4.411	0.0	27.52	9.61
70				.620	27.29	9.247
71				1.032	27.93	9.465
72				1.539	30.28	10.31

Approved for Public Release

Contrails

SHARED EXIT EJECTOR NOZZLE TESTS - R.N.T.F.

RUN HISTORY

TEST RUN #	MODEL CONFIG. #	A_{MIN}/A_8	A_9/A_8	$W_F\sqrt{T_{T_F}}/W_P\sqrt{T_{T_P}}$	P_{T_P}/P_∞ MAX	P_{T_P}/P_∞ MIN
73	21	2.644	4.411	1.995	33.71	11.07
74	22	2.644	5.508	1.963	16.61	9.99
75				1.967	25.09	11.46
76				1.542	25.32	9.867
77				1.01	23.17	9.205
78				.601	25.31	10.04
79				0.0	24.91	9.843
80	CALIBRATION					
81	1	1.074	1.145	0.0	14.74	5.114
82				0.0	2.075	1.431
83				.024	15.31	1.483
84				.100	15.91	1.504
85				.099	1.747	1.525
86				.176	14.47	1.493
87				.175	1.76	1.494
88	2	1.074	1.433	0.0	15.12	1.498
89				.024	14.88	1.45
90				.097	16.4	1.544
91				.173	14.84	1.434
92	1	1.074	1.145	.176	15.1	1.477
93				.176	1.957	1.473
94				.099	14.32	1.484
95				.024	15.7	1.539
96				0.0	15.97	1.541
97	3	1.074	1.792	0.0	13.8	1.488
98				.024	14.67	1.489
99				.099	15.31	1.446
100				.175	14.32	1.472
101				.175	15.21	1.449
102	5	1.074	2.796	.175	14.19	1.469
103				.099	15.58	1.471
104				.024	14.46	1.472
105				0.0	14.52	1.506
106	10	1.701	1.814	.196	15.58	2.046
107				.195	1.714	1.574
108				0.0	16.0	2.091

Approved for Public Release

Contrails

SHARED EXIT EJECTOR NOZZLE TESTS - R.N.T.F.

RUN HISTORY

TEST RUN #	MODEL CONFIG #	A_{MIN}/A_B	A_9/A_B	$W_F\sqrt{T_{T_F}}/W_P\sqrt{T_{T_P}}$	P_{T_P}/P_{∞} MAX	P_{T_P}/P_{∞} MIN
109	10	1.701	1.814	0.0	1.82	1.554
110				.458	17.1	1.621
111				.76	15.11	1.52
112	CALIBRATION					
113				.971	15.2	1.545
114	11	1.701	2.27	.964	14.99	1.492
115				.476	13.58	1.412
116				.195	14.73	1.511
117				0.0	15.79	1.522
118	12	1.701	2.838	0.0	15.95	1.553
119				.196	15.52	1.5
120				.471	14.36	1.499
121				.962	16.17	1.628
122	4	1.074	2.237	0.0	16.09	1.484
123				.024	14.84	1.506
124				.100	15.09	1.499
125				.174	14.76	2.941
126				.173	1.848	1.44
		FAN	MODE			
127	25	2.077	1.005	NOT CALCULATED		
128				"	"	
129				"	"	
130				"	"	
131				"	"	
132				.386	3.413	1.307
133				0.0	3.353	1.173
134				.184	3.580	1.227
135				.590	2.538	1.271
136				.588	3.472	2.698
137				NO DATA		
138				.712	3.567	1.297
139				.607	3.261	1.302
140	28	2.077	.516	0.0	3.3	1.319
141				.202	3.498	1.339

Approved for Public Release

Contrails

SHARED EXIT EJECTOR NOZZLE TESTS - R.N.T.F.

RUN HISTORY

TEST RUN #	MODEL CONFIG #	A_{MIN}/A_8	A_9/A_8	$W_F\sqrt{T_{T_F}}/W_P\sqrt{T_{T_P}}$	P_{T_P}/P_{∞} MAX	P_{T_P}/P_{∞} MIN
142	28	2.077	.516	.415	3.581	1.306
143				.623	3.514	1.304
144				.833	3.601	1.339
145	26	2.077	.804	0.0	3.44	1.307
146				.188	3.731	1.22
147				.391	3.426	1.287
148				.582	3.486	1.281
149				.747	3.413	1.285
150	27	2.077	.645	.786	3.501	1.306
151				.589	3.443	1.272
152				.39	3.462	1.308
153				.198	3.631	1.248
154				0.0	3.259	1.257
155	31	3.289	1.021	0.0	3.221	1.247
156				.194	3.427	1.272
157				0.0	3.449	1.23
158				.389	3.279	1.29
159				.274	3.349	1.269
160				.121	3.387	1.226
161	32	3.289	.817	.243	3.328	1.236
162				0.0	3.414	1.178
163				.095	3.329	1.183
164				.193	3.547	1.225
165				.268	3.507	1.195
166				.343	3.576	1.194
167	29	3.289	1.592	.425	3.539	1.198
168				.287	3.515	1.181
169				NO DATA		
170				.094	3.562	1.259
171				0.0	3.271	1.186
172				NO DATA		
173	30	3.289	1.274	.346	3.187	1.246
174				NO DATA		
175				.294	3.547	1.168
176				.197	3.52	1.151
177				.102	3.439	1.132

Approved for Public Release

Contrails

SHARED EXIT EJECTOR NOZZLE TESTS - R.N.T.F.

RUN HISTORY

TEST RUN #	MODEL CONFIG. #	A_{min}/A_8	A_9/A_8	$W_F\sqrt{T_{T_F}}/W_P\sqrt{T_{T_P}}$	P_{T_P}/P_∞ MAX	P_{T_P}/P_∞ MIN
178	30	3.289	1.274	0.0	3.602	1.117
179	34	5.113	1.98	0.0	3.507	1.108
180				.343	3.54	1.18
181				.203	3.598	1.231
182				.104	3.459	1.153
183				0.0	3.33	1.149
184	35	5.113	1.587	0.0	3.164	1.17
185				.101	3.346	1.158
186				.199	3.663	1.192
187				NO DATA		
188				.405	3.512	1.221
189	33	5.113	2.475	.286	3.432	1.172
190				.190	3.34	1.176
191				.094	3.645	1.581
192				.089	1.95	1.125
193				NO DATA		
194				" "		
195				.044	3.615	1.119
196				0.0	3.505	1.105
197	36	5.113	1.27	0.0	3.579	1.171
199				.288	3.548	1.207
200				.235	3.439	1.184
201				.179	3.367	1.17
				.09	3.544	1.138
		SATELLITE MODE				
202	1	1.074	1.145	NO DATA		
203				CALIBRATION		
204				.099	3.972	1.976
205				.176	3.926	1.993
206				.252	16.03	1.506
207	6	1.354	1.443	0.0	16.32	1.478
208				.421	16.04	1.513
209				.614	16.2	1.501
210				.211	16.33	2.406

Approved for Public Release

Contrails

SHARED EXIT EJECTOR NOZZLE TESTS - R.N.T.F.

RUN HISTORY

TEST RUN #	MODEL CONFIG #	A_{MIN}/A_B	A_9/A_B	$W_F\sqrt{T_{T_F}}/W_P\sqrt{T_{T_P}}$	P_{T_P}/P_{∞} MAX	P_{T_P}/P_{∞} MIN
211	6	1.354	1.443	.211	2.437	1.368
212	10	1.701	1.814	.773	4.06	1.991
213				.971	4.066	2.027
214				1.22	16.48	1.497
215	13	2.132	2.273	.81	7.884	1.995
216				1.78	8.268	2.033
217				1.23	8.257	1.947
218				.45	7.911	1.972
219	19	2.644	2.819	.614	7.763	2.058
220				1.043	7.976	2.008
221				1.575	7.999	1.992
222				2.059	8.075	1.965
223				4.125	8.175	2.044

Approved for Public Release

Contrails

APPENDIX II

SECONDARY NOZZLE STATIC PRESSURE DISTRIBUTIONS

(The reverse of this page is blank)

Approved for Public Release

Contrails

Approved for Public Release

Contrails

APPENDIX II

SECONDARY NOZZLE STATIC PRESSURE DISTRIBUTIONS

Static pressure distributions along the inner wall of the secondary nozzles are shown in figures 88 through 212. These distributions were produced directly from processed raw data by means of CRT (Cathode Ray Tube) automatic plotting equipment. The data were obtained from seventeen static pressure taps imbedded along the inner wall of each secondary nozzle.

Wall static pressure, P_W, has been non-dimensionalized for these distributions by primary plenum chamber total pressure, P_{T_P}, in the satellite mode, and fan duct total pressure, P_{T_F}, in the fan mode. These pressure ratios have been plotted as a function of the full size distance, in inches, from the exit plane of the secondary nozzle. The ratio P_T/P_A on the plots denotes the ratio between the primary or fan total pressure and the ambient static pressure.

Figures 88 through 147 present wall pressure distributions for satellite mode configurations 1 through 6 and 10 through 12. These configurations were tested over an approximate nozzle pressure ratio range of 1.5 to 15. Each figure corresponds to a given nozzle geometric configuration and fan to primary temperature-corrected weight flow ratio. Pressure distributions for several nozzle pressure ratios P_{T_P}/P_A are shown on each plot. Separation of the boundary layer from the secondary nozzle wall occurs quite frequently at low nozzle pressure ratios. For unseparated flow the distributions are coincident and independent of nozzle pressure ratio.

Satellite mode configurations 13 through 17 and 19 through 22 were tested over an approximate nozzle pressure ratio range of 10 to 25. Since separation will not occur at these high pressure ratios, each figure shows all the weight flow ratios tested for a given configuration.

Nozzle wall static pressure distributions in the fan mode are presented in a manner similar to the low pressure satellite mode distribution. However, fan duct total pressure P_{T_F}, replaces the primary plenum chamber pressure P_{T_P} in figures 148 through 212. Large irregularities in the pressure level at the static pressure tap located 1.9 inches from the nozzle exit plane were due to malfunctions in the instrumentation system.

Approved for Public Release

Contrails

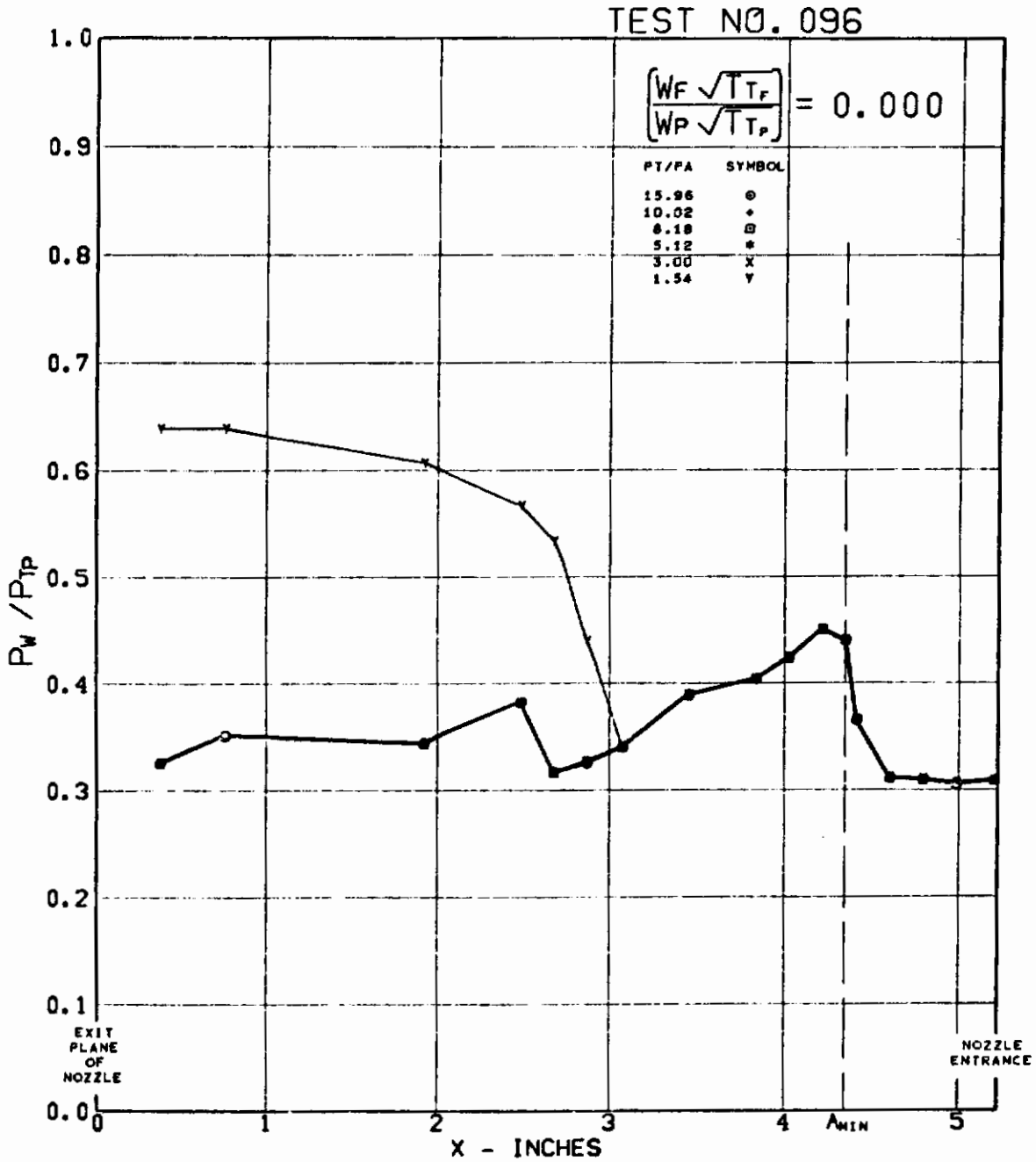


FIGURE 88. WALL PRESSURES - CONFIGURATION 01 AT 0.000 FAN FLOW RATIO $(W_F\sqrt{T_{T_F}} / W_P\sqrt{T_{T_P}})$

Approved for Public Release

Contrails

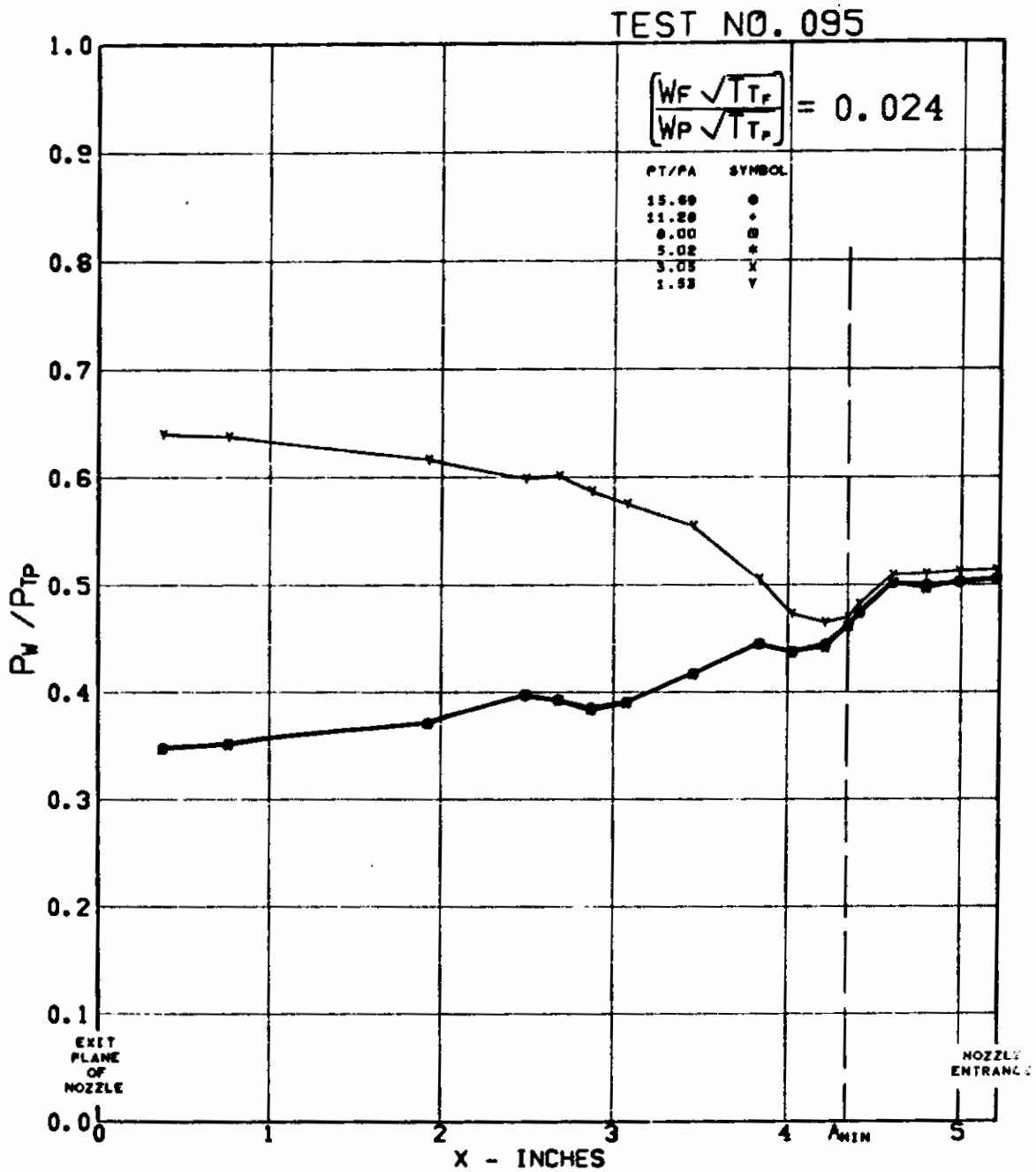


FIGURE 89. WALL PRESSURES - CONFIGURATION 01 AT 0.024 FAN FLOW RATIO $(W_F\sqrt{T_{T_F}}/W_P\sqrt{T_{T_P}})$

Approved for Public Release

Contrails

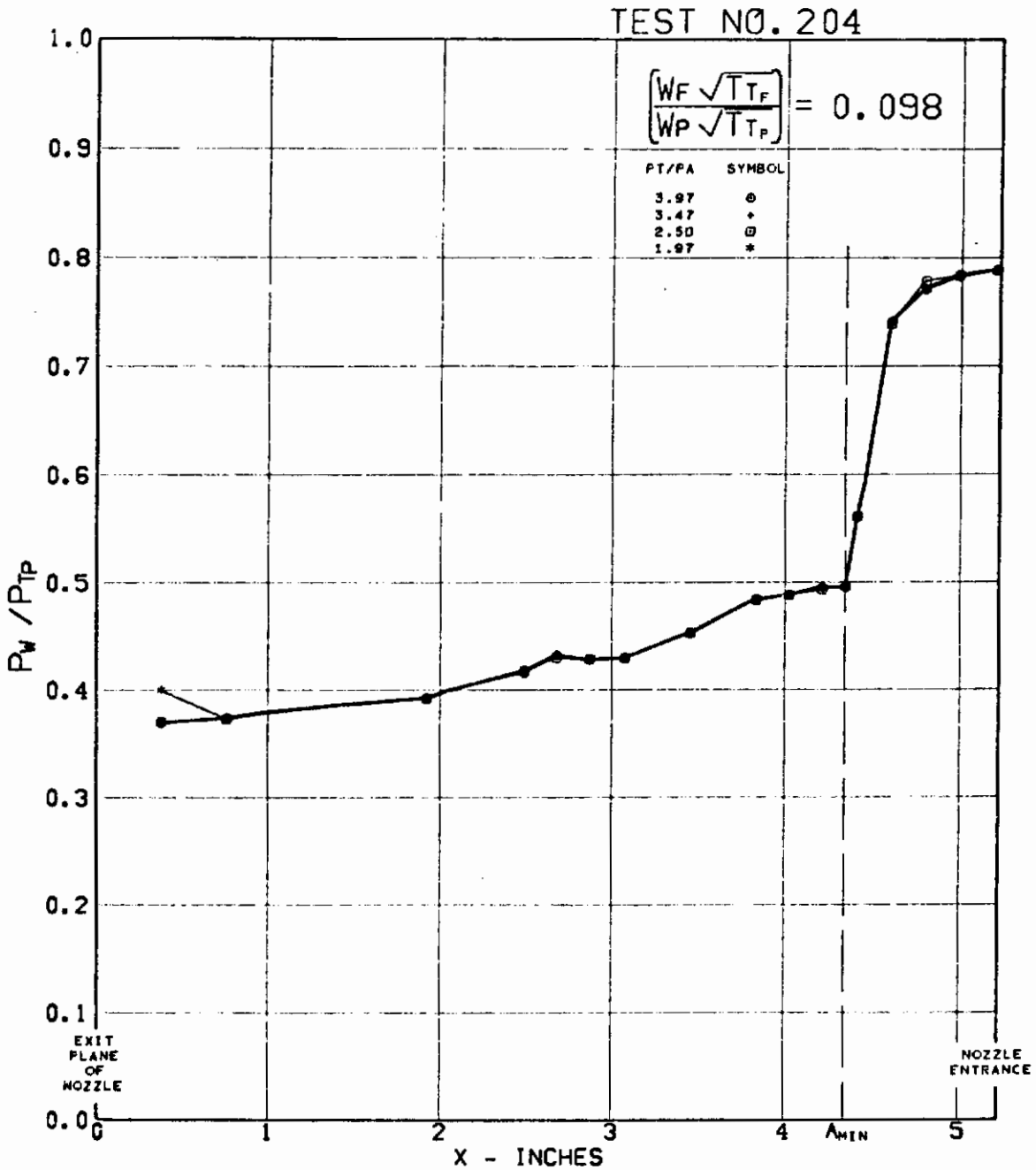


FIGURE 90. WALL PRESSURES - CONFIGURATION 01 AT 0.098 FAN FLOW RATIO $(W_F\sqrt{T_{T_F}} / W_P\sqrt{T_{T_P}})$

Approved for Public Release

Contrails

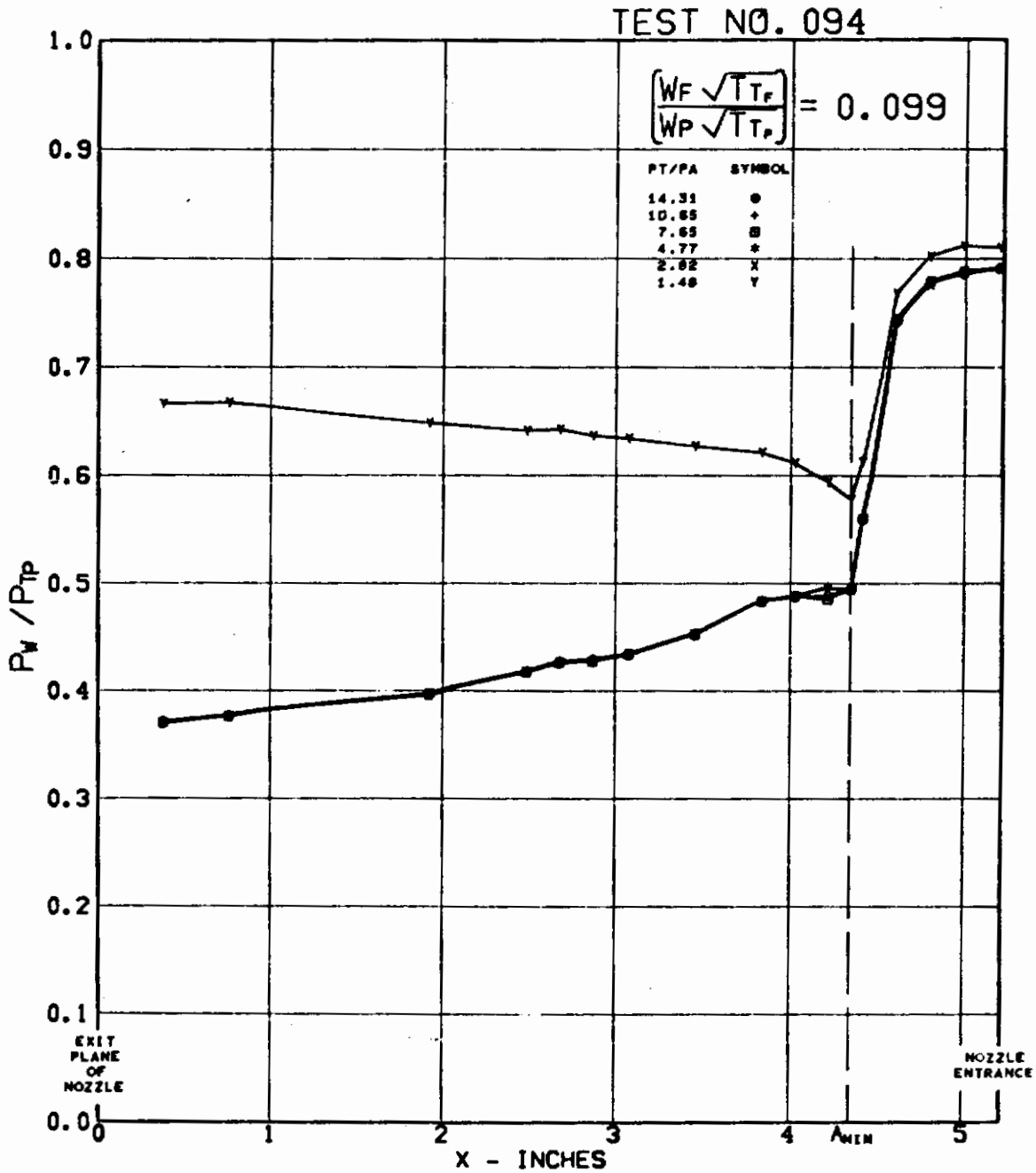


FIGURE 91. WALL PRESSURES - CONFIGURATION 01 AT 0.099 FAN FLOW RATIO $(W_F\sqrt{T_{T_F}}/W_P\sqrt{T_{T_P}})$

Approved for Public Release

Contrails

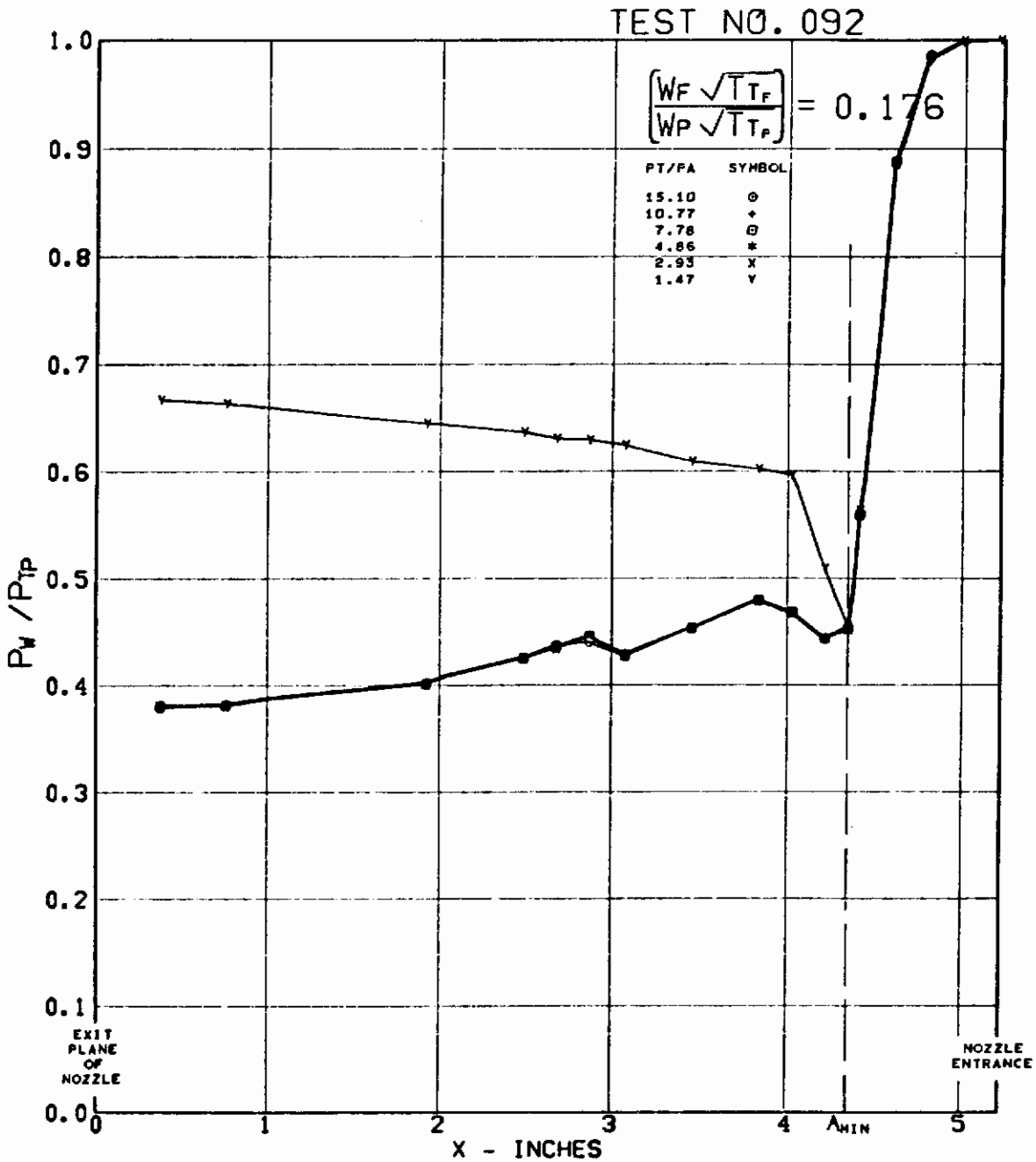


FIGURE 92. WALL PRESSURES - CONFIGURATION 01 AT 0.176 FAN FLOW RATIO $(W_F\sqrt{T_{T_F}} / W_P\sqrt{T_{T_P}})$

Approved for Public Release

Contrails

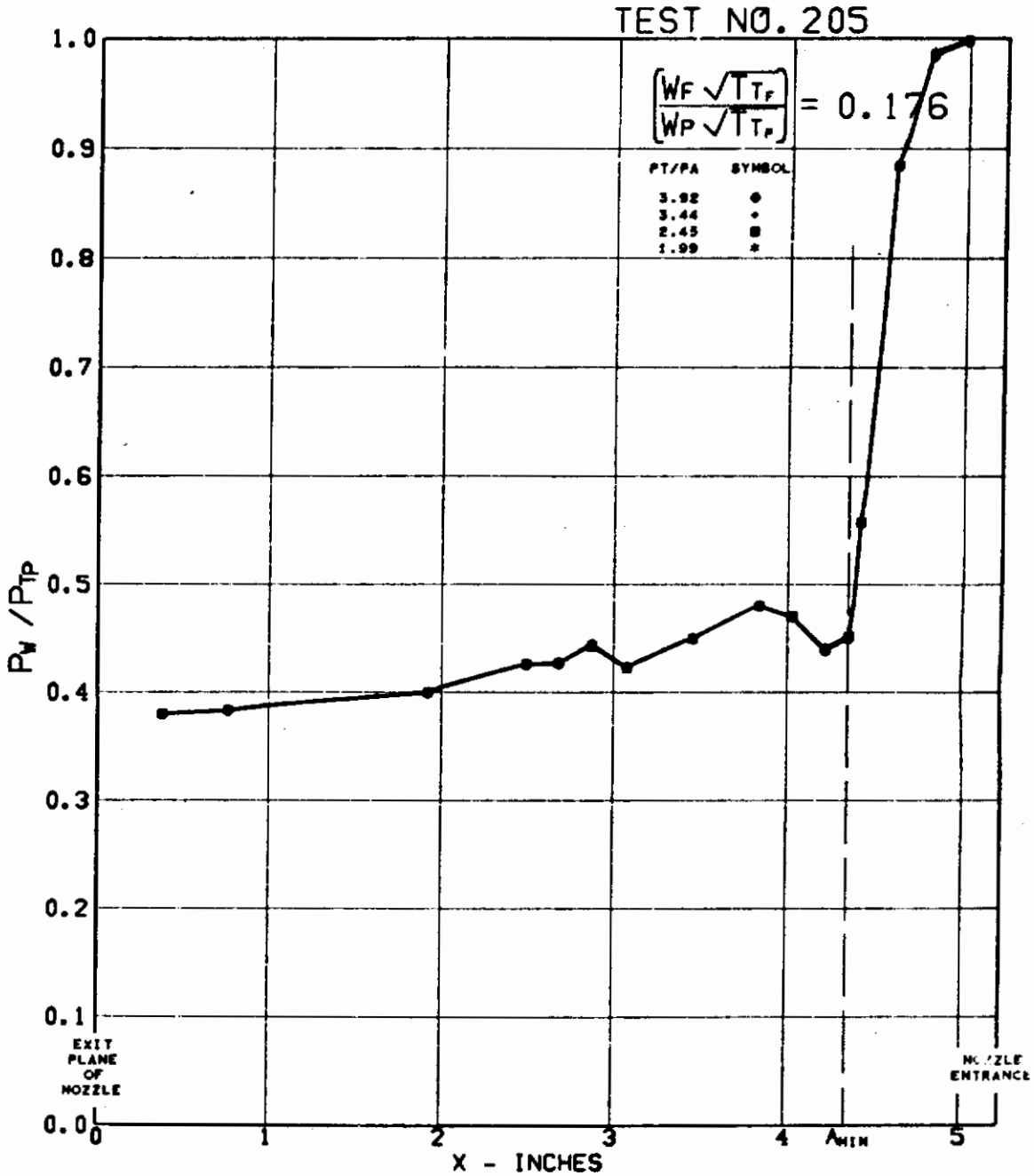


FIGURE 93. WALL PRESSURES - CONFIGURATION 01 AT 0.176 FAN FLOW RATIO $(W_F\sqrt{T_{T_F}}/W_P\sqrt{T_{T_P}})$

Approved for Public Release

Contrails

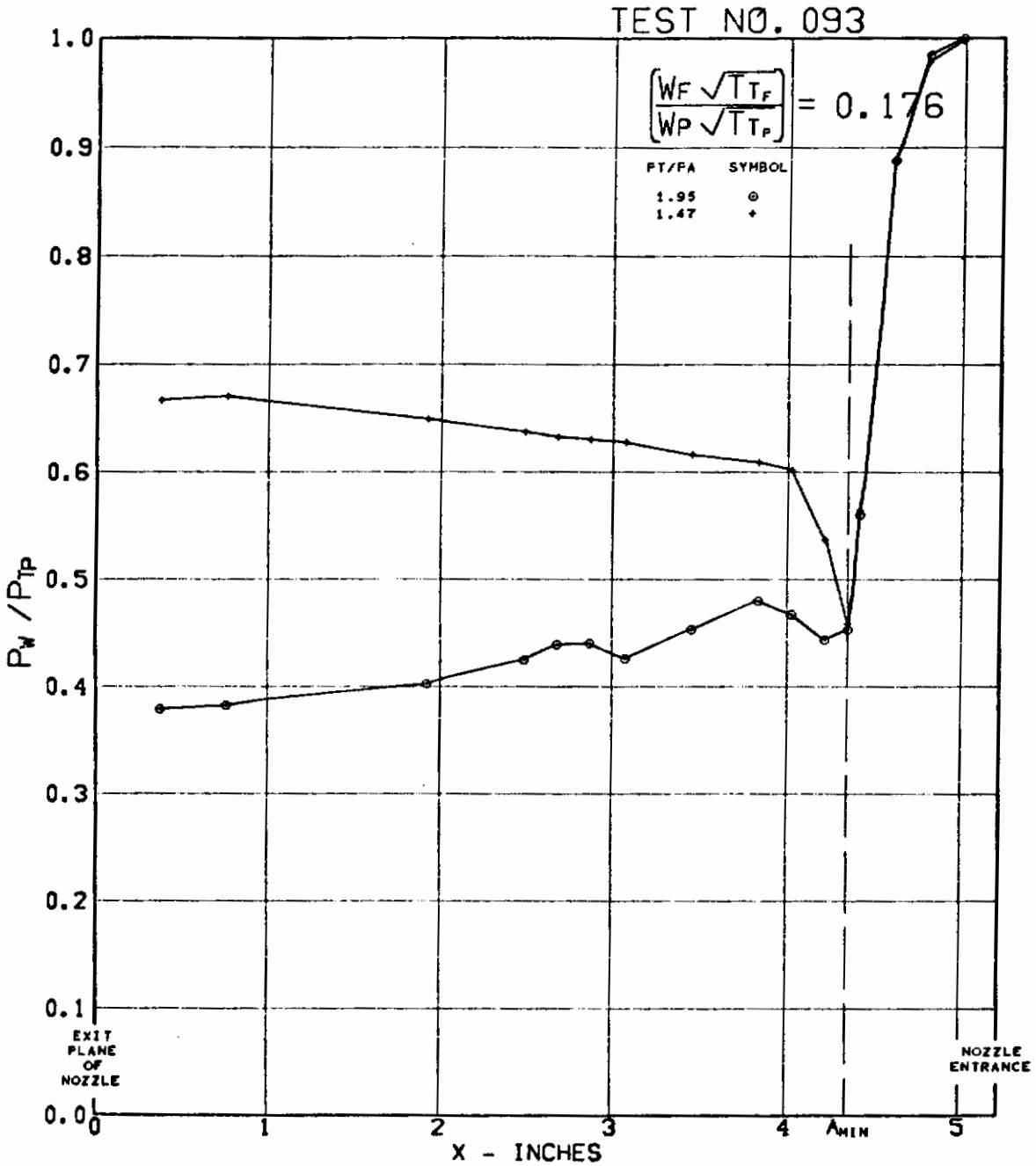


FIGURE 94. WALL PRESSURES - CONFIGURATION 01 AT 0.176 FAN FLOW RATIO ($W_F\sqrt{T_{T_F}} / W_P\sqrt{T_{T_P}}$)

Approved for Public Release

Contrails

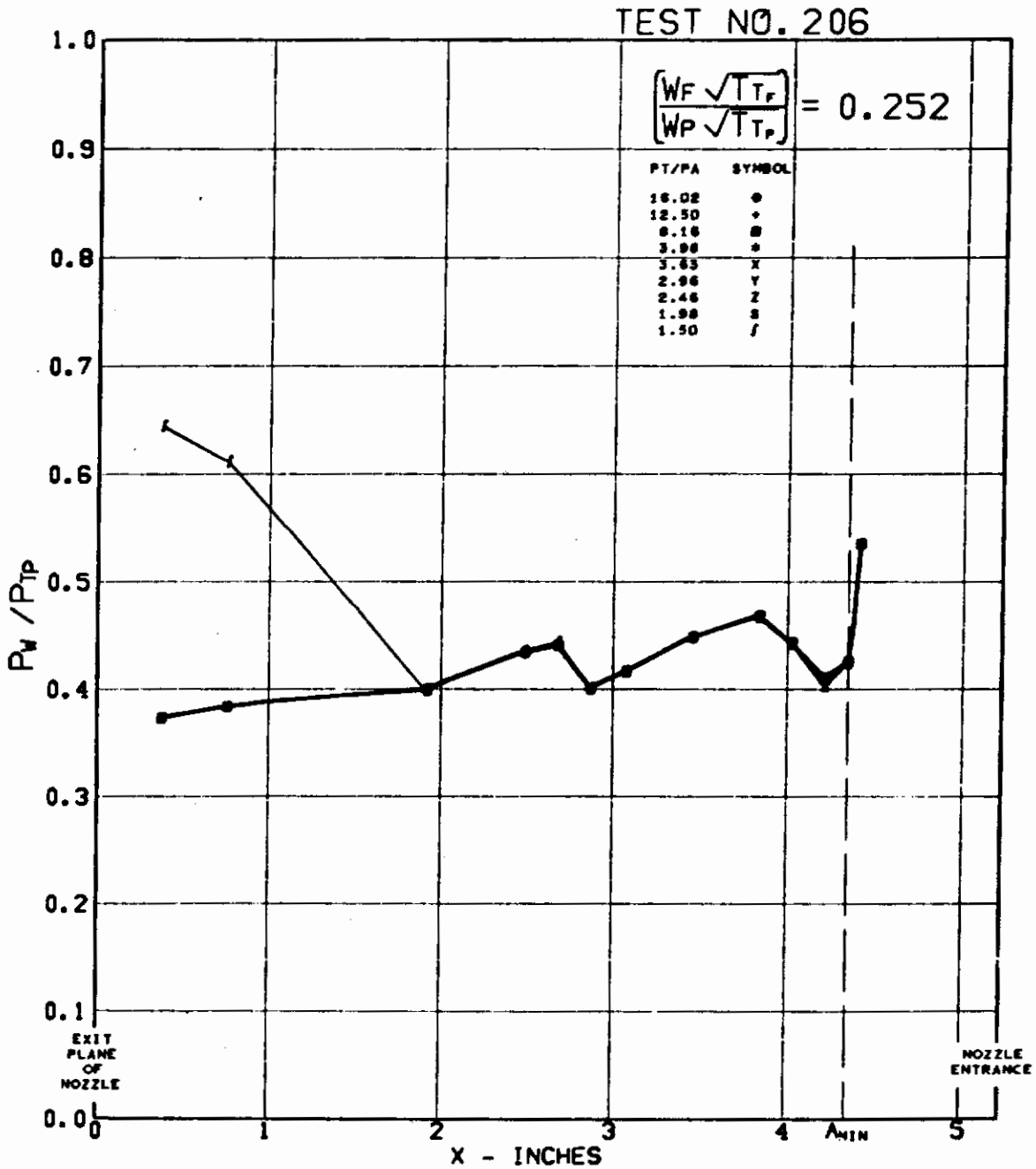


FIGURE 95. WALL PRESSURES - CONFIGURATION 01 AT 0.252 FAN FLOW RATIO ($W_F\sqrt{T_{T_F}}/W_P\sqrt{T_{T_P}}$)

Approved for Public Release

Contrails

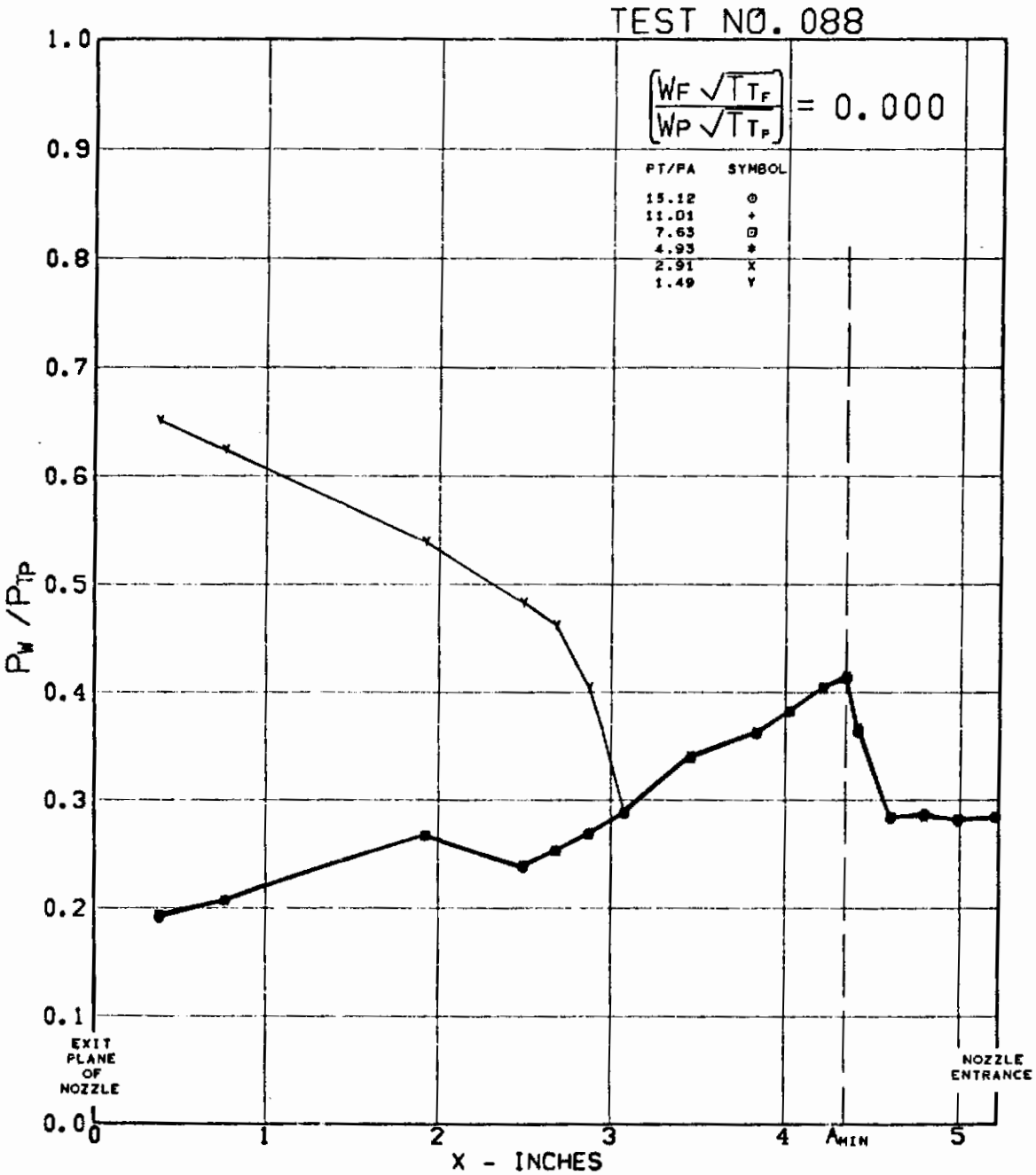


FIGURE 96. WALL PRESSURES - CONFIGURATION 02 AT 0.000 FAN FLOW RATIO $(W_F\sqrt{T_{T_F}} / W_P\sqrt{T_{T_P}})$

Approved for Public Release

Contrails

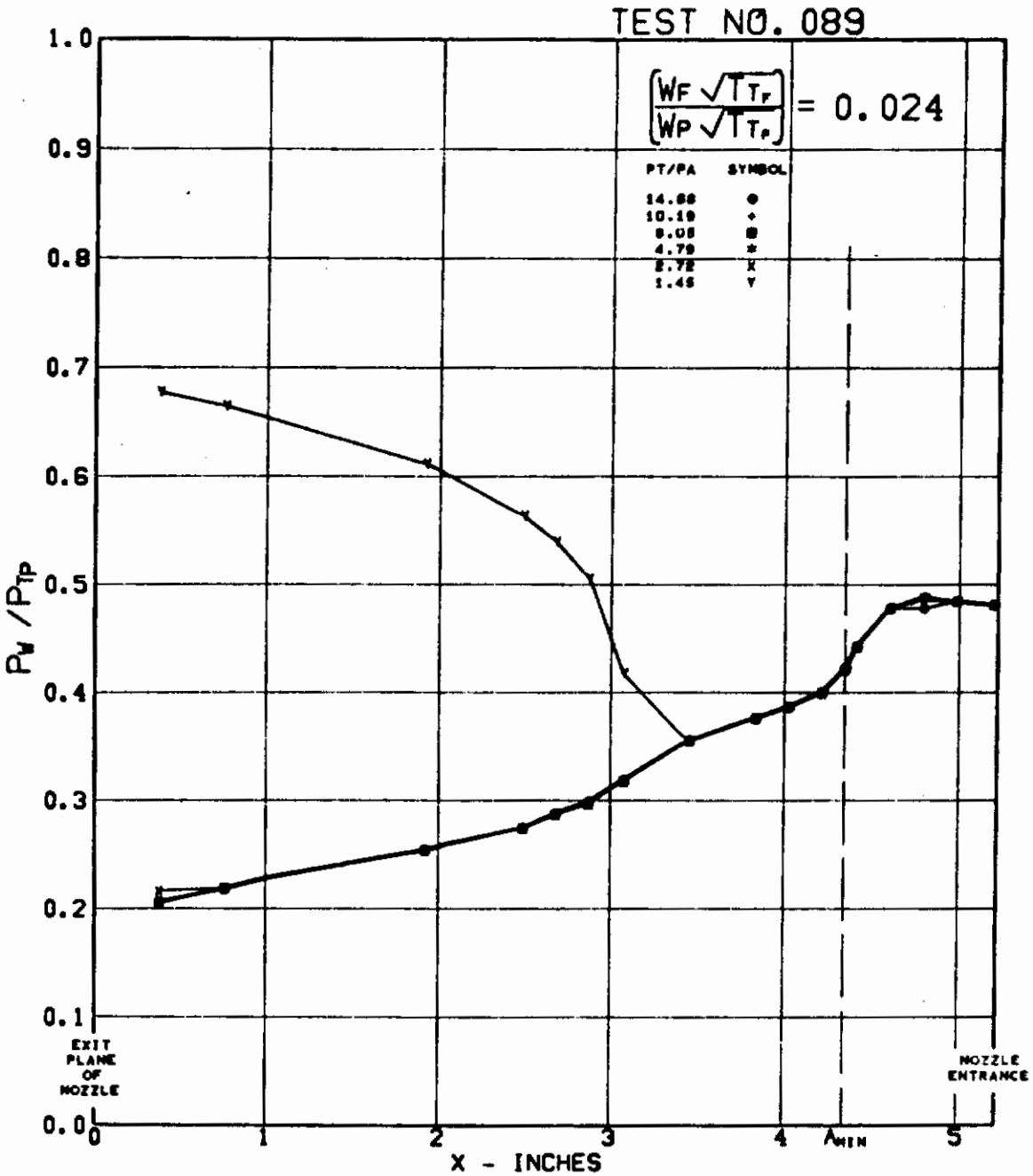


FIGURE 97. WALL PRESSURES - CONFIGURATION 02 AT 0.024 FAN FLOW RATIO $(W_F\sqrt{T_{T_F}}/W_P\sqrt{T_{T_P}})$

Approved for Public Release

Contrails

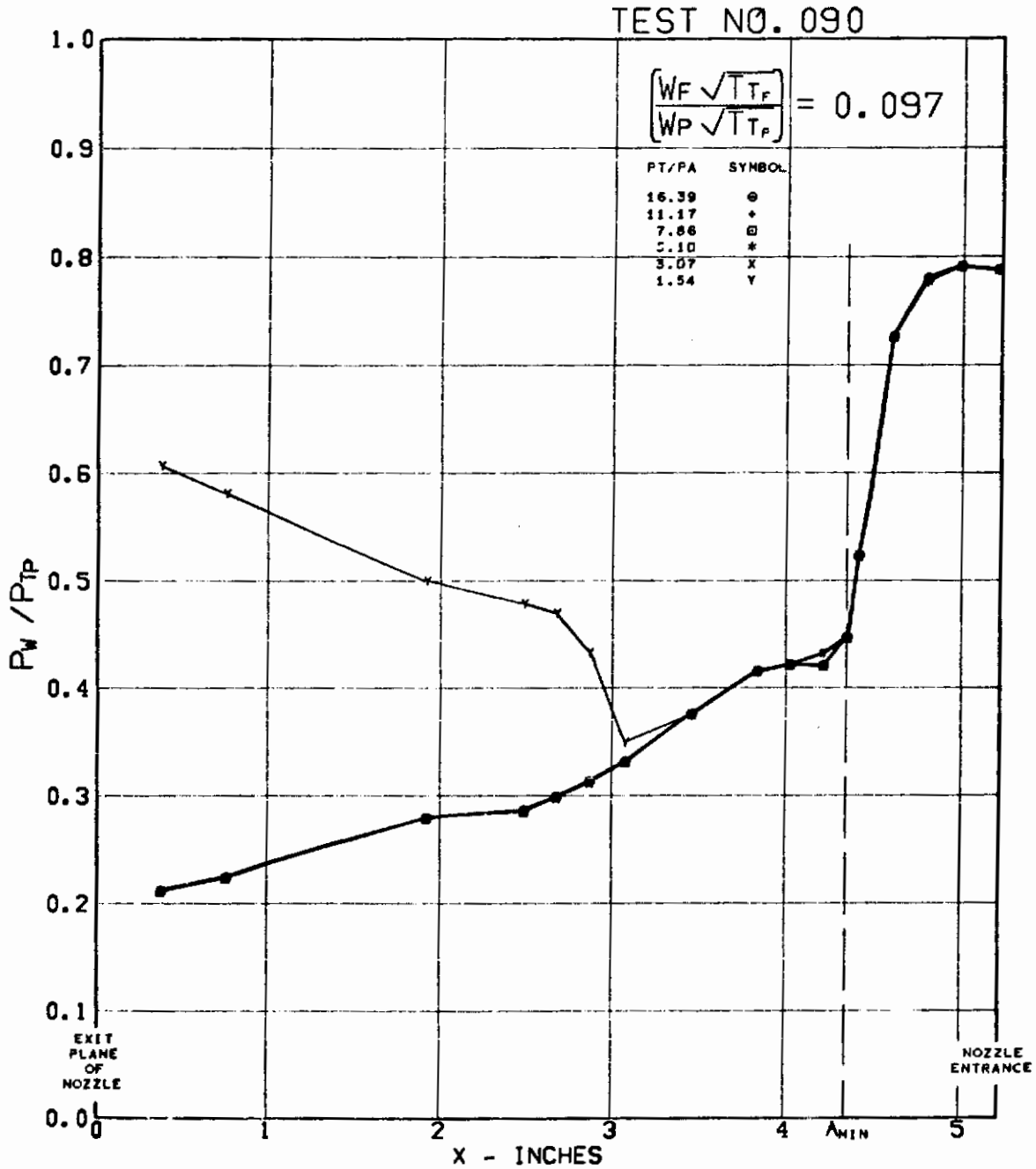


FIGURE 98. WALL PRESSURES - CONFIGURATION 02 AT 0.097 FAN FLOW RATIO $(W_F\sqrt{T_{T_F}} / W_P\sqrt{T_{T_P}})$

Approved for Public Release

Contrails

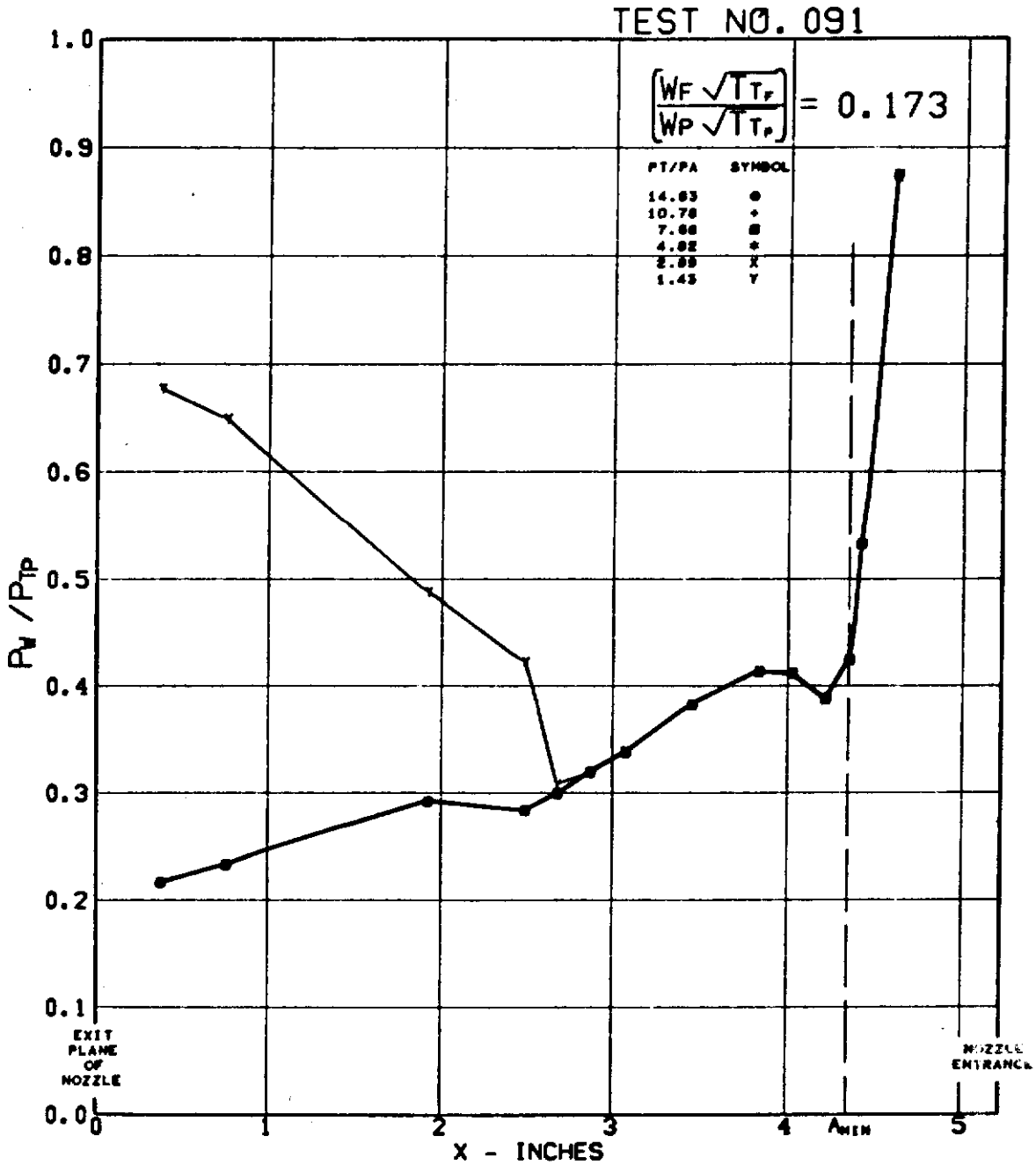


FIGURE 99. WALL PRESSURES - CONFIGURATION 02 AT 0.173 FAN FLOW RATIO $(W_F\sqrt{T_{T_F}} / W_P\sqrt{T_{T_P}})$

Approved for Public Release

Contrails

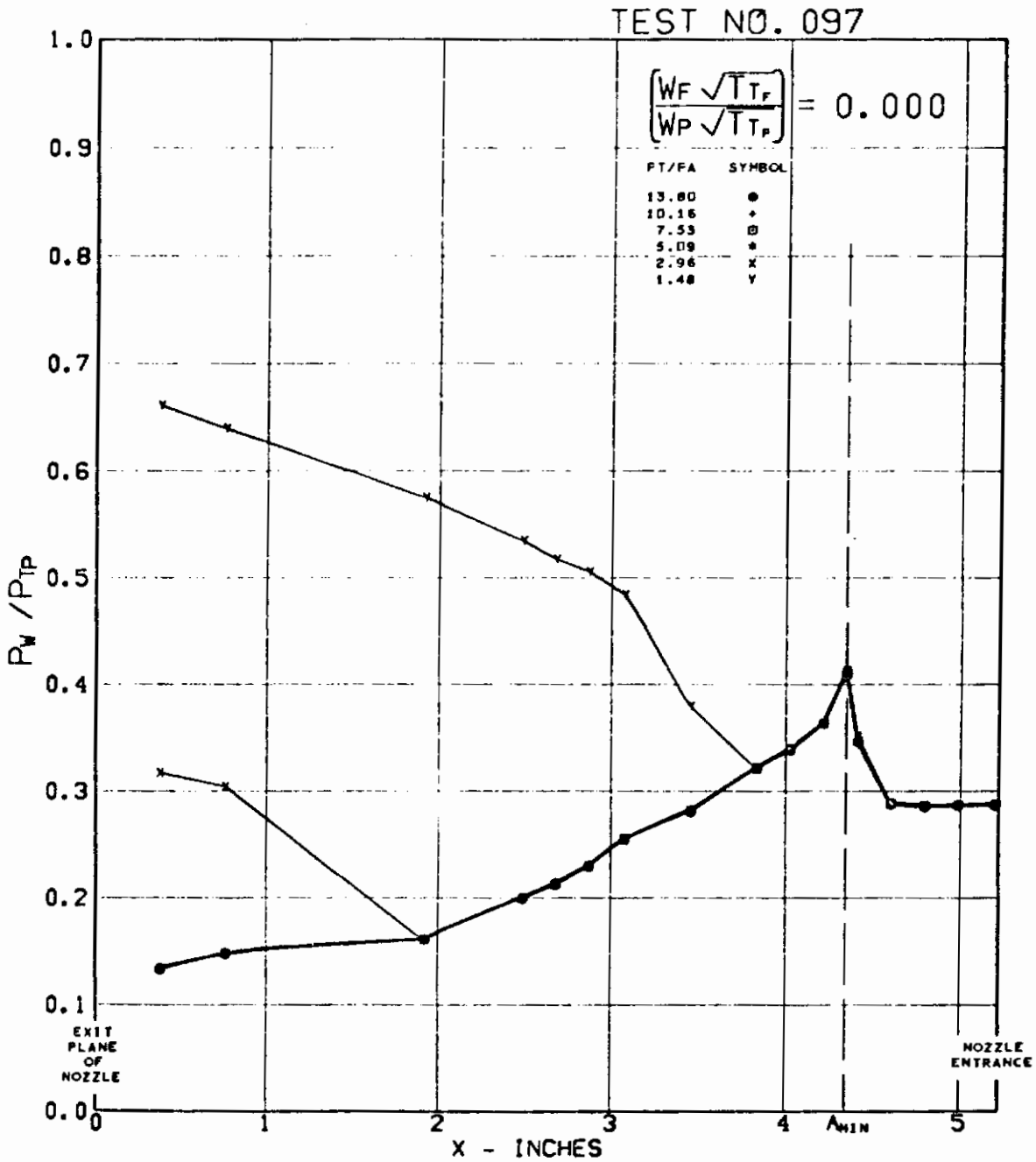


FIGURE 100. WALL PRESSURES - CONFIGURATION 03 AT 0.000 FAN FLOW RATIO $(W_F\sqrt{T_{T_F}} / W_P\sqrt{T_{T_P}})$

Approved for Public Release

Contrails

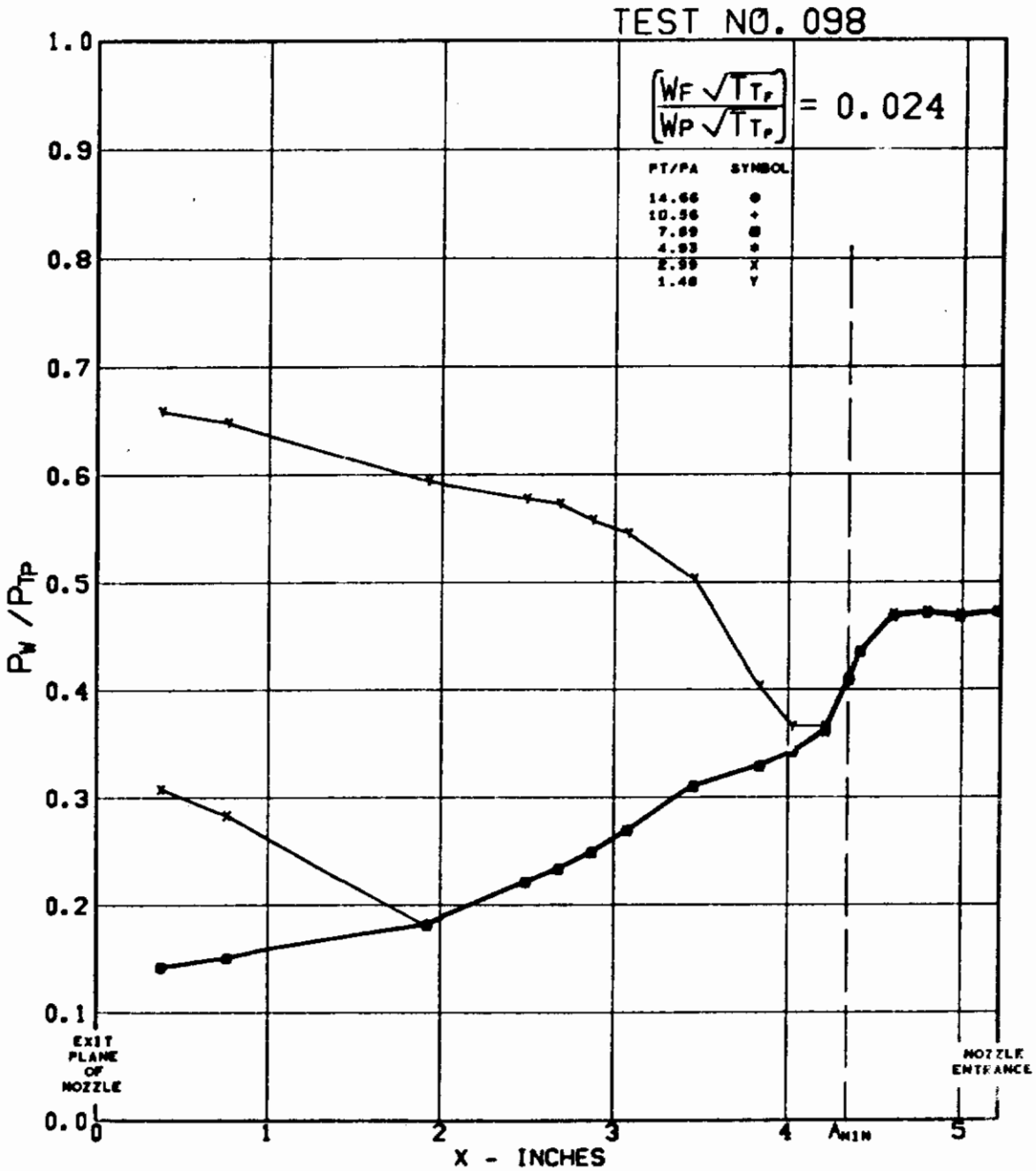


FIGURE 101. WALL PRESSURES - CONFIGURATION 03 AT 0.024 FAN FLOW RATIO $(W_F\sqrt{T_{T_F}}/W_P\sqrt{T_{T_P}})$

Approved for Public Release

Contrails

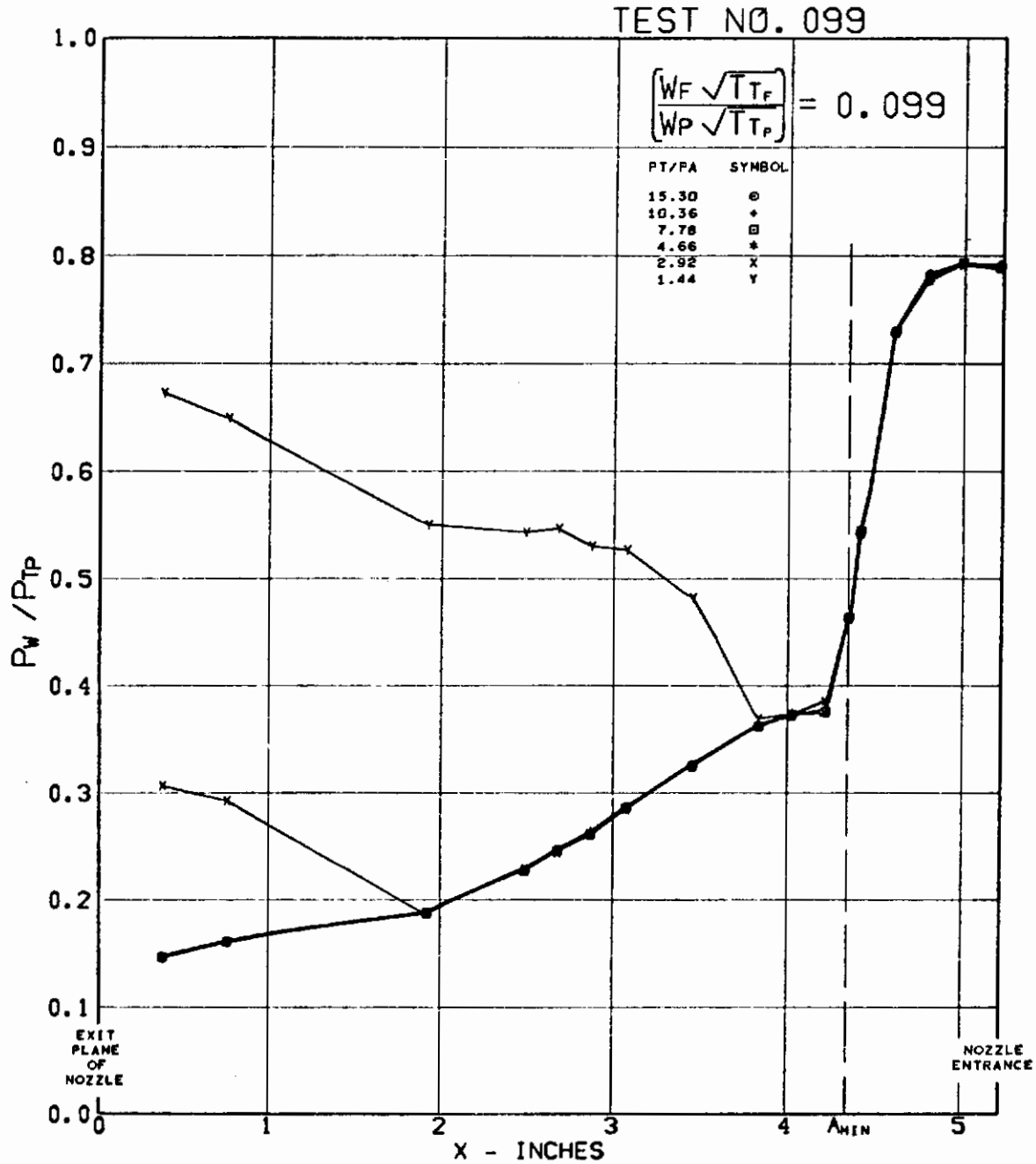


FIGURE 102. WALL PRESSURES - CONFIGURATION 03 AT 0.099 FAN FLOW RATIO ($W_F\sqrt{T_{T_F}}/W_P\sqrt{T_{T_P}}$)

Approved for Public Release

Contrails

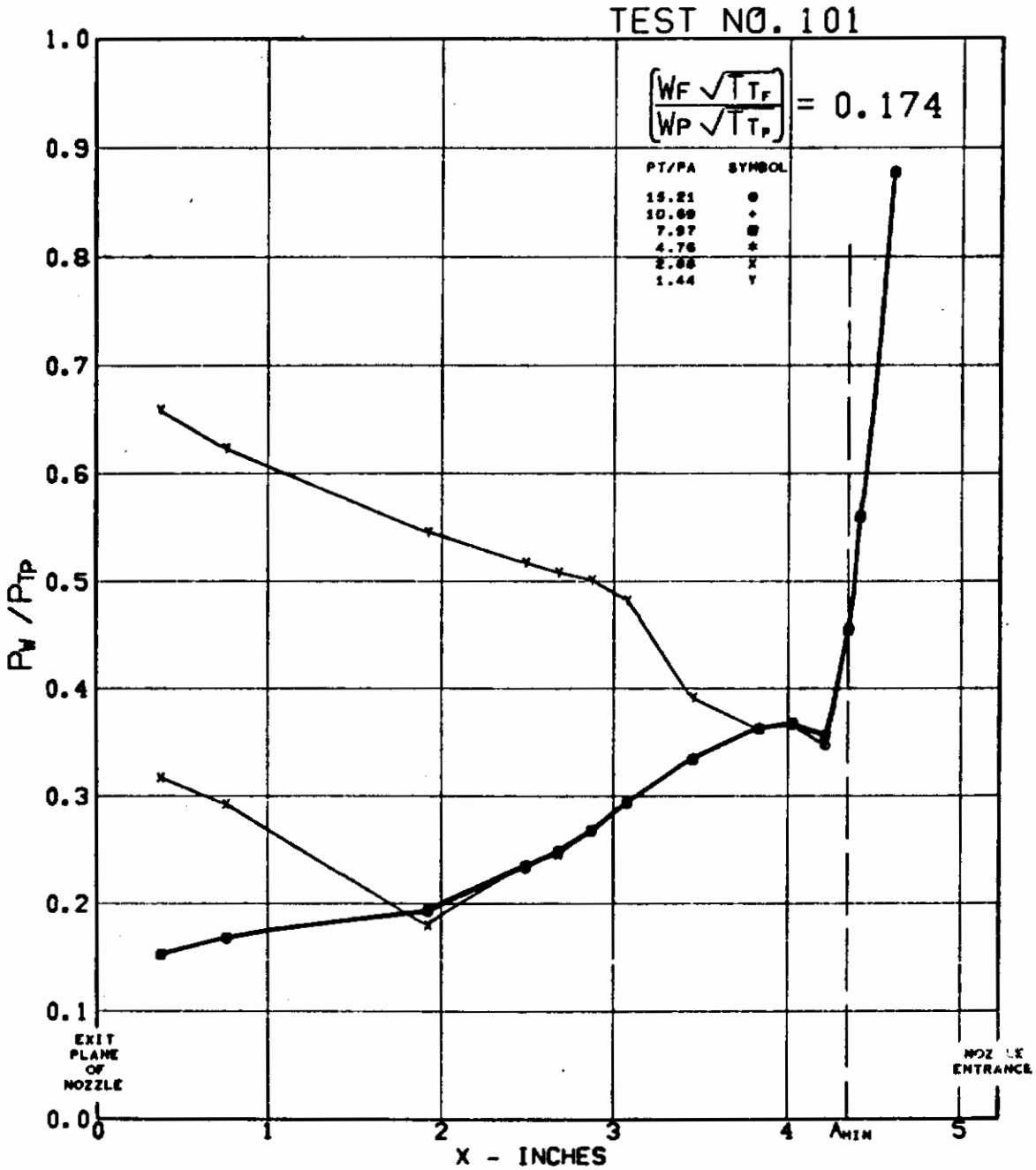


FIGURE 103. WALL PRESSURES - CONFIGURATION 03 AT 0.174 FAN FLOW RATIO ($W_F\sqrt{T_{T_F}}/W_P\sqrt{T_{T_P}}$)

Approved for Public Release

Contrails

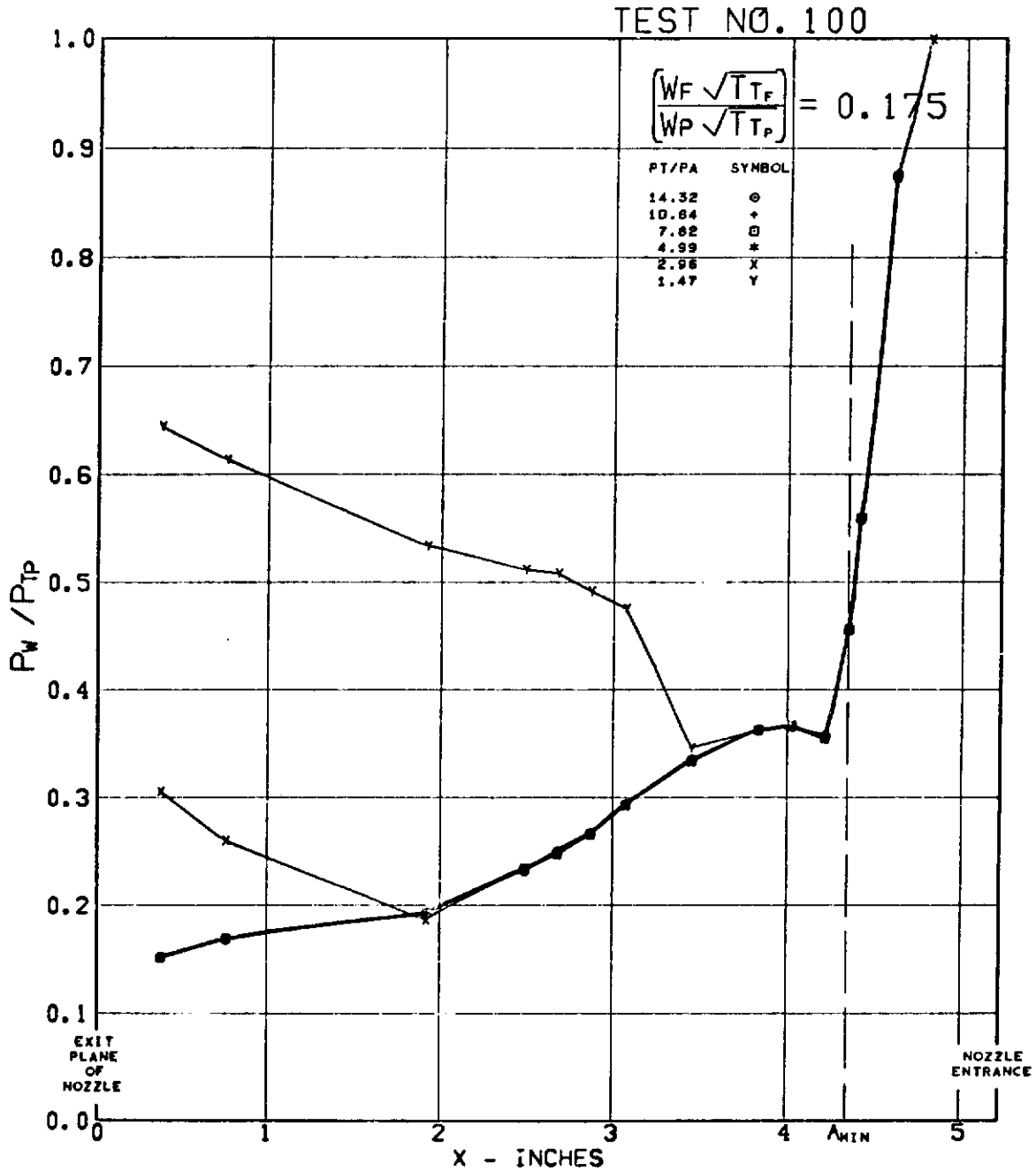


FIGURE 104. WALL PRESSURES - CONFIGURATION 03 AT 0.175 FAN FLOW RATIO $(W_F\sqrt{T_{T_F}}/W_P\sqrt{T_{T_P}})$

Approved for Public Release

Contrails

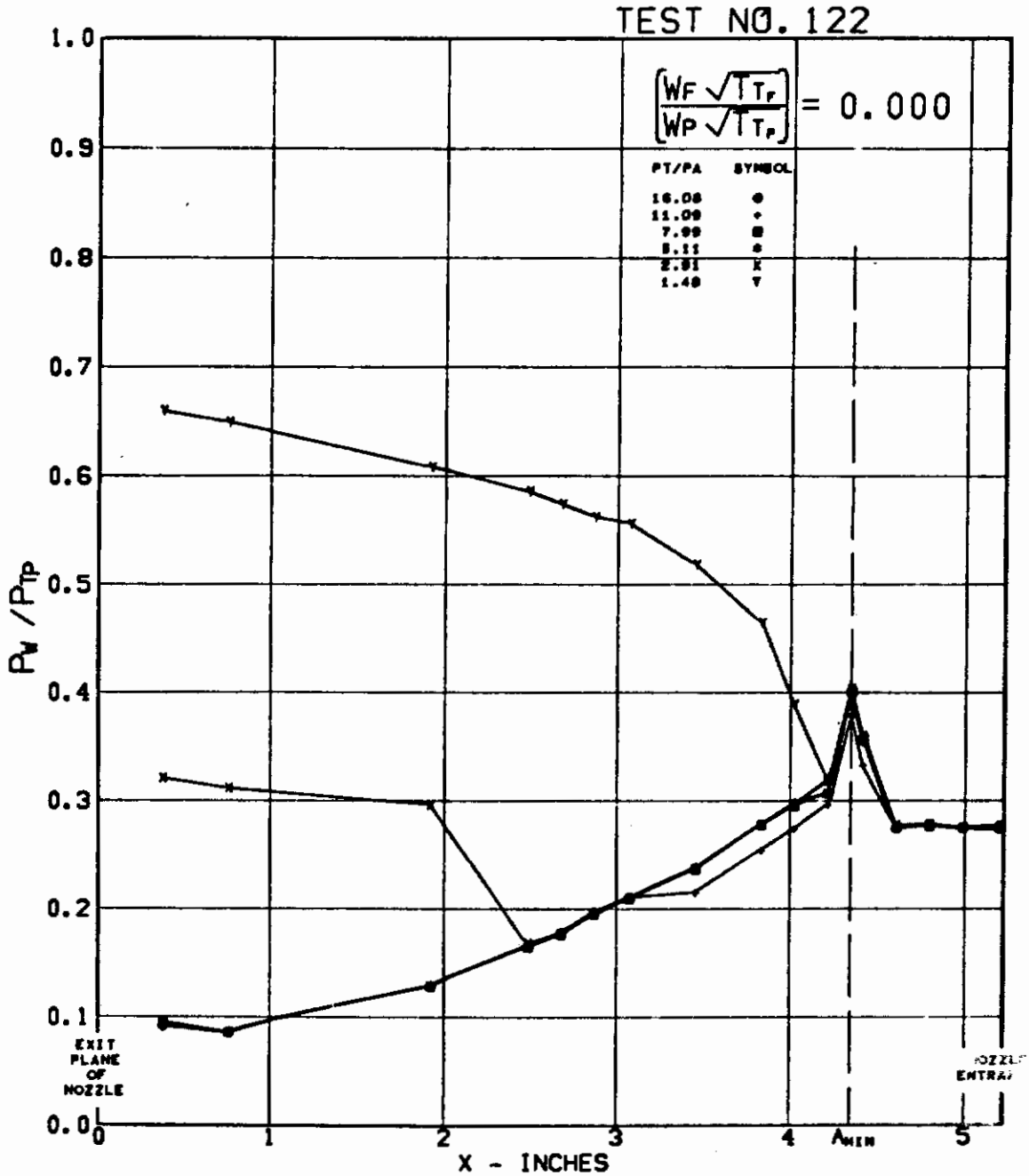


FIGURE 105. WALL PRESSURES - CONFIGURATION 04 A
0.000 FAN FLOW RATIO $(W_F\sqrt{T_{T_F}}/W_P\sqrt{T_{T_P}})$

Approved for Public Release

Contrails

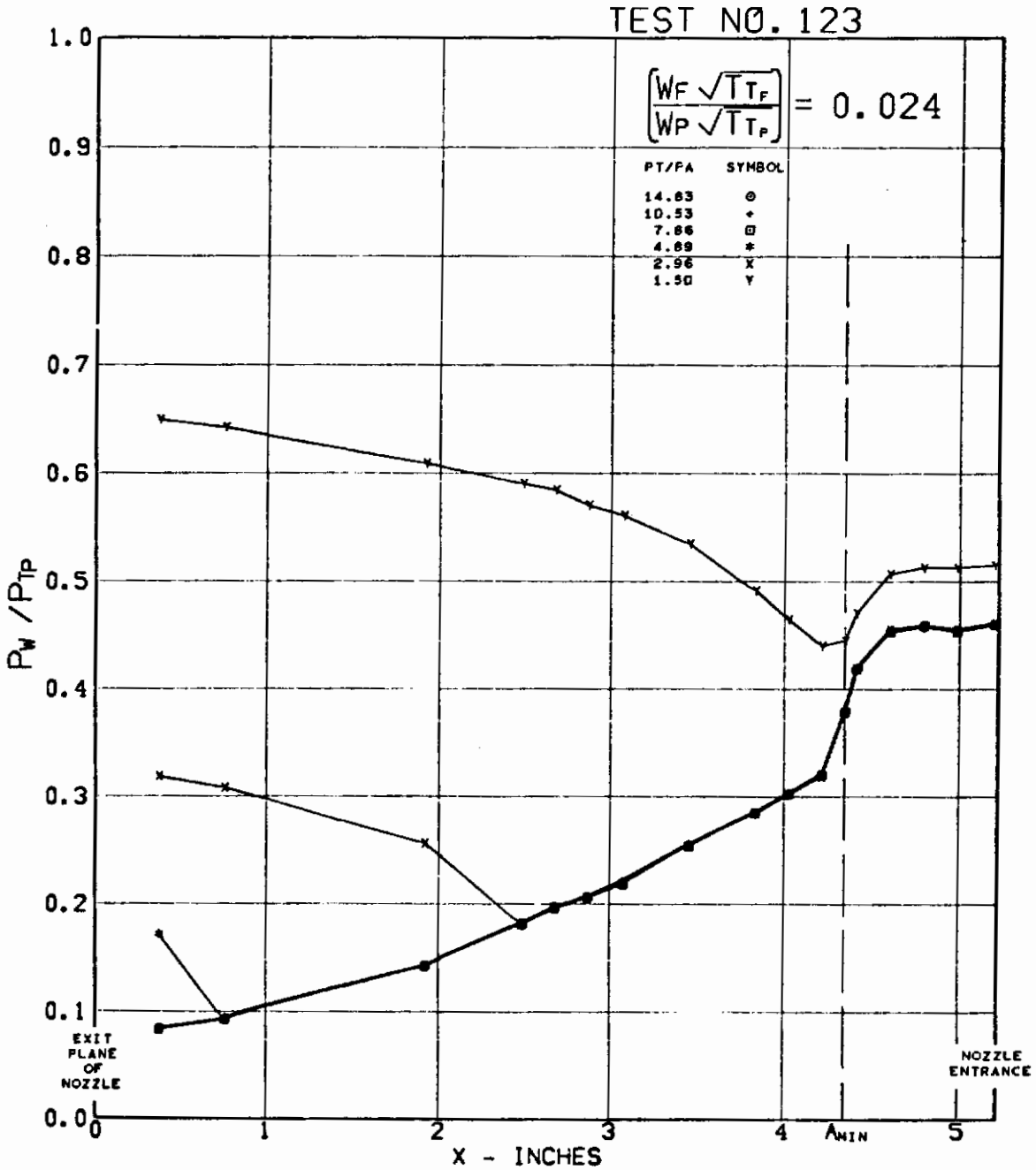


FIGURE 106. WALL PRESSURES - CONFIGURATION 04 AT 0.024 FAN FLOW RATIO ($W_F\sqrt{T_{T_F}}/W_P\sqrt{T_{T_P}}$)

Approved for Public Release

Contrails

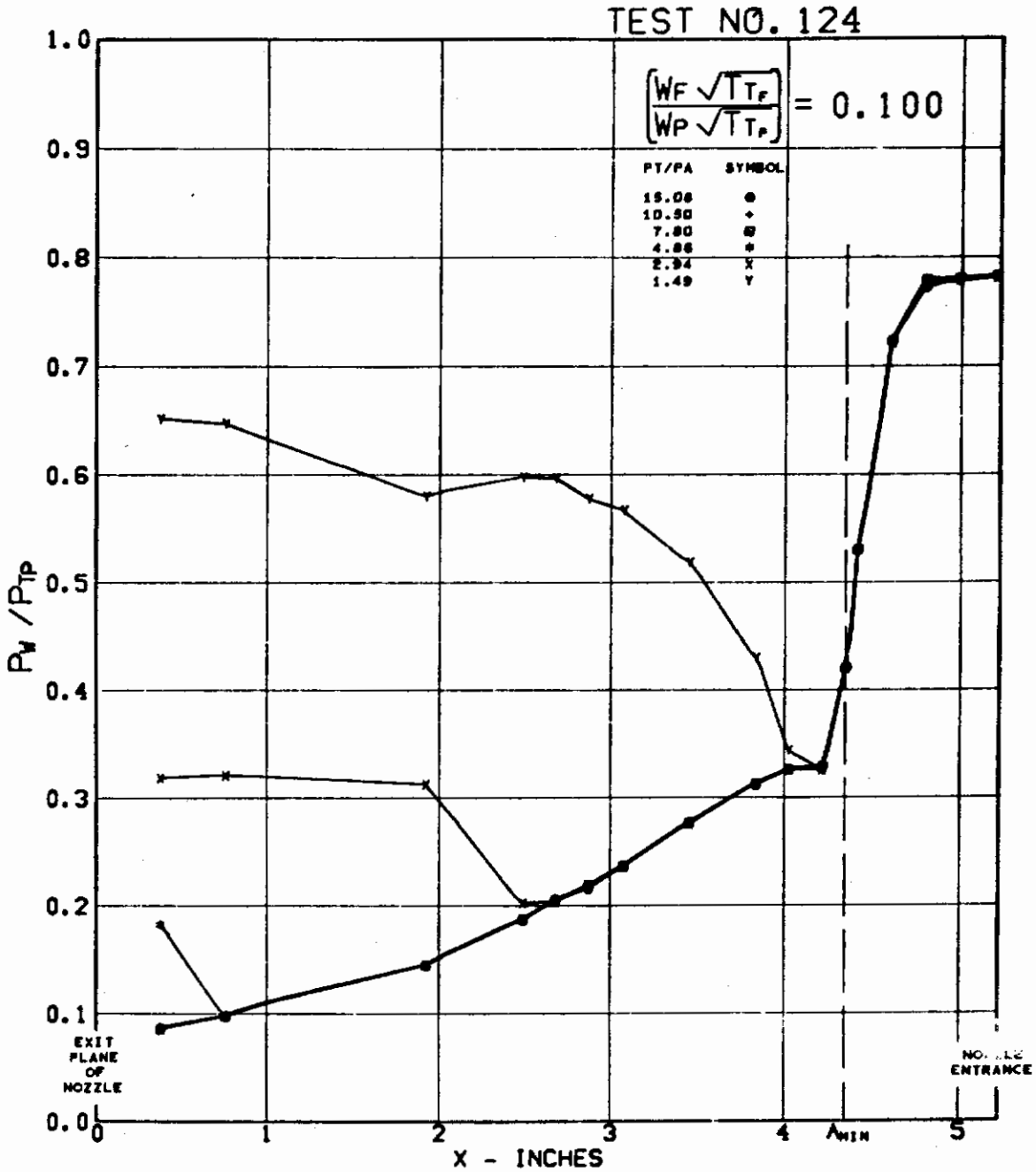


FIGURE 107. WALL PRESSURES - CONFIGURATION 04 AT 0.100 FAN FLOW RATIO $(W_F\sqrt{T_{T_F}}/W_P\sqrt{T_{T_P}})$

Approved for Public Release

Contrails

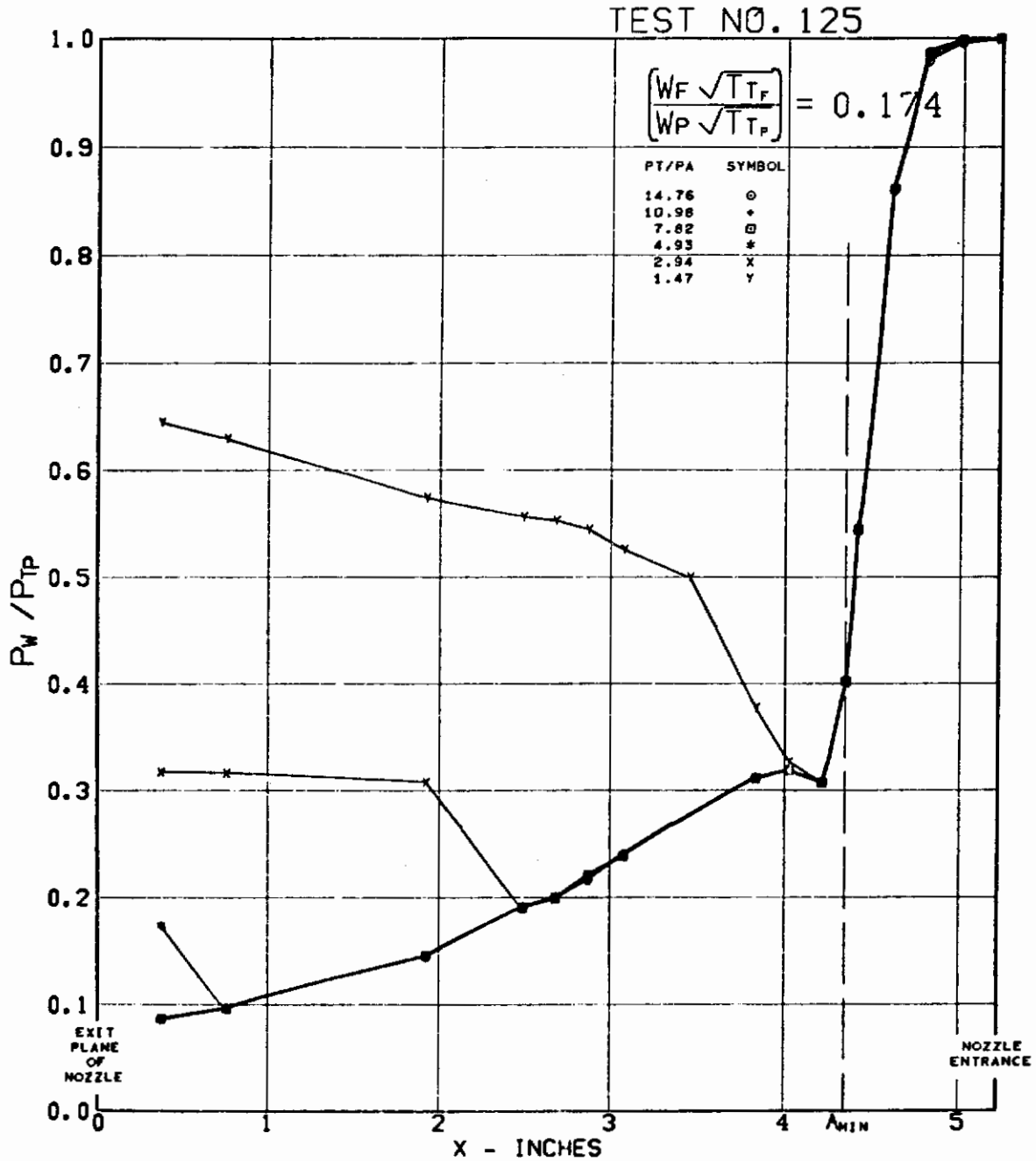


FIGURE 108. WALL PRESSURES - CONFIGURATION 04 AT 0.174 FAN FLOW RATIO $(W_F\sqrt{T_{T_F}}/W_P\sqrt{T_{T_P}})$

Approved for Public Release

Contrails

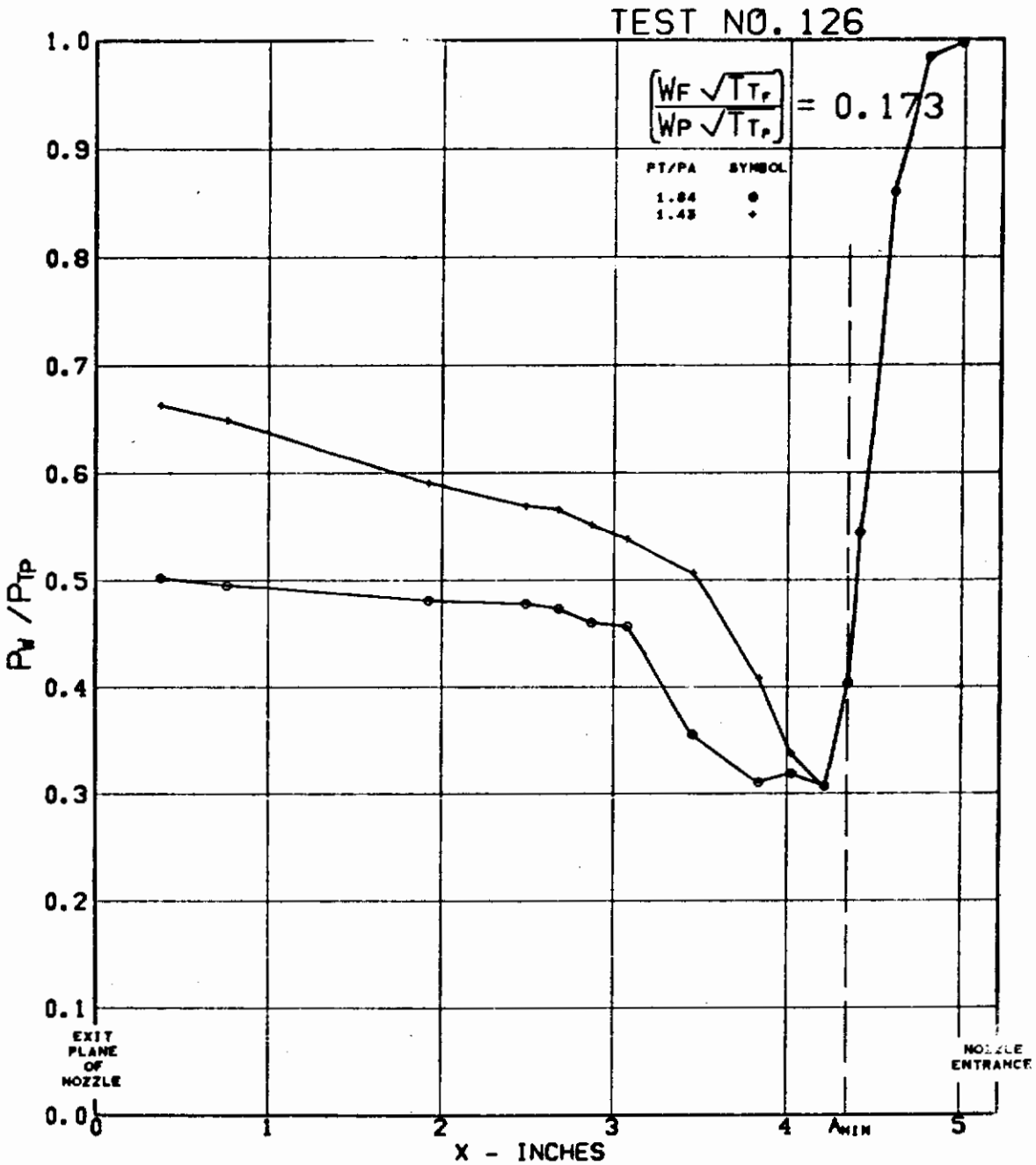


FIGURE 109. WALL PRESSURES - CONFIGURATION 04 AT 0.173 FAN FLOW RATIO $(W_F\sqrt{T_{T_F}}/W_P\sqrt{T_{T_P}})$

Approved for Public Release

Contrails

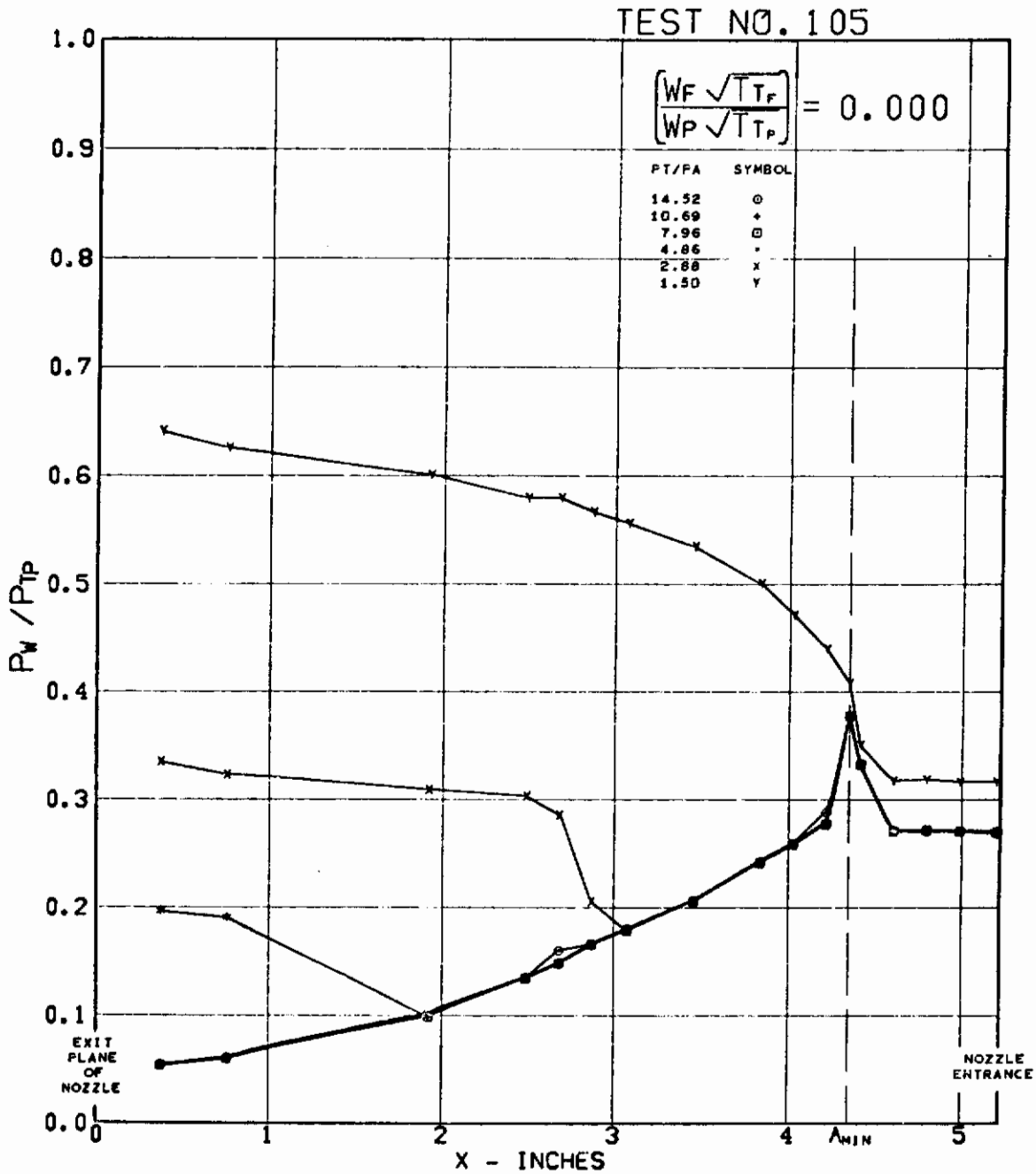


FIGURE 110. WALL PRESSURES - CONFIGURATION 05 AT 0.000 FAN FLOW RATIO $(W_F\sqrt{T_{T_F}}/W_P\sqrt{T_{T_P}})$

Approved for Public Release

Contrails

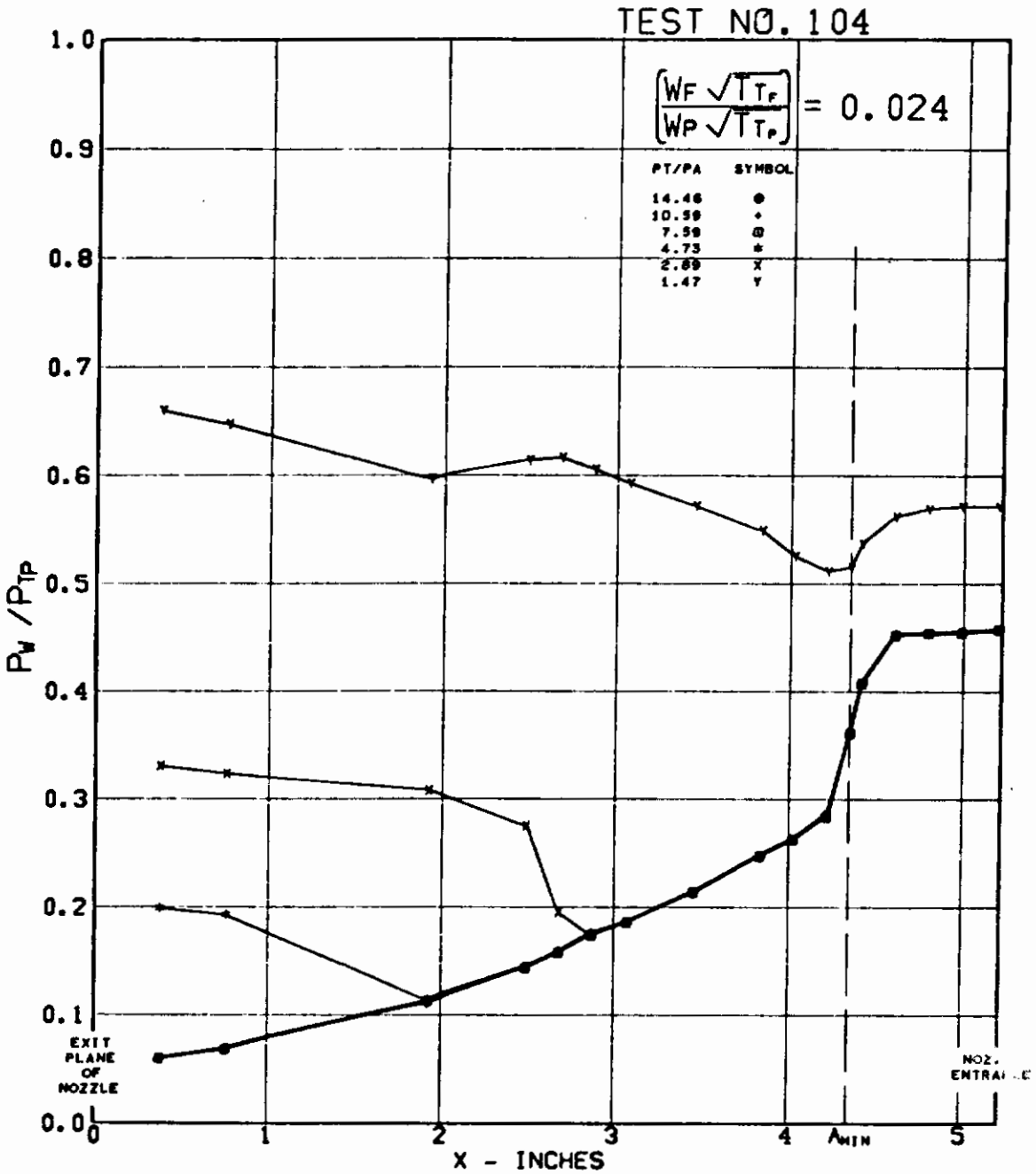


FIGURE III. WALL PRESSURES - CONFIGURATION 05 AT 0.024 FAN FLOW RATIO $(W_F\sqrt{T_{T_F}} / W_P\sqrt{T_{T_P}})$

Approved for Public Release

Contrails

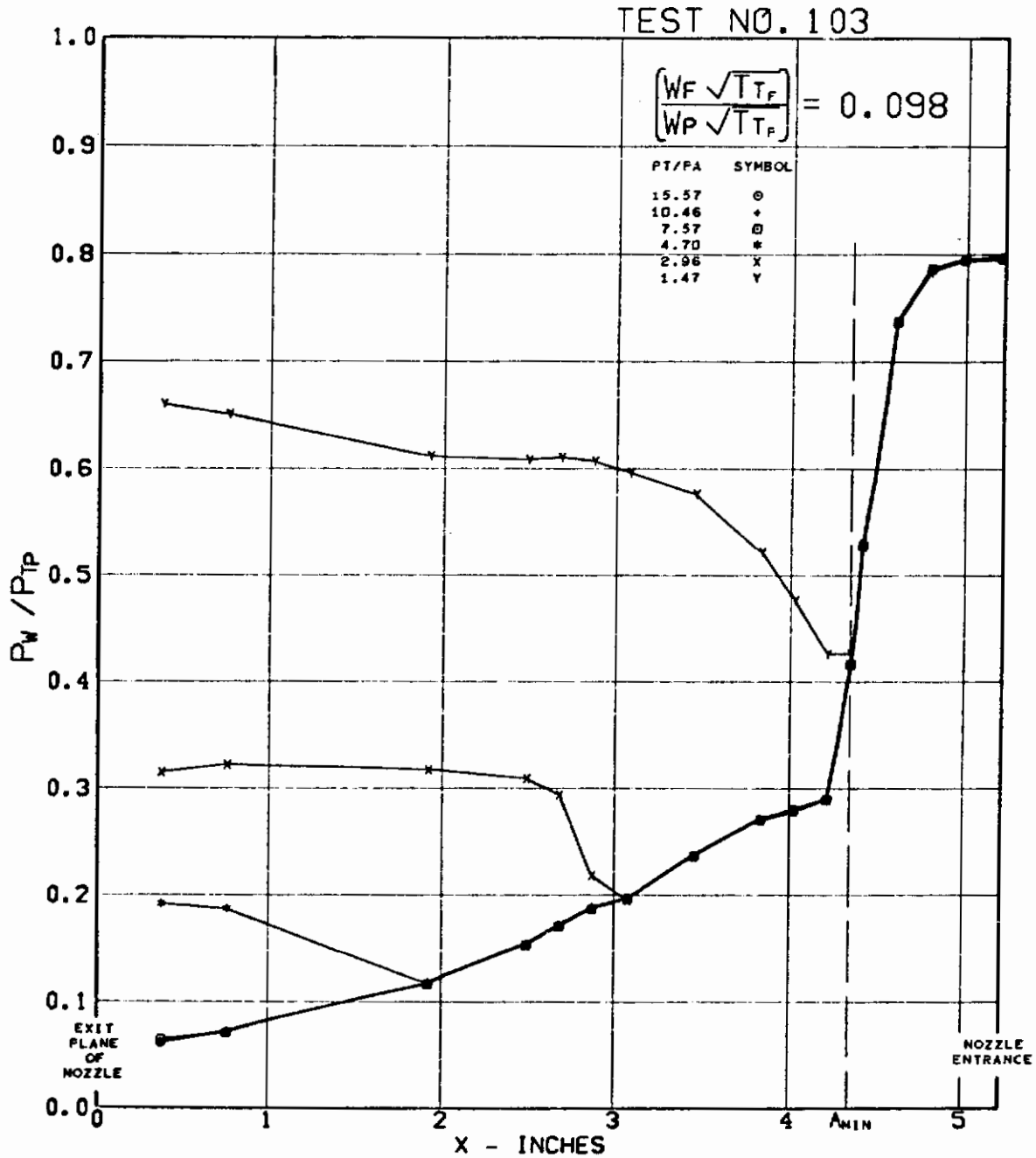


FIGURE 112. WALL PRESSURES - CONFIGURATION 05 AT 0.098 FAN FLOW RATIO $(W_F\sqrt{T_{T_F}}/W_P\sqrt{T_{T_P}})$

Approved for Public Release

Contrails

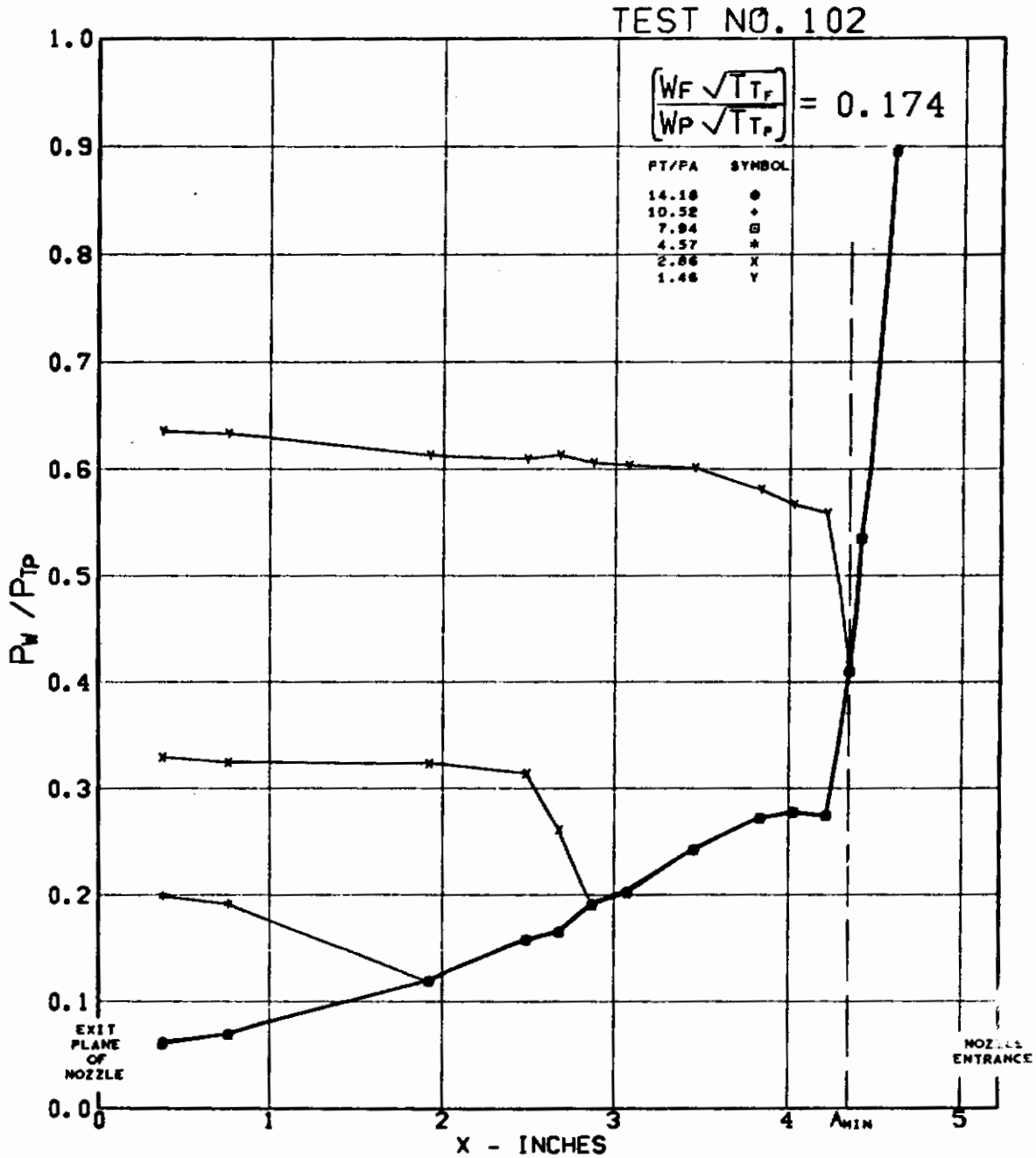


FIGURE 113. WALL PRESSURES - CONFIGURATION 05 AT 0.174 FAN FLOW RATIO $(W_F\sqrt{T_{T_F}}/W_P\sqrt{T_{T_P}})$

Approved for Public Release

Contrails

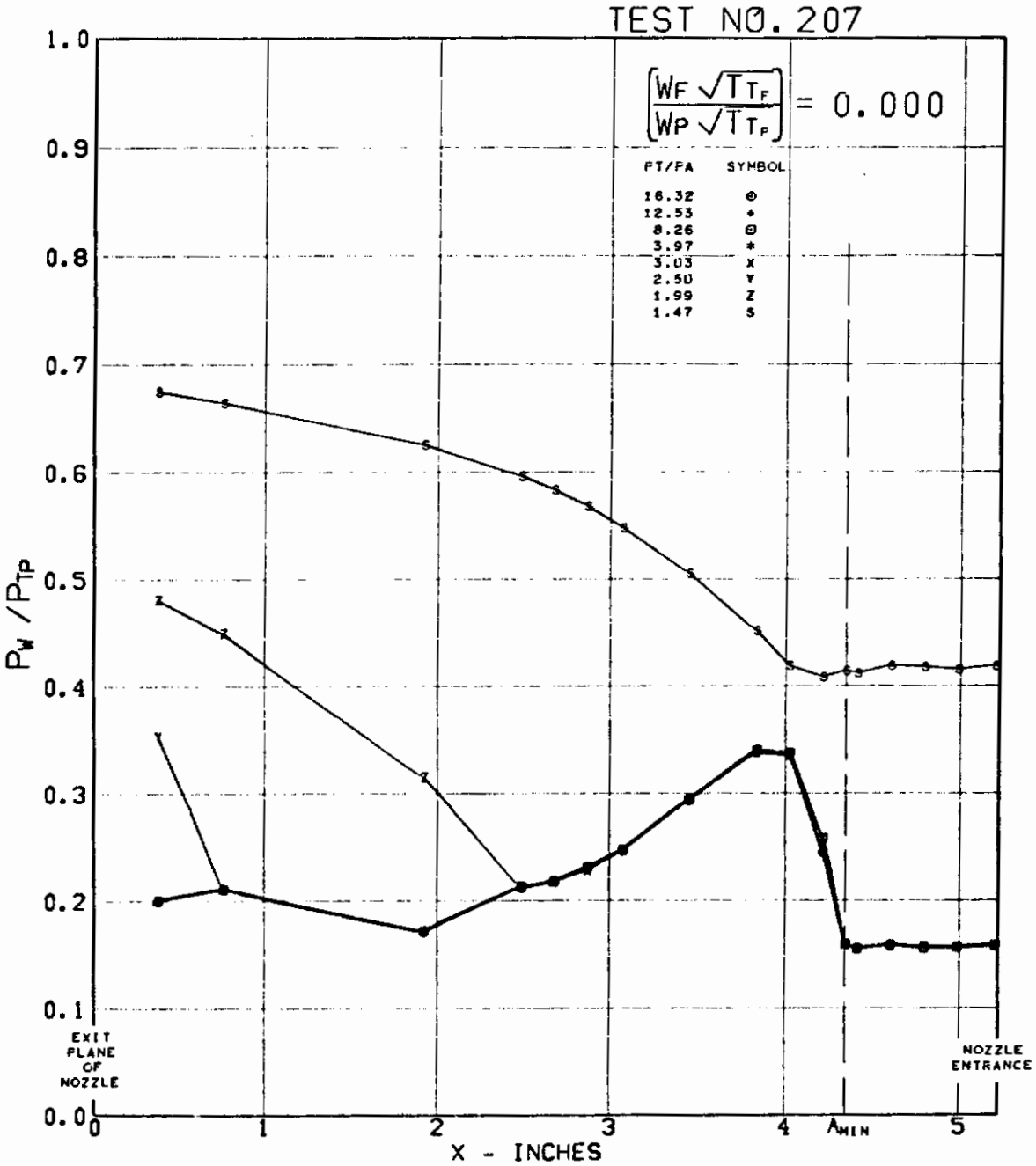


FIGURE 114. WALL PRESSURES - CONFIGURATION 06 AT 0.000 FAN FLOW RATIO ($W_F\sqrt{T_{T_F}}$ / $W_P\sqrt{T_{T_P}}$)

Approved for Public Release

Contrails

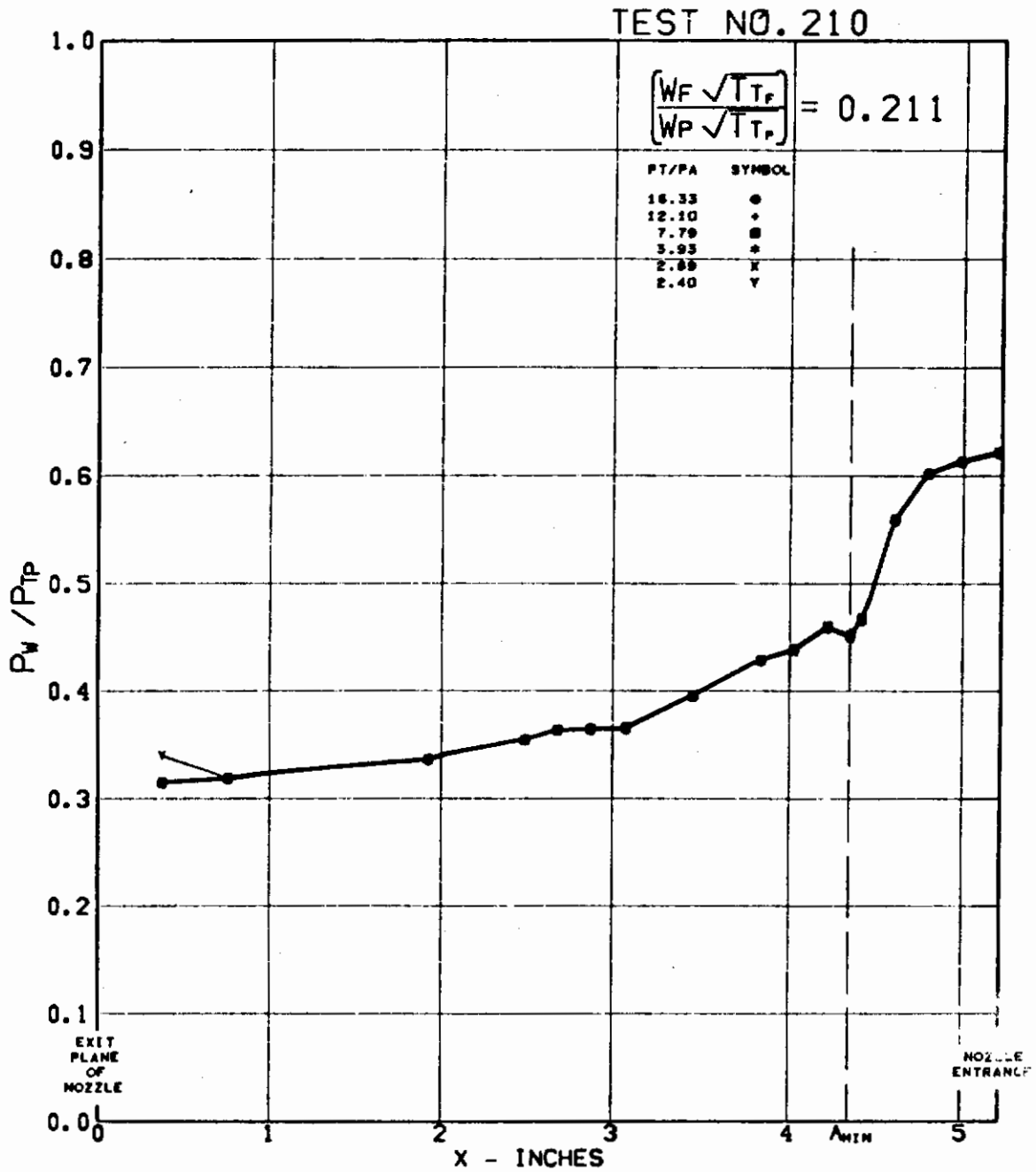


FIGURE 115. WALL PRESSURES - CONFIGURATION 06 AT 0.211 FAN FLOW RATIO $(W_F\sqrt{T_{T_F}}/W_P\sqrt{T_{T_P}})$

Approved for Public Release

Contrails

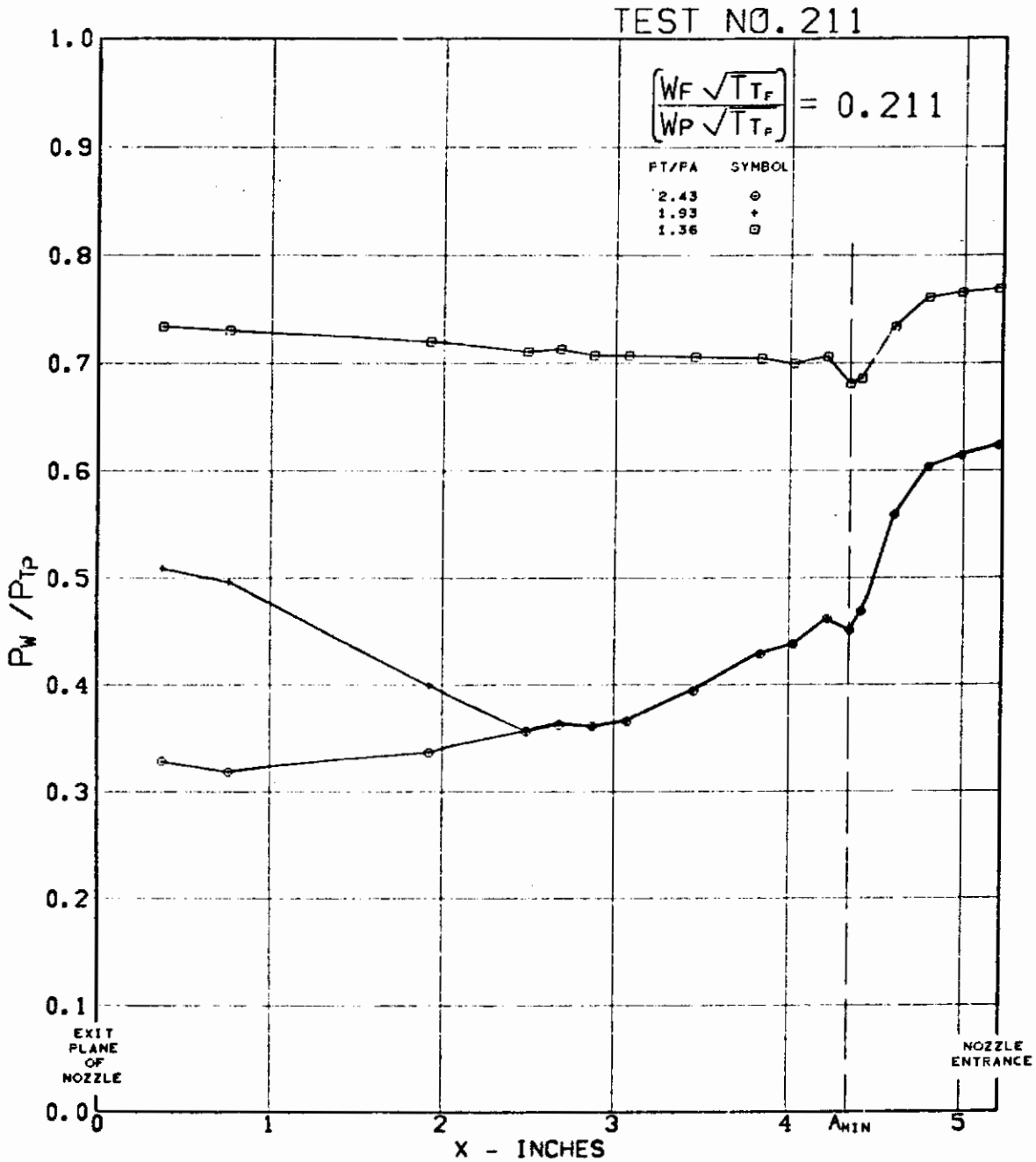


FIGURE 116. WALL PRESSURES - CONFIGURATION 06 AT 0.211 FAN FLOW RATIO $(W_F\sqrt{T_{T_F}} / W_P\sqrt{T_{T_P}})$

Approved for Public Release

Contrails

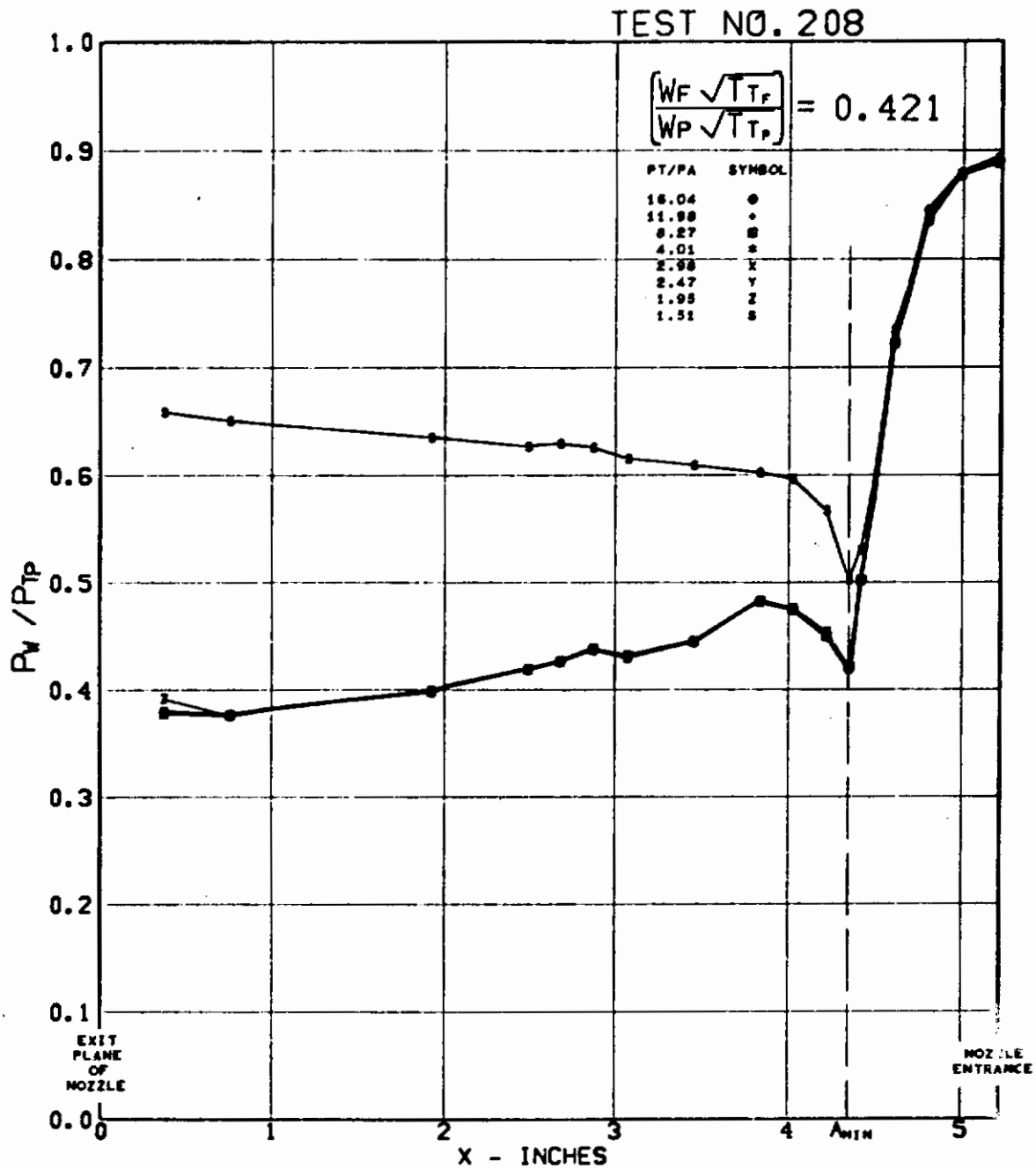


FIGURE 117. WALL PRESSURES - CONFIGURATION 06 AT 0.421 FAN FLOW RATIO ($W_F\sqrt{T_{T_F}}/W_P\sqrt{T_{T_P}}$)

Approved for Public Release

Contrails

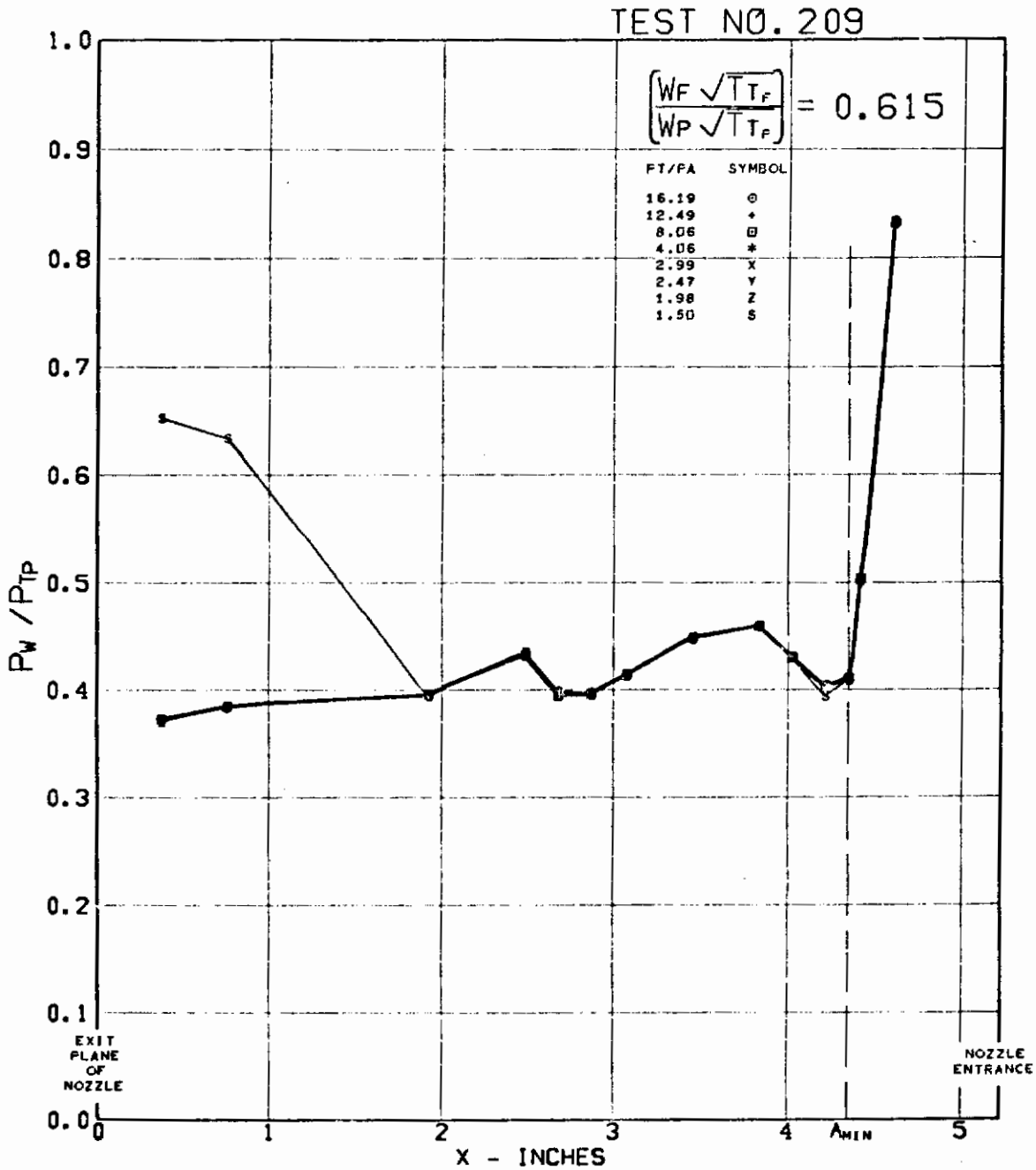


FIGURE 118. WALL PRESSURES - CONFIGURATION 06 AT 0.615 FAN FLOW RATIO $(W_F\sqrt{T_{T_F}} / W_P\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

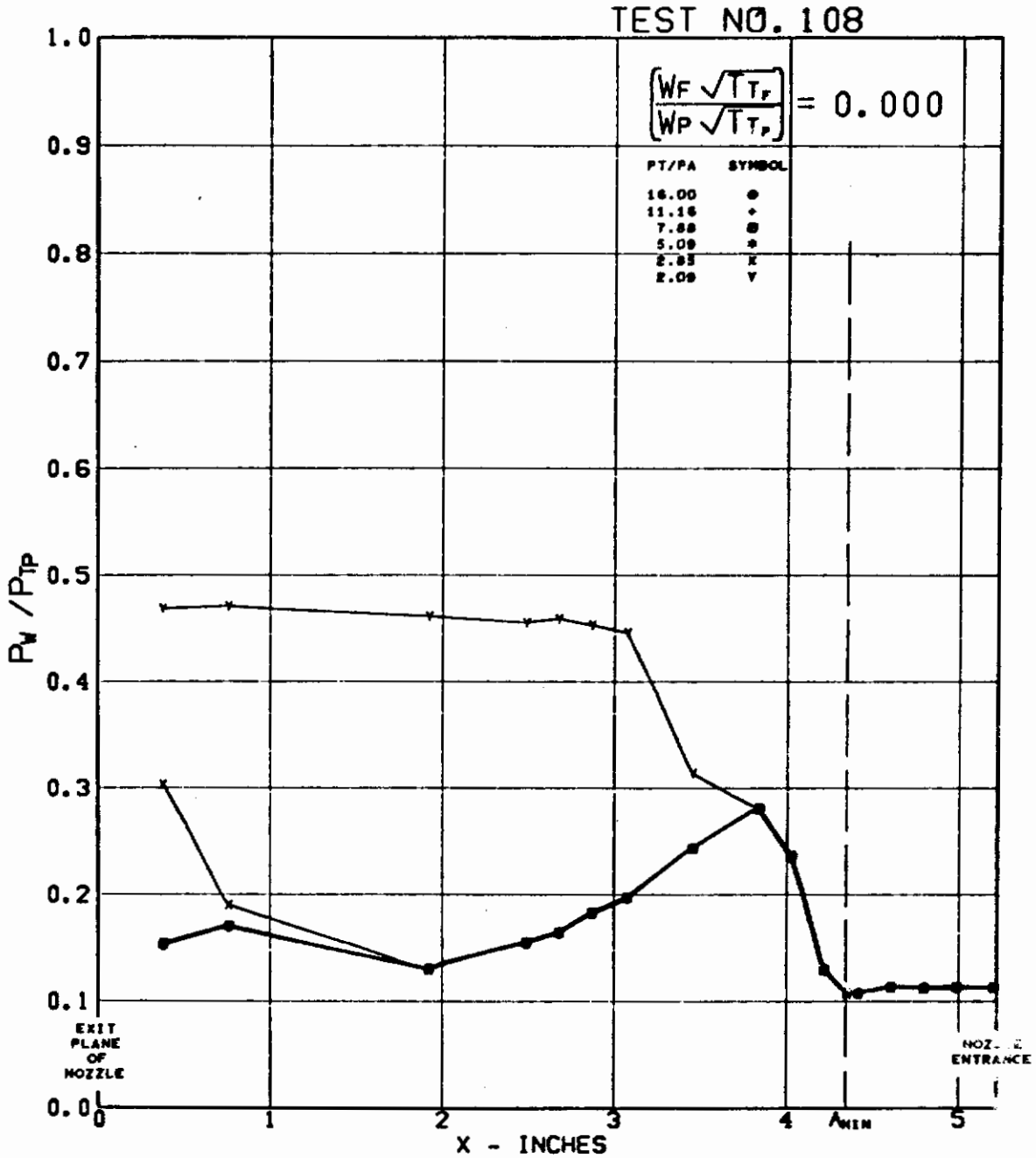


FIGURE 119. WALL PRESSURES - CONFIGURATION 10 AT 0.000 FAN FLOW RATIO $(W_F\sqrt{T_{T_F}}/W_P\sqrt{T_{T_P}})$

Approved for Public Release

Contrails

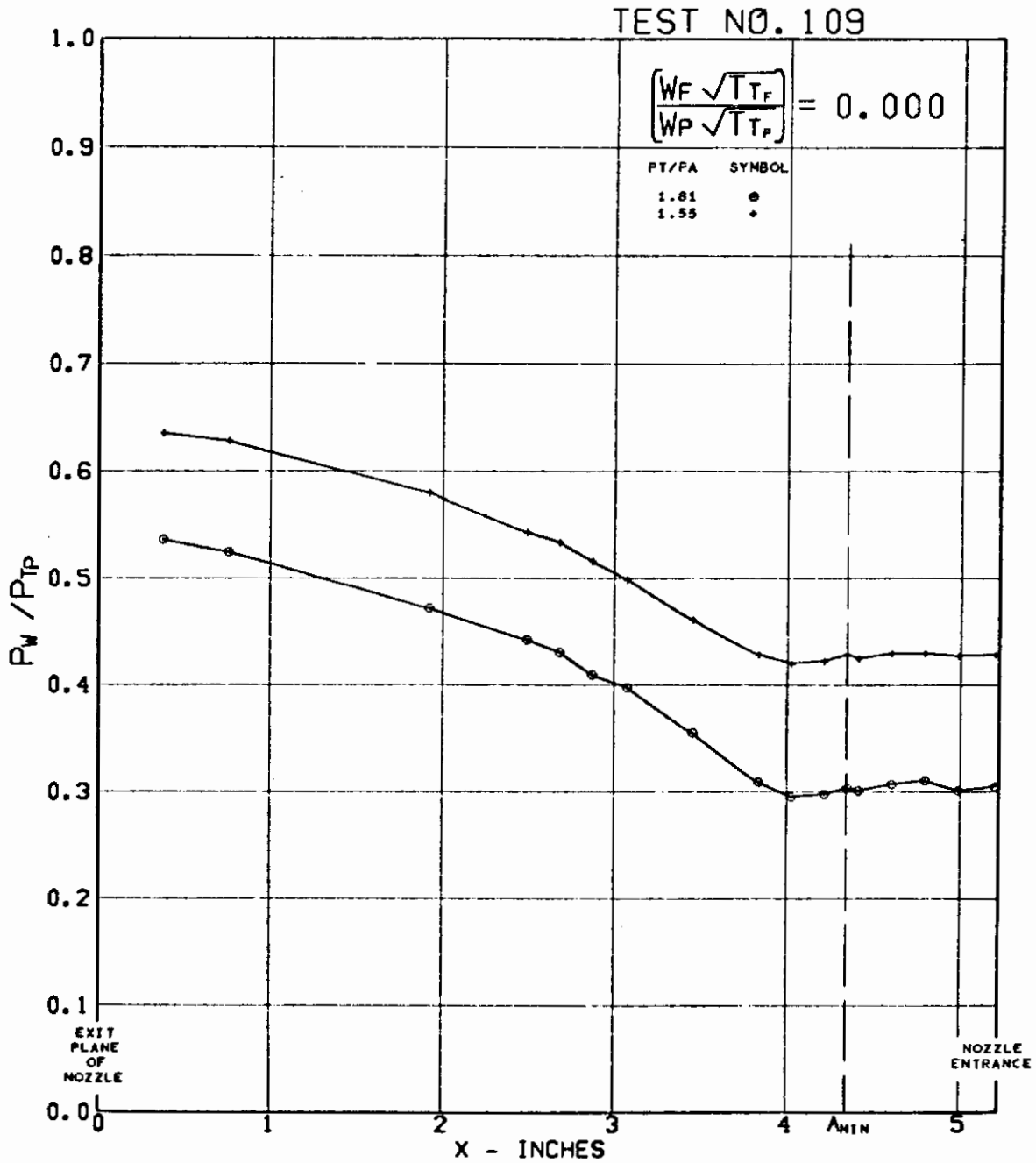


FIGURE 120. WALL PRESSURES - CONFIGURATION 10 AT 0.000 FAN FLOW RATIO $(W_F\sqrt{T_{T_F}} / W_P\sqrt{T_{T_P}})$

Approved for Public Release

Contrails

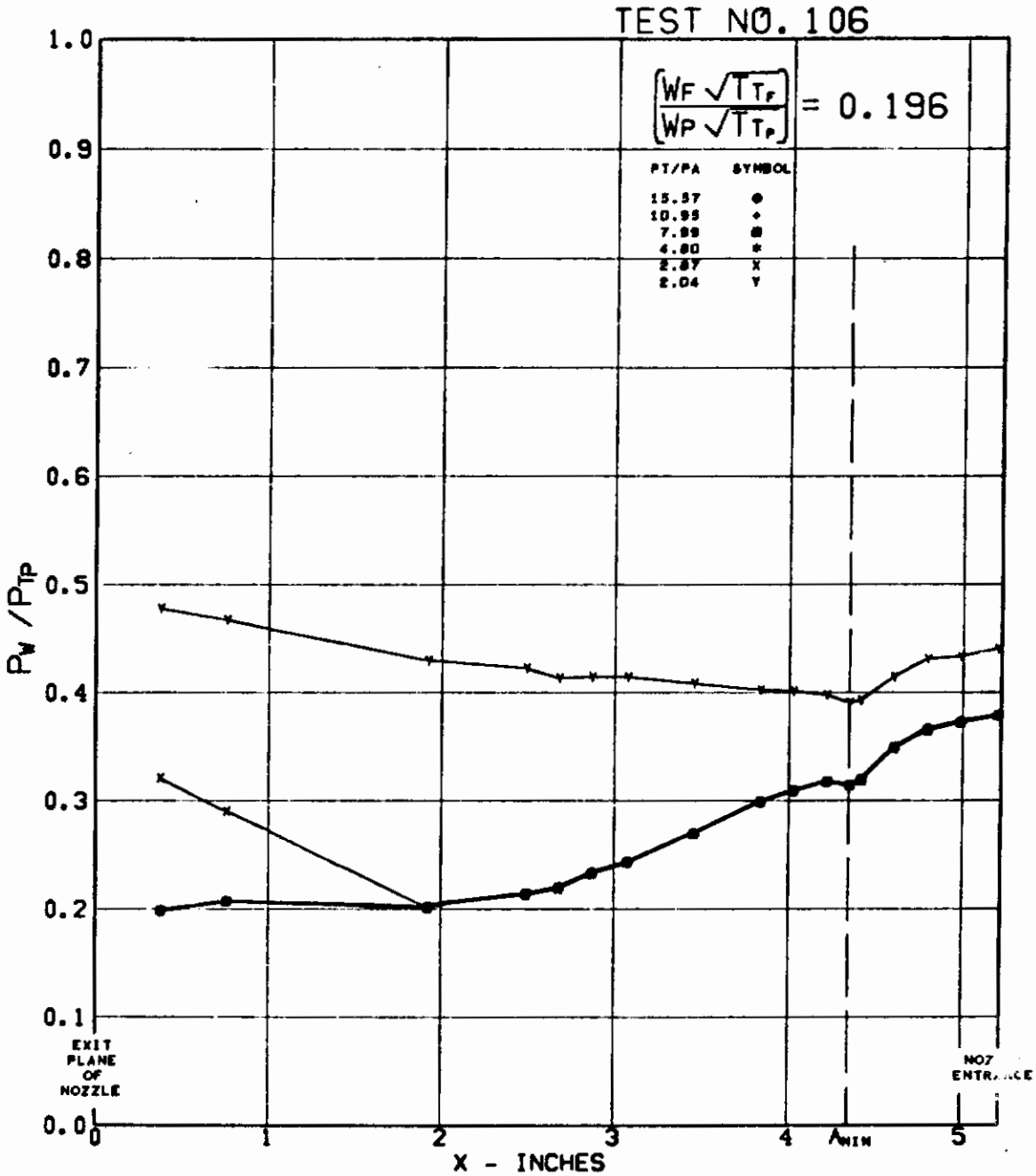


FIGURE 121. WALL PRESSURES - CONFIGURATION 10 AT 0.196 FAN FLOW RATIO $(W_F\sqrt{T_{T_F}} / W_P\sqrt{T_{T_P}})$

Approved for Public Release

Contrails

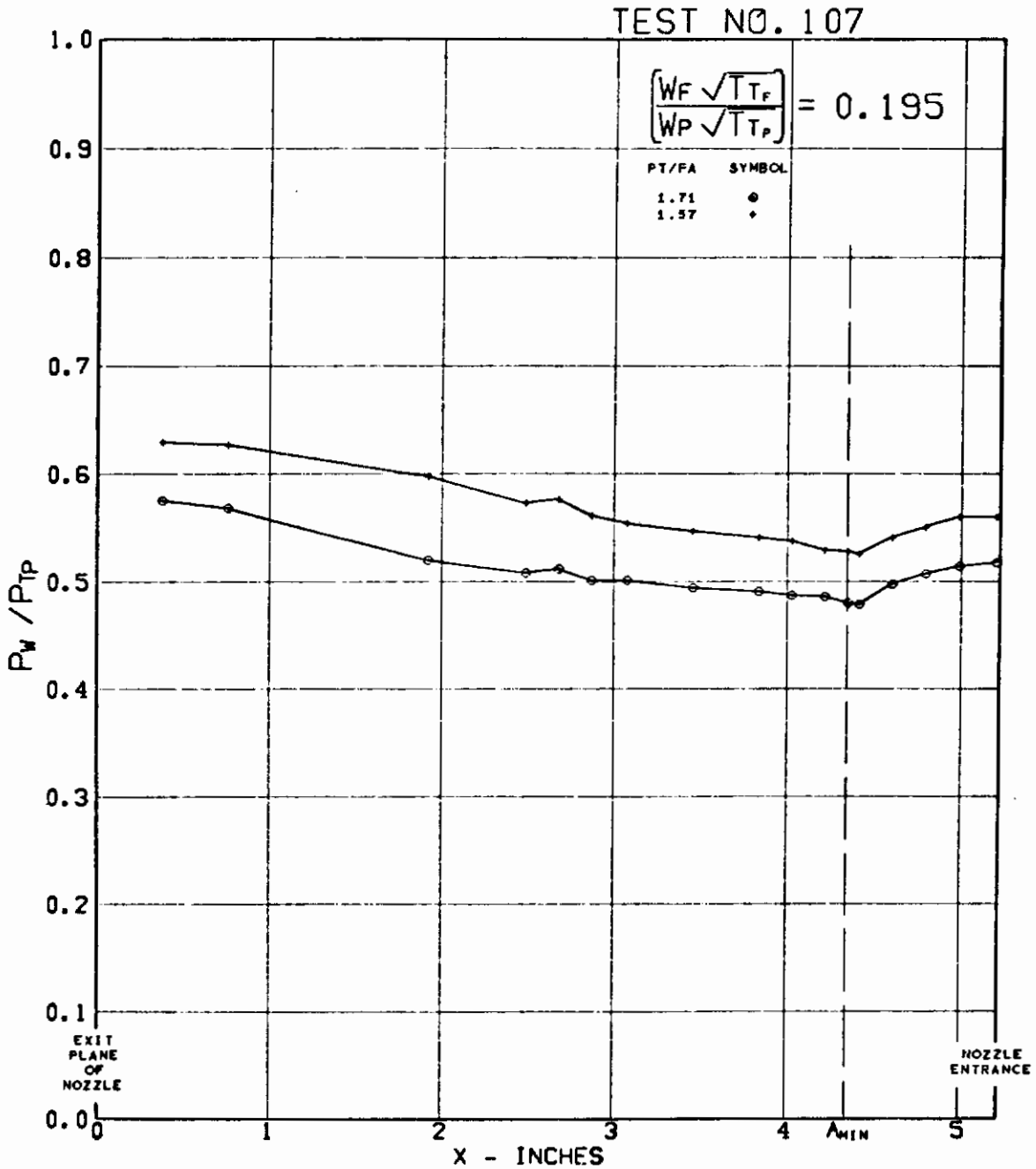


FIGURE 122. WALL PRESSURES - CONFIGURATION 10 AT 0.195 FAN FLOW RATIO $(W_F\sqrt{T_{T_F}} / W_P\sqrt{T_{T_P}})$

Approved for Public Release

Contrails

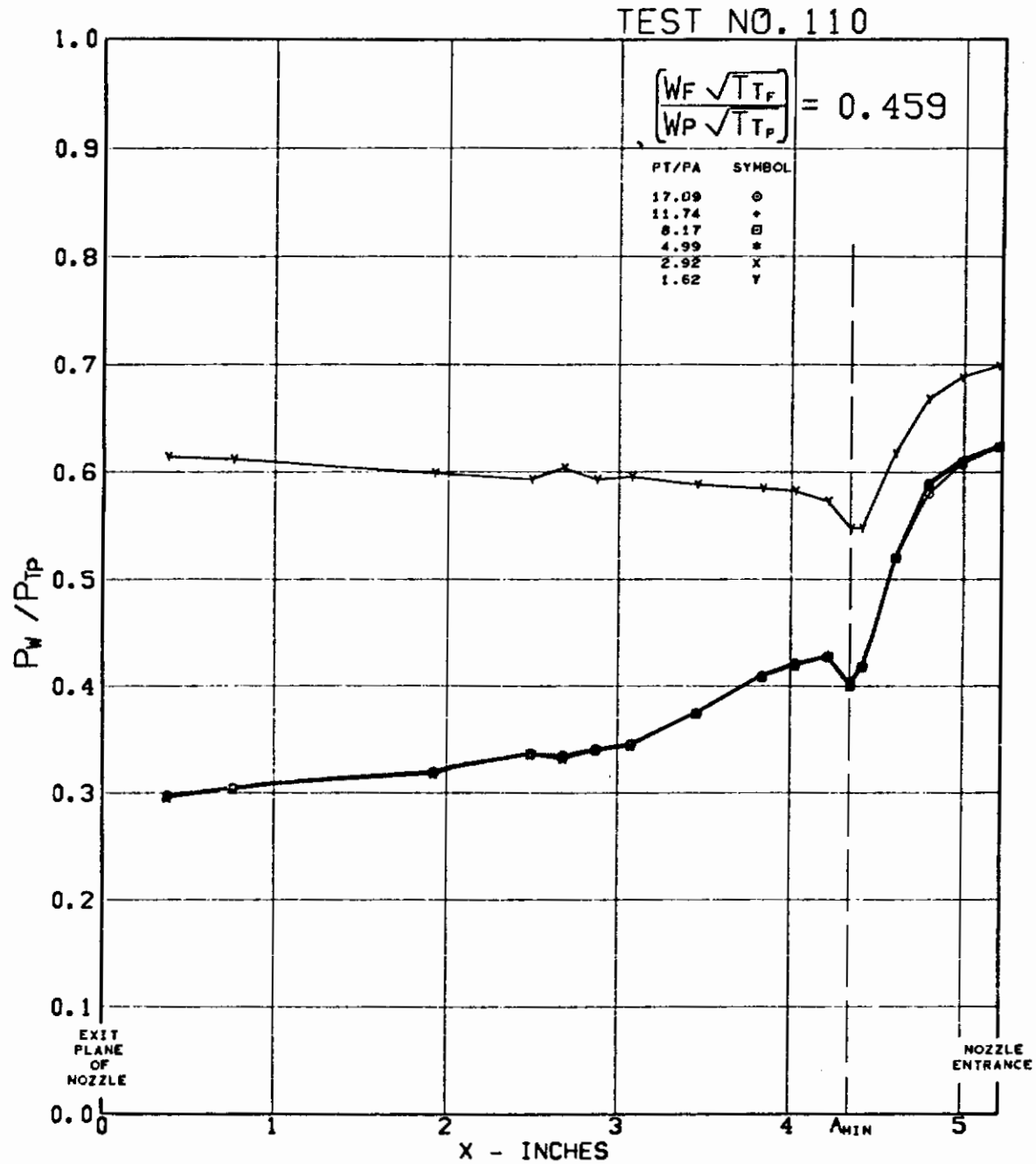


FIGURE 123. WALL PRESSURES - CONFIGURATION 10 AT 0.459 FAN FLOW RATIO $(W_F\sqrt{T_{T_F}}/W_P\sqrt{T_{T_P}})$

Approved for Public Release

Contrails

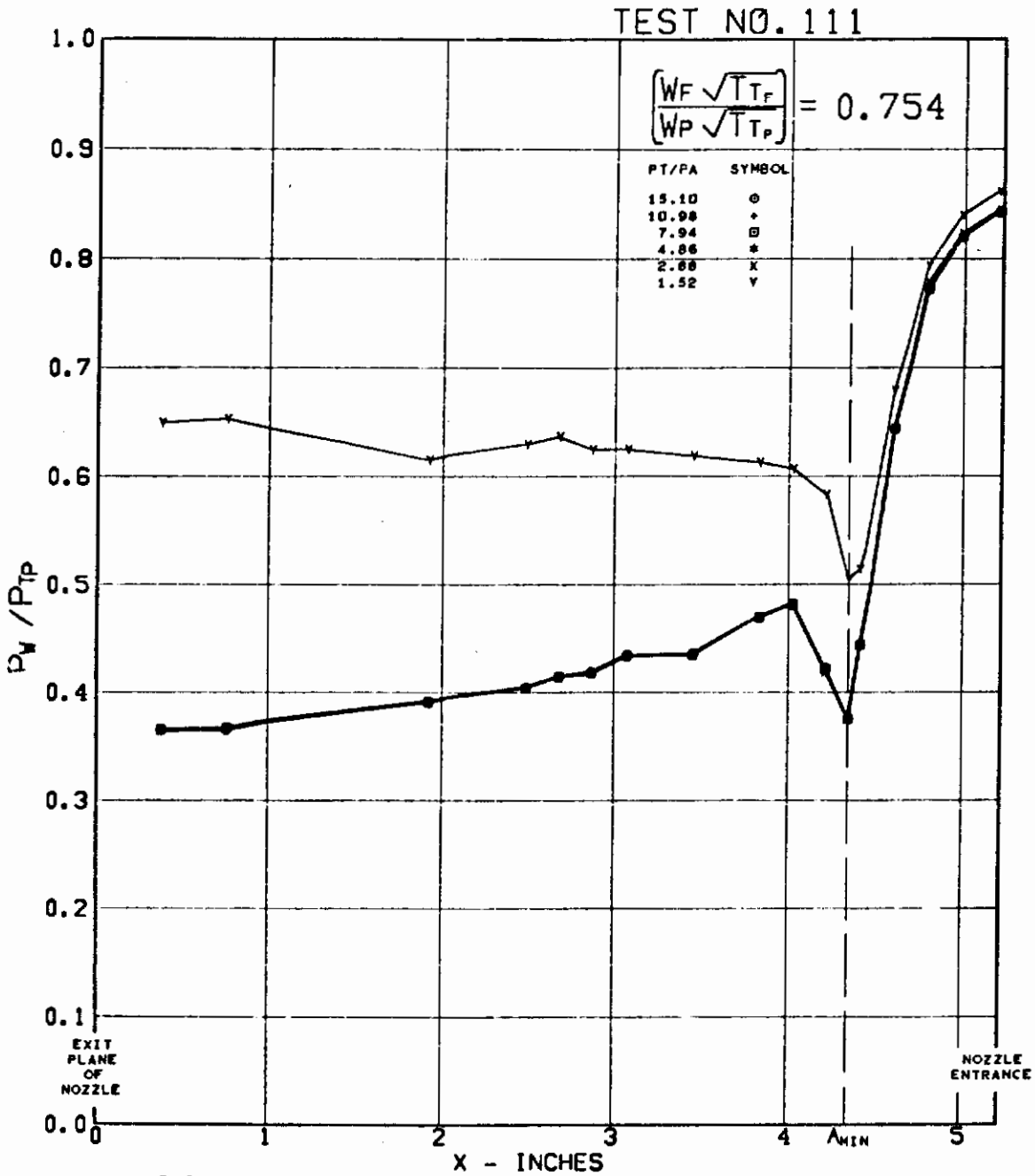


FIGURE 124. WALL PRESSURES - CONFIGURATION 10 AT 0.754 FAN FLOW RATIO $(W_F\sqrt{T_{T_F}}/W_P\sqrt{T_{T_P}})$

Approved for Public Release

Contrails

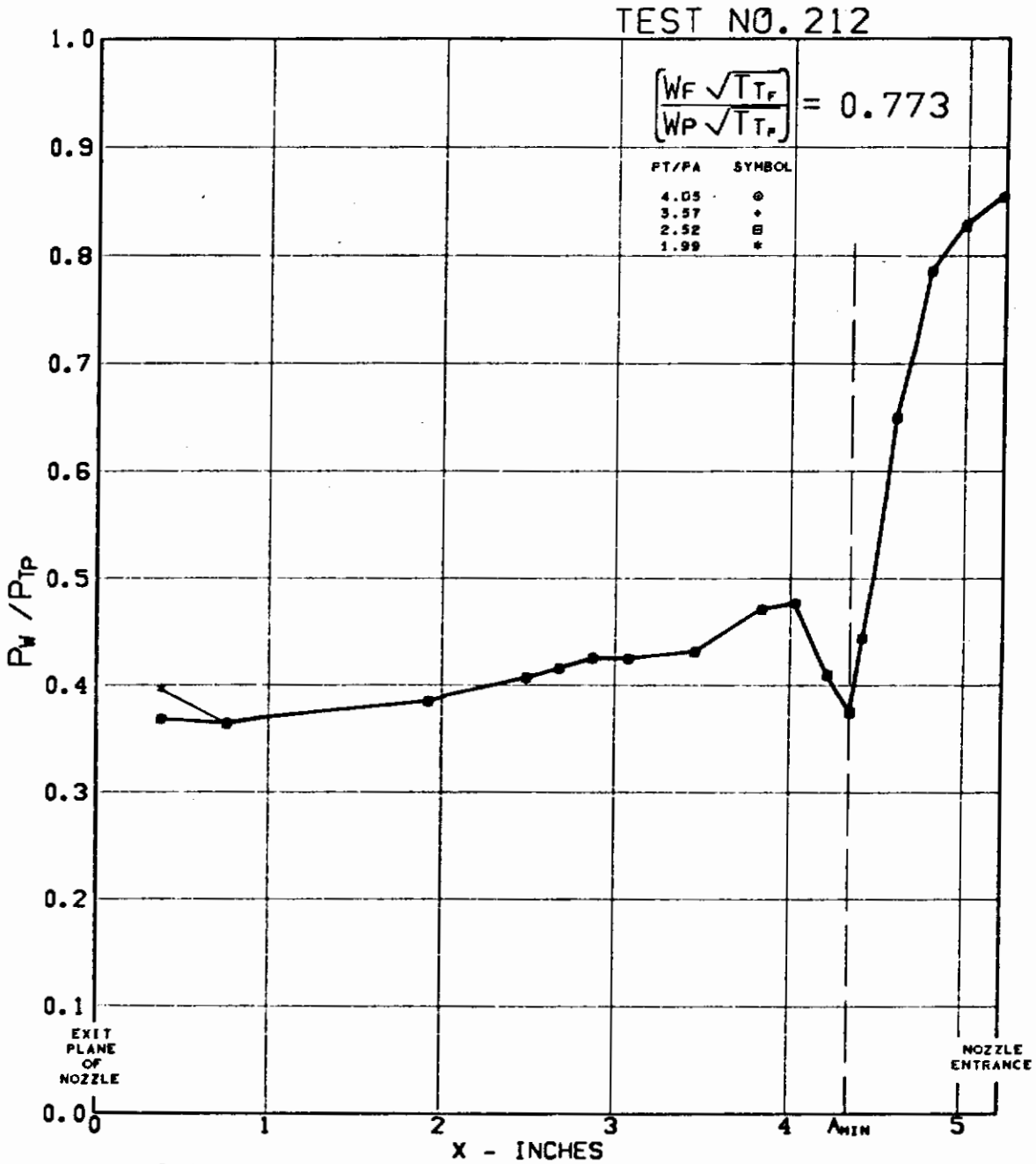


FIGURE 125. WALL PRESSURES - CONFIGURATION 10 AT 0.773 FAN FLOW RATIO $(W_F\sqrt{T_{T_F}}/W_P\sqrt{T_{T_P}})$

Approved for Public Release

Contrails

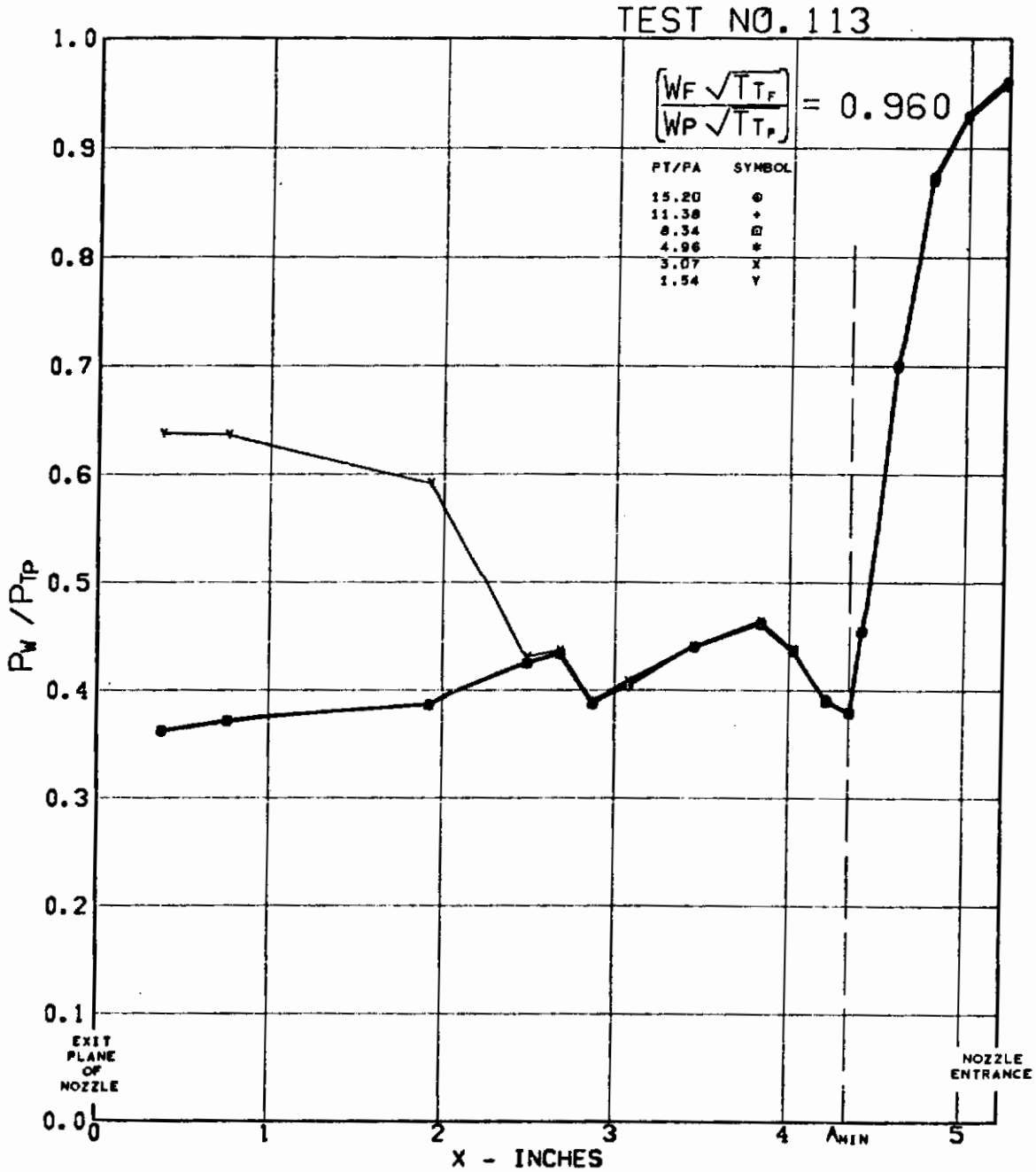


FIGURE 126. WALL PRESSURES - CONFIGURATION 10 AT 0.960 FAN FLOW RATIO $(W_F\sqrt{T_{T_F}}/W_P\sqrt{T_{T_P}})$

Approved for Public Release

Contrails

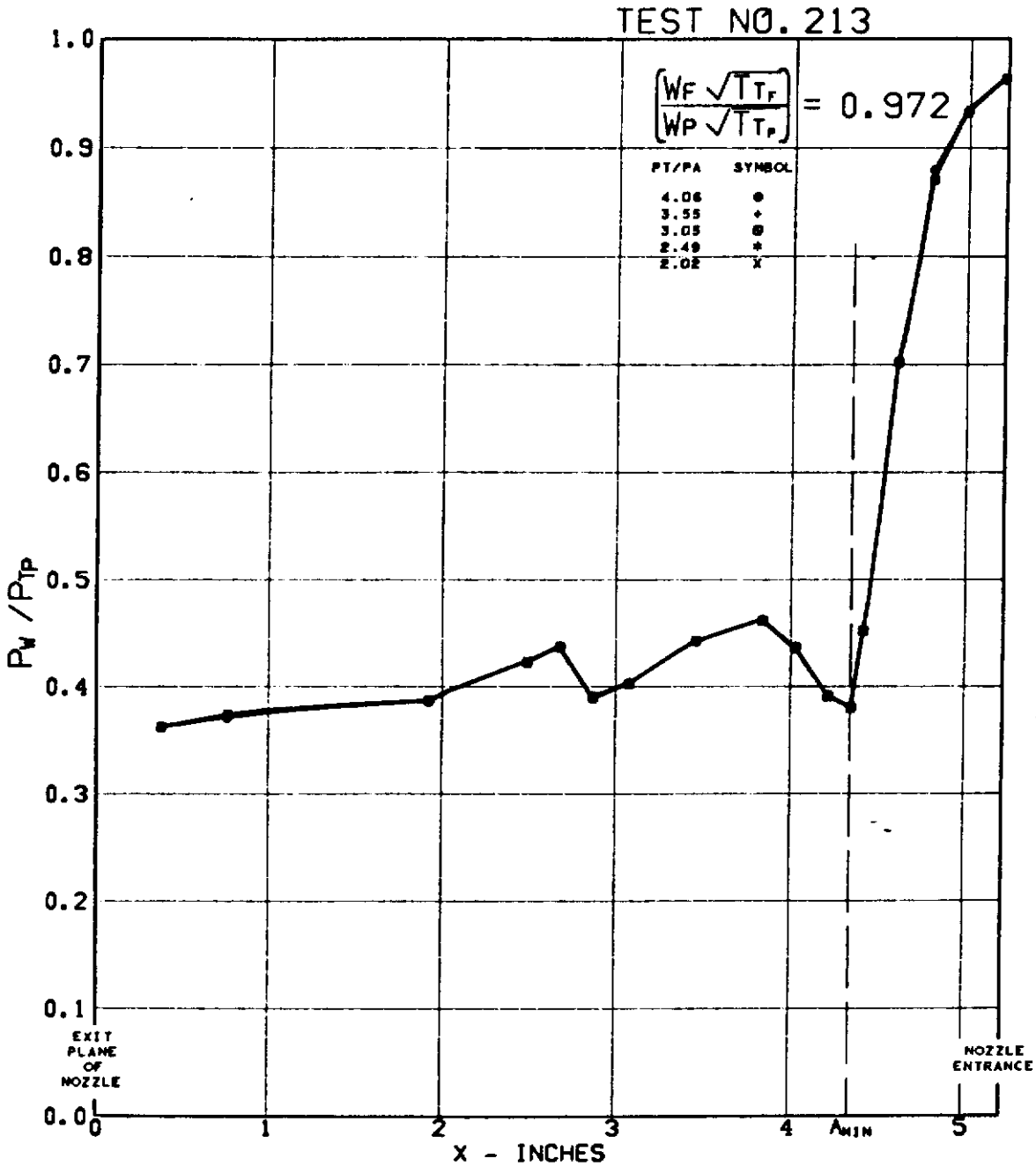


FIGURE 127. WALL PRESSURES - CONFIGURATION 10 AT 0.972 FAN FLOW RATIO $(W_F\sqrt{T_{T_F}}/W_P\sqrt{T_{T_P}})$

Approved for Public Release

Contrails

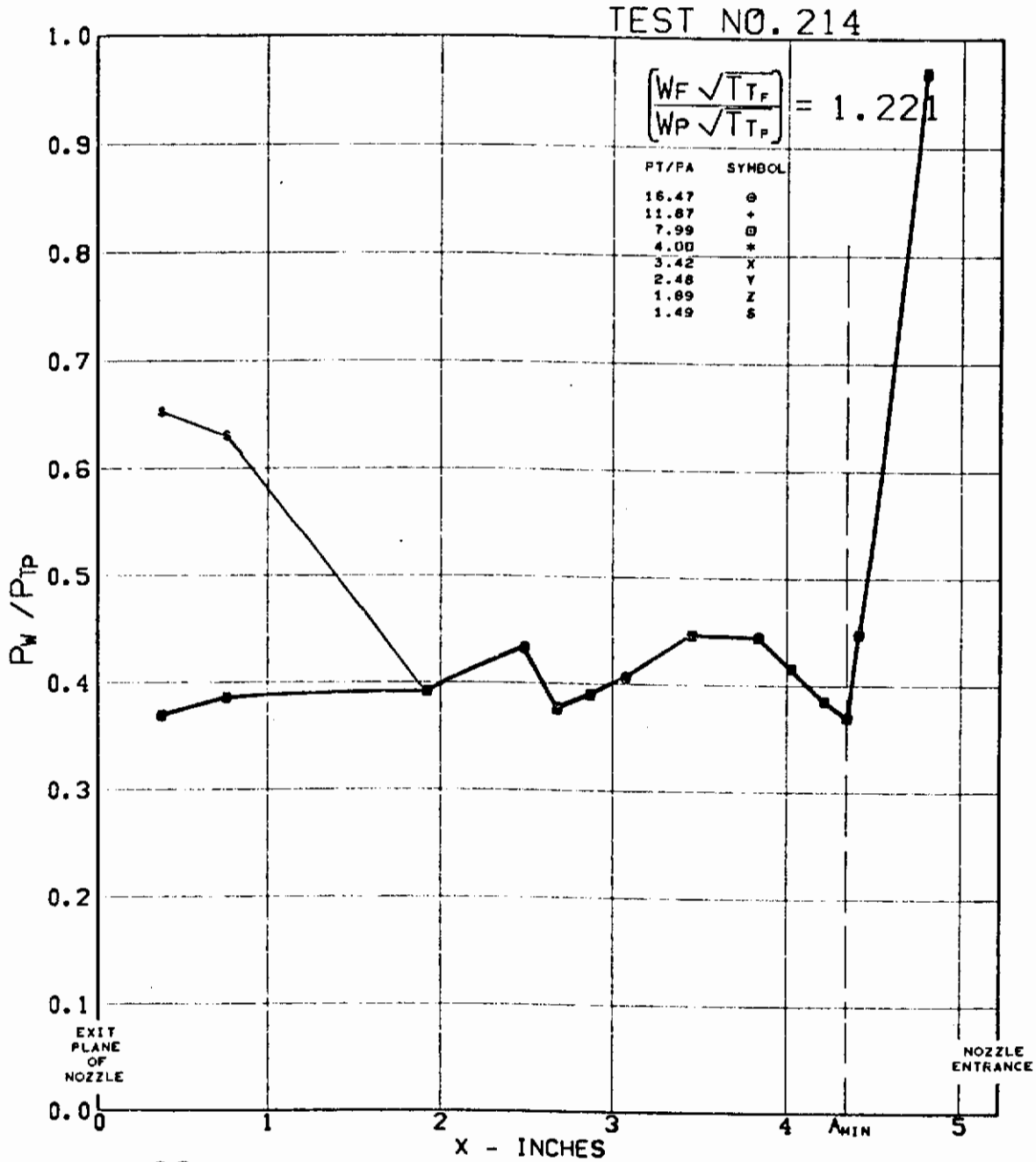


FIGURE 128. WALL PRESSURES - CONFIGURATION 10 AT 1.221 FAN FLOW RATIO $(W_F\sqrt{T_{T_F}}/W_P\sqrt{T_{T_P}})$

Approved for Public Release

Contrails

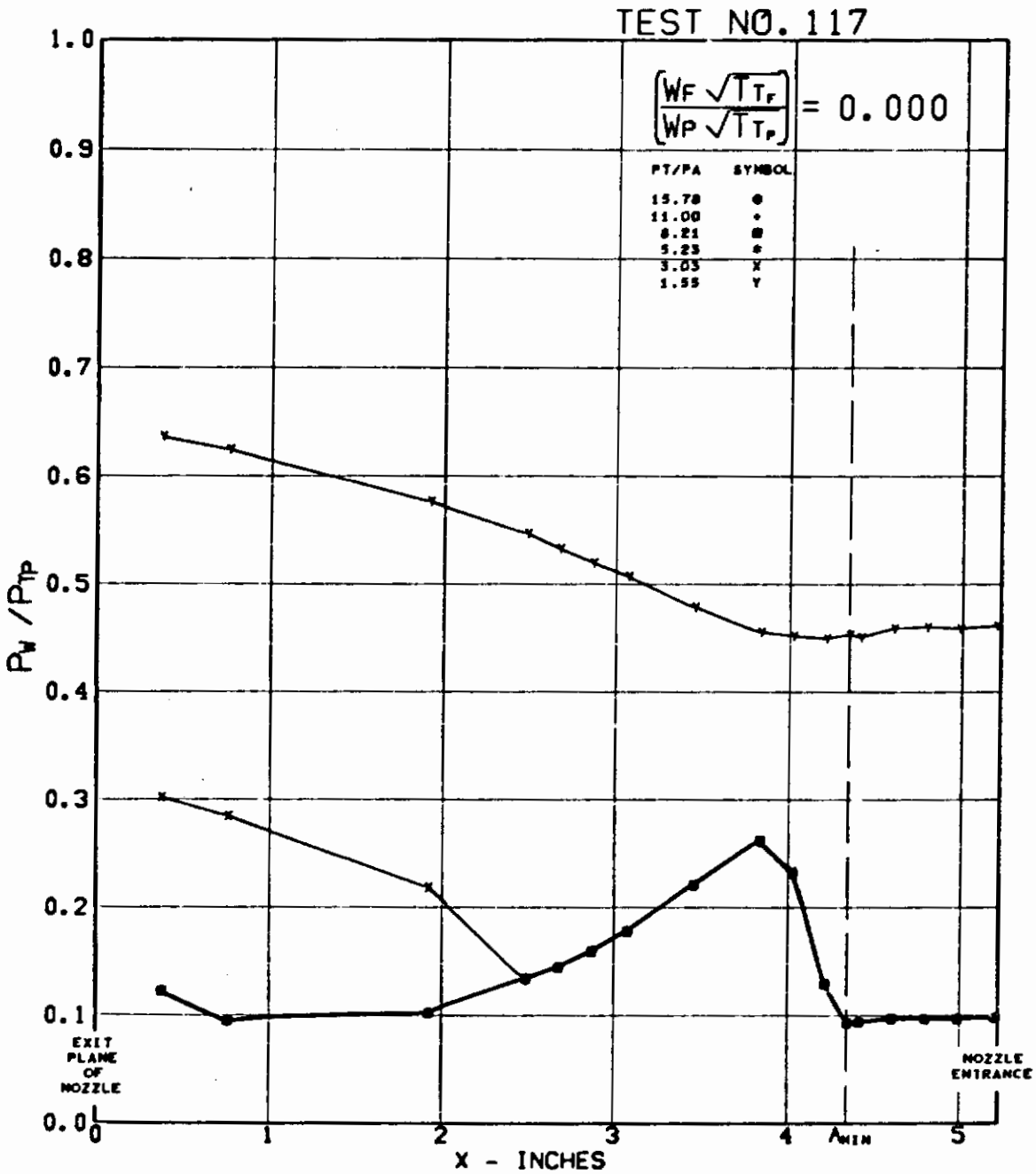


FIGURE 129. WALL PRESSURES - CONFIGURATION 11 AT 0.000 FAN FLOW RATIO $(W_F\sqrt{T_{T_F}} / W_P\sqrt{T_{T_P}})$

Approved for Public Release

Contrails

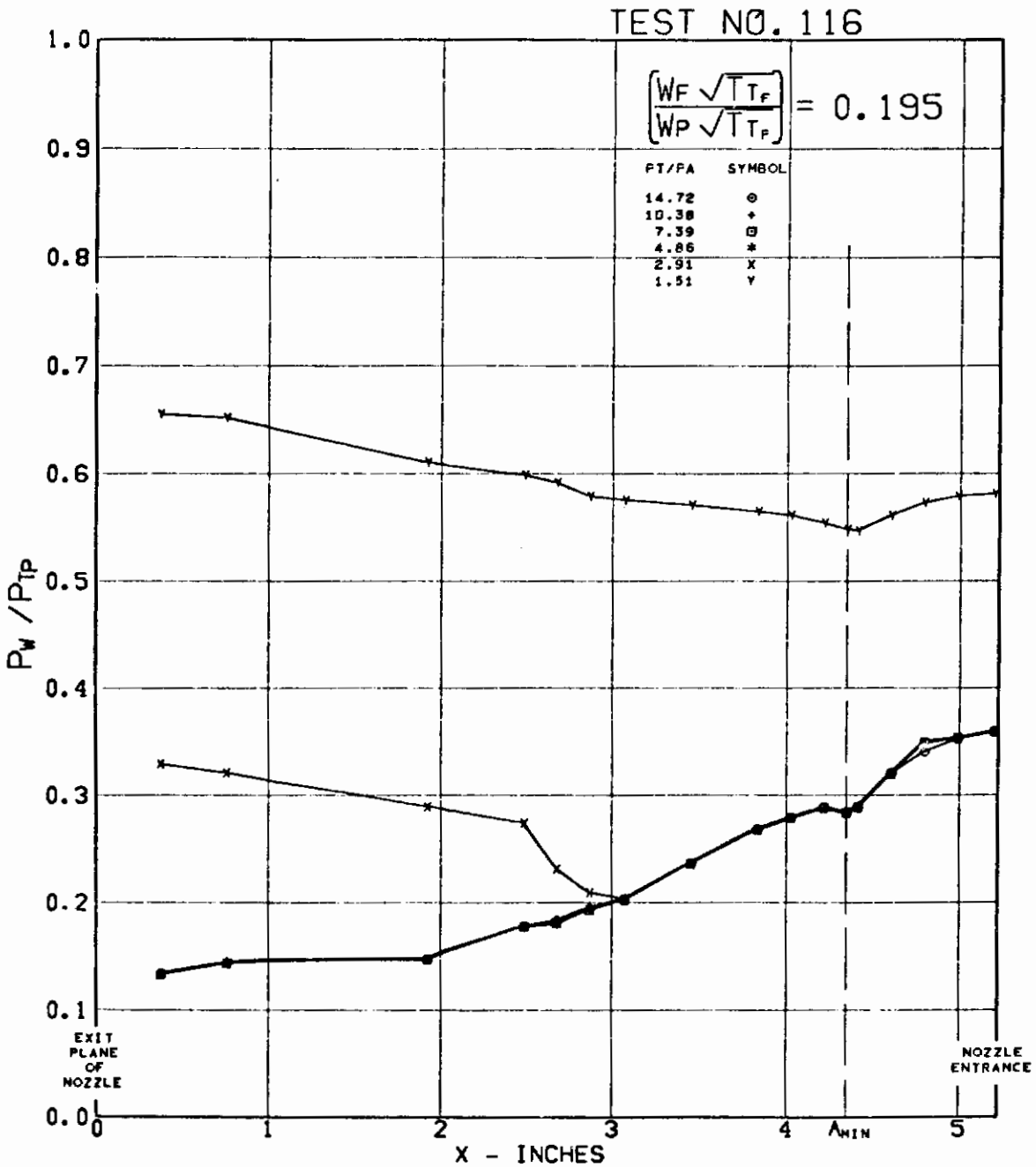


FIGURE 130. WALL PRESSURES - CONFIGURATION 11 AT 0.195 FAN FLOW RATIO $(W_F\sqrt{T_{T_F}} / W_P\sqrt{T_{T_P}})$

Approved for Public Release

Contrails

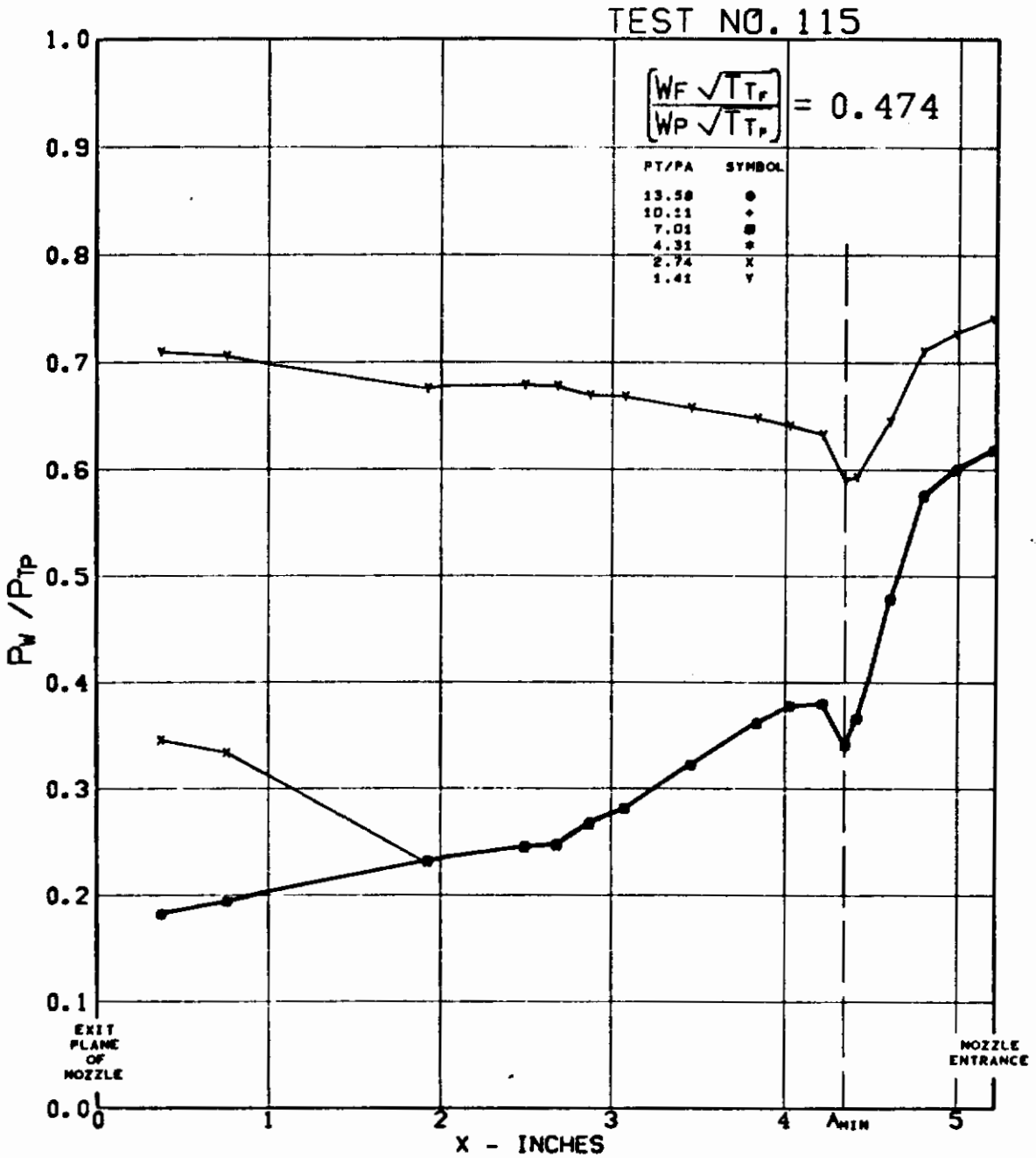


FIGURE 131. WALL PRESSURES - CONFIGURATION 11 AT 0.474 FAN FLOW RATIO $(W_F\sqrt{T_{T_F}} / W_P\sqrt{T_{T_P}})$

Approved for Public Release

Contrails

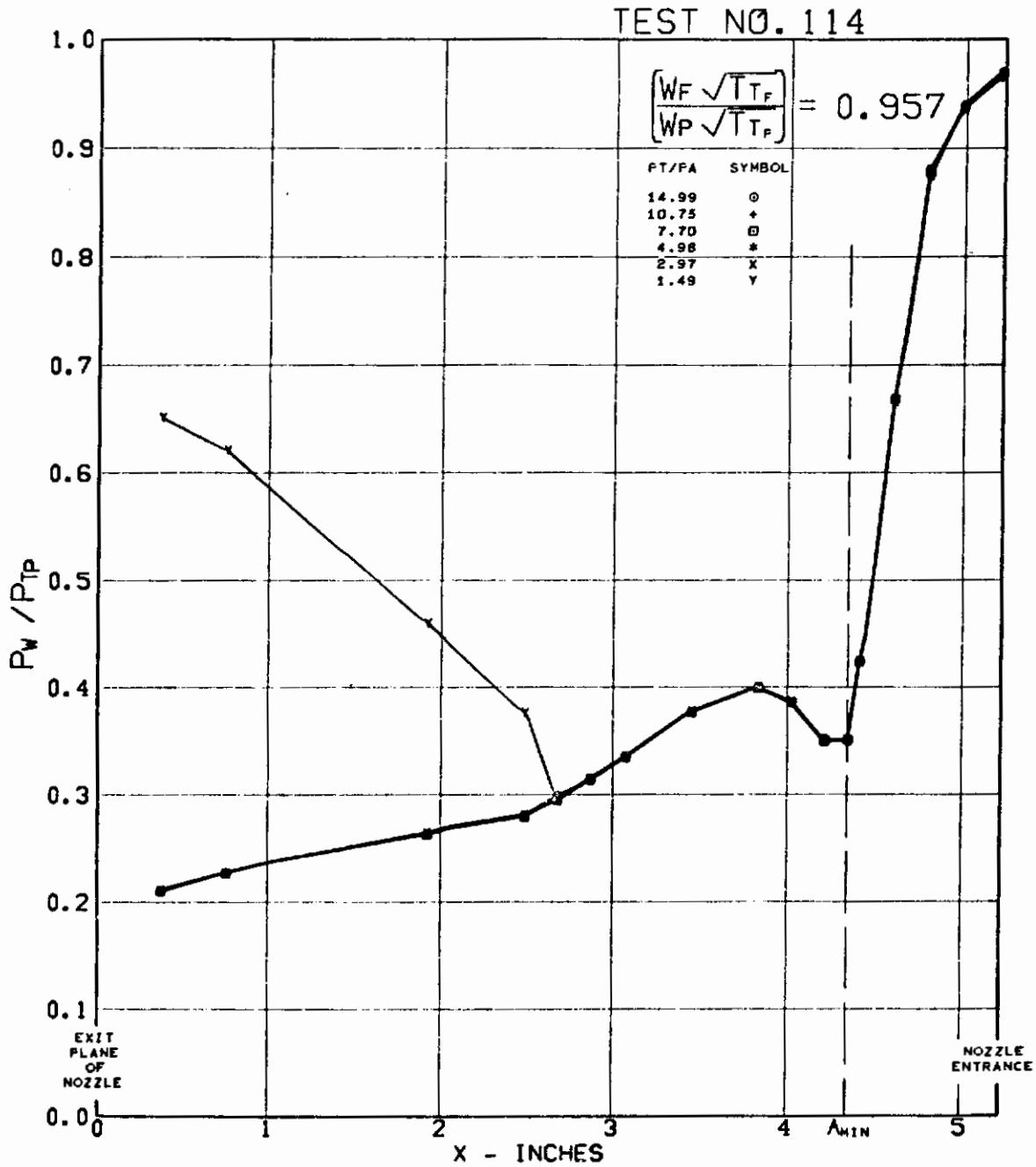


FIGURE 132. WALL PRESSURES - CONFIGURATION 11 AT 0.957 FAN FLOW RATIO $(W_F\sqrt{T_{T_F}} / W_P\sqrt{T_{T_P}})$

Approved for Public Release

Contrails

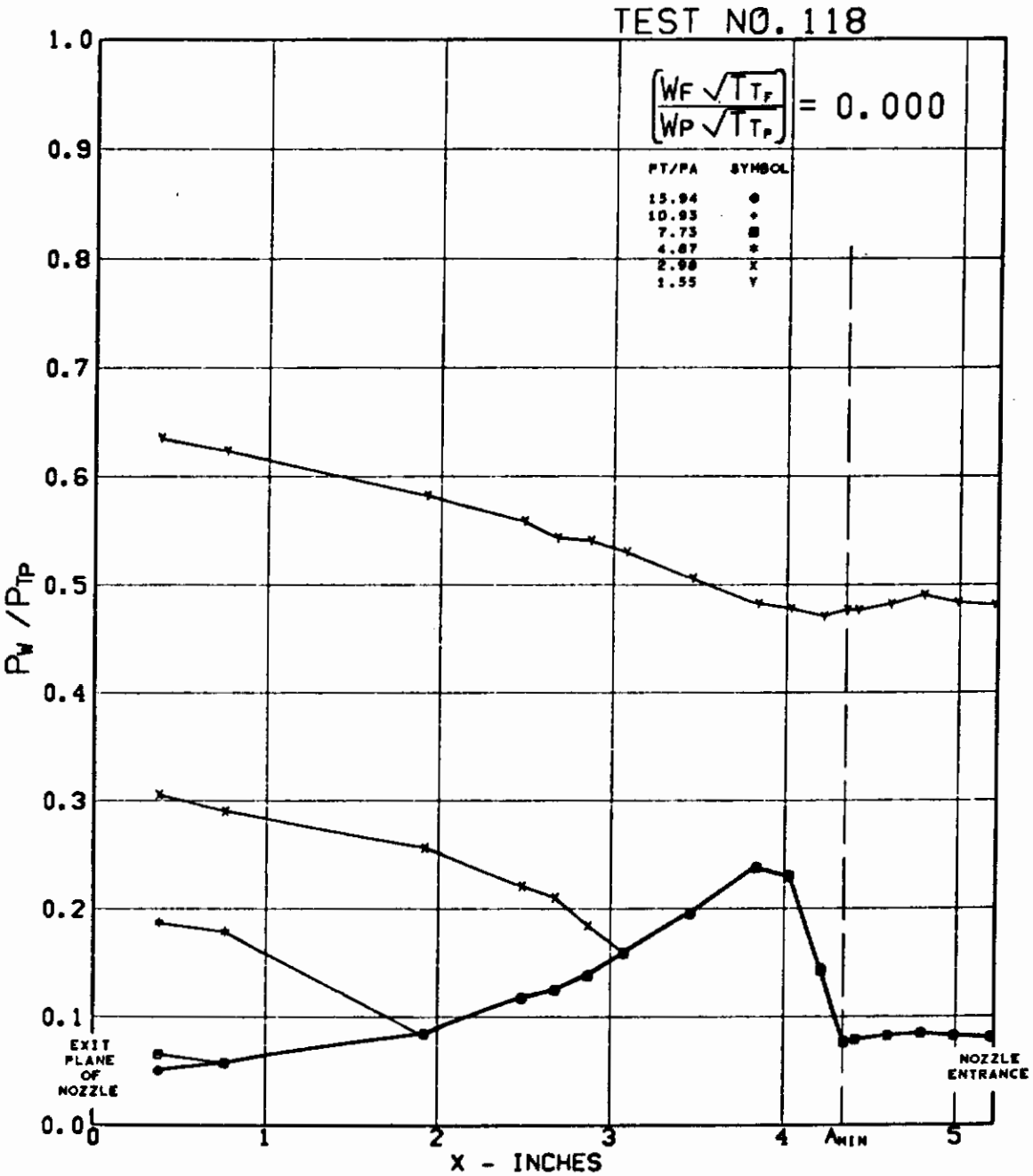


FIGURE 133. WALL PRESSURES - CONFIGURATION 12 AT 0.000 FAN FLOW RATIO $(W_F\sqrt{T_{T_F}} / W_P\sqrt{T_{T_P}})$

Approved for Public Release

Contrails

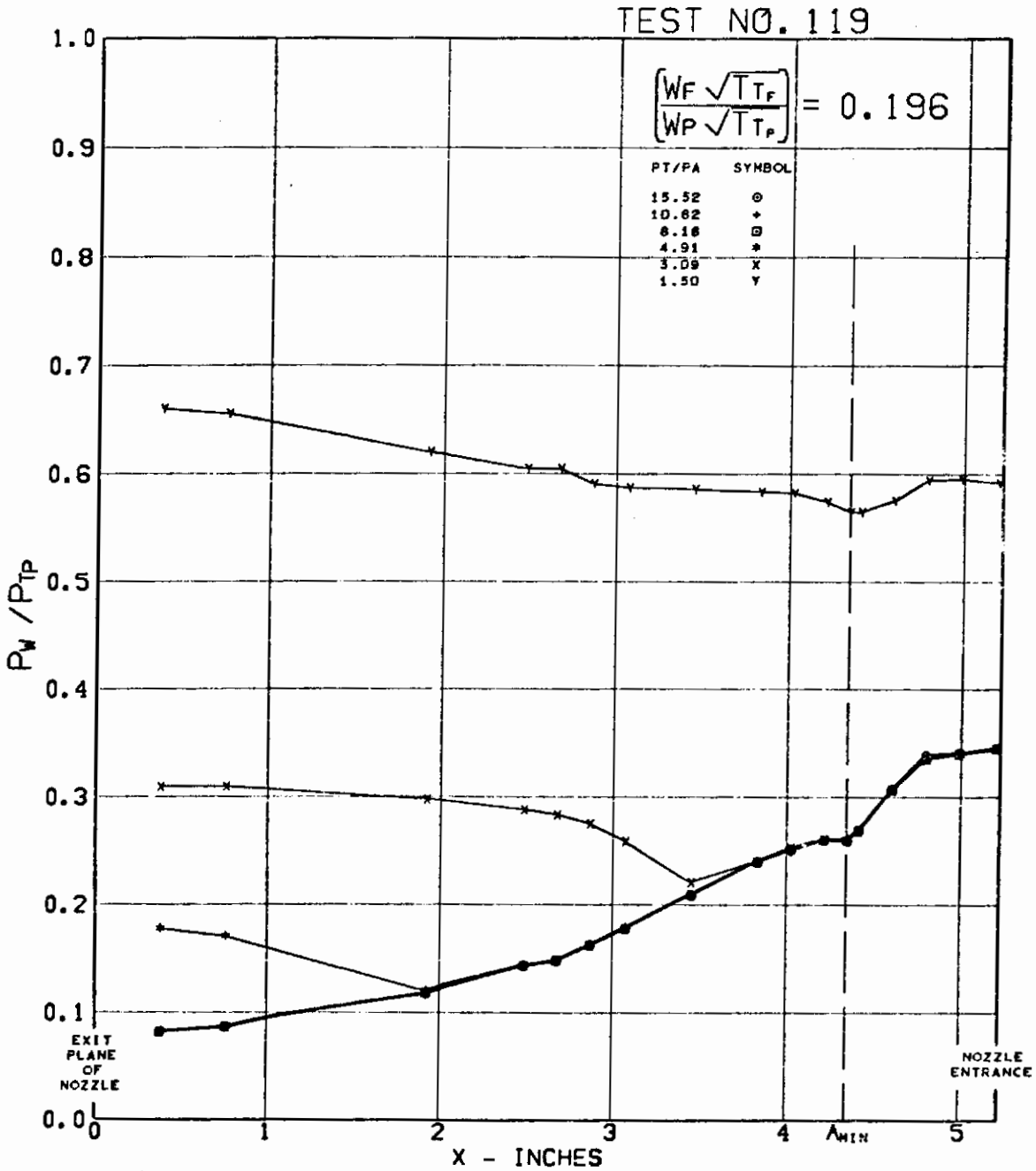


FIGURE 134. WALL PRESSURES - CONFIGURATION 12 AT 0.196 FAN FLOW RATIO $(W_F\sqrt{T_{T_F}}/W_P\sqrt{T_{T_P}})$

Approved for Public Release

Contrails

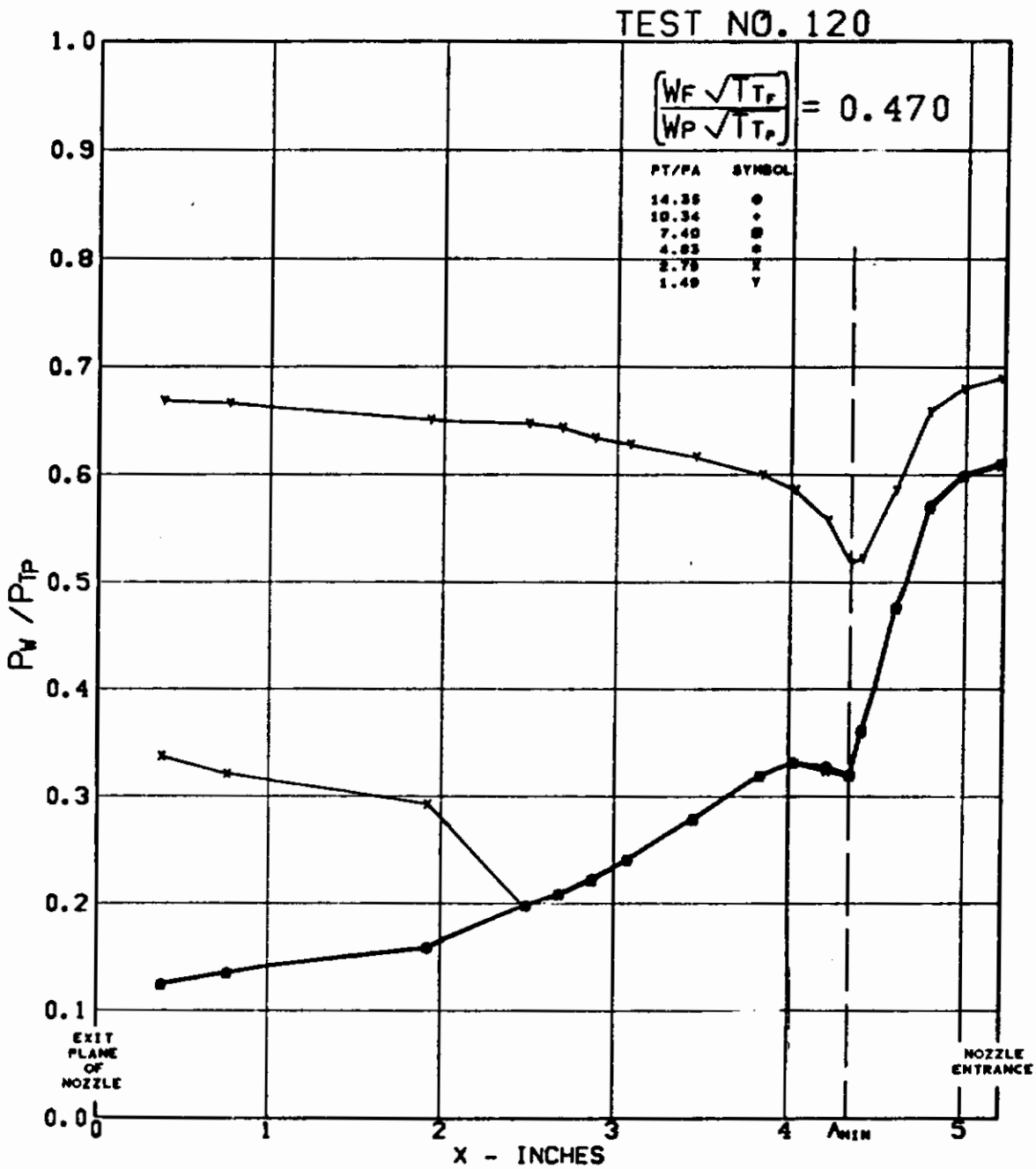


FIGURE 135. WALL PRESSURES - CONFIGURATION 12 AT 0.470 FAN FLOW RATIO $(W_F\sqrt{T_{T_F}}/W_P\sqrt{T_{T_P}})$

Approved for Public Release

Contrails

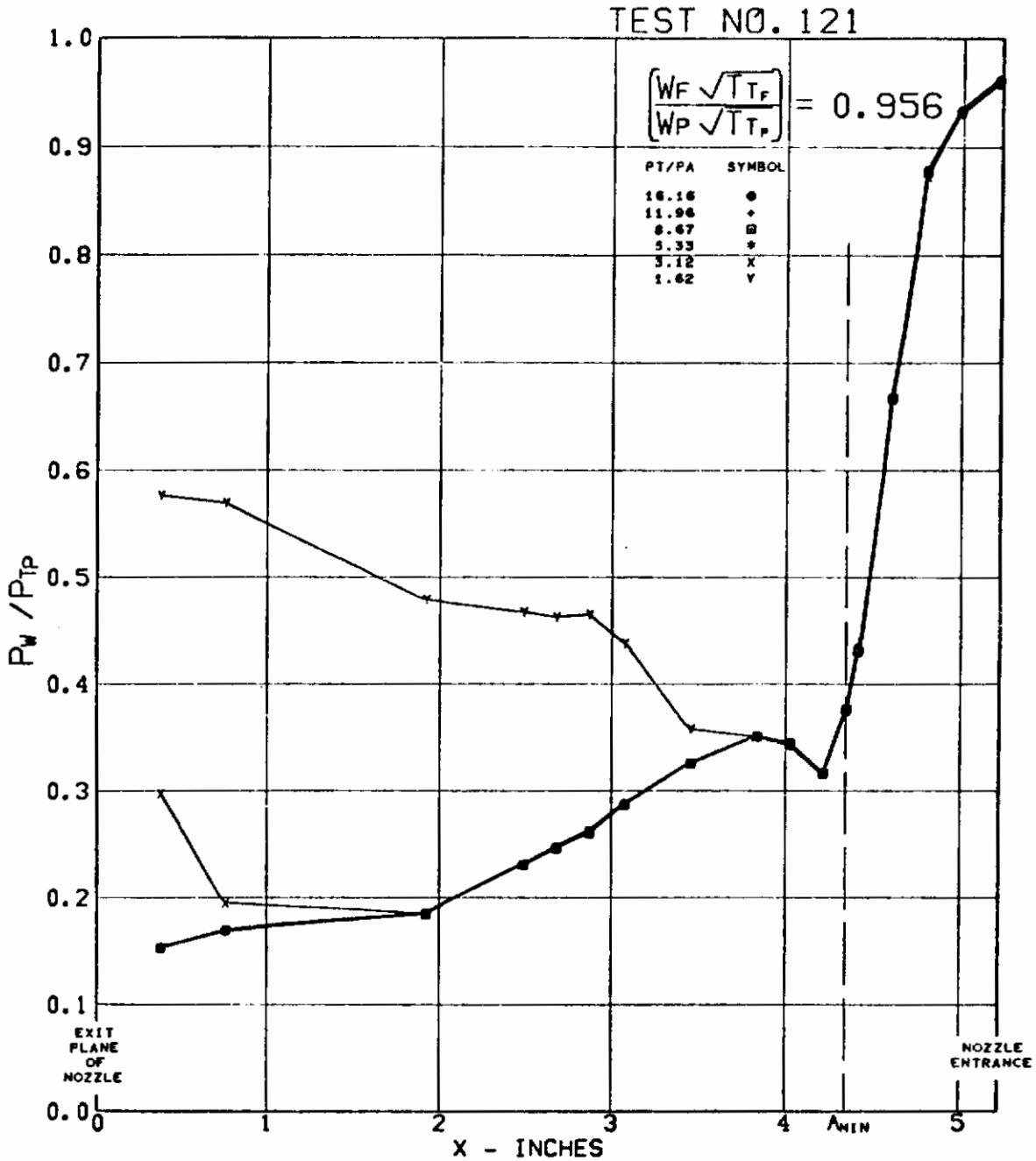


FIGURE 136. WALL PRESSURES - CONFIGURATION 12 AT 0.956 FAN FLOW RATIO $(W_F\sqrt{T_{T_F}} / W_P\sqrt{T_{T_P}})$

Approved for Public Release

Contrails

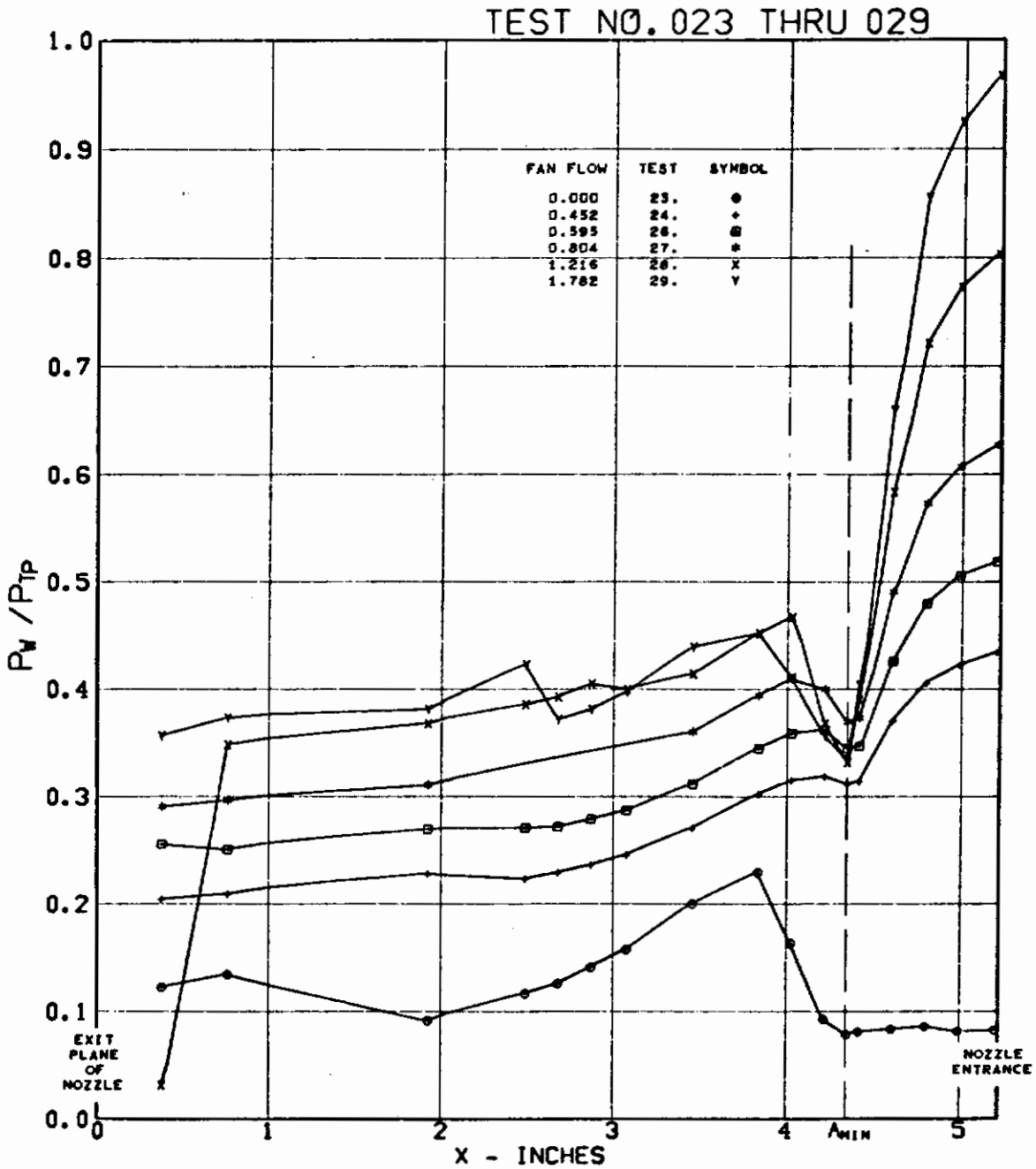


FIGURE 137. WALL PRESSURES - CONFIGURATION 13
VARIABLE FAN FLOW RATIO ($W_F\sqrt{T_{T_F}} / W_P\sqrt{T_{T_P}}$)

Approved for Public Release

Contrails

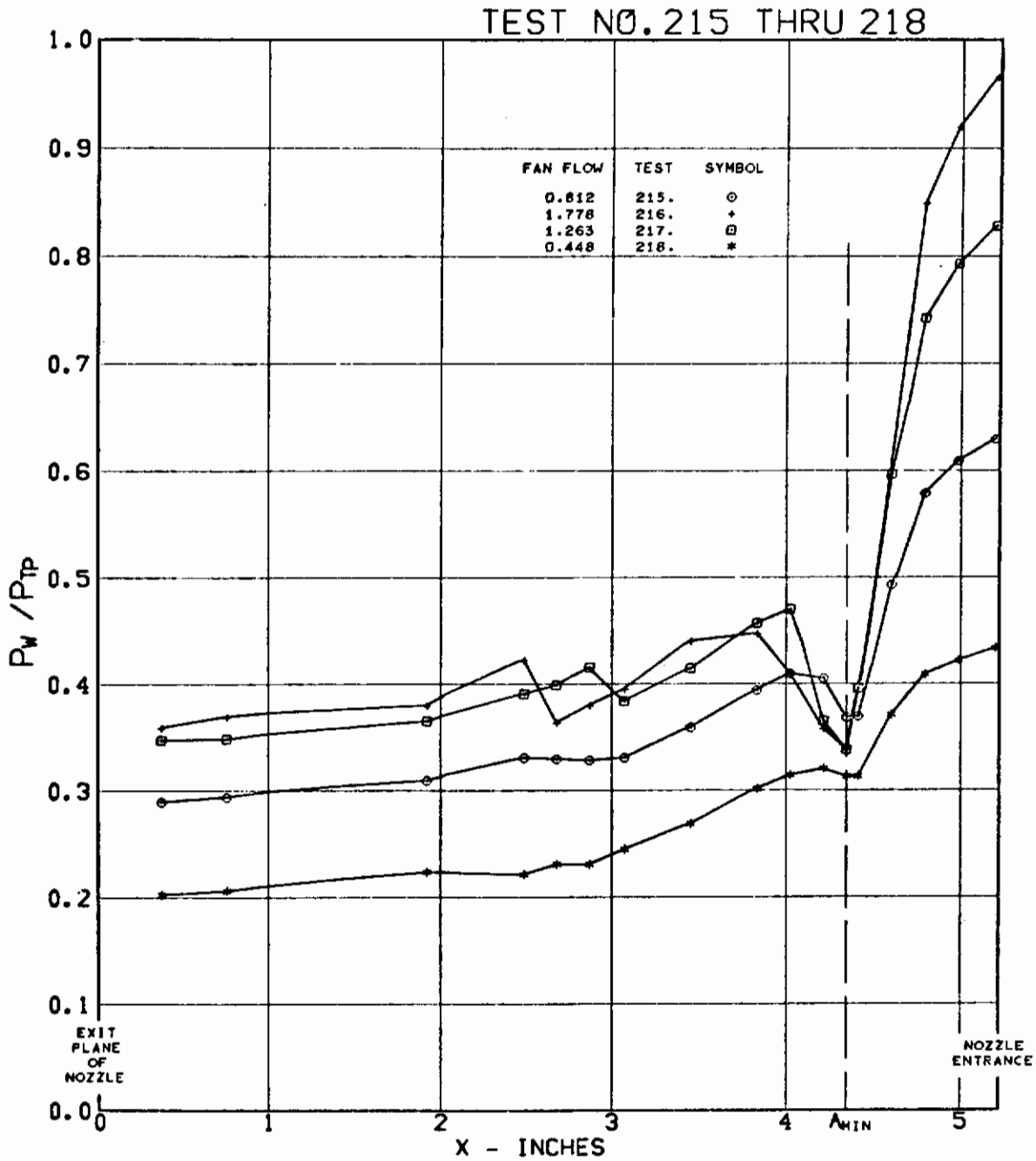


FIGURE 138. WALL PRESSURES - CONFIGURATION 13
VARIABLE FAN FLOW RATIO ($W_F\sqrt{T_{T_F}} / W_P\sqrt{T_{T_P}}$)

Approved for Public Release

Contrails

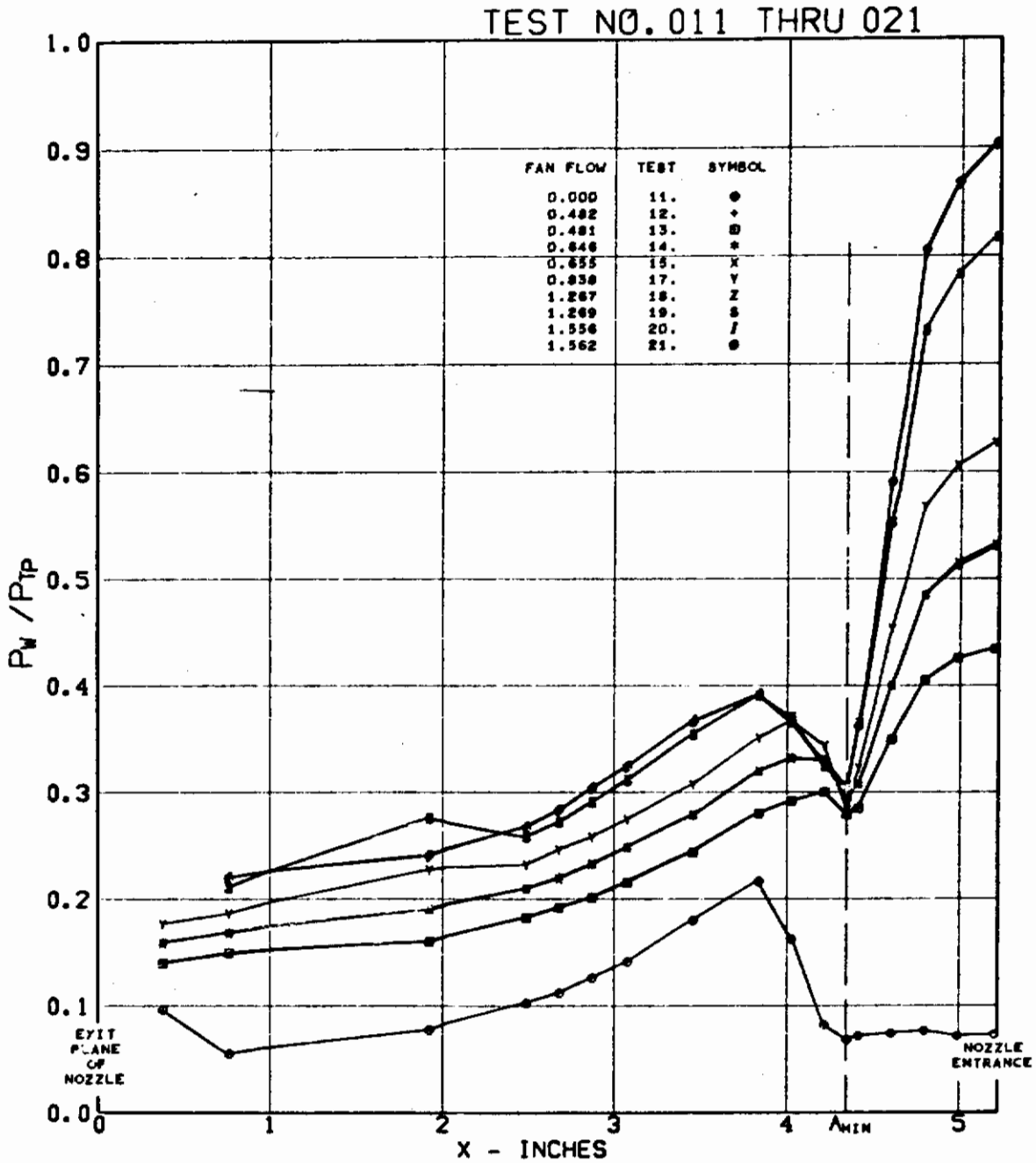


FIGURE 139. WALL PRESSURES - CONFIGURATION 14
VARIABLE FAN FLOW RATIO ($W_F\sqrt{T_{T_F}} / W_P\sqrt{T_{T_P}}$)

Approved for Public Release

Contrails

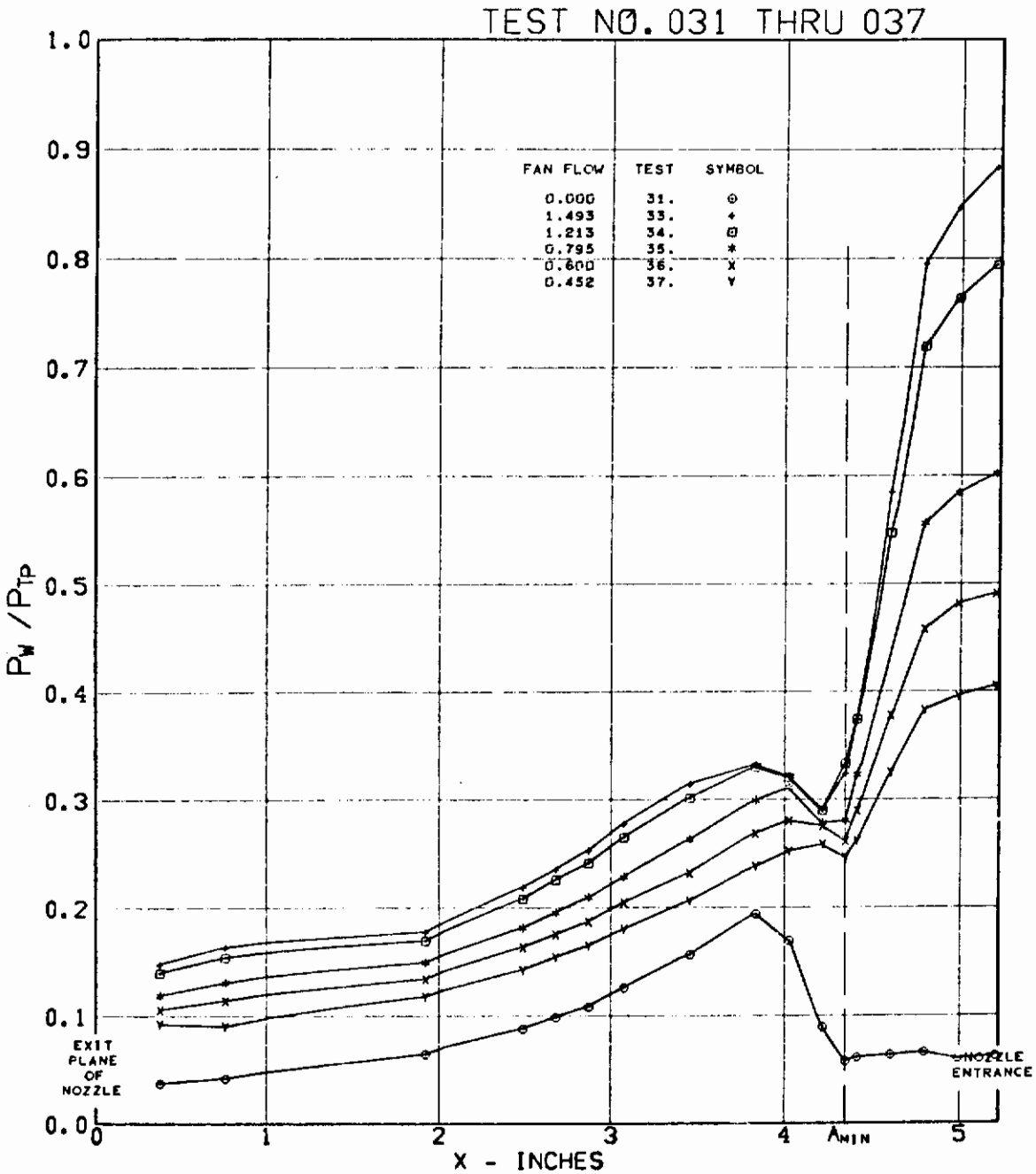


FIGURE 140. WALL PRESSURES - CONFIGURATION 15
VARIABLE FAN FLOW RATIO ($W_F\sqrt{T_{T_F}} / W_P\sqrt{T_{T_P}}$)

Approved for Public Release

Contrails

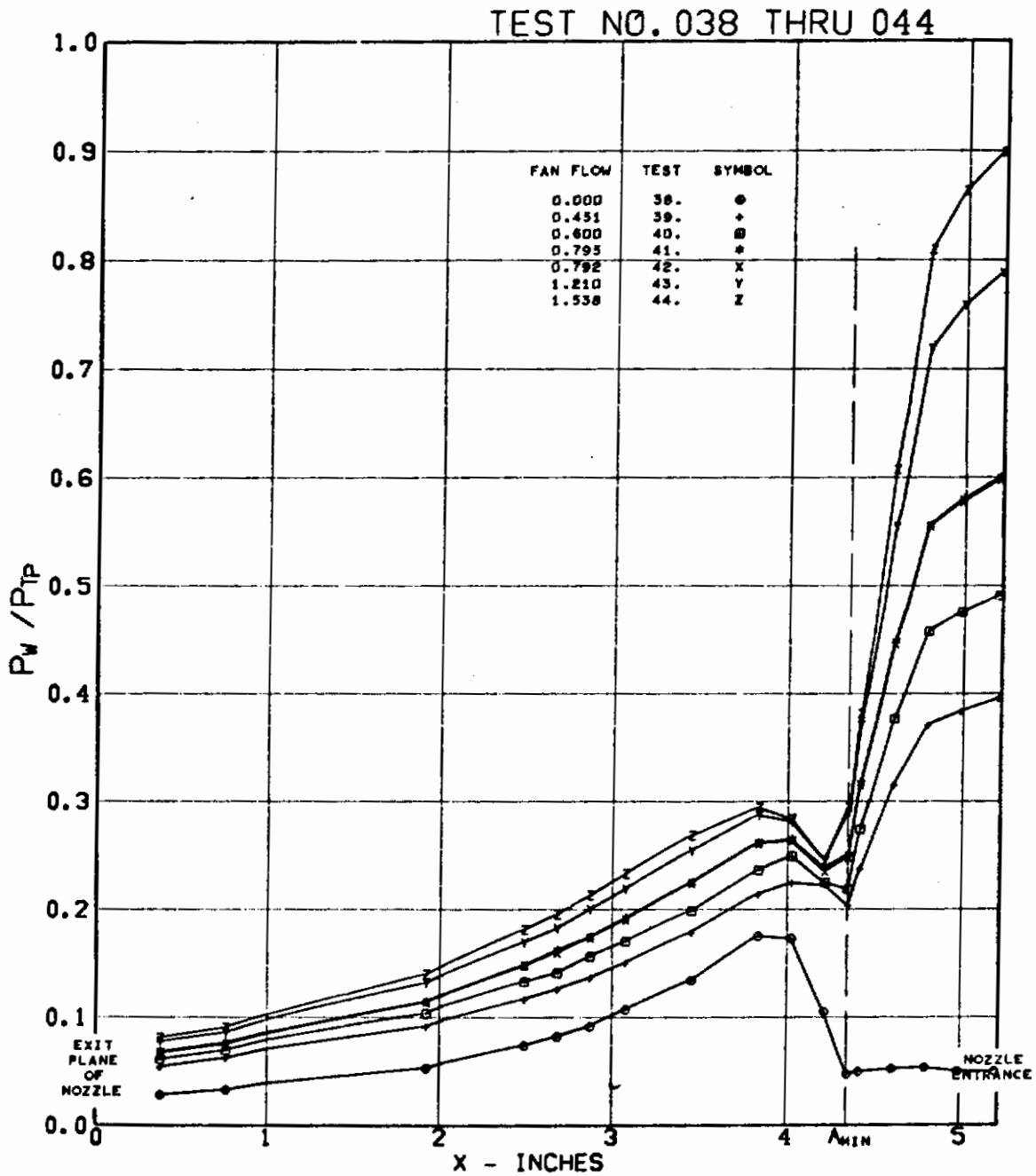


FIGURE 141. WALL PRESSURES - CONFIGURATION 16
VARIABLE FAN FLOW RATIO ($W_F\sqrt{T_{T_F}} / W_P\sqrt{T_{T_P}}$)

Approved for Public Release

Contrails

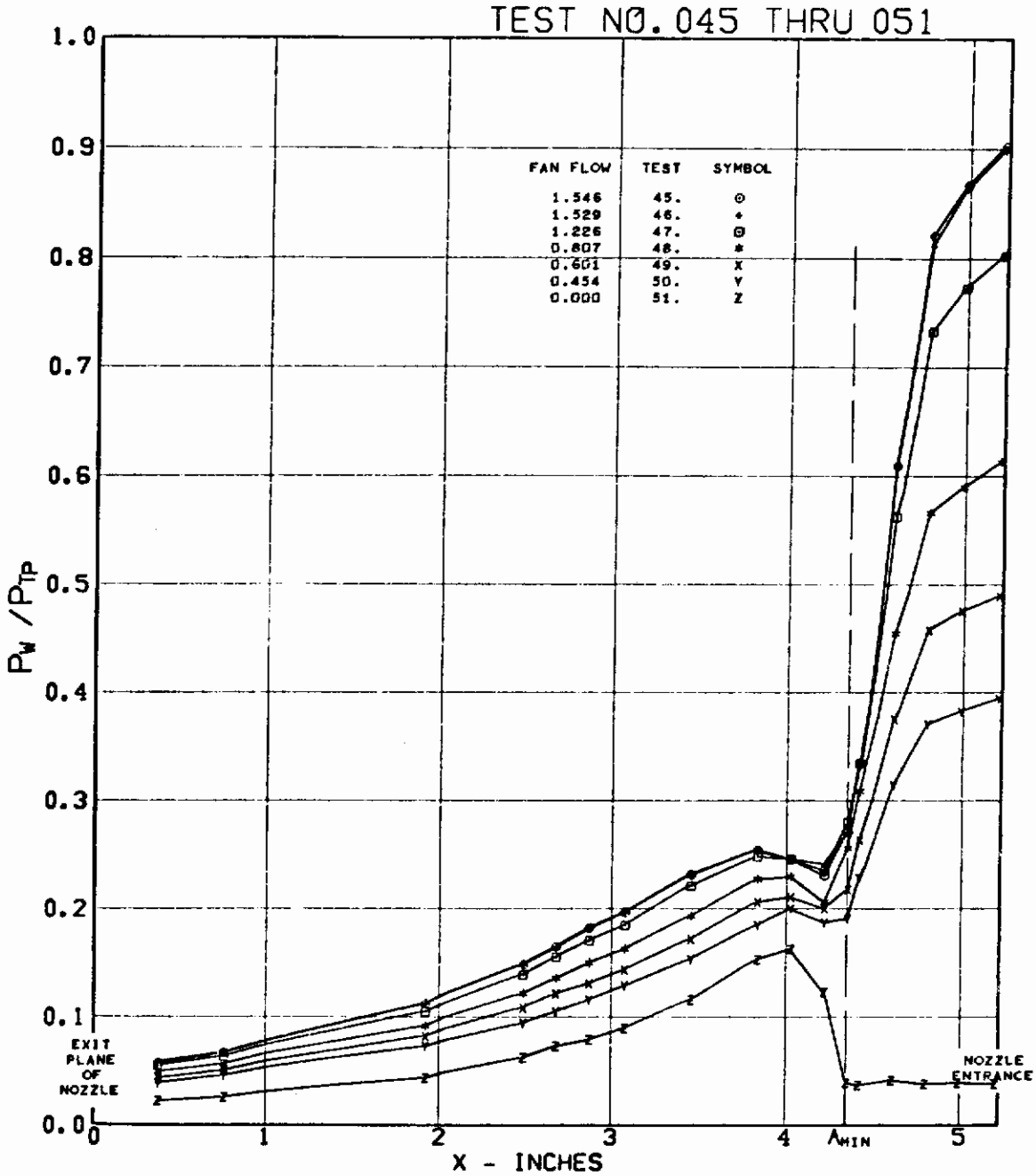


FIGURE 142. WALL PRESSURES - CONFIGURATION 17
VARIABLE FAN FLOW RATIO ($W_F\sqrt{T_{T_F}} / W_P\sqrt{T_{T_P}}$)

Approved for Public Release

Contrails

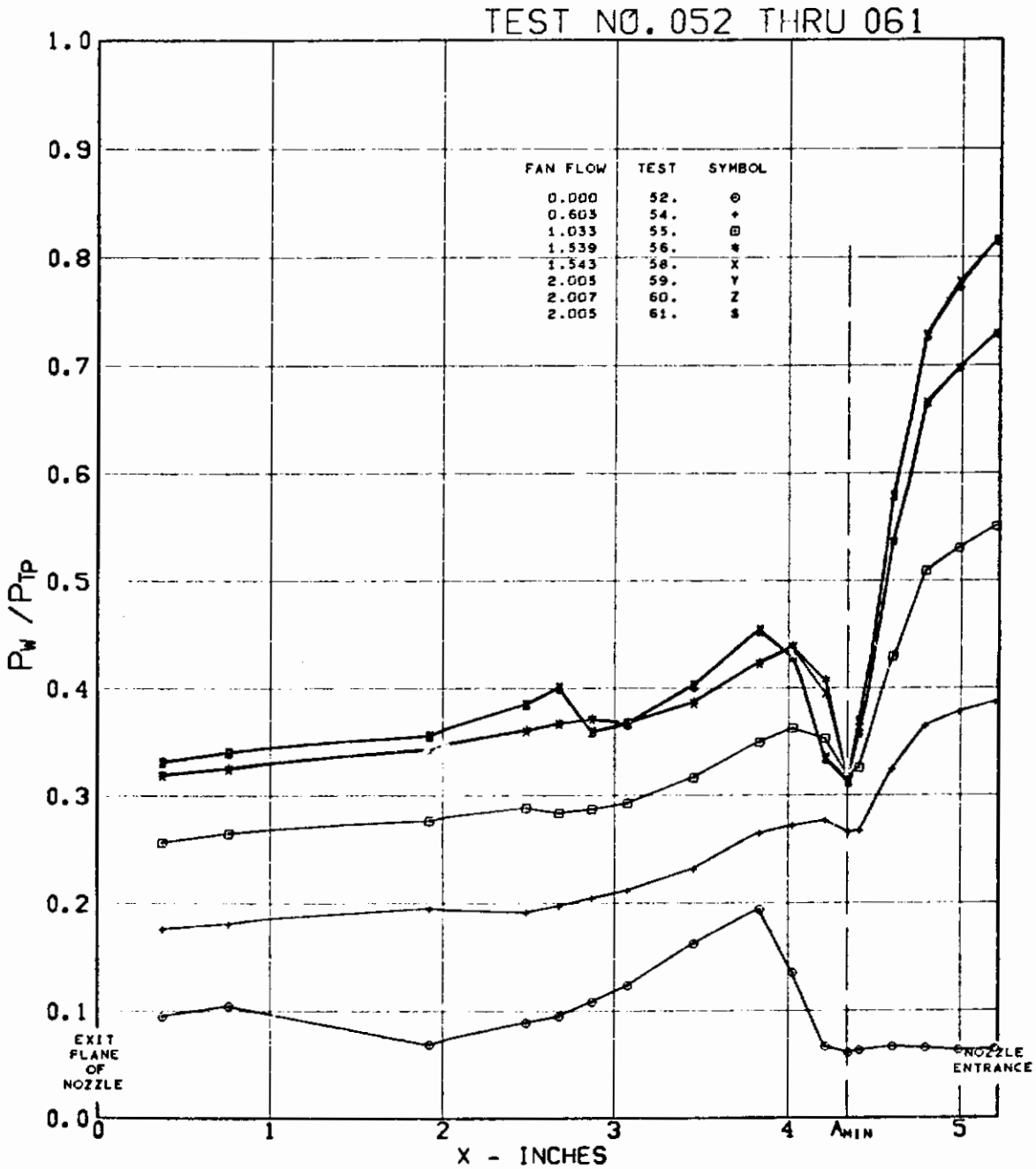


FIGURE 143. WALL PRESSURES - CONFIGURATION 19
VARIABLE FAN FLOW RATIO $(W_F\sqrt{T_{T_F}} / W_P\sqrt{T_{T_P}})$

Approved for Public Release

Contrails

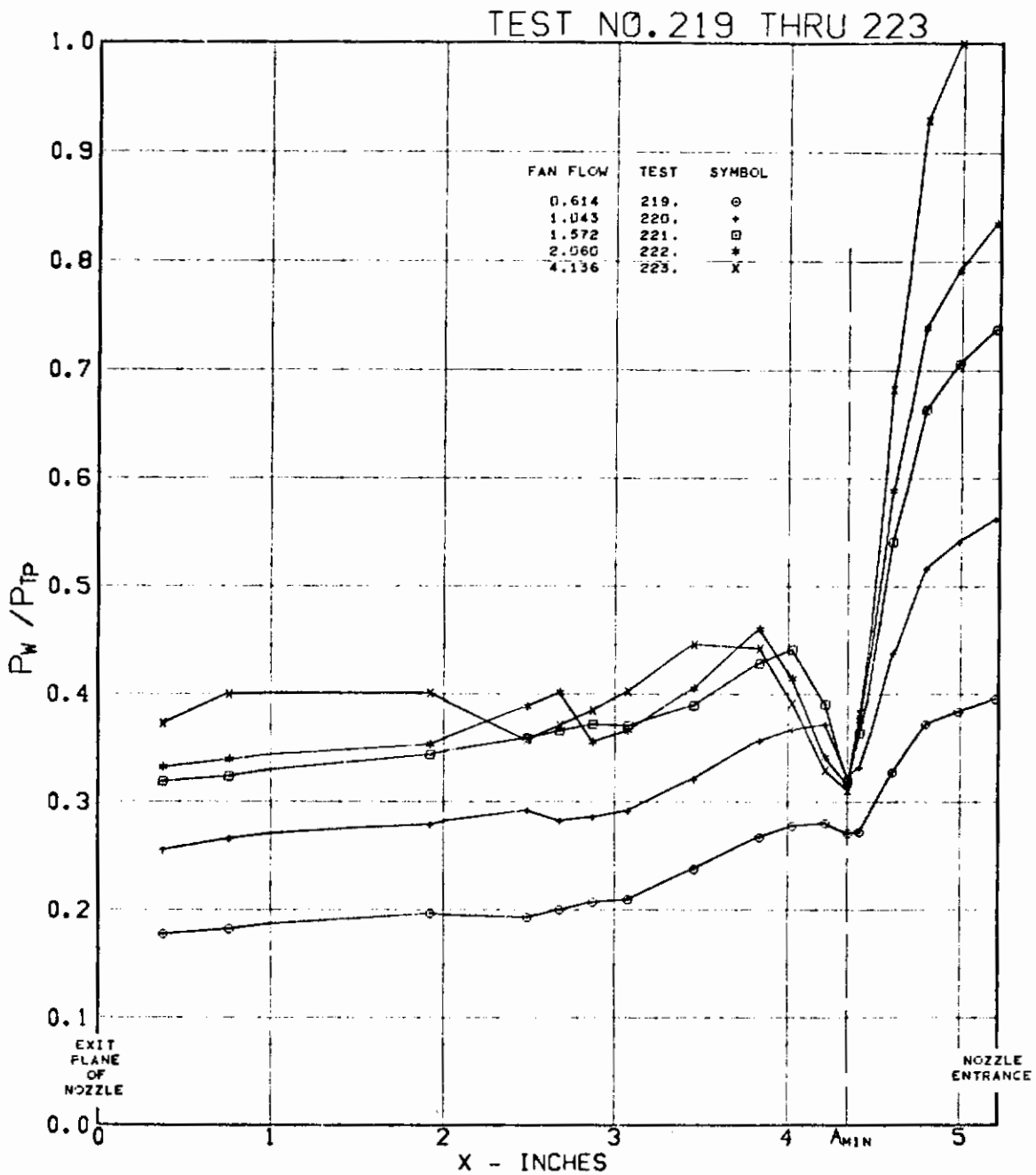


FIGURE 144. WALL PRESSURES - CONFIGURATION 19
VARIABLE FAN FLOW RATIO ($W_F\sqrt{T_{T_F}} / W_P\sqrt{T_{T_P}}$)

Approved for Public Release

Contrails

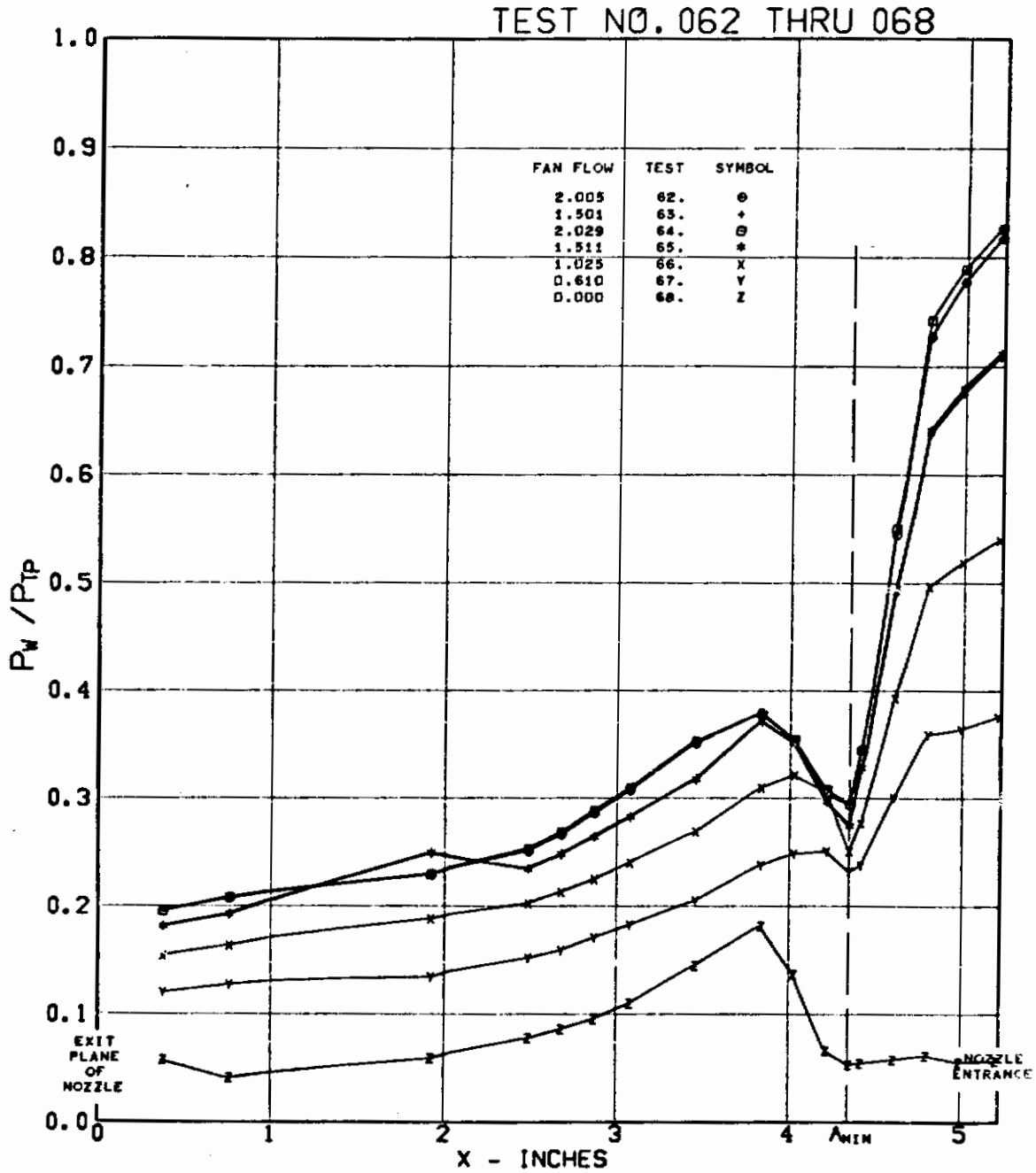


FIGURE 145. WALL PRESSURES - CONFIGURATION 20
VARIABLE FAN FLOW RATIO ($W_F\sqrt{T_{T_F}} / W_P\sqrt{T_{T_P}}$)

Approved for Public Release

Contrails

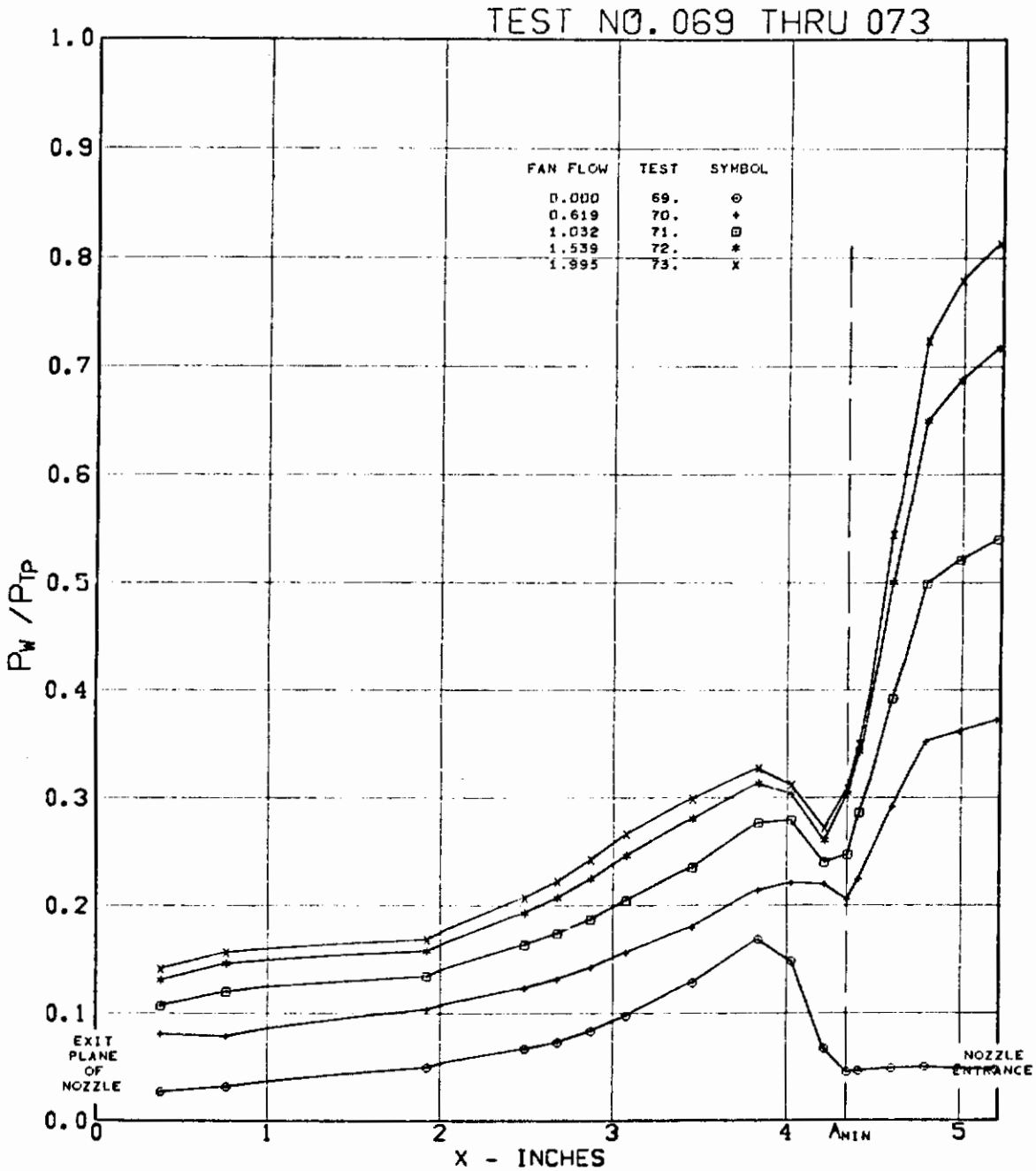


FIGURE 146. WALL PRESSURES - CONFIGURATION 21
VARIABLE FAN FLOW RATIO ($W_F\sqrt{T_{T_F}} / W_P\sqrt{T_{T_P}}$)

Approved for Public Release

Contrails

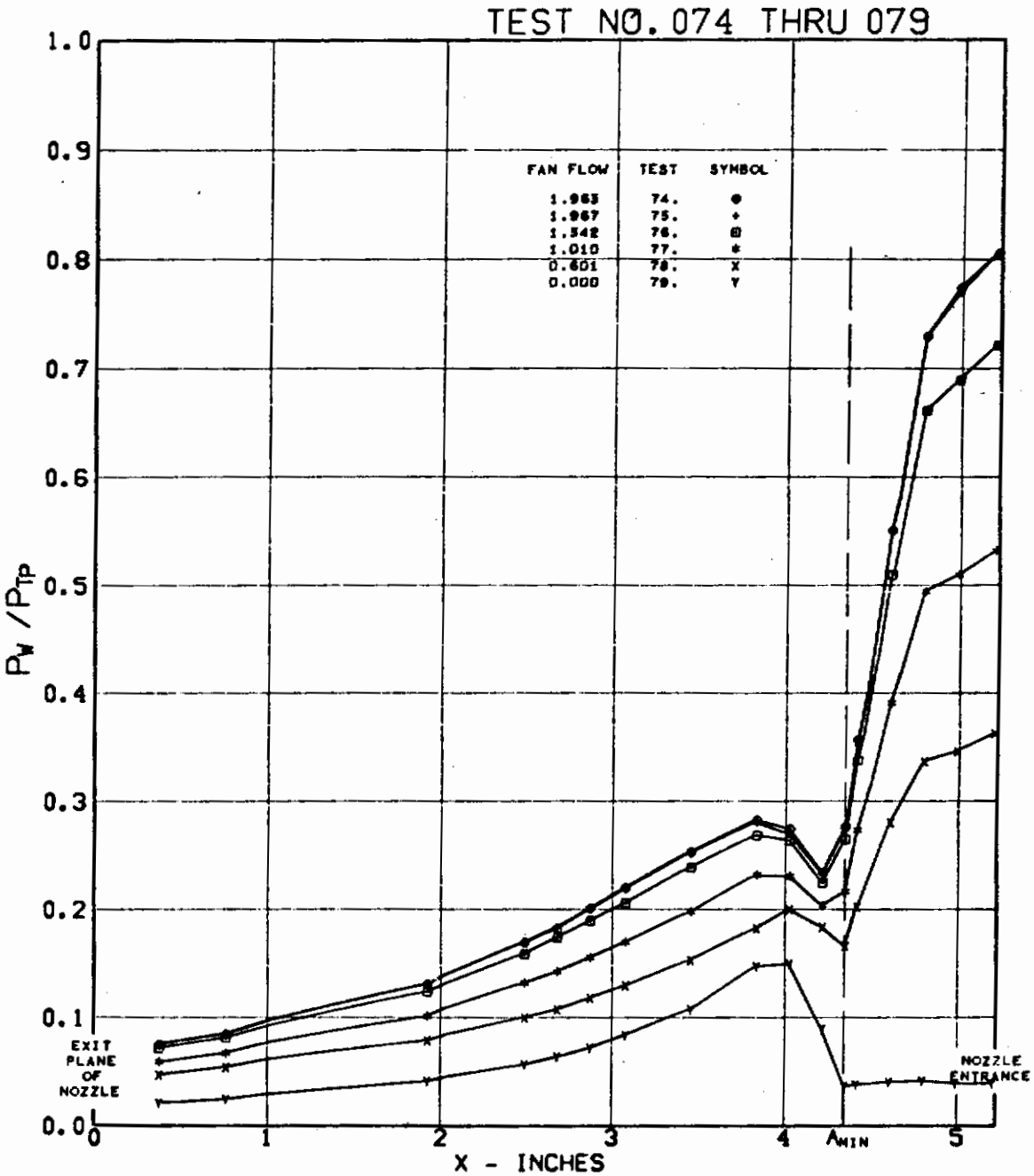


FIGURE 147. WALL PRESSURES - CONFIGURATION 22
VARIABLE FAN FLOW RATIO ($W_F\sqrt{T_{T_F}} / W_P\sqrt{T_{T_P}}$)

Approved for Public Release

Contrails

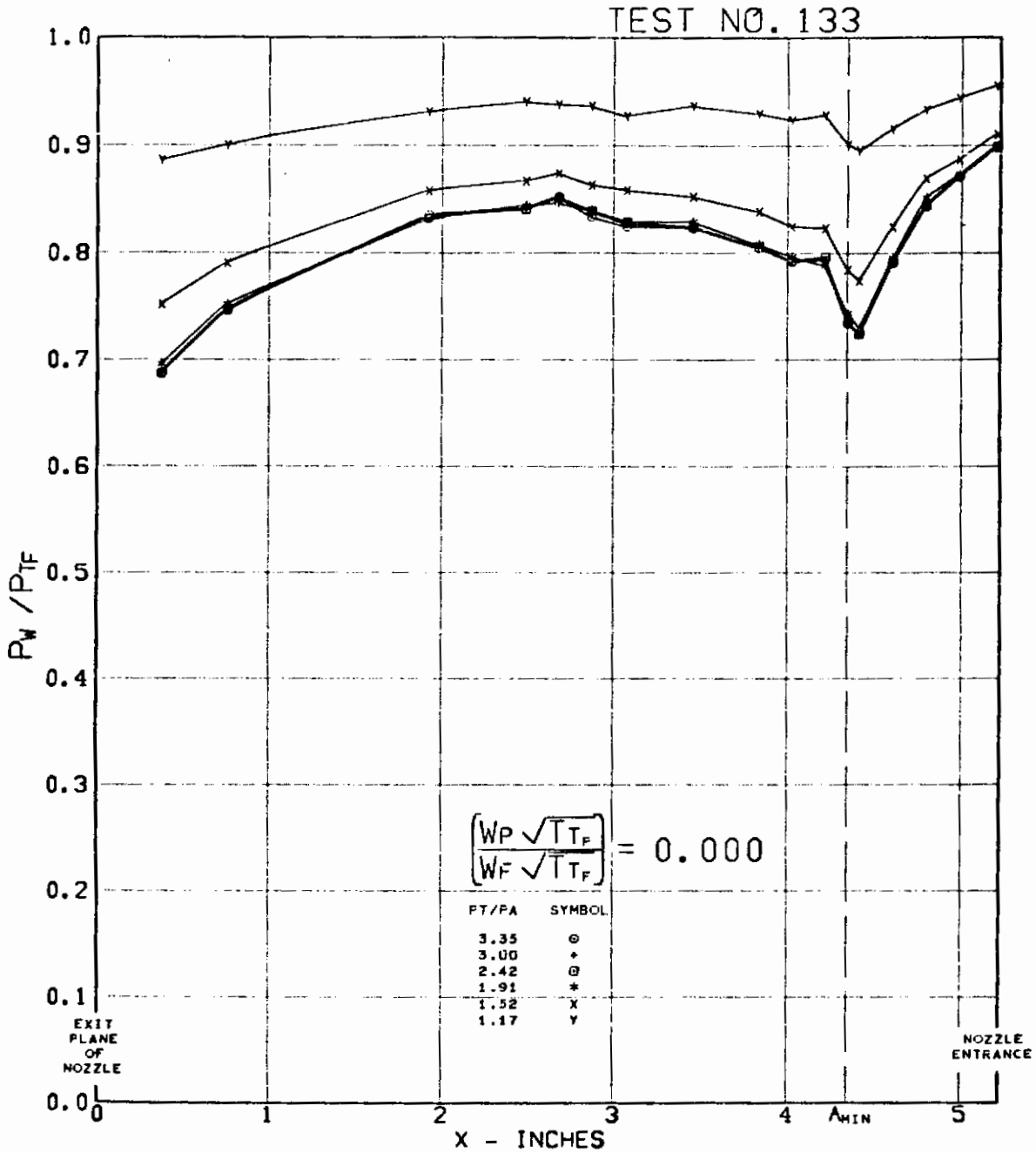


FIGURE 148. WALL PRESSURES - CONFIGURATION 25 AT 0.000 FAN FLOW RATIO $(W_P\sqrt{T_{T_F}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

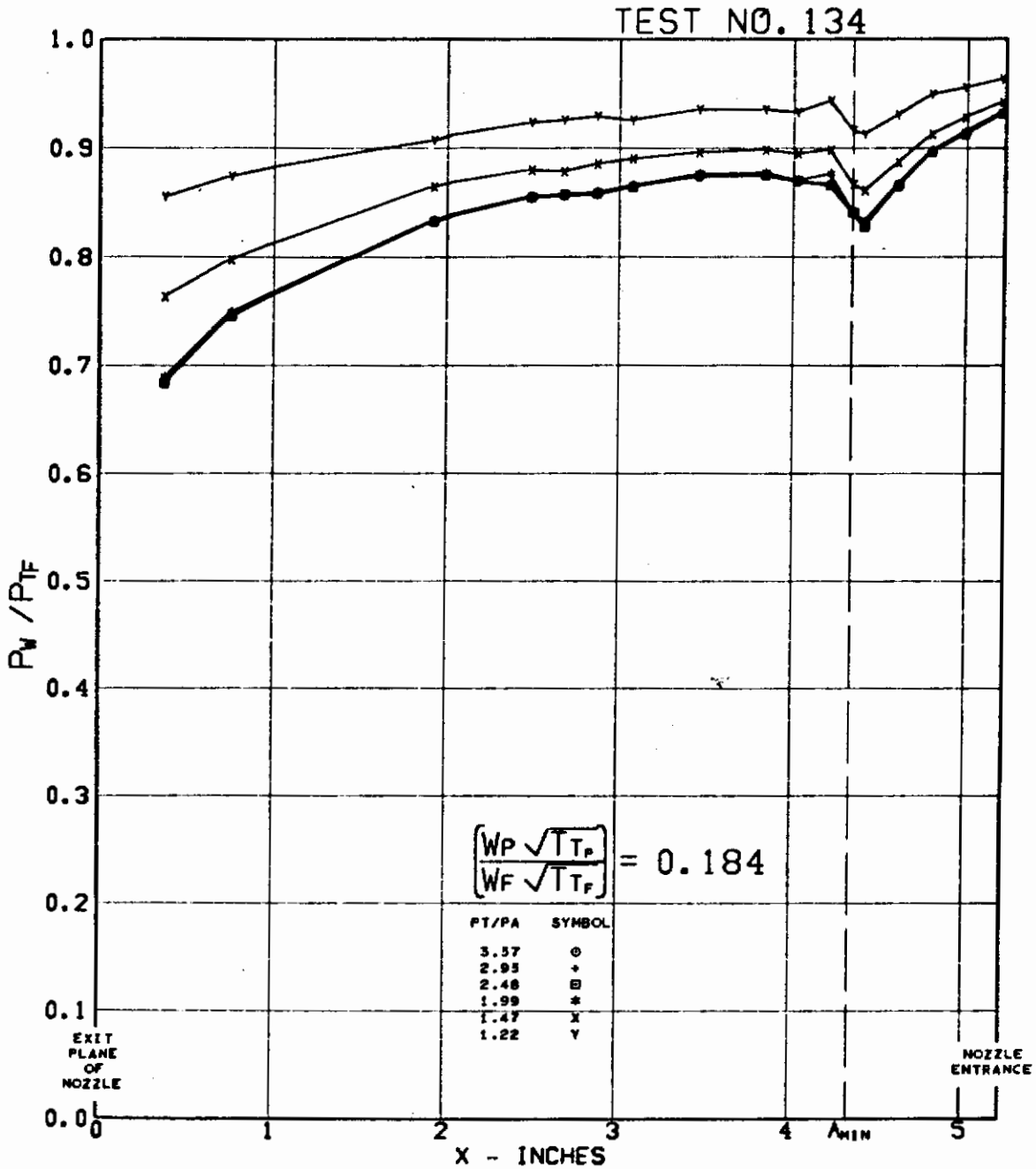


FIGURE 149. WALL PRESSURES - CONFIGURATION 25 AT 0.184 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

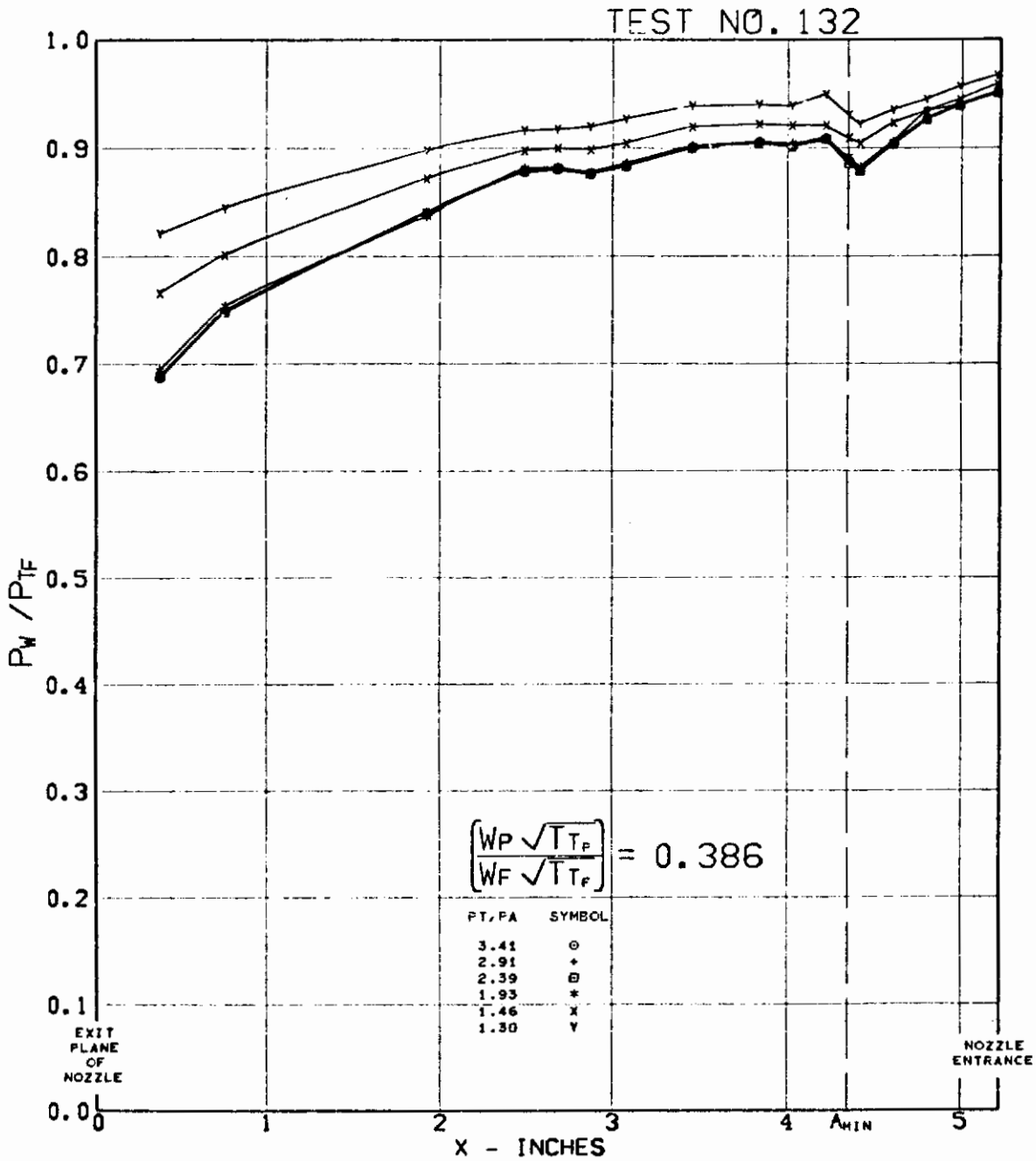


FIGURE 150. WALL PRESSURES - CONFIGURATION 25 AT 0.386 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

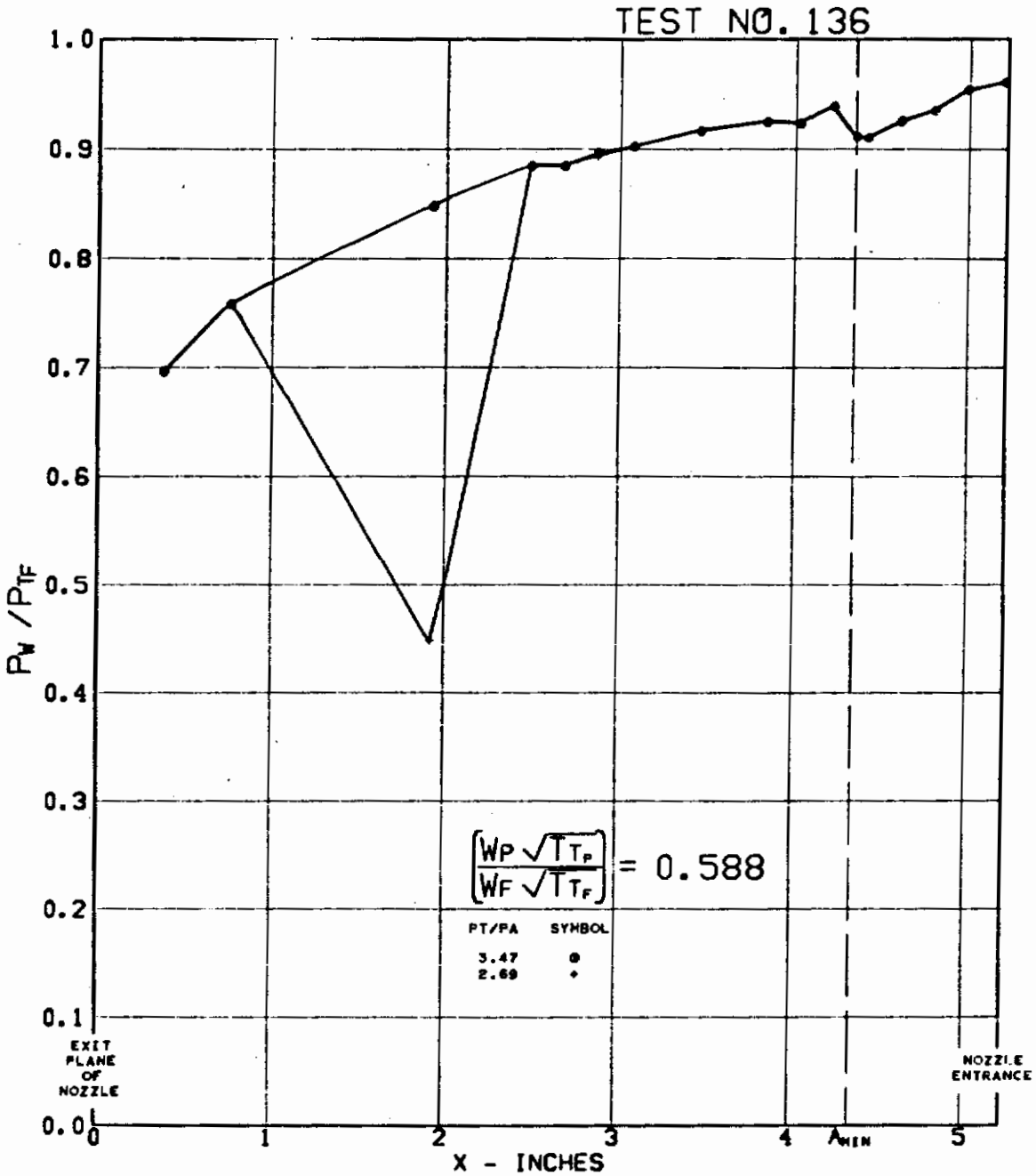


FIGURE 151. WALL PRESSURES - CONFIGURATION 25 AT 0.588 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

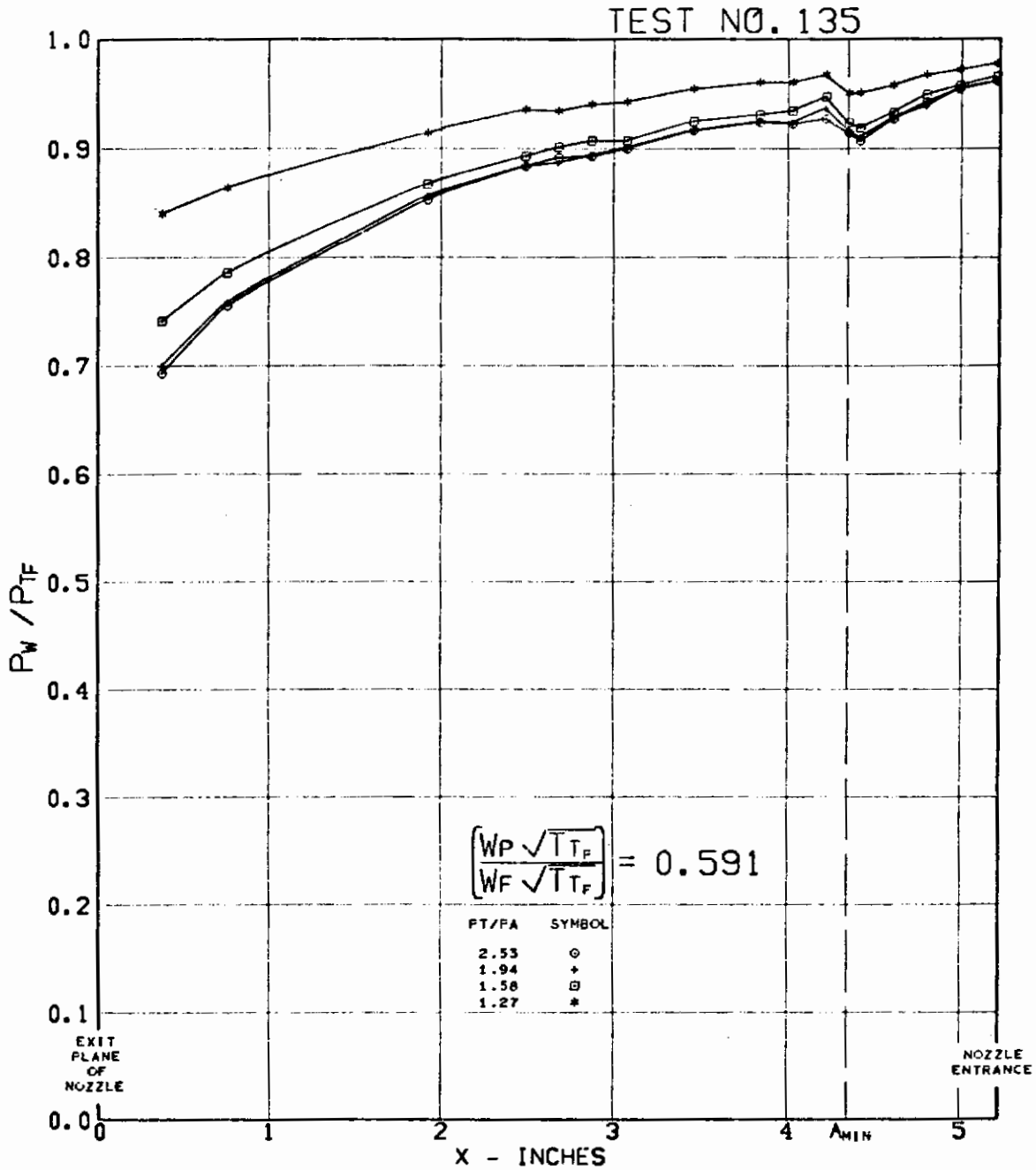


FIGURE 152. WALL PRESSURES - CONFIGURATION 25 AT 0.591 FAN FLOW RATIO $(W_P\sqrt{T_{T_F}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

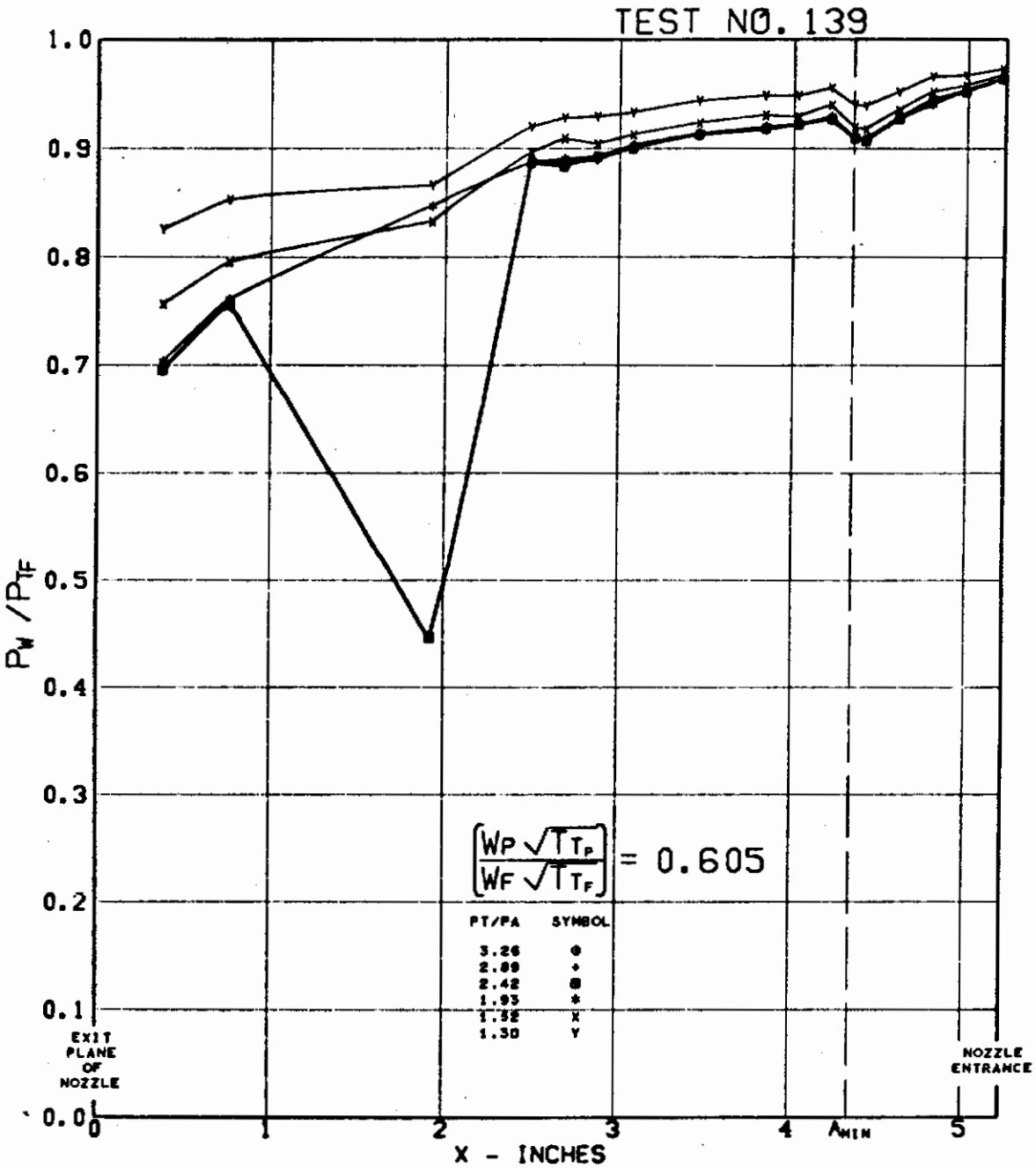


FIGURE 153. WALL PRESSURES - CONFIGURATION 25 AT 0.605 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

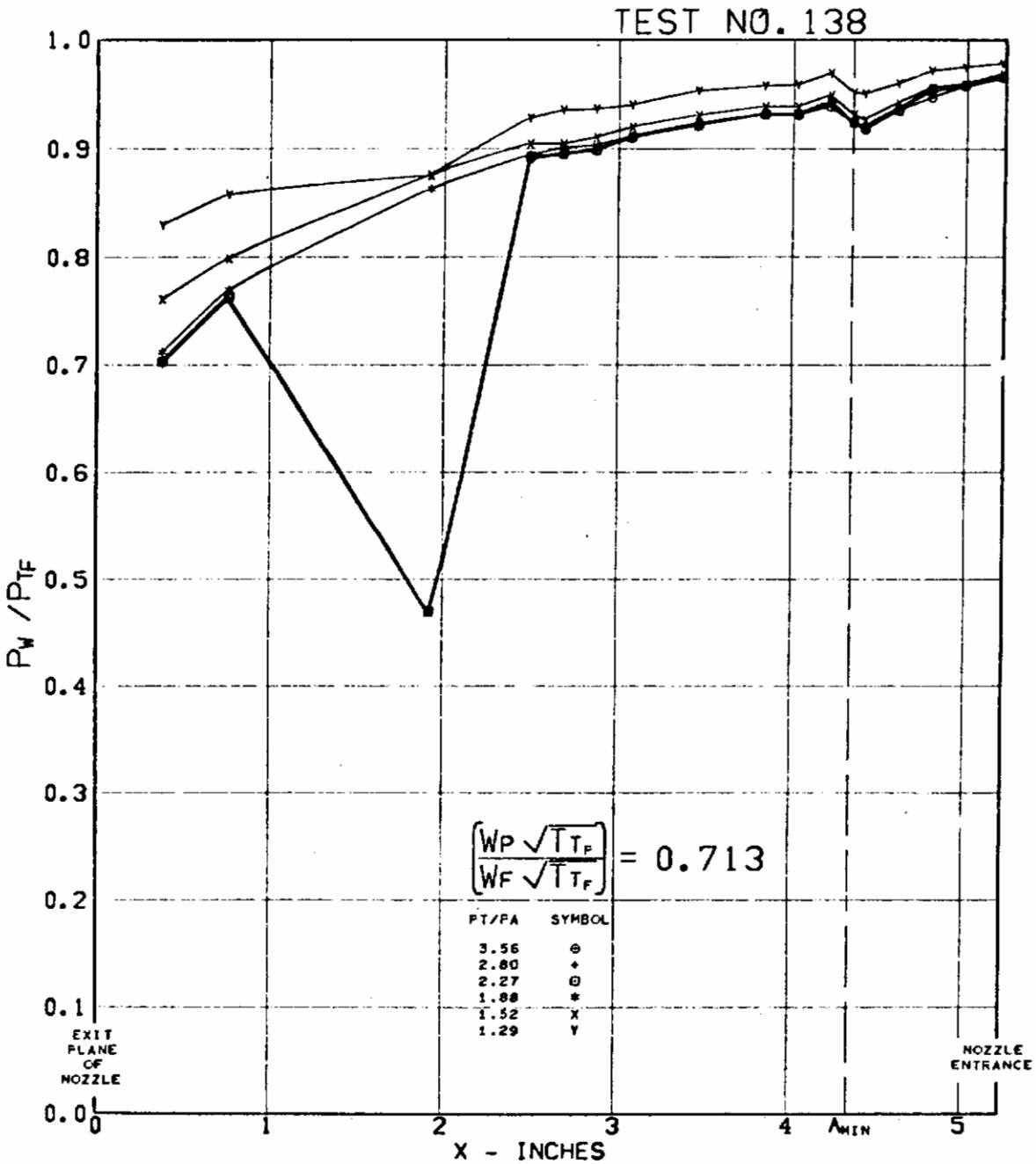


FIGURE 154. WALL PRESSURES - CONFIGURATION 25 AT 0.713 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

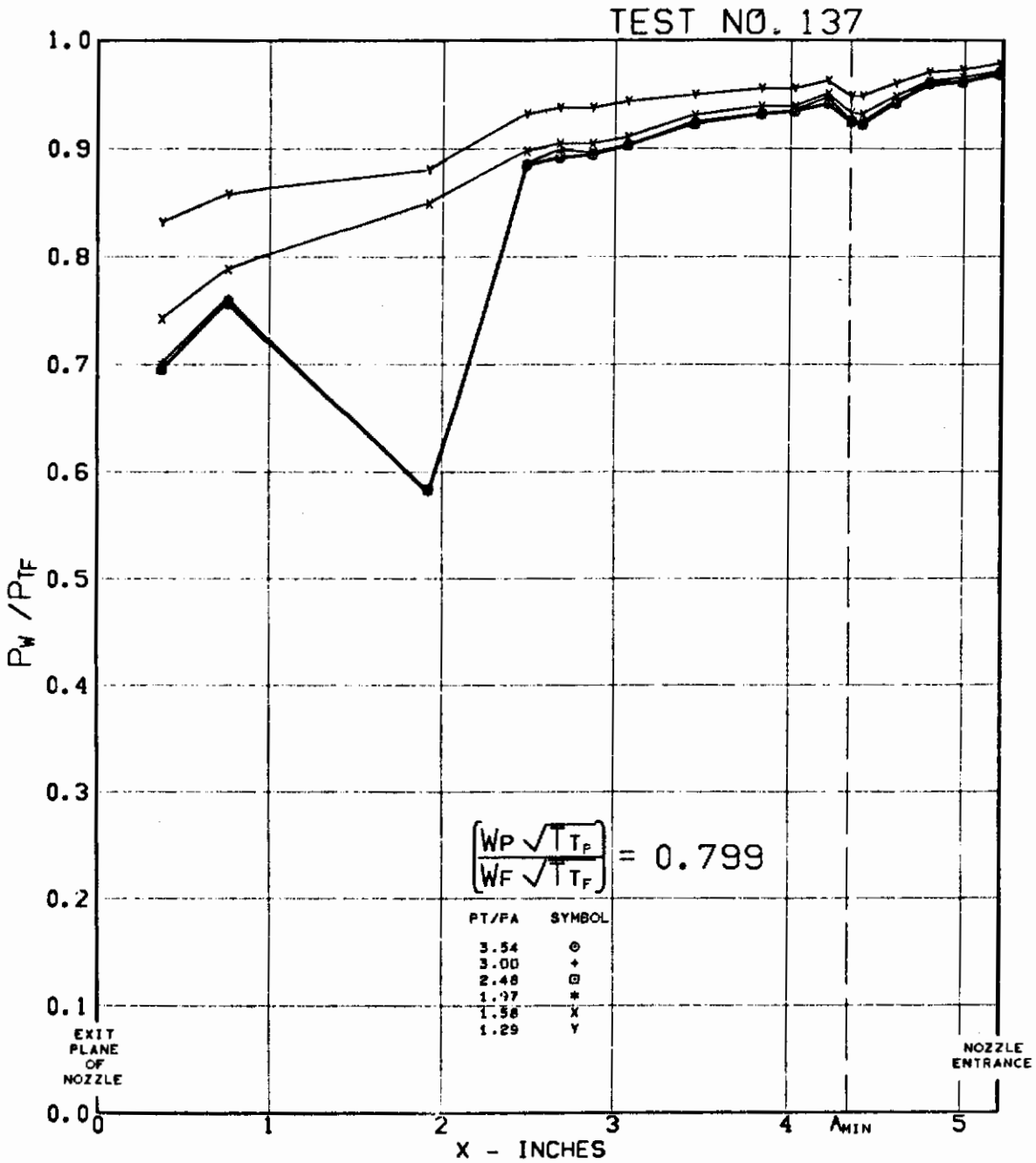


FIGURE 155. WALL PRESSURES - CONFIGURATION 25 AT 0.799 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

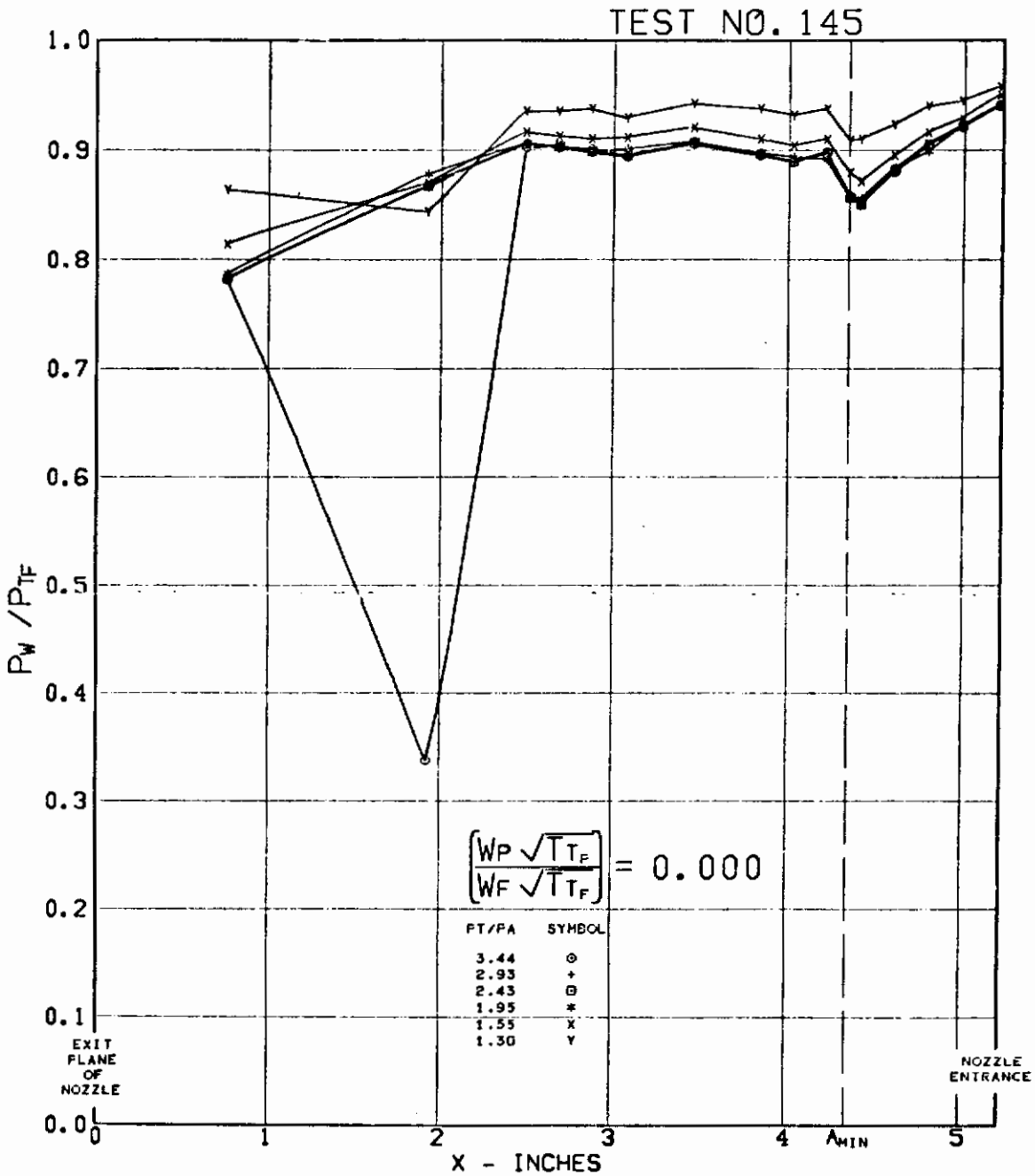


FIGURE 156. WALL PRESSURES - CONFIGURATION 26 AT 0.000 FAN FLOW RATIO $(W_P\sqrt{T_{T_F}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

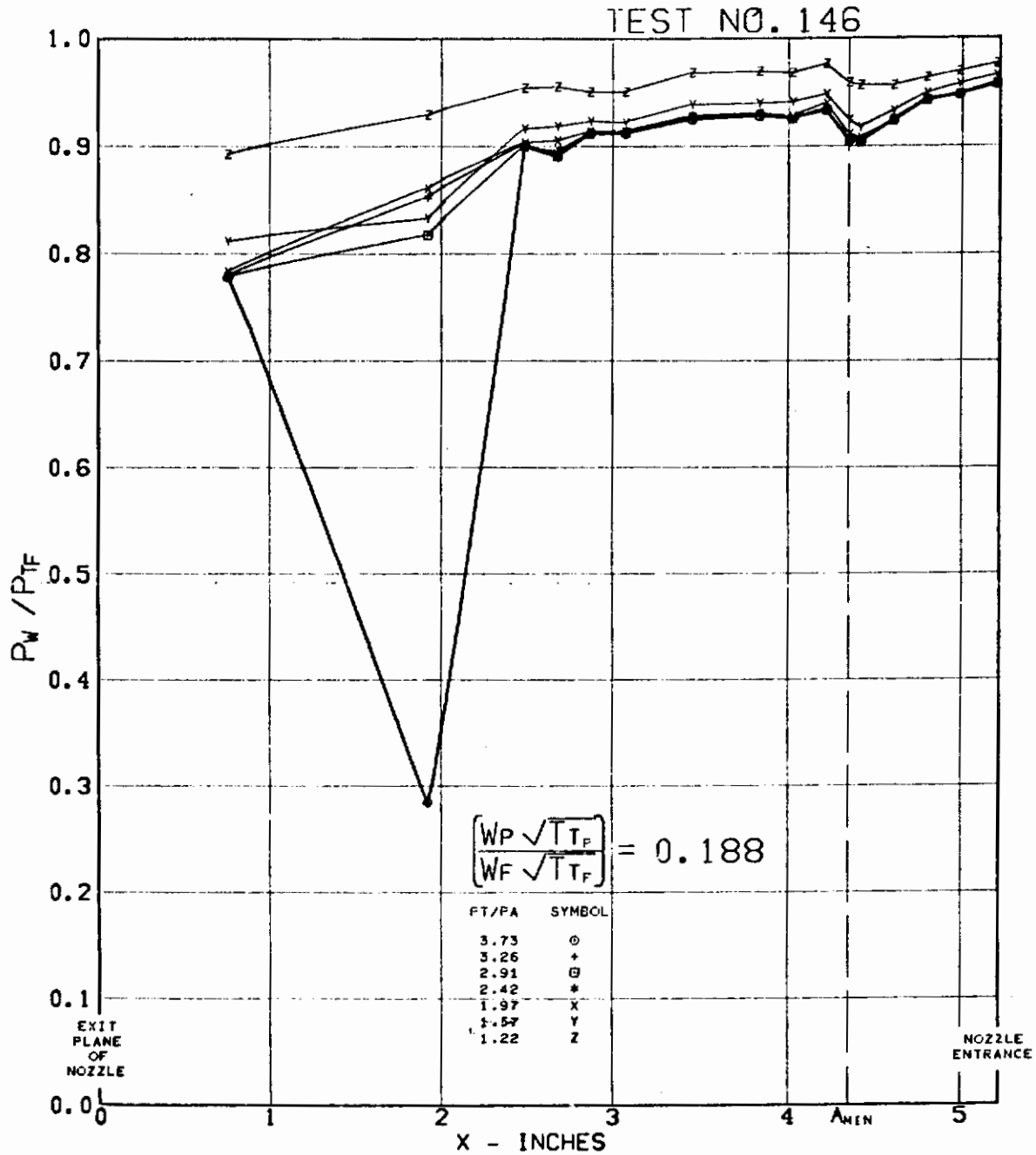


FIGURE 157. WALL PRESSURES - CONFIGURATION 26 AT 0.188 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

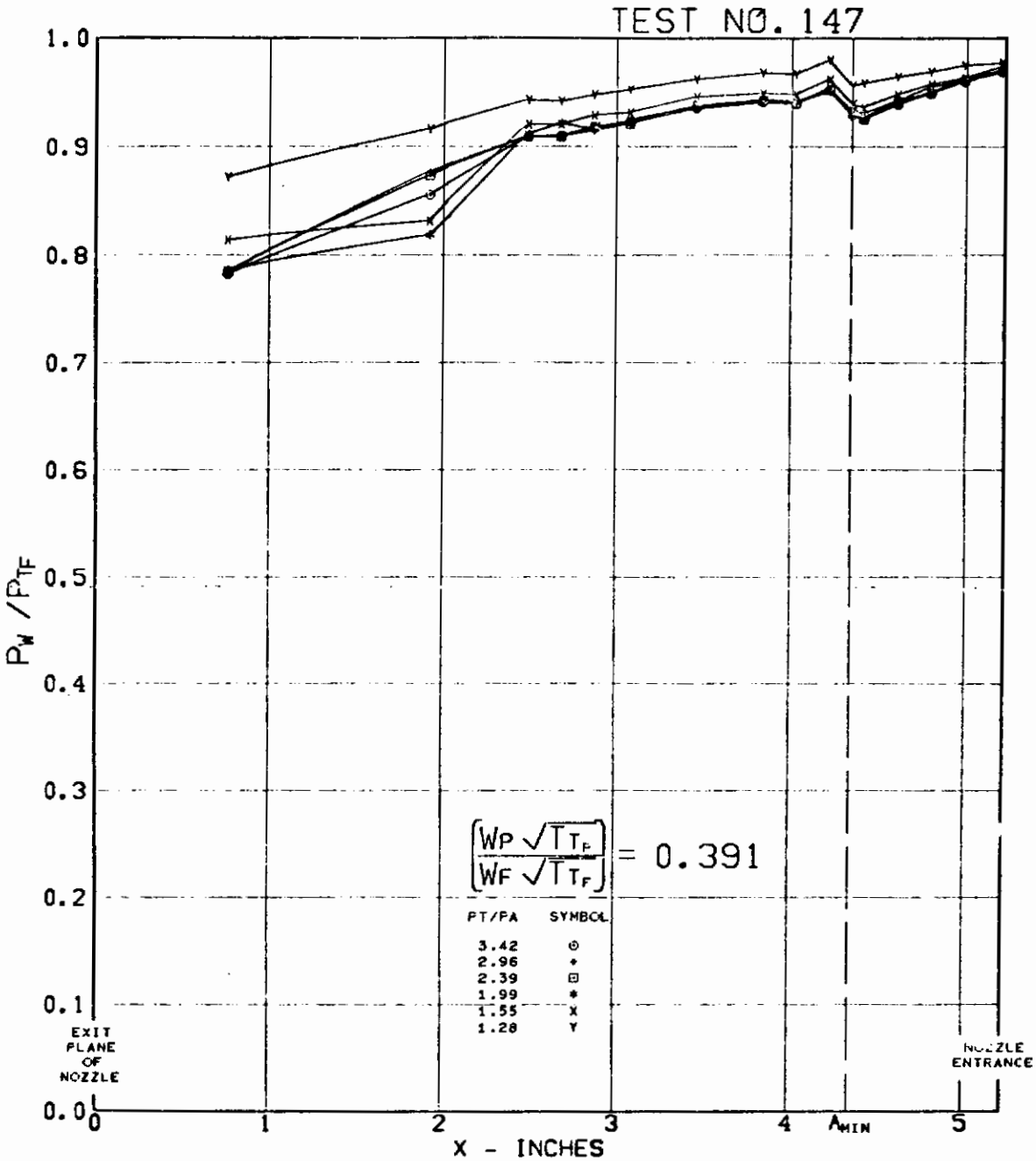


FIGURE 158. WALL PRESSURES - CONFIGURATION 26 AT 0.391 FAN FLOW RATIO $(W_P\sqrt{T_{T_F}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

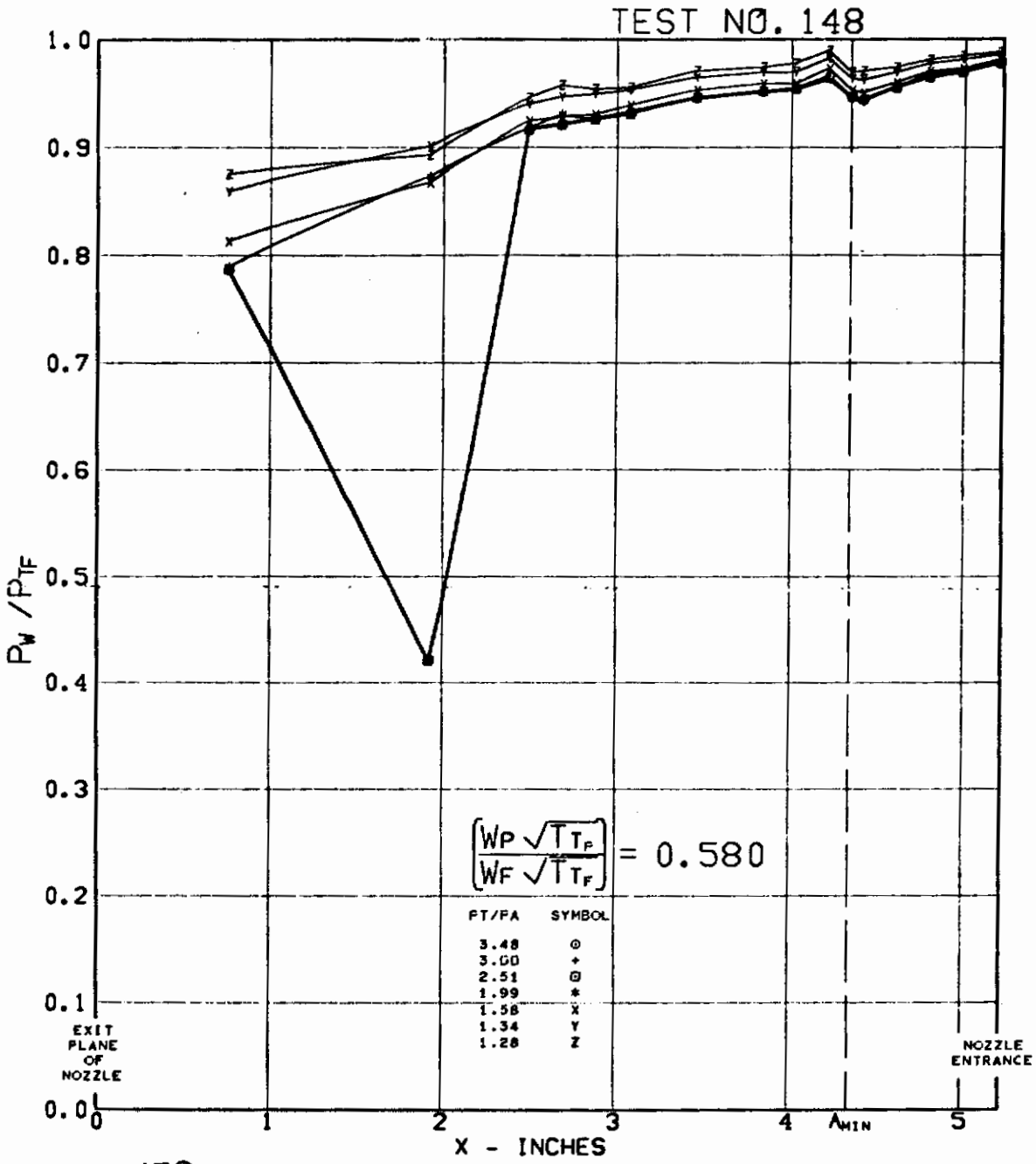


FIGURE 159. WALL PRESSURES - CONFIGURATION 26 AT 0.580 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

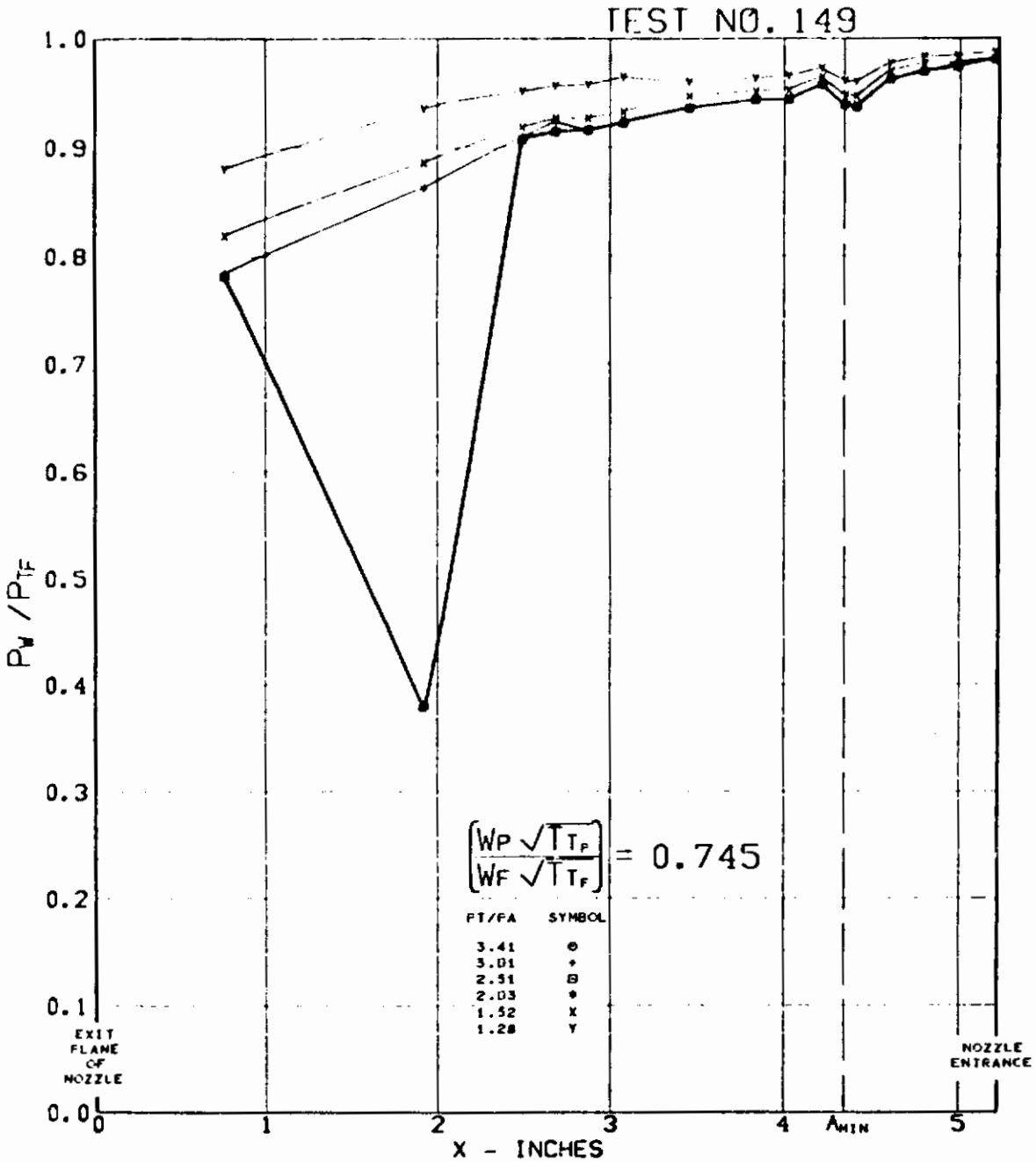


FIGURE 160. WALL PRESSURES - CONFIGURATION 26 AT 0.745 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

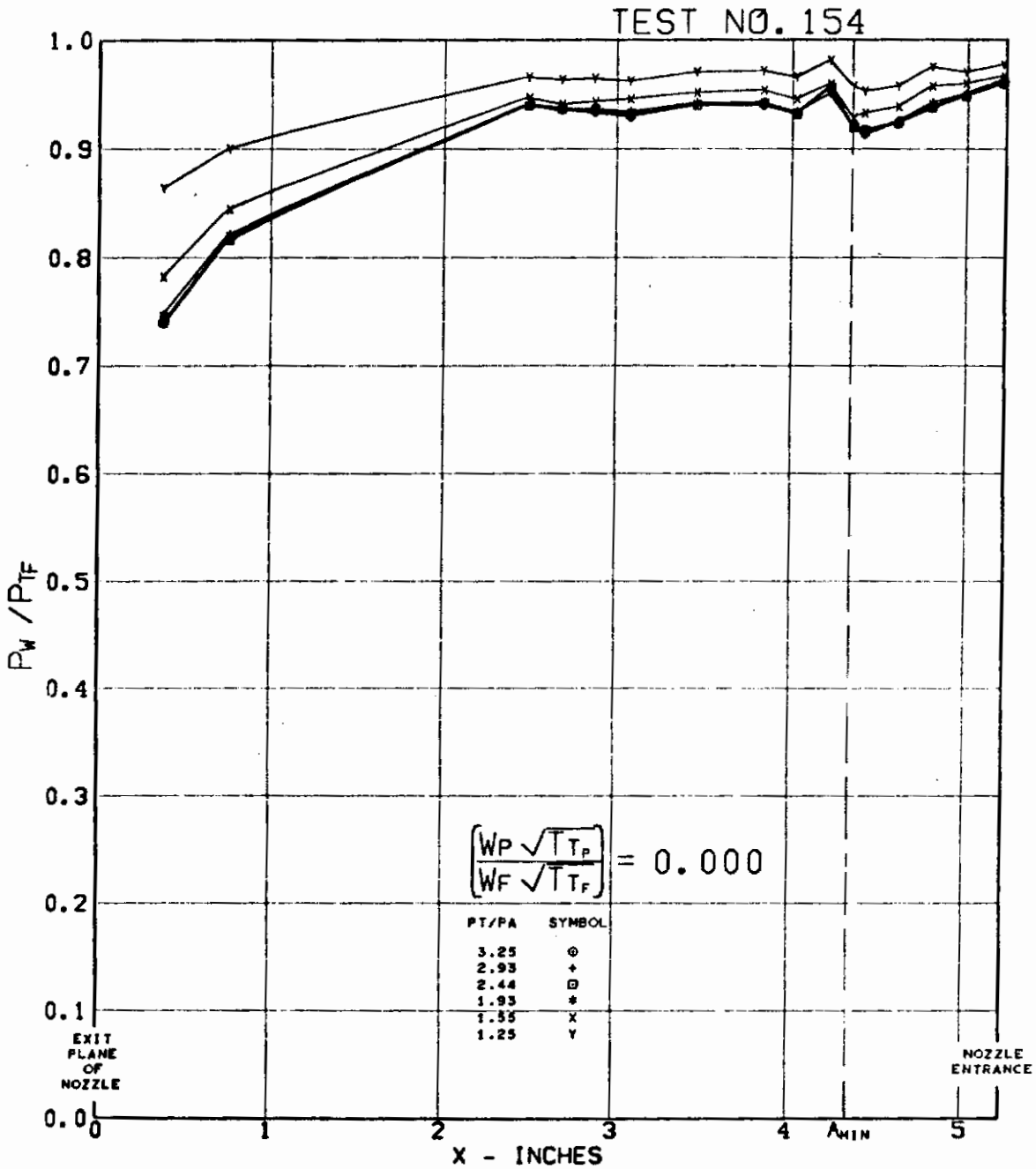


FIGURE 161. WALL PRESSURES - CONFIGURATION 27 AT 0.000 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

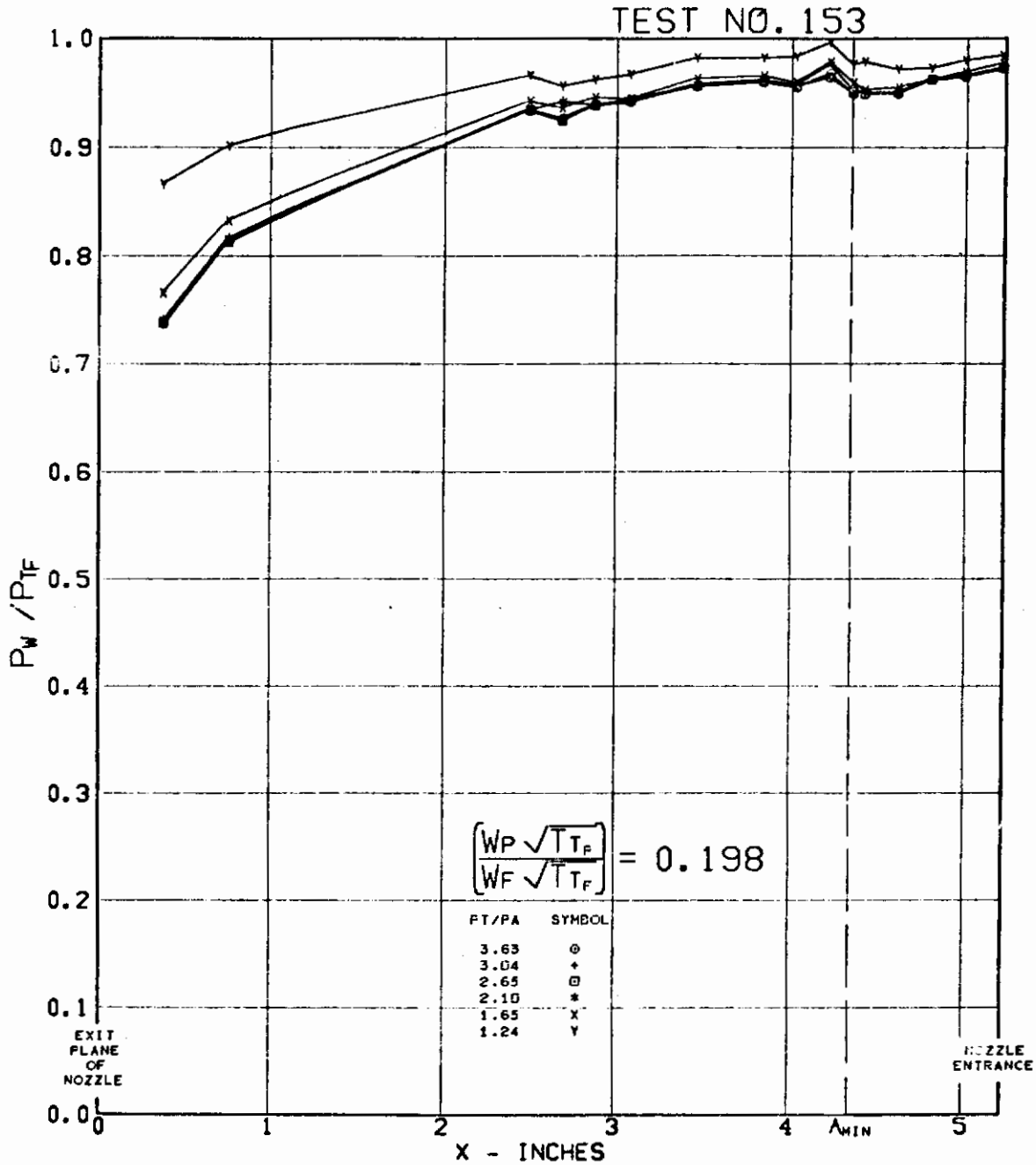


FIGURE 162. WALL PRESSURES - CONFIGURATION 27 AT 0.198 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

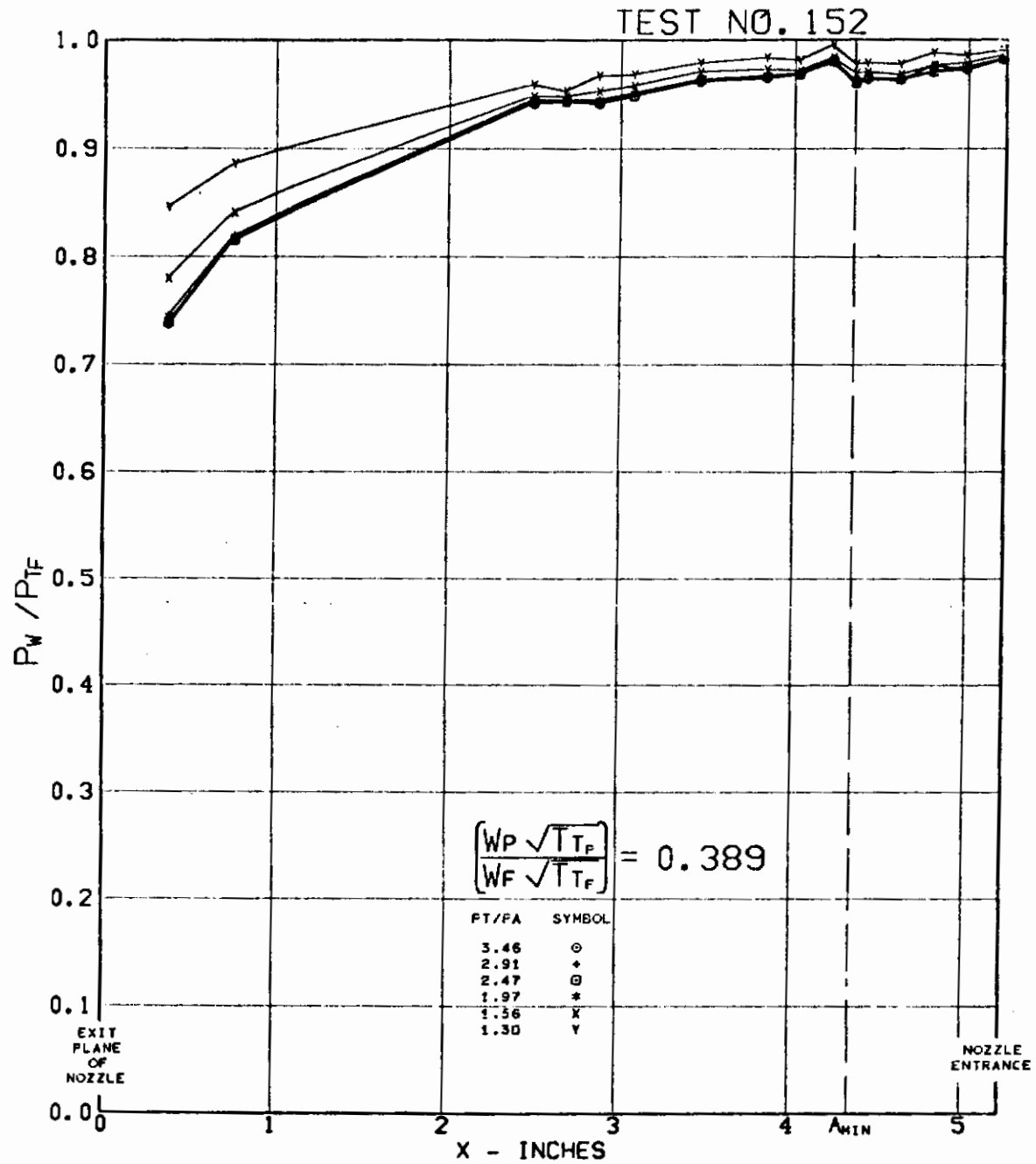


FIGURE 163. WALL PRESSURES - CONFIGURATION 27 AT 0.389 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

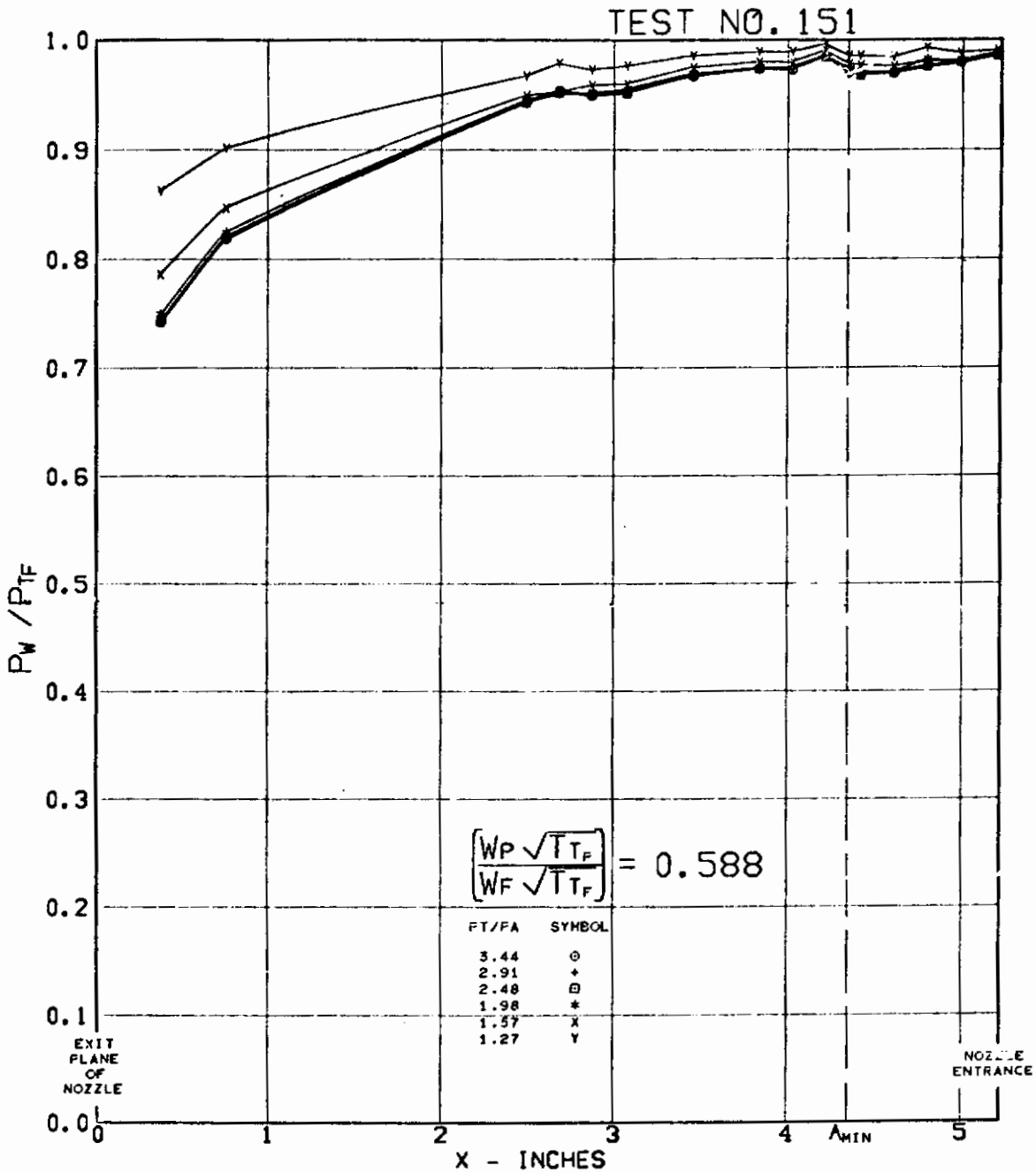


FIGURE 164. WALL PRESSURES - CONFIGURATION 27 AT 0.588 FAN FLOW RATIO $(W_P\sqrt{T_{T_F}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

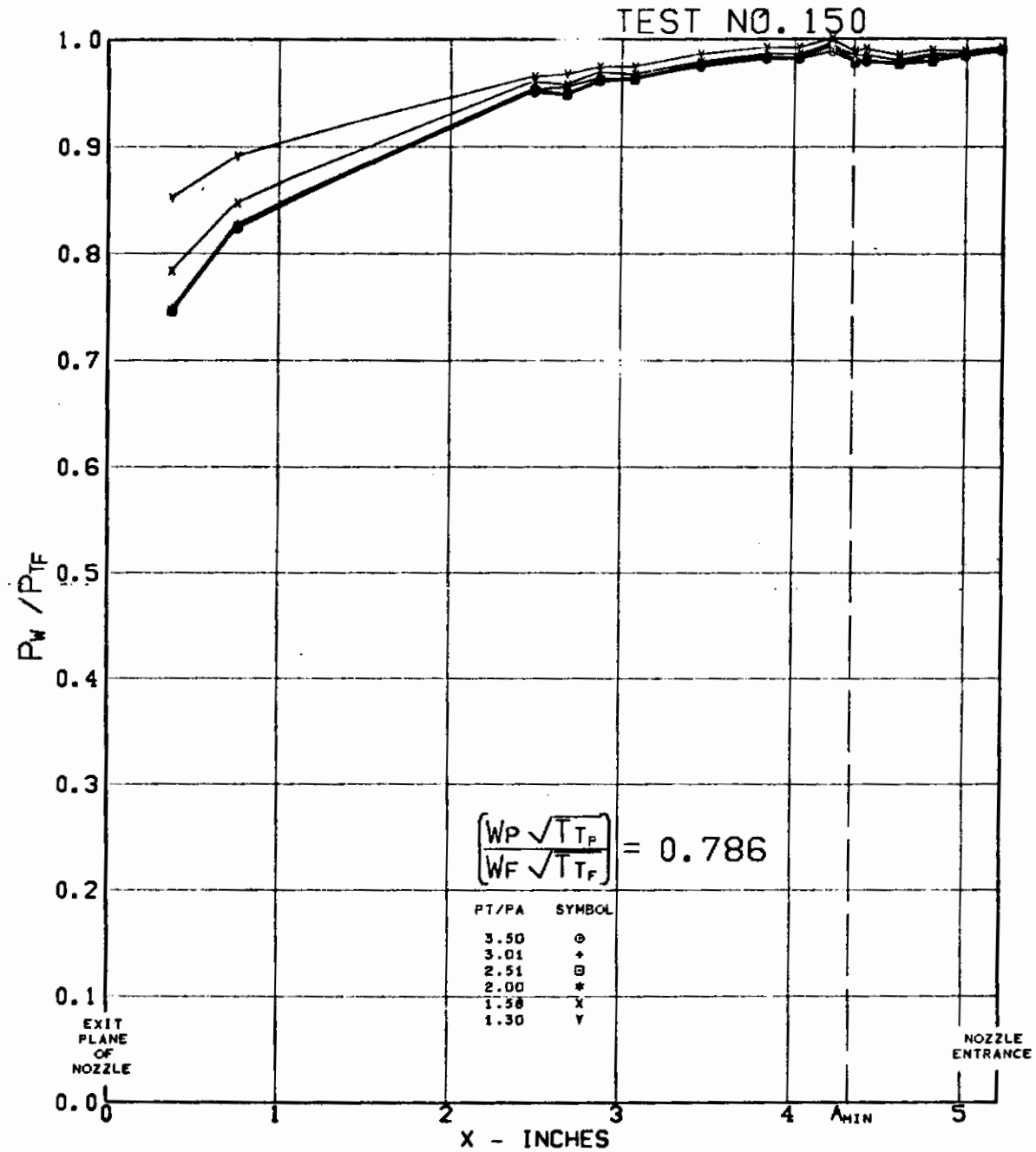


FIGURE 165. WALL PRESSURES - CONFIGURATION 27 AT 0.786 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

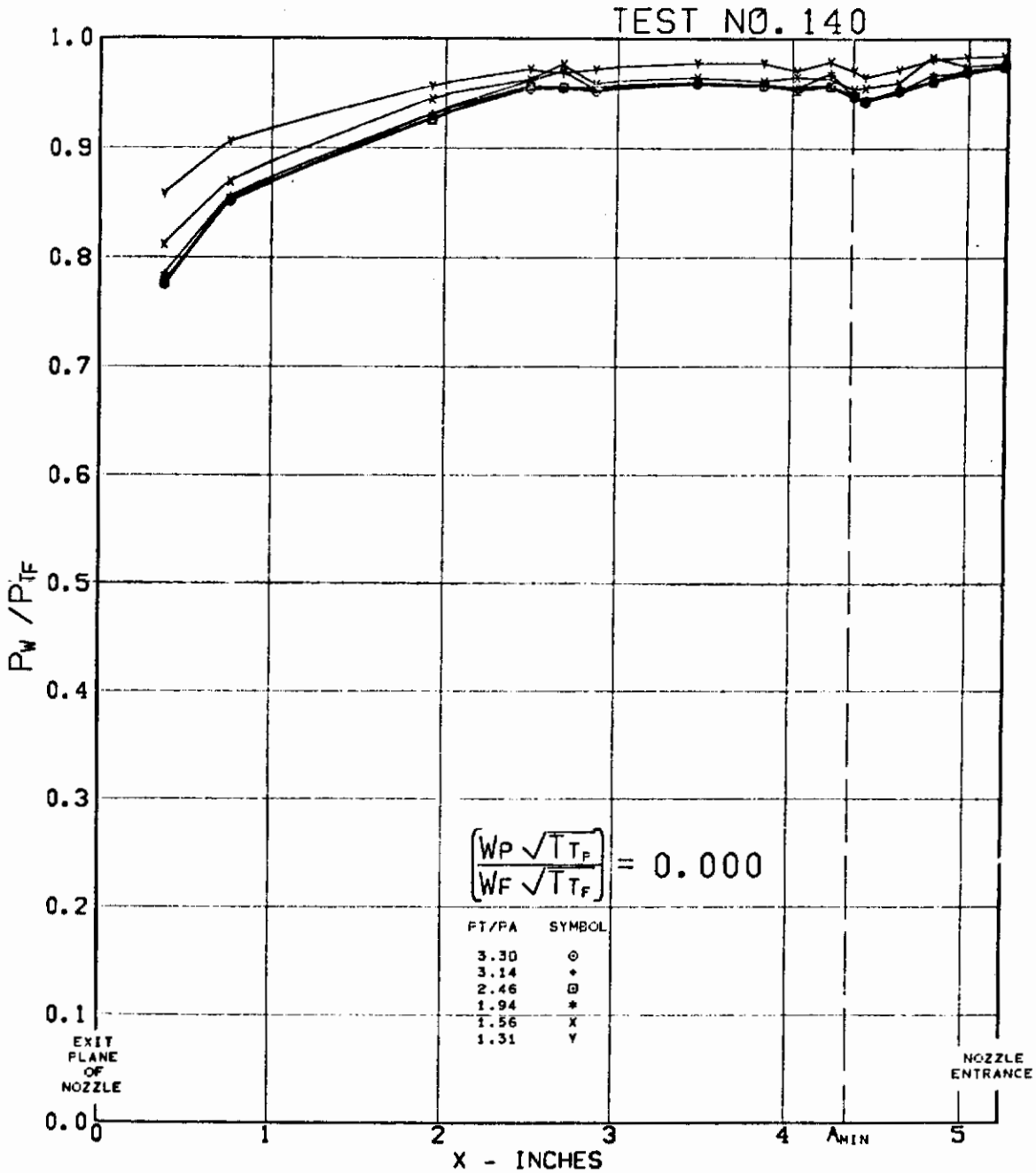


FIGURE 166. WALL PRESSURES - CONFIGURATION 28 AT 0.000 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

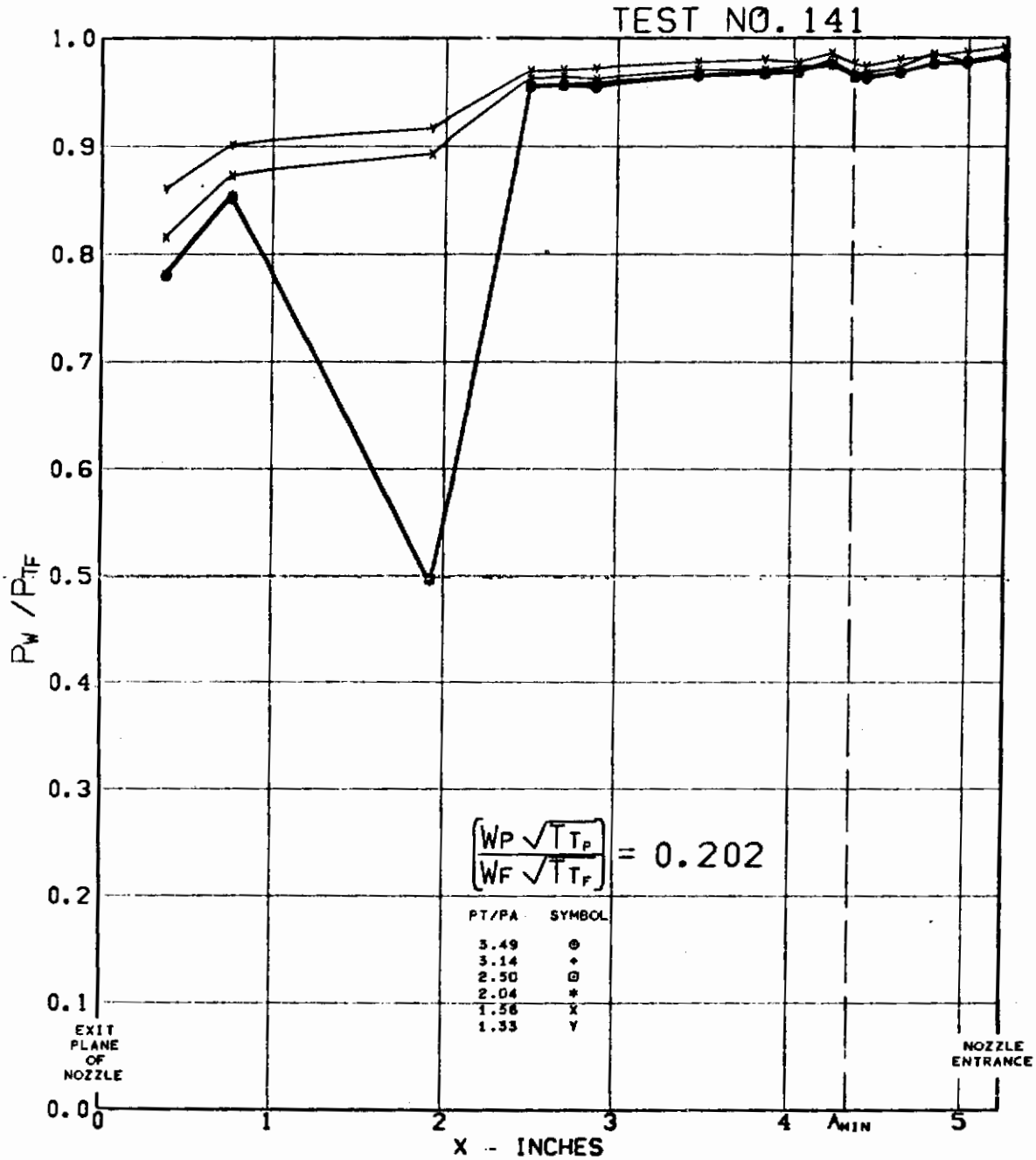


FIGURE 167. WALL PRESSURES - CONFIGURATION 28 AT 0.202 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

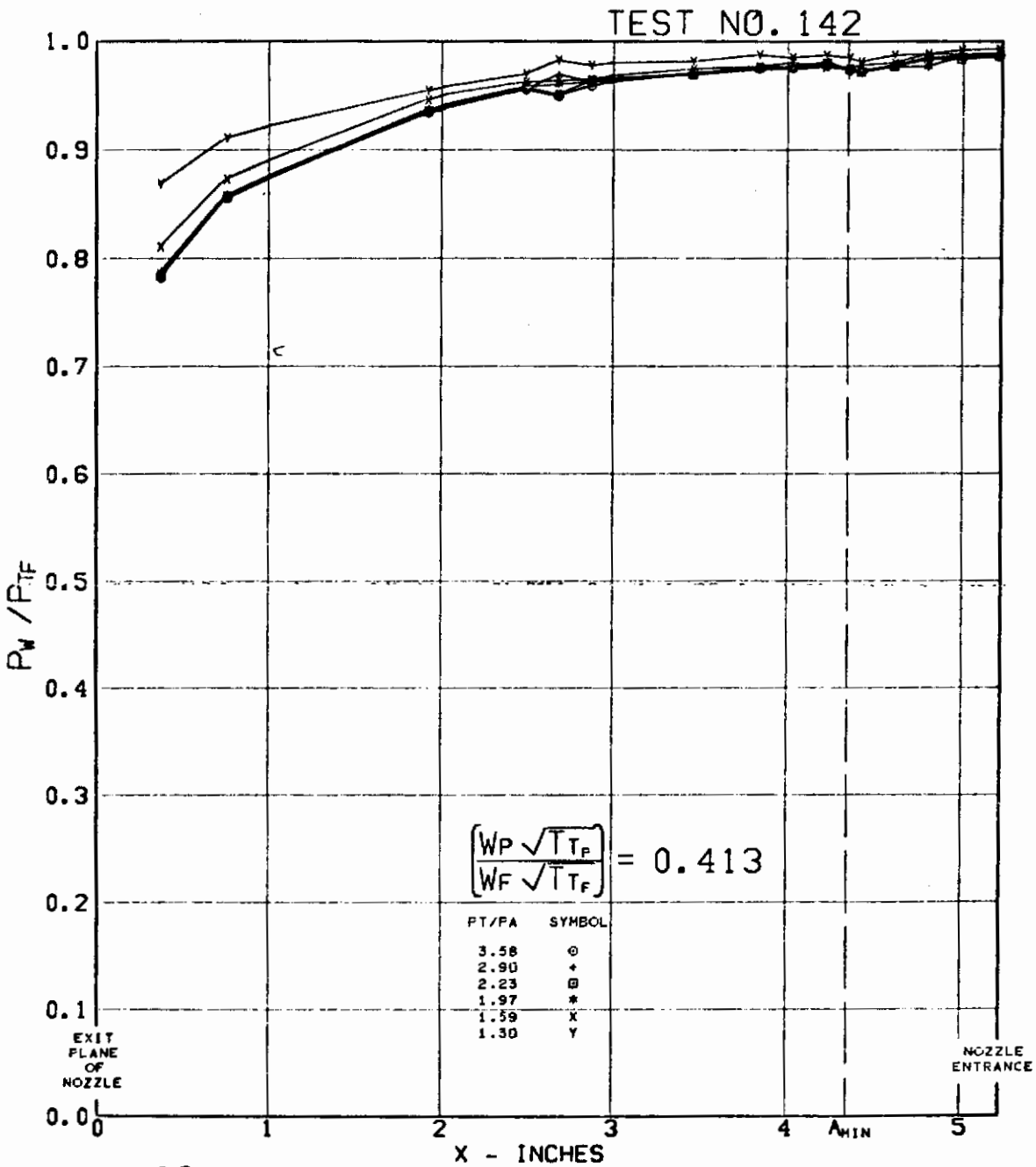


FIGURE 168. WALL PRESSURES - CONFIGURATION 28 AT 0.413 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

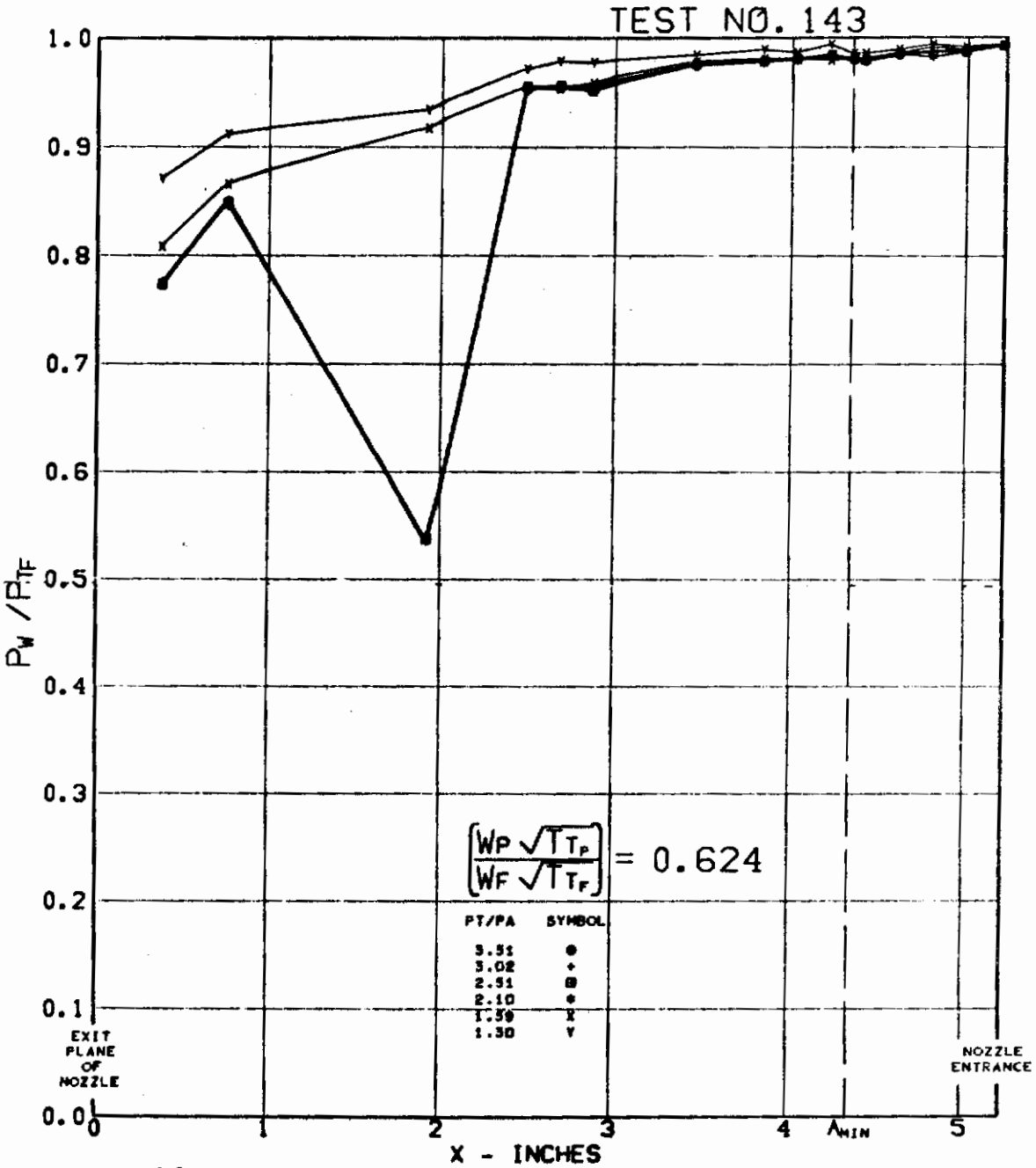


FIGURE 169. WALL PRESSURES - CONFIGURATION 28 AT 0.624 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

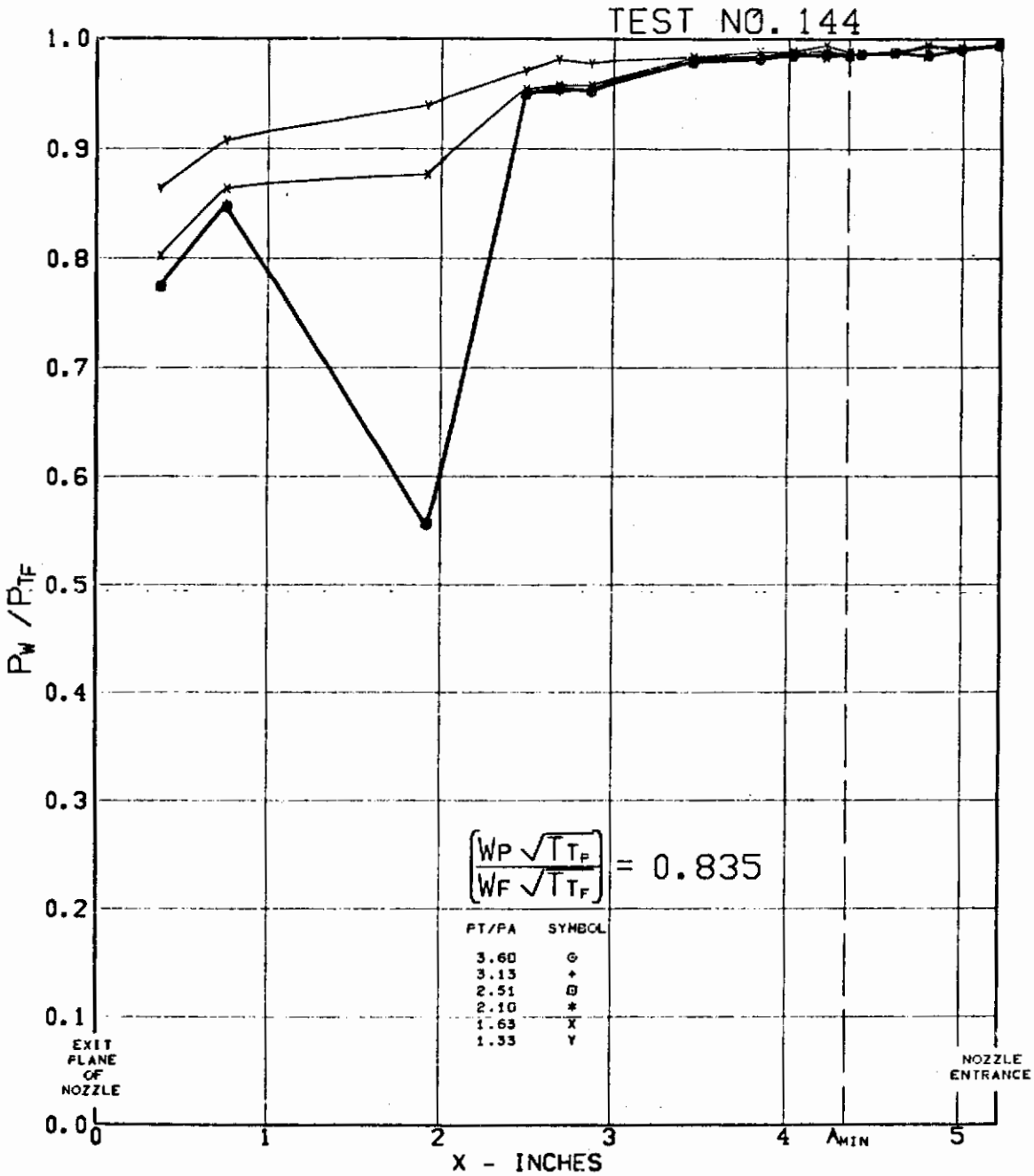


FIGURE 170. WALL PRESSURES - CONFIGURATION 28 AT 0.835 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

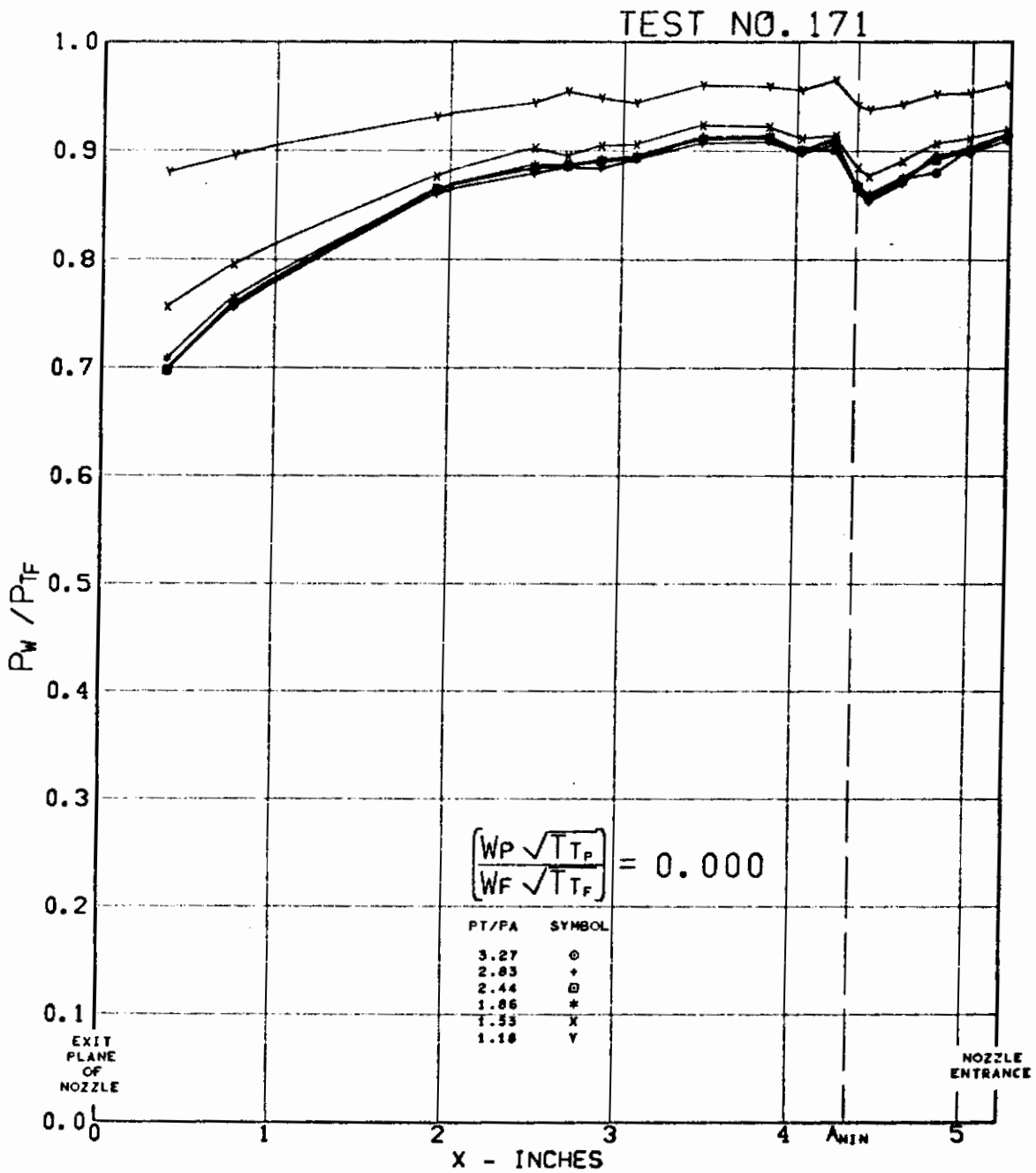


FIGURE 171. WALL PRESSURES - CONFIGURATION 29 AT 0.000 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

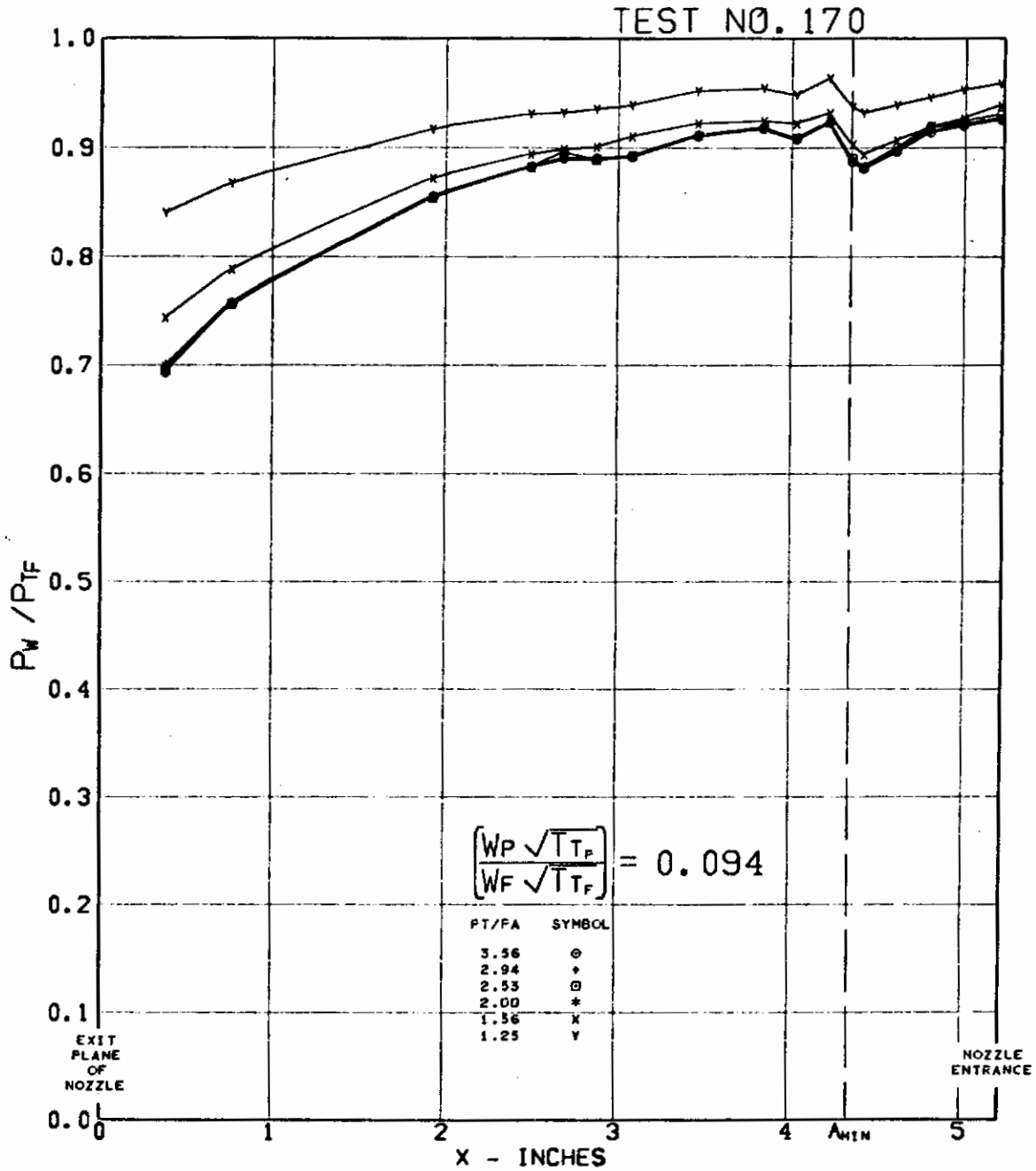


FIGURE 172. WALL PRESSURES - CONFIGURATION 29 AT 0.094 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

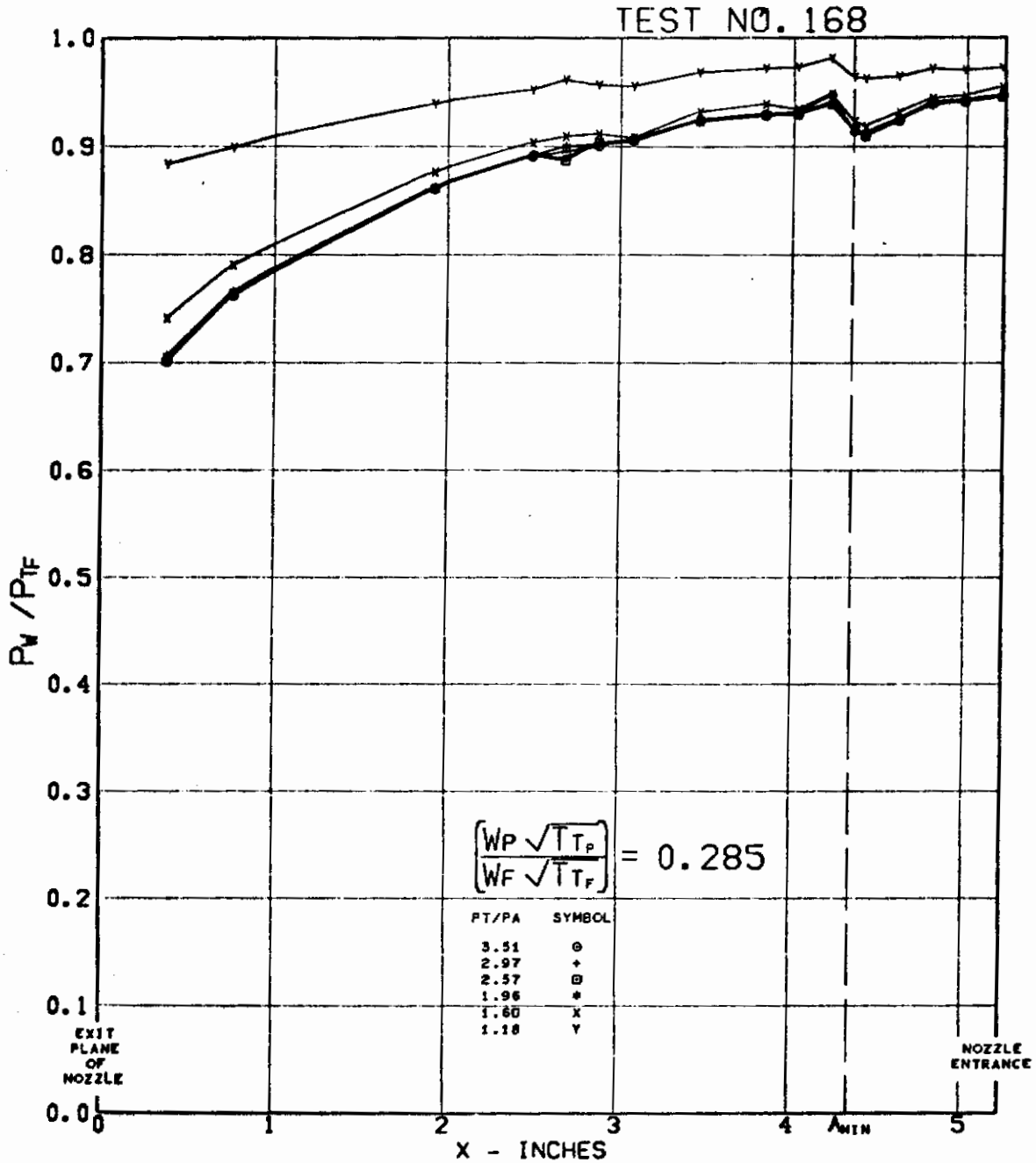


FIGURE 173. WALL PRESSURES - CONFIGURATION 29 AT 0.285 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

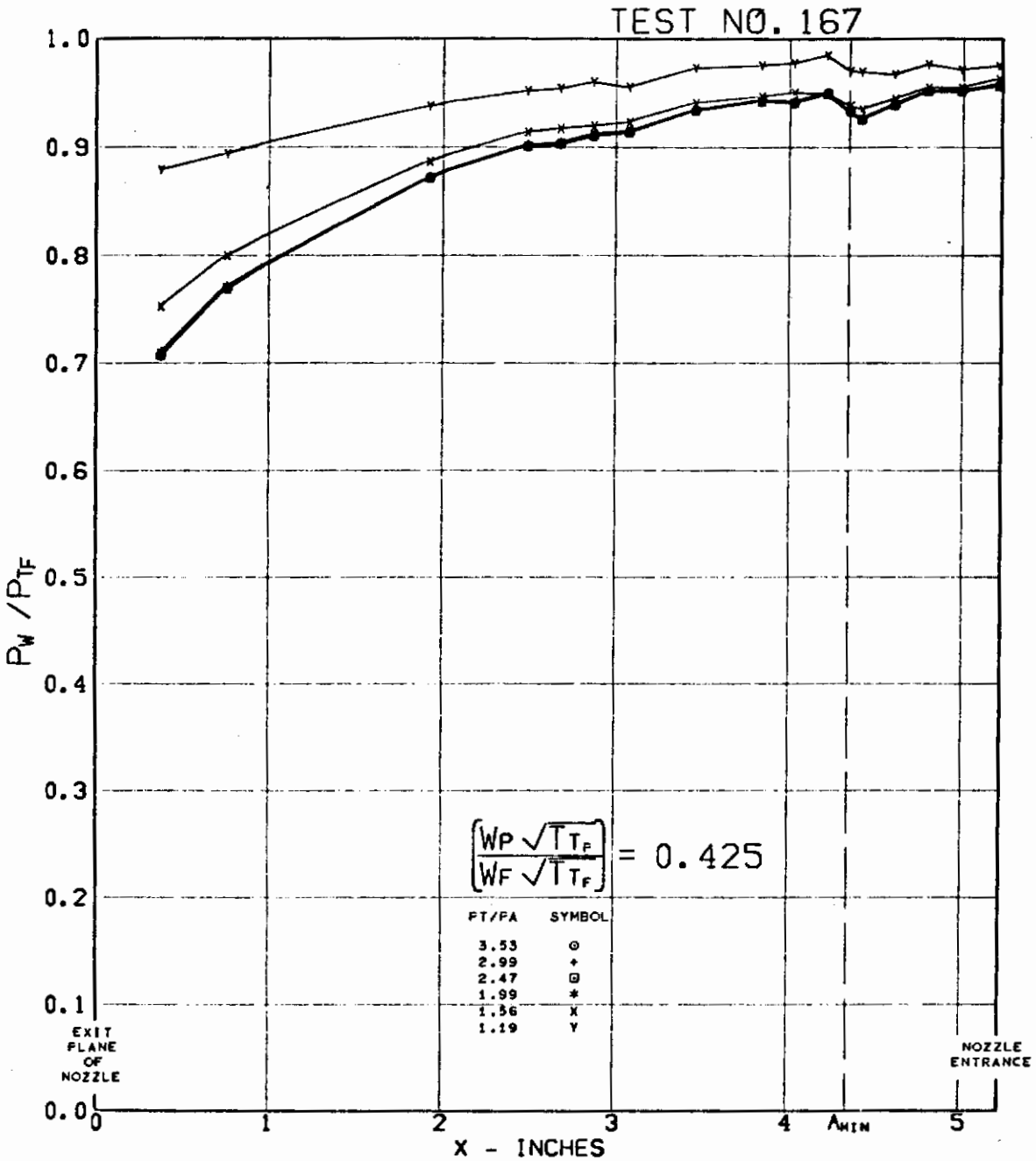


FIGURE 174. WALL PRESSURES - CONFIGURATION 29 AT 0.425 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

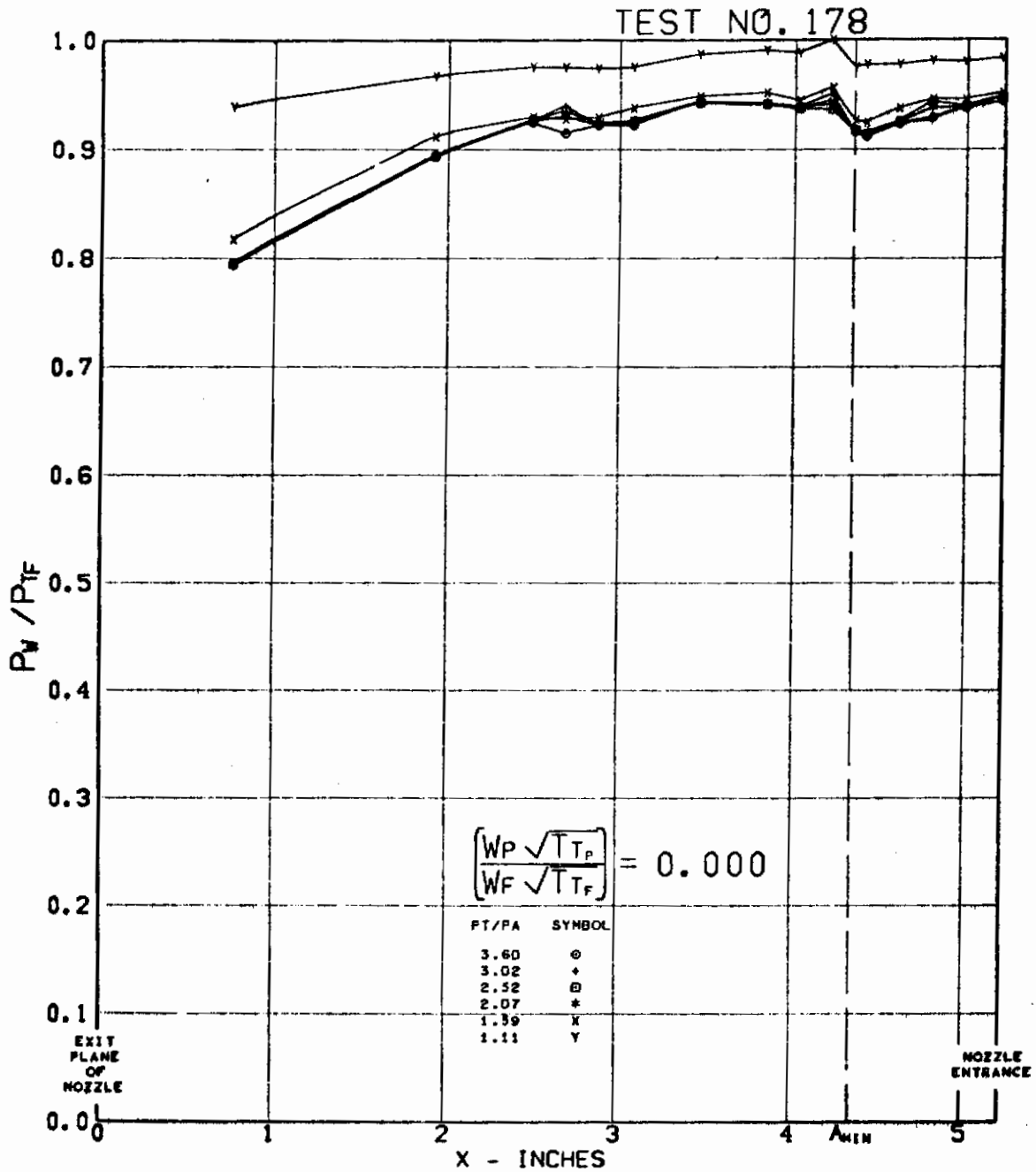


FIGURE 175. WALL PRESSURES - CONFIGURATION 30 AT 0.000 FAN FLOW RATIO ($W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}}$)

Approved for Public Release

Contrails

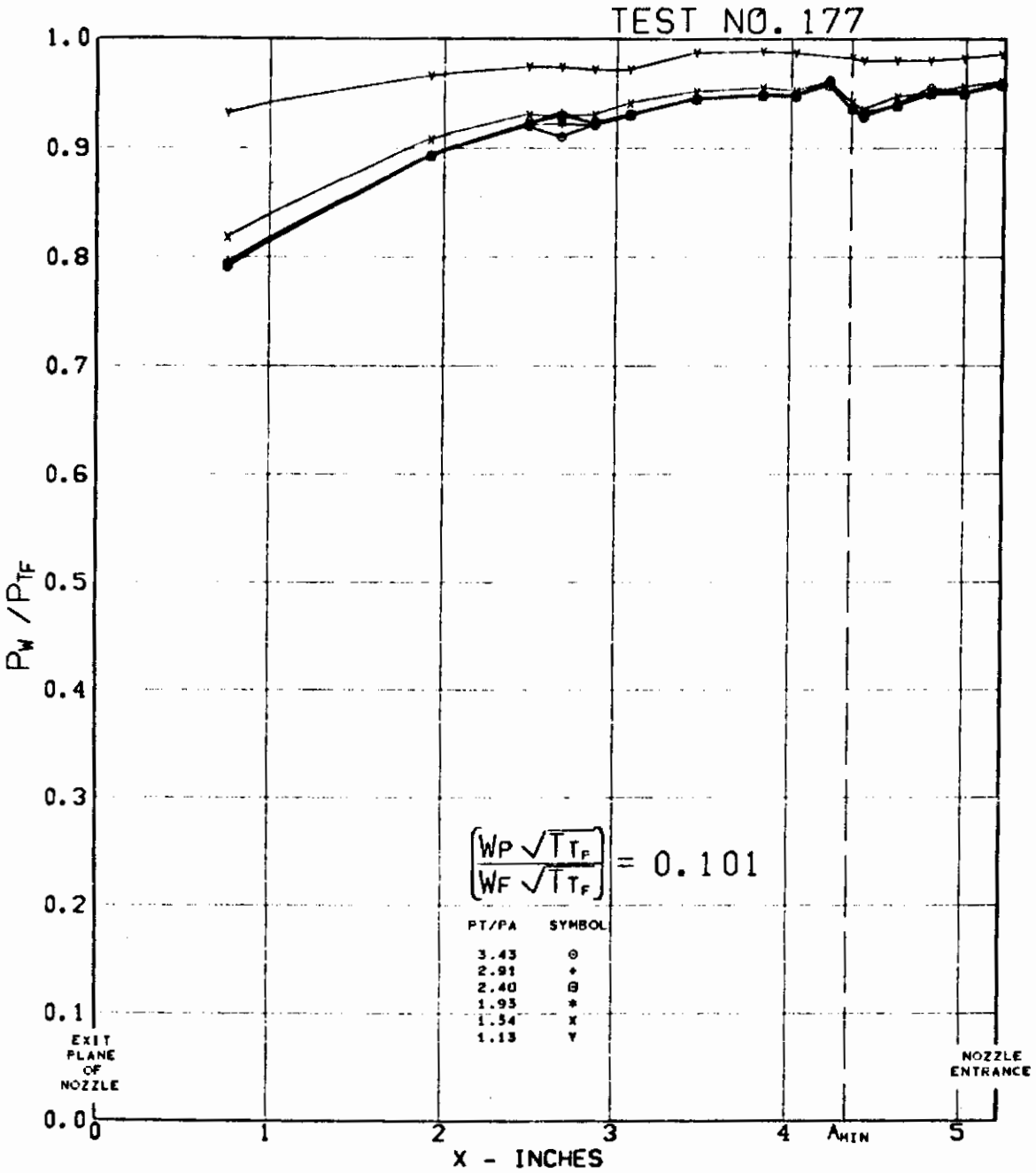


FIGURE 176. WALL PRESSURES - CONFIGURATION 30 AT 0.101 FAN FLOW RATIO $(W_P\sqrt{T_{T_F}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

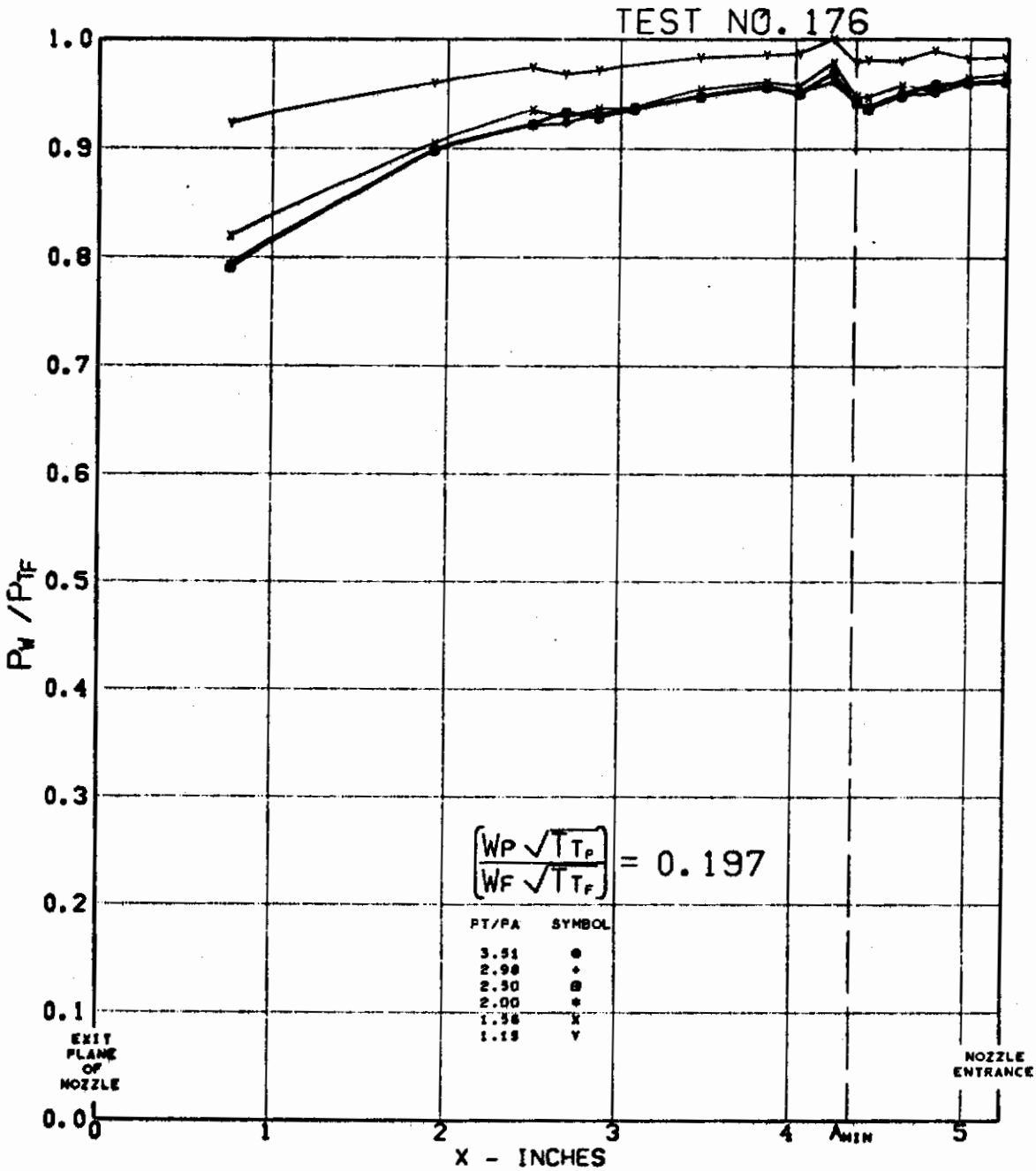


FIGURE 177. WALL PRESSURES - CONFIGURATION 30 AT 0.197 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

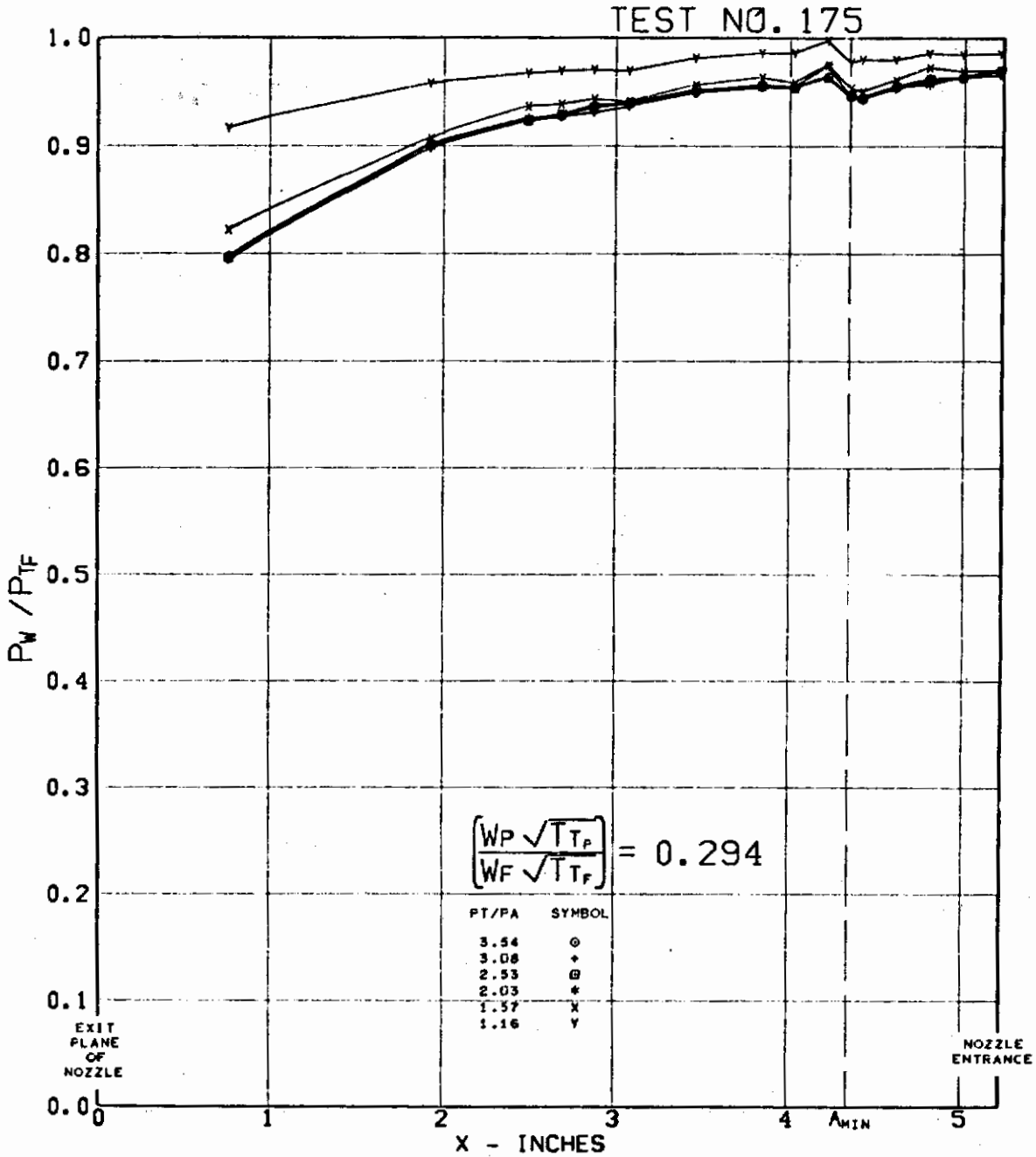


FIGURE 178. WALL PRESSURES - CONFIGURATION 30 AT 0.294 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

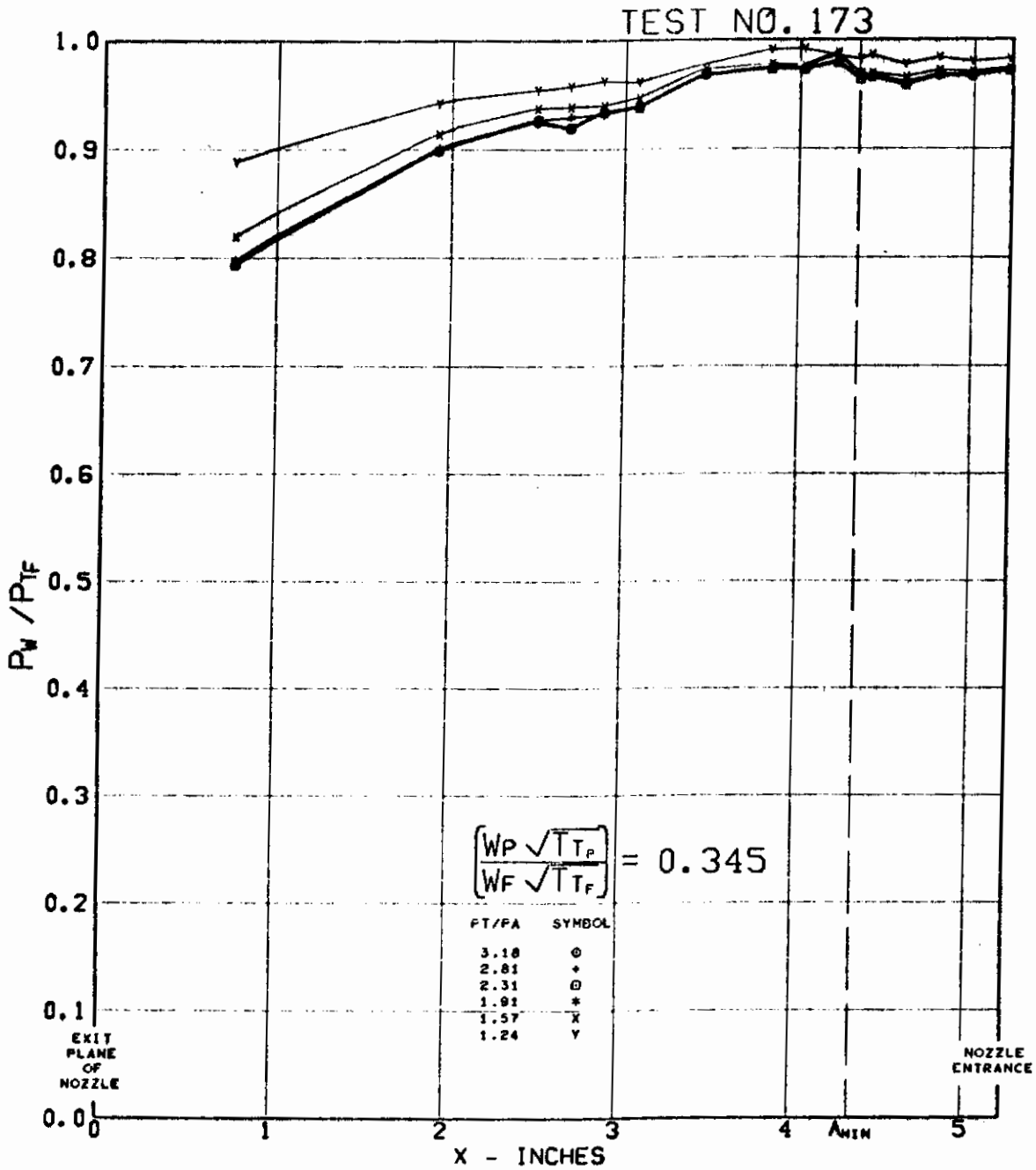


FIGURE 179. WALL PRESSURES - CONFIGURATION 30 AT 0.345 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

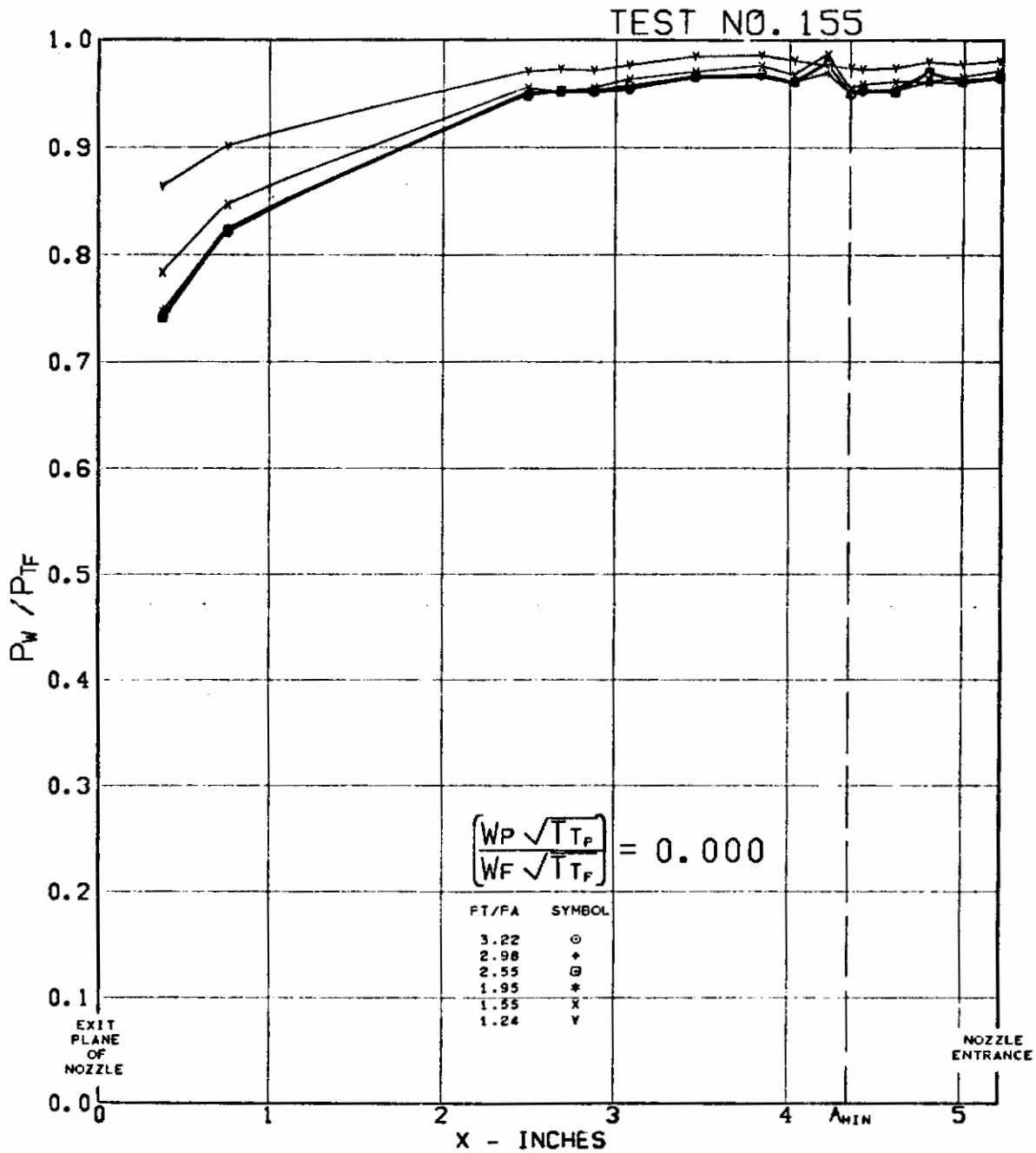


FIGURE 180. WALL PRESSURES - CONFIGURATION 31 AT 0.000 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

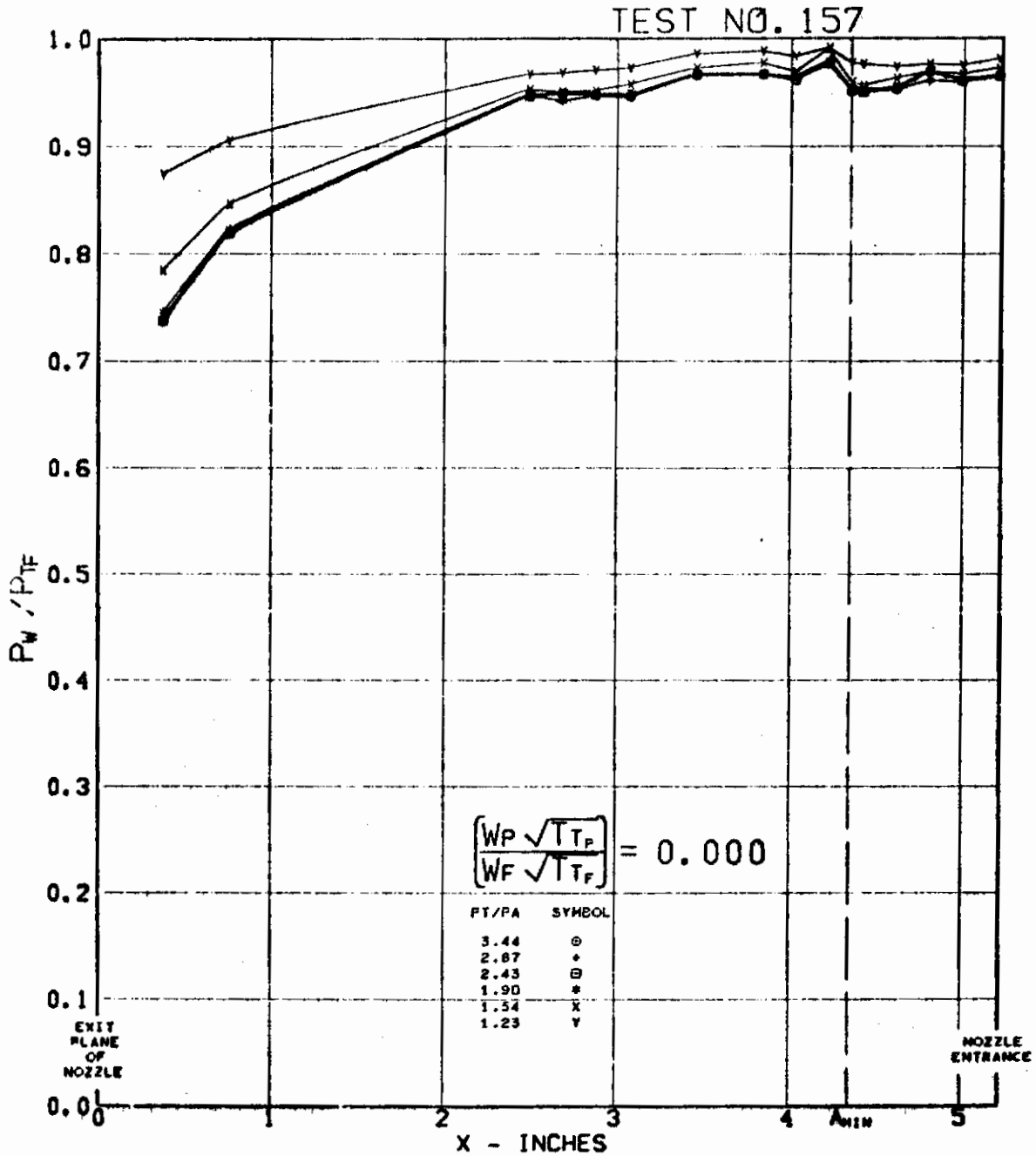


FIGURE 181. WALL PRESSURES - CONFIGURATION 31 AT 0.000 FAN FLOW RATIO ($W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}}$)

Approved for Public Release

Contrails

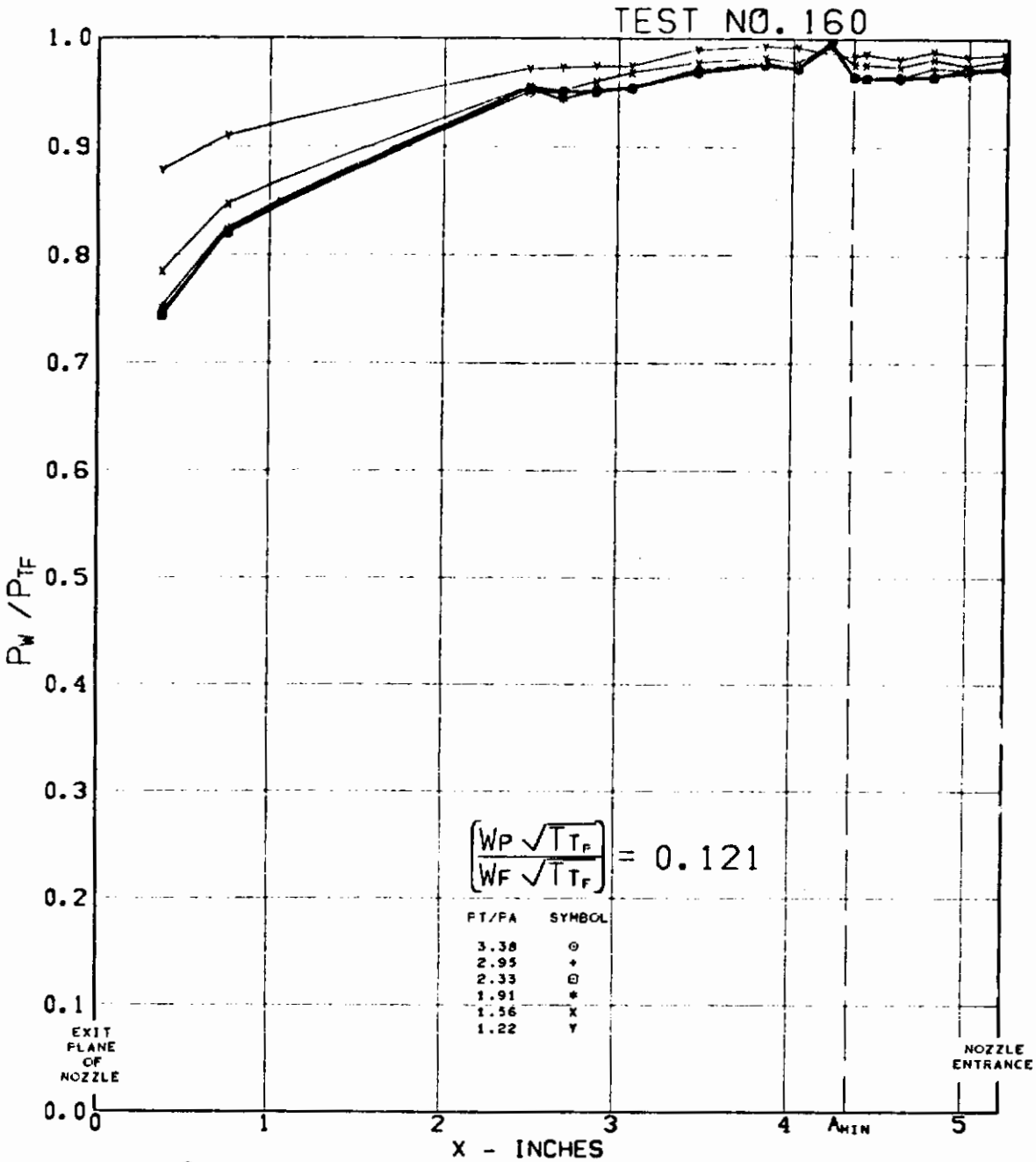


FIGURE 182. WALL PRESSURES - CONFIGURATION 31 AT 0.121 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

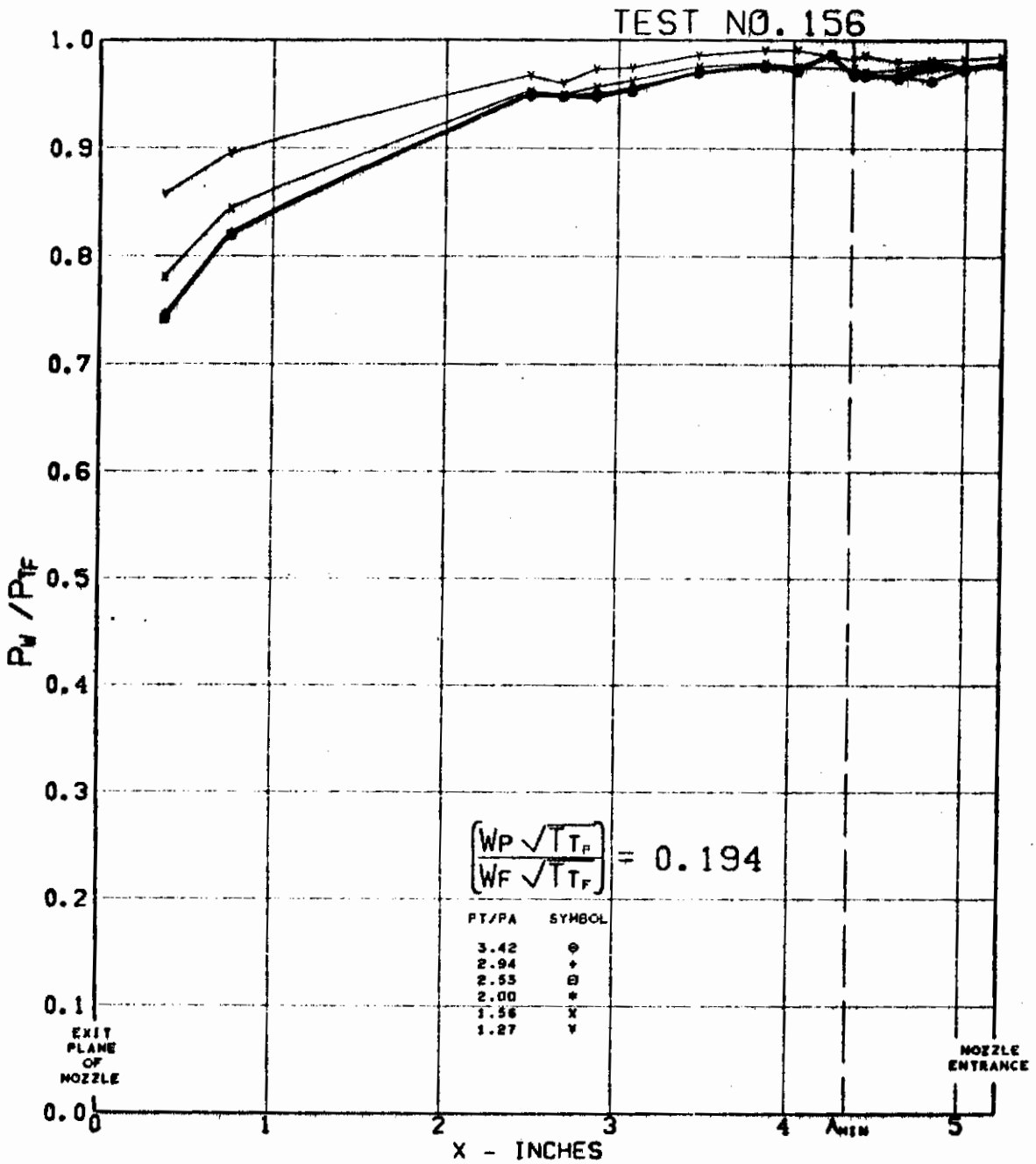


FIGURE 183. WALL PRESSURES - CONFIGURATION 31 AT 0.194 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

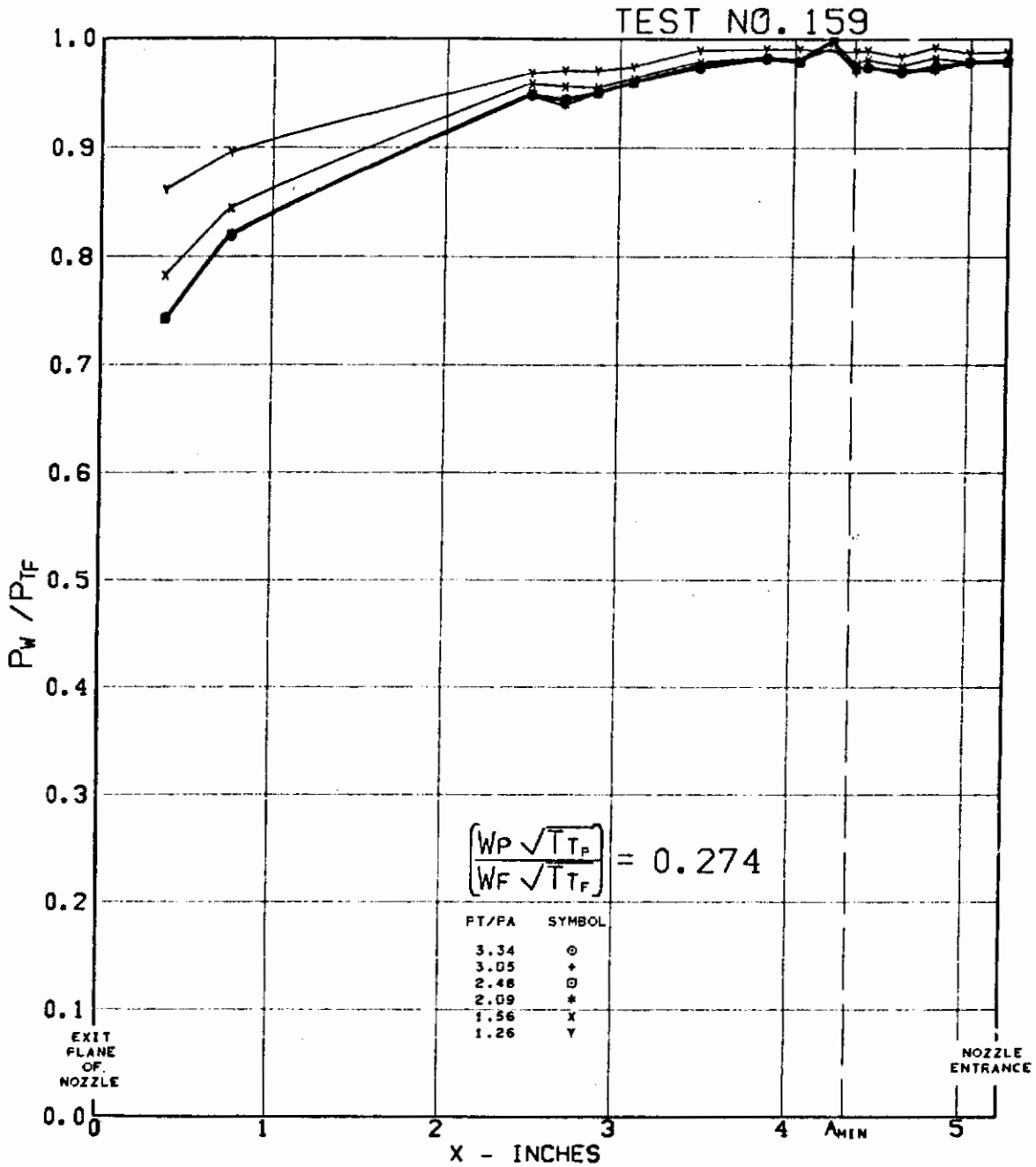


FIGURE 184. WALL PRESSURES - CONFIGURATION 31 AT 0.274 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

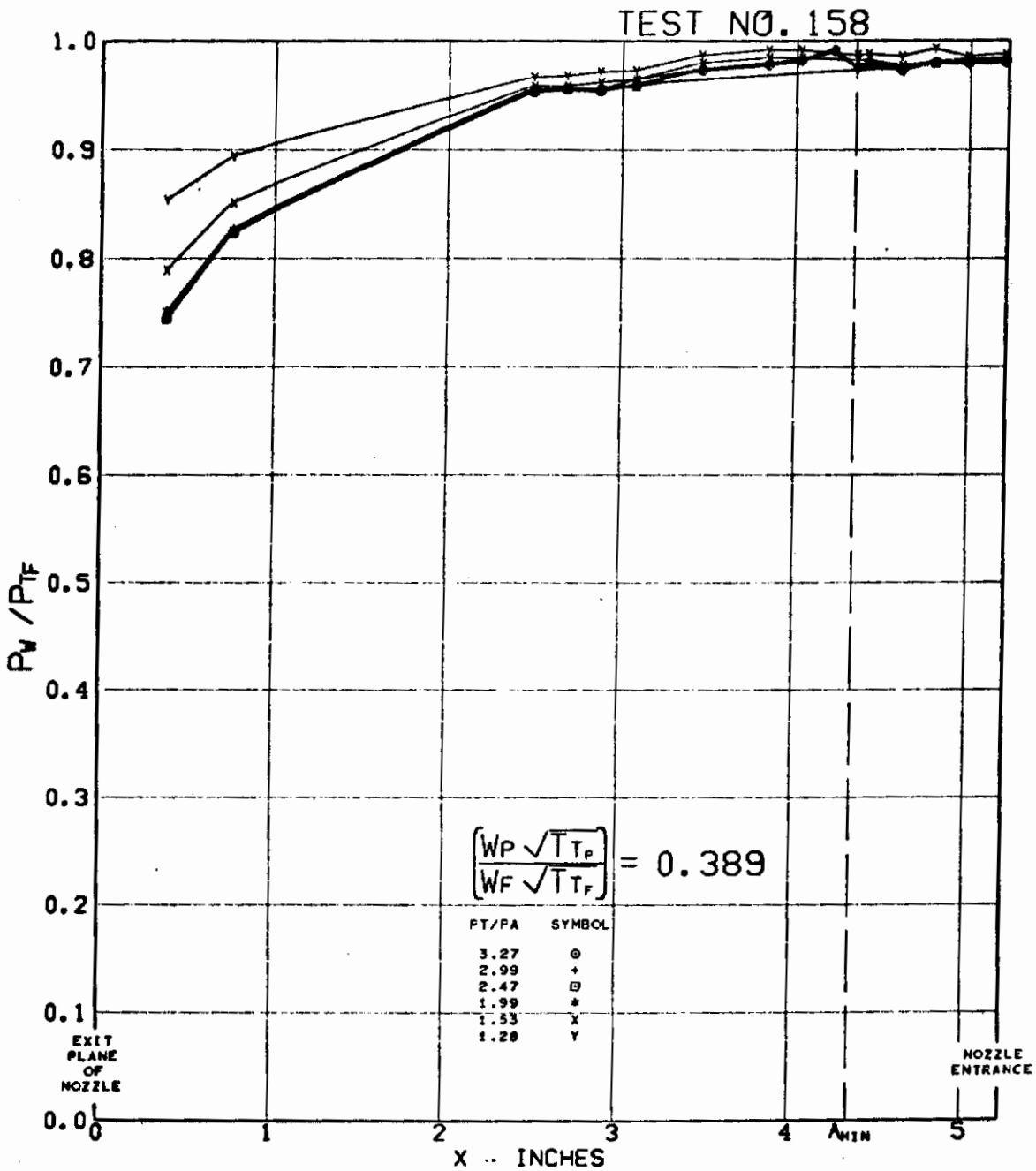


FIGURE 185. WALL PRESSURES - CONFIGURATION 31 AT 0.389 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

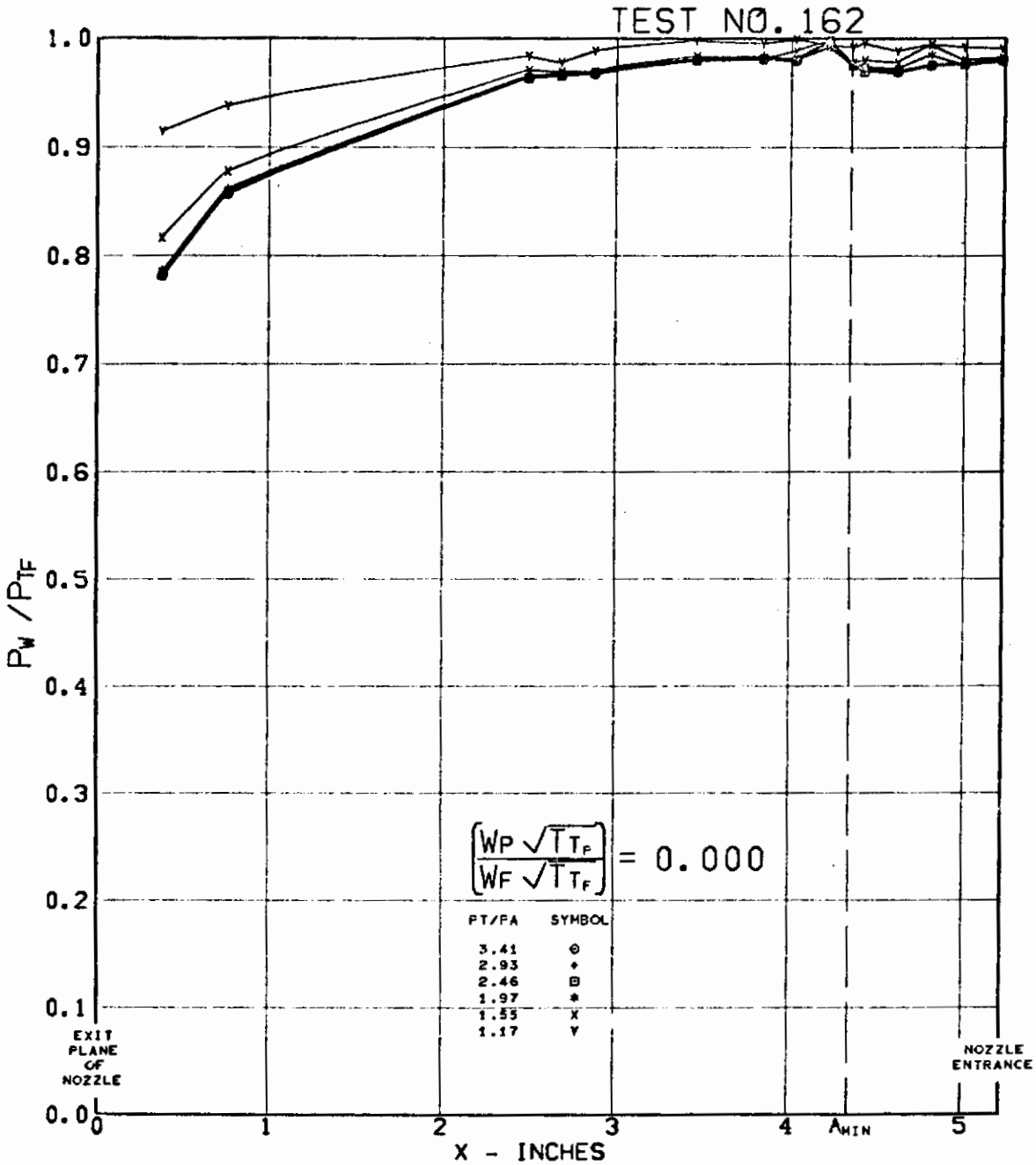


FIGURE 186 WALL PRESSURES - CONFIGURATION 32 AT 0.000 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

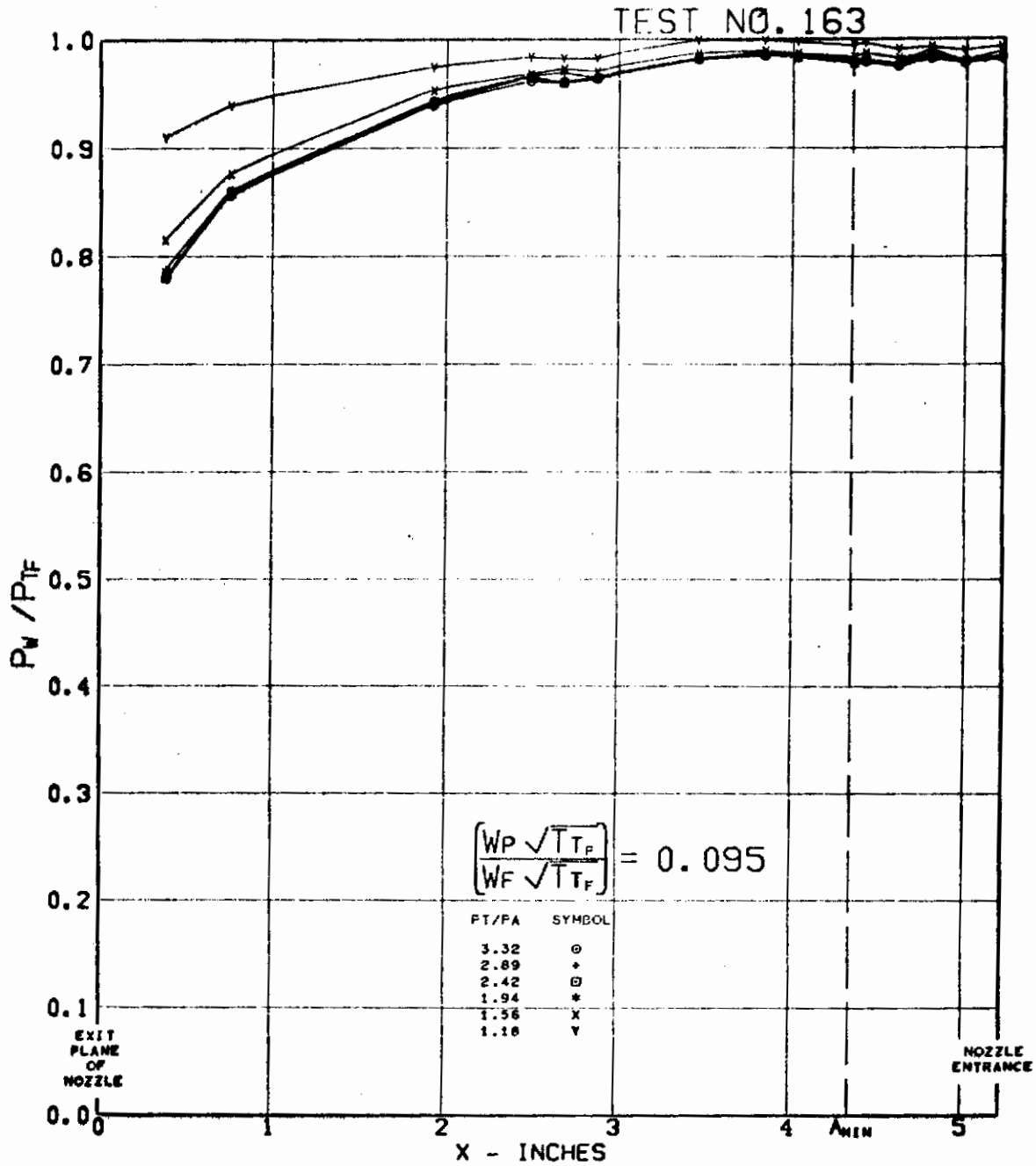


FIGURE 187. WALL PRESSURES - CONFIGURATION 32 AT 0.095 FAN FLOW RATIO ($W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}}$)

Approved for Public Release

Contrails

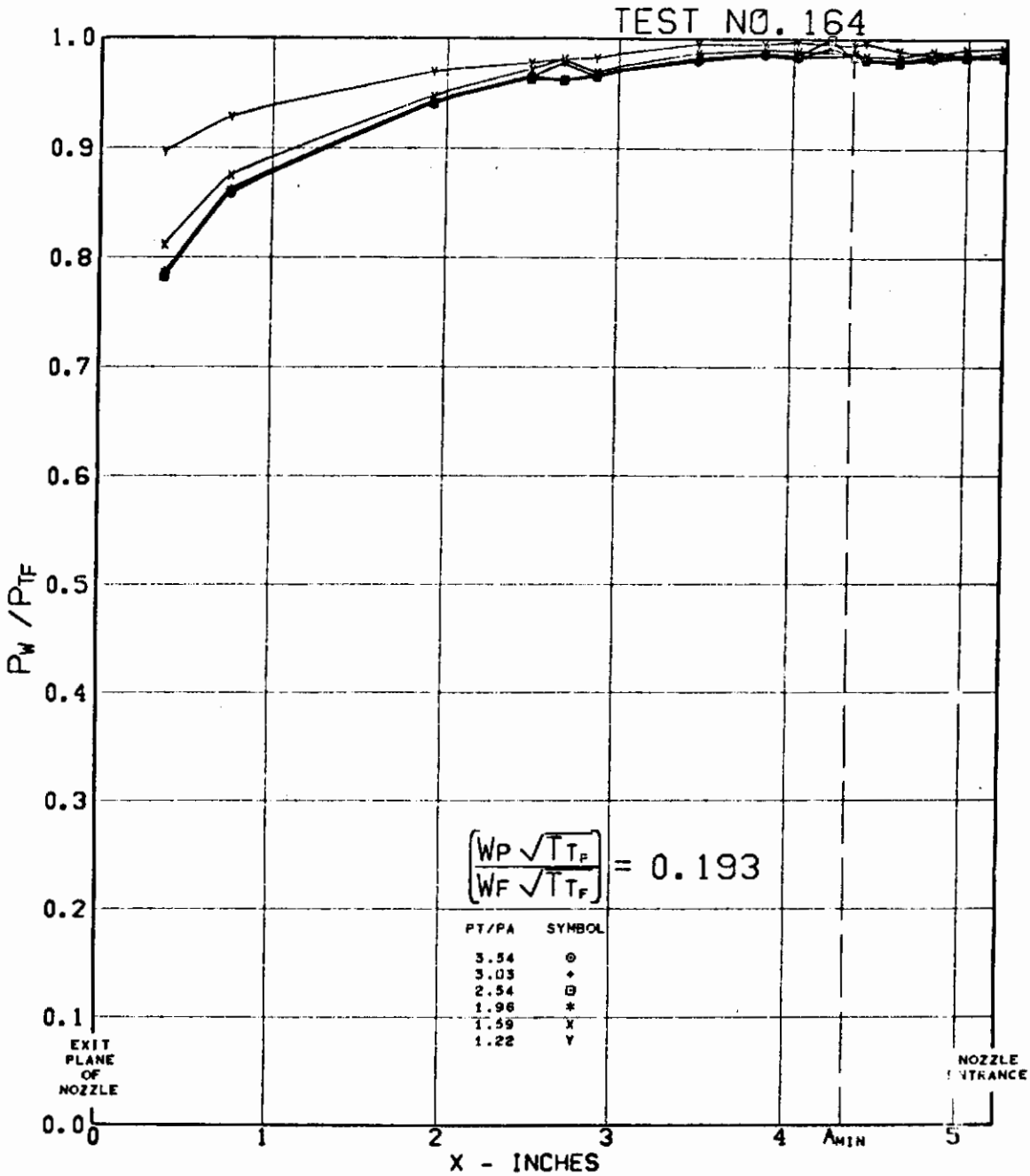


FIGURE 188. WALL PRESSURES - CONFIGURATION 32 AT 0.193 FAN FLOW RATIO $(W_P\sqrt{T_{T_F}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

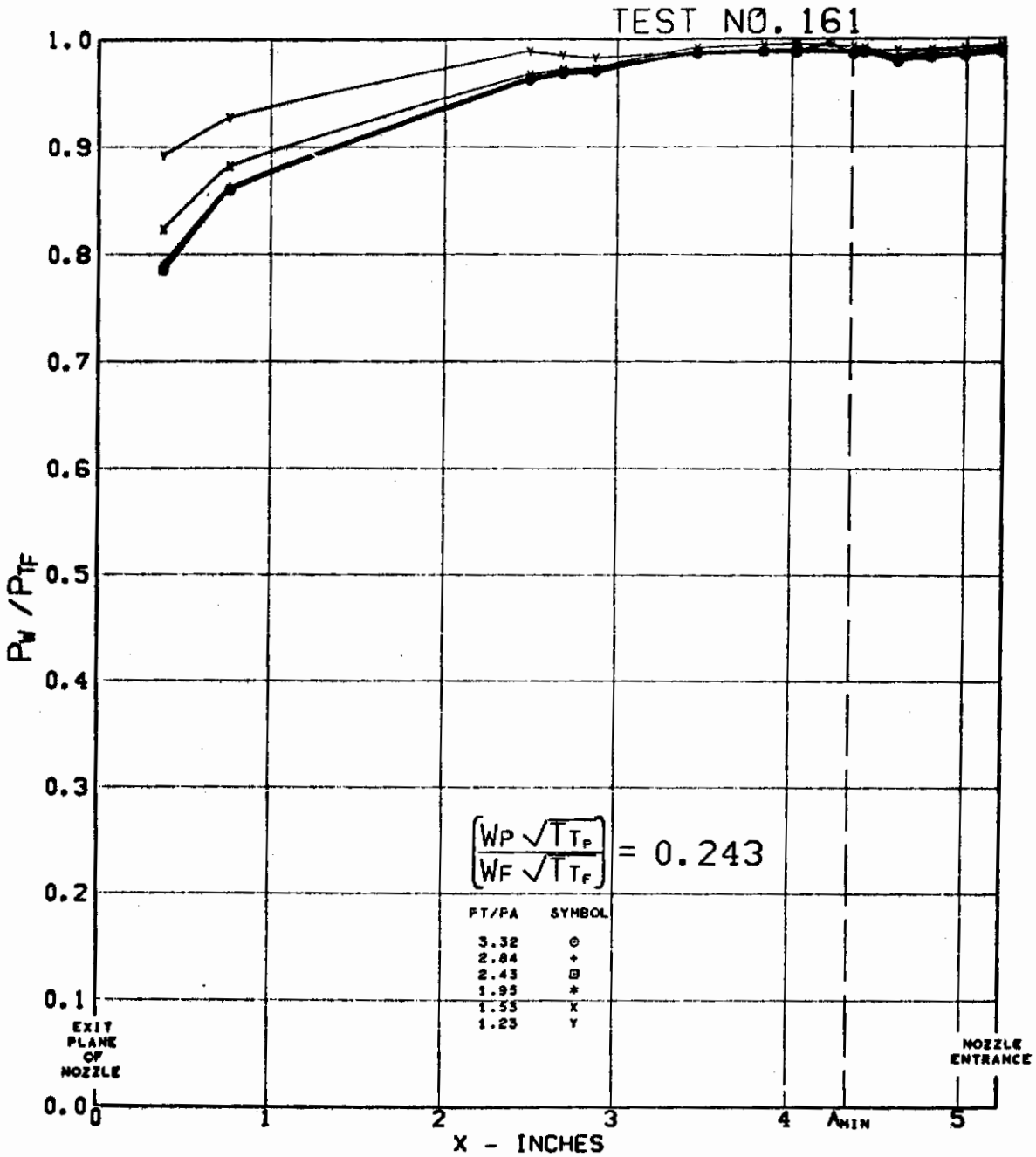


FIGURE 189. WALL PRESSURES - CONFIGURATION 32 AT 0.243 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

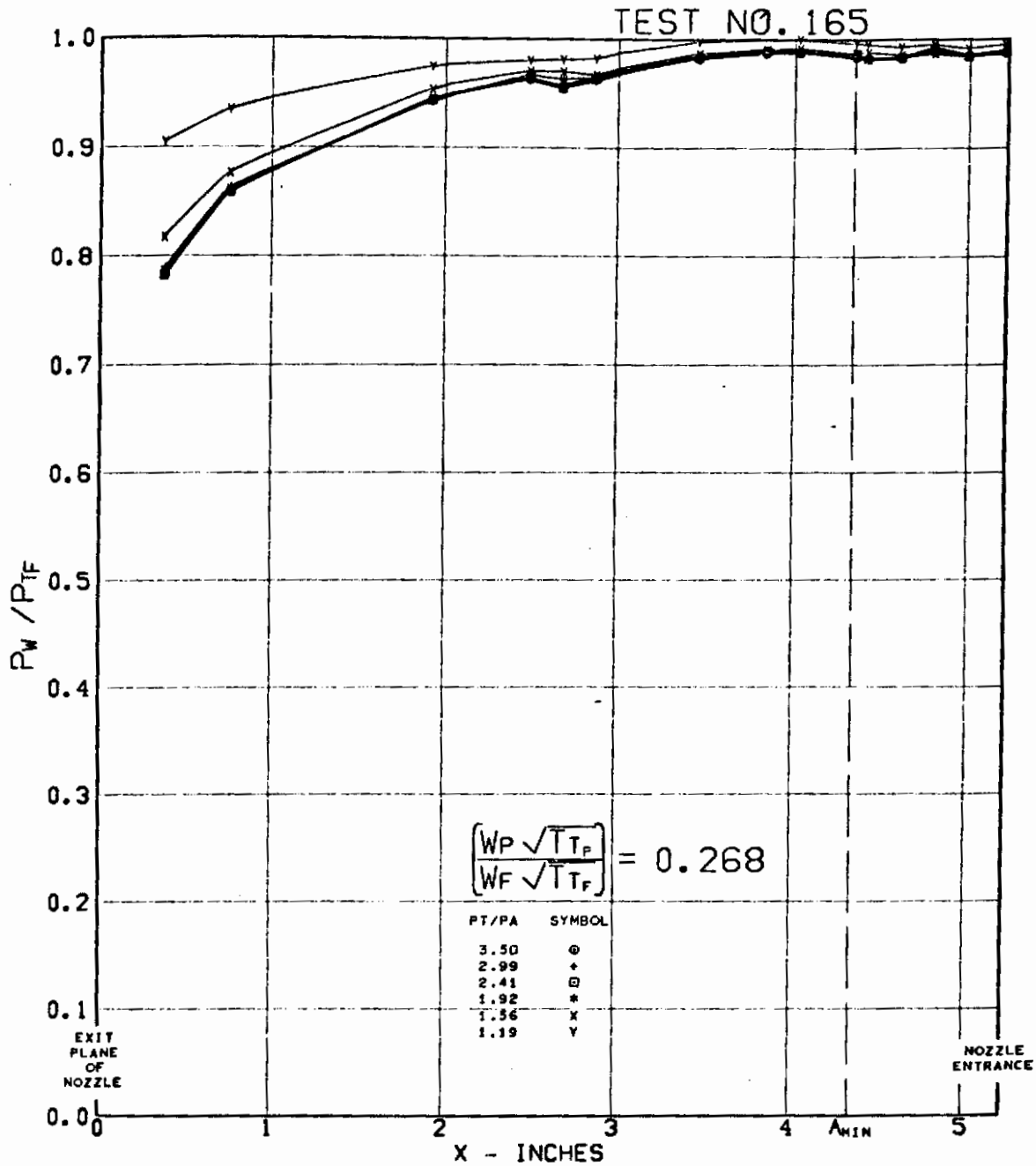


FIGURE 190. WALL PRESSURES - CONFIGURATION 32 AT 0.268 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

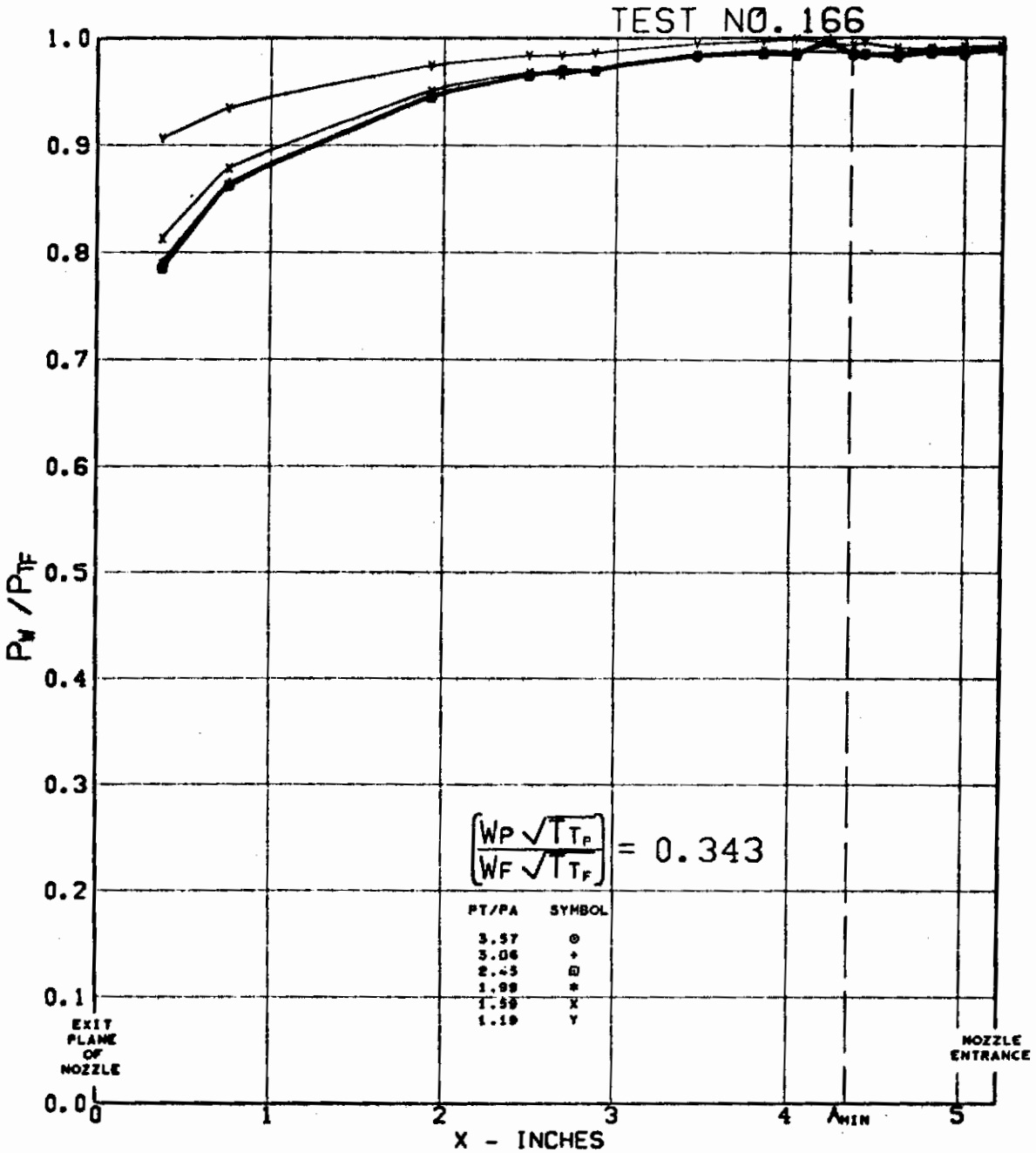


FIGURE 191. WALL PRESSURES - CONFIGURATION 32 AT 0.343 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

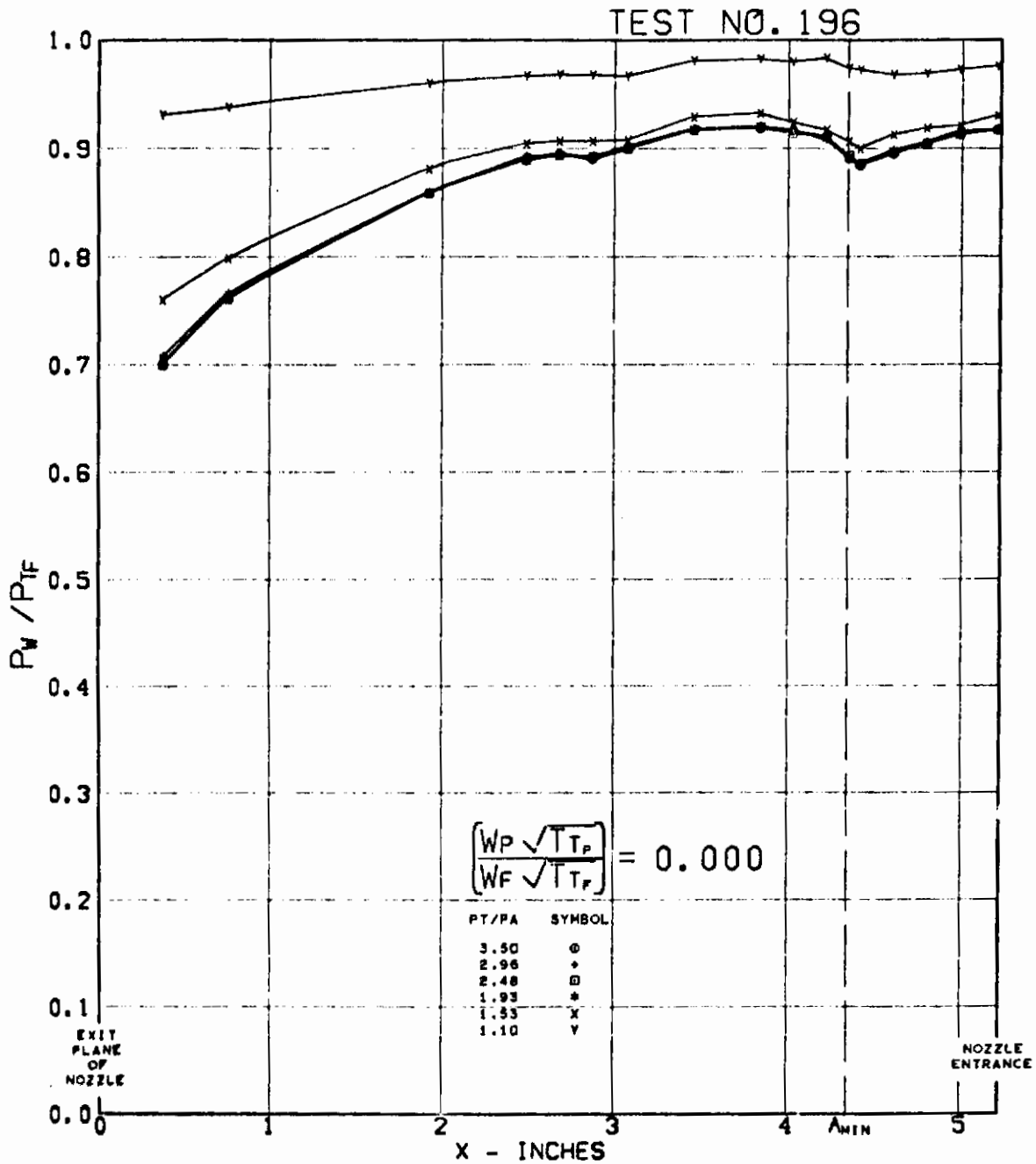


FIGURE 192. WALL PRESSURES - CONFIGURATION 33 AT 0.000 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

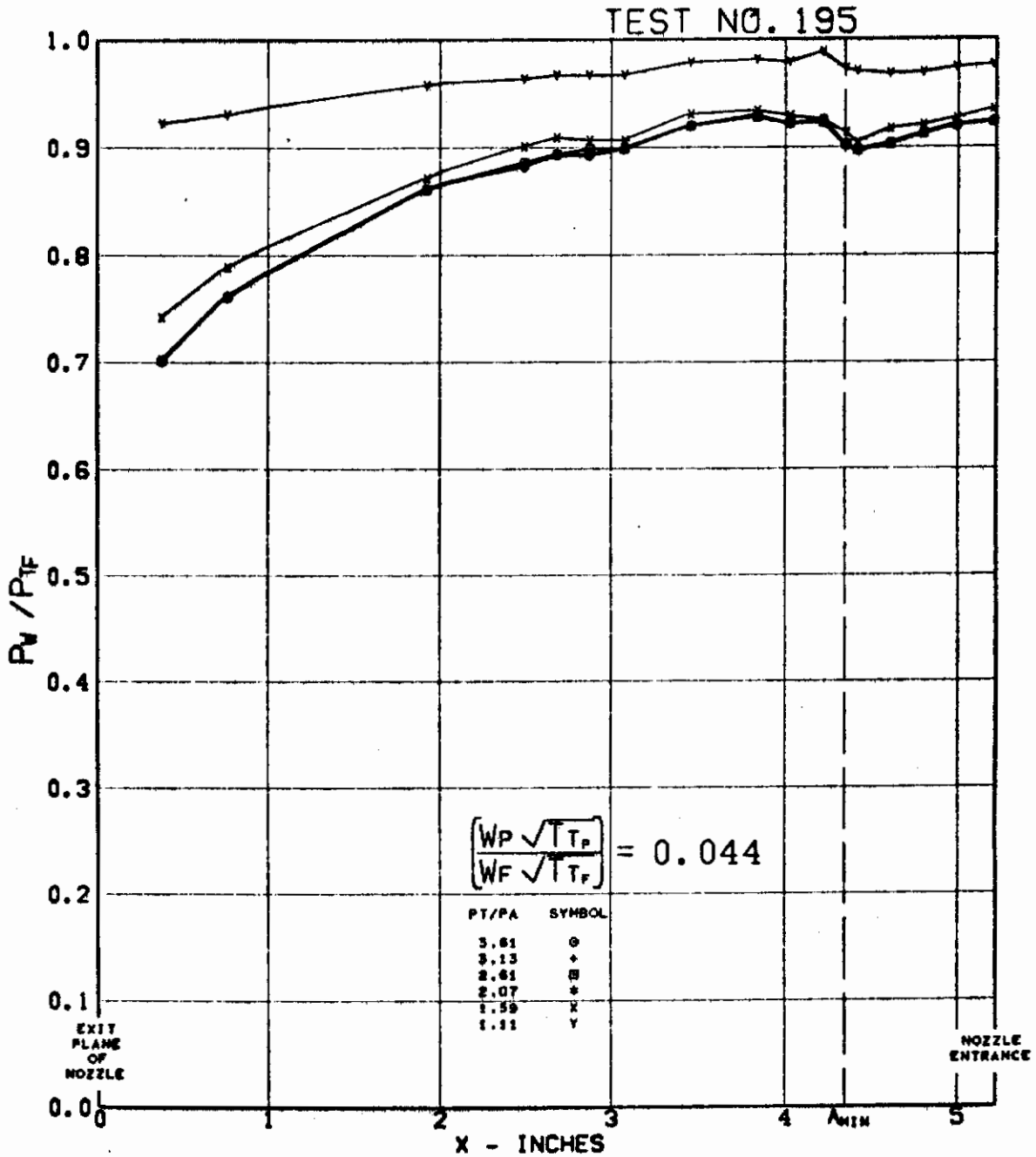


FIGURE 193. WALL PRESSURES - CONFIGURATION 33 AT 0.044 FAN FLOW RATIO ($W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}}$)

Approved for Public Release

Contrails

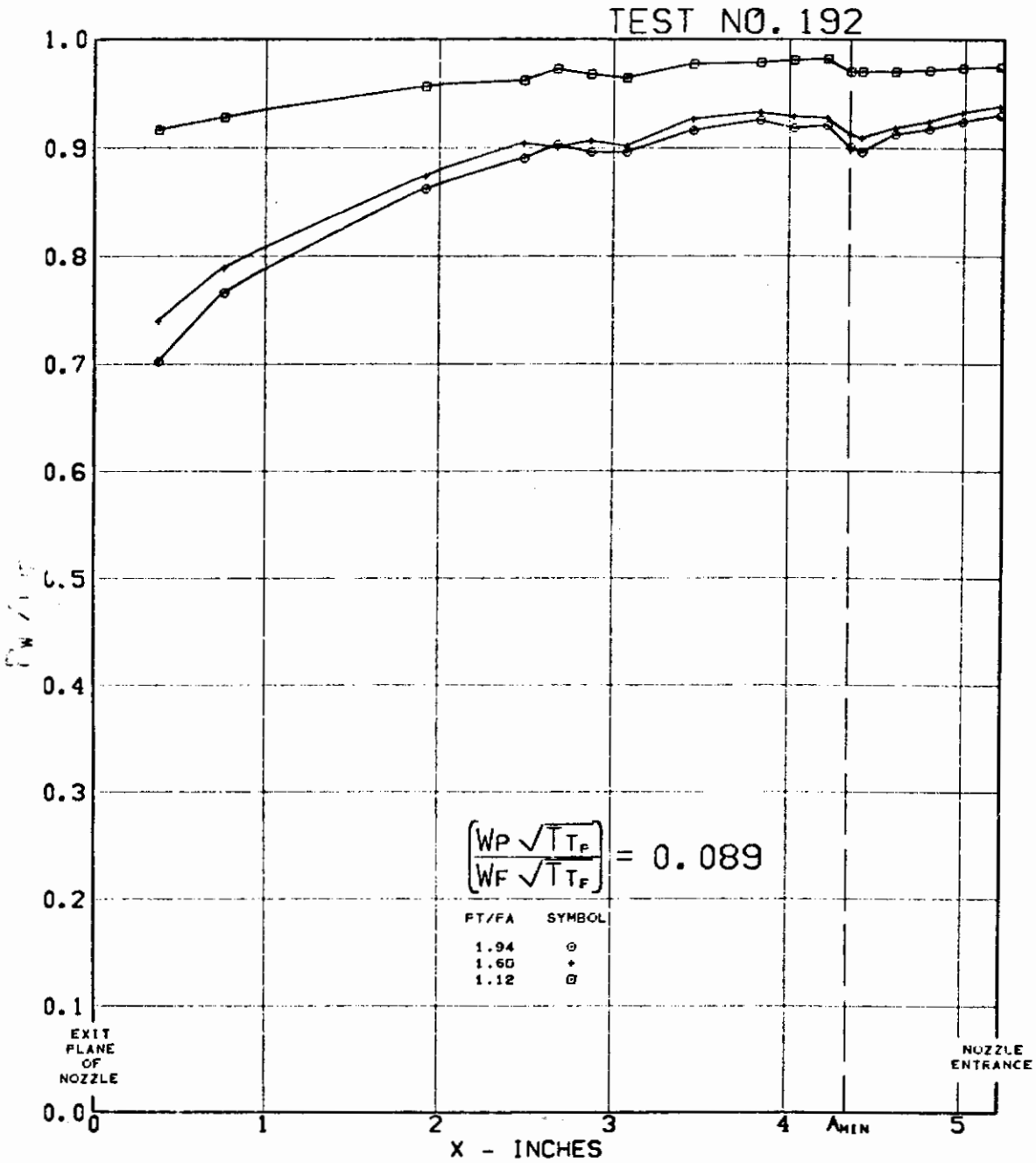


FIGURE 194. WALL PRESSURES - CONFIGURATION 33 AT 0.089 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}}/W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

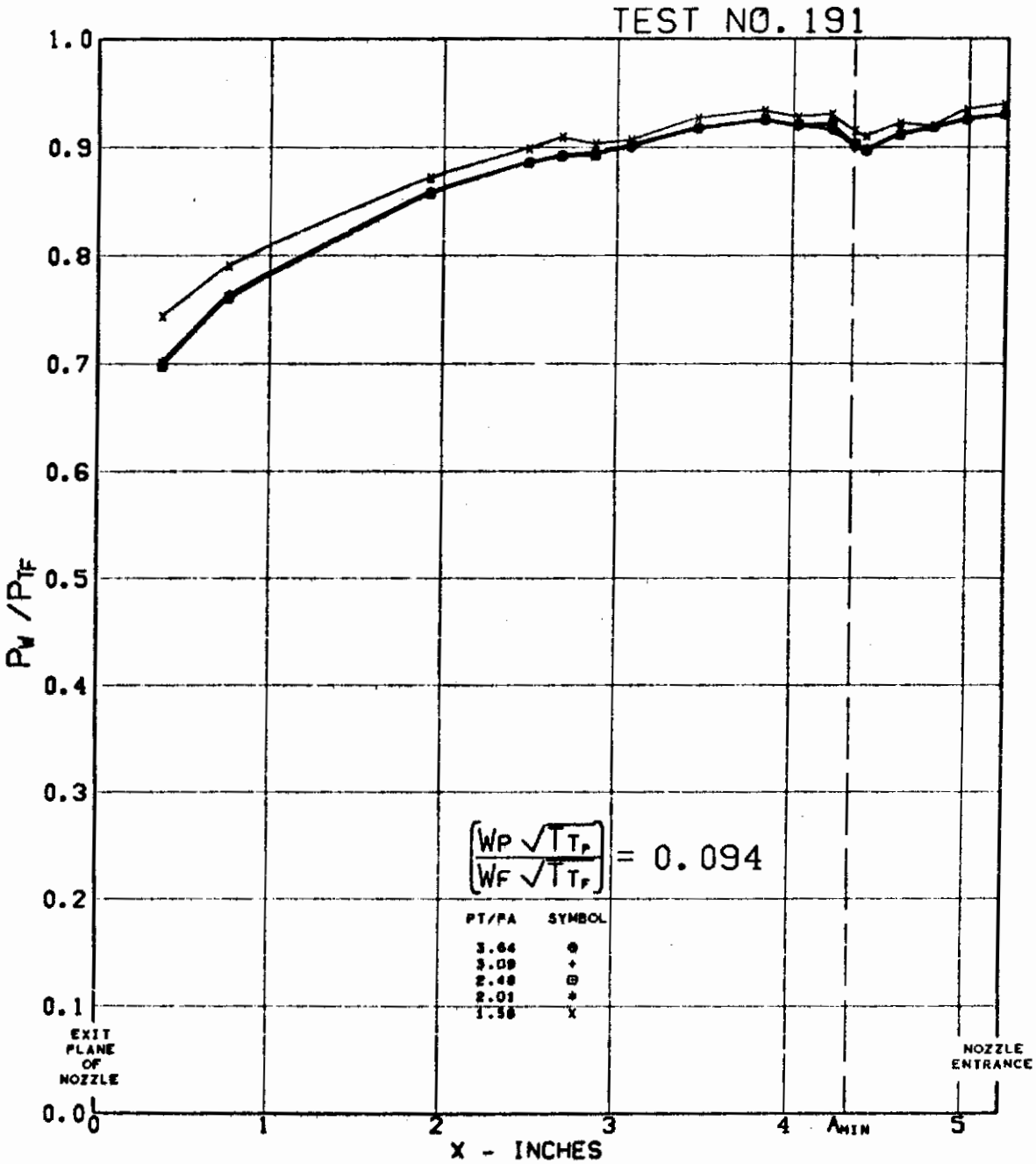


FIGURE 195. WALL PRESSURES - CONFIGURATION 33 AT 0.094 FAN FLOW RATIO $(W_P\sqrt{T_{T_F}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

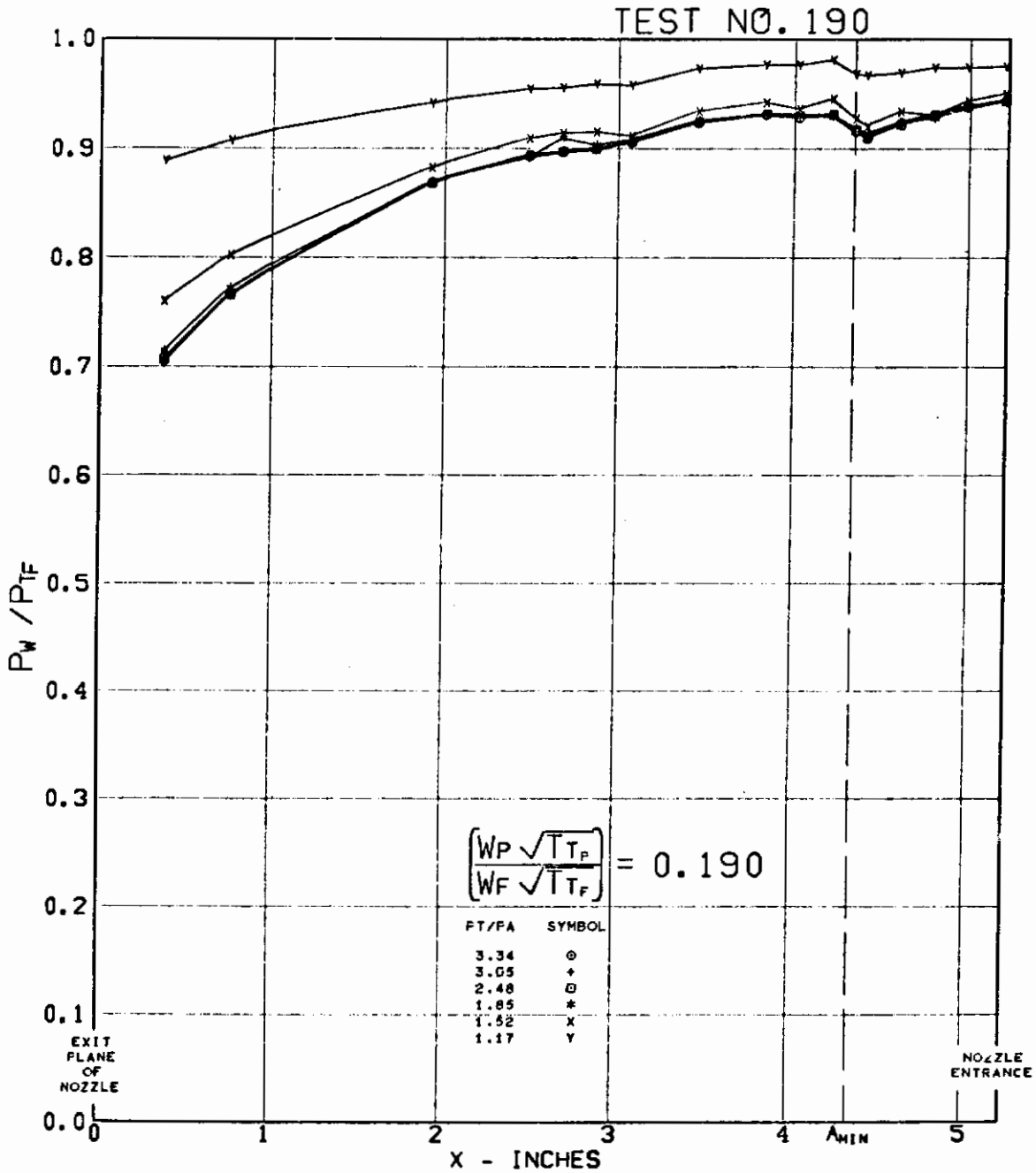


FIGURE 196. WALL PRESSURES - CONFIGURATION 33 AT 0.190 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

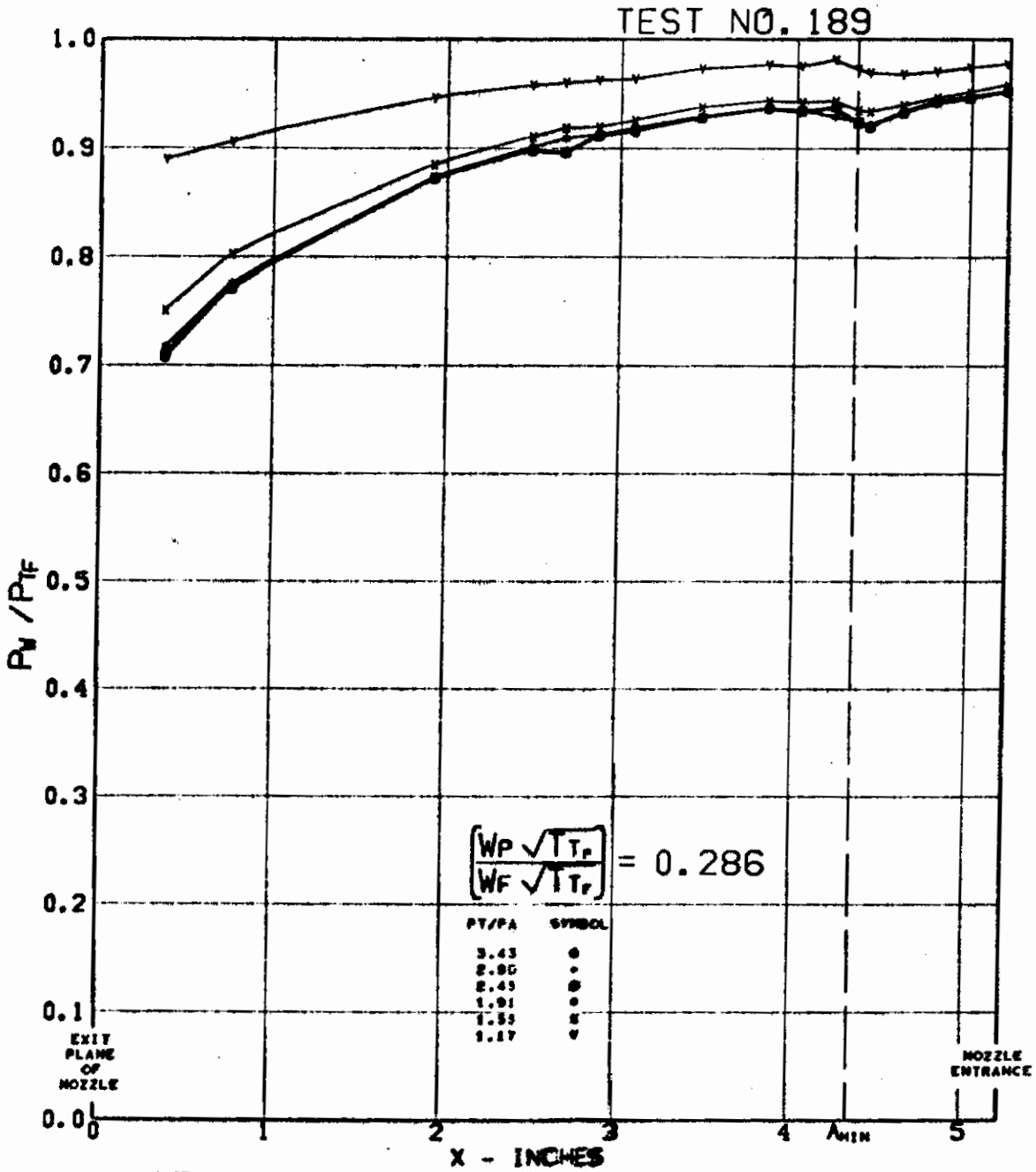


FIGURE 197. WALL PRESSURES - CONFIGURATION 33 AT 0.286 FAN FLOW RATIO ($W_P\sqrt{T_{T_F}} / W_F\sqrt{T_{T_F}}$)

Approved for Public Release

Contrails

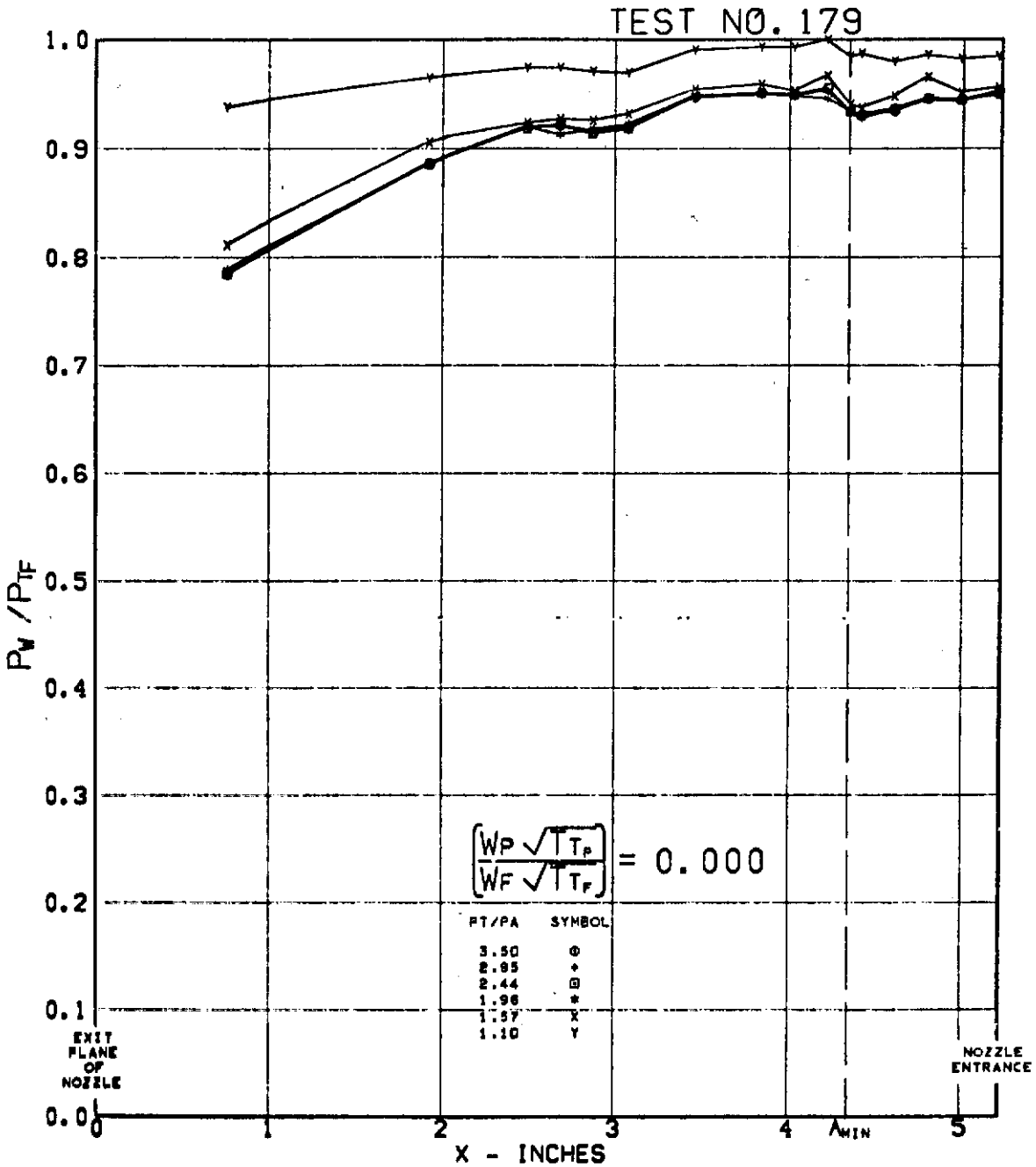


FIGURE 198. WALL PRESSURES - CONFIGURATION 34 AT 0.000 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

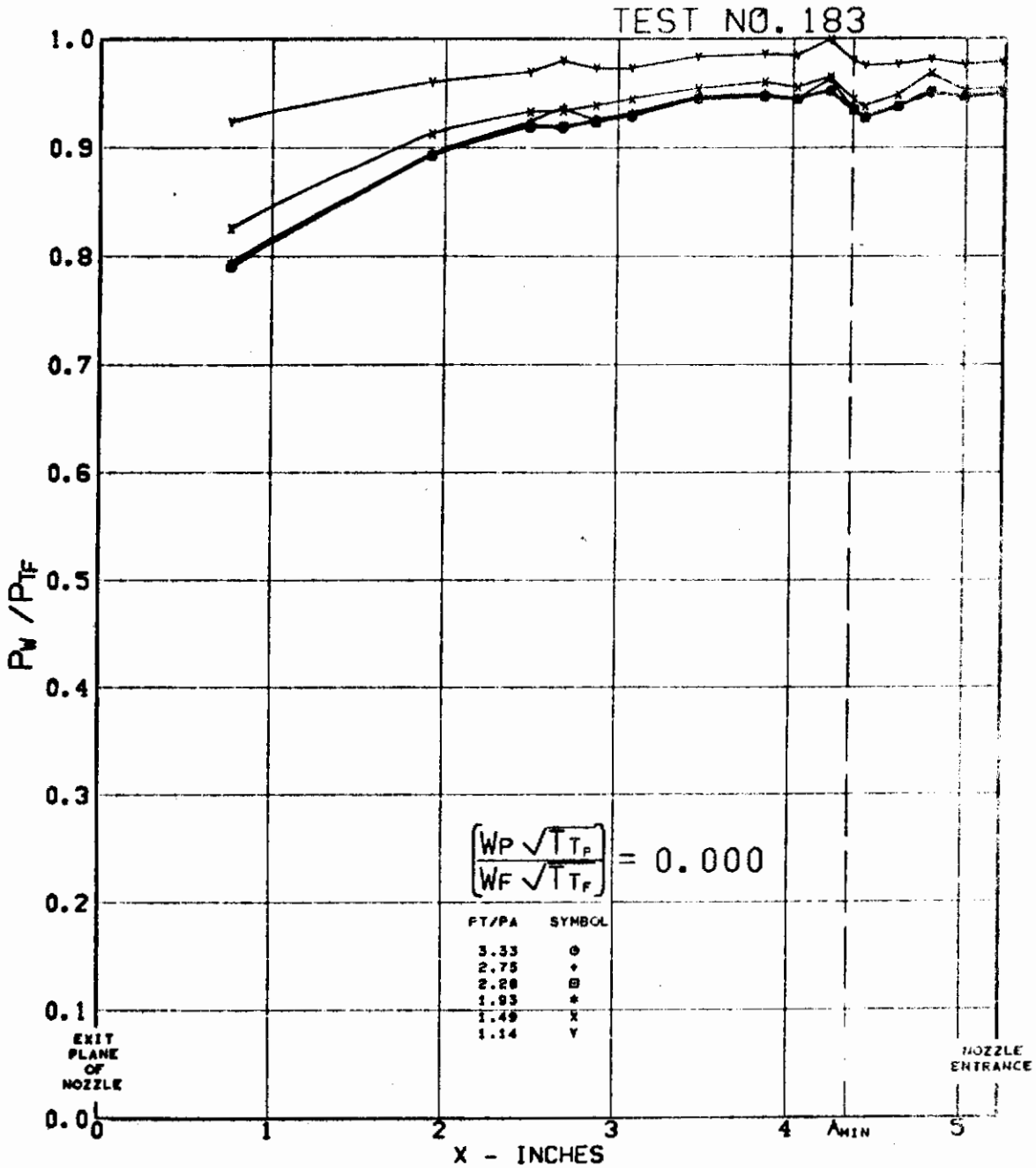


FIGURE 199. WALL PRESSURES - CONFIGURATION 34 AT 0.000 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

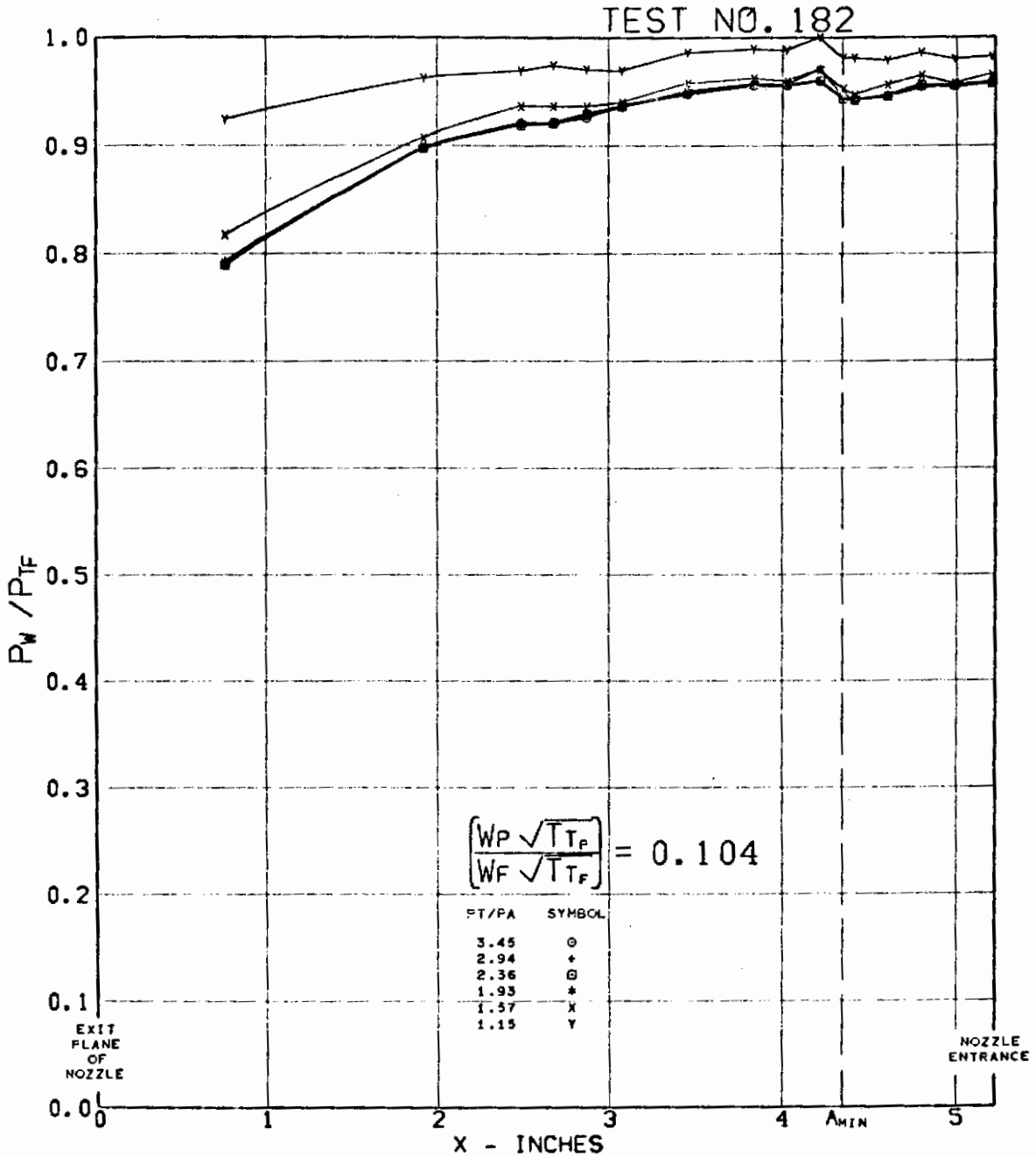


FIGURE 200. WALL PRESSURES - CONFIGURATION 34 AT 0.104 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

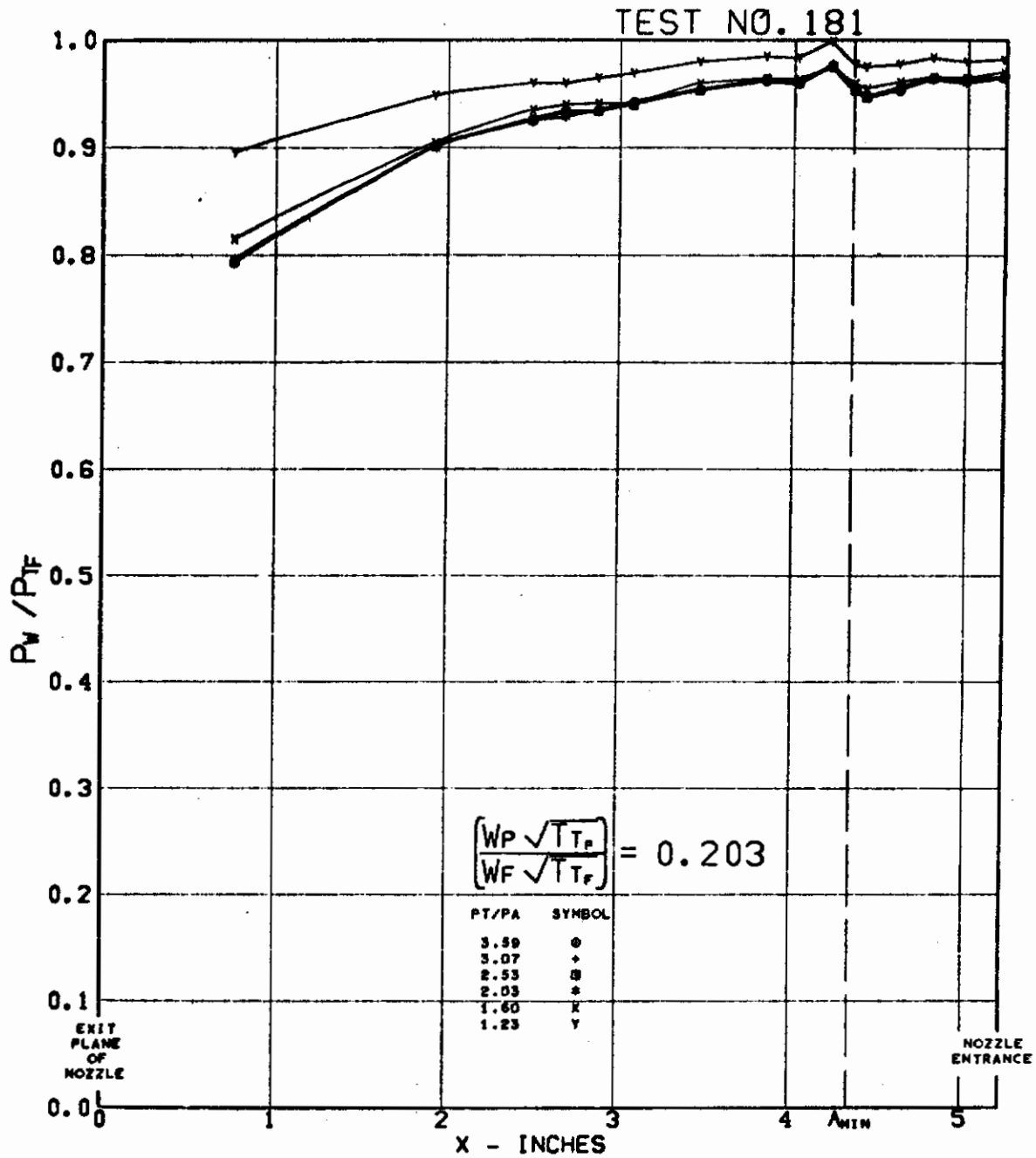


FIGURE 201. WALL PRESSURES - CONFIGURATION 34 AT 0.203 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

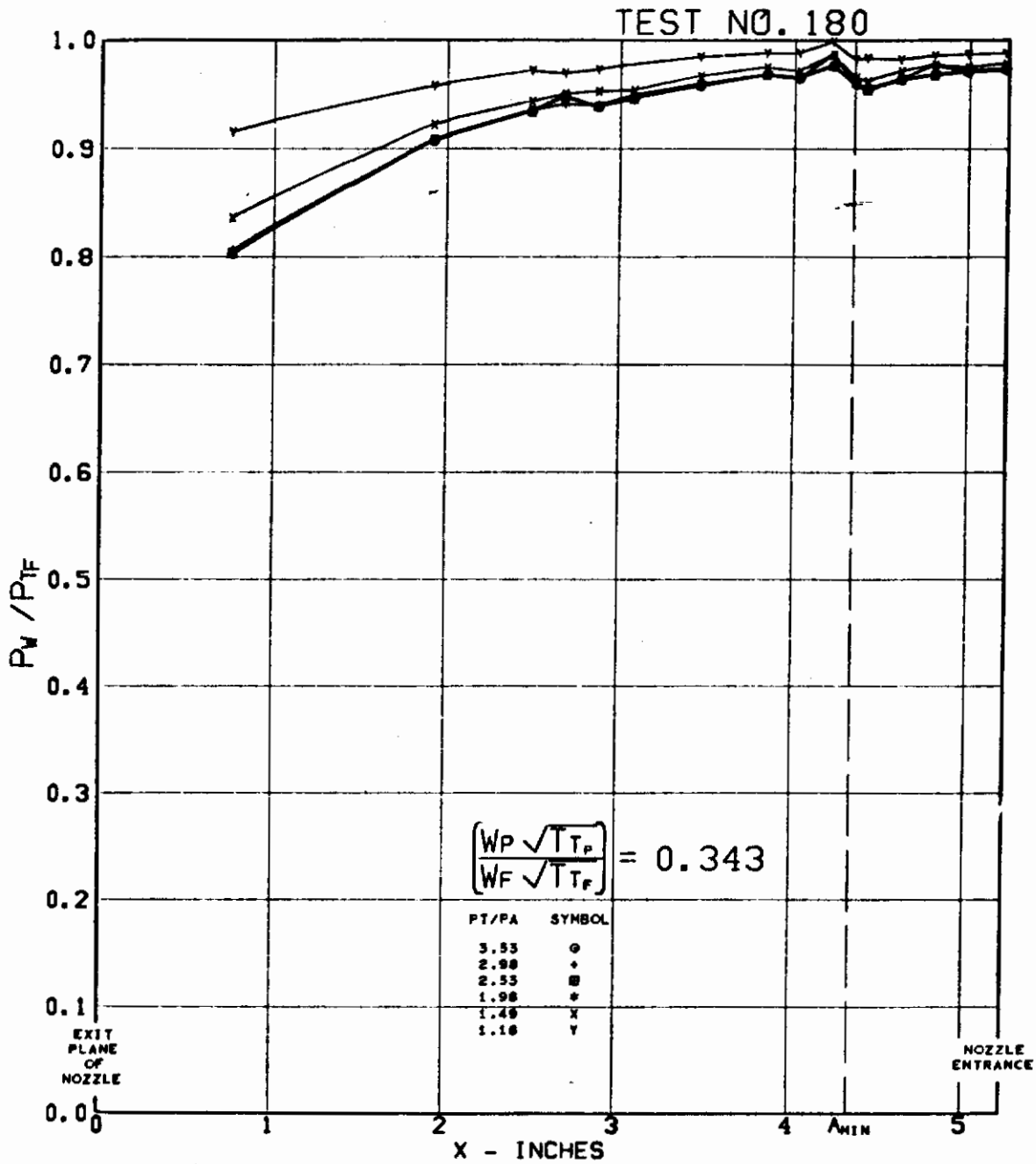


FIGURE 202. WALL PRESSURES - CONFIGURATION 34 AT 0.343 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

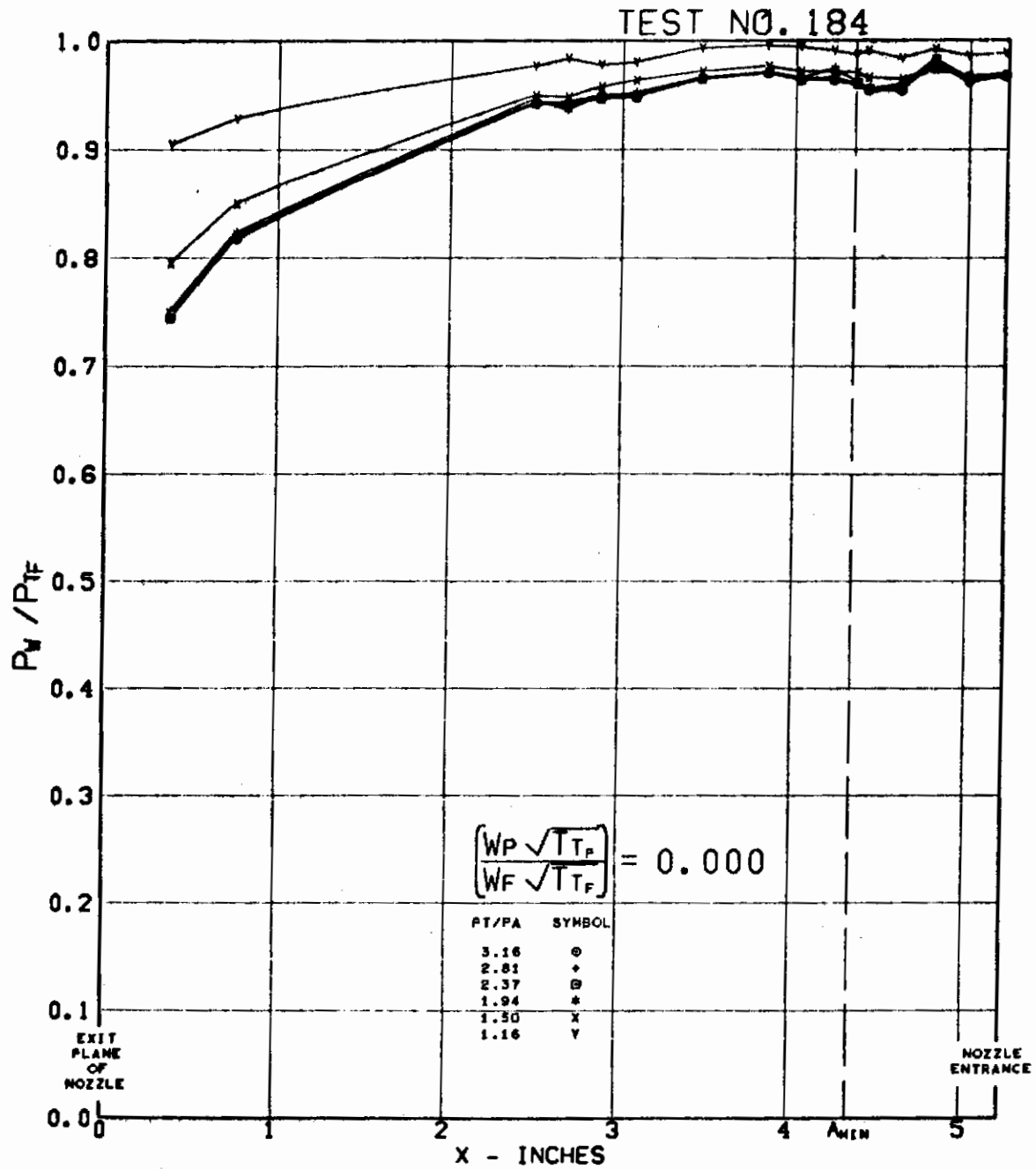


FIGURE 203. WALL PRESSURES - CONFIGURATION 35 AT 0.000 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

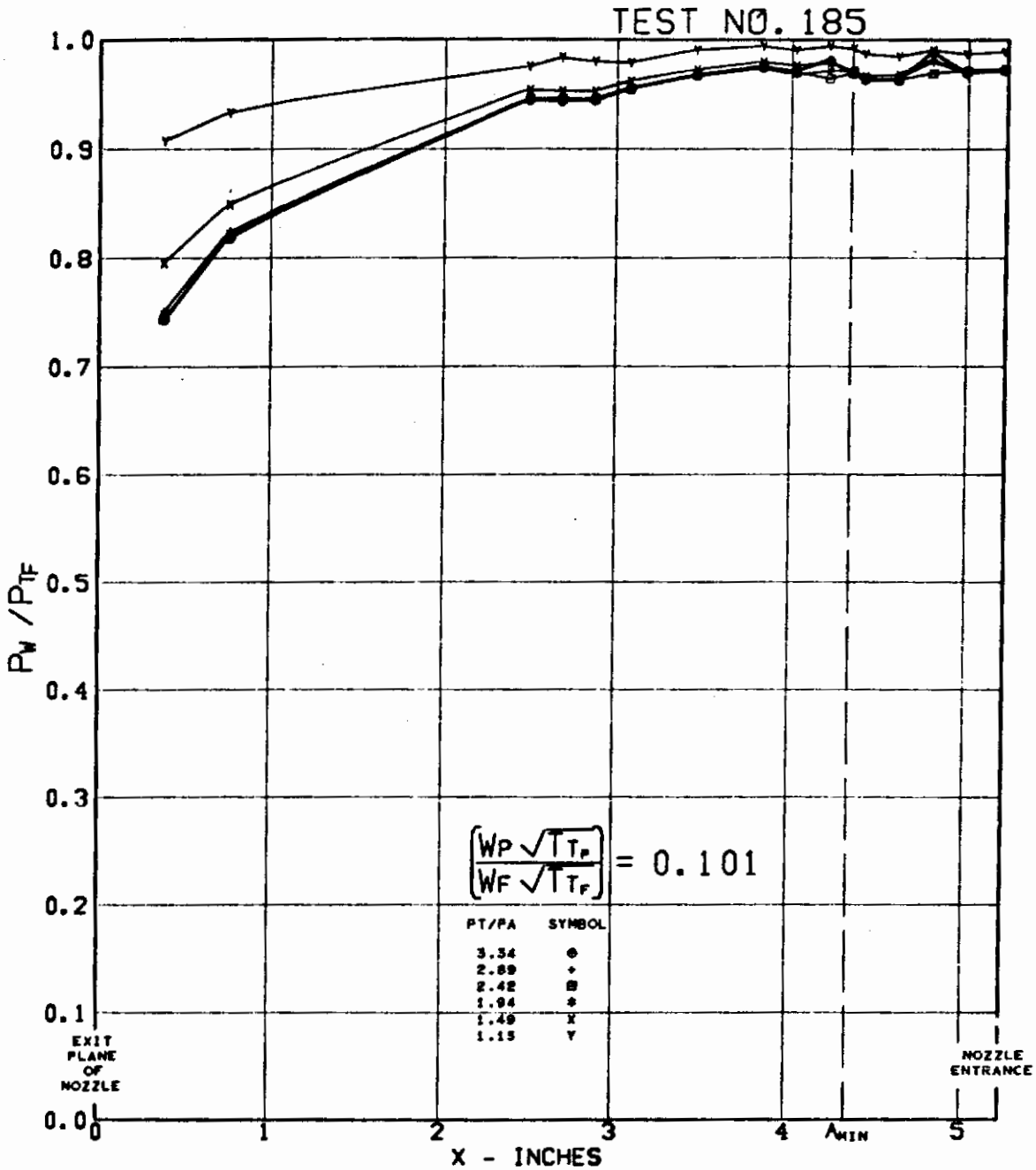


FIGURE 204. WALL PRESSURES - CONFIGURATION 35 AT 0.101 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

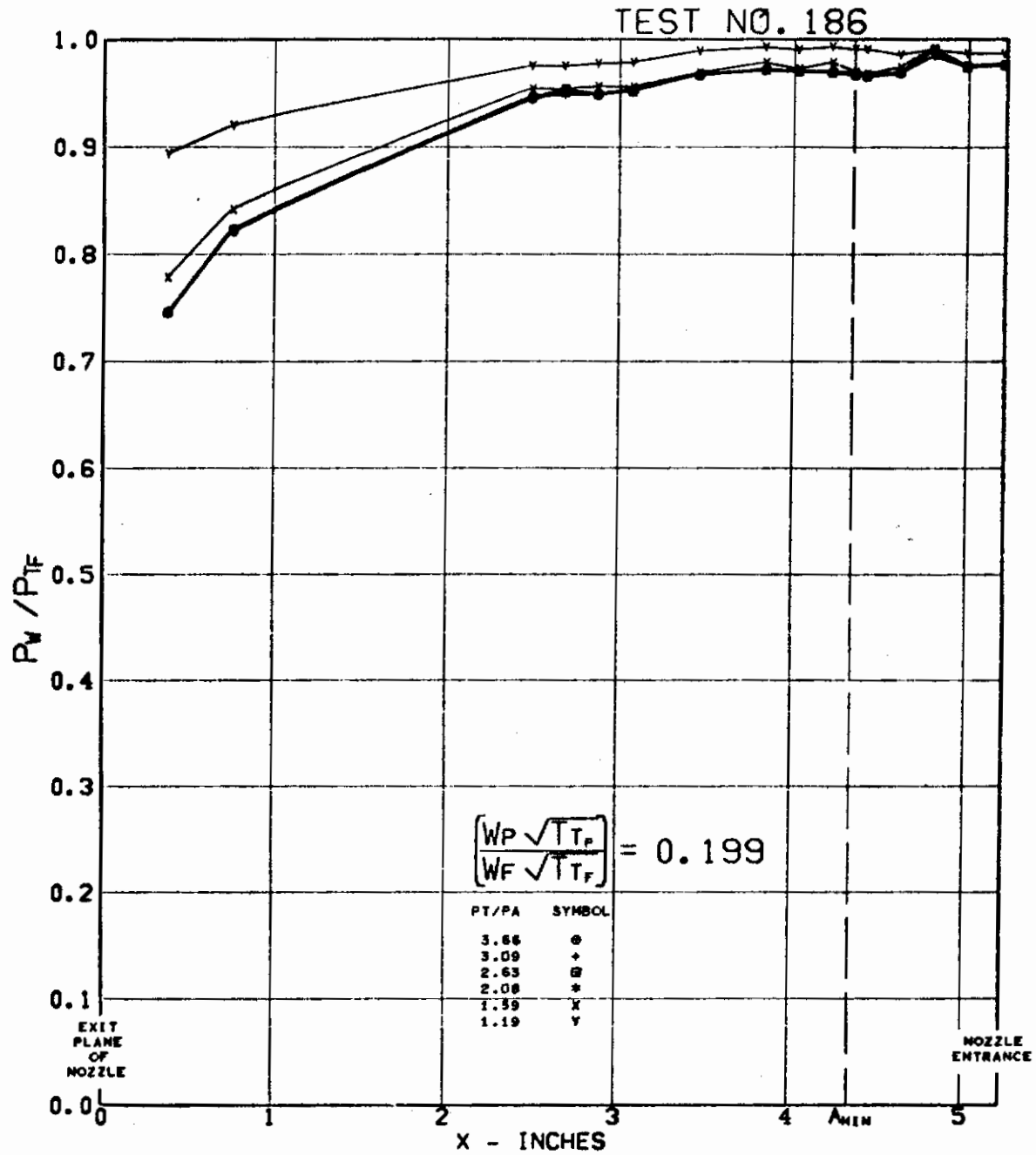


FIGURE 205. WALL PRESSURES - CONFIGURATION 35 AT 0.199 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

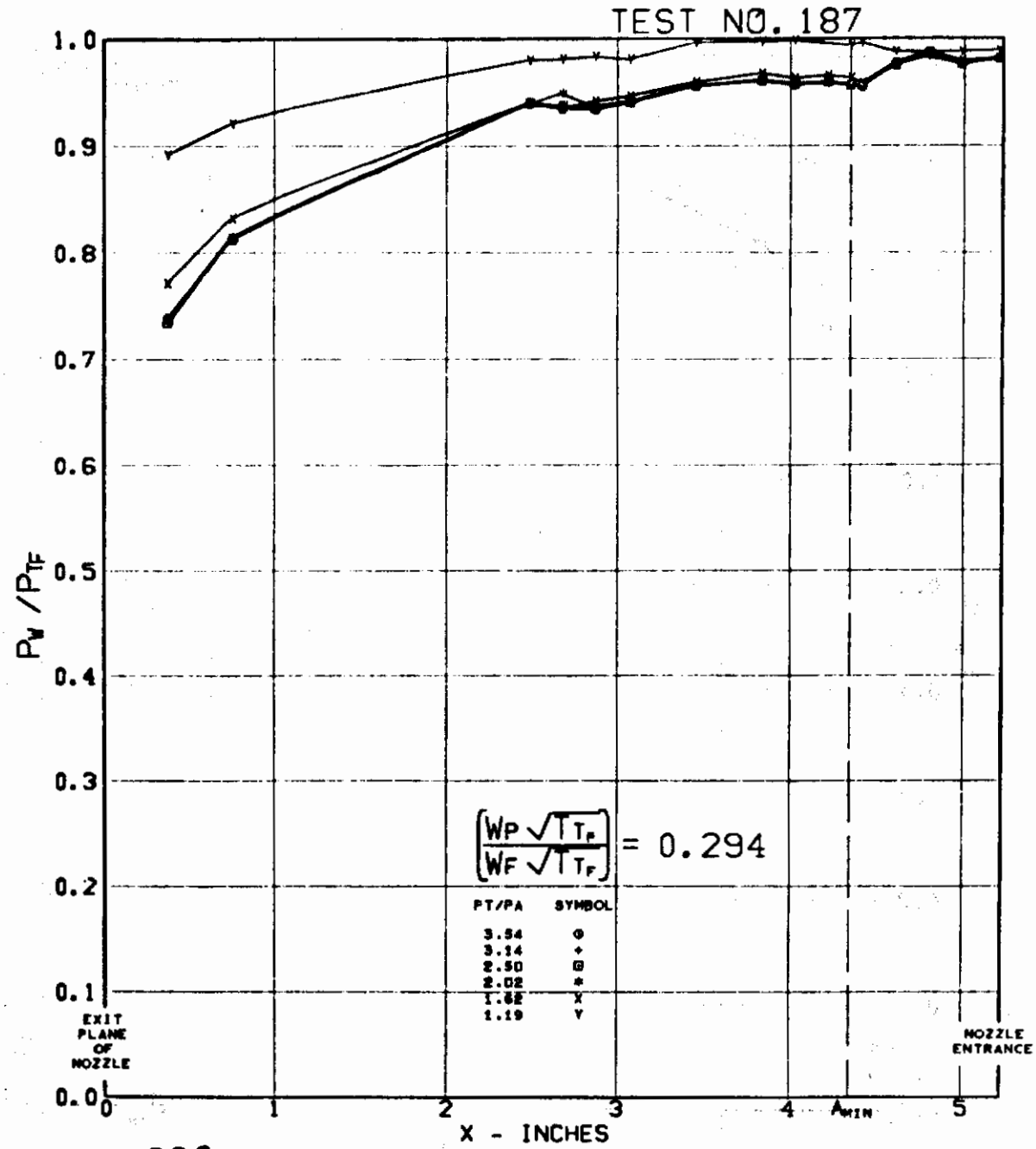


FIGURE 206. WALL PRESSURES - CONFIGURATION 35 AT 0.294 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

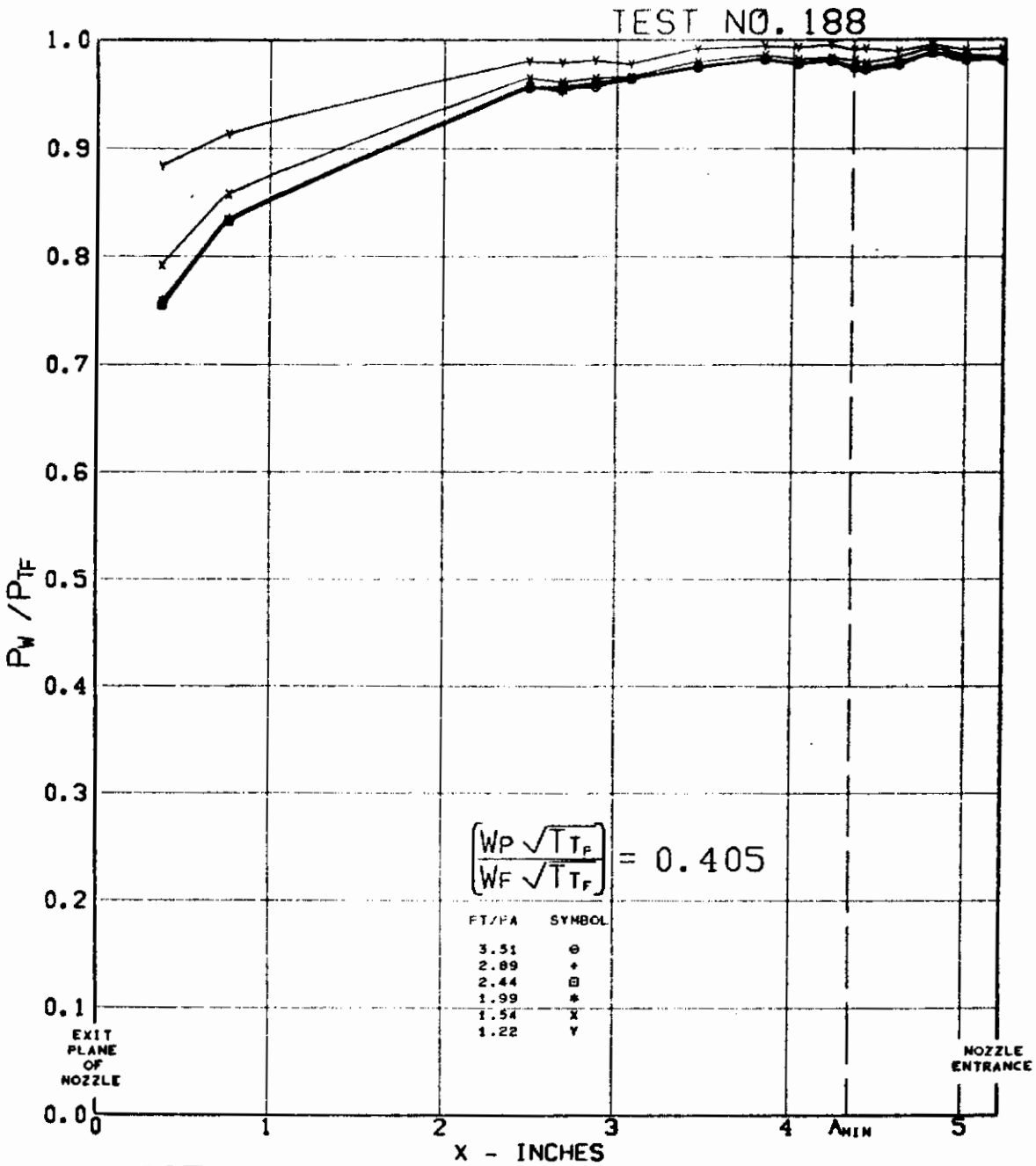


FIGURE 207. WALL PRESSURES - CONFIGURATION 35 AT 0.405 FAN FLOW RATIO $(W_P\sqrt{T_{T_F}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

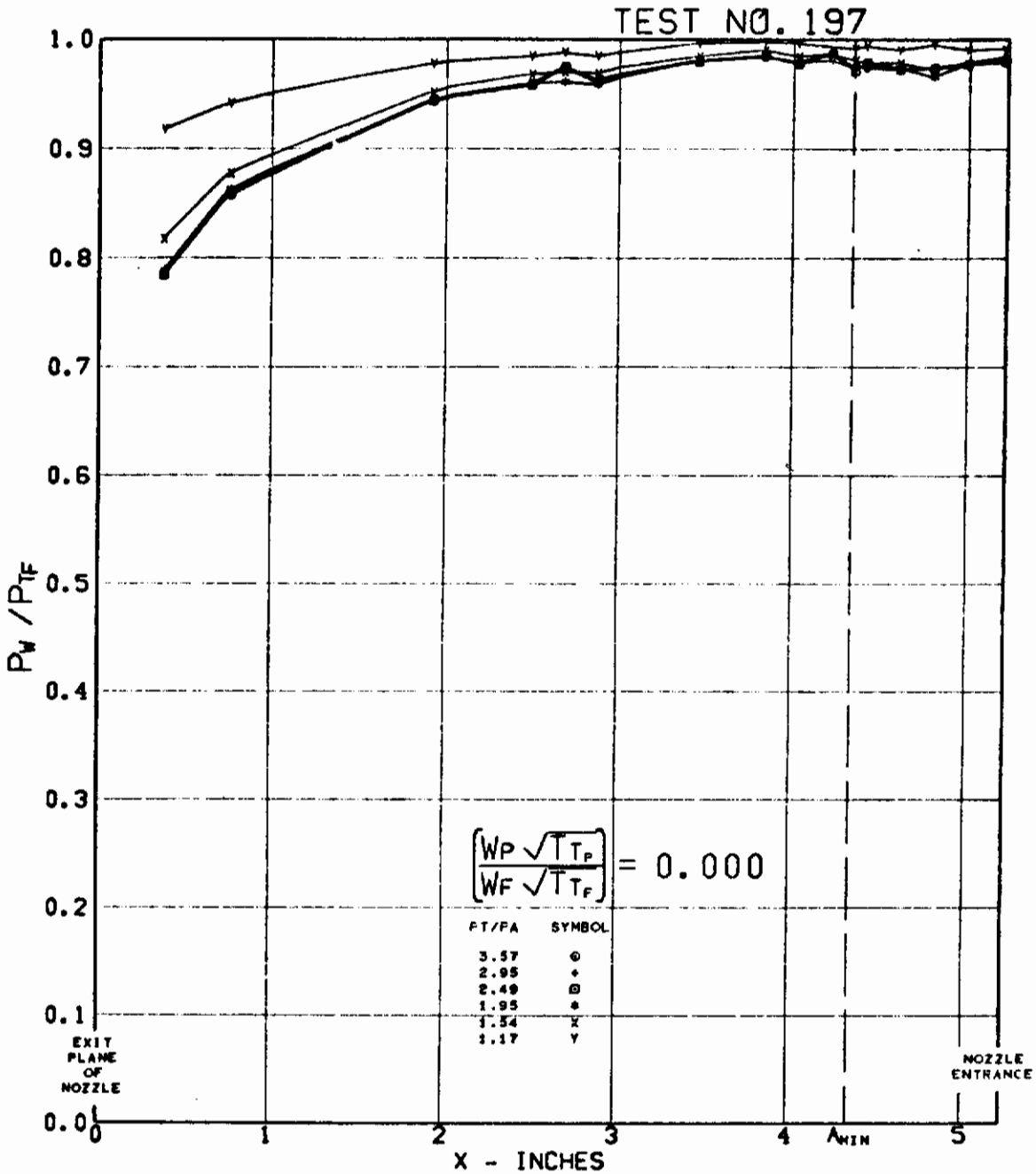


FIGURE 208. WALL PRESSURES - CONFIGURATION 36 AT 0.000 FAN FLOW RATIO ($W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}}$)

Approved for Public Release

Contrails

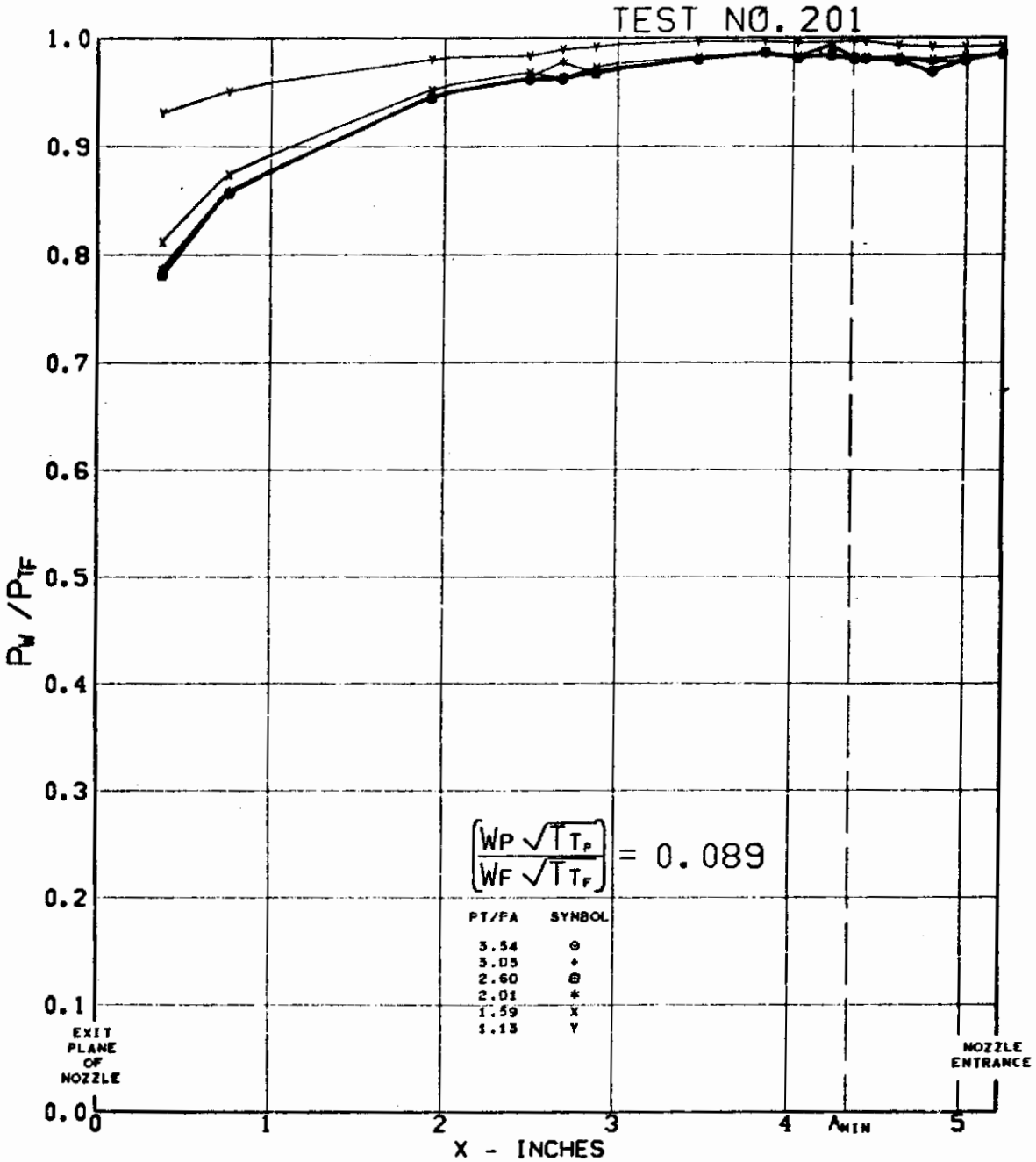


FIGURE 209. WALL PRESSURES - CONFIGURATION 36 AT 0.089 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

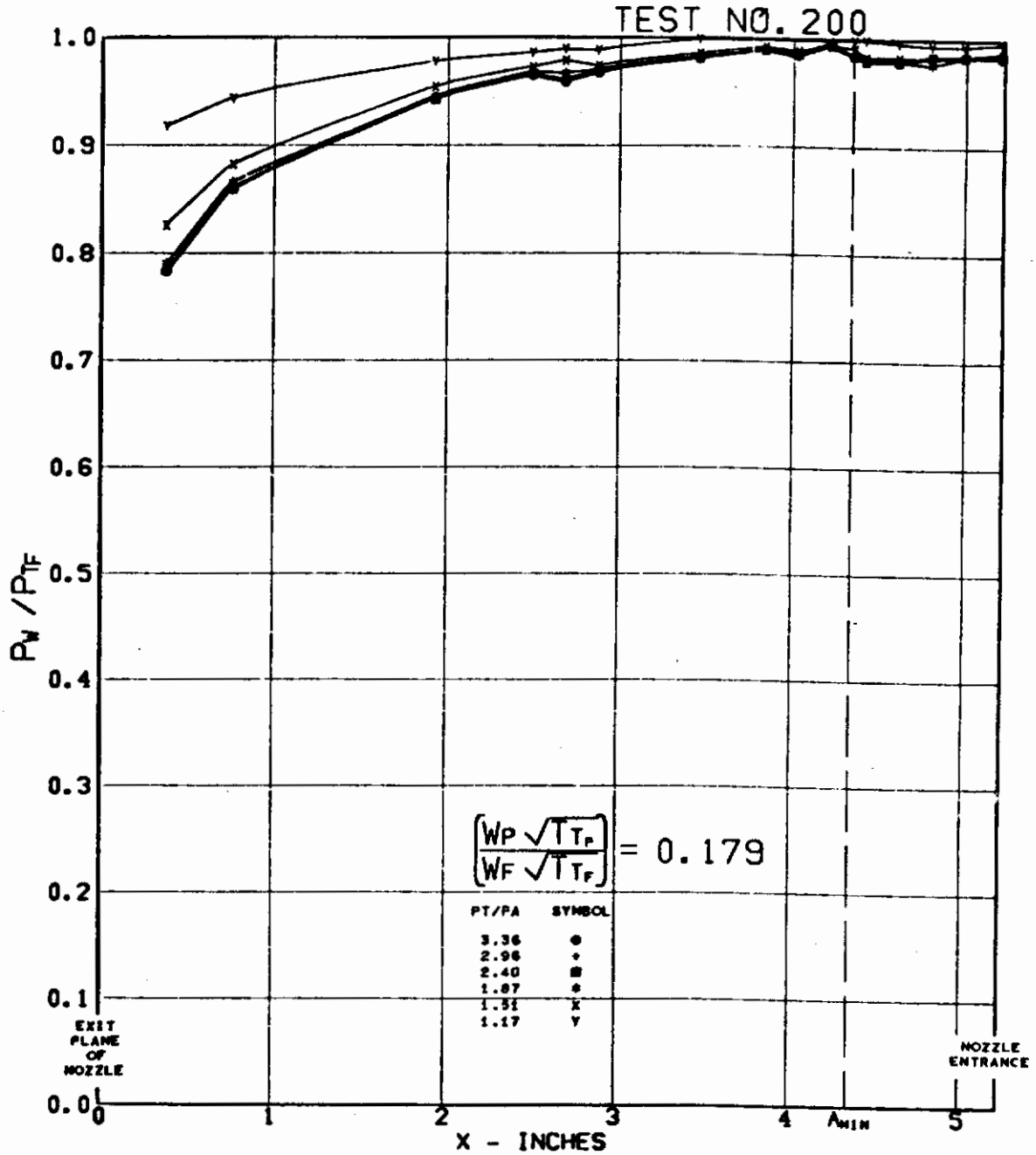


FIGURE 210. WALL PRESSURES - CONFIGURATION 36 AT 0.179 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

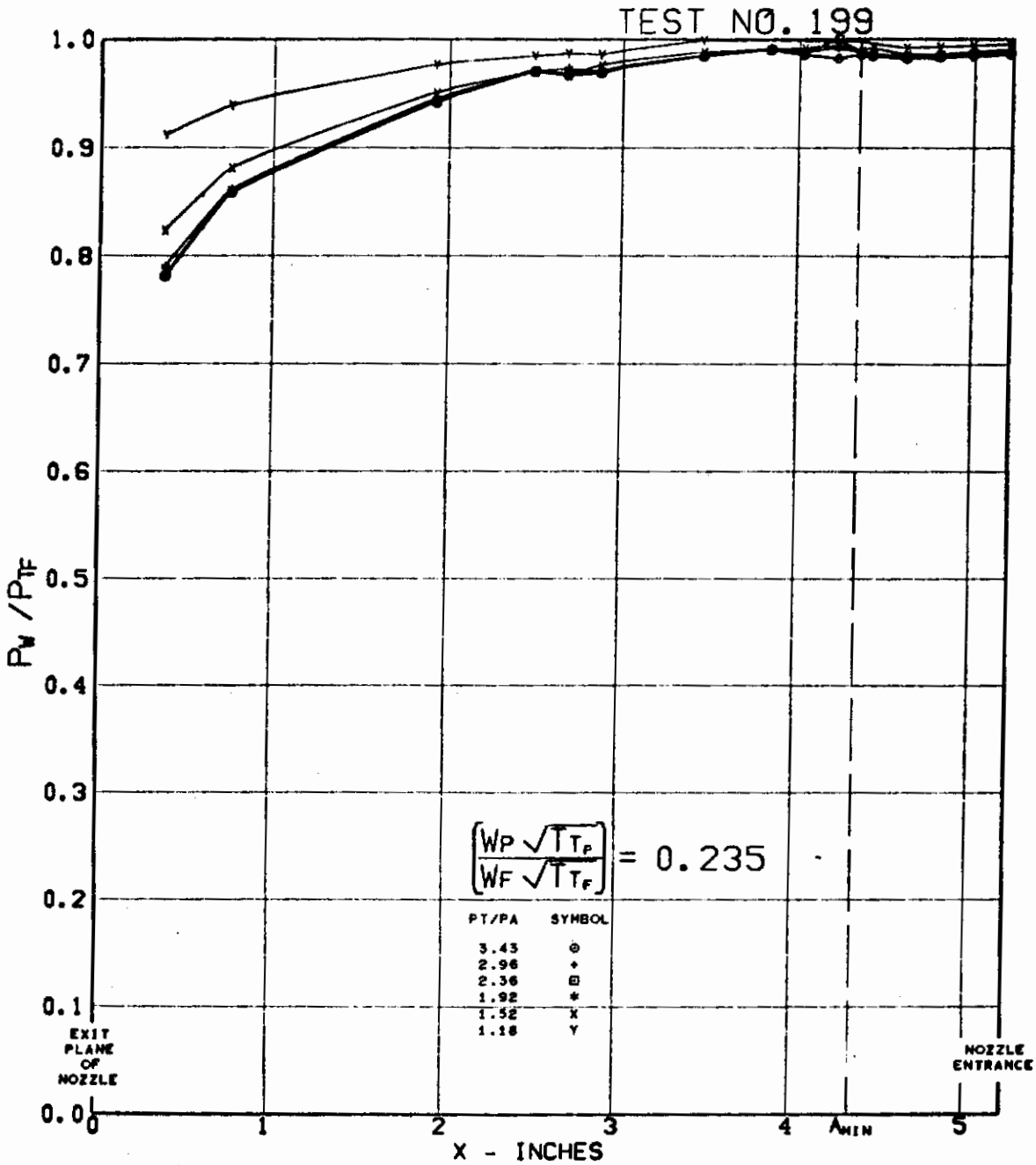


FIGURE 211. WALL PRESSURES - CONFIGURATION 36 AT 0.235 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

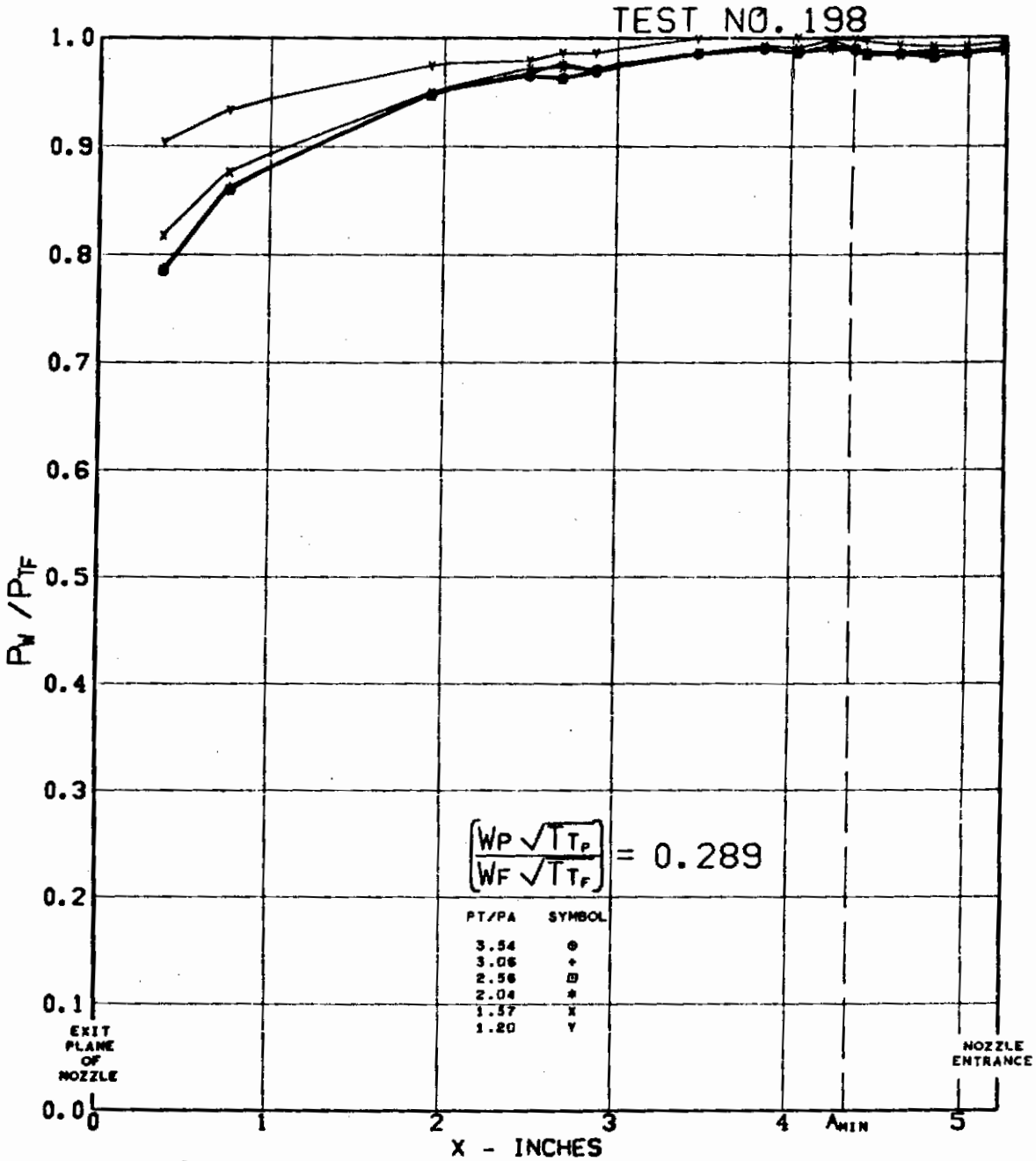


FIGURE 212. WALL PRESSURES - CONFIGURATION 36 AT 0.289 FAN FLOW RATIO $(W_P\sqrt{T_{T_P}} / W_F\sqrt{T_{T_F}})$

Approved for Public Release

Contrails

APPENDIX III

ACCURACY

(The reverse of this page is blank)

Approved for Public Release

Contrails

Approved for Public Release

Contrails

APPENDIX III

ACCURACY

Accuracies of the independent instruments are as follows:

Force Balance	± 0.25 percent
Flow Meters	± 0.15 percent
Pressures	± 0.4 percent
Temperatures	± 0.1 percent

Low differential pressure transducers were used to increase the accuracy of the pressure data by keeping reference pressures close to measured pressures. The estimated effect of these individual accuracies on thrust coefficient is ± 0.5 percent at the worst conditions; i.e., P_{T_F}/P_∞ = 1.1. At most conditions the accuracy would be about ± 0.25 percent.

(The reverse of this page is blank)

Approved for Public Release

Contrails

Approved for Public Release

Contrails

APPENDIX IV

THRUST PERFORMANCE

(The reverse of this page is blank)

Approved for Public Release

Contrails

Approved for Public Release

Contrails

APPENDIX IV

THRUST PERFORMANCE

Figures 213 through 242 present thrust performance as a function of nozzle pressure ratio for all shared exit ejector nozzle configurations tested. Figures 213 through 230 pertain to the satellite mode for which nozzle pressure ratio is defined as the ratio of total pressure in the primary plenum chamber to ambient static pressure, P_{TP}/P_{∞}. Thrust coefficient is equal to the ratio of the actual thrust, measured by the single component force balance, to the sum of the ideal thrusts of both the fan and primary streams.

Figures 231 through 242 are similar to figures 213 through 230 and pertain to the fan mode configuration. In this mode, nozzle pressure ratio is defined as the ratio of total pressure in the fan duct to ambient static pressure, P_{T_F}/P_{∞}.

Approved for Public Release

Contrails

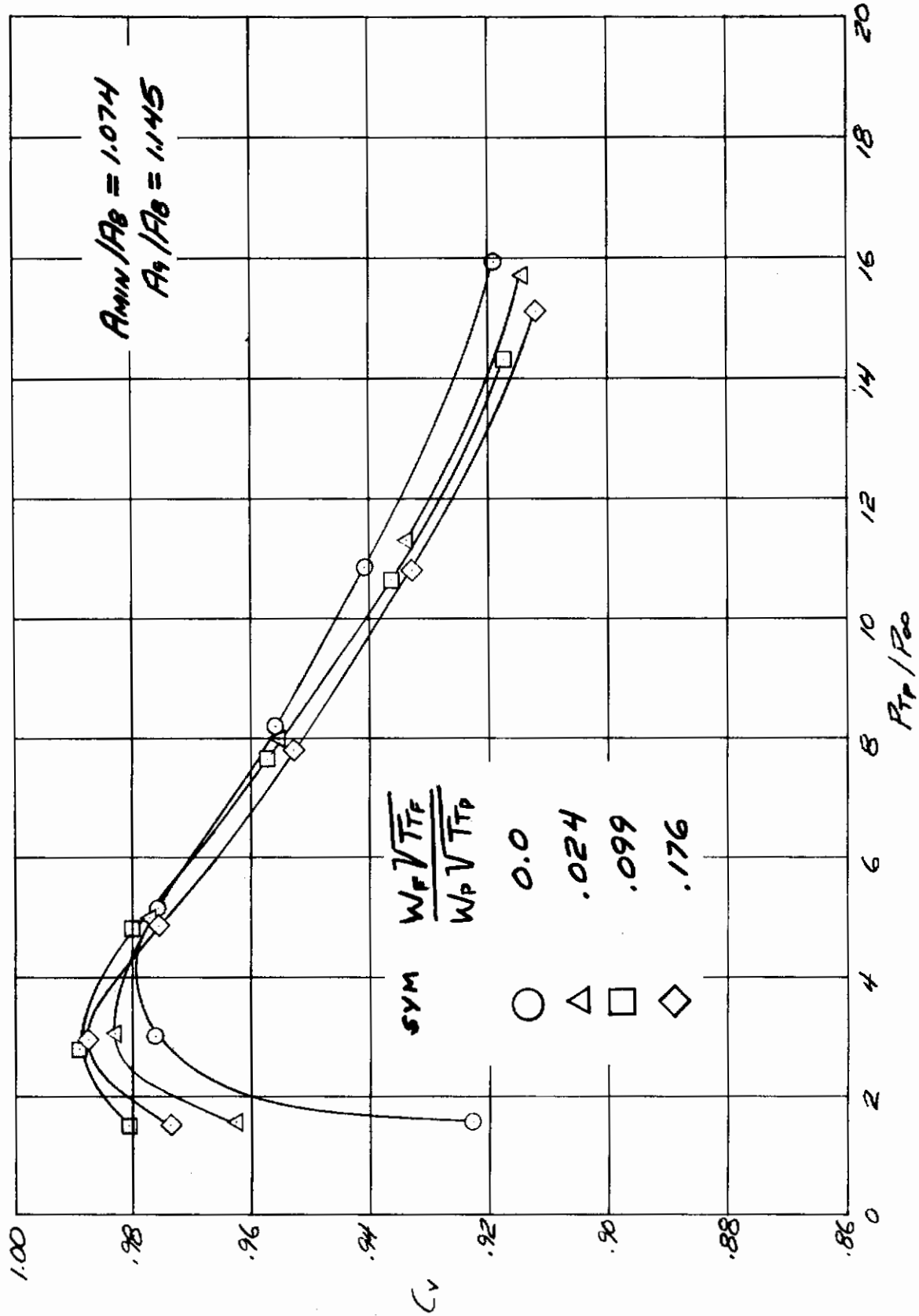


Figure 213. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Performance (Versus Nozzle Pressure Ratio)

Approved for Public Release

Contrails

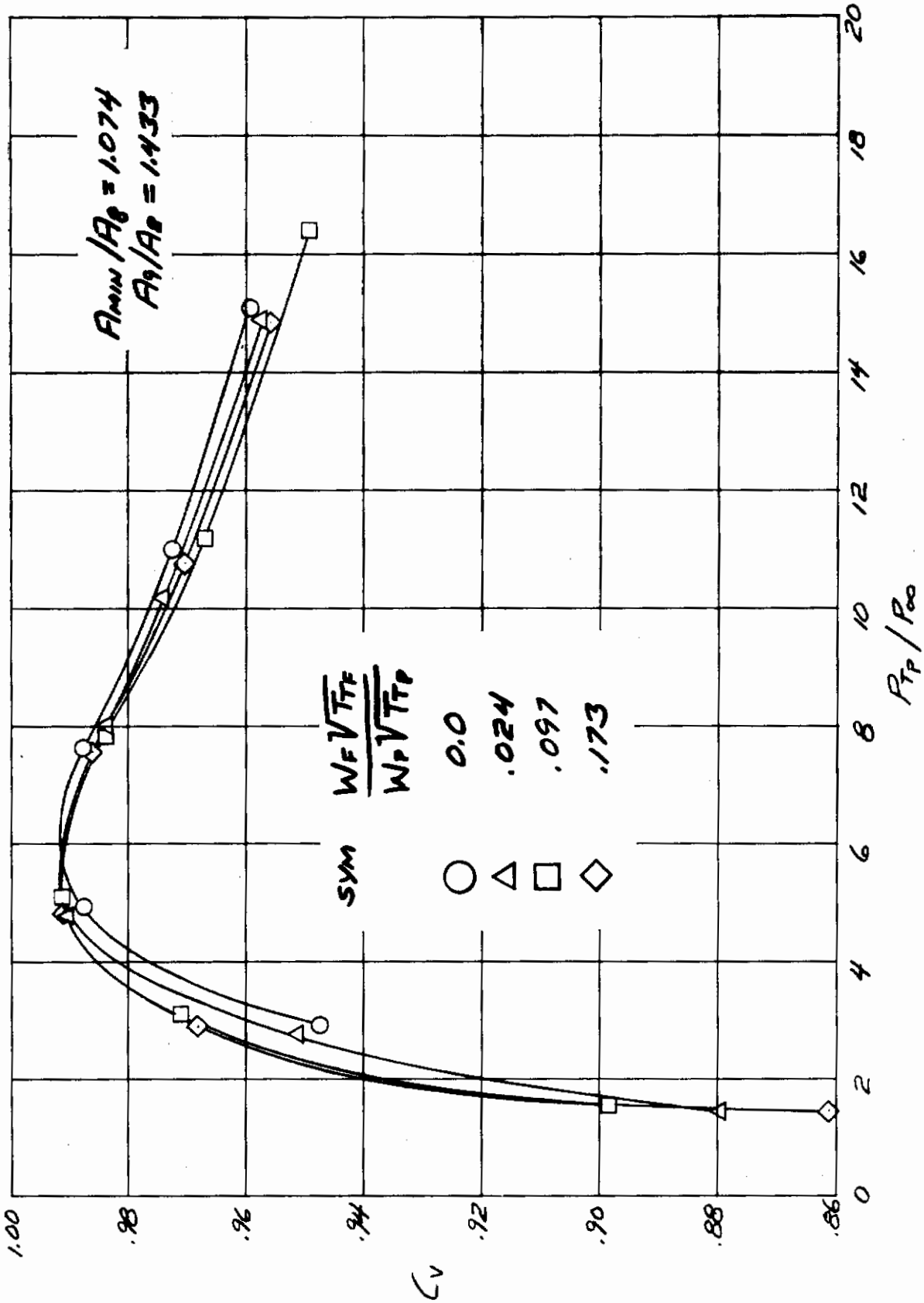


Figure 214. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Performance (Versus Nozzle Pressure Ratio)

Approved for Public Release

Contrails

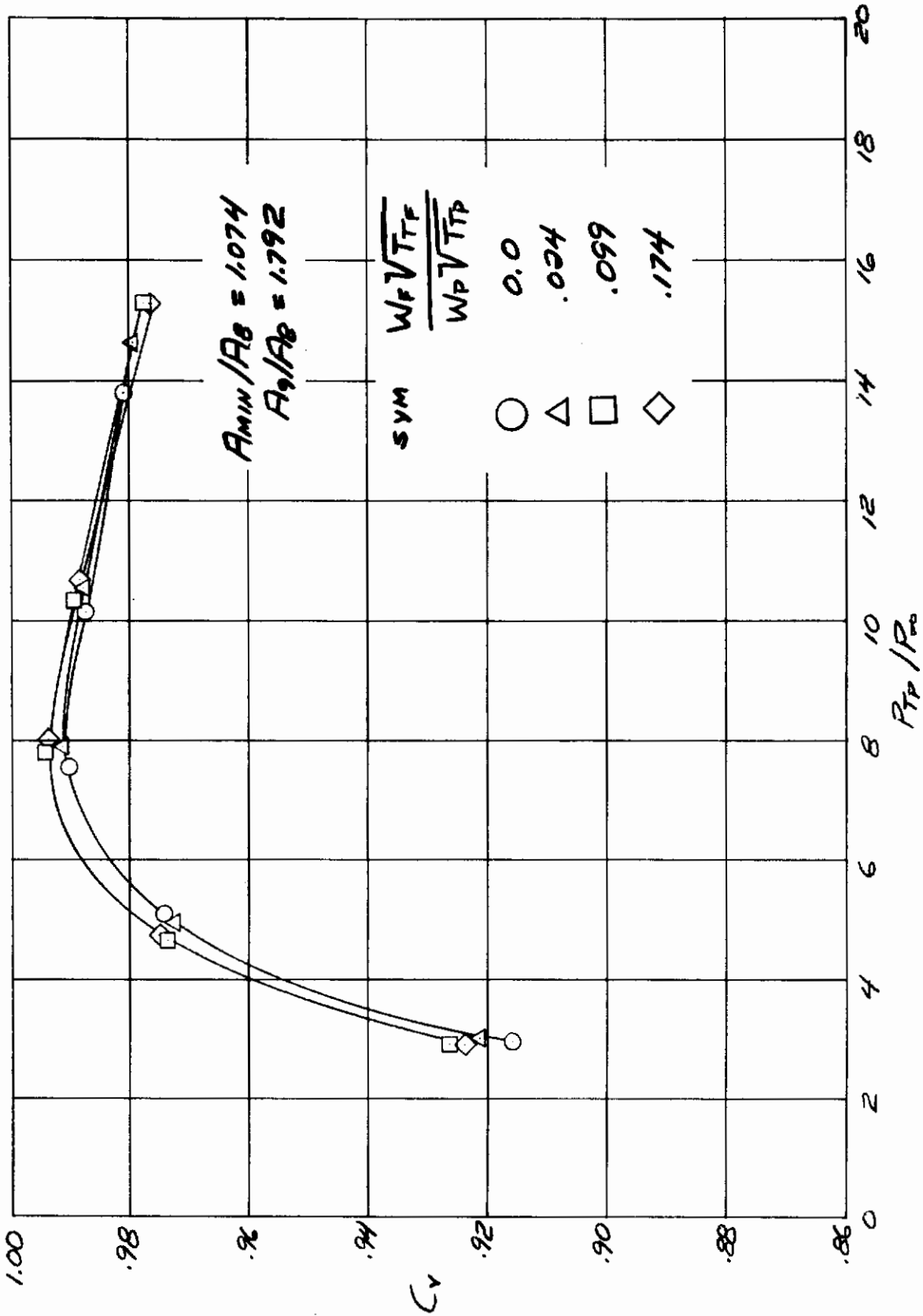


Figure 215. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Performance (Versus Nozzle Pressure Ratio)

Approved for Public Release

Contrails

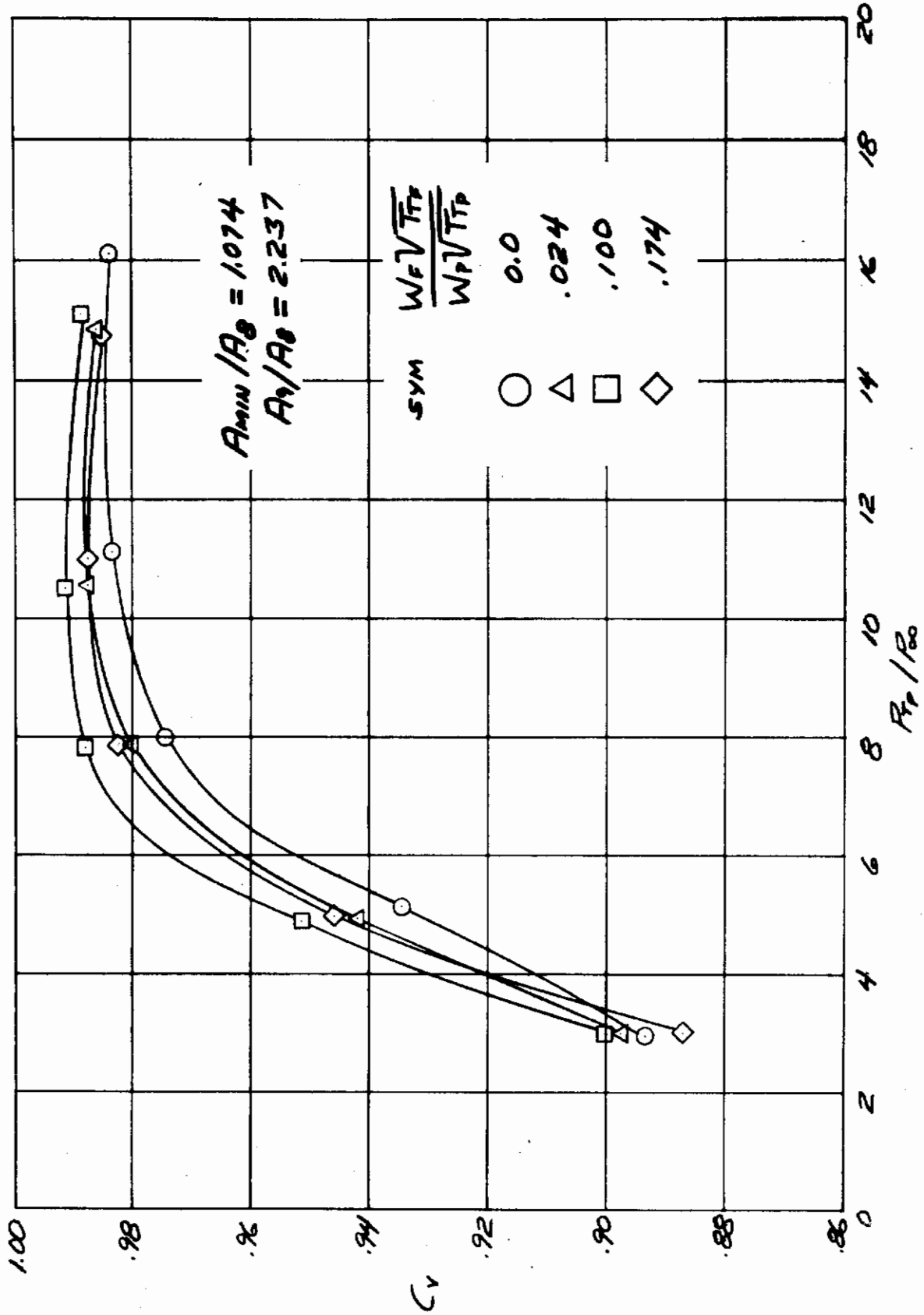


Figure 216. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Performance (Versus Nozzle Pressure Ratio)

Approved for Public Release

Contrails

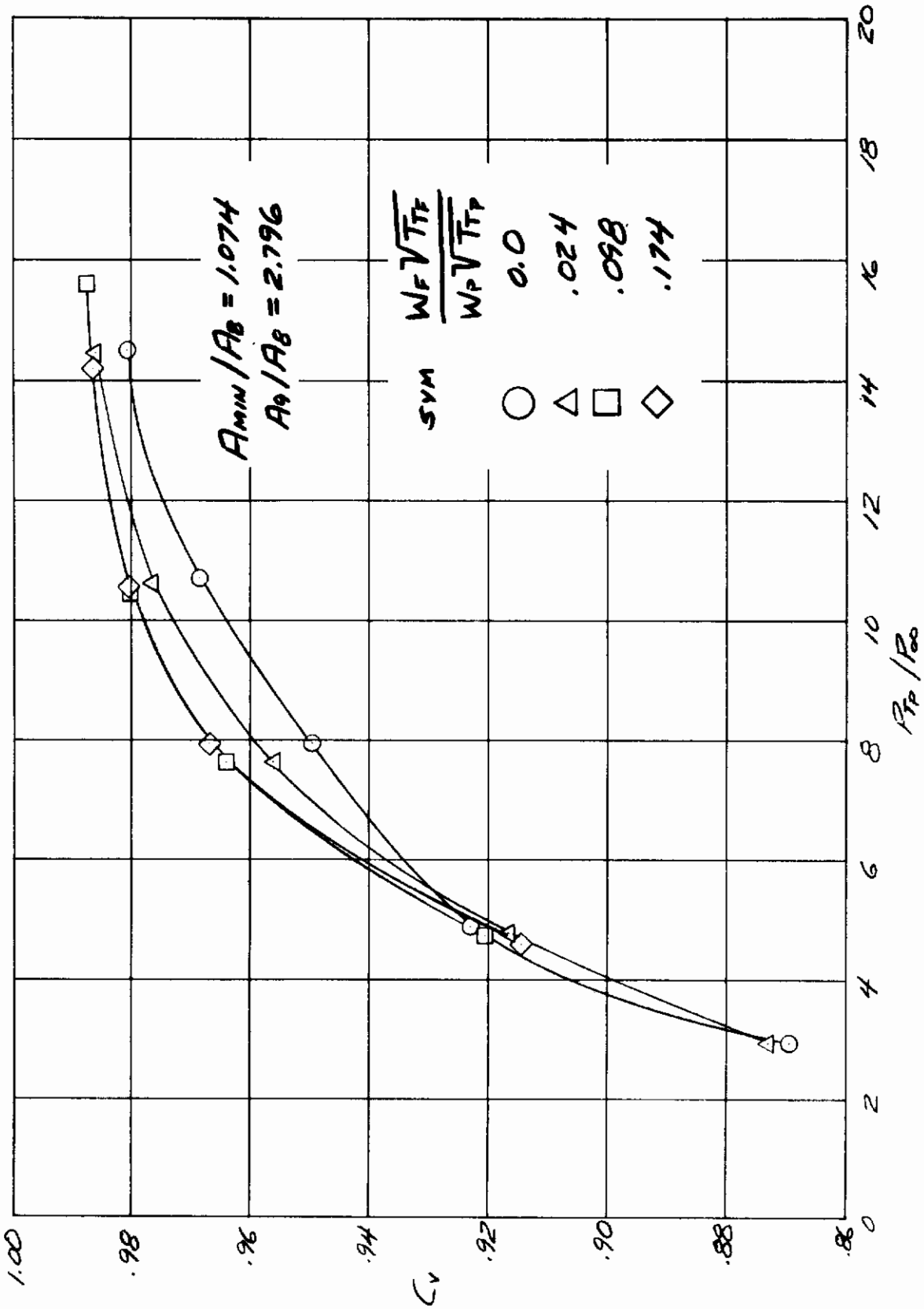


Figure 217. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Performance (Versus Nozzle Pressure Ratio)

Approved for Public Release

Contrails

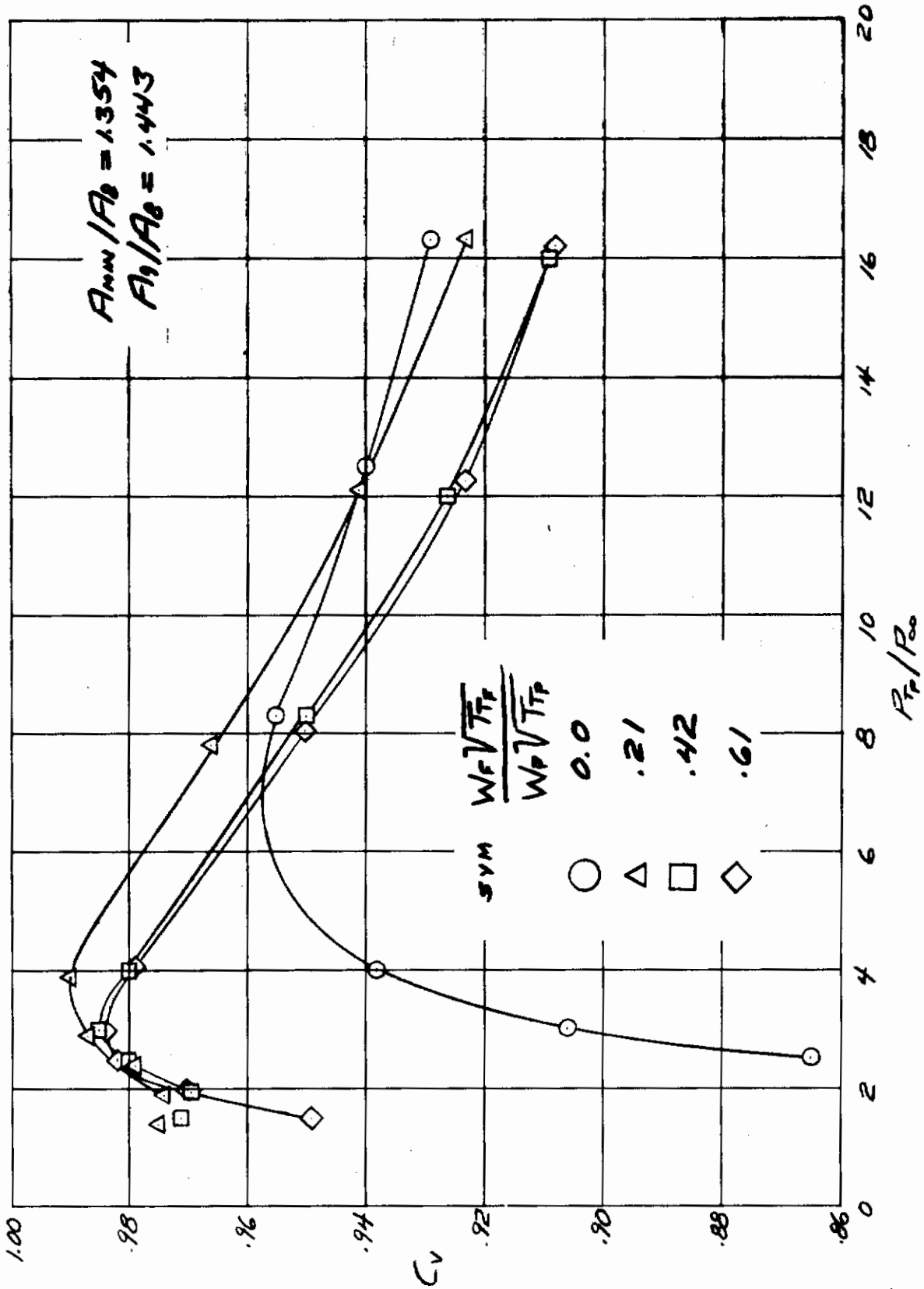


Figure 218. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Performance (Versus Nozzle Pressure Ratio)

Approved for Public Release

Contrails

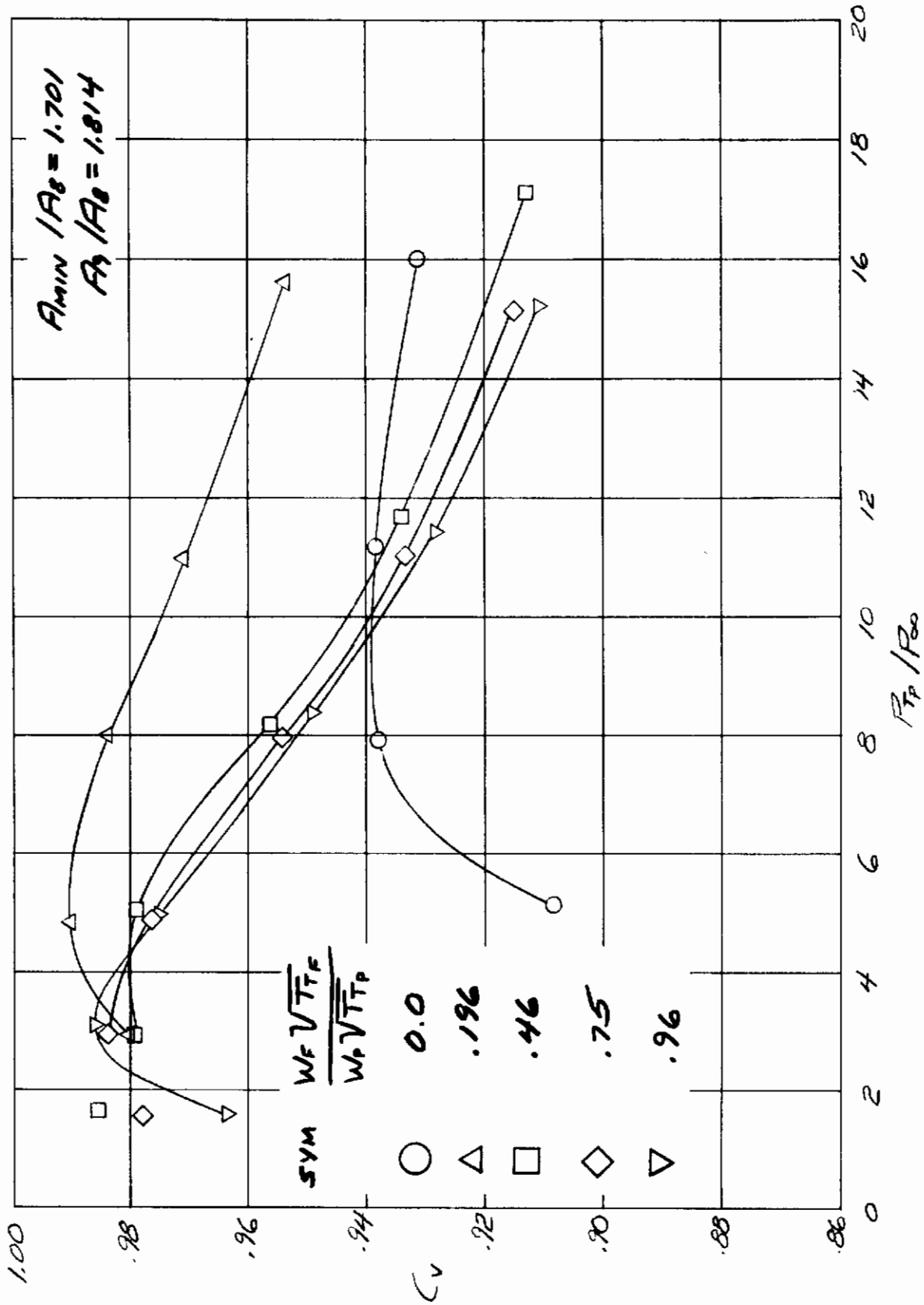


Figure 219. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Performance (Versus Nozzle Pressure Ratio)

Approved for Public Release

Contrails

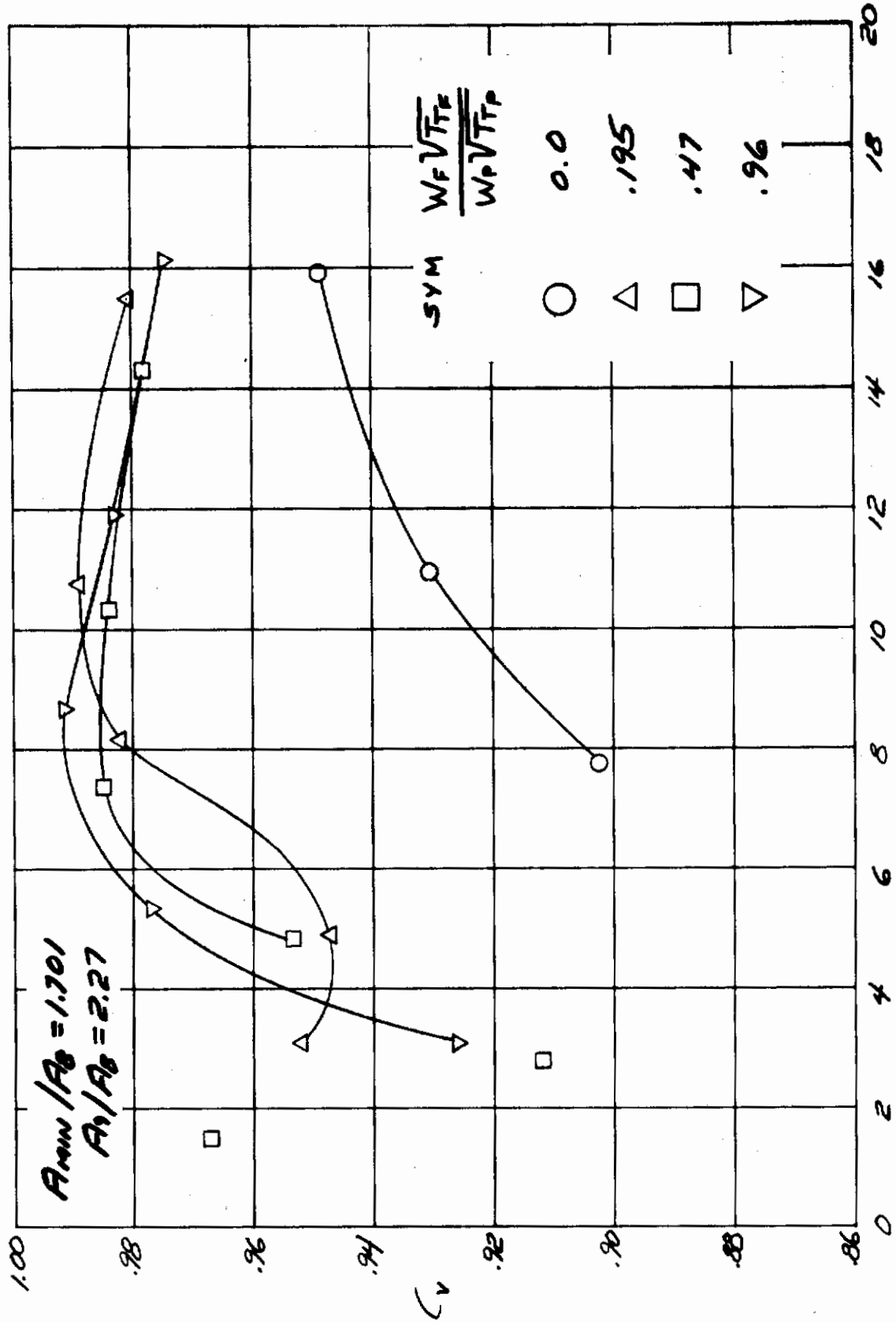


Figure 220. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Performance (Versus Nozzle Pressure Ratio)

Approved for Public Release

Contrails

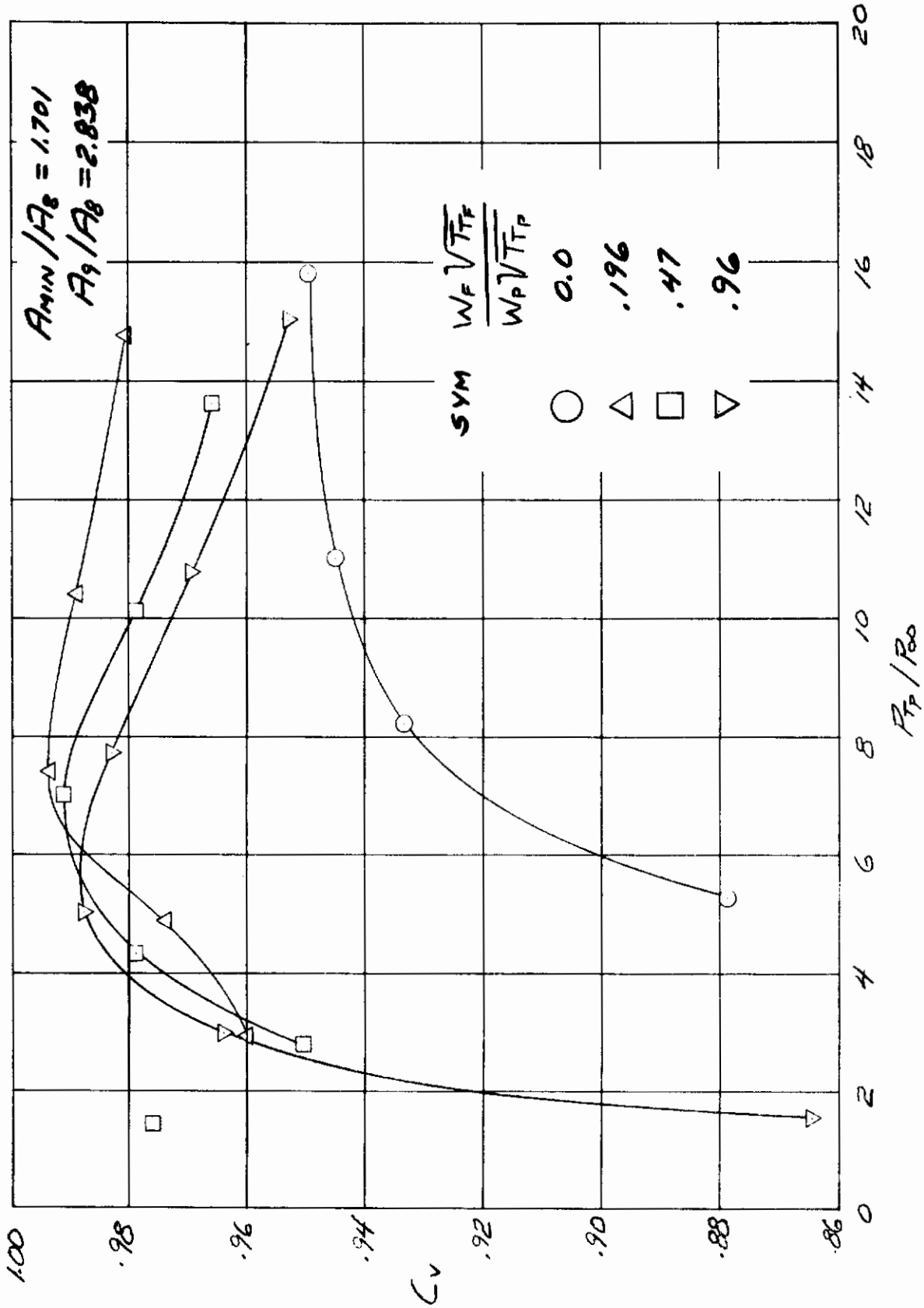


Figure 221. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Performance (Versus Nozzle Pressure Ratio)

Approved for Public Release

Contrails

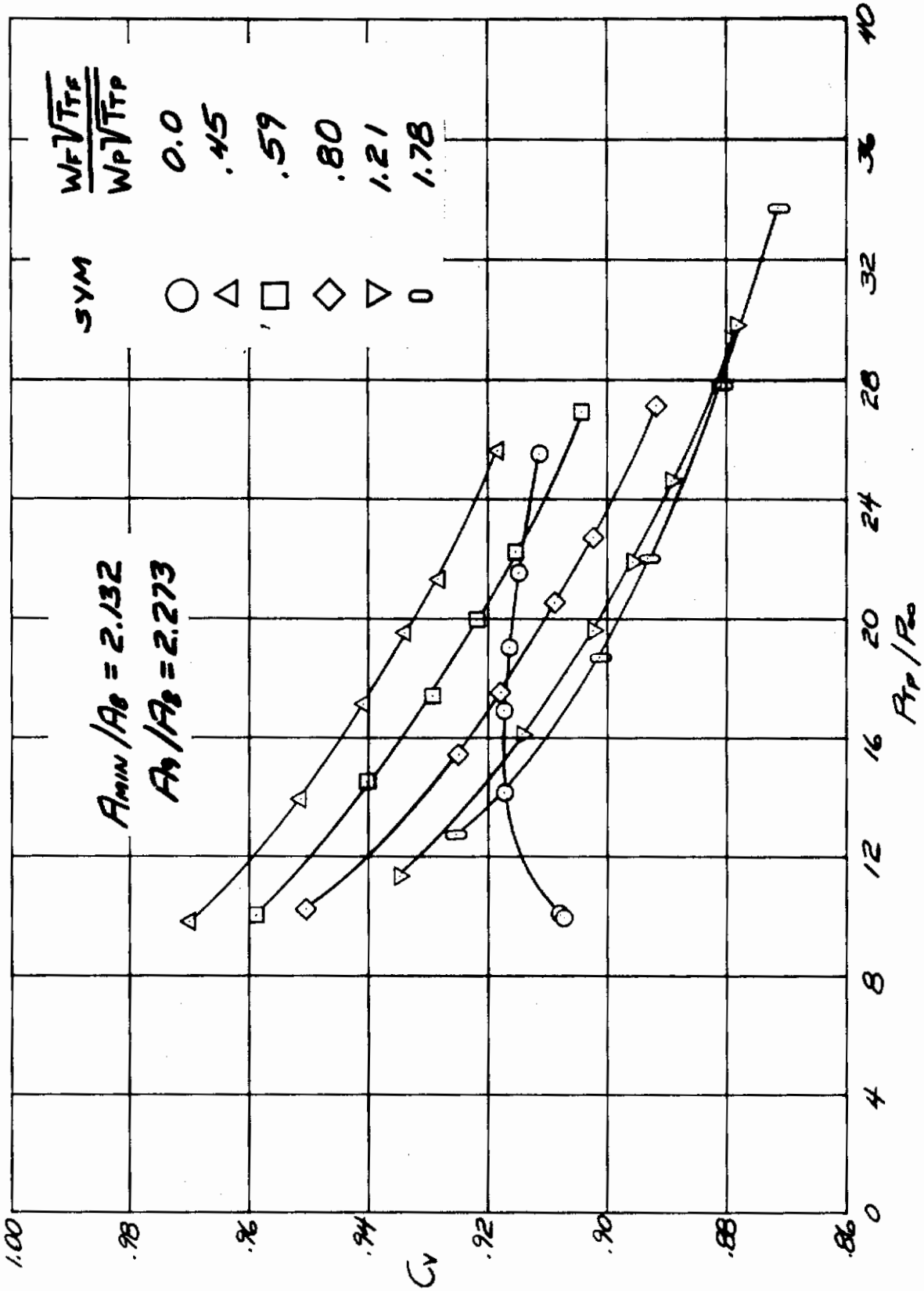


Figure 222. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Performance (Versus Nozzle Pressure Ratio)

Approved for Public Release

Contrails

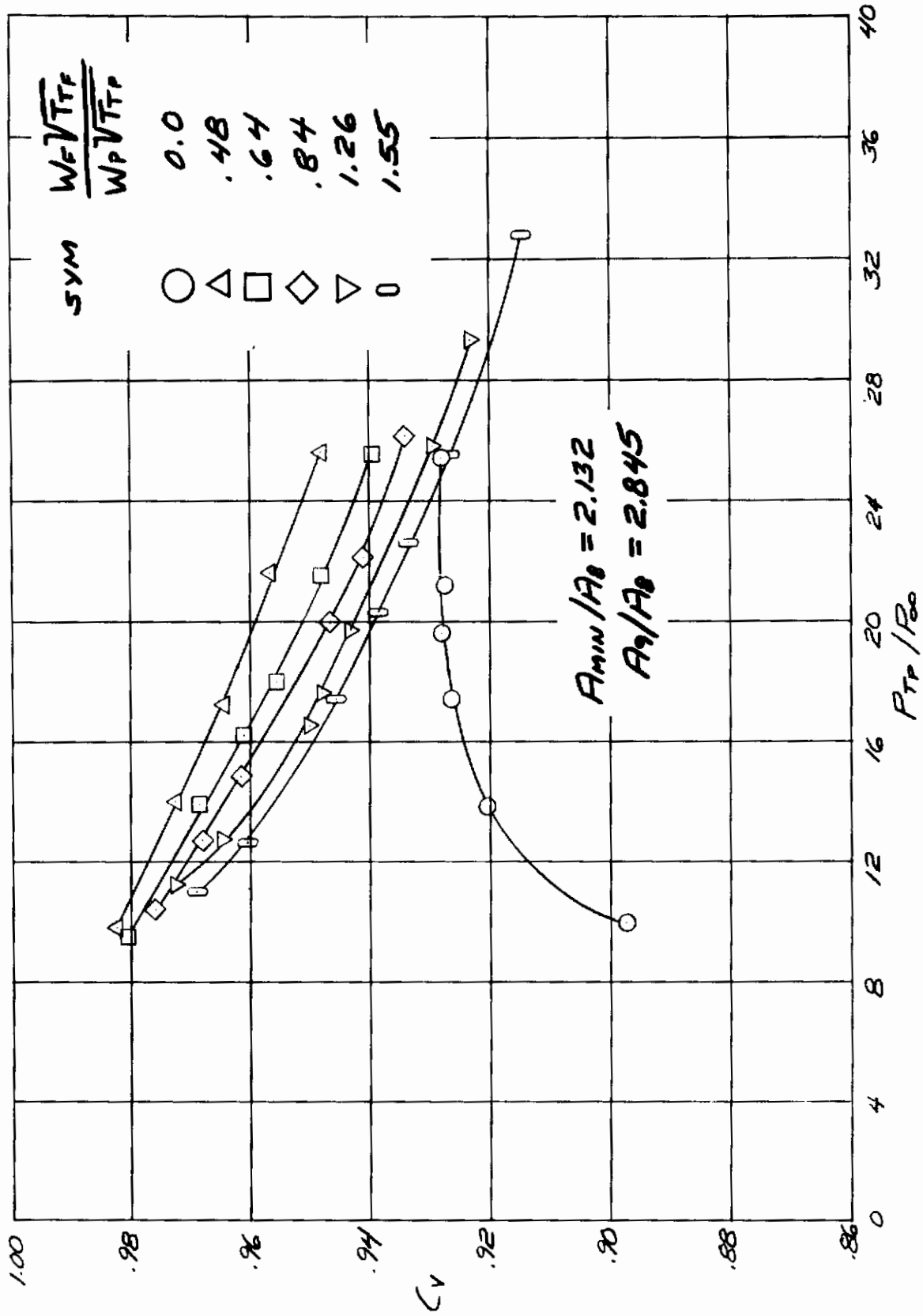


Figure 223. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Performance (Versus Nozzle Pressure Ratio)

Approved for Public Release

Contrails

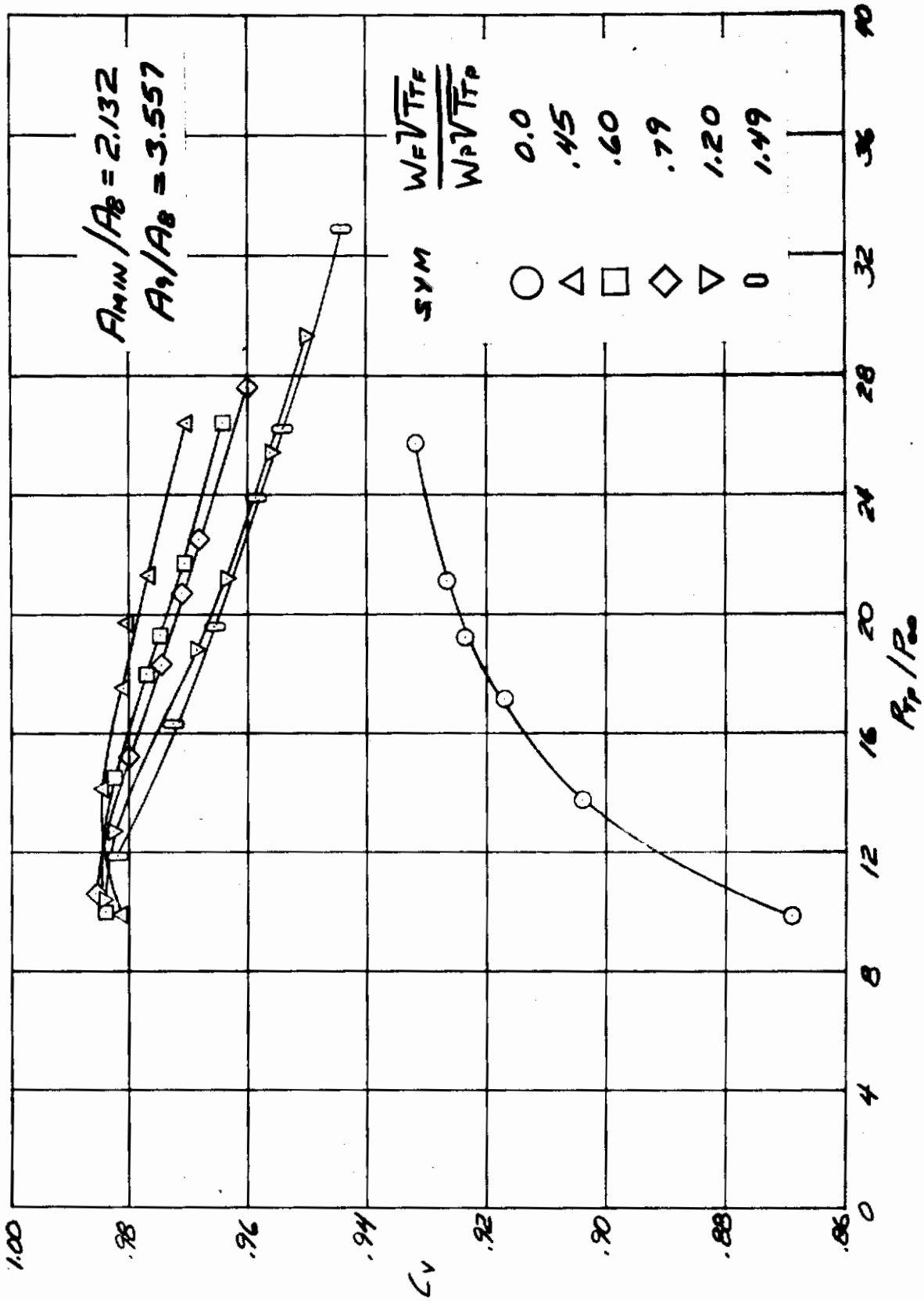


Figure 224. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Performance (Versus Nozzle Pressure Ratio)

Approved for Public Release

Contrails

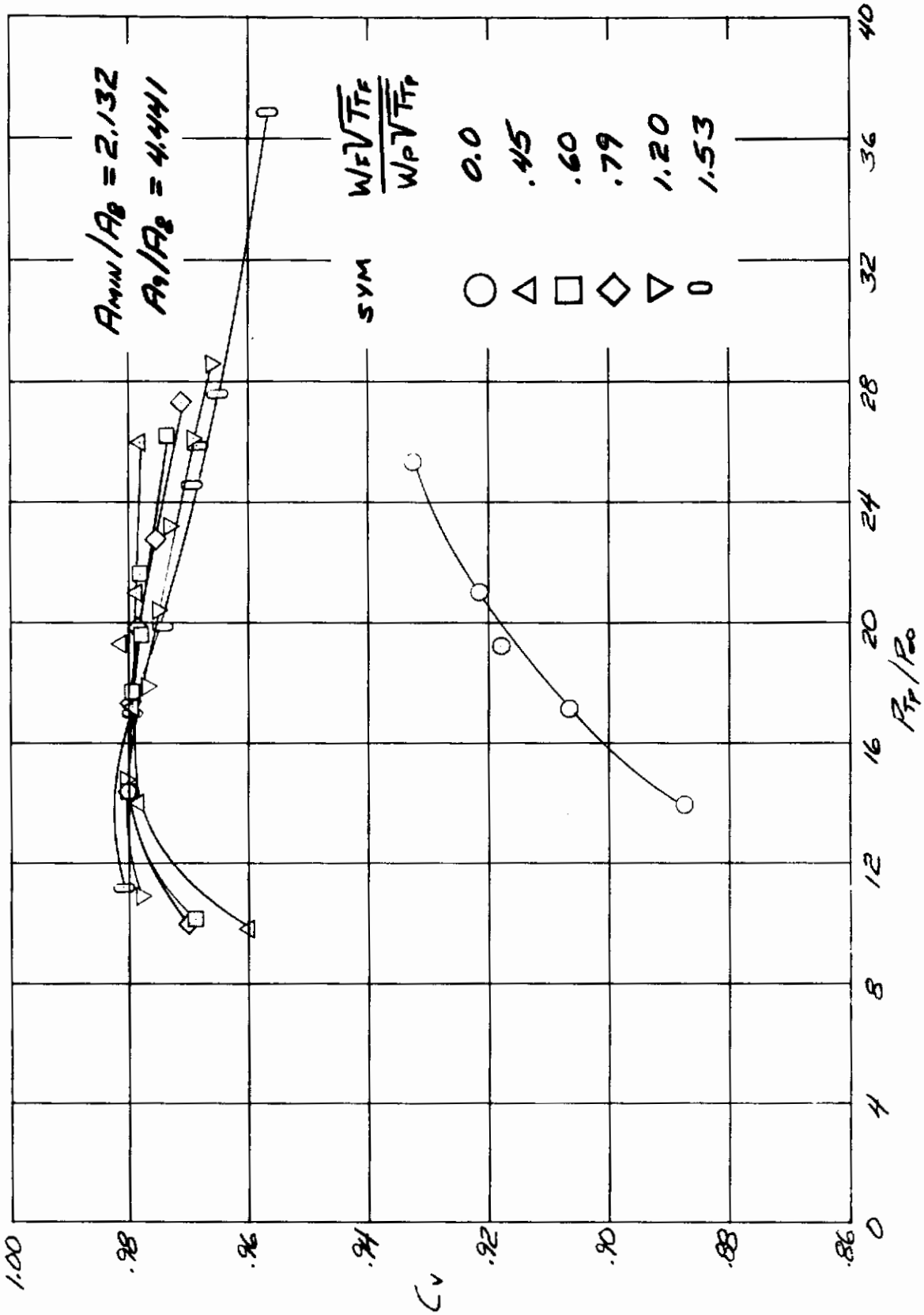


Figure 225. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Performance (Versus Nozzle Pressure Ratio)

Approved for Public Release

Contrails

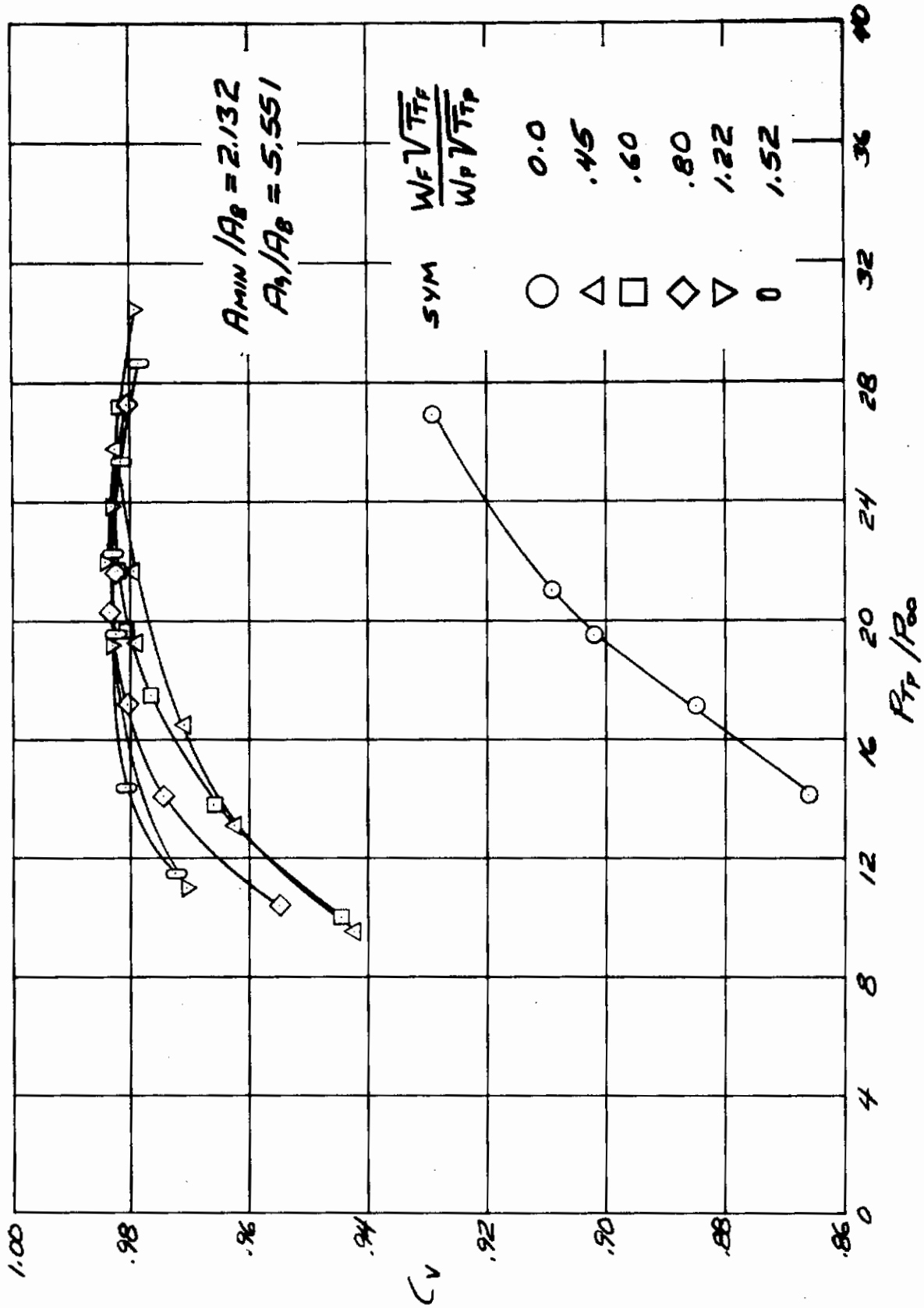


Figure 226. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Performance (Versus Nozzle Pressure Ratio)

Approved for Public Release

Contrails

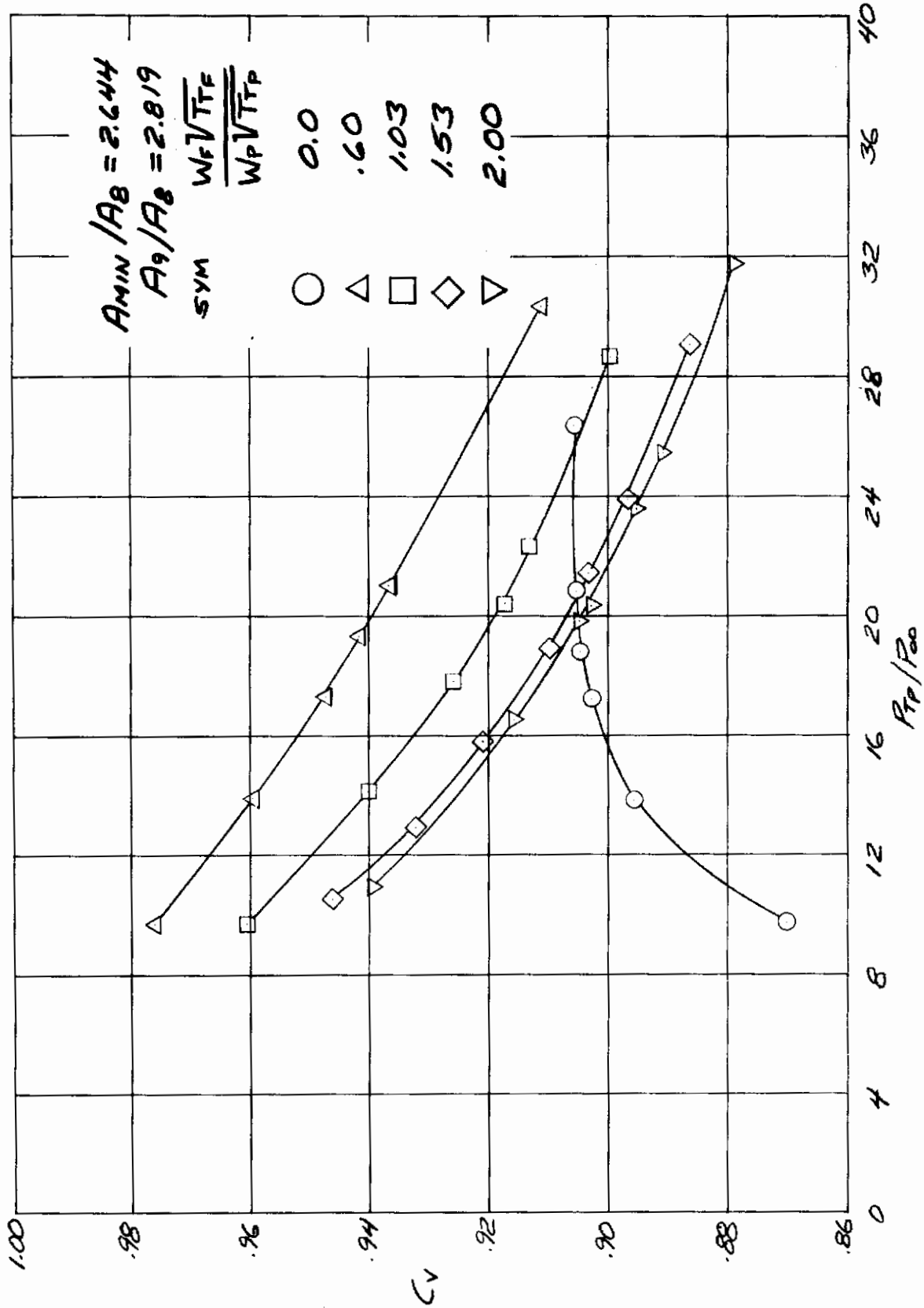


Figure 227. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Performance (Versus Nozzle Pressure Ratio)

Approved for Public Release

Contrails

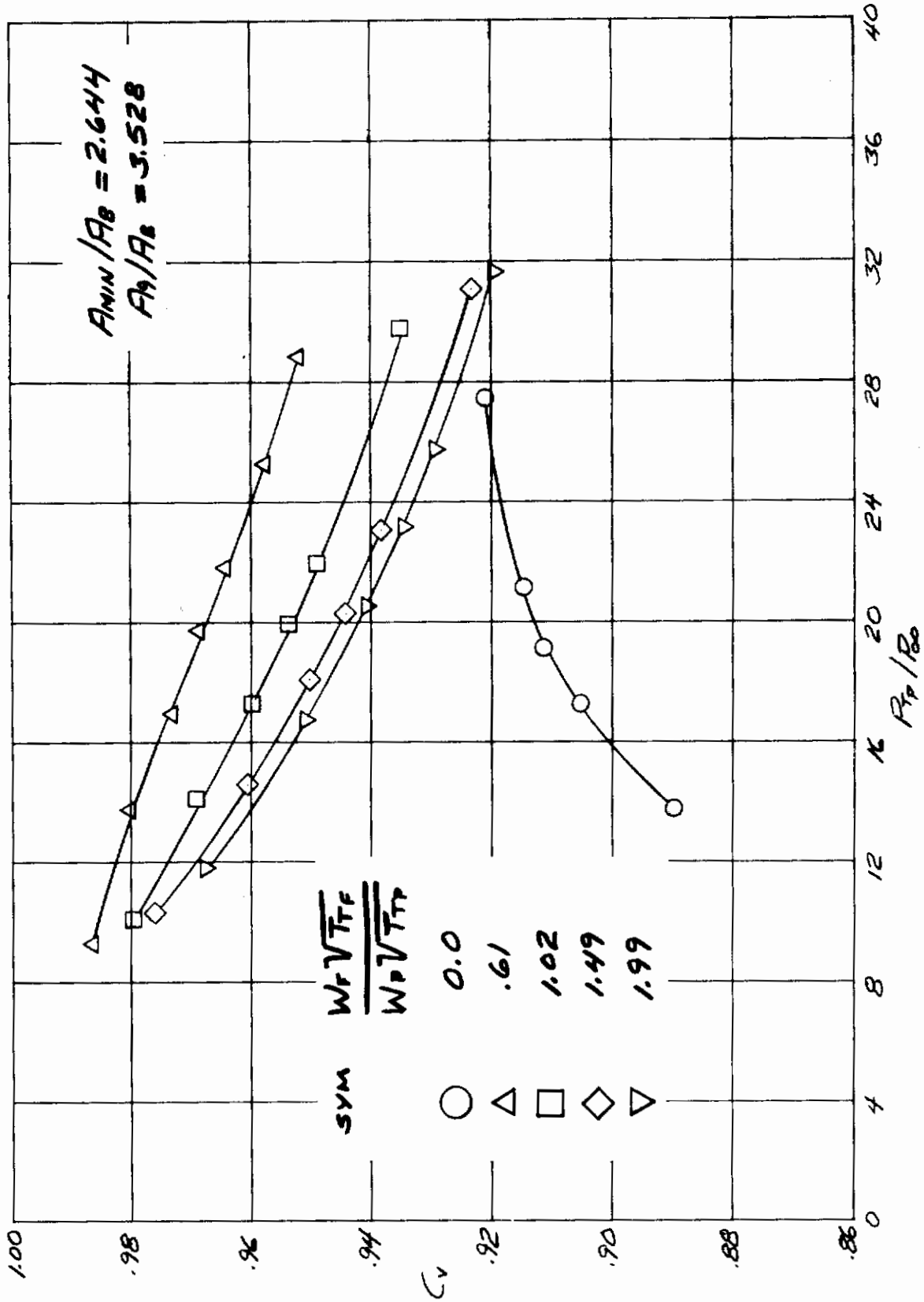


Figure 228. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Performance (Versus Nozzle Pressure Ratio)

Approved for Public Release

Contrails

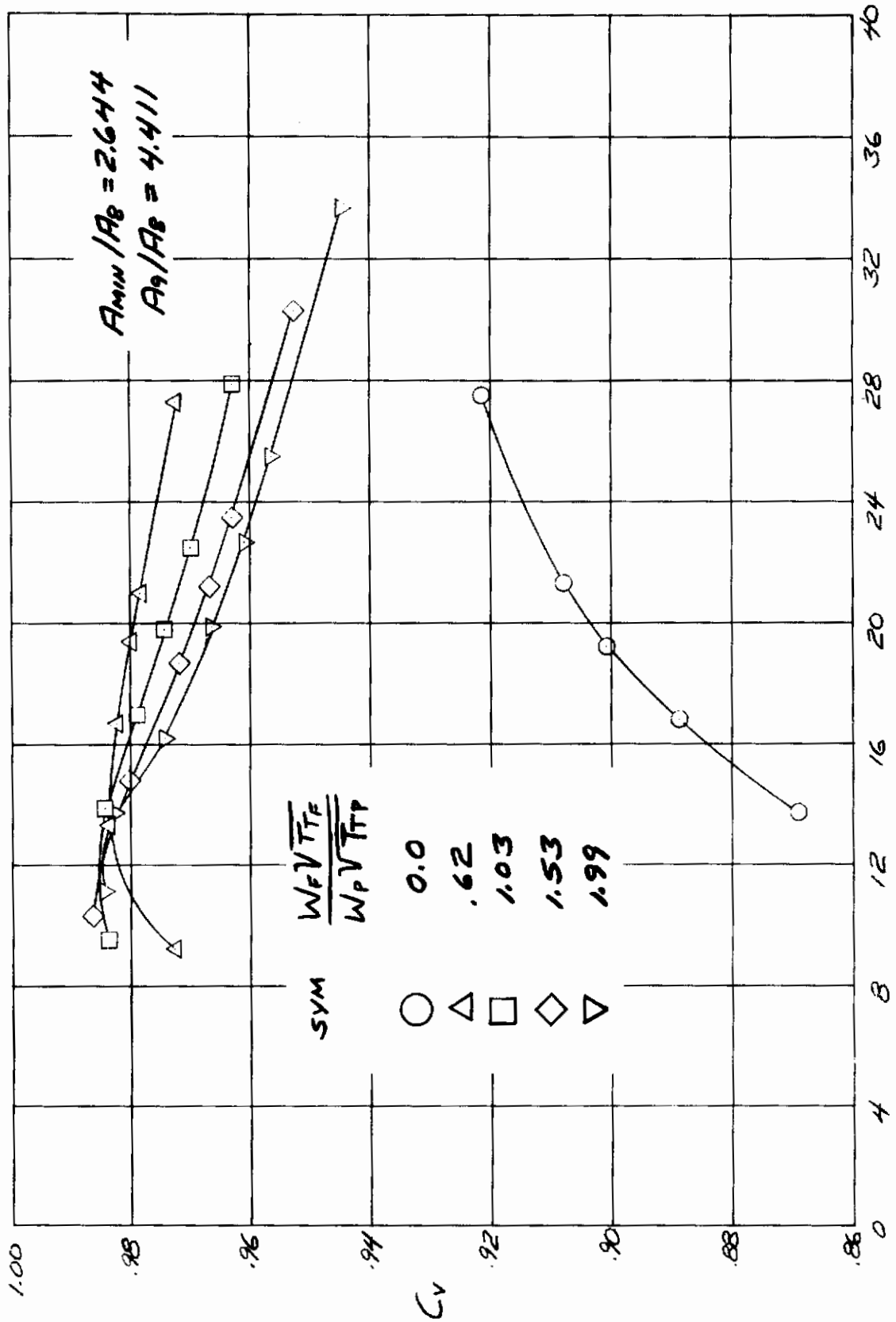


Figure 229. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Performance (Versus Nozzle Pressure Ratio)

Approved for Public Release

Contrails

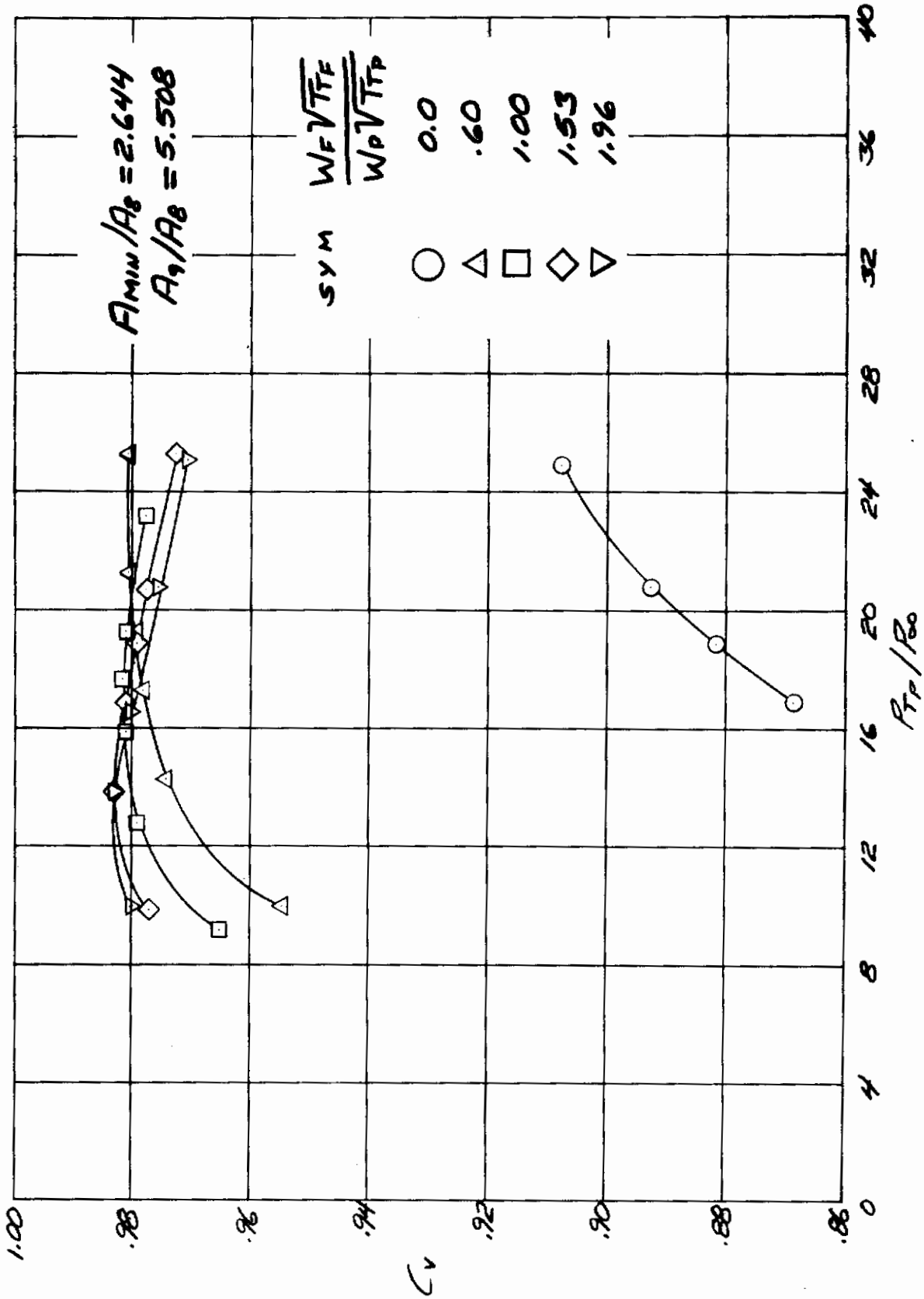


Figure 230. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Performance (Versus Nozzle Pressure Ratio)

Approved for Public Release

Contrails

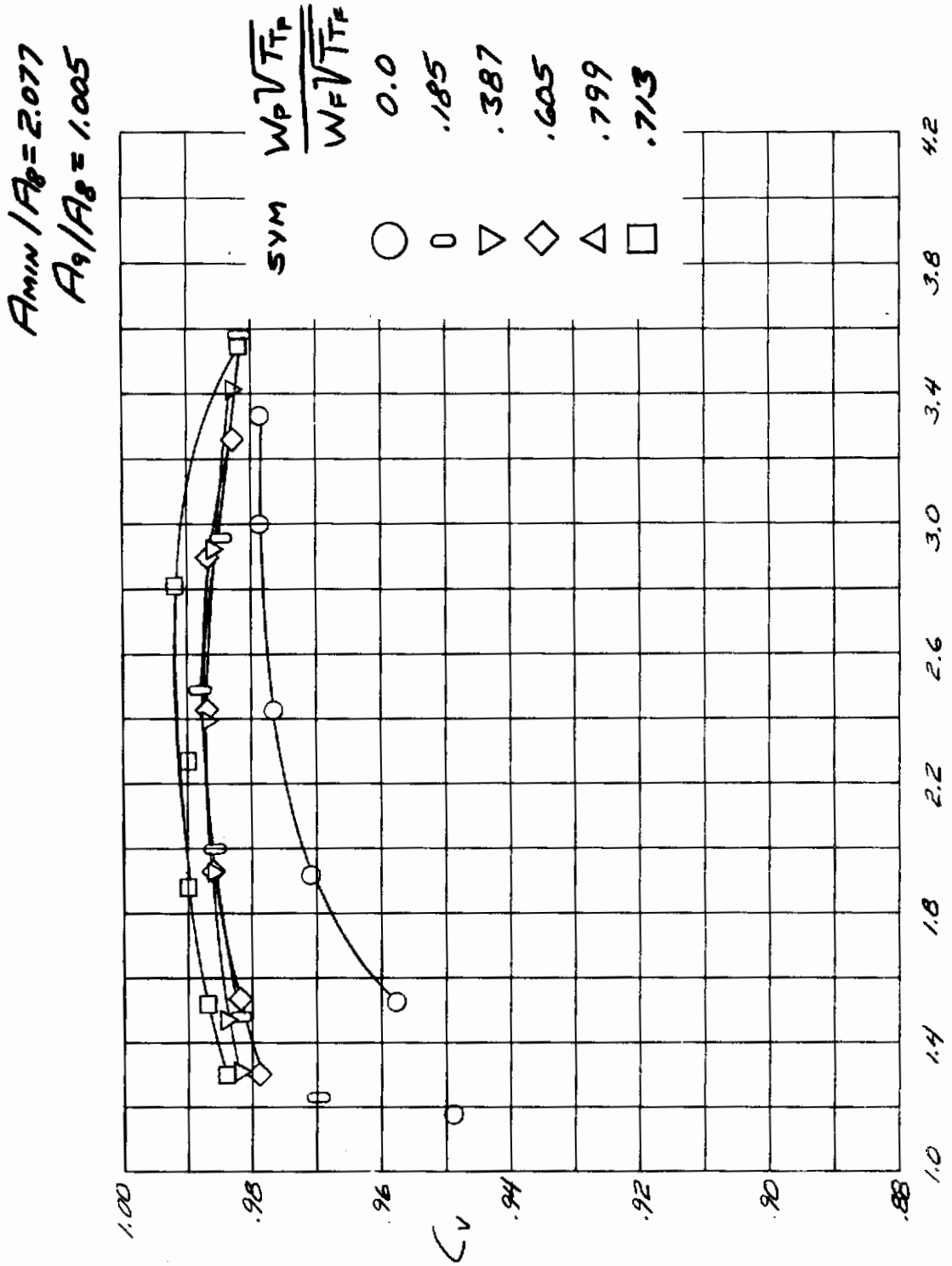


Figure 231. Shared Exit Ejector Nozzle Static Tests - Fan Mode Performance (Versus Nozzle Pressure Ratio)

Approved for Public Release

Contrails

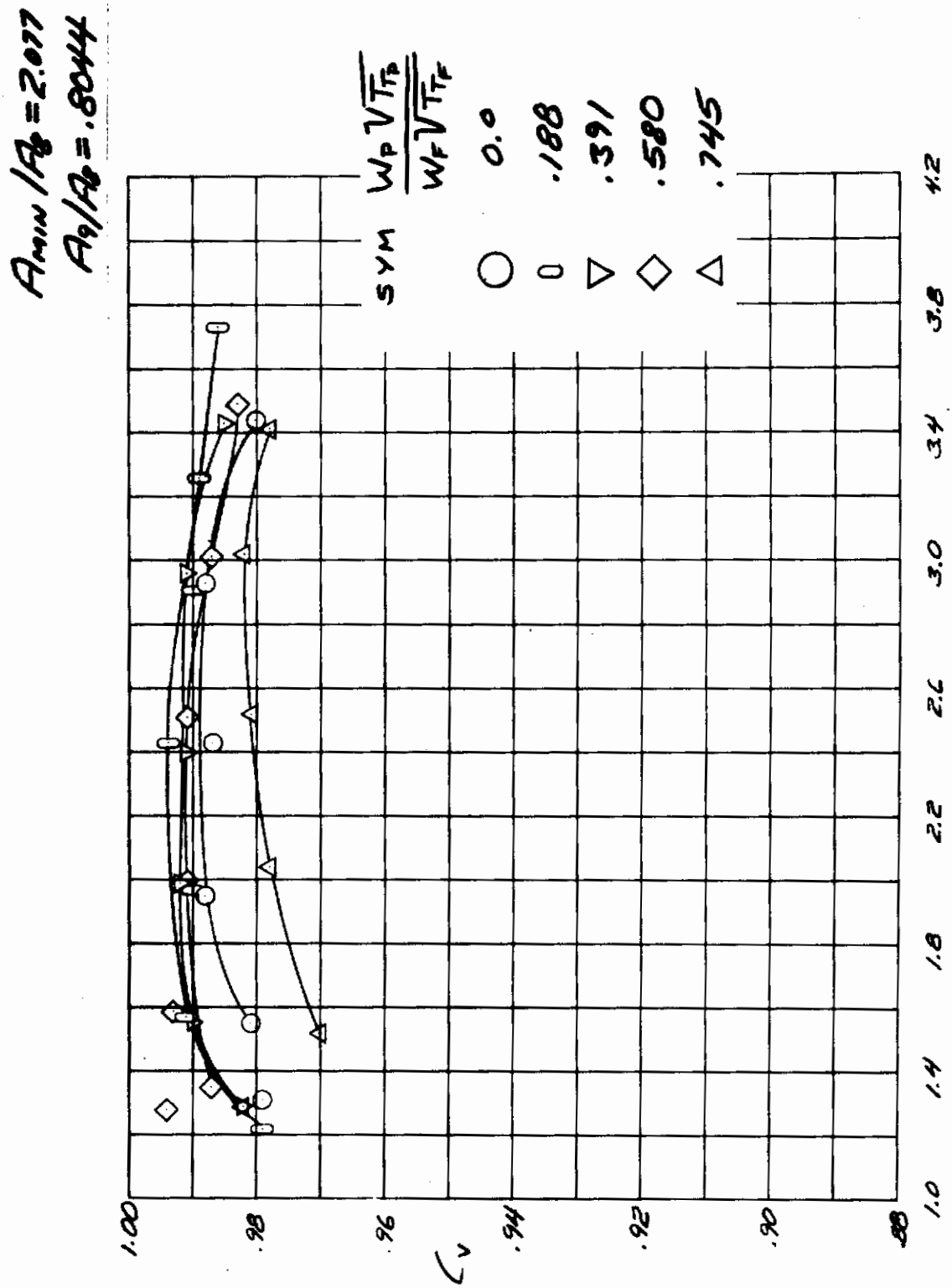


Figure 232. Shared Exit Ejector Nozzle Static Tests - Fan Mode Performance (Versus Nozzle Pressure Ratio)

Approved for Public Release

Contrails

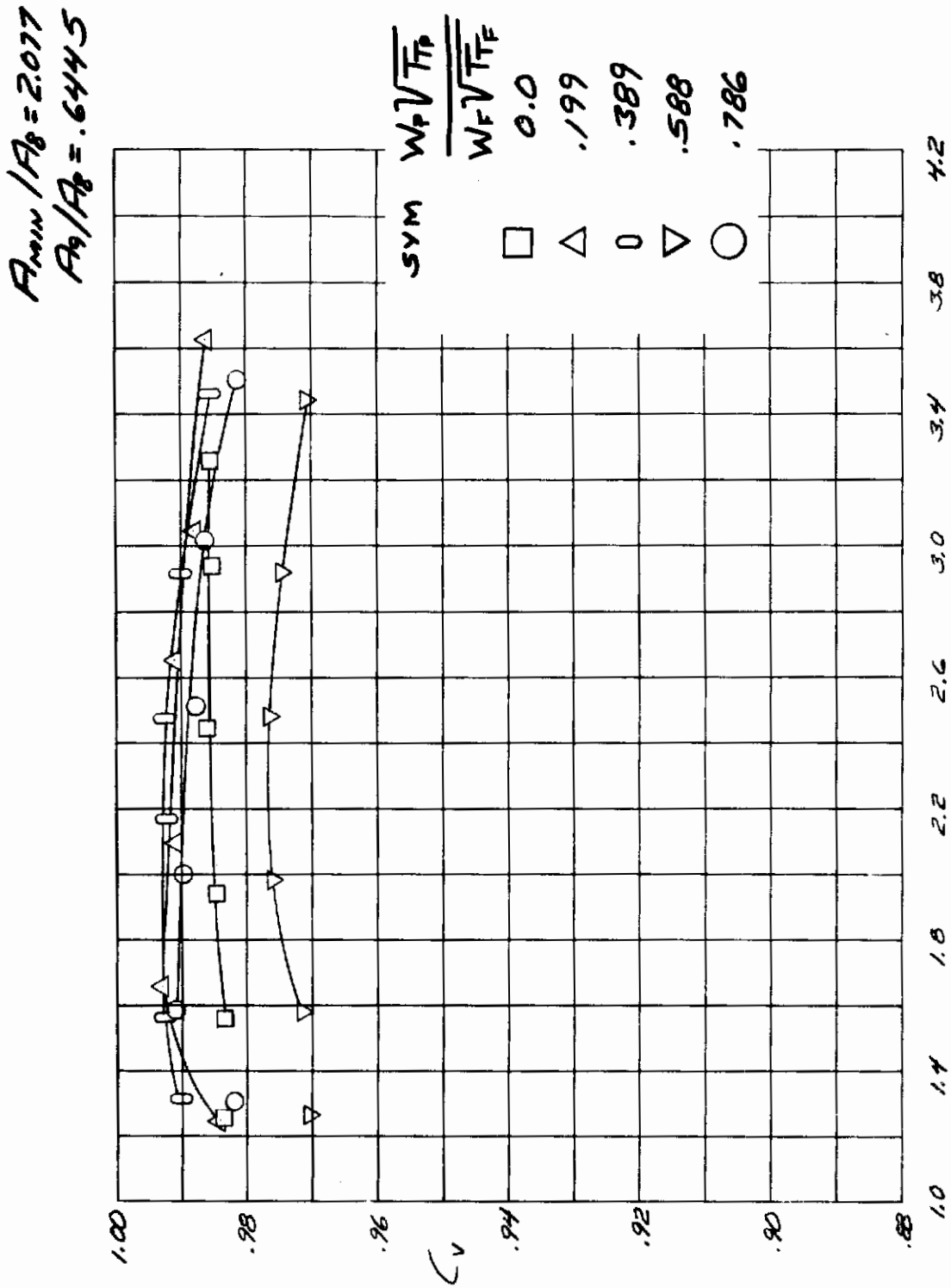


Figure 233. Shared Exit Ejector Nozzle Static Tests - Fan Mode Performance (Versus Nozzle Pressure Ratio)

Approved for Public Release

Contrails

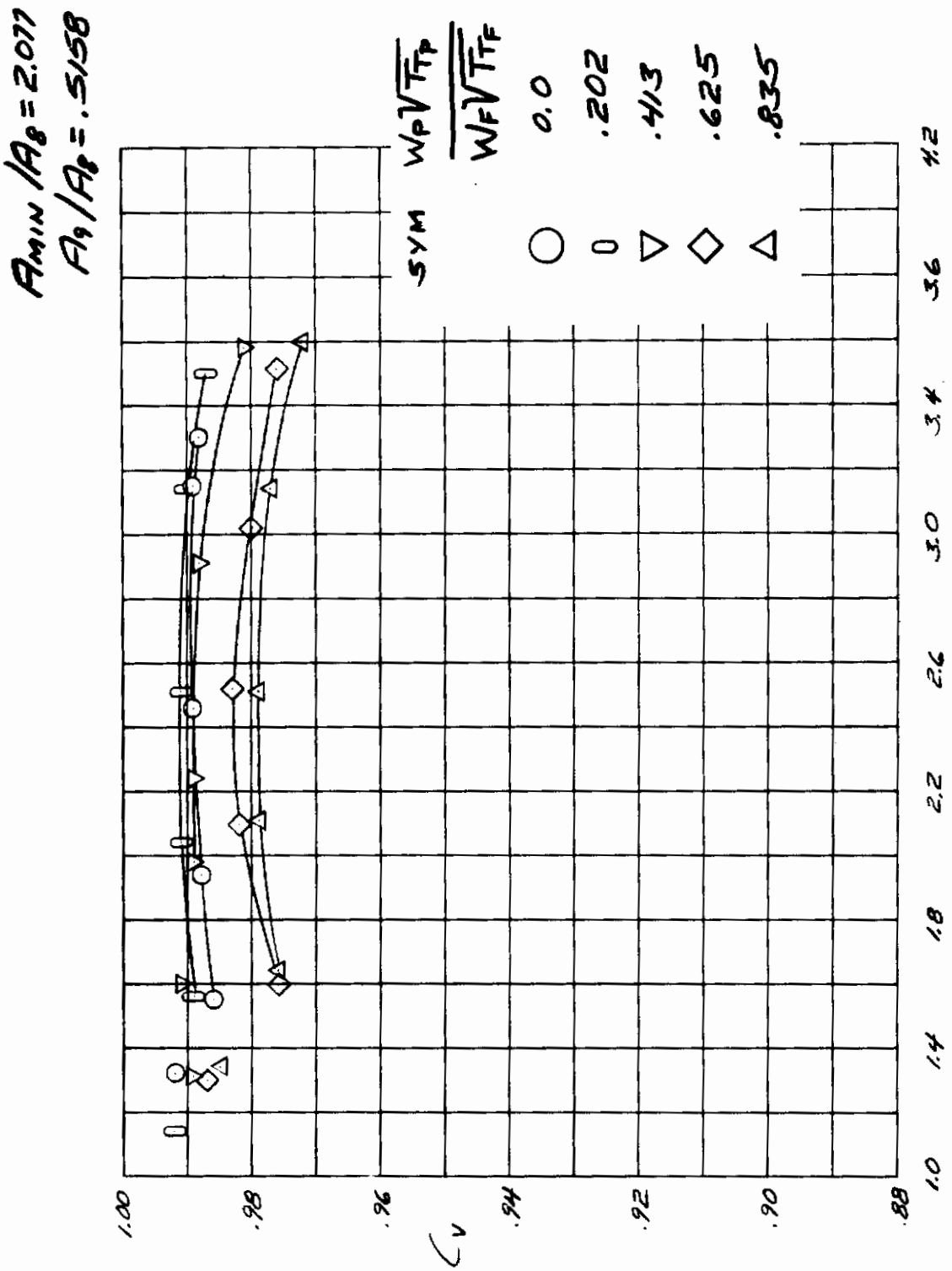


Figure 234. Shared Exit Ejector Nozzle Static Tests - Fan Mode Performance (Versus Nozzle Pressure Ratio)

Approved for Public Release

Contrails

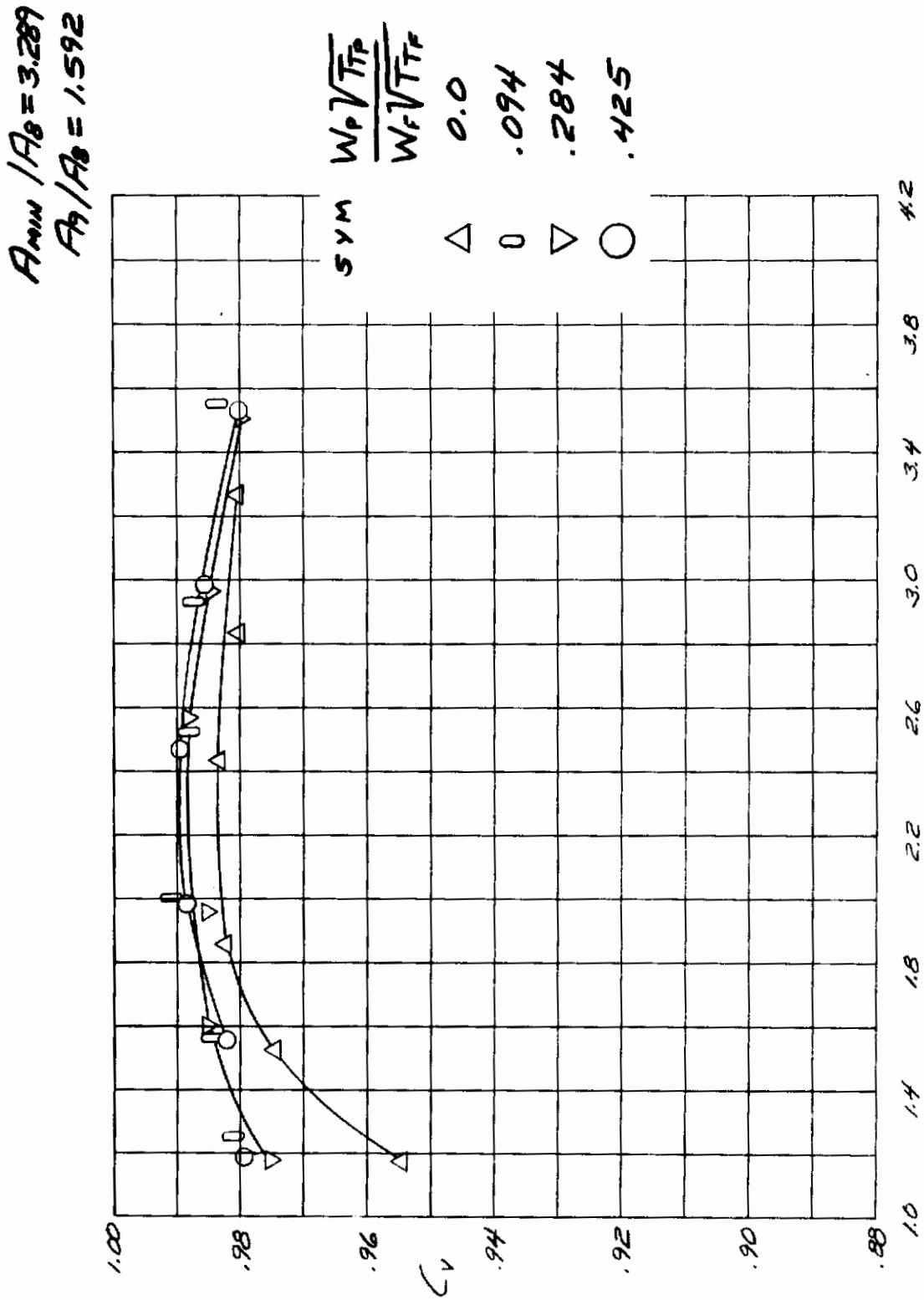


Figure 235. Shared Exit Ejector Nozzle Static Tests - Fan Mode Performance (Versus Nozzle Pressure Ratio)

Approved for Public Release

Contrails

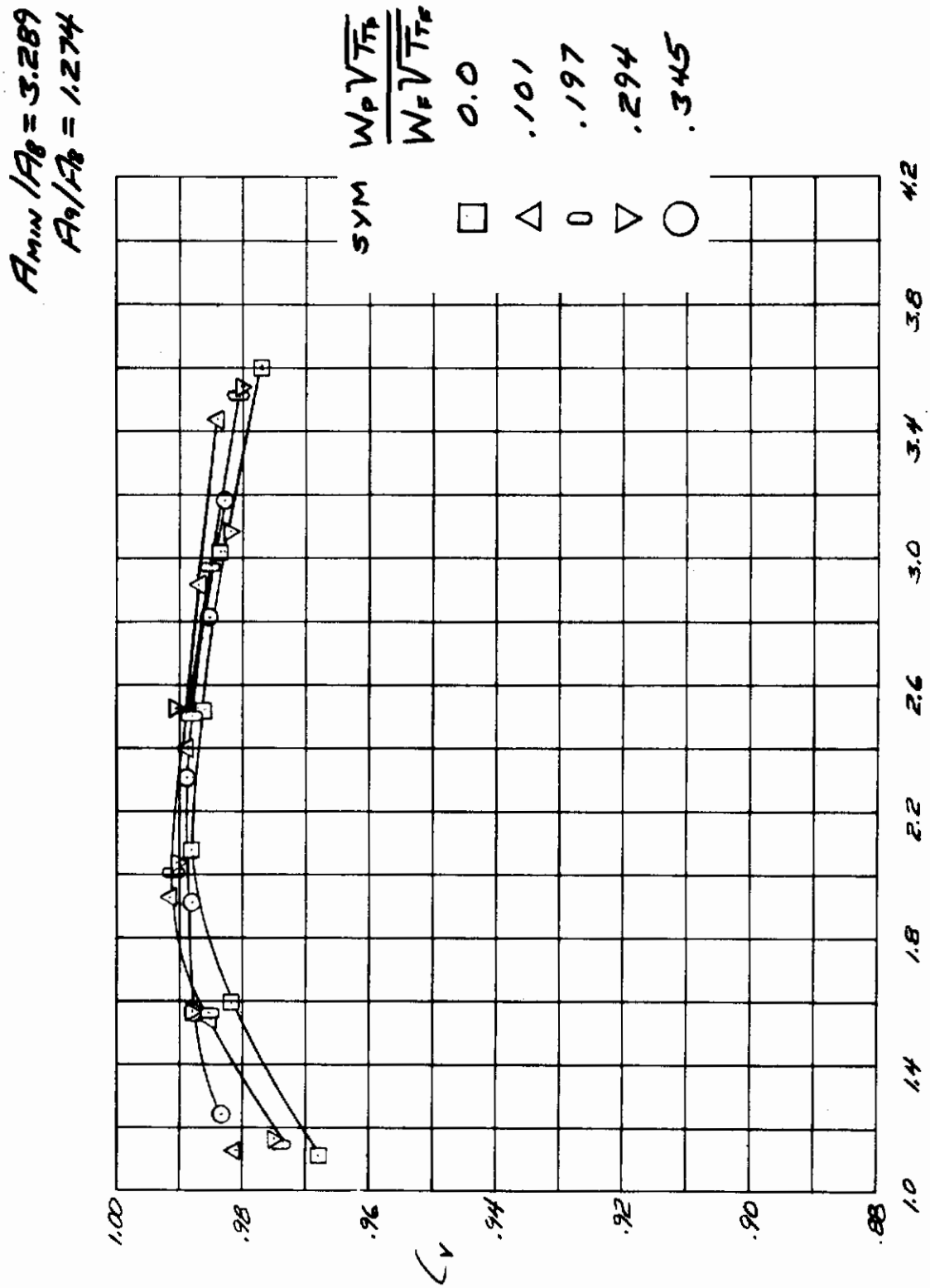


Figure 236. Shared Exit Ejector Nozzle Static Tests - Fan Mode Performance (Versus Nozzle Pressure Ratio)

Approved for Public Release

Contrails

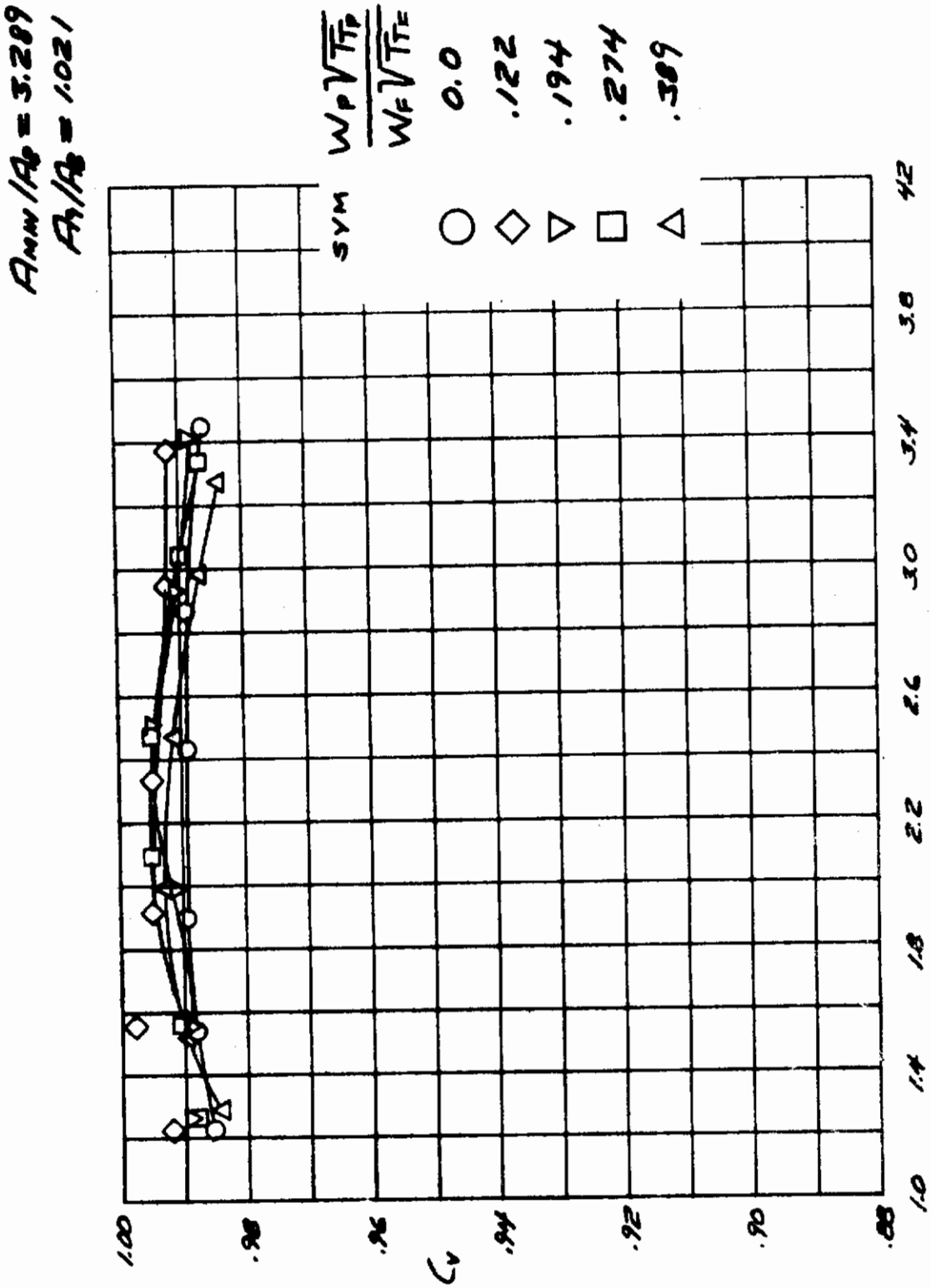


Figure 237. Shared Exit Ejector Nozzle Static Tests - Fan Mode Performance (Versus Nozzle Pressure Ratio)

Approved for Public Release

Contrails

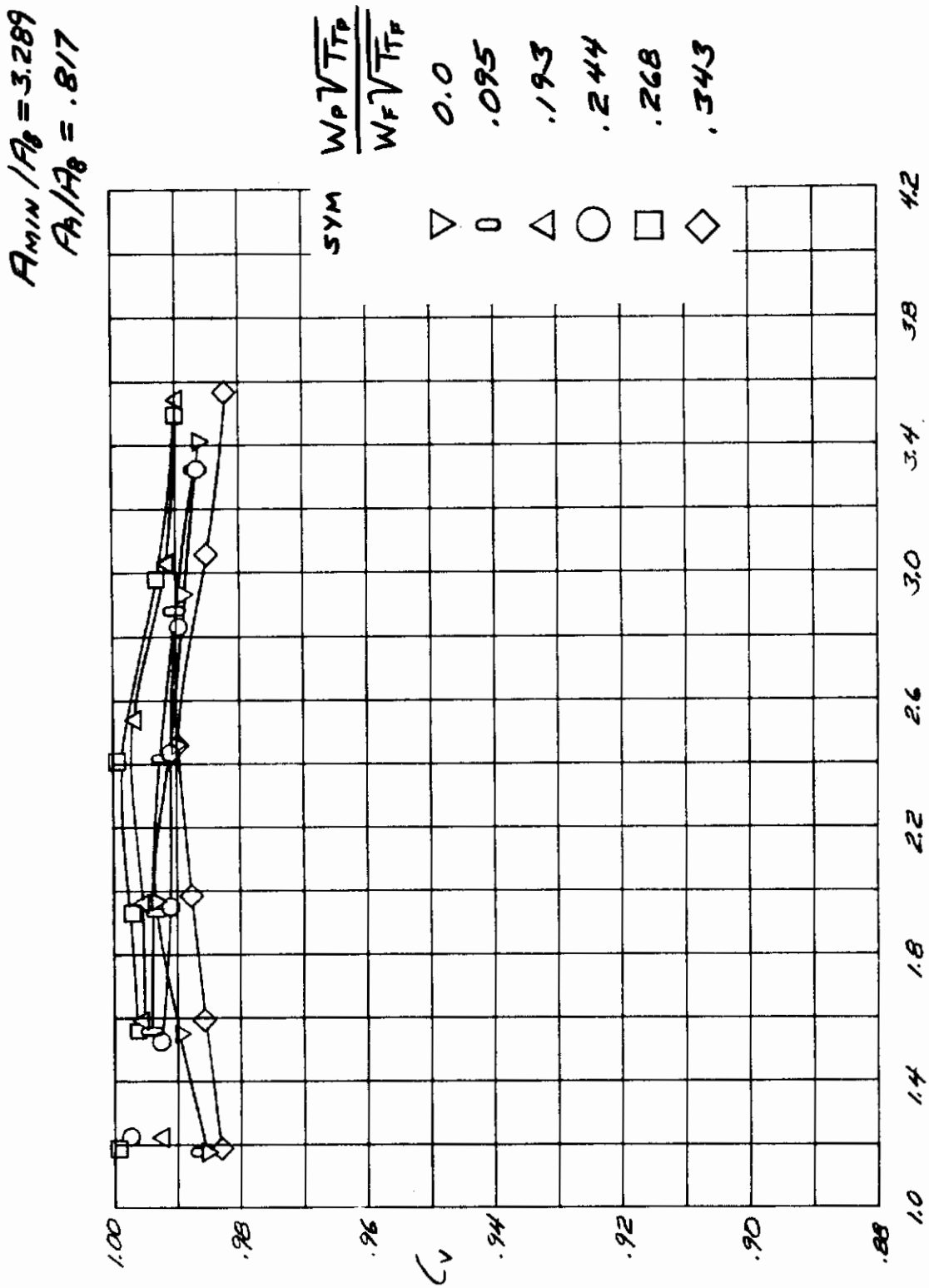


Figure 238. Shared Exit Ejector Nozzle Static Tests - Fan Mode Performance (Versus Nozzle Pressure Ratio)

Approved for Public Release

Contrails

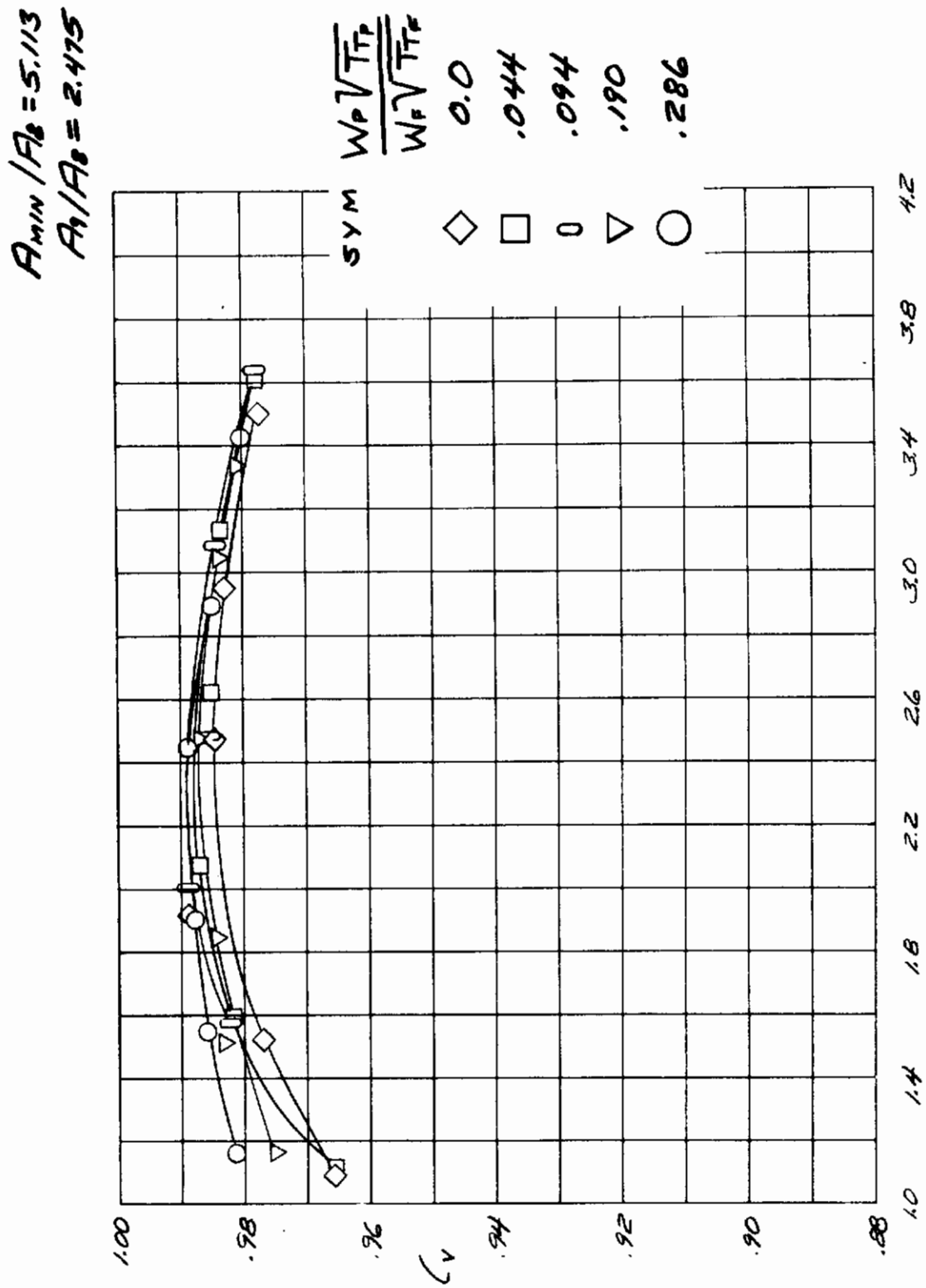


Figure 239. Shared Exit Ejector Nozzle Static Tests - Fan Mode Performance (Versus Nozzle Pressure Ratio)

Approved for Public Release

Contrails

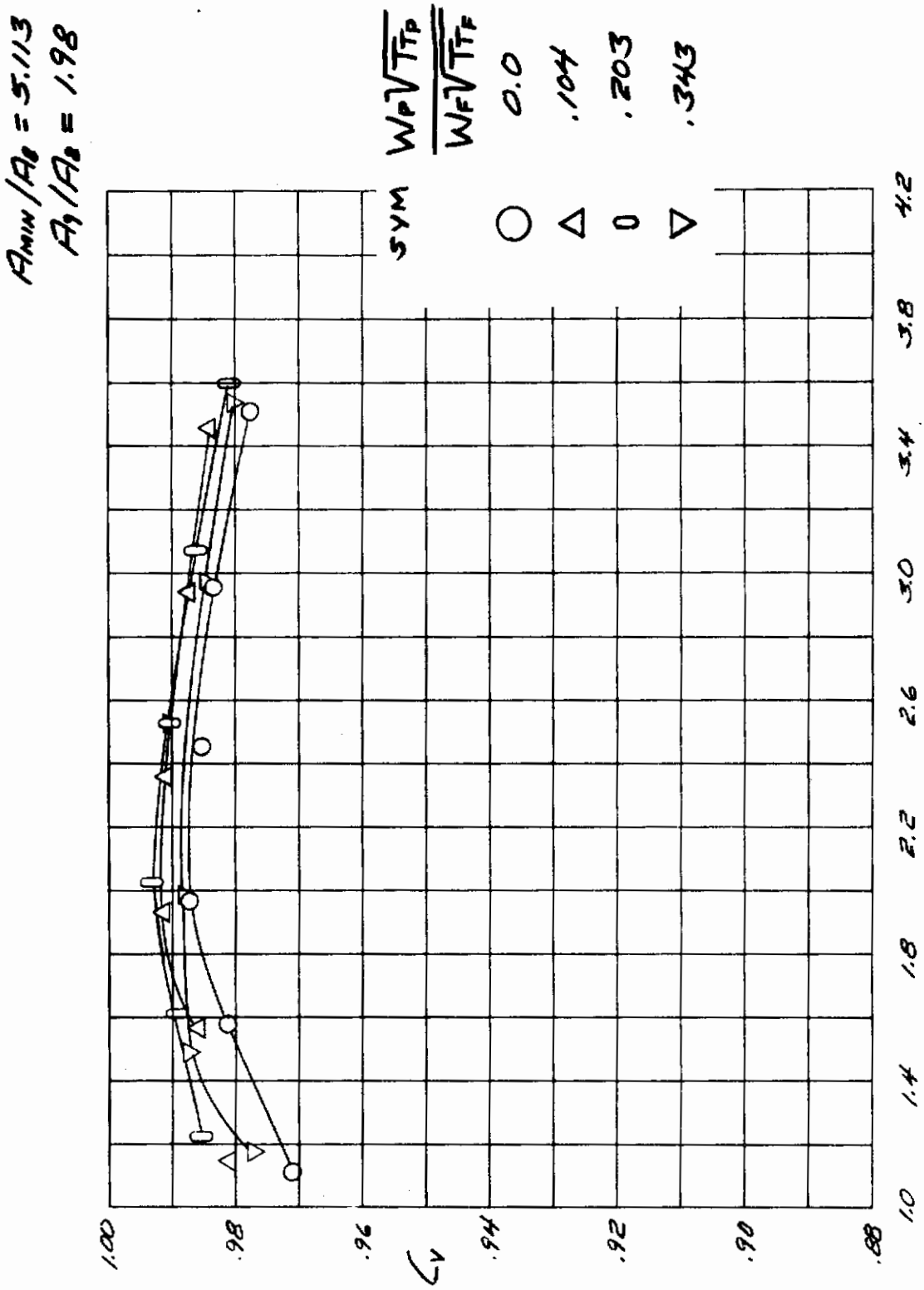


Figure 240. Shared Exit Ejector Nozzle Static Tests - Fan Mode Performance (Versus Nozzle Pressure Ratio)

Approved for Public Release

Contrails

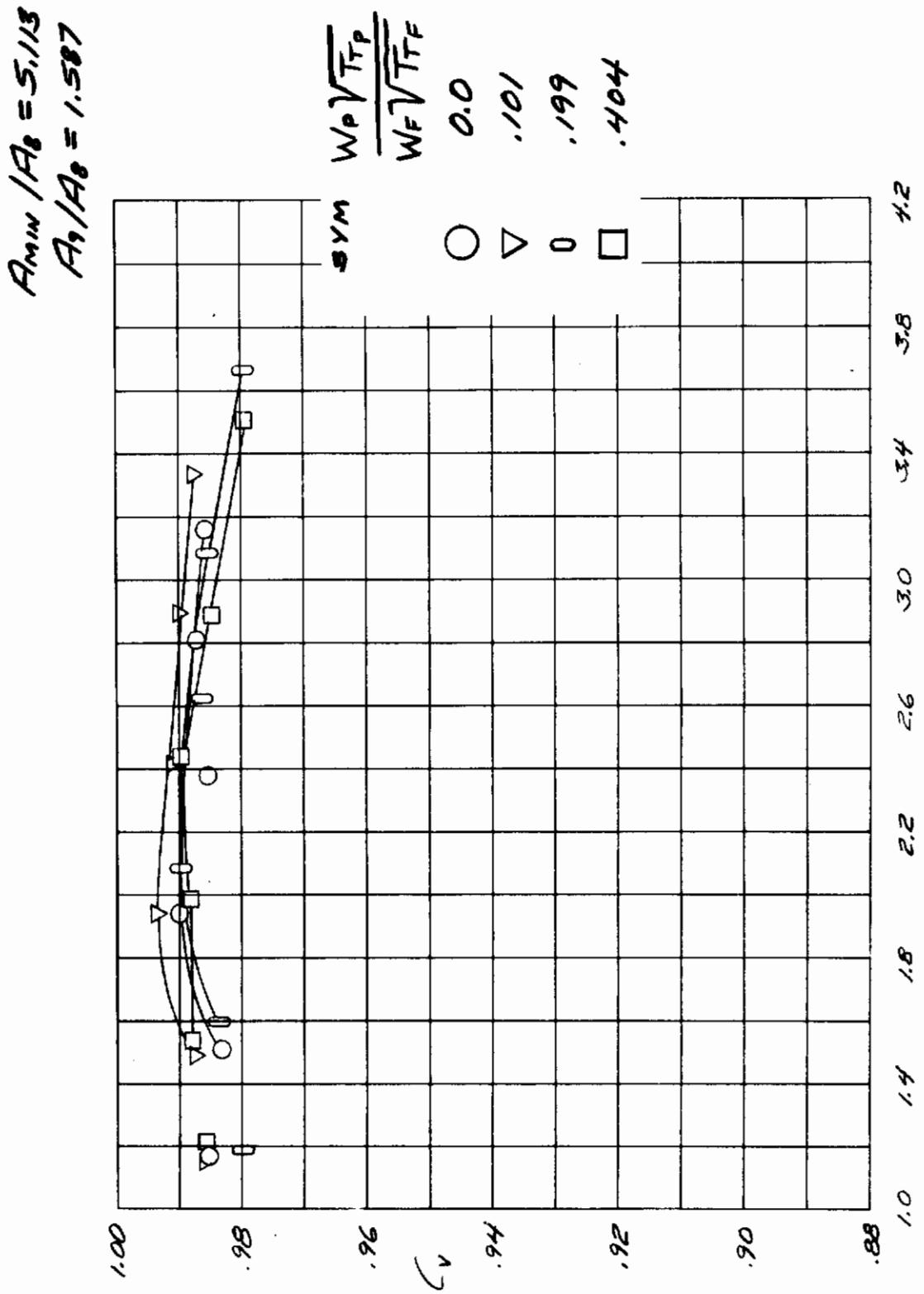


Figure 241. Shared Exit Ejector Nozzle Static Tests - Fan Mode Performance (Versus Nozzle Pressure Ratio)

Approved for Public Release

Contrails

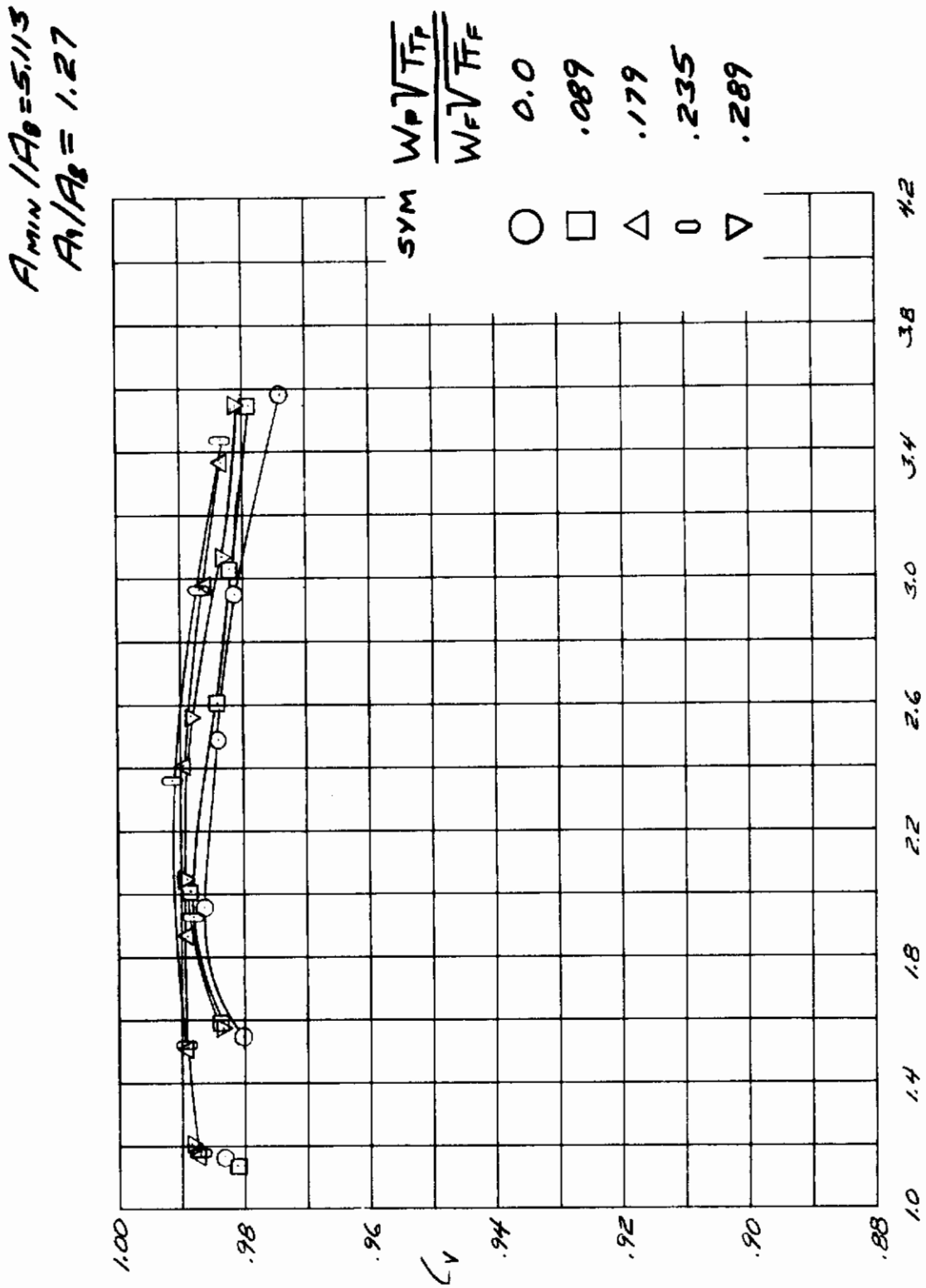


Figure 242. Shared Exit Ejector Nozzle Static Tests - Fan Mode Performance (Versus Nozzle Pressure Ratio)

(The reverse of this page is blank)

Approved for Public Release

Contrails

Approved for Public Release

Contrails

APPENDIX V

PUMPING CHARACTERISTICS

(The reverse of this page is blank)

Approved for Public Release

Contrails

Approved for Public Release

Contrails

APPENDIX V

PUMPING CHARACTERISTICS

Figures 243 through 263 present pumping characteristics as a function of nozzle pressure ratio. Figures 243 through 251 pertain to the satellite mode configuration for which pumping characteristic is defined as the ratio of pressure in the fan duct to total pressure in the primary plenum chamber, P_{T_F}/P_{T_P}. Nozzle pressure ratio is defined as the total pressure in the primary plenum chamber divided by the ambient static pressure, P_{T_P}/P_{∞}. When plotted in the manner shown, pumping characteristic is independent of nozzle pressure ratio as long as the ejector is choked. Configurations 10 through 17 and 19 through 22, which were tested over a nominal pressure ratio range of 10 to 25, are therefore omitted from this series of plots.

In figures 252 through 263, which apply to fan mode configurations, pumping characteristic is the reciprocal of that which was defined for the satellite mode; i.e., P_{T_P}/P_{T_F}. Nozzle pressure ratio in the fan mode is the ratio of total pressure in the fan duct to ambient static pressure, P_{T_F}/P_{∞}.

Approved for Public Release

Contrails

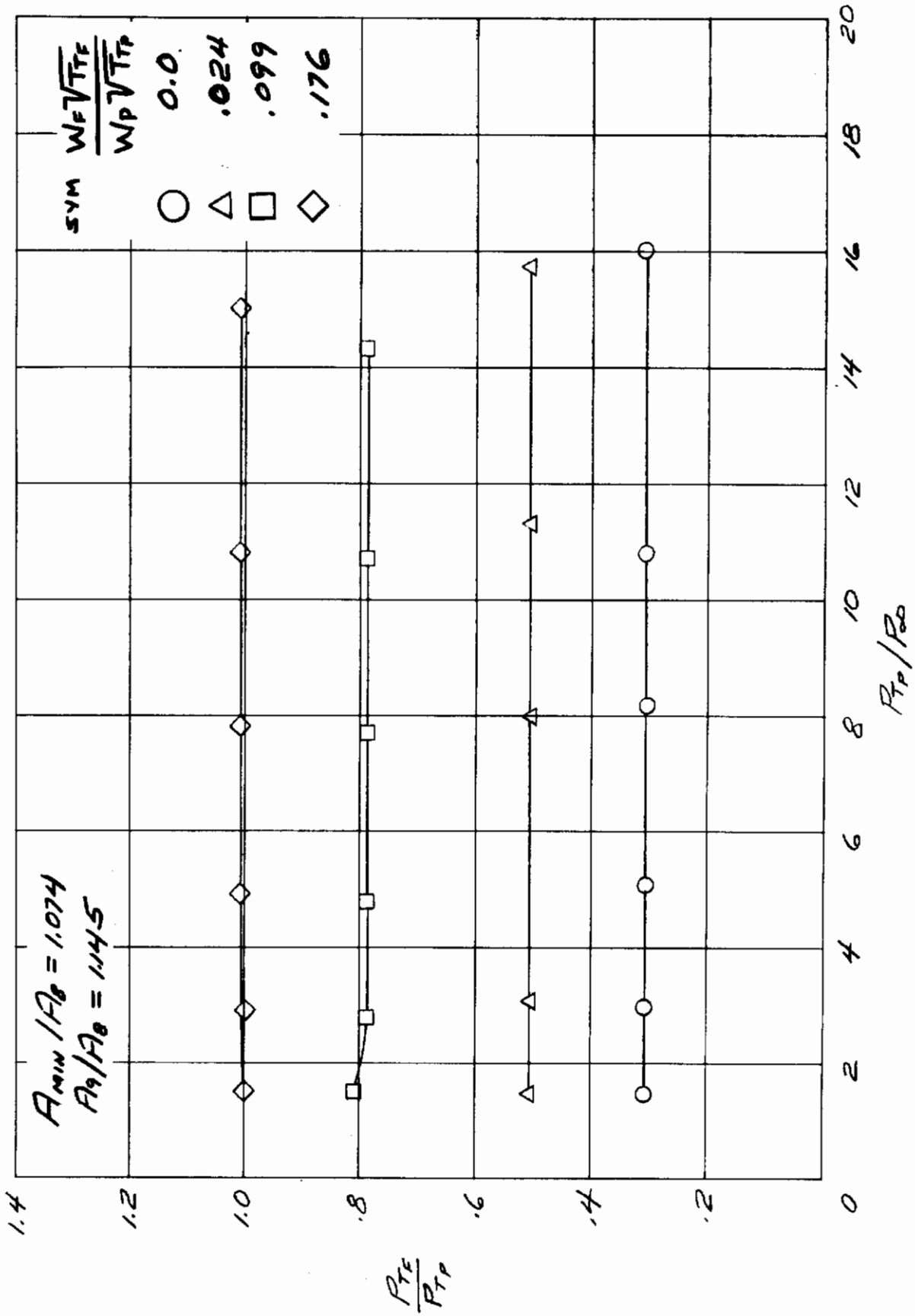


Figure 243. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Pumping Characteristics

Approved for Public Release

Contrails

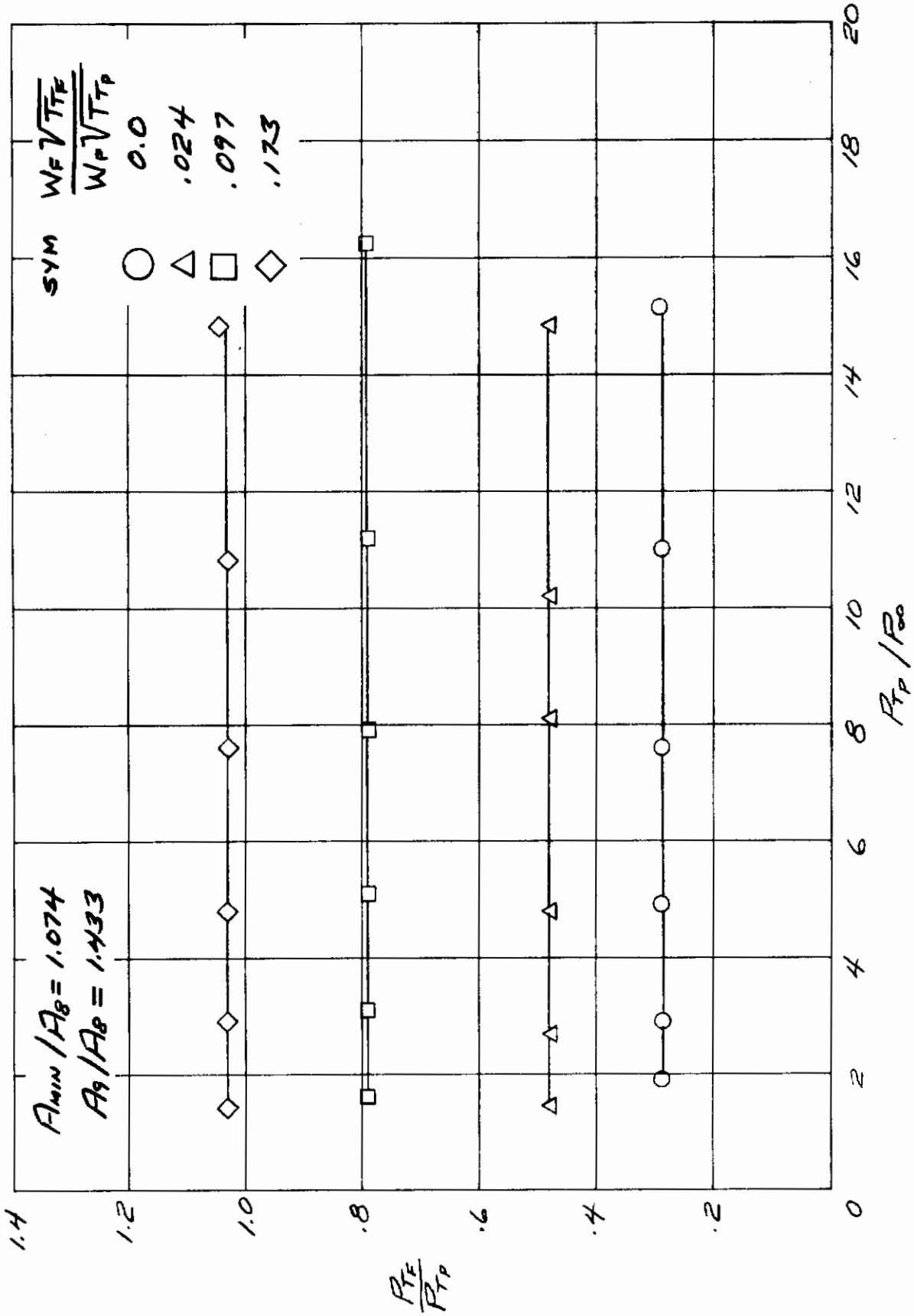


Figure 244. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Pumping Characteristics

Approved for Public Release

Contrails

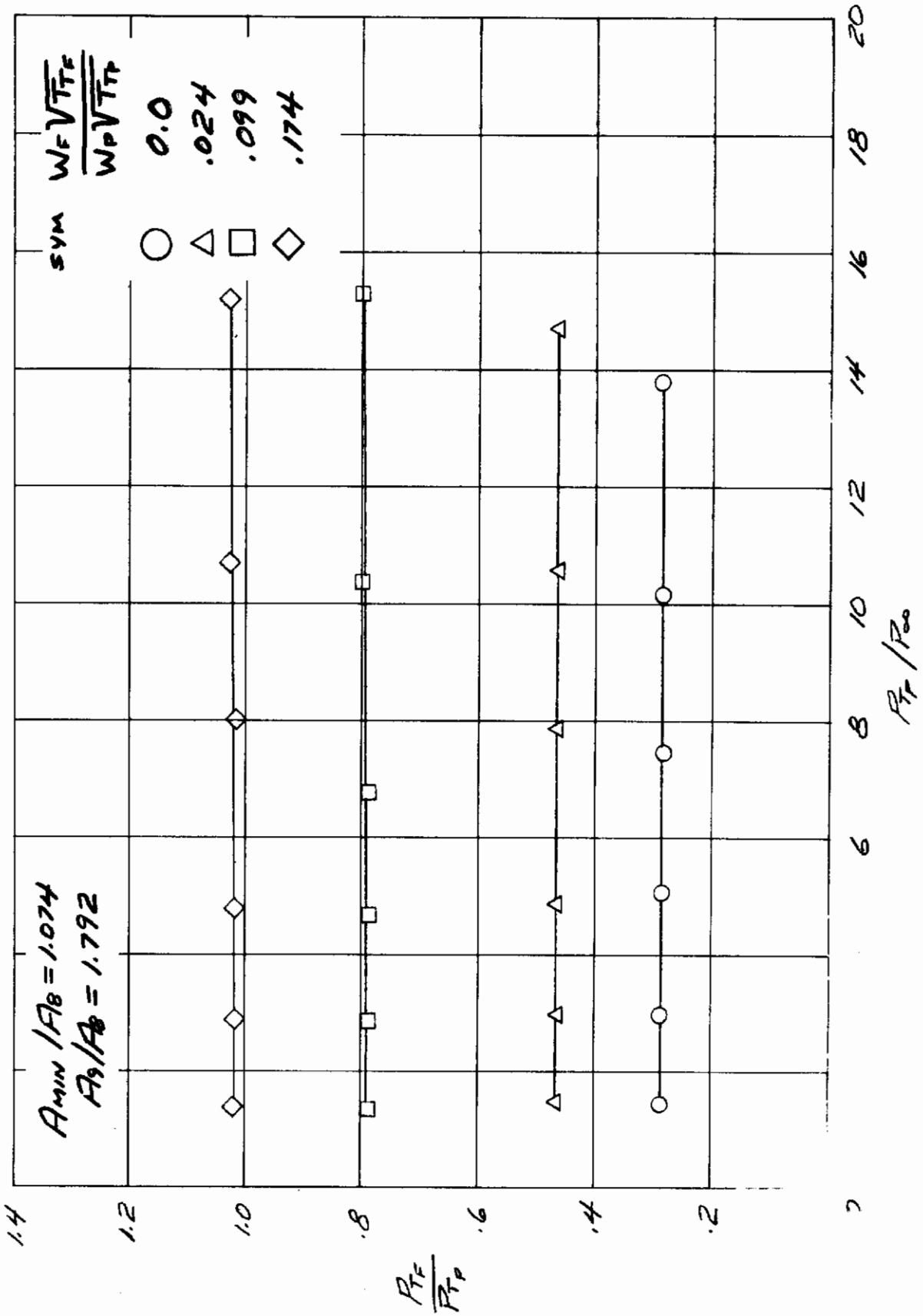


Figure 245. Shared Exit Fan Nozzle Static Tests - Satellite Mode Pumping Characteristics

Approved for Public Release

Contrails

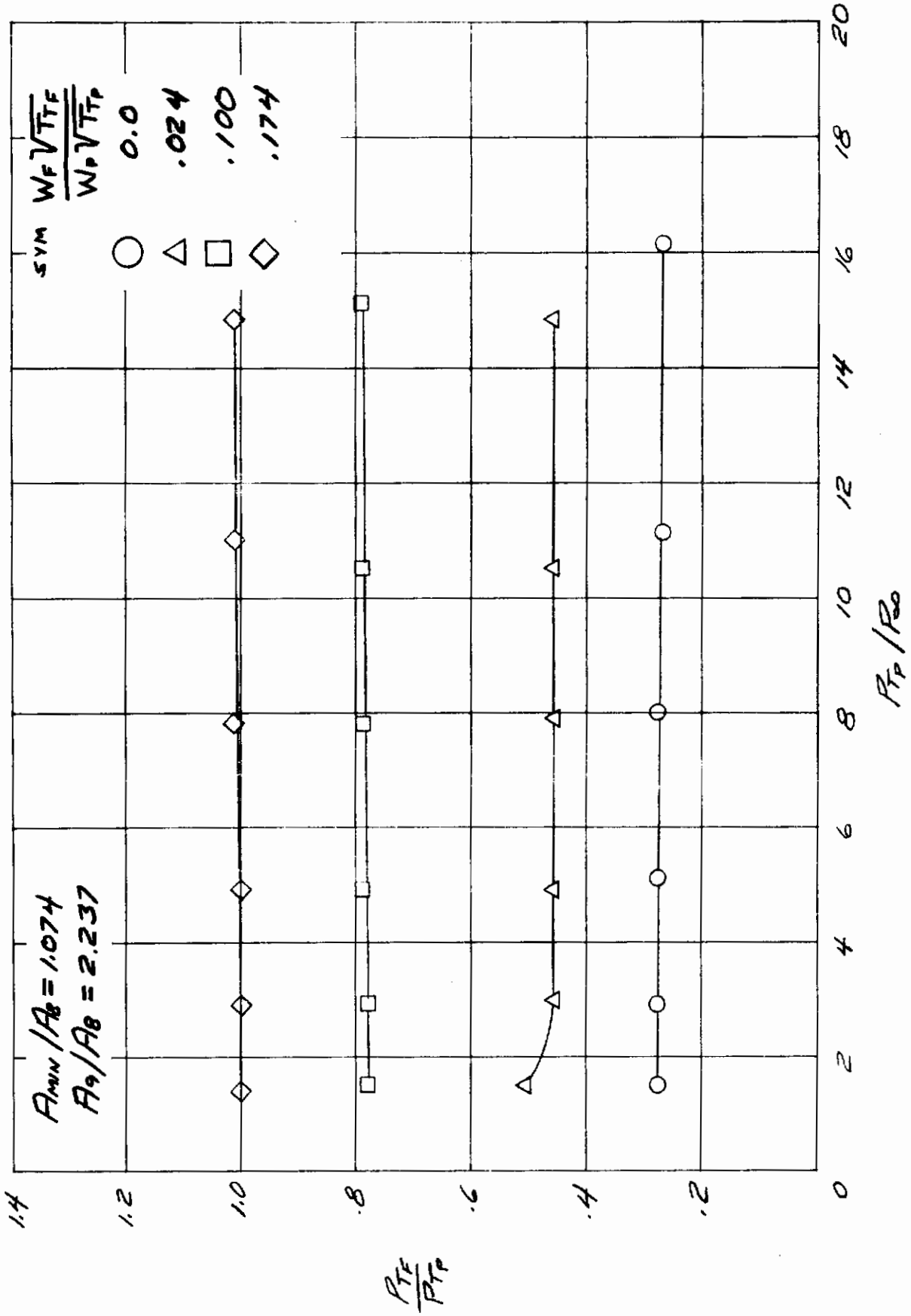


Figure 246. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Pumping Characteristics

Approved for Public Release

Contrails

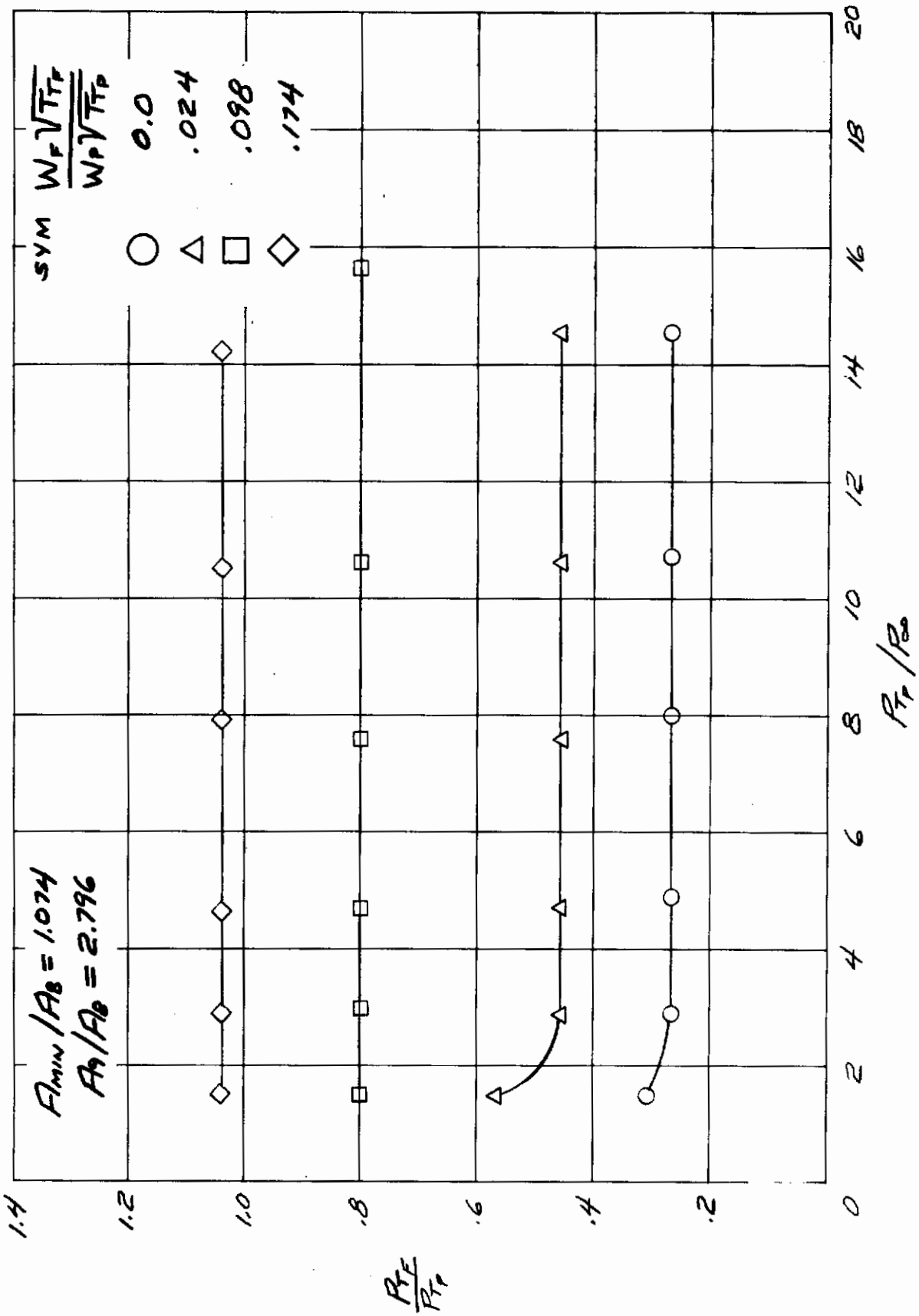


Figure 247. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Pumping Characteristics

Approved for Public Release

Contrails

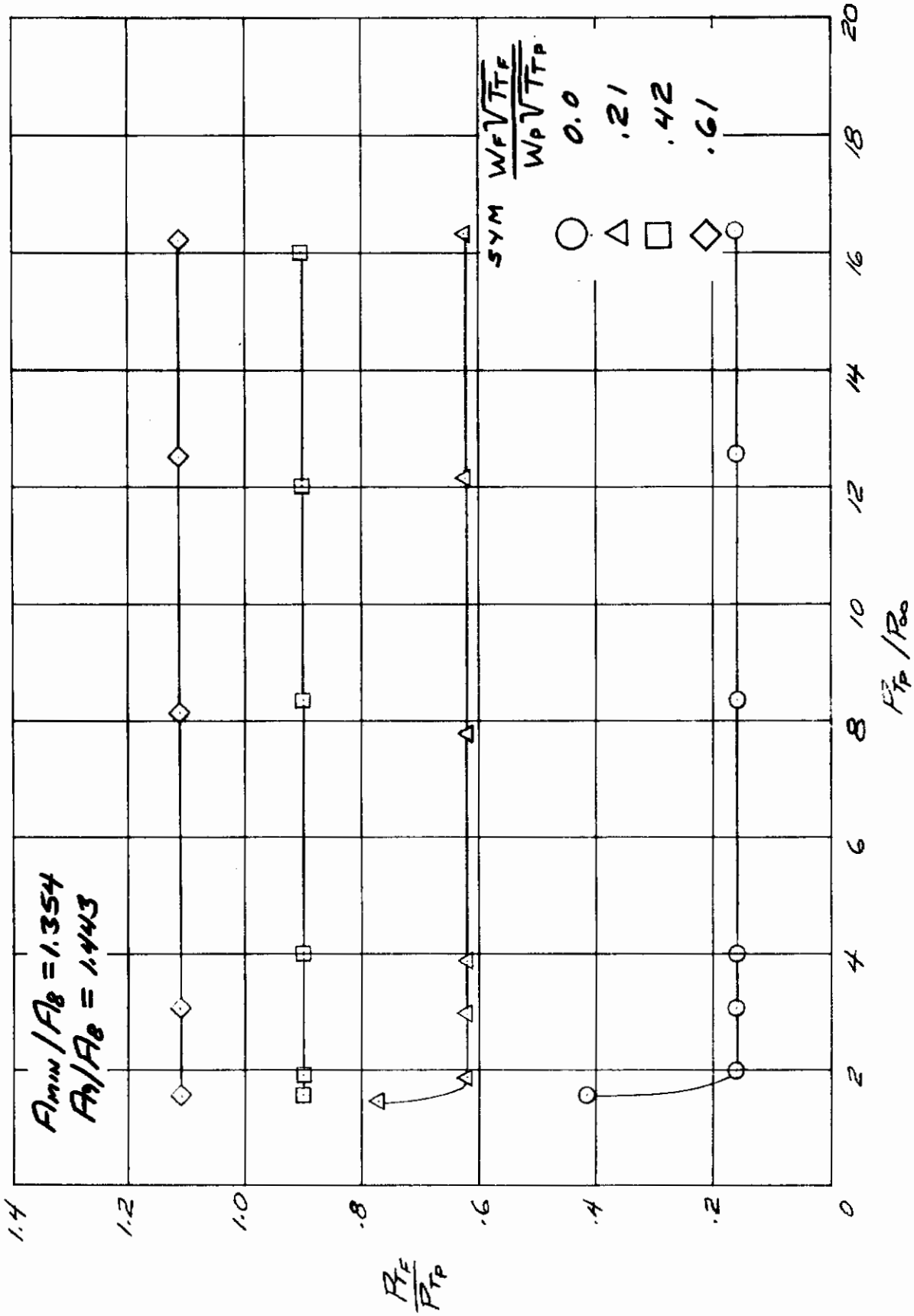


Figure 248. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Pumping Characteristics

Approved for Public Release

Contrails

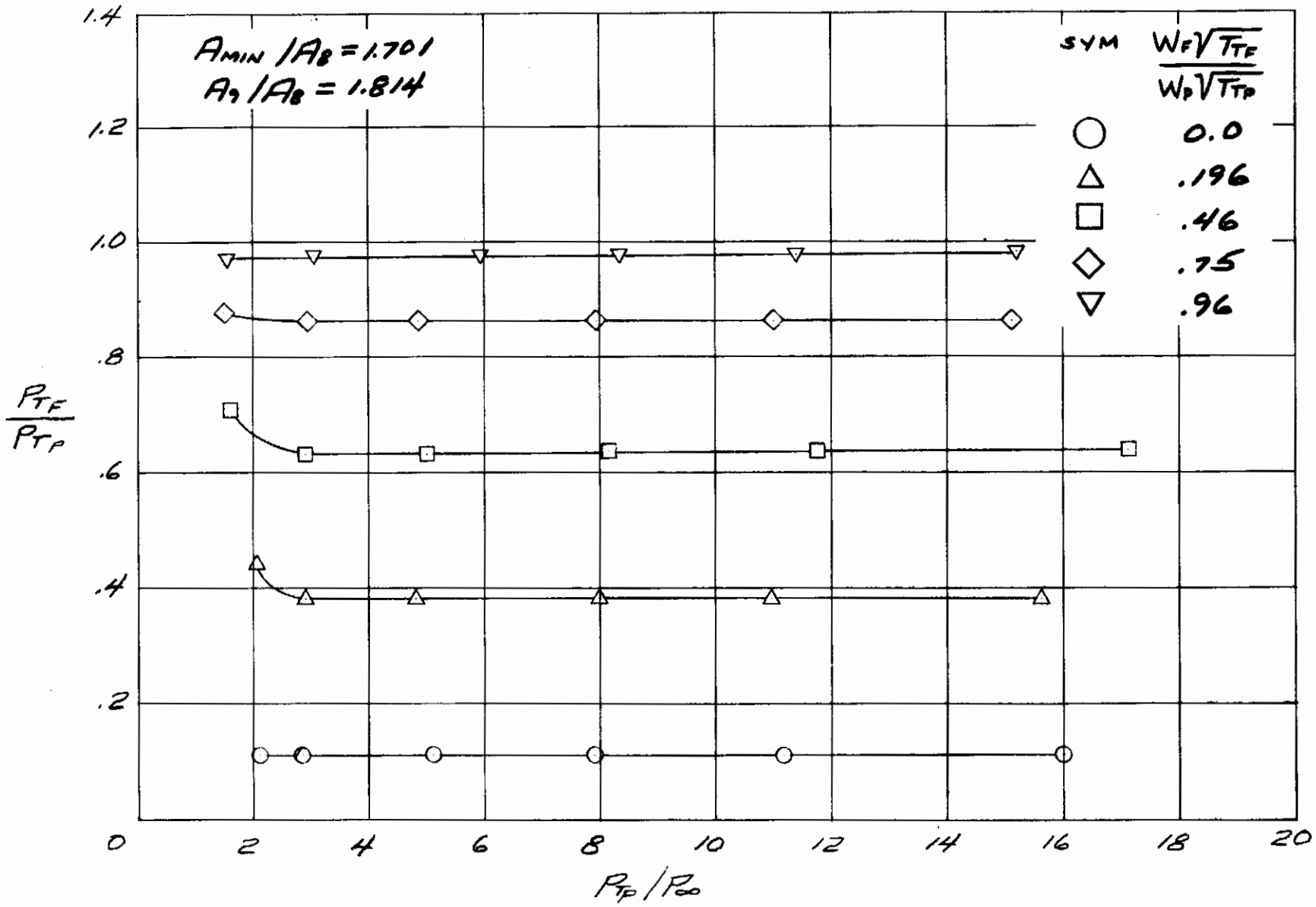


Figure 249. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Pumping Characteristics

Approved for Public Release

Contrails

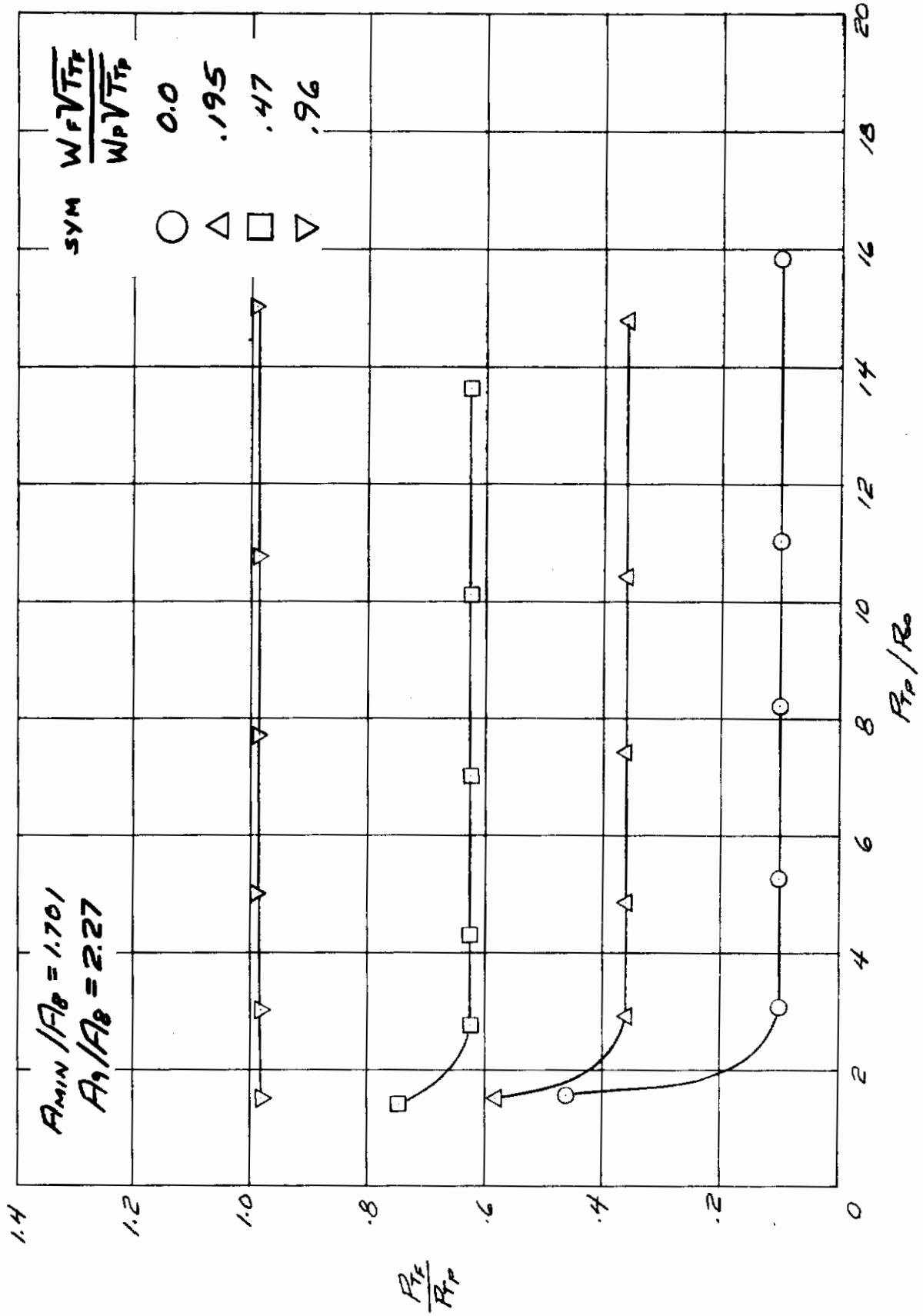


Figure 250. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Pumping Characteristics

Approved for Public Release

Contrails

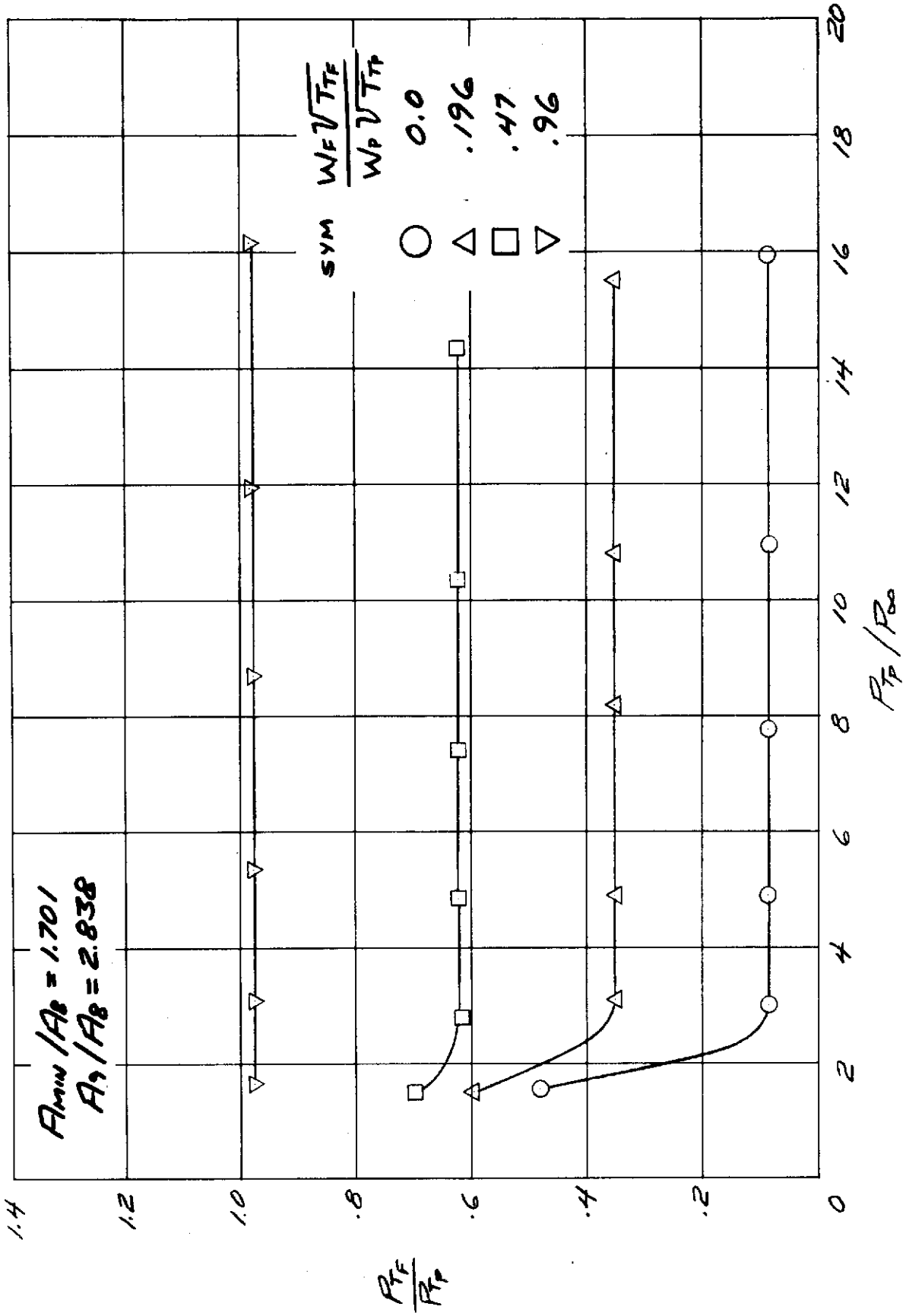


Figure 251. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Pumping Characteristics

Approved for Public Release

Contrails

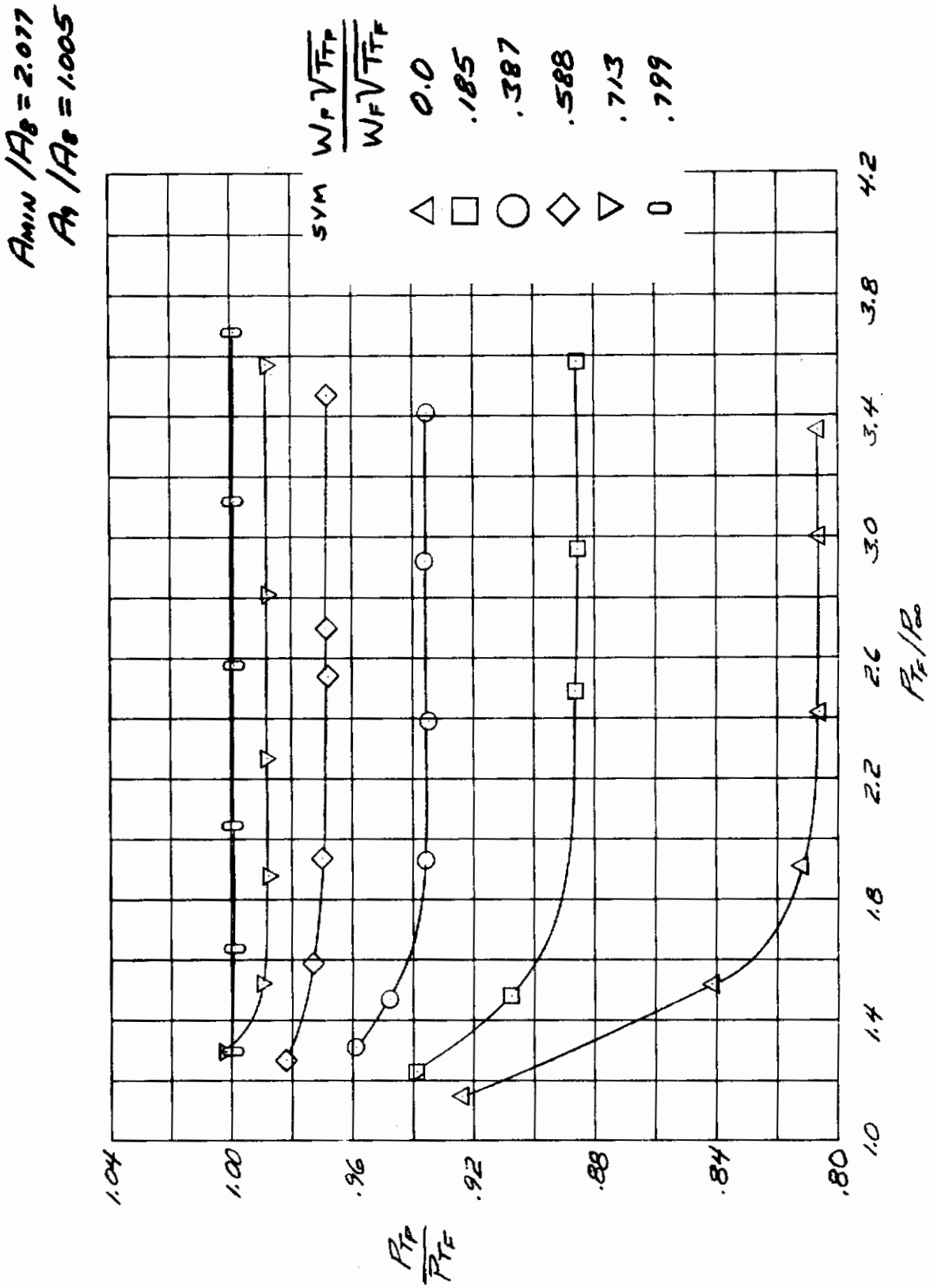


Figure 252. Shared Exit Ejector Nozzle Static Tests - Fan Mode Pumping Characteristics

Approved for Public Release

Contrails

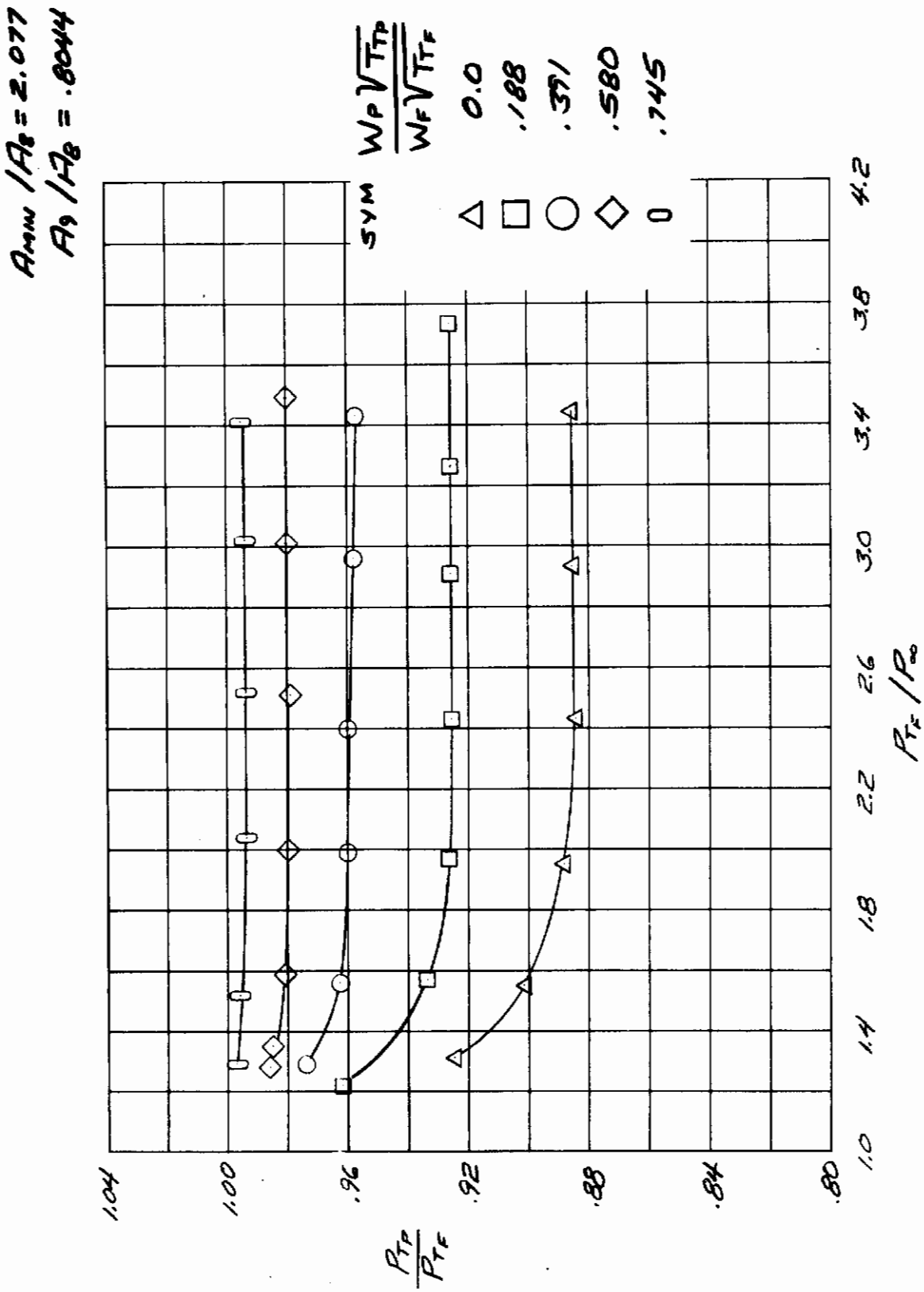


Figure 253. Shared Exit Ejector Nozzle Static Tests - Fan Mode Pumping Characteristics

Approved for Public Release

Contrails

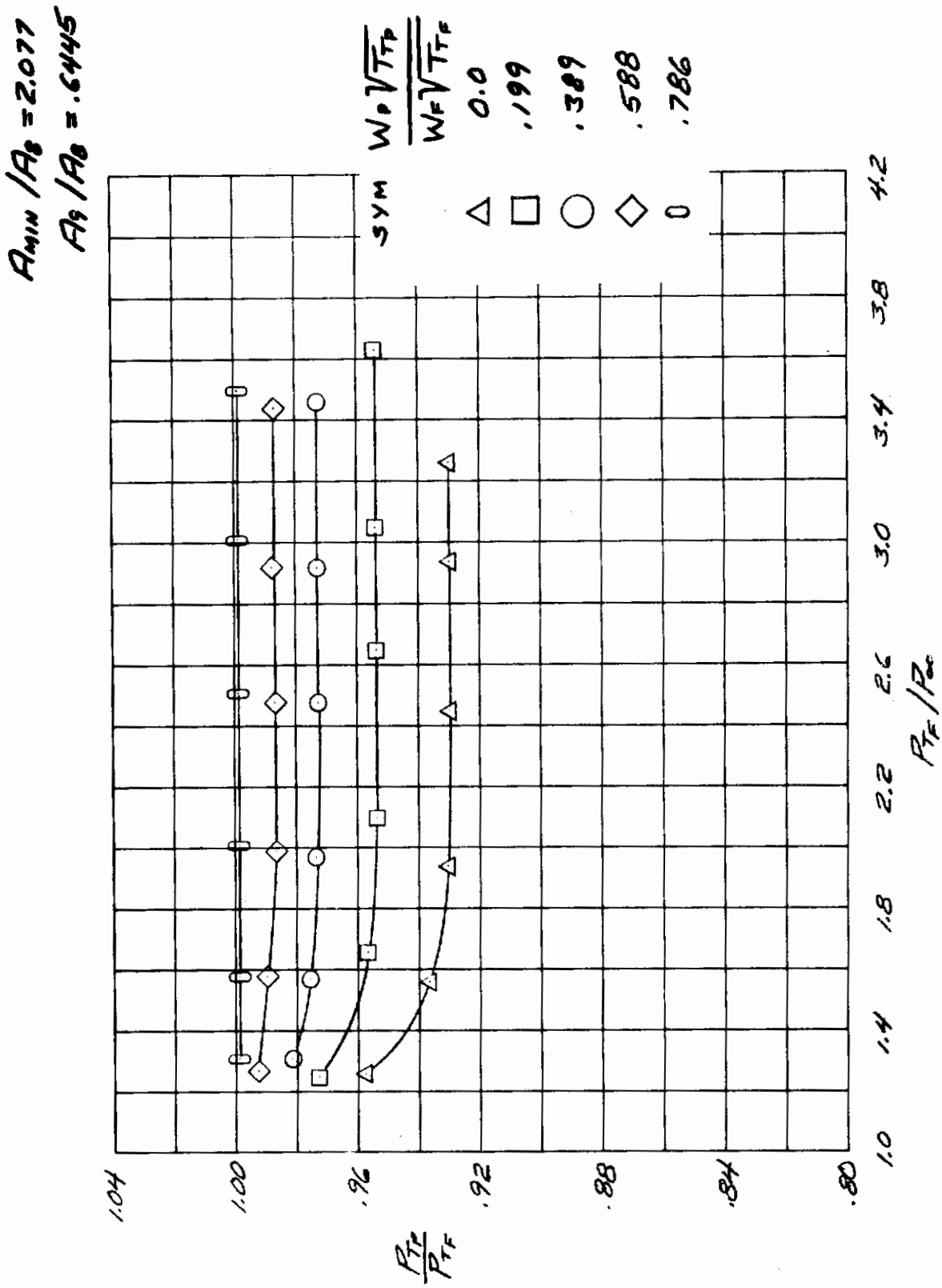


Figure 254. Shared Exit Ejector Nozzle Static Tests - Fan Mode Pumping Characteristics

Approved for Public Release

Contrails

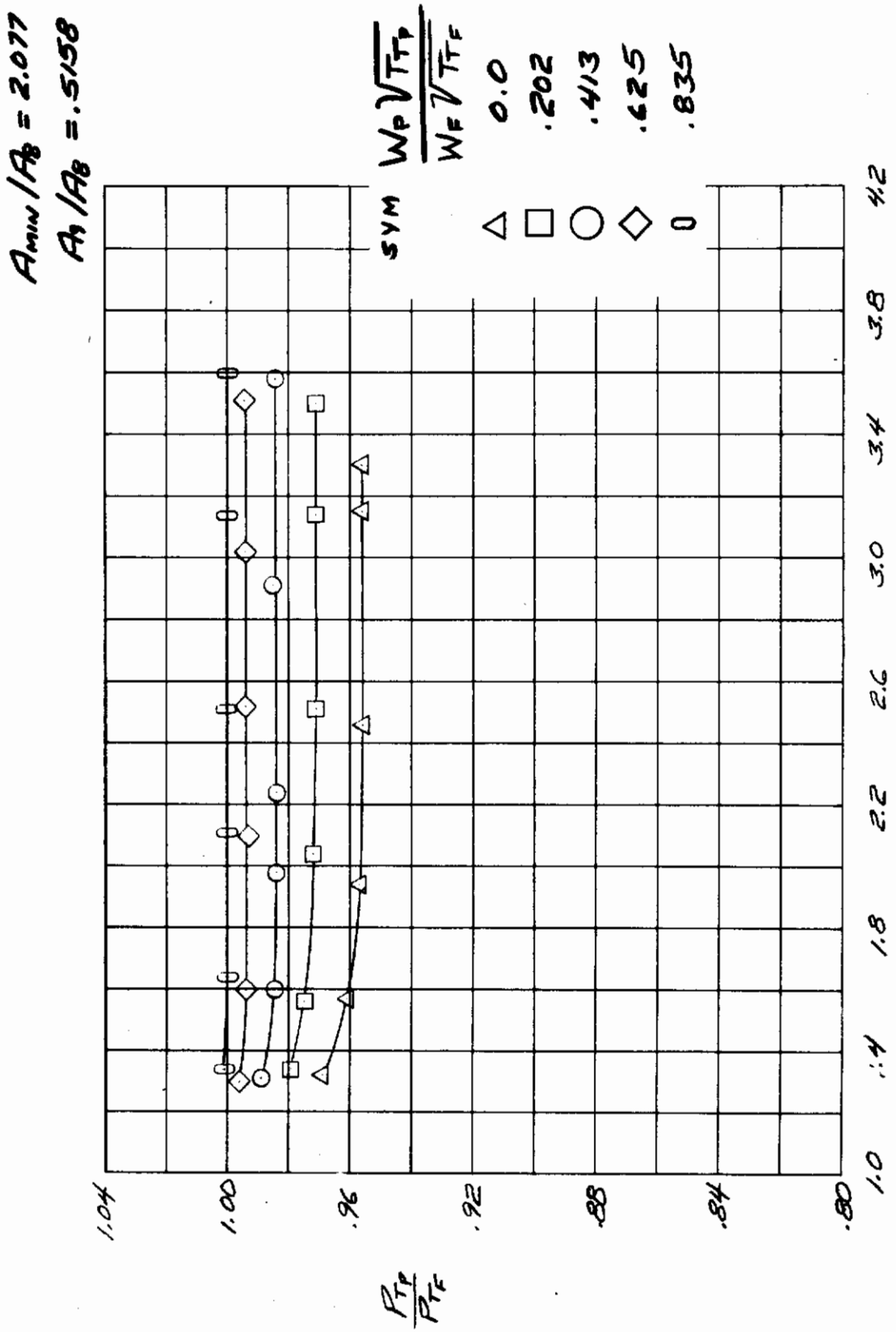


Figure 255. Shared Exit Ejector Nozzle Static Tests - Fan Mode Pumping Characteristics

Approved for Public Release

Contrails

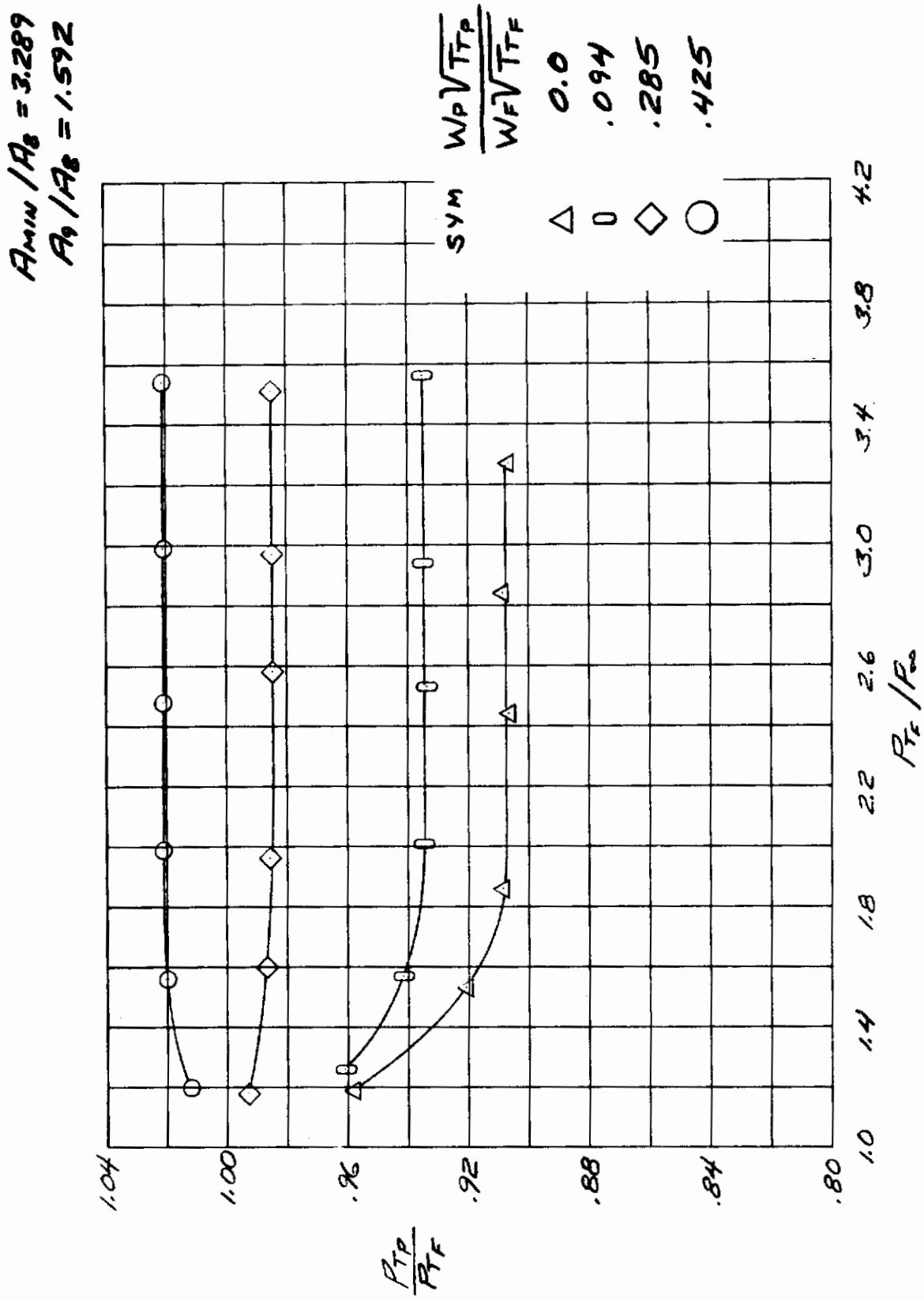


Figure 256. Shared Exit Ejector Nozzle Static Tests - Fan Mode Pumping Characteristics

Approved for Public Release

Contrails

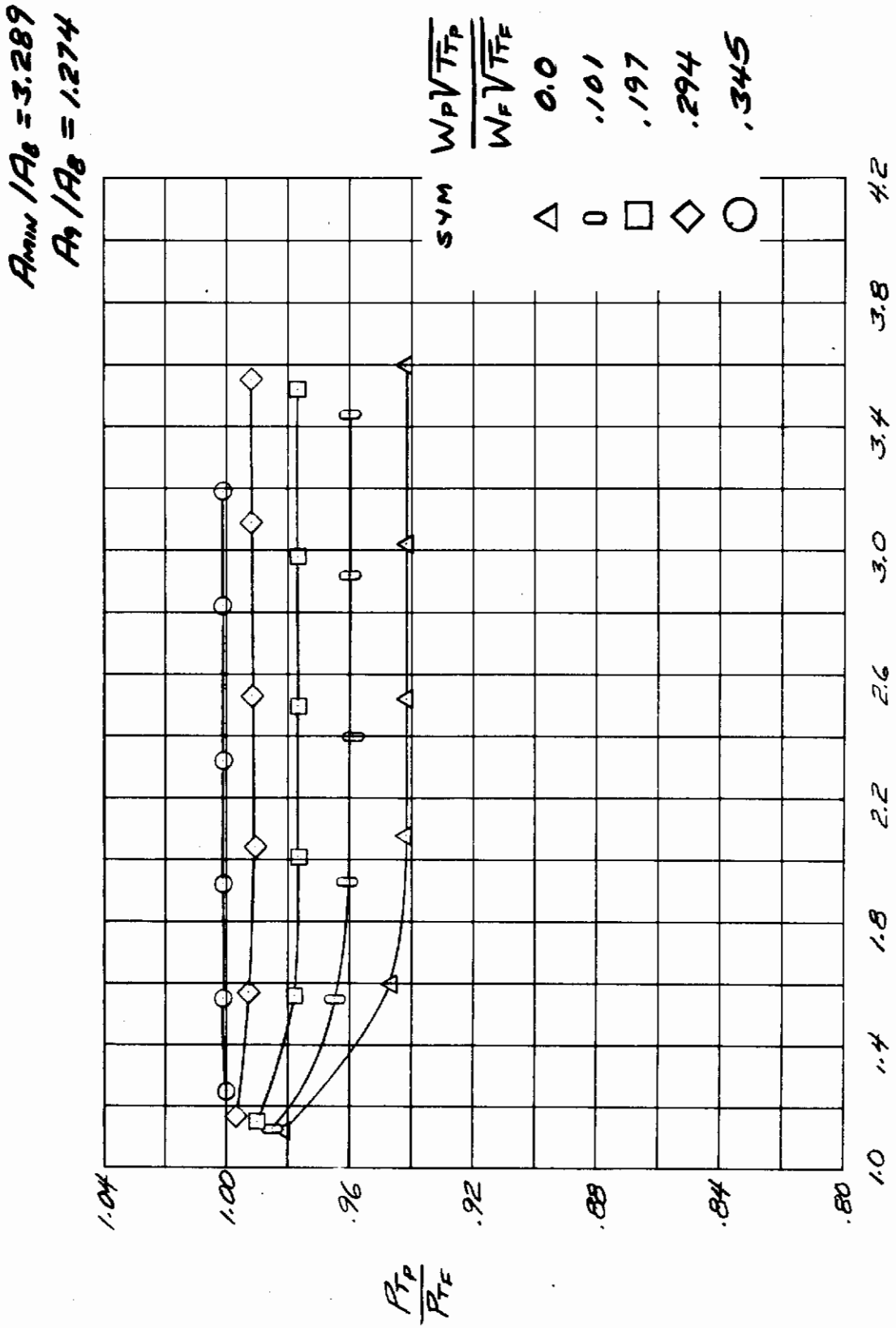


Figure 257. Shared Exit Ejector Nozzle Static Tests - Fan Mode Pumping Characteristics

Approved for Public Release

Contrails

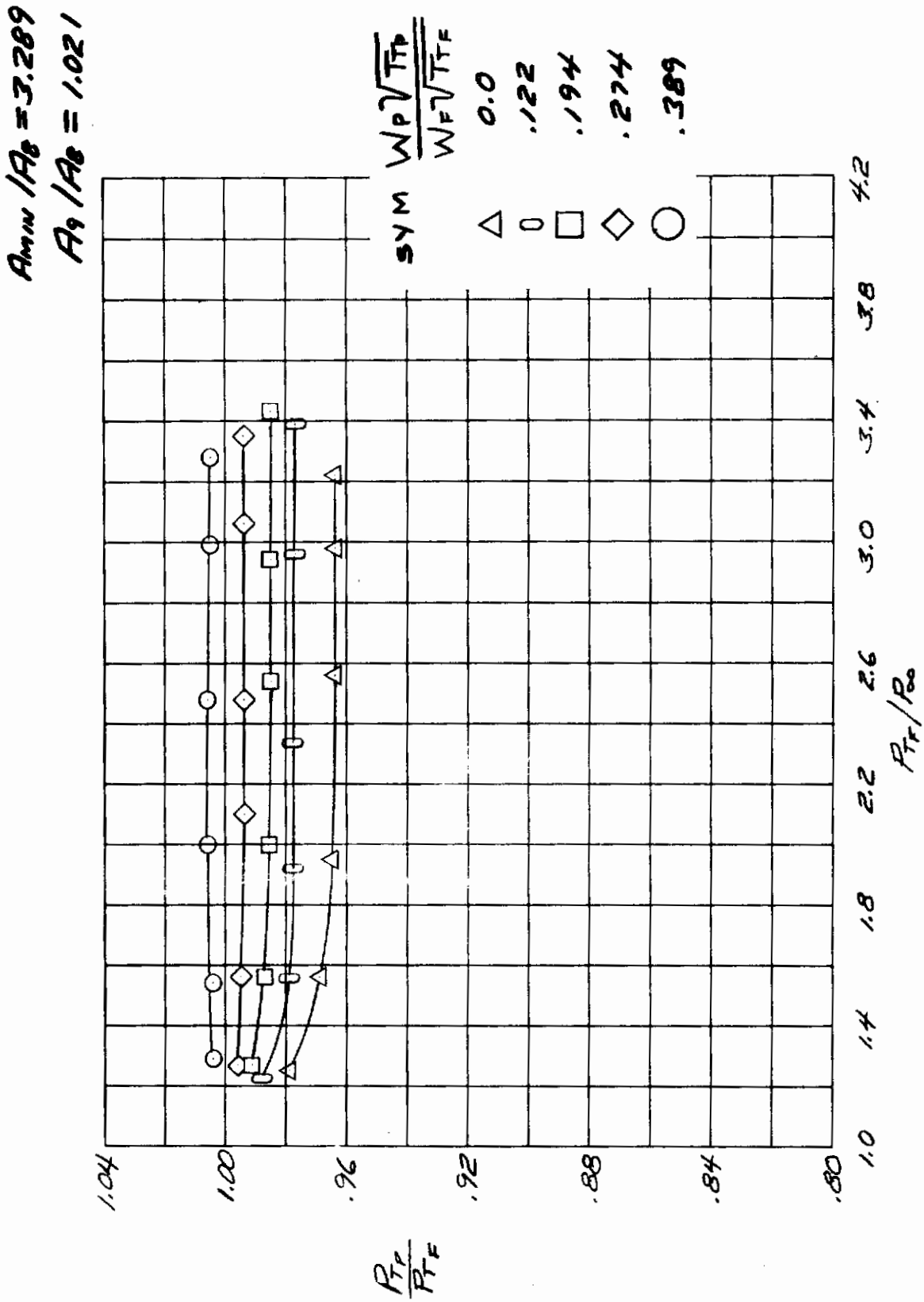


Figure 258. Shared Exit Ejector Nozzle Static Tests - Fan Mode Pumping Characteristics

Approved for Public Release

Contrails

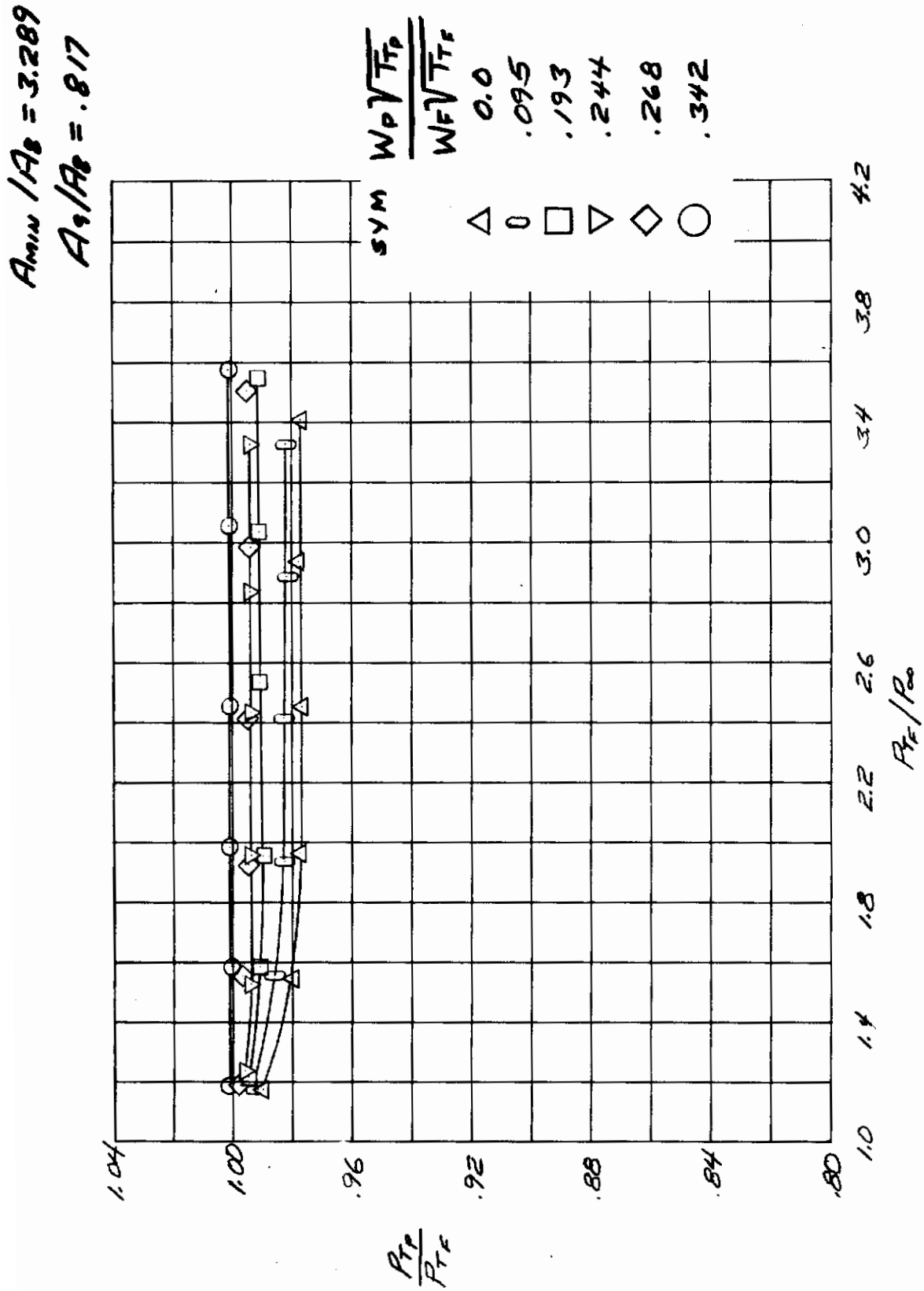


Figure 259. Shared Exit Ejector Nozzle Static Tests - Fan Mode Pumping Characteristics

Approved for Public Release

Contrails

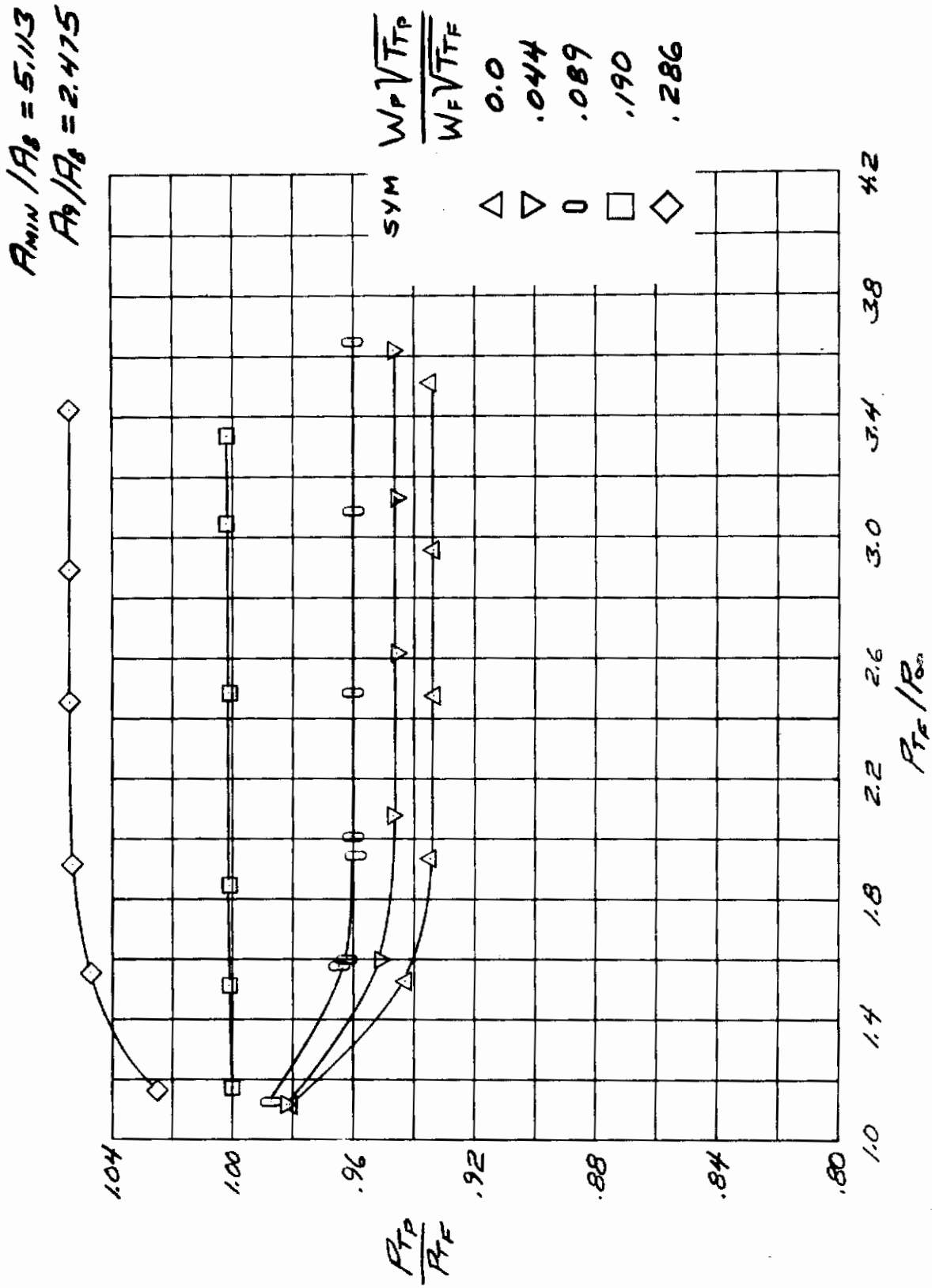


Figure 260. Shared Exit Ejector Nozzle Static Tests - Fan Mode Pumping Characteristics

Approved for Public Release

Contrails

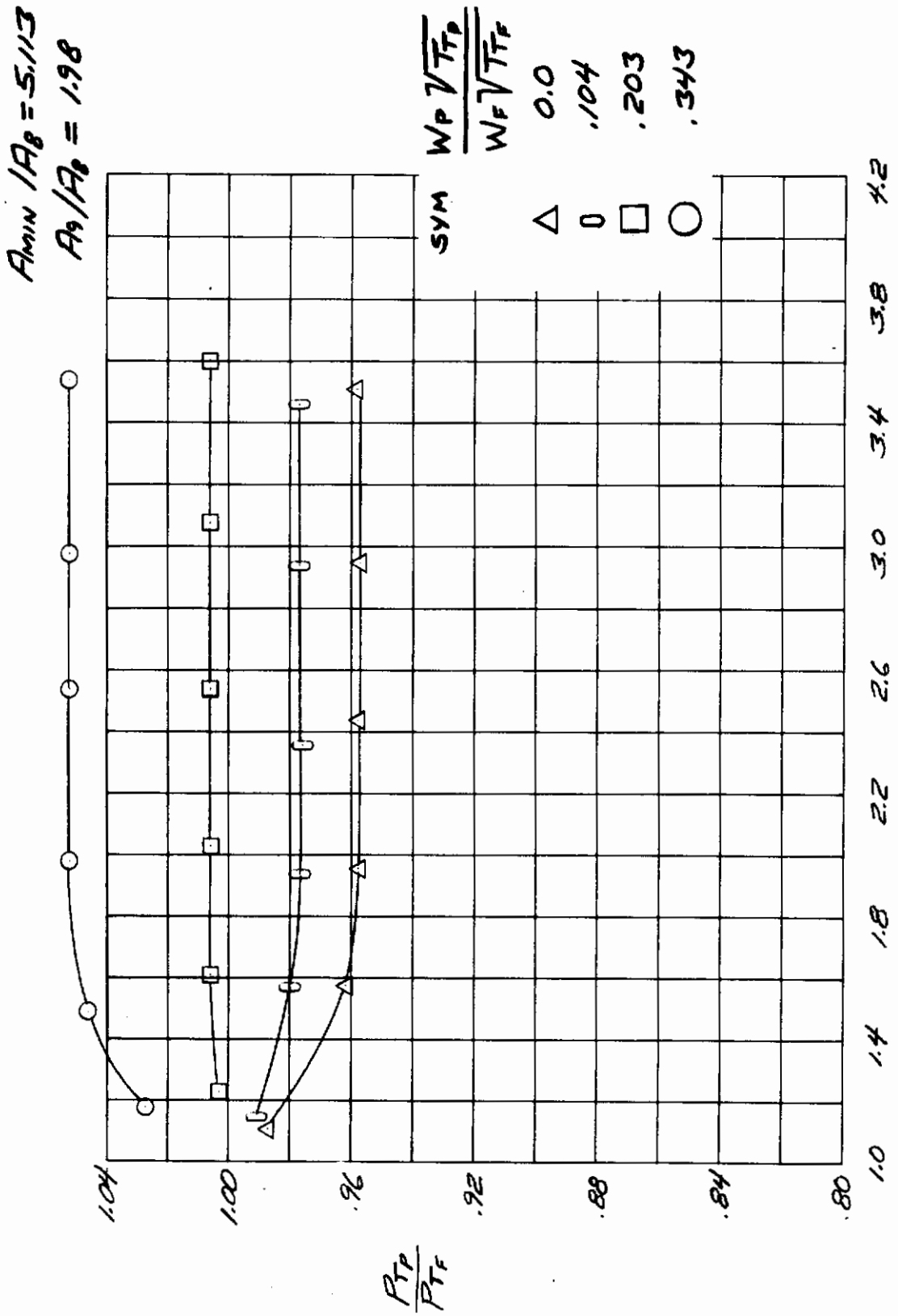


Figure 261. Shared Exit Ejector Nozzle Static Tests - Fan Mode Pumping Characteristics

Approved for Public Release

Contrails

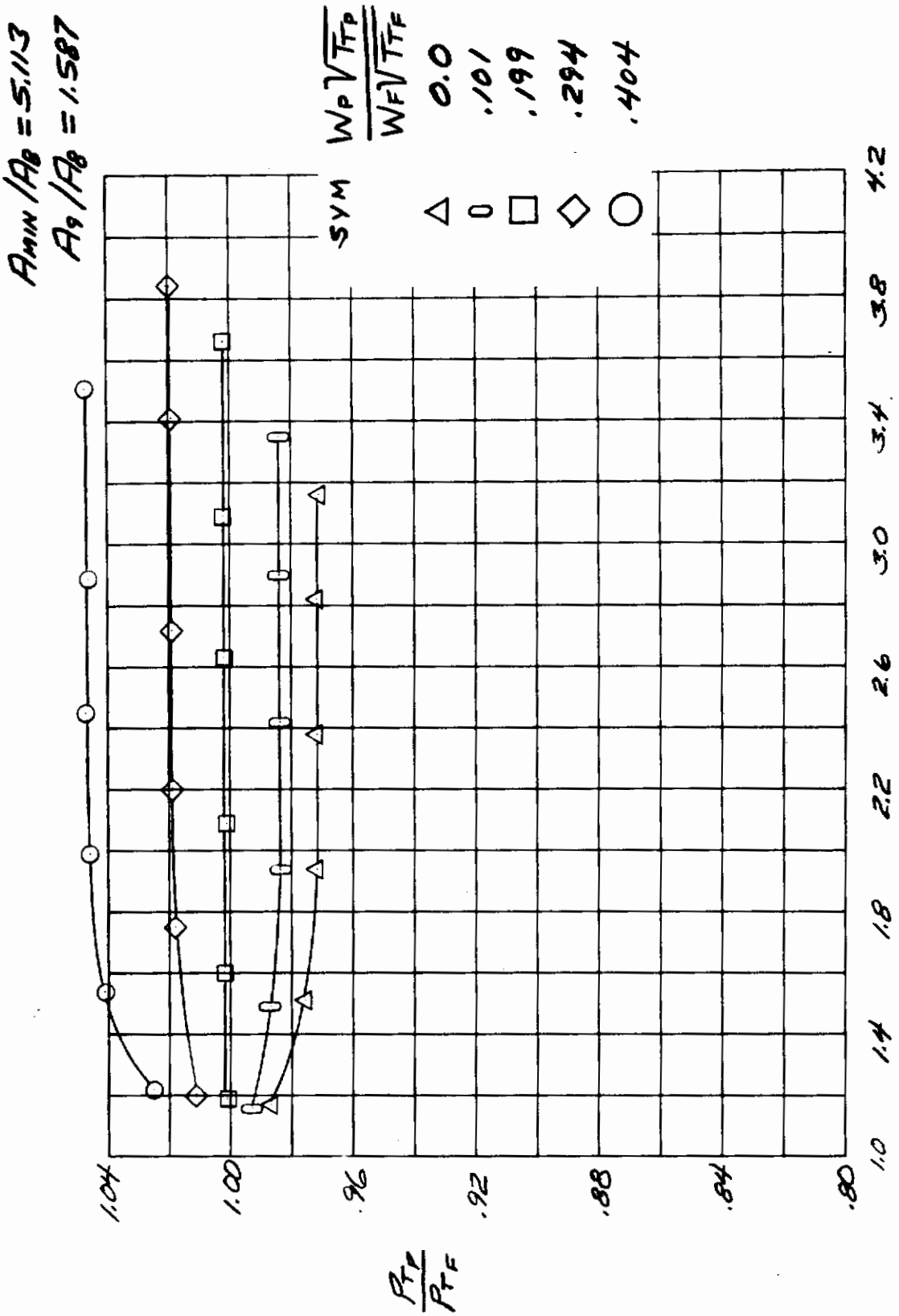


Figure 262. Shared Exit Ejector Nozzle Static Tests - Fan Mode Pumping Characteristics

Approved for Public Release

Contrails

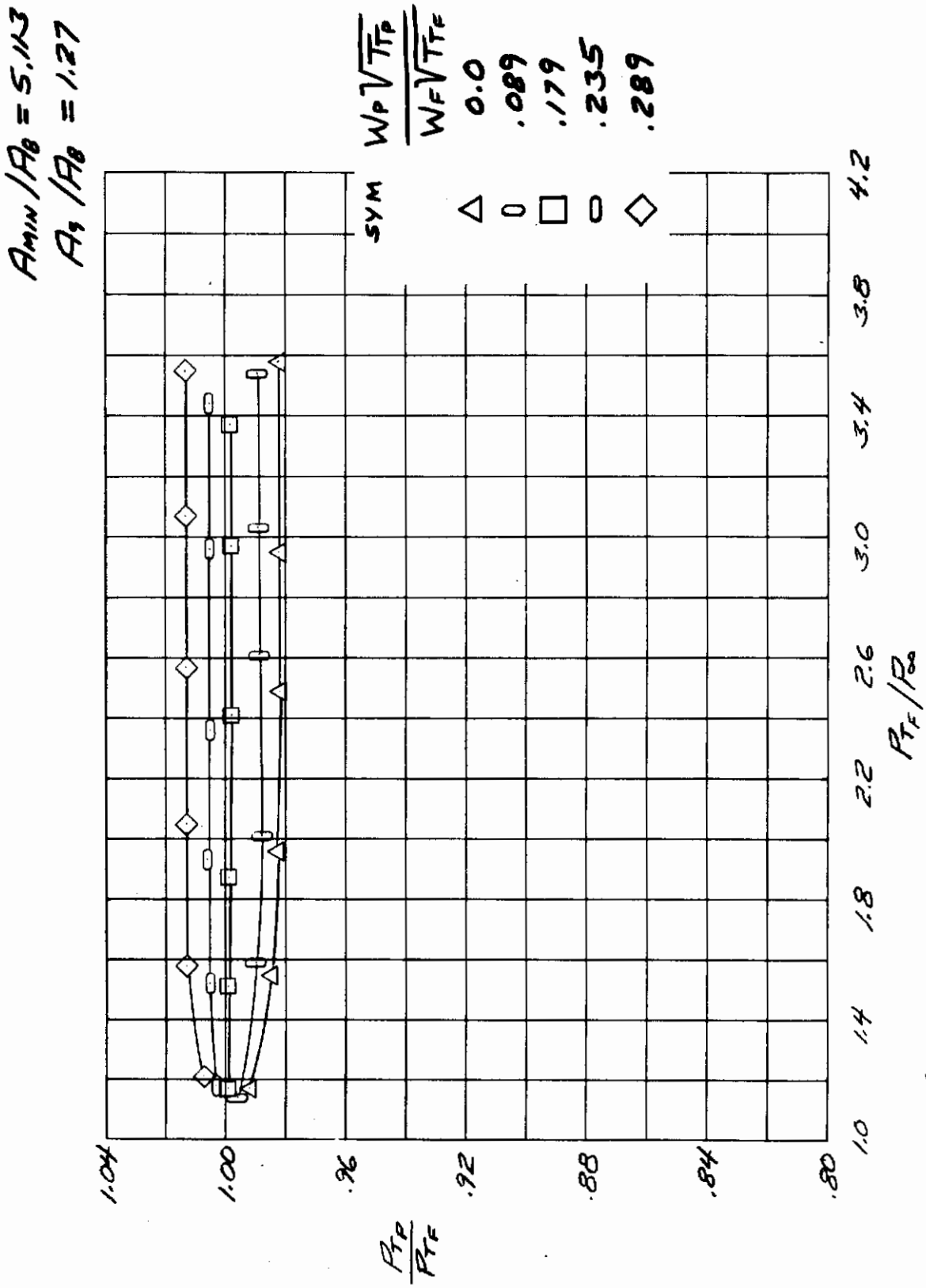


Figure 263. Shared Exit Ejector Nozzle Static Tests - Fan Mode Pumping Characteristics

Approved for Public Release

Contrails

APPENDIX VI

SCHLIEREN PHOTOGRAPHS

(The reverse of this page is blank)

Approved for Public Release

Contrails

Approved for Public Release

Contrails

APPENDIX VI

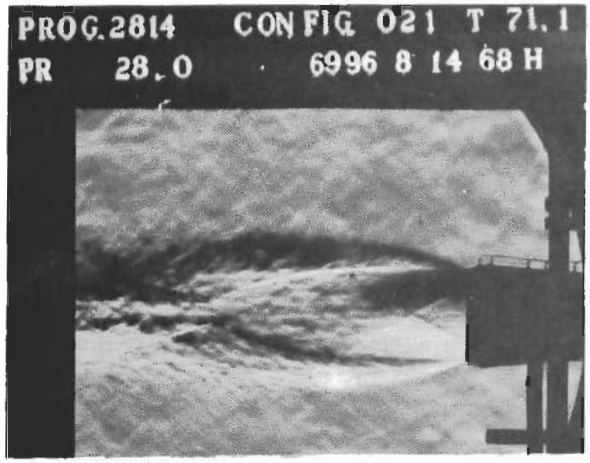
SCHLIEREN PHOTOGRAPHS

Schlieren photographs of the exhaust jet plume and shock pattern from the secondary nozzle exit were taken during the testing of satellite mode configurations 13, 15 through 17 and 19 through 22. These configurations were tested over a nominal pressure ratio range of 10 to 25. Photographs of other configurations, tested at lower pressure ratios, were not possible due to the construction of the schlieren windows in the test chamber.

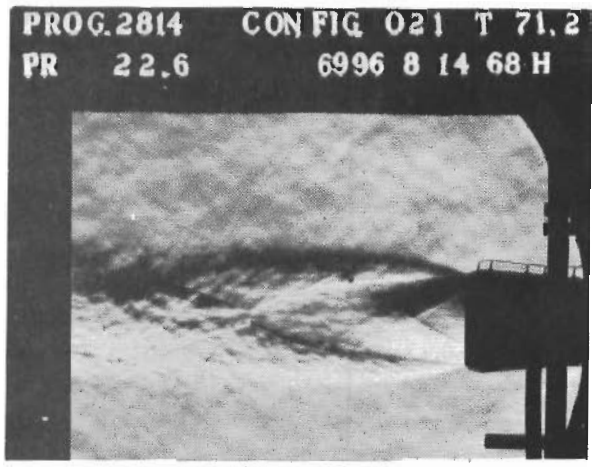
Figures 264 through 317 present all the schlieren photographs taken during the tests. Figures 264 through 266 are composites made to show the effect of pressure ratio on plume structure.

Approved for Public Release

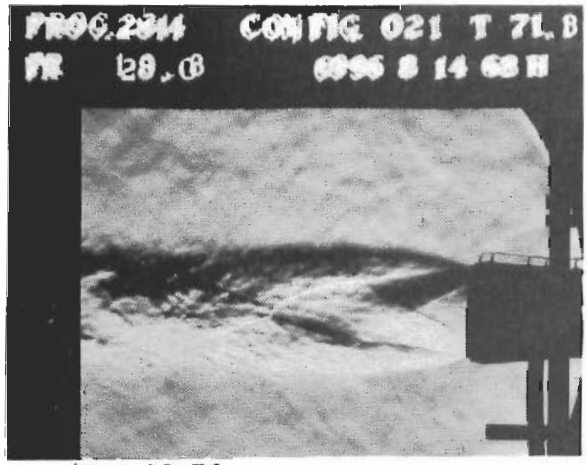
Contrails



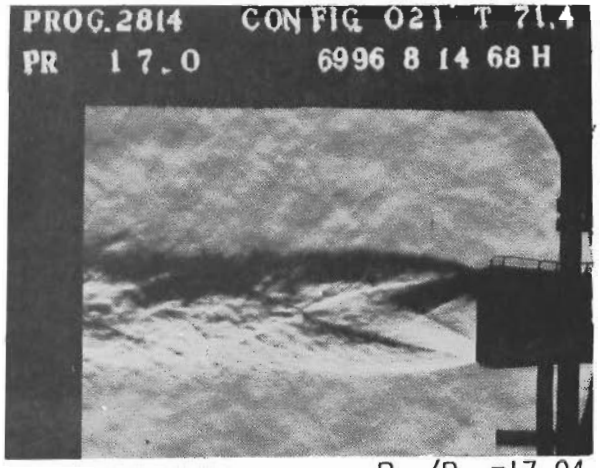
$P_{T_P}/P_{oo}=27.93$



$P_{T_P}/P_{oo}=22.49$



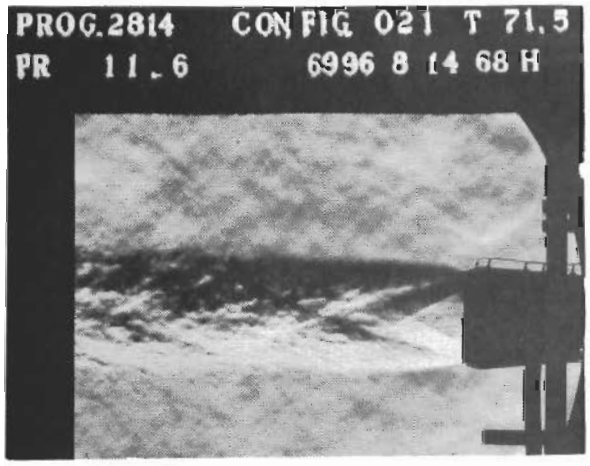
$P_{T_P}/P_{oo}=19.76$

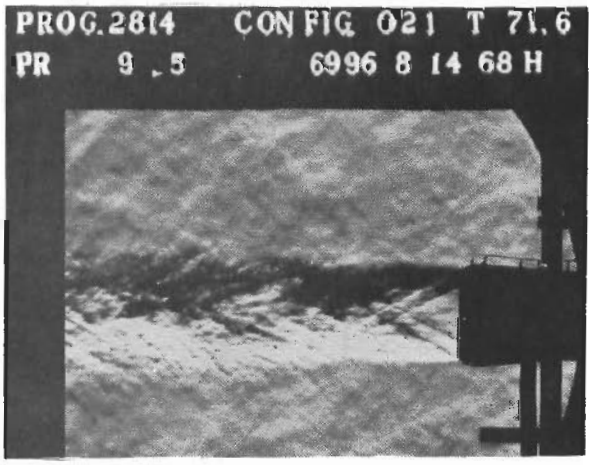


$P_{T_P}/P_{oo}=17.04$

$P_{T_P}/P_{oo}=13.93$

$P_{T_P}/P_{oo}=9.465$



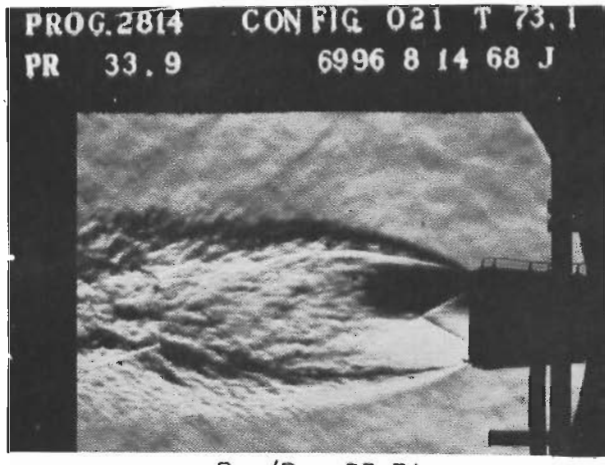


(a) $A_{min}/A_8=2.644$, $A_9/A_8=4.411$, $W_F\sqrt{T_{TF}}/W_P\sqrt{T_{TP}}=1.032$

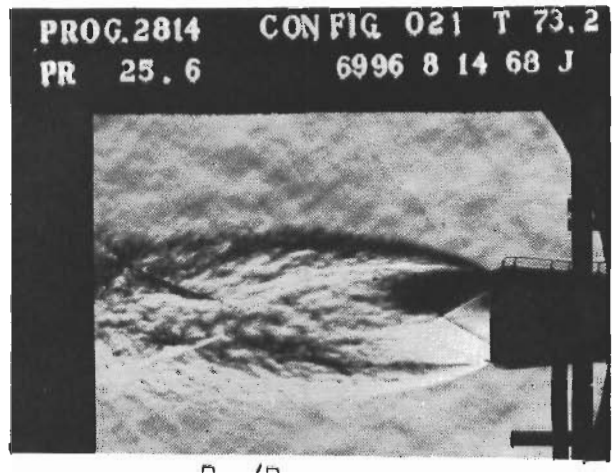
Figure 264. Shared Exit Ejector Nozzle Static Tests - Satellite Mode - Schlieren Photograph

Approved for Public Release

Contrails

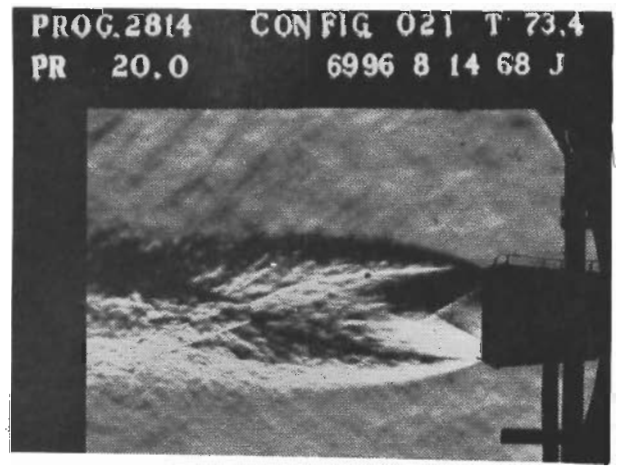


$P_{T_P}/P_{oo}=33.71$



$P_{T_P}/P_{oo}=25.49$

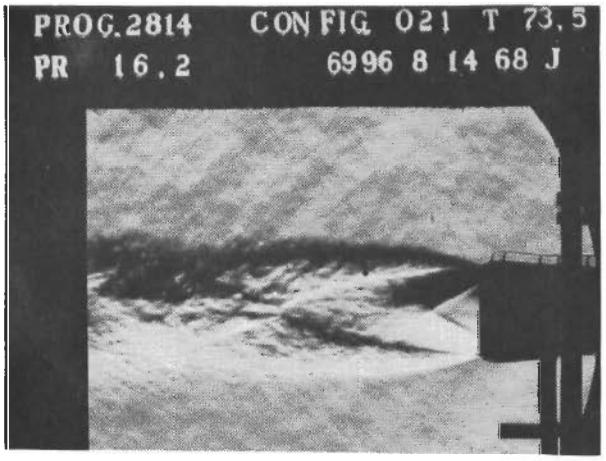
$P_{T_P}/P_{oo}=22.68$

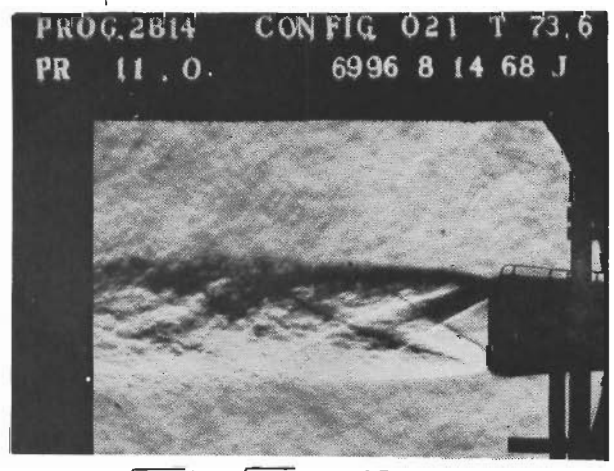


$P_{T_P}/P_{oo}=19.93$

$P_{T_P}/P_{oo}=16.23$

$P_{T_P}/P_{oo}=11.07$



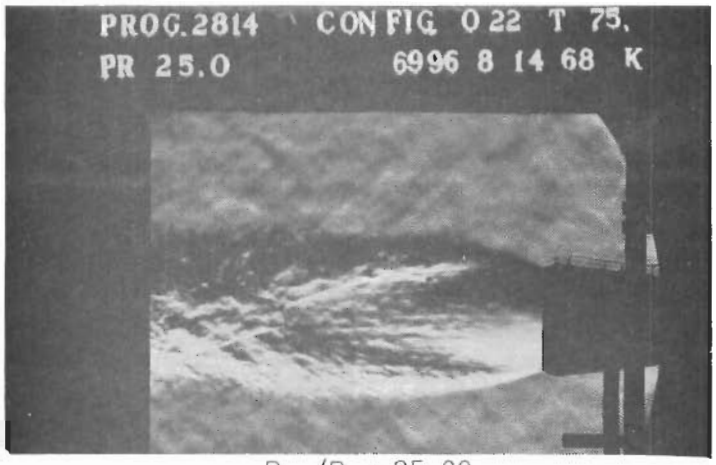


(b) $A_{min}/A_8=2.644$, $A_9/A_8=4.411$, $W_F\sqrt{T_{T_F}}/W_P\sqrt{T_{T_P}}=1.995$

Figure 265. Shared Exit Ejector Nozzle Static Tests - Satellite Mode - Schlieren Photograph

Approved for Public Release

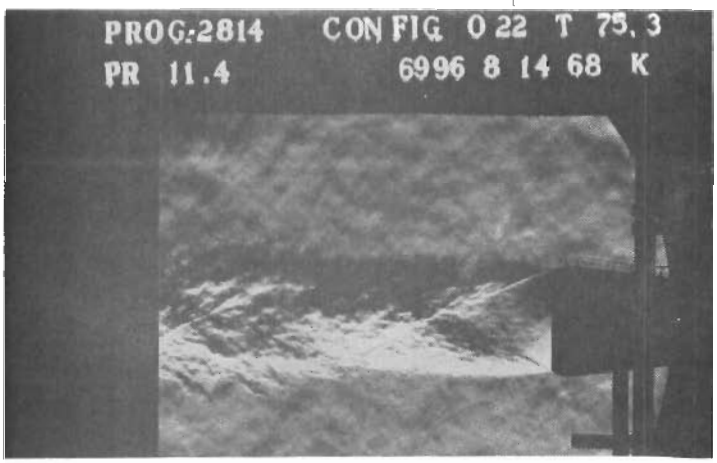
Contrails



$P_{T_P}/P_{oo}=25.09$

$P_{T_P}/P_{oo}=15.46$

$P_{T_P}/P_{oo}=11.46$



(c) $A_{min}/A_8=2.644$, $A_9/A_8=4.411$, $W_F\sqrt{T_{T_F}}/W_P\sqrt{T_{T_P}}=1.967$

Figure 266. Shared Exit Ejector Nozzle Static Tests - Satellite Mode - Schlieren Photograph

Approved for Public Release

Contrails

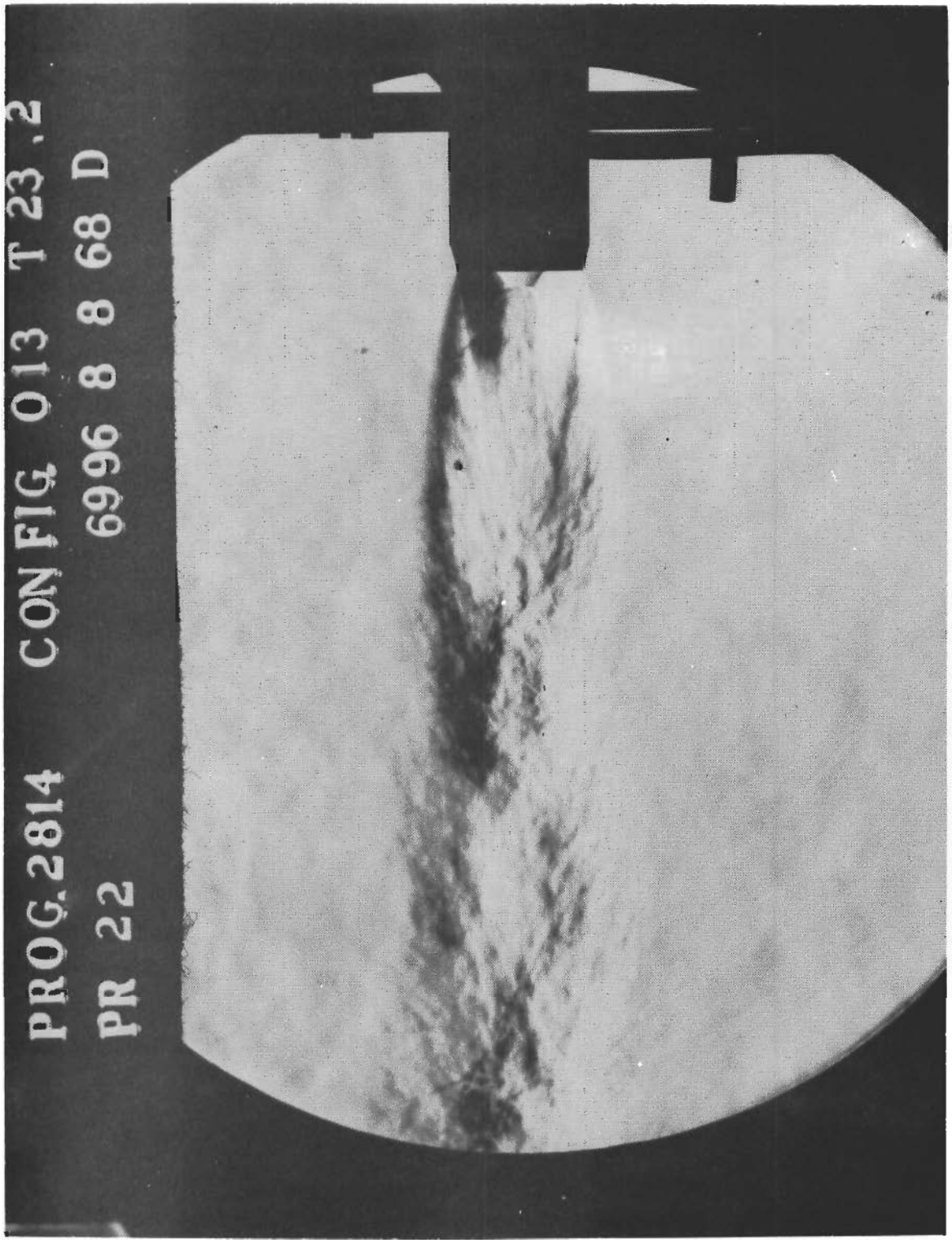


Figure 267. Shared Exit Ejector Nozzle Static Tests - Satellite Mode - Schlieren Photograph

Approved for Public Release

Contrails

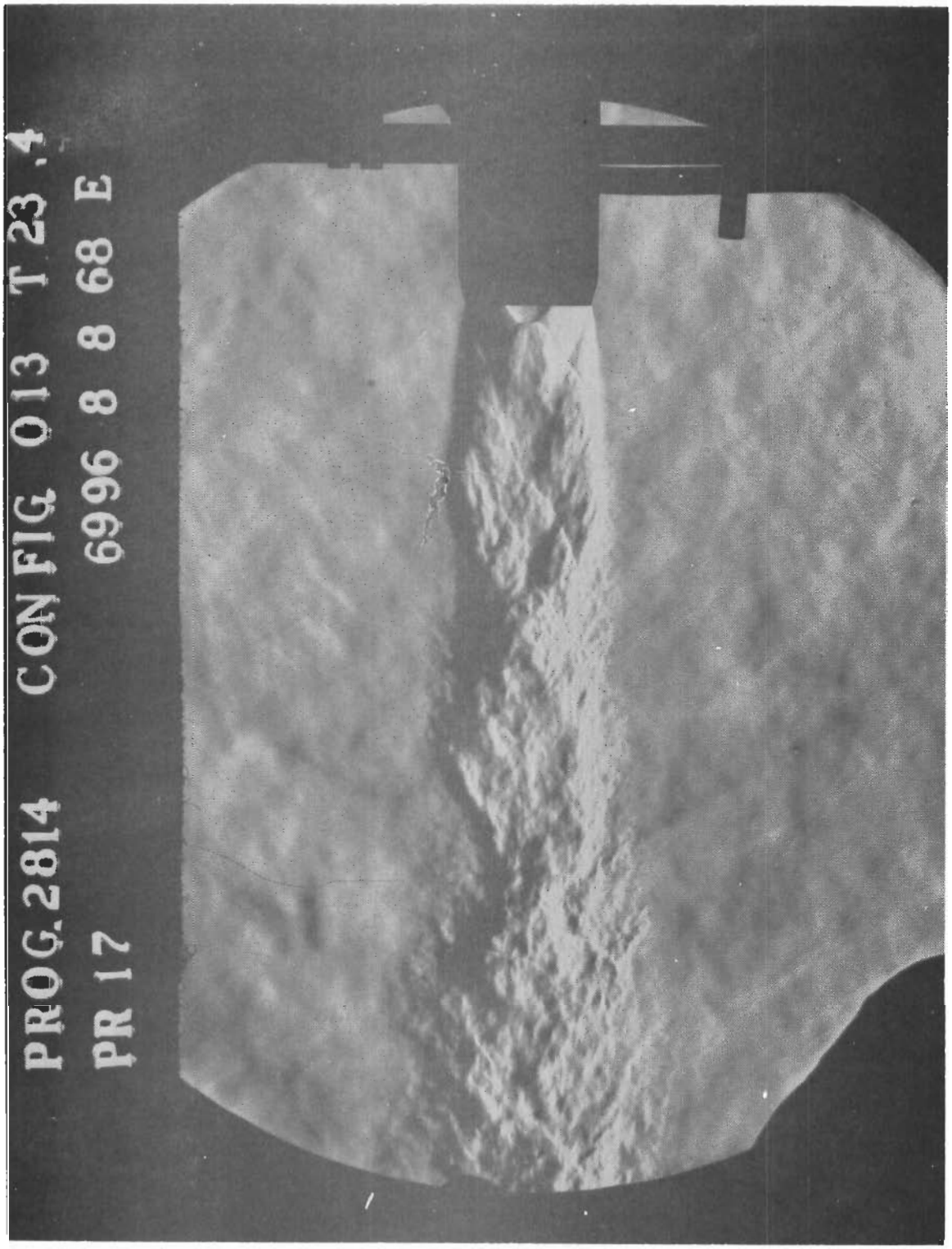


Figure 268. Shared Exit Ejector Nozzle Static Tests - Satellite Mode - Schlieren Photograph

Approved for Public Release

Contrails

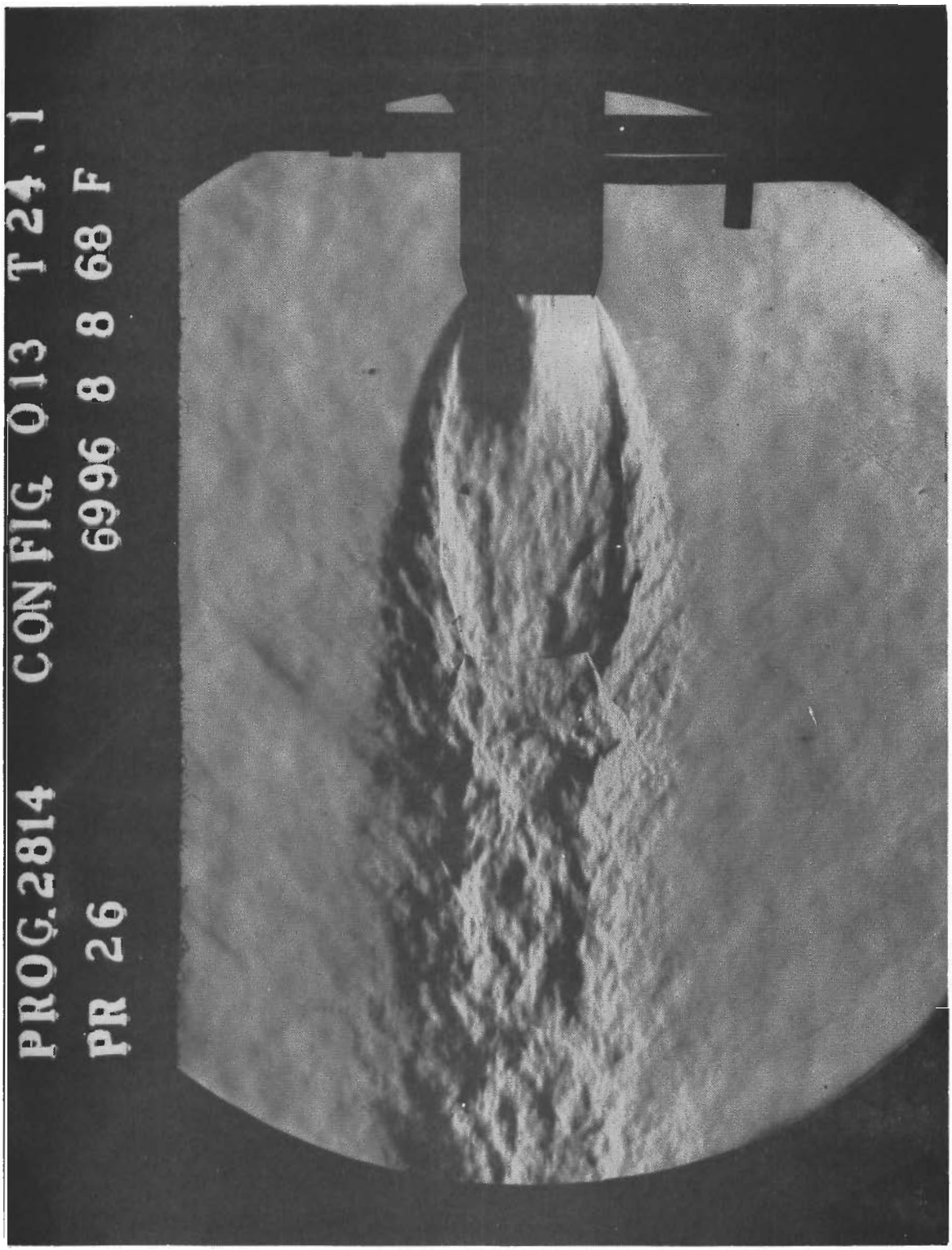


Figure 269. Shared Exit Ejector Nozzle Static Tests - Satellite Mode - Schlieren Photograph

Approved for Public Release

Contrails

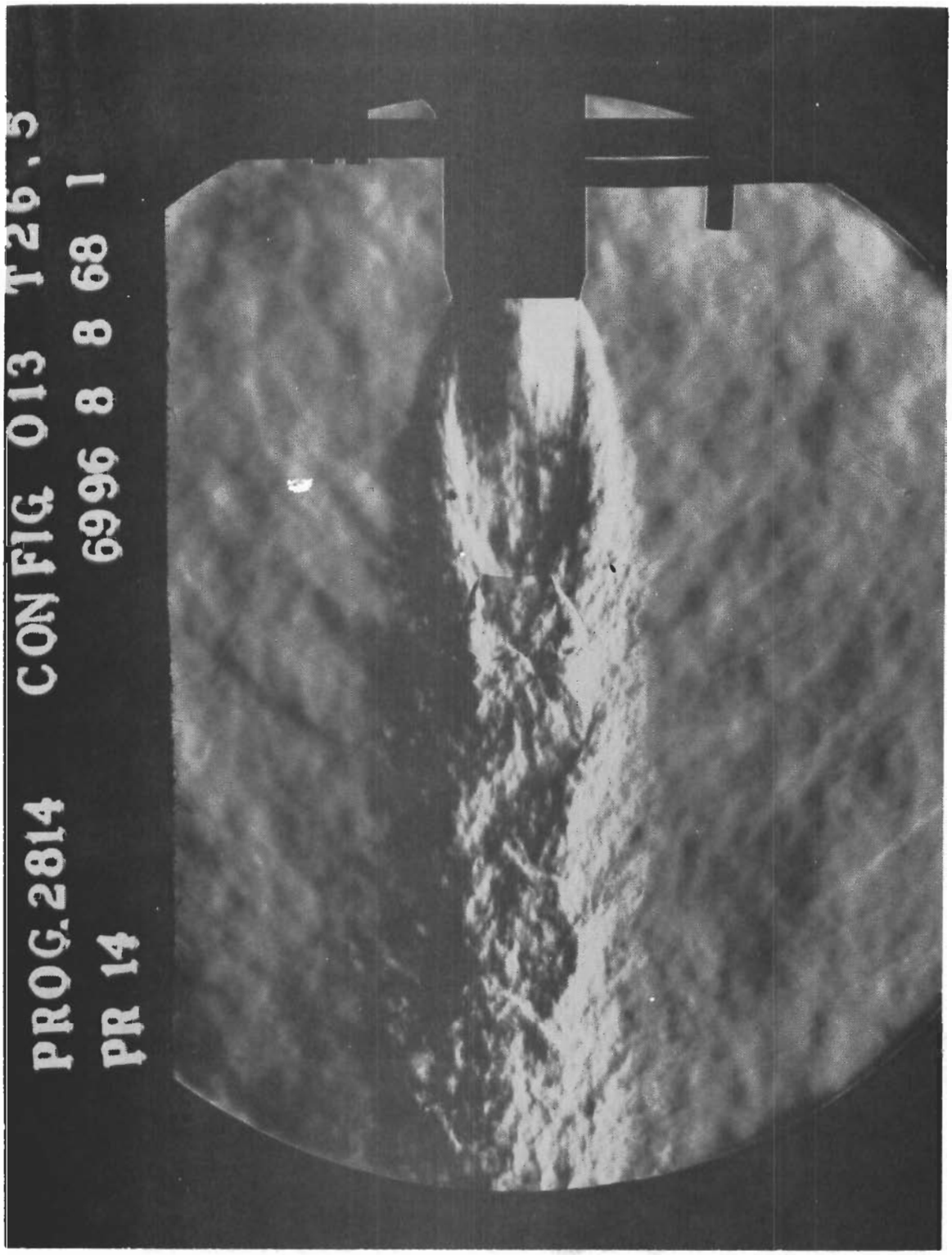


Figure 270. Shared Exit Ejector Nozzle Static Tests - Satellite Mode - Schlieren Photograph

Approved for Public Release

Contrails

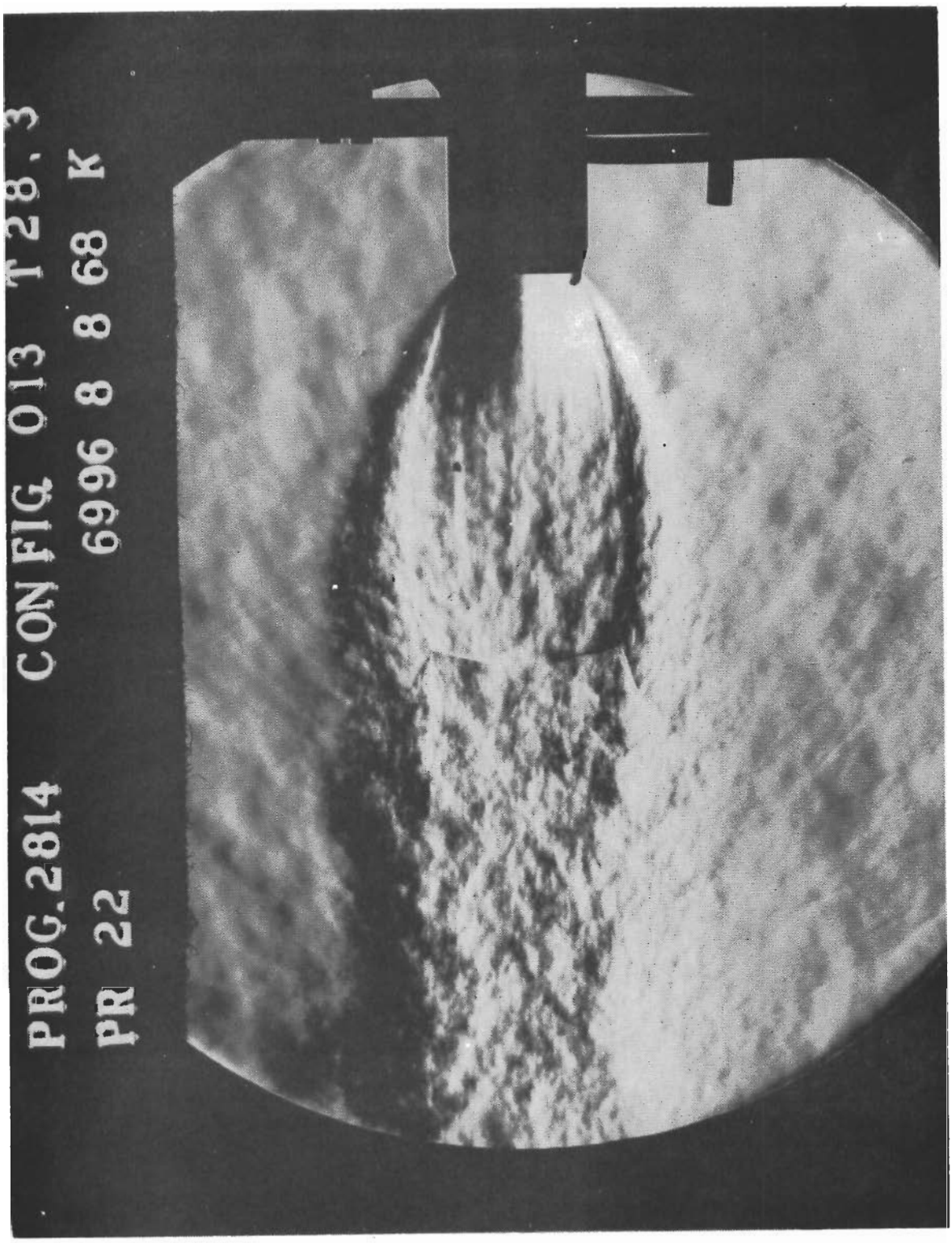


Figure 271. Shared Exit Ejector Nozzle Static Tests - Satellite Mode - Schlieren Photograph

Approved for Public Release

Contrails

Figure 272. Shared Exit Ejector Nozzle Static Tests - Satellite Mode - Schlieren Photograph

Approved for Public Release

Contrails

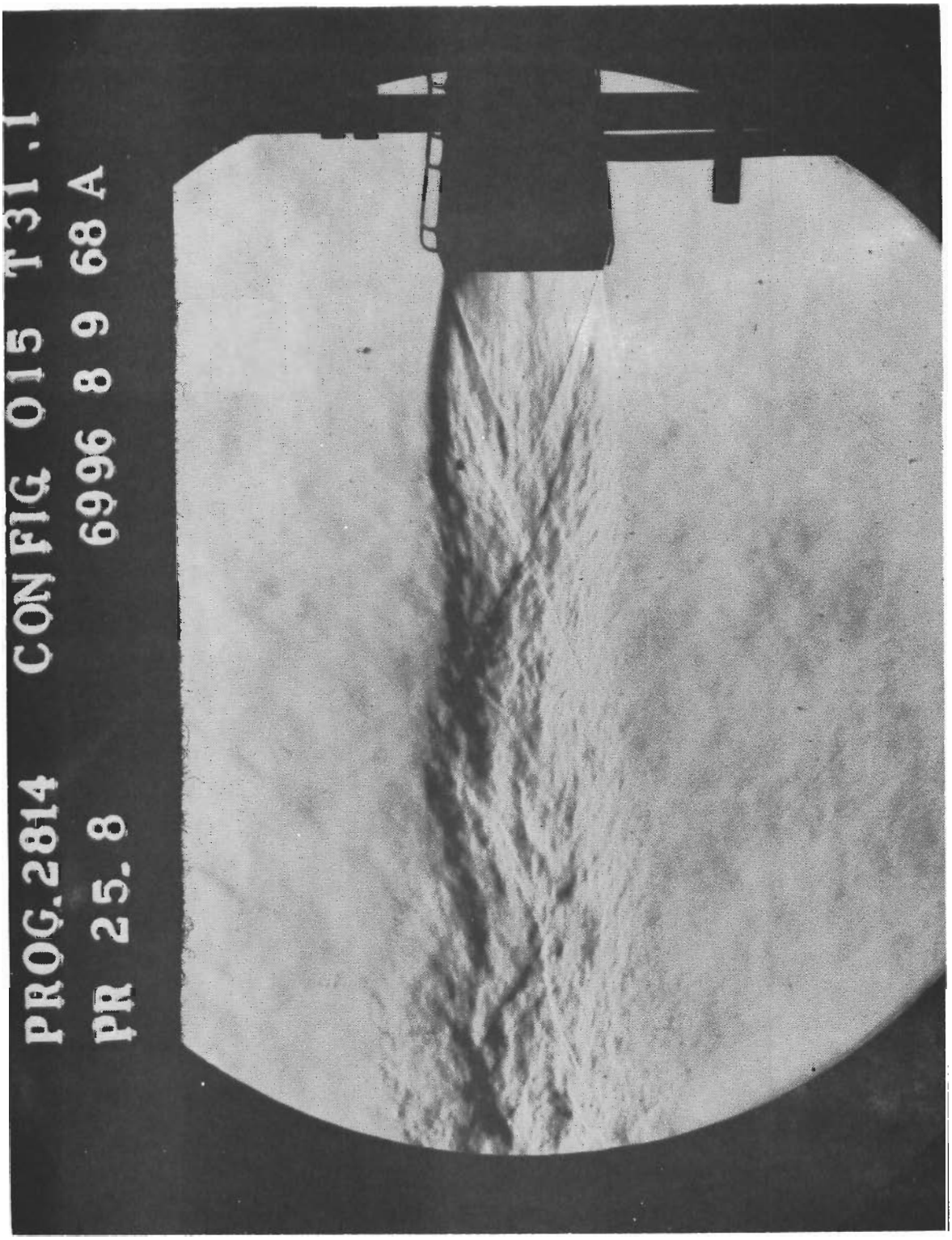


Figure 273. Shared Exit Ejector Nozzle Static Tests - Satellite Mode - Schlieren Photograph

Approved for Public Release

Contrails

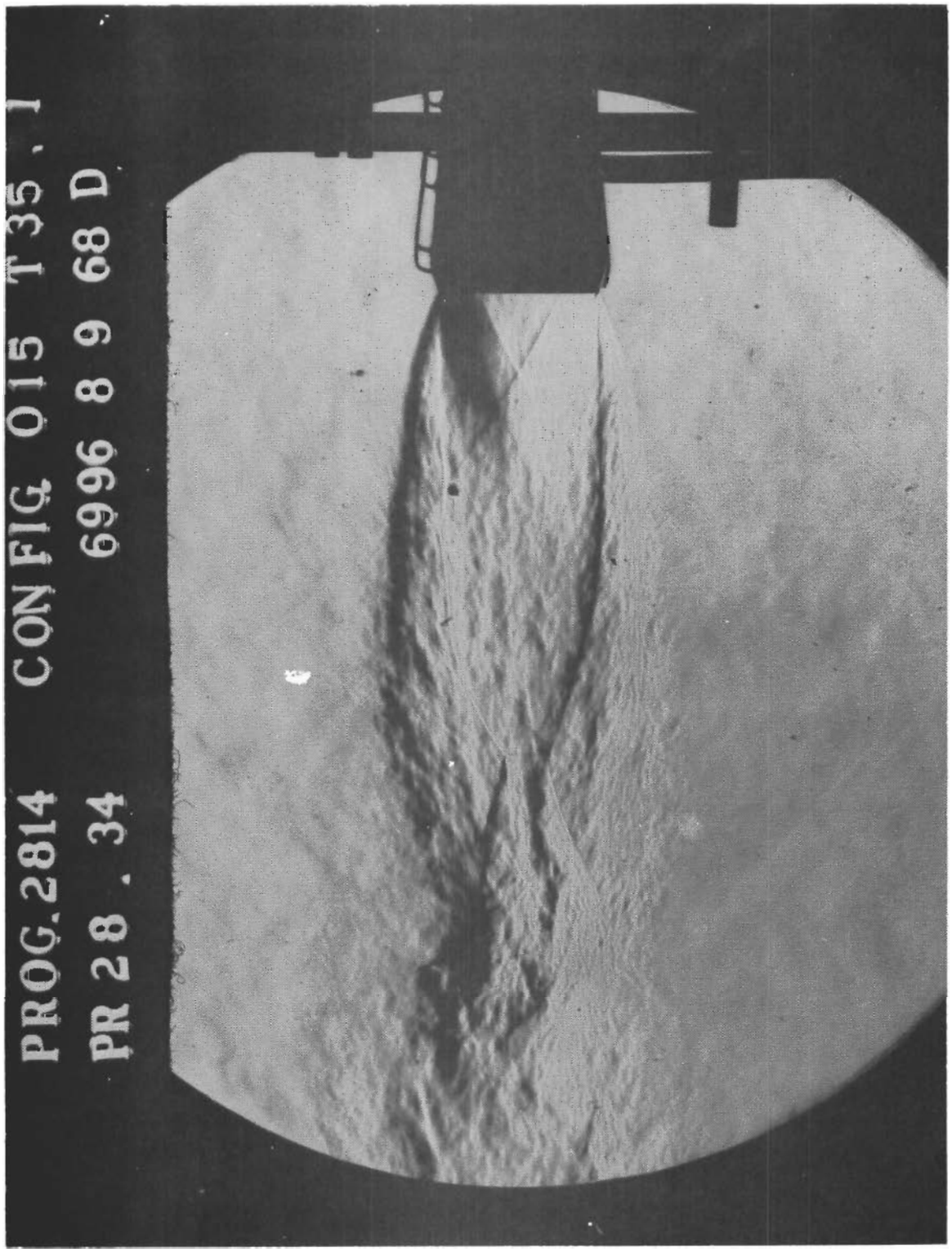


Figure 274. Shared Exit Ejector Nozzle Static Tests - Satellite Mode - Schlieren Photograph

Approved for Public Release

Contrails

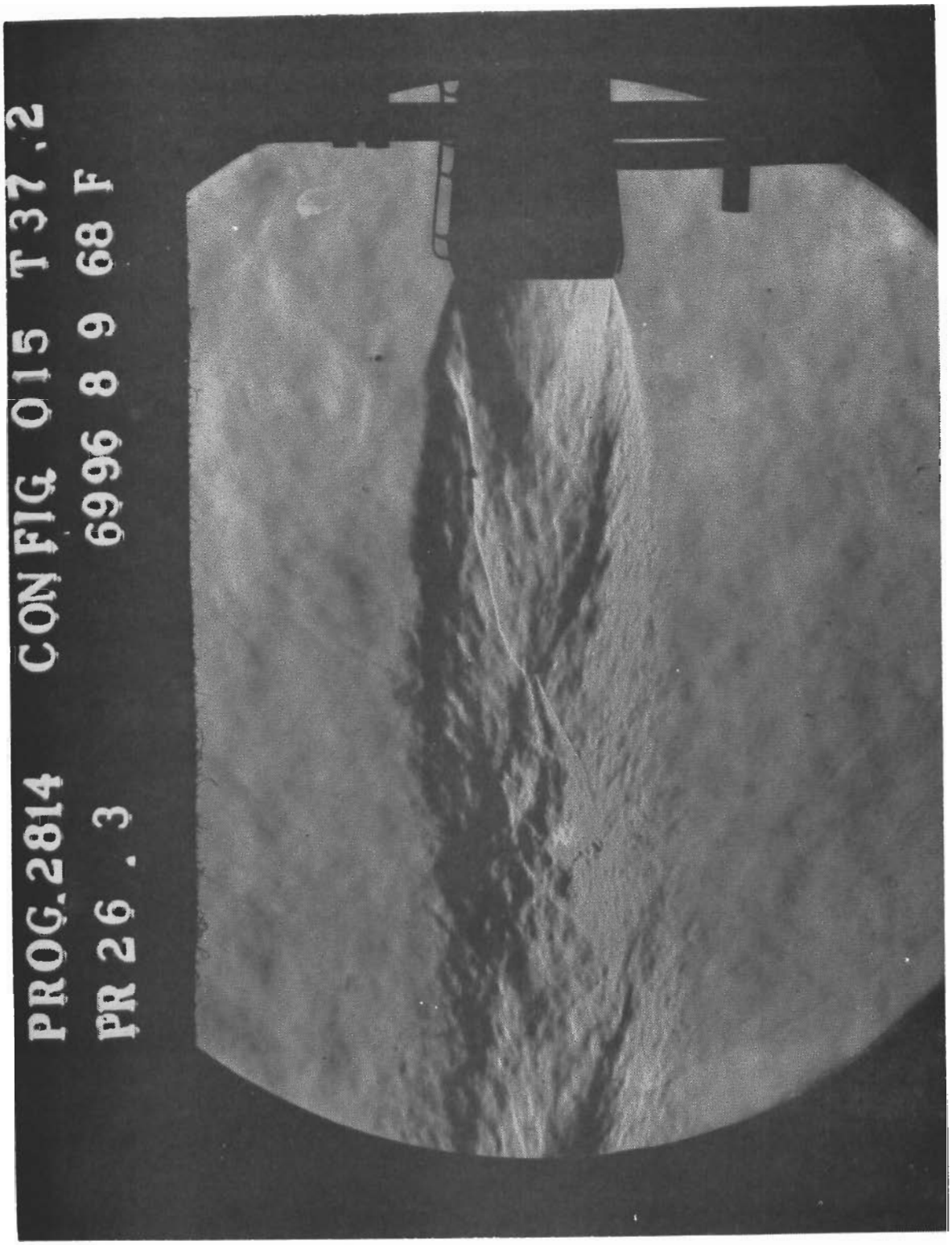


Figure 275. Shared Exit Ejector Nozzle Static Tests - Satellite Mode - Schlieren Photograph

Approved for Public Release

Contrails

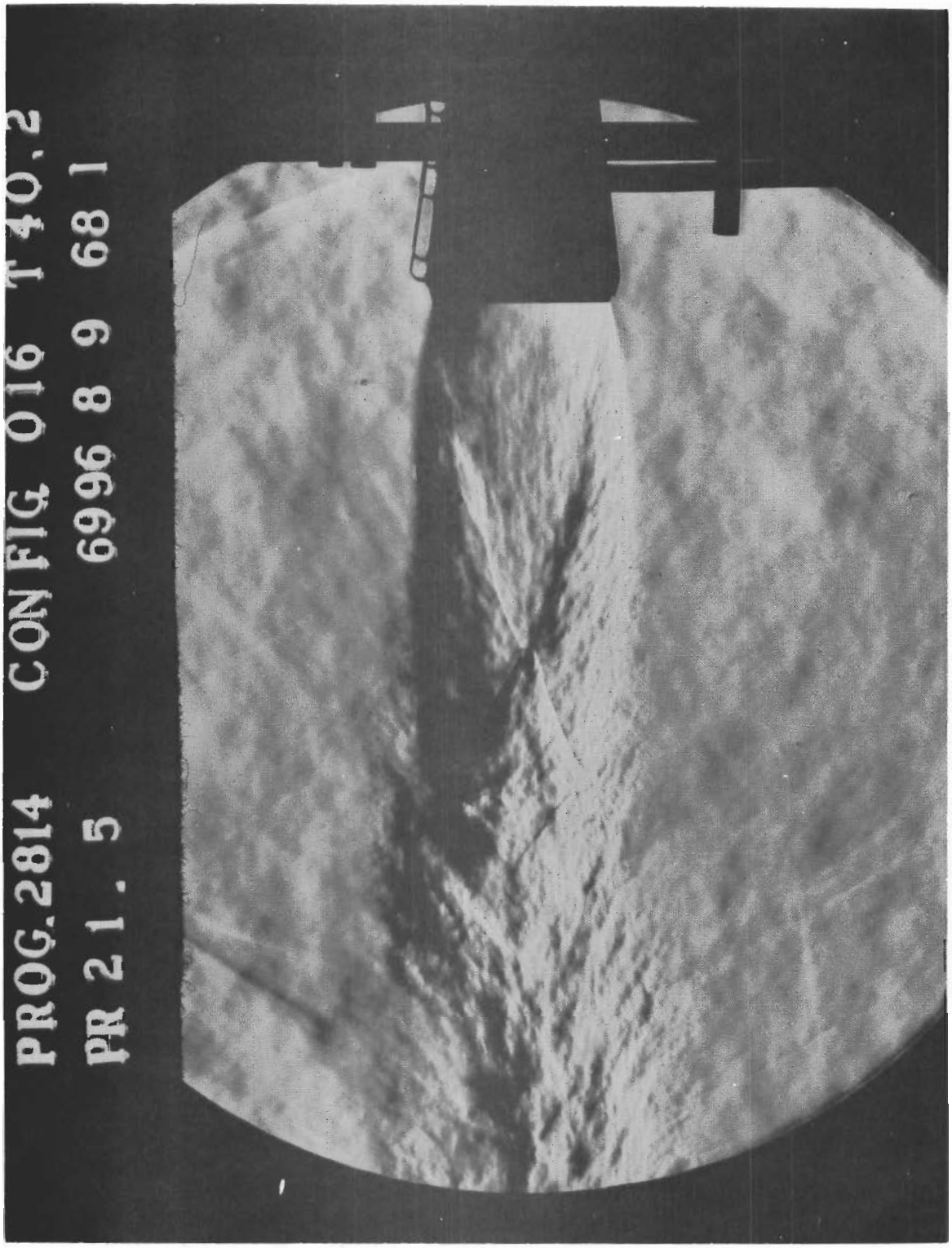


Figure 276. Shared Exit Ejector Nozzle Static Tests - Satellite Mode - Schlieren Photograph

Approved for Public Release

Contrails

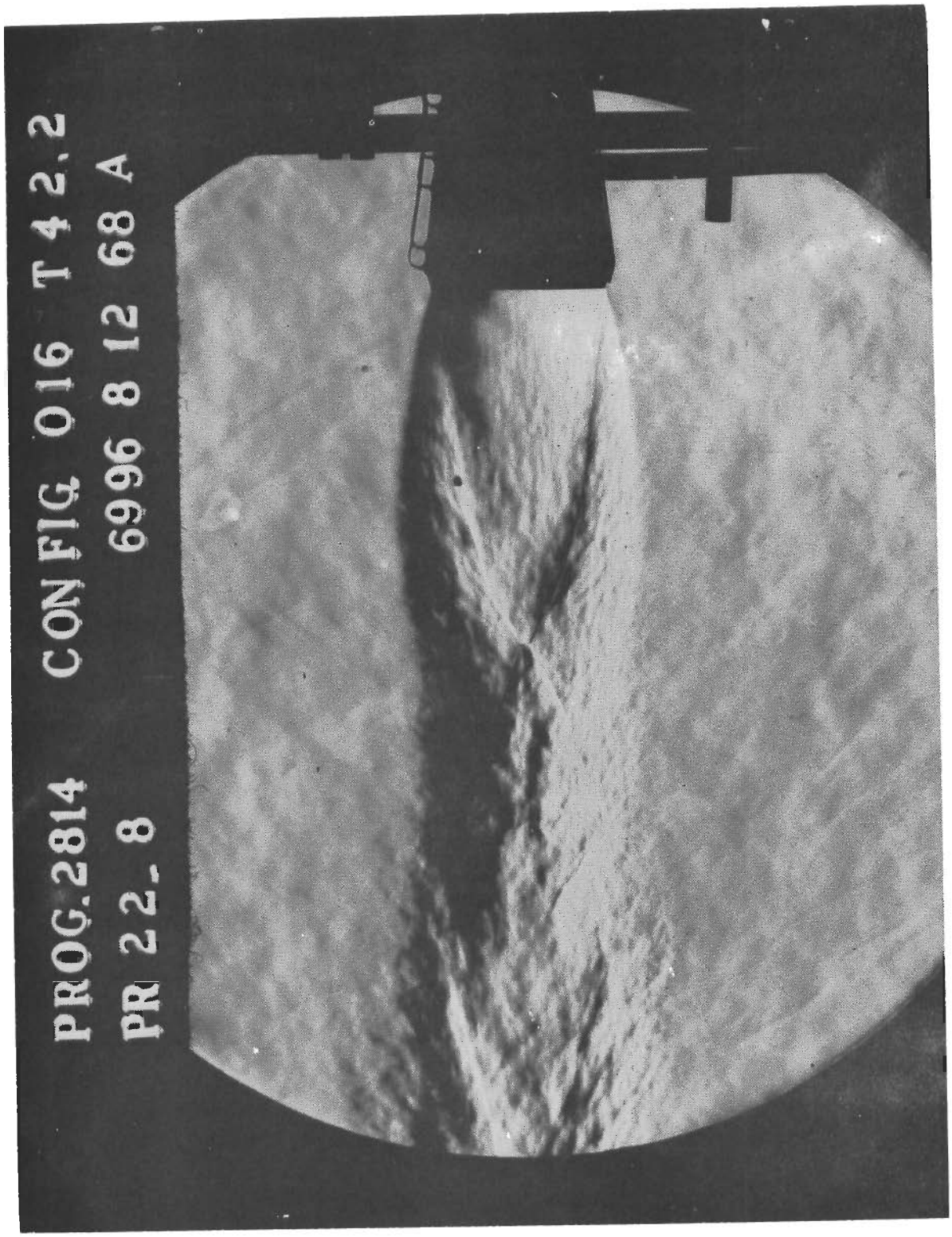


Figure 277. Shared Exit Ejector Nozzle Static Tests - Satellite Mode - Schlieren Photograph

Approved for Public Release

Contrails

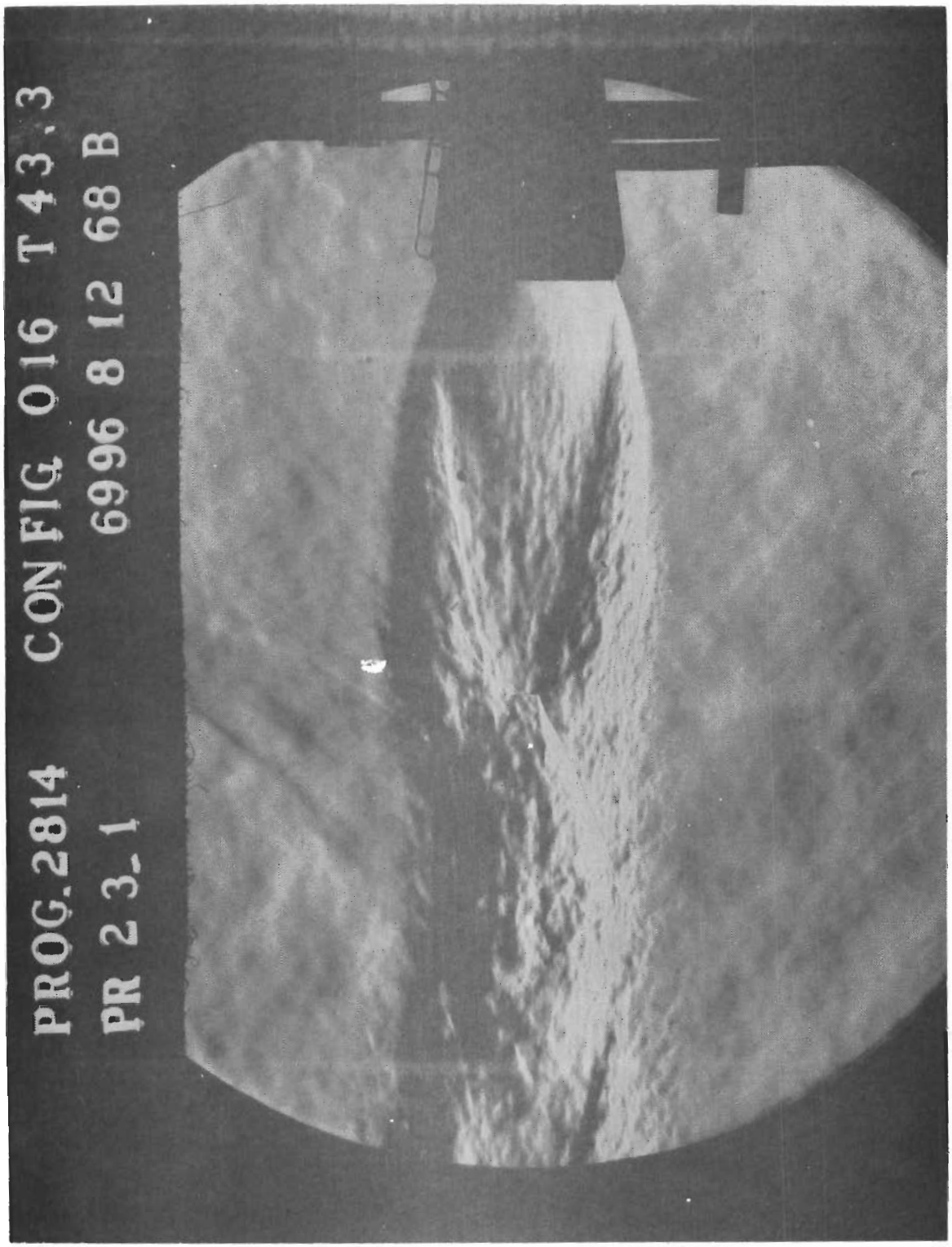


Figure 278. Shared Exit Ejector Nozzle Static Tests - Satellite Mode - Schlieren Photograph

Approved for Public Release

Contrails

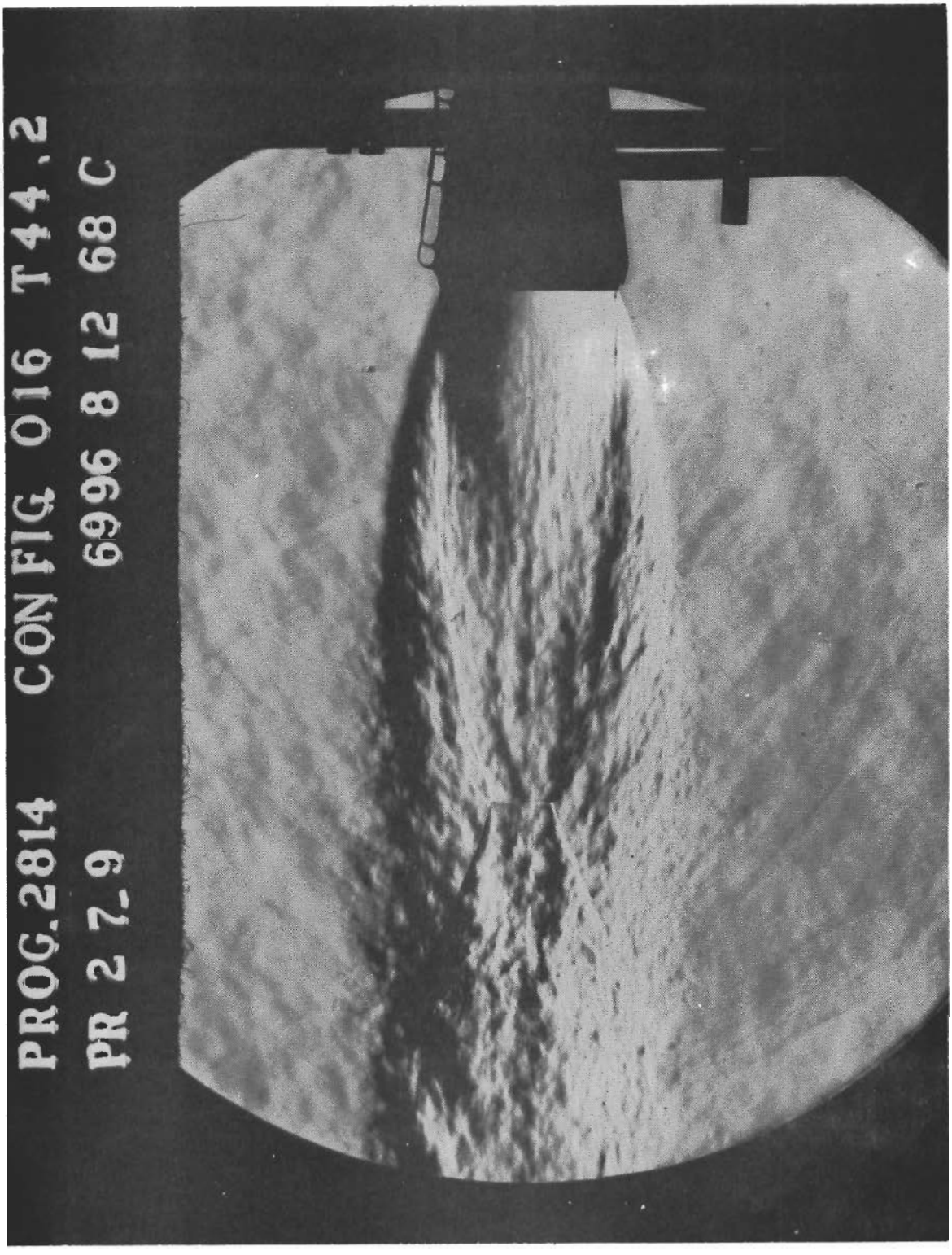


Figure 279. Shared Exit Ejector Nozzle Static Tests - Satellite Mode - Schlieren Photograph

Approved for Public Release

Contrails

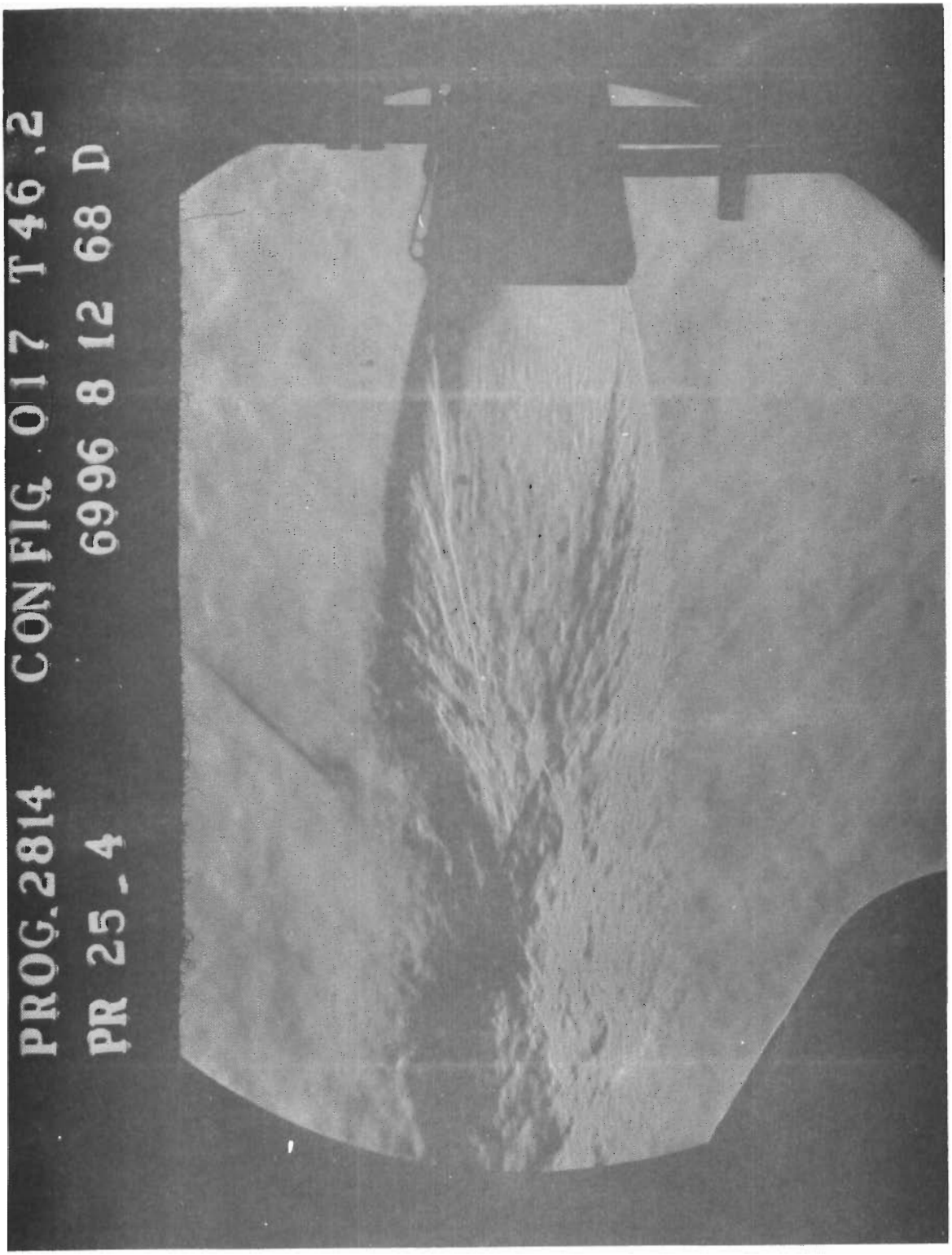


Figure 280. Shared Exit Ejector Nozzle Static Tests - Satellite Mode - Schlieren Photograph

Approved for Public Release

Contrails

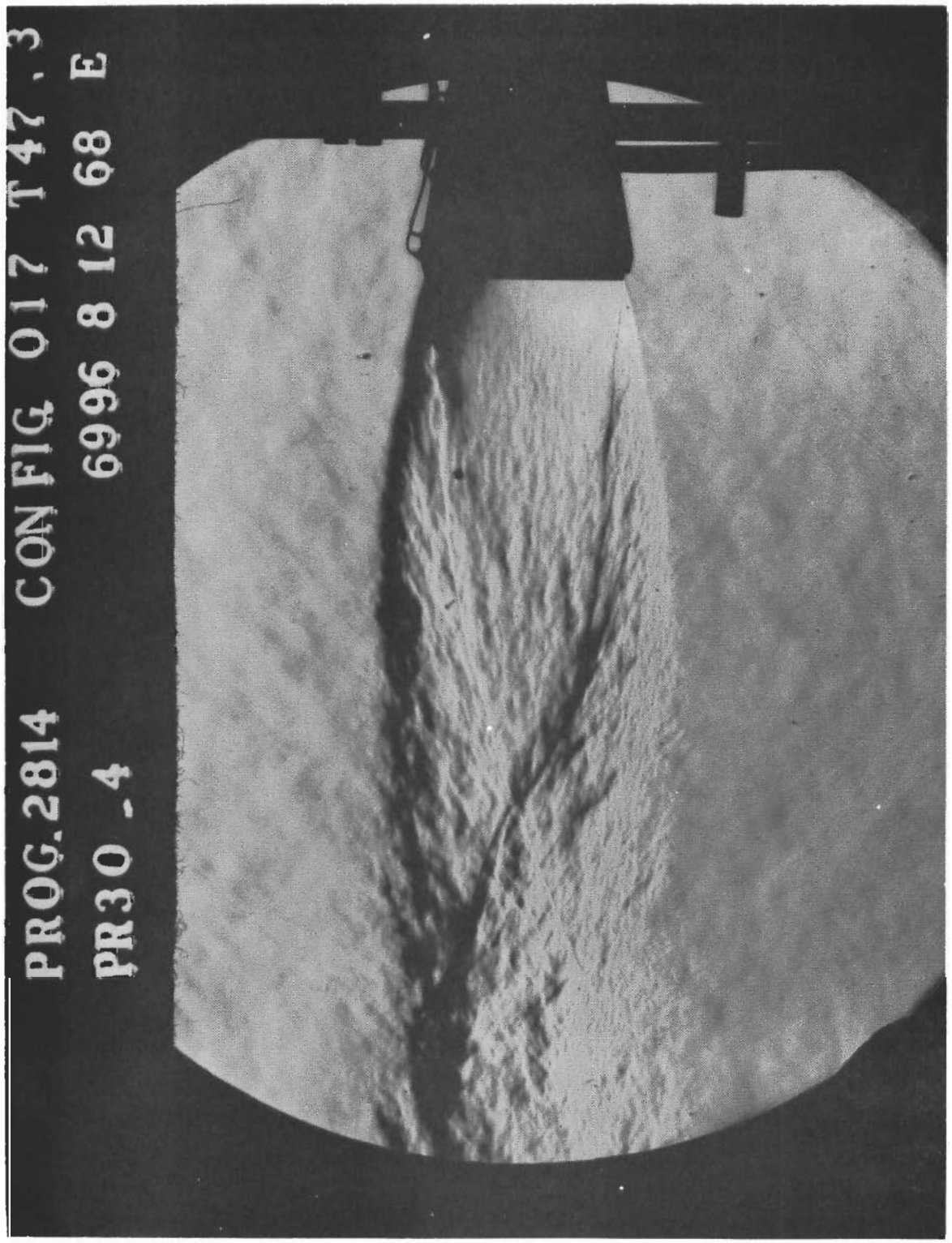


Figure 281. Shared Exit Ejector Nozzle Static Tests - Satellite Mode - Schlieren Photograph

Approved for Public Release

Contrails

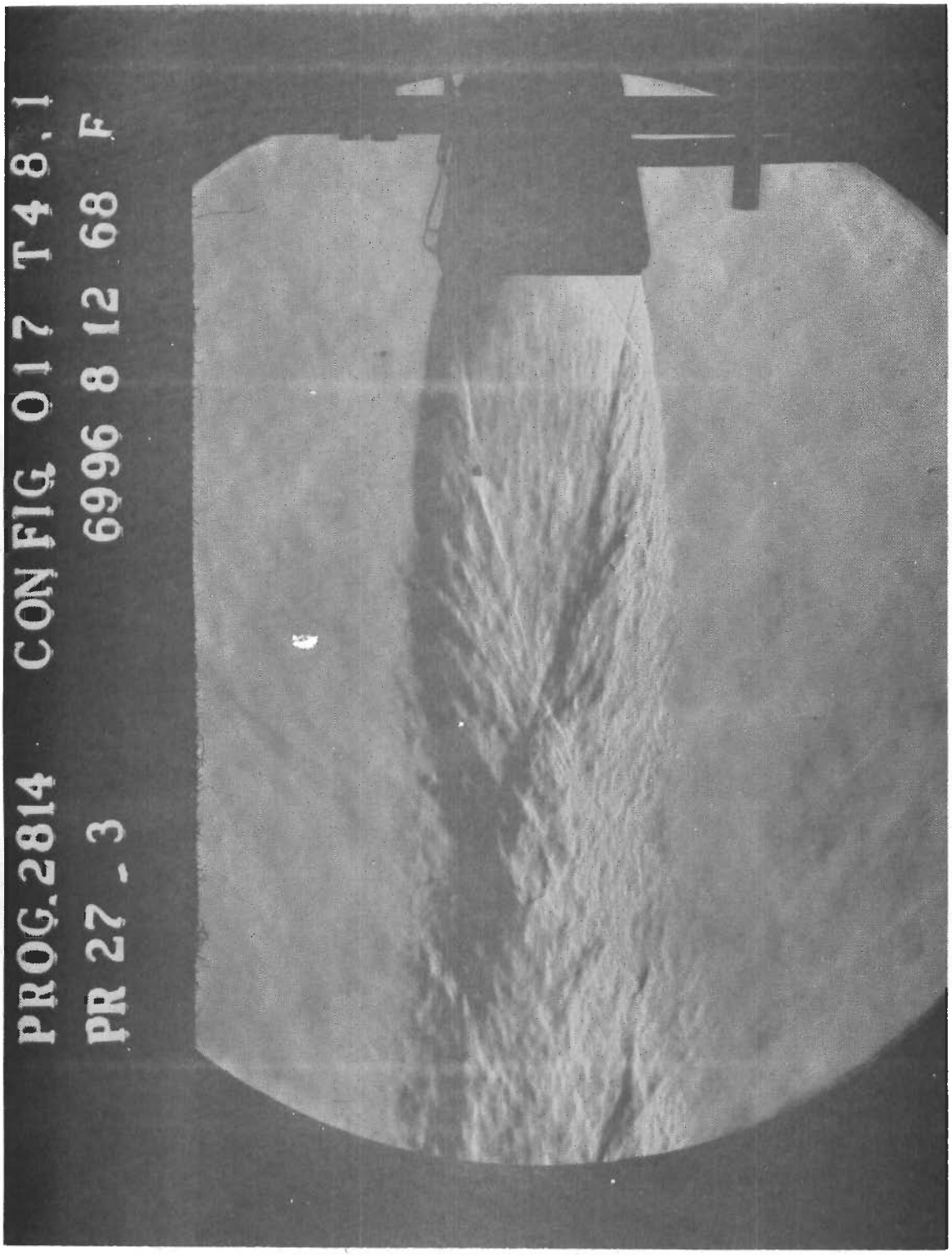


Figure 282. Shared Exit Ejector Nozzle Static Tests - Satellite Mode - Schlieren Photograph

Approved for Public Release

Contrails

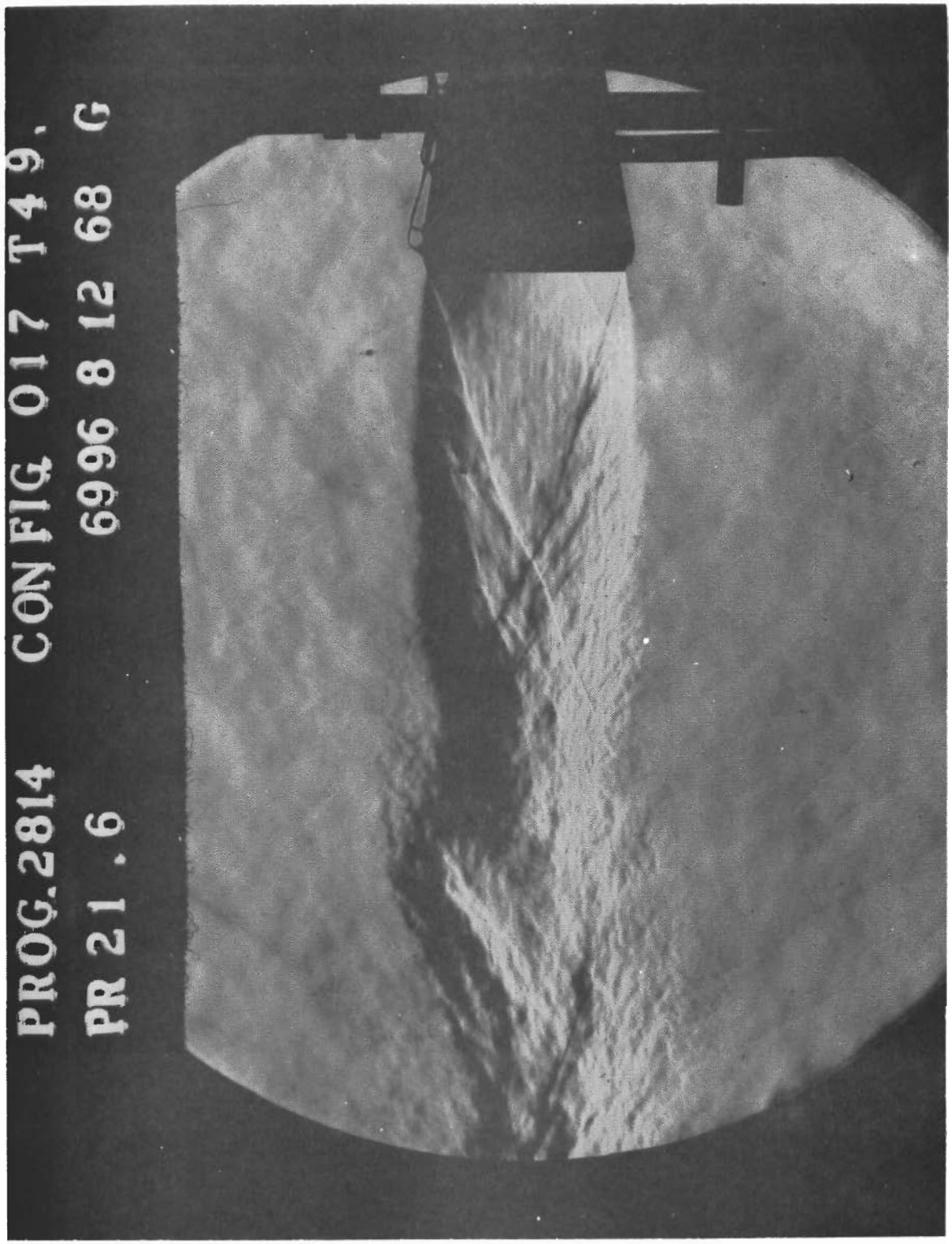


Figure 283. Shared Exit Ejector Nozzle Static Tests - Satellite Mode - Schlieren Photograph

Approved for Public Release

Contrails

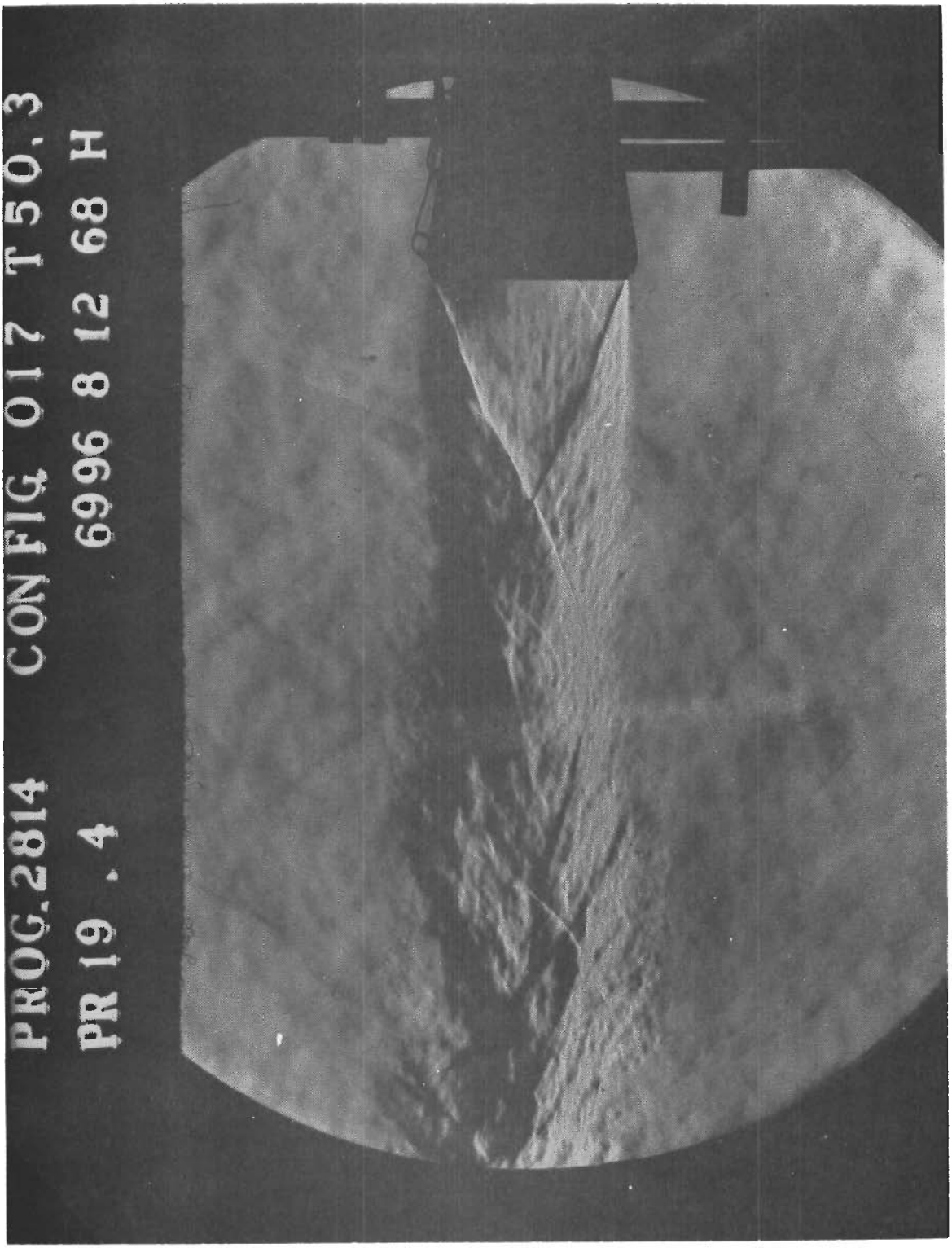


Figure 284. Shared Exit Ejector Nozzle Static Tests - Satellite Mode - Schlieren Photograph

Approved for Public Release

Contrails

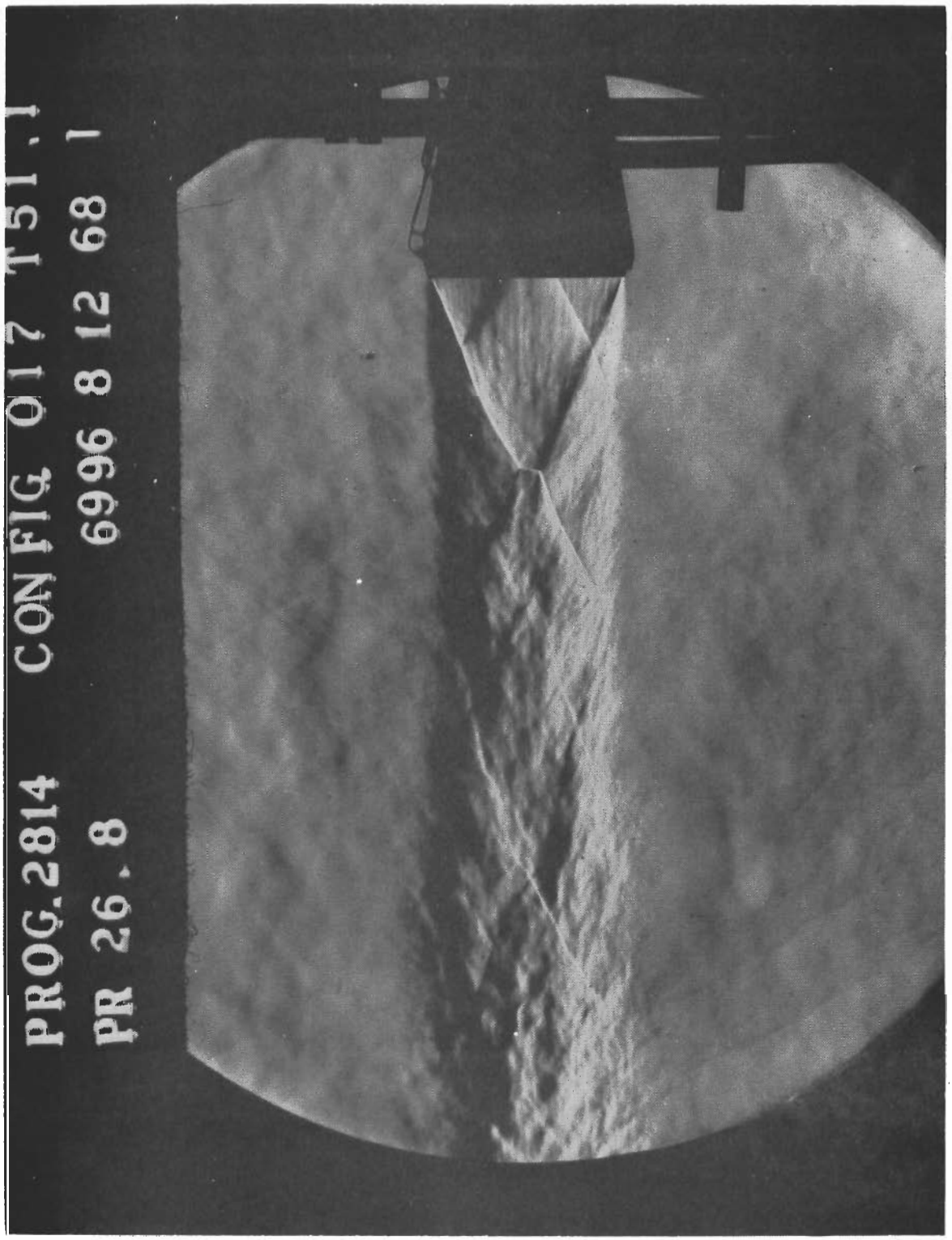


Figure 285. Shared Exit Ejector Nozzle Static Tests - Satellite Mode - Schlieren Photograph

Approved for Public Release

Contrails

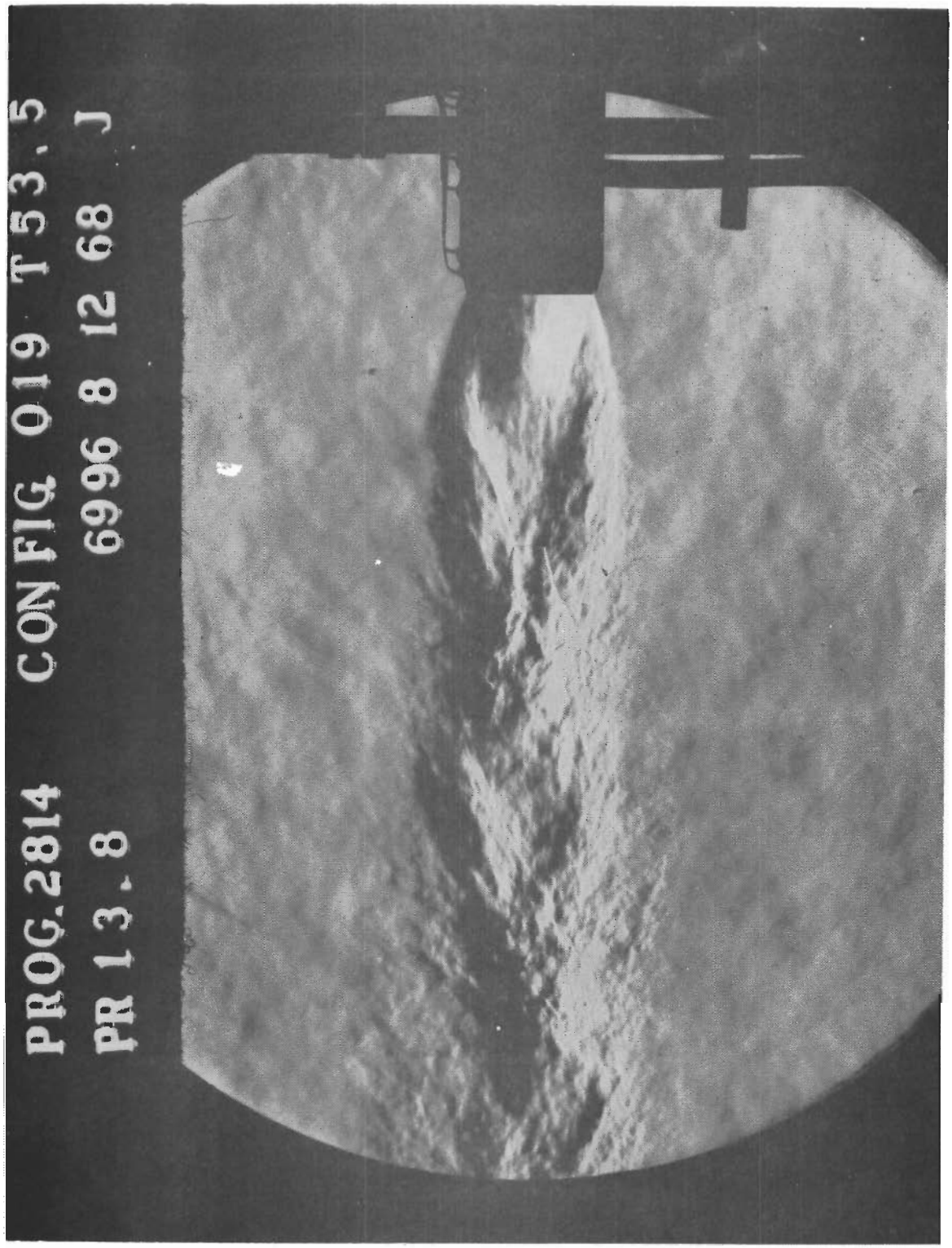


Figure 286. Shared Exit Ejector Nozzle Static Tests - Satellite Mode - Schlieren Photograph

Approved for Public Release

Contrails

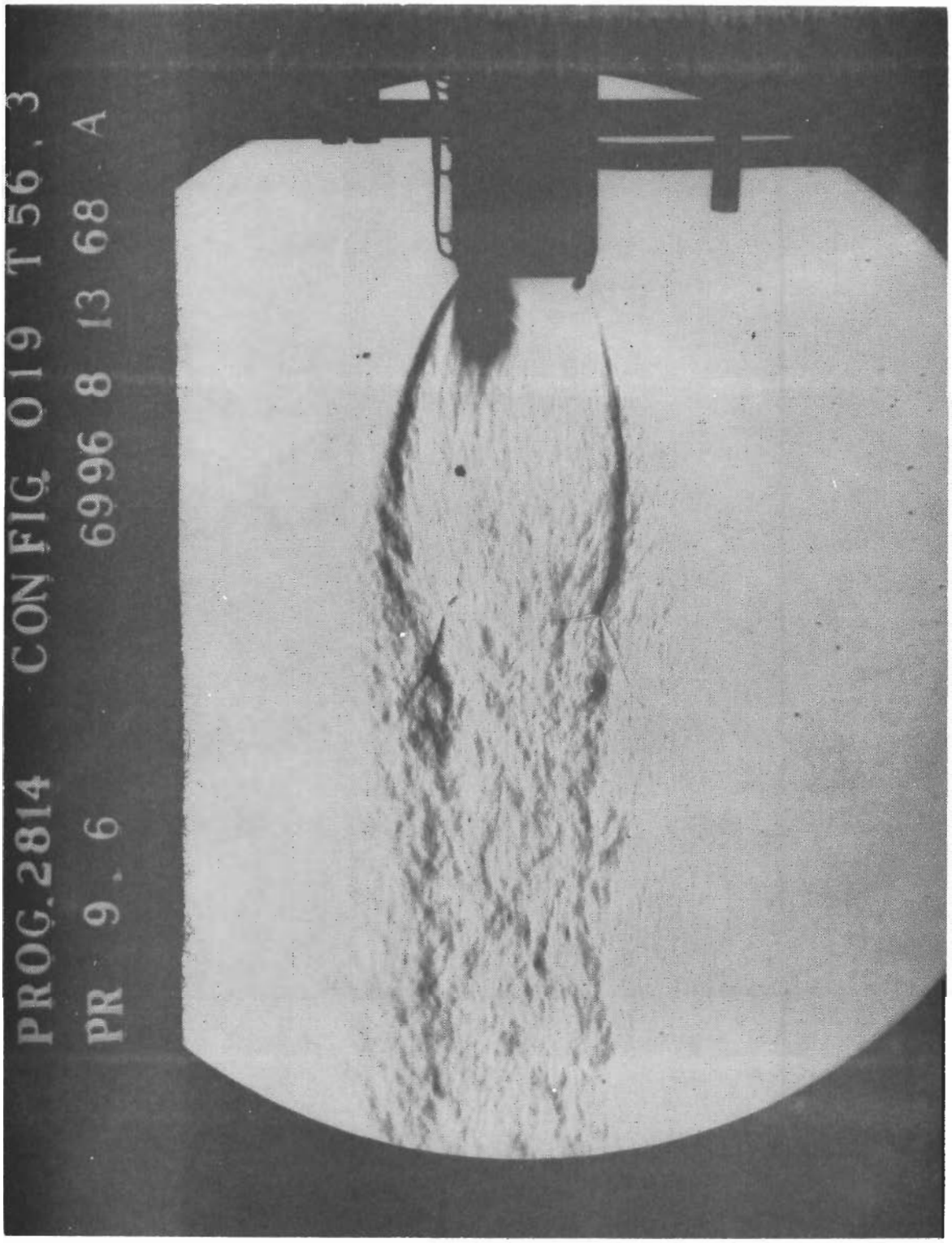


Figure 287. Shared Exit Ejector Nozzle Static Tests - Satellite Mode - Schlieren Photograph

Approved for Public Release

Contrails

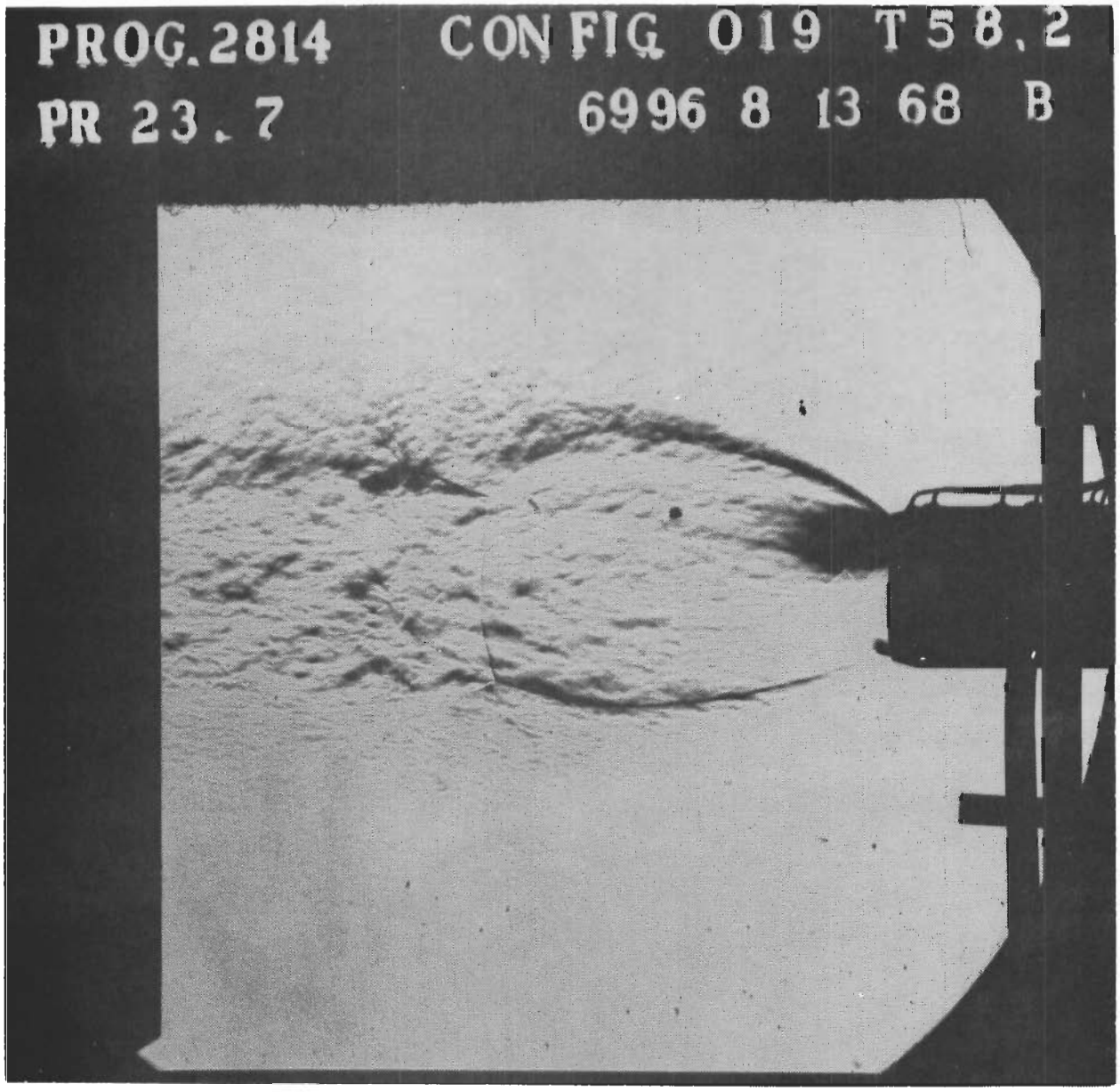


Figure 288. Shared Exit Ejector Nozzle Static Tests - Satellite Mode - Schlieren Photograph

Approved for Public Release

Contrails

Figure 289. Shared Exit Ejector Nozzle Static Tests - Satellite Mode - Schlieren Photograph

Approved for Public Release

Contrails

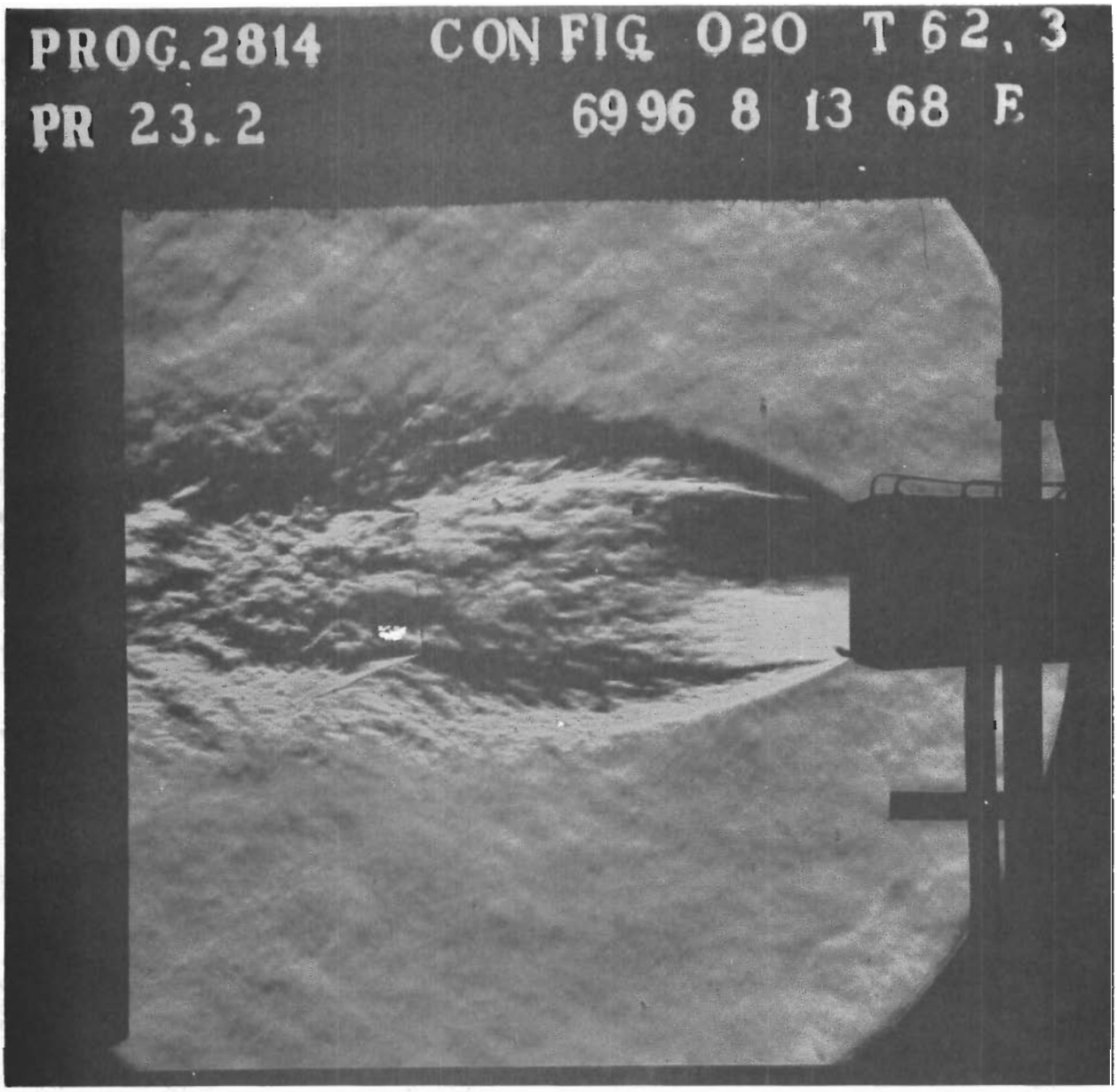


Figure 290. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Schlieren Photograph

Approved for Public Release

Contrails

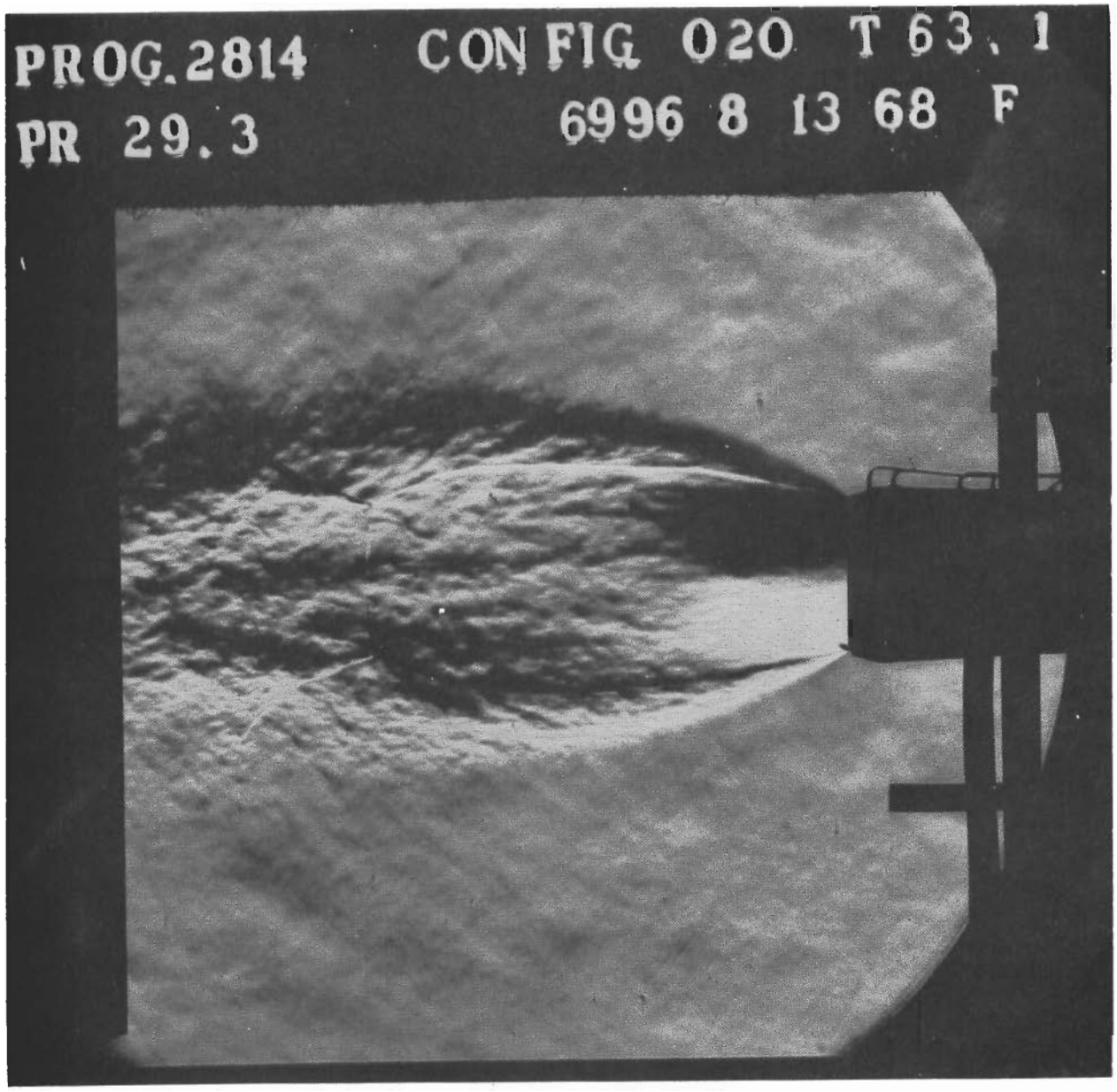


Figure 291. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Schlieren Photograph

Approved for Public Release

Contrails

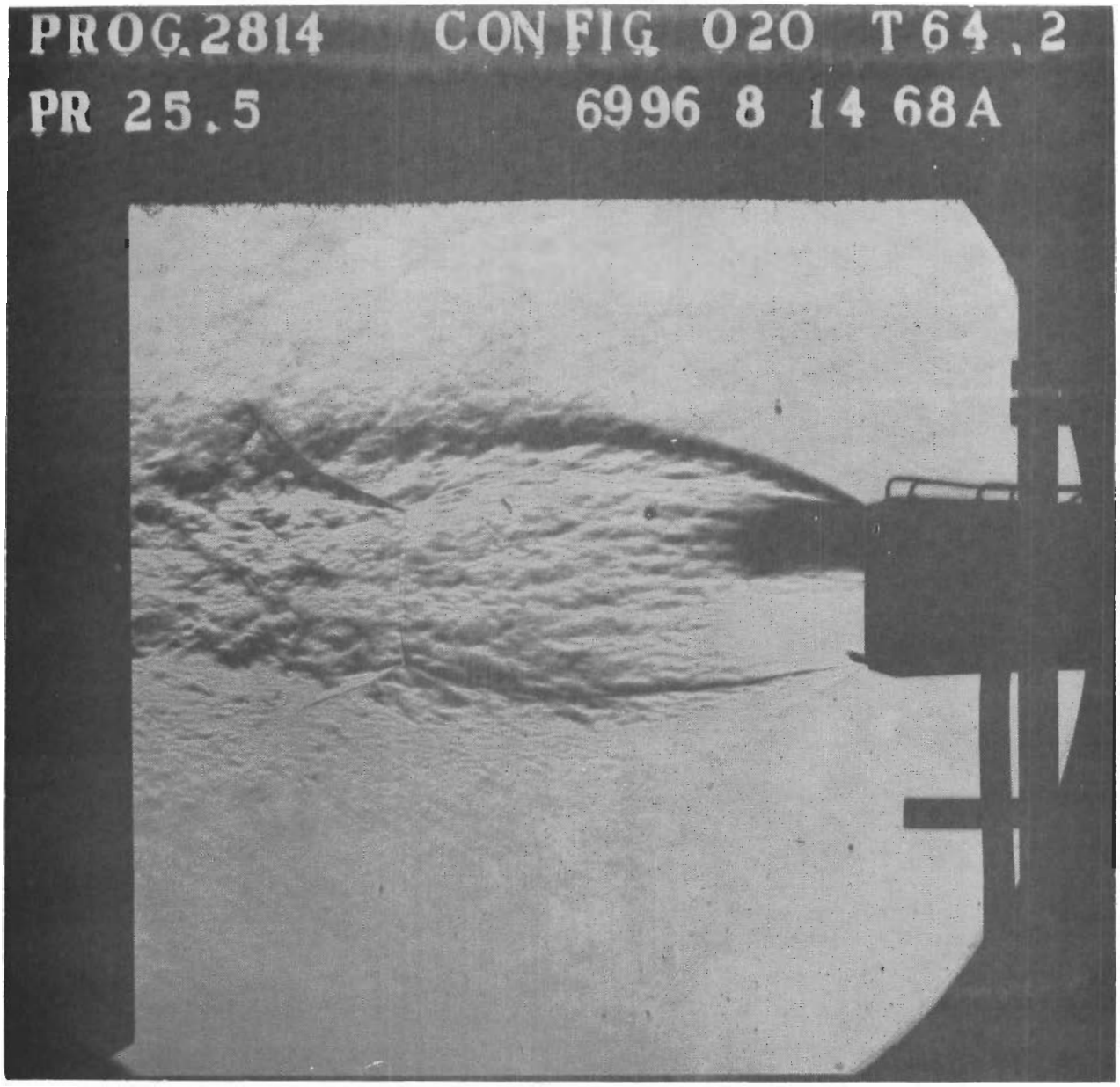


Figure 292. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Schlieren Photograph

Approved for Public Release

Contrails

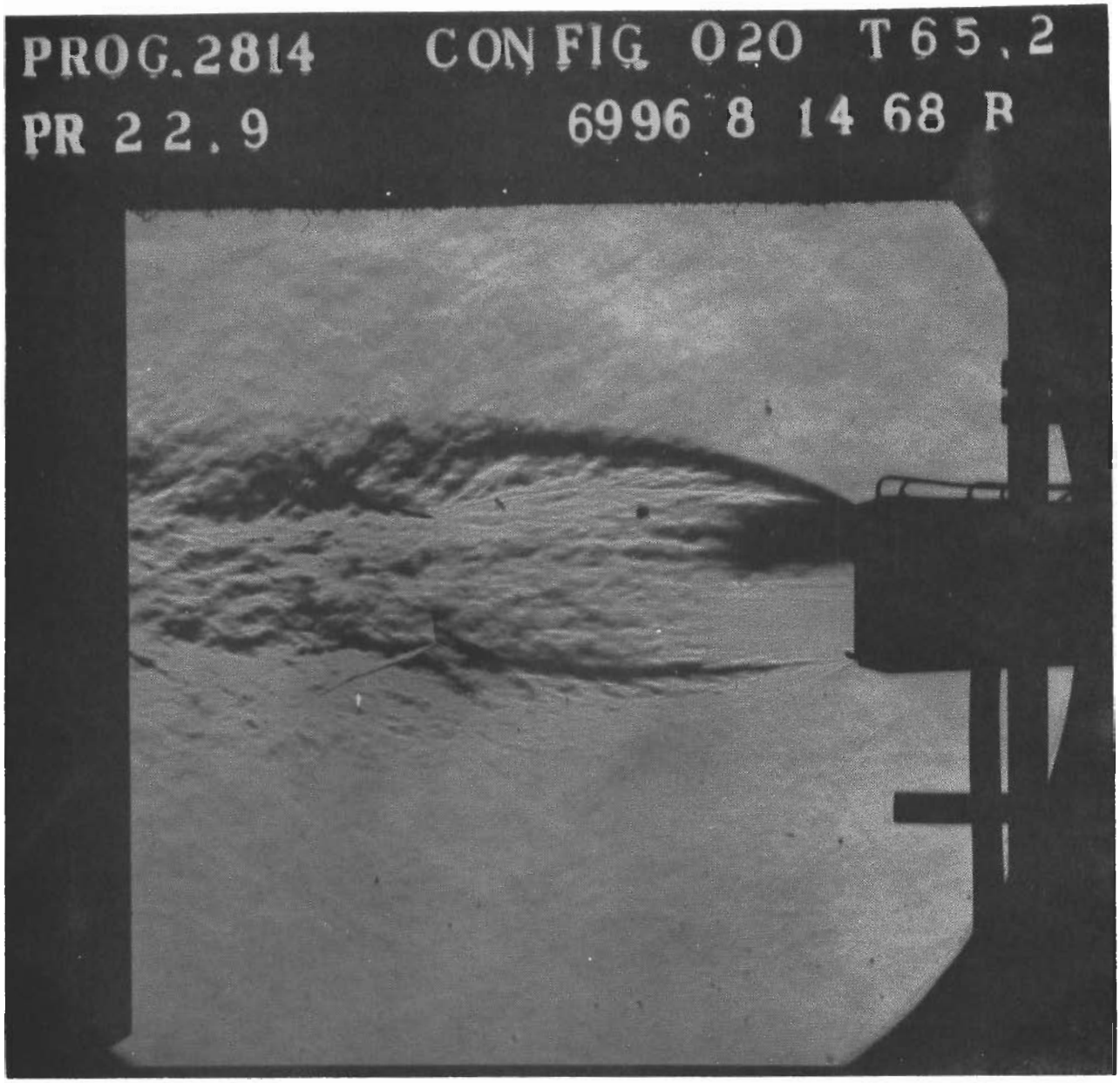


Figure 293. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Schlieren Photograph

Approved for Public Release

Contrails

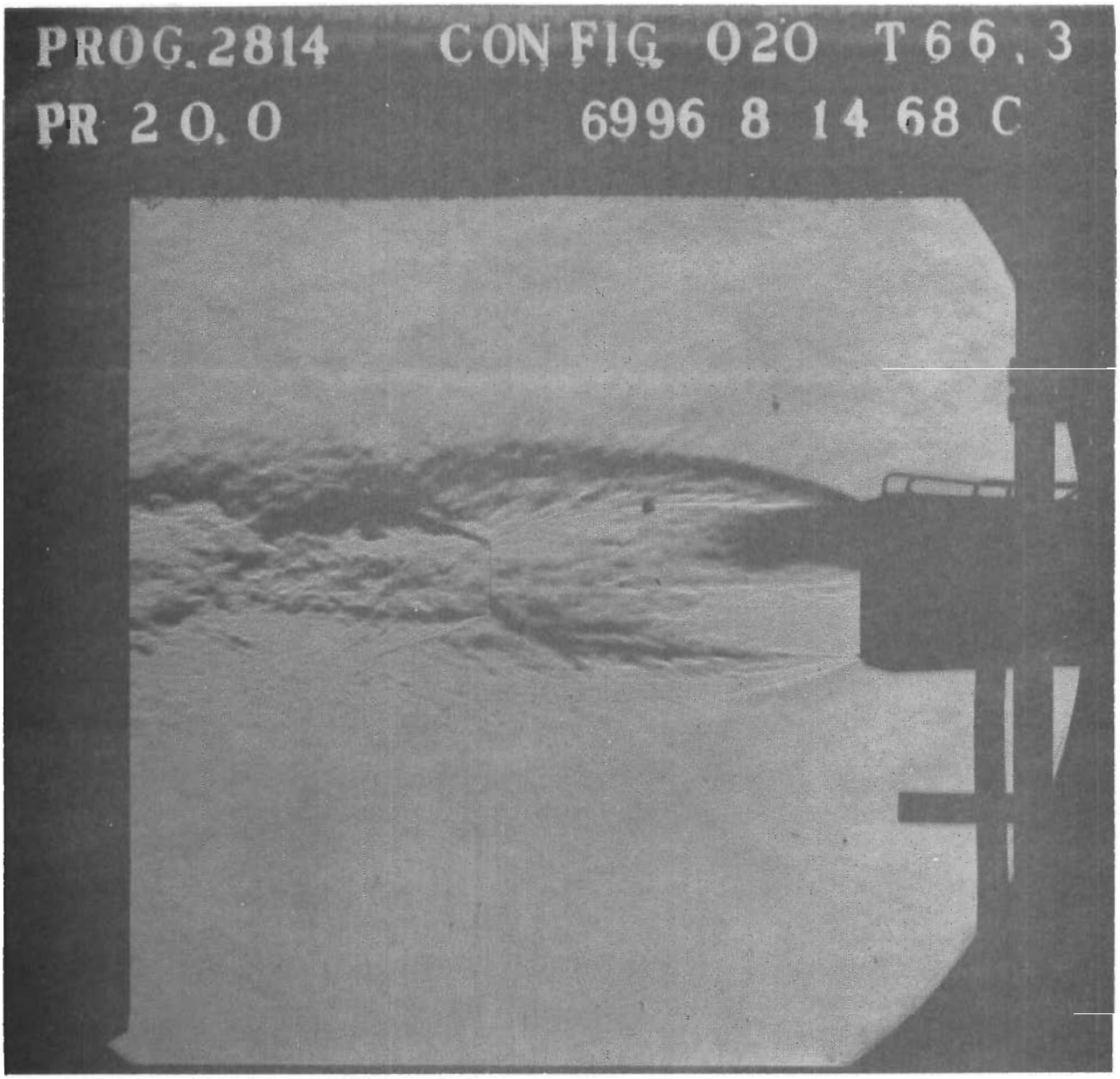


Figure 294. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Schleiren Photograph

Approved for Public Release

Contrails

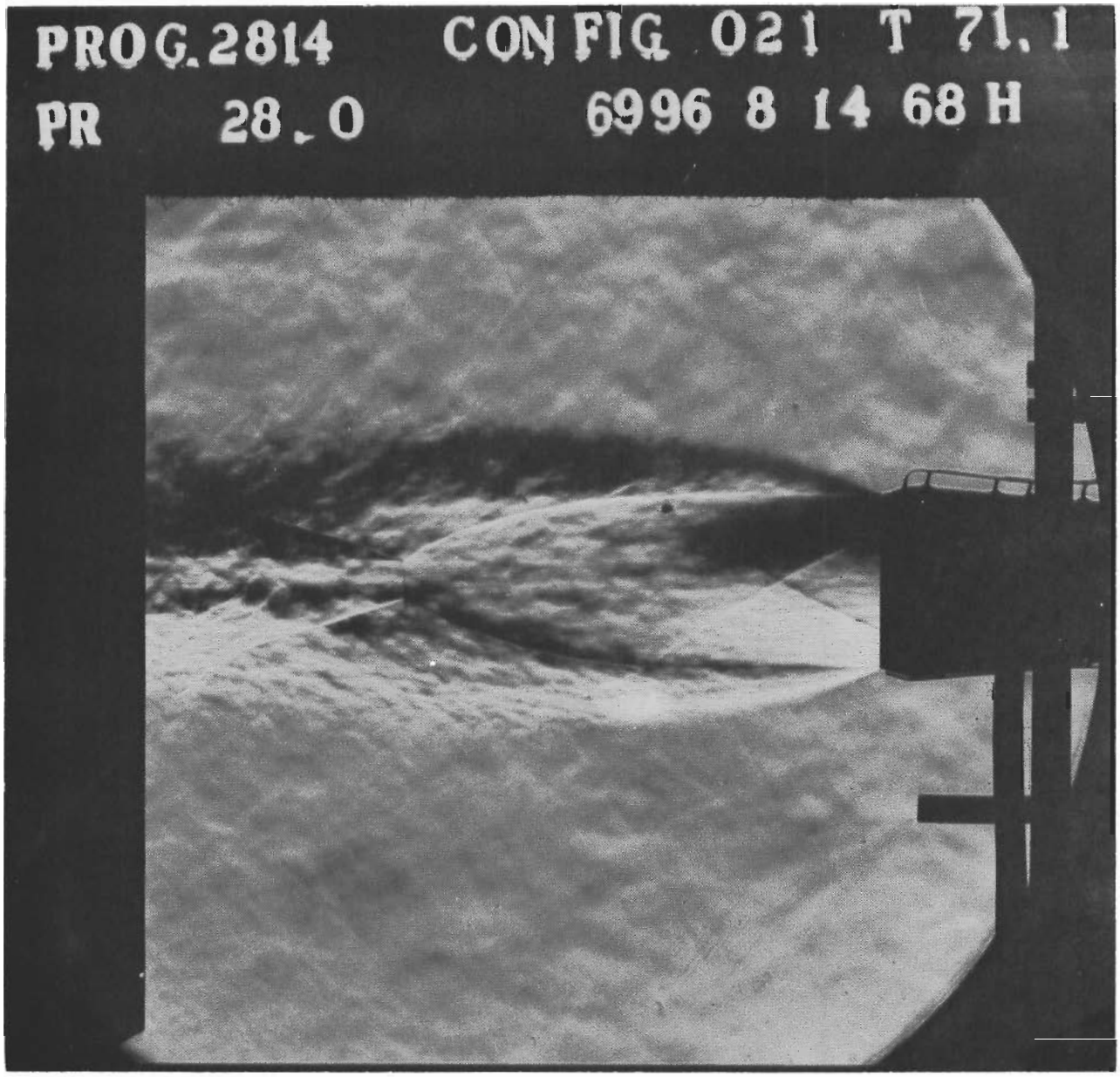


Figure 295. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Schlieren Photograph

Approved for Public Release

Contrails

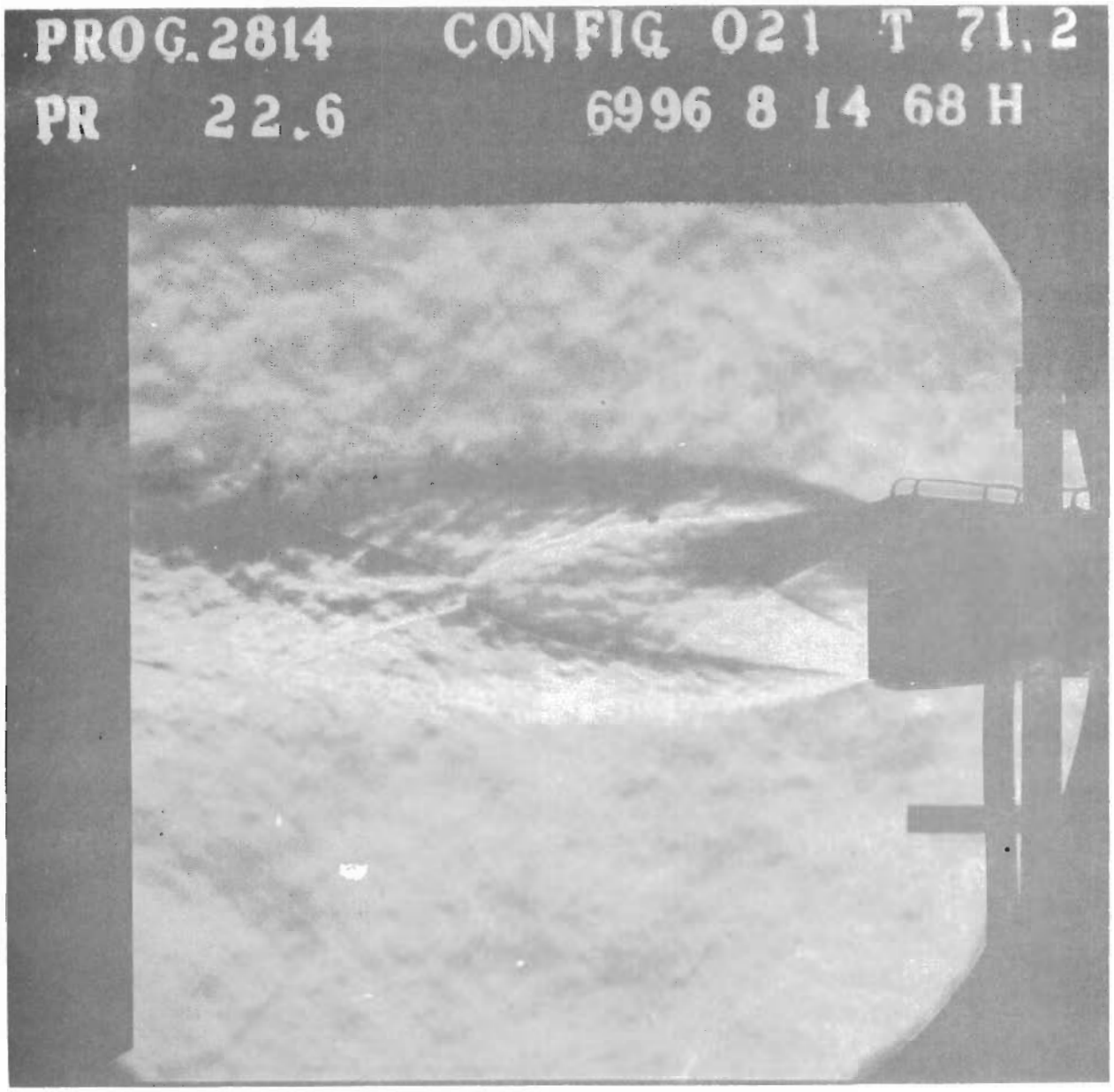


Figure 296. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Schlieren Photograph

Approved for Public Release

Contrails

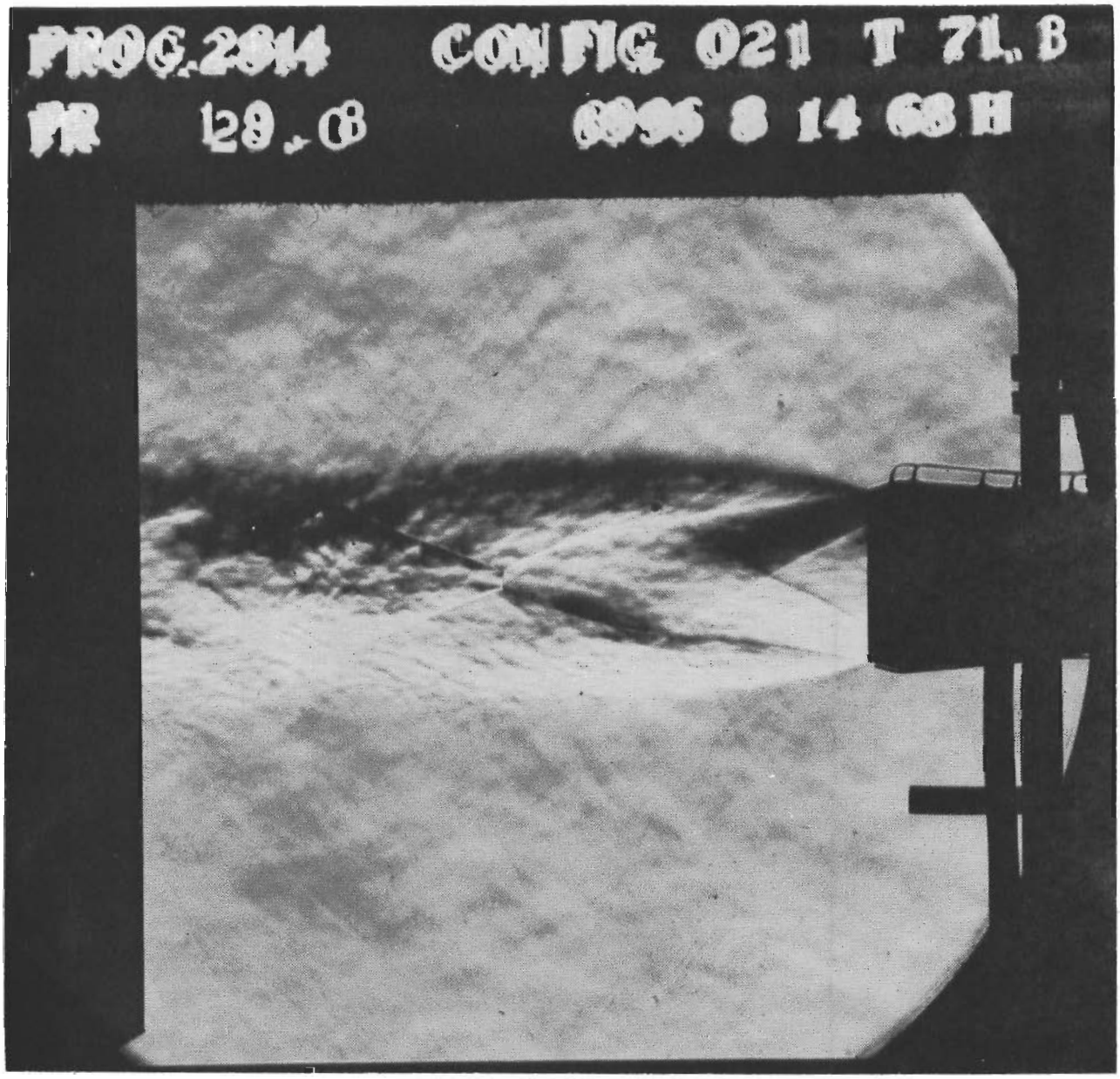


Figure 297. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Schlieren Photograph

Approved for Public Release

Contrails

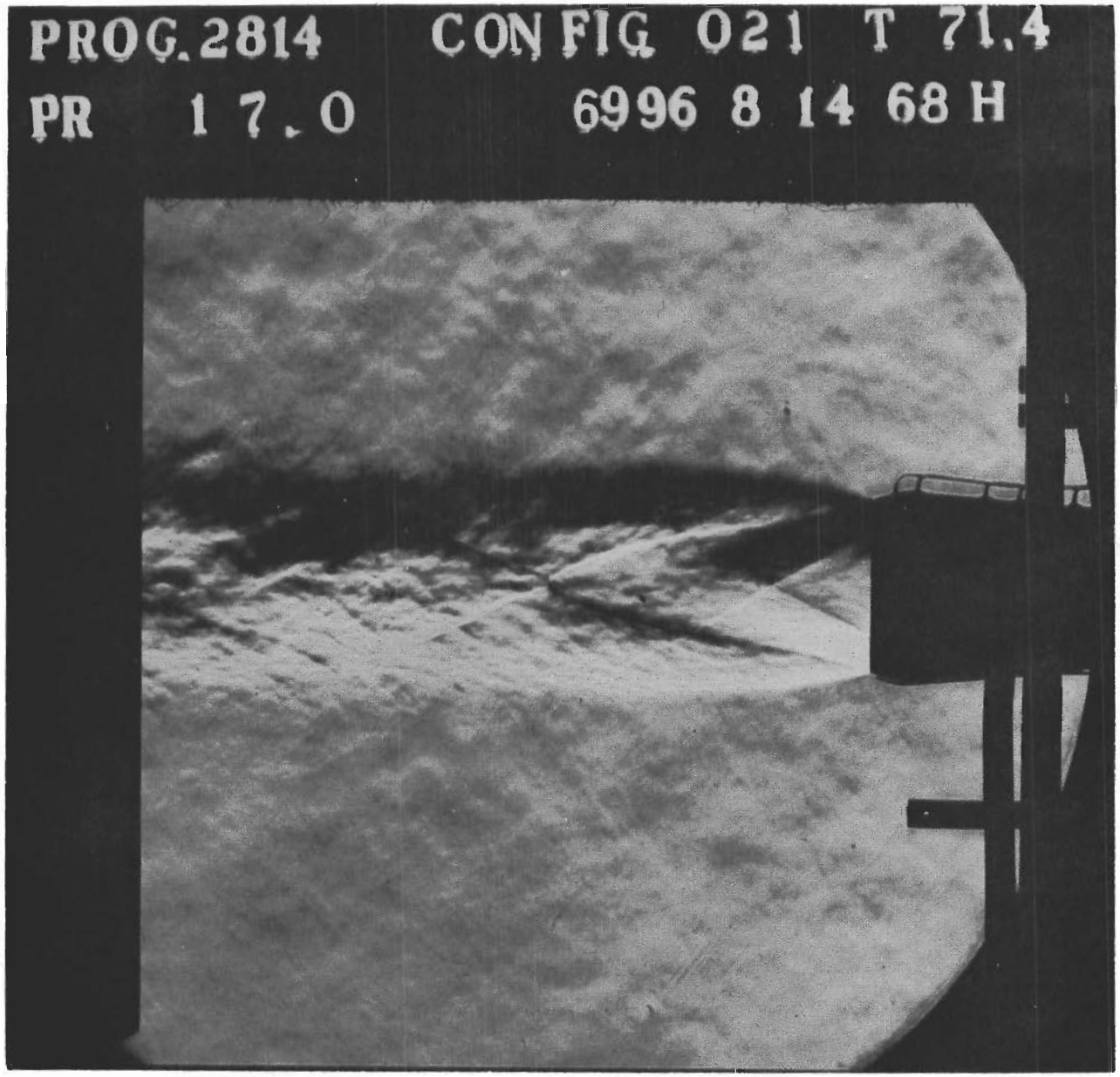


Figure 298. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Schlieren Photograph

Approved for Public Release

Contrails

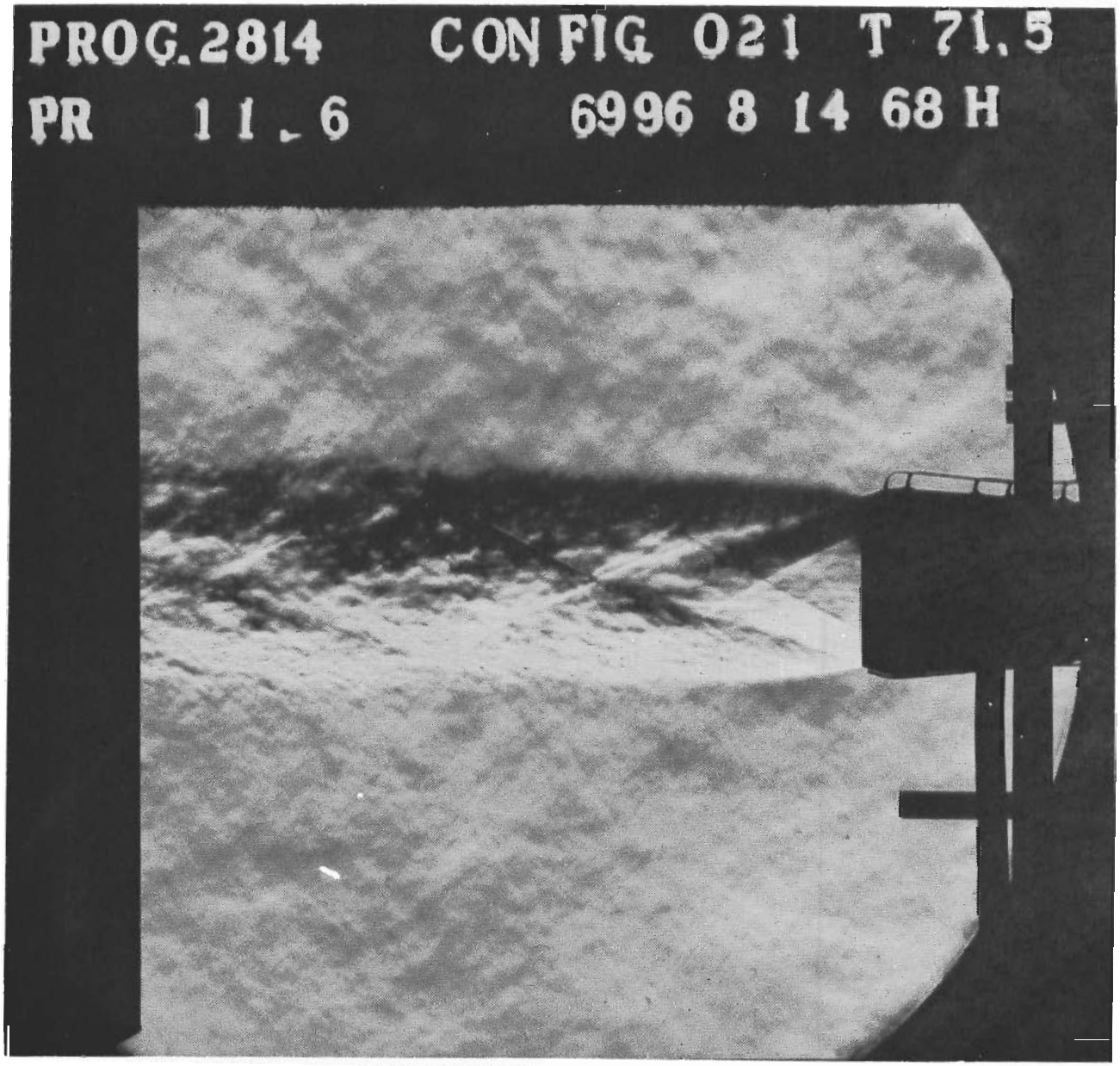


Figure 299. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Schlieren Photograph

Approved for Public Release

Contrails

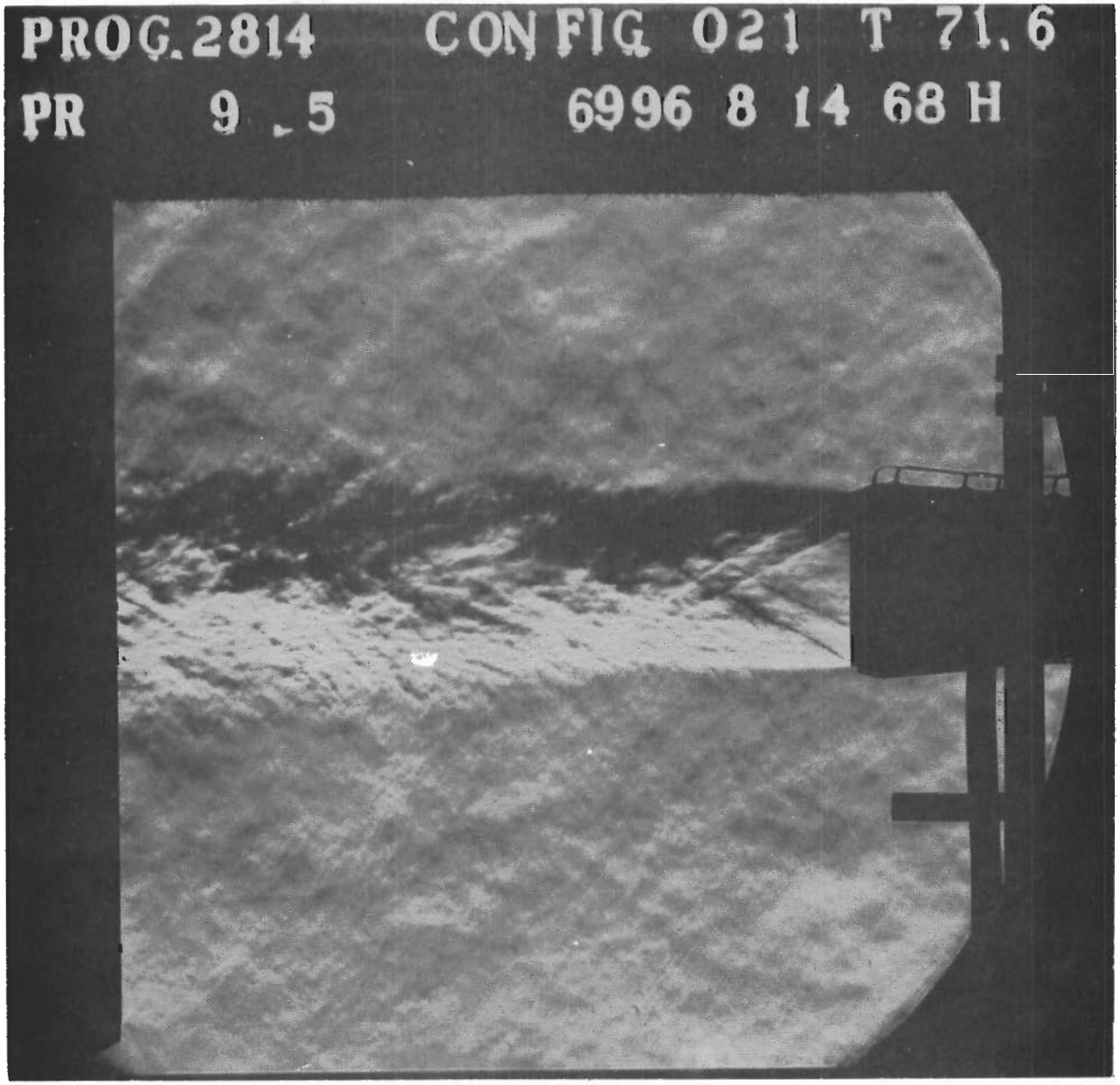


Figure 300. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Schlieren Photograph

Approved for Public Release

Contrails

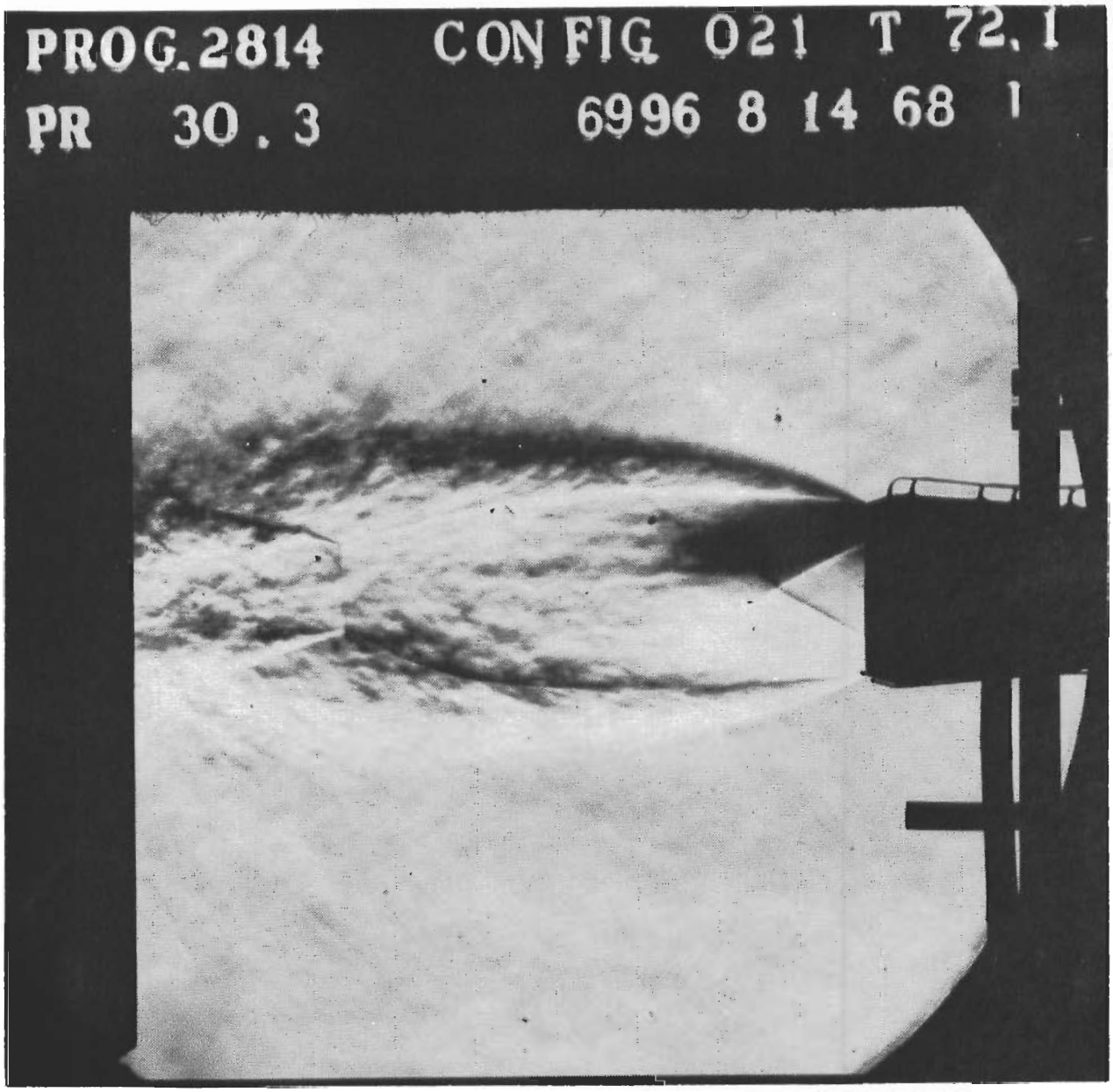


Figure 301. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Schlieren Photograph

Approved for Public Release

Contrails

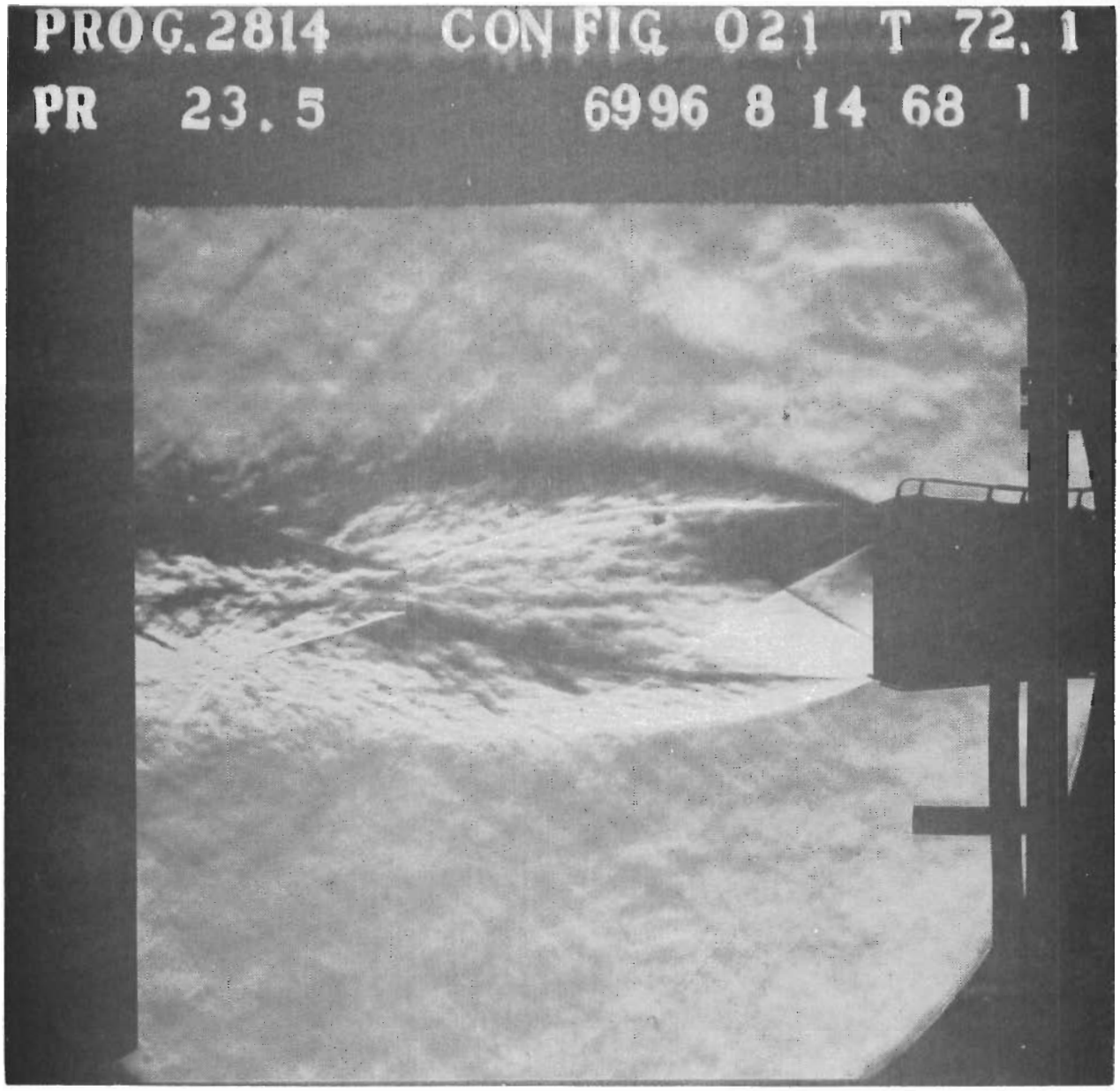


Figure 302. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Schlieren Photograph

Approved for Public Release

Contrails

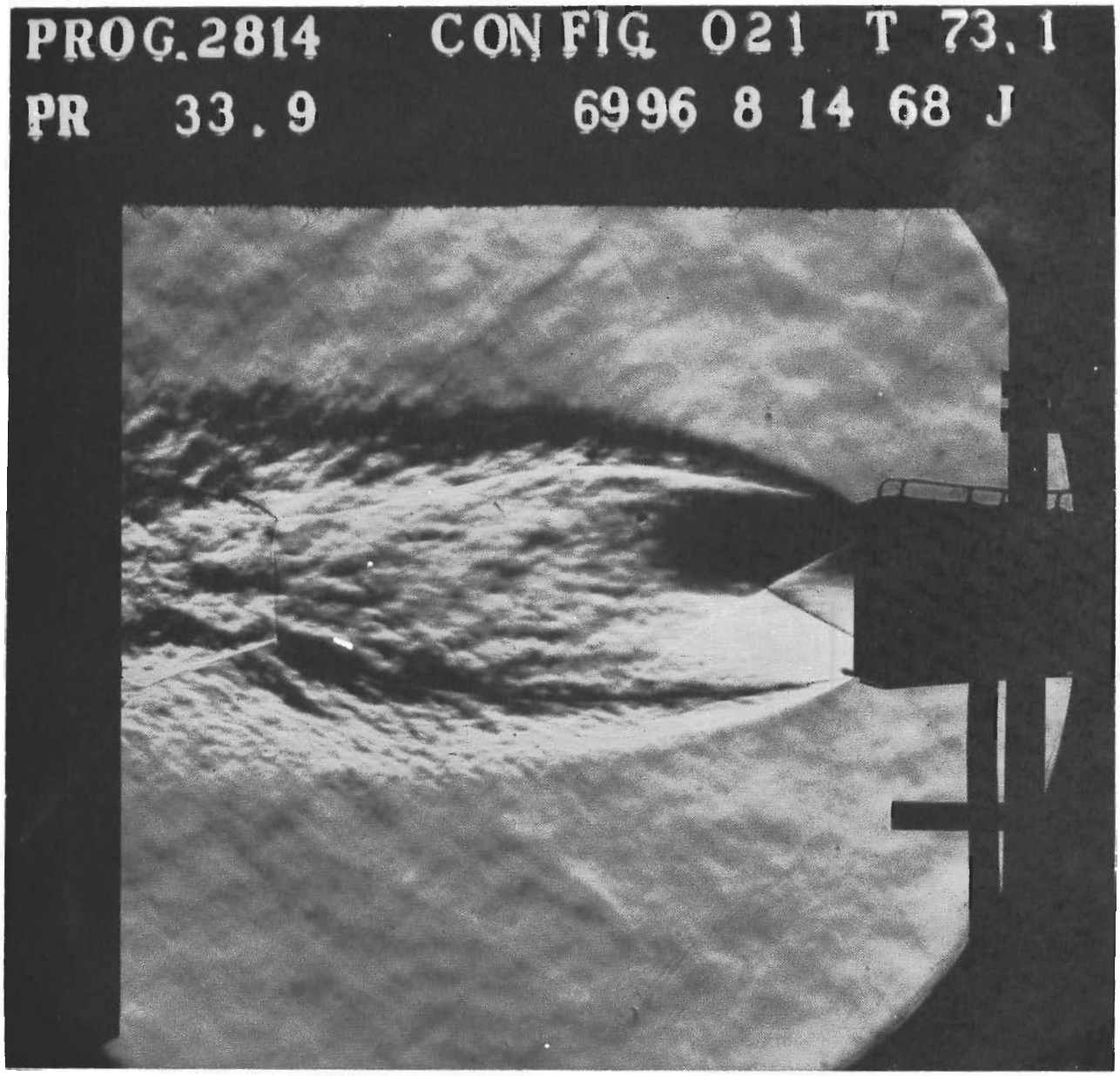


Figure 303. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Schlieren Photograph

Approved for Public Release

Contrails

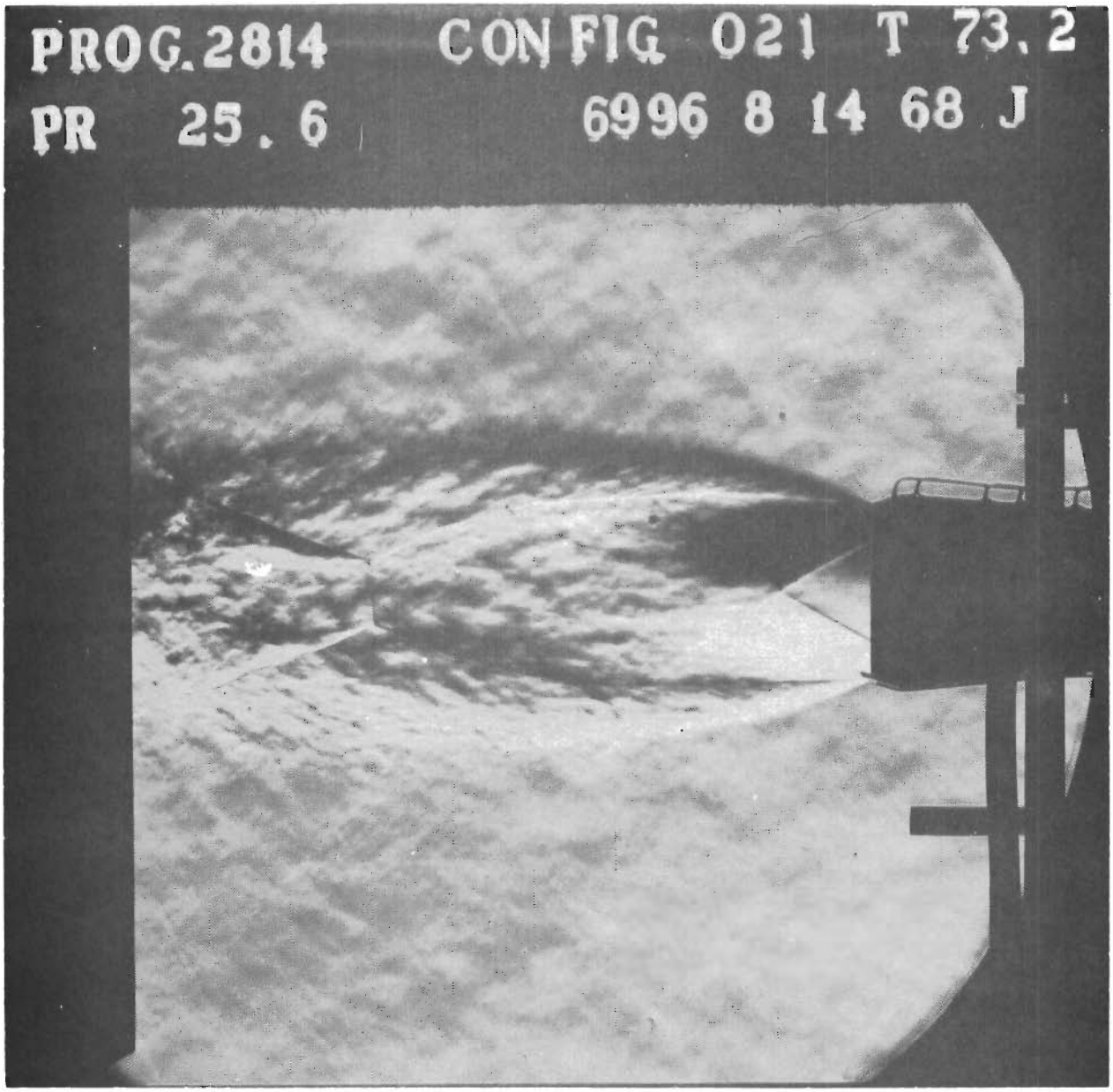


Figure 304. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Schlieren Photograph

Approved for Public Release

Contrails

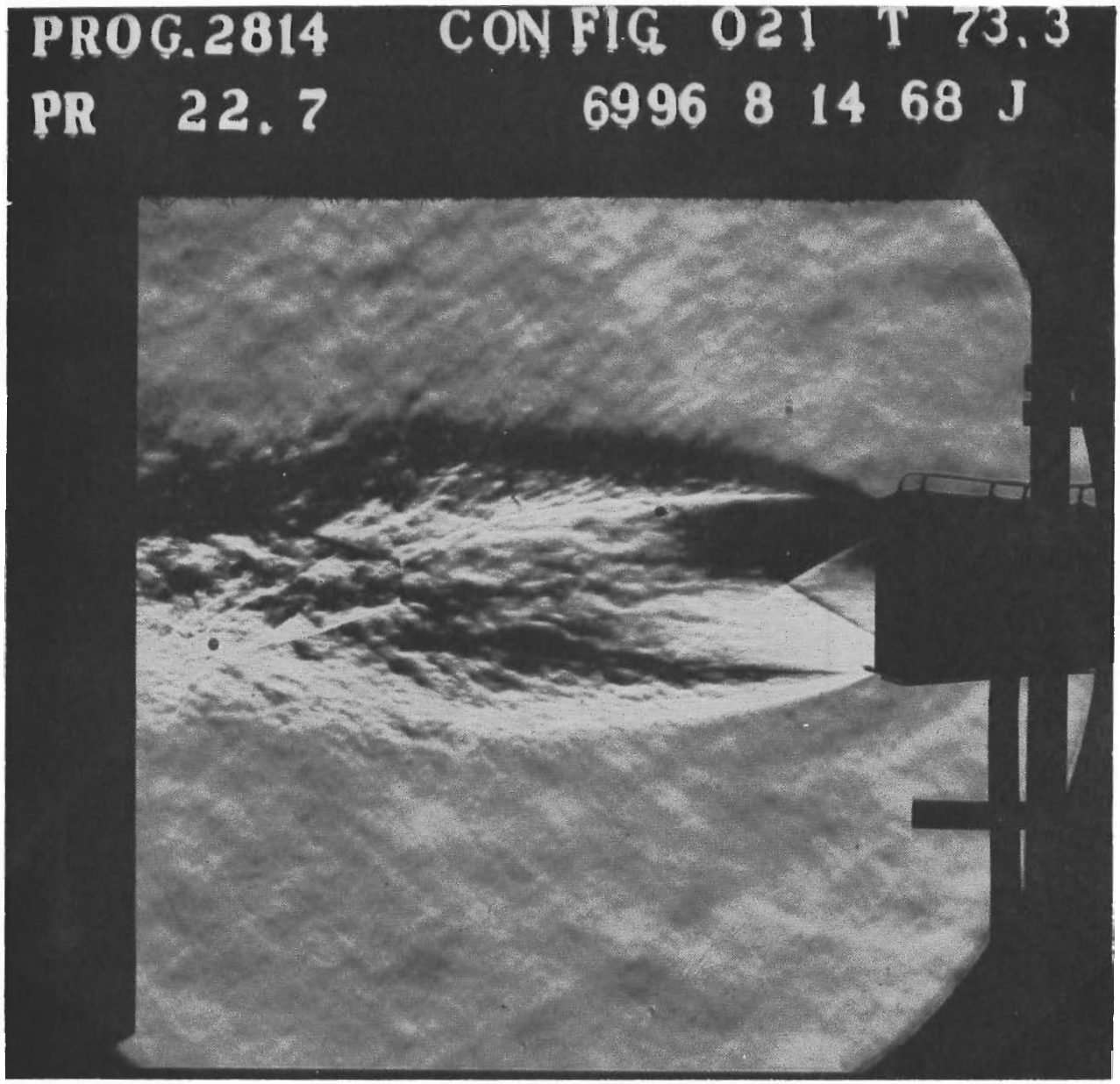


Figure 305. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Schlieren Photograph

Approved for Public Release

Contrails

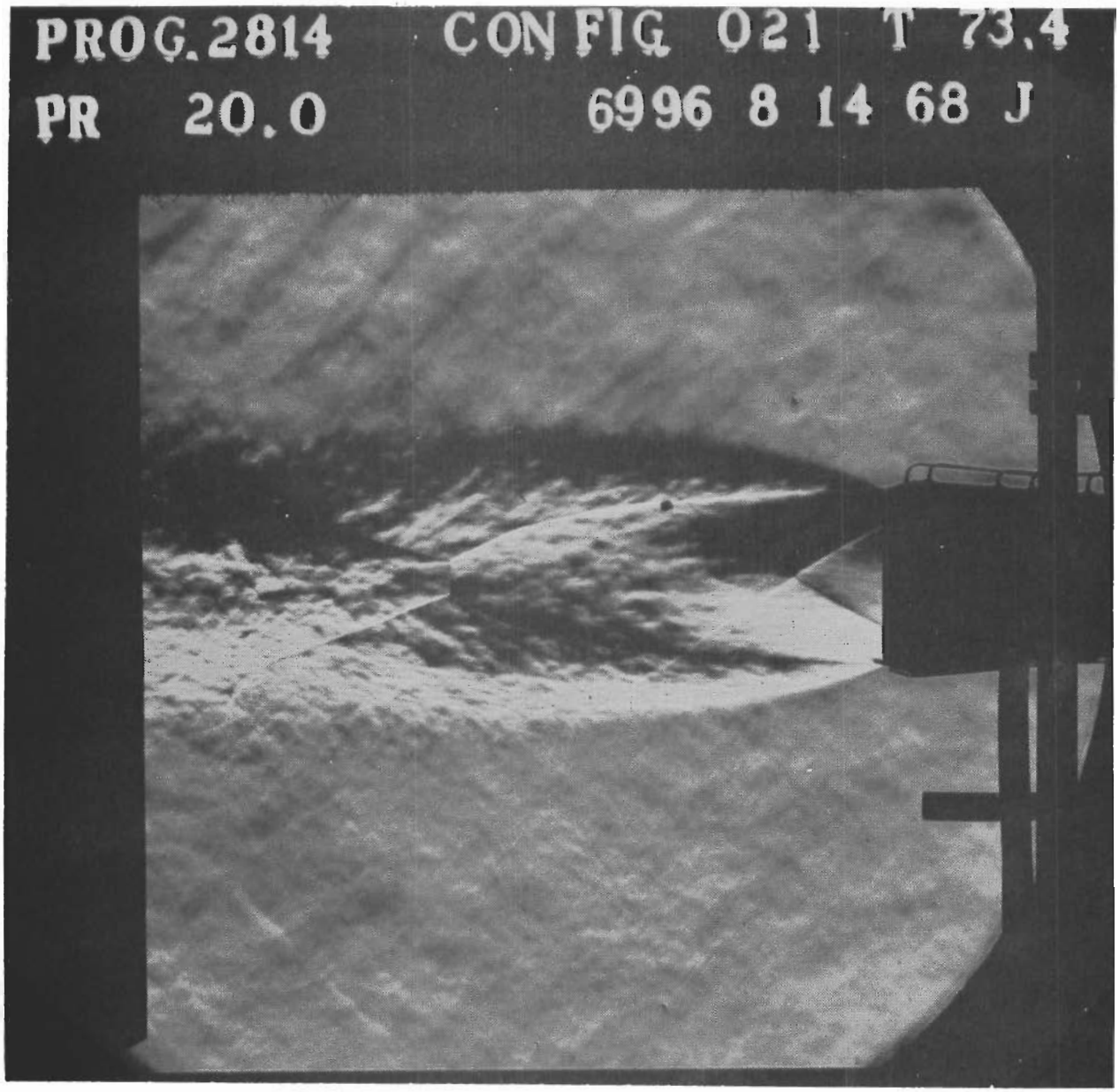


Figure 306. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Schlieren Photograph

Approved for Public Release

Contrails

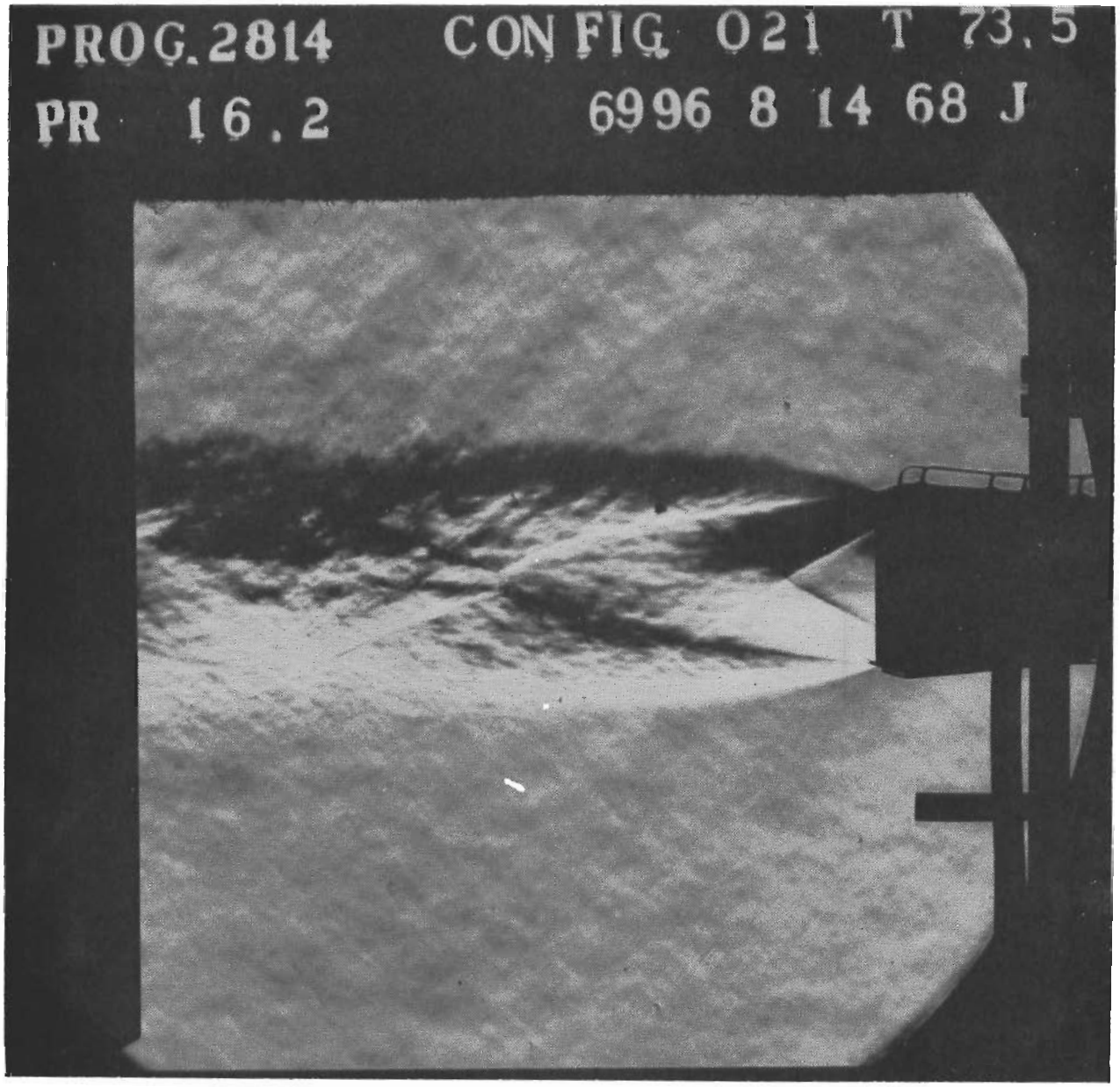


Figure 307. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Schlieren Photograph

Approved for Public Release

Contrails

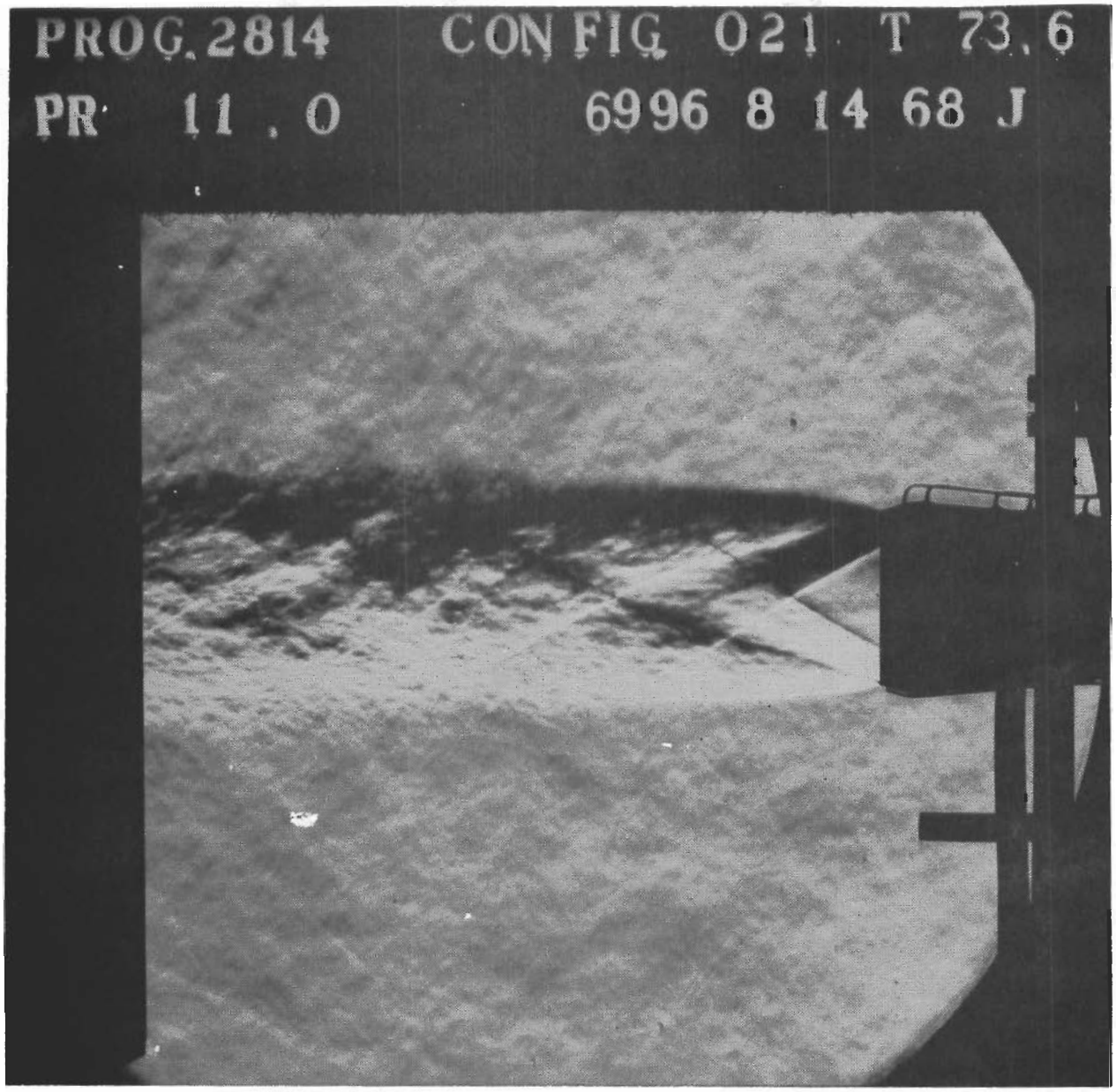


Figure 308. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Schlieren Photograph

Approved for Public Release

Contrails

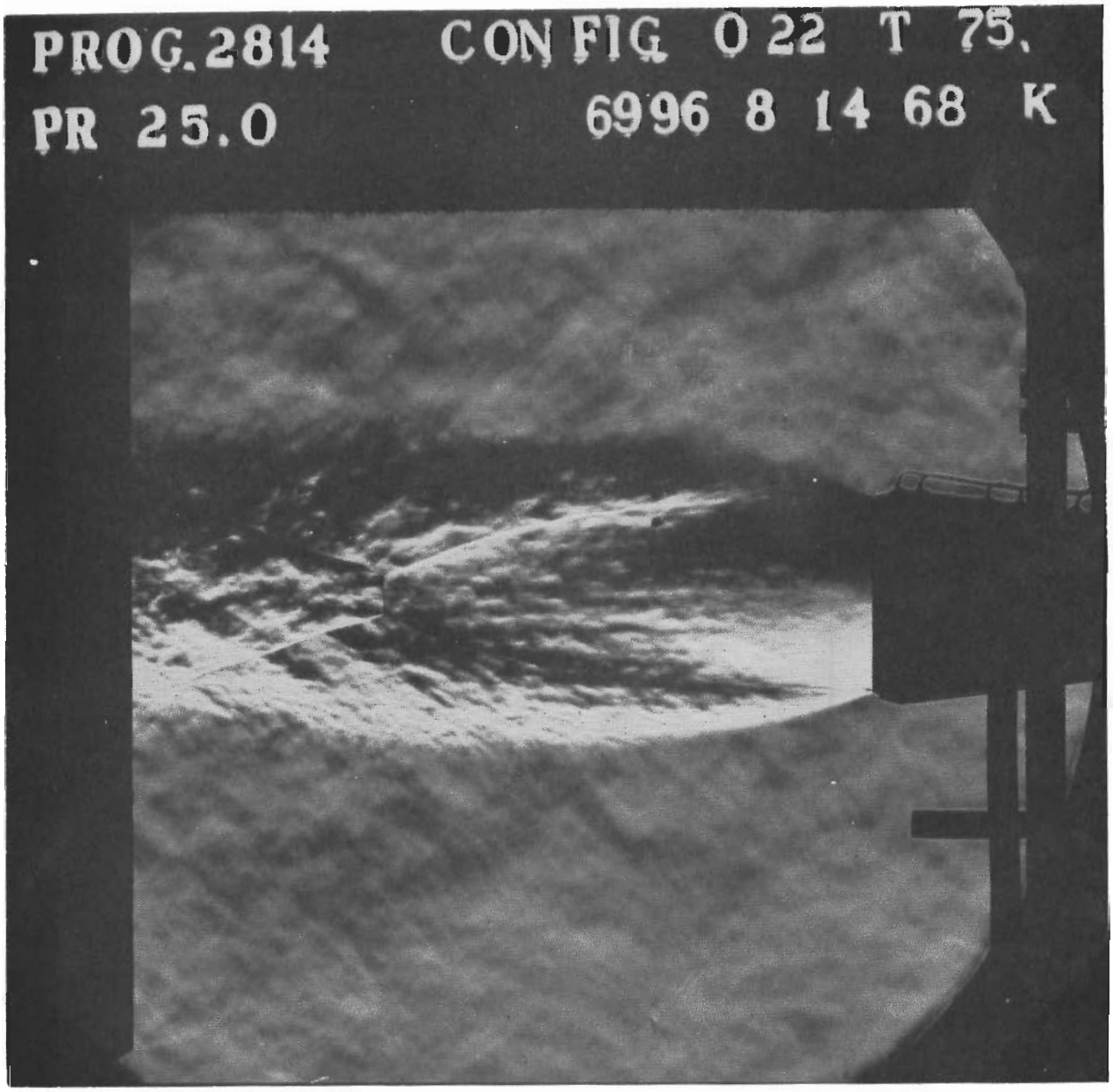


Figure 309. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Schlieren Photograph

Approved for Public Release

Contrails

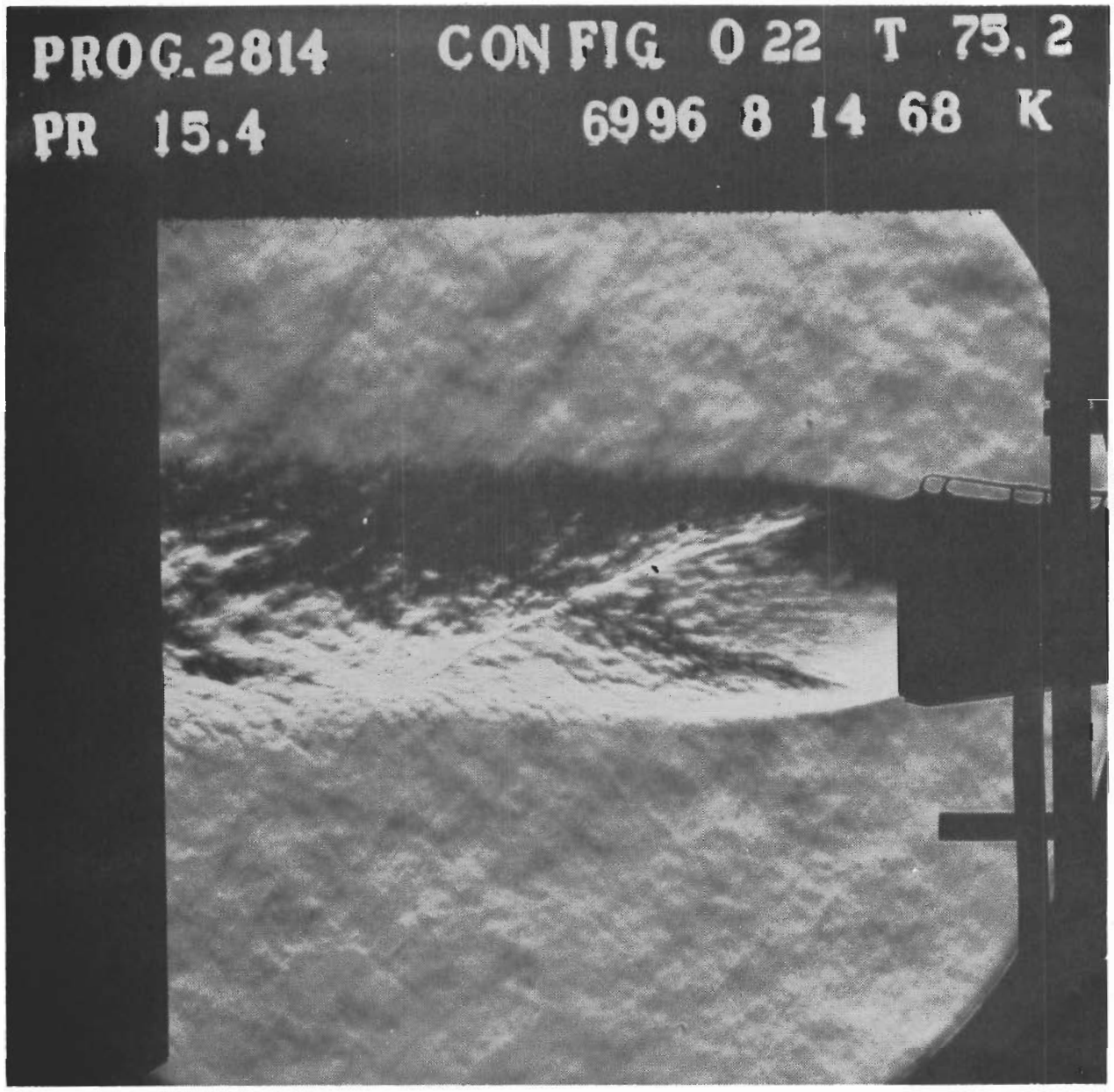


Figure 310. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Schlieren Photograph

Approved for Public Release

Contrails

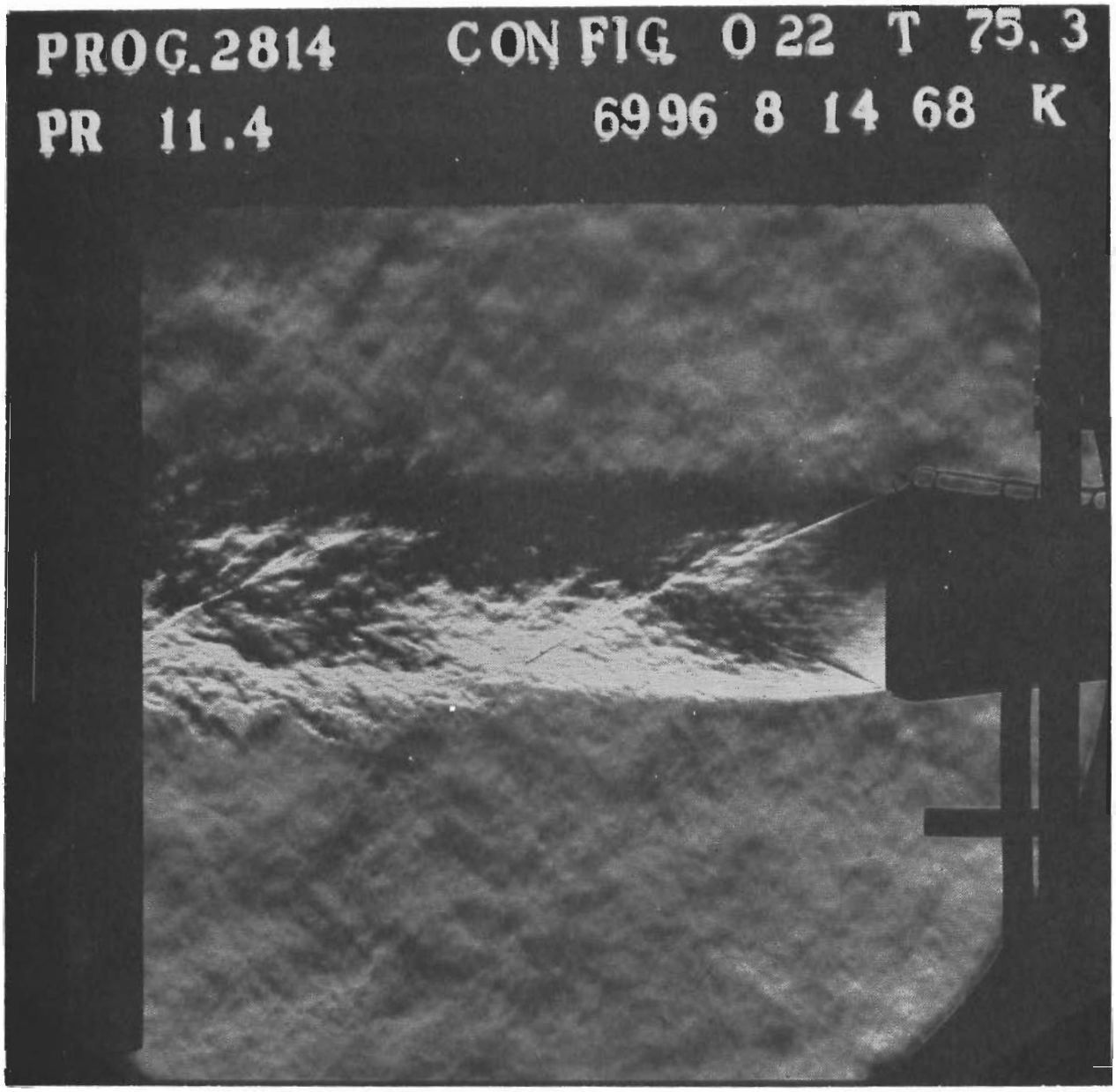


Figure 311. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Schlieren Photograph

Approved for Public Release

Contrails

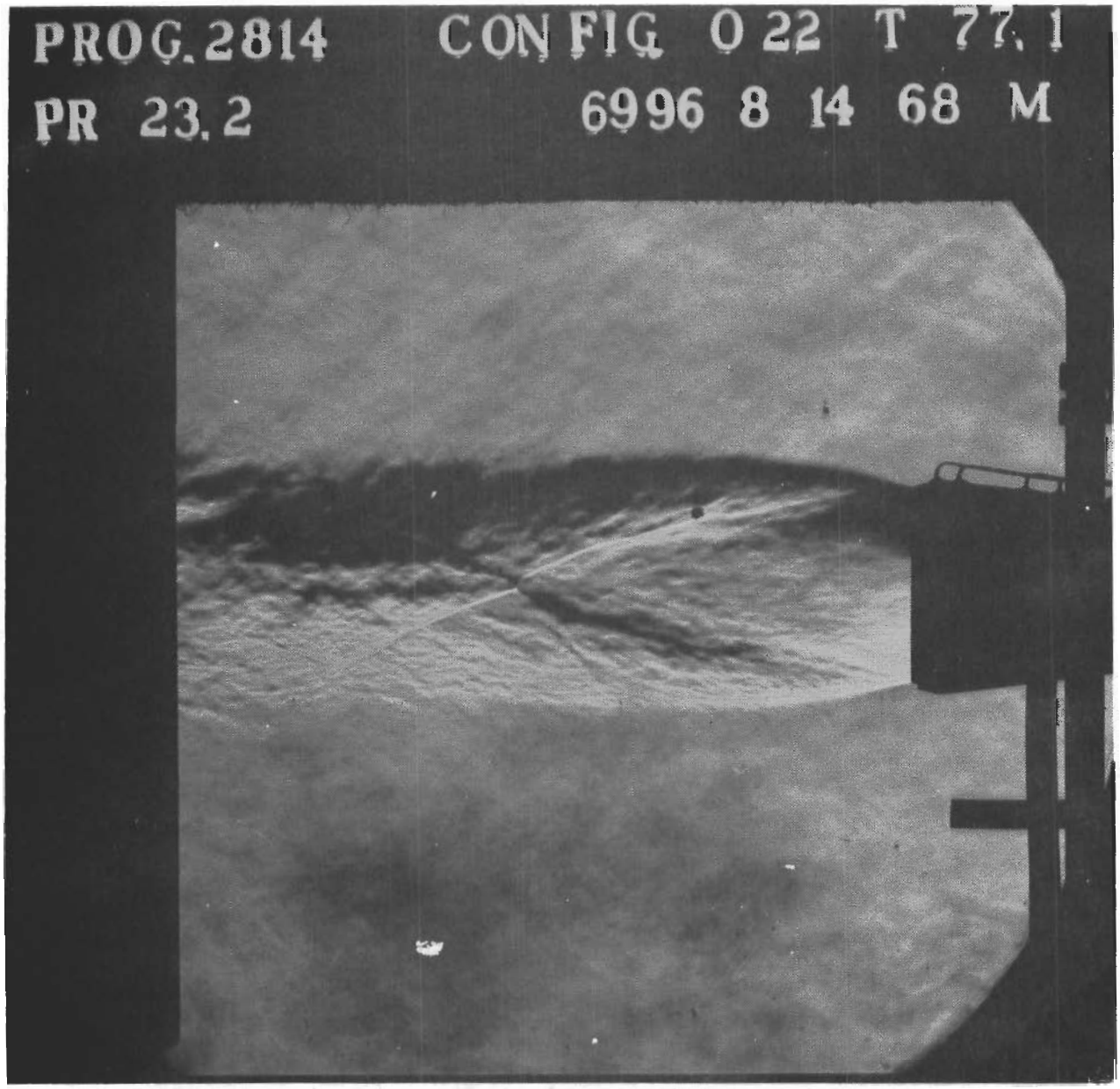


Figure 312. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Schlieren Photograph

Approved for Public Release

Contrails

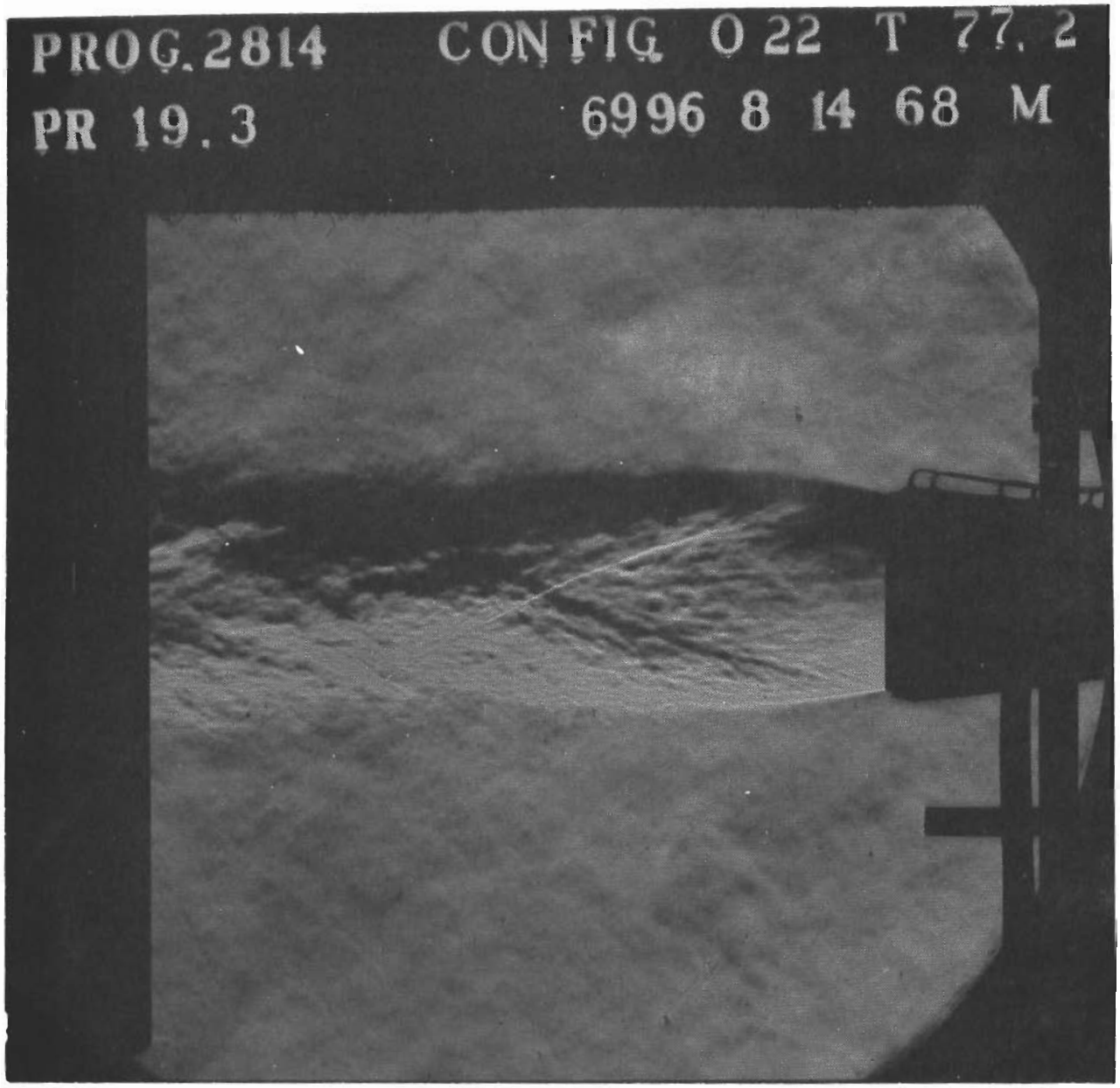


Figure 313. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Schlieren Photograph

Approved for Public Release

Contrails

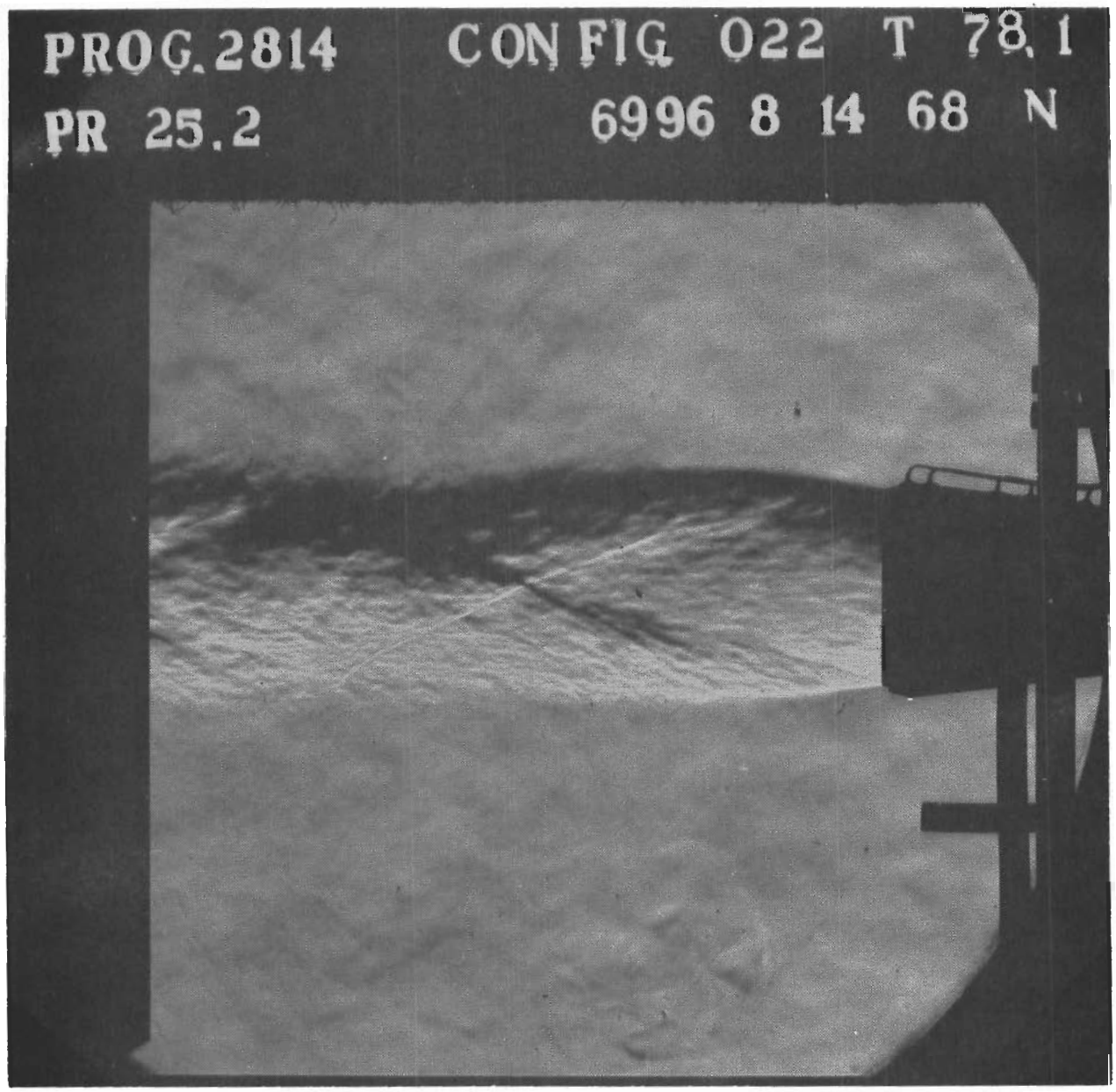


Figure 314. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Schlieren Photograph

Approved for Public Release

Contrails

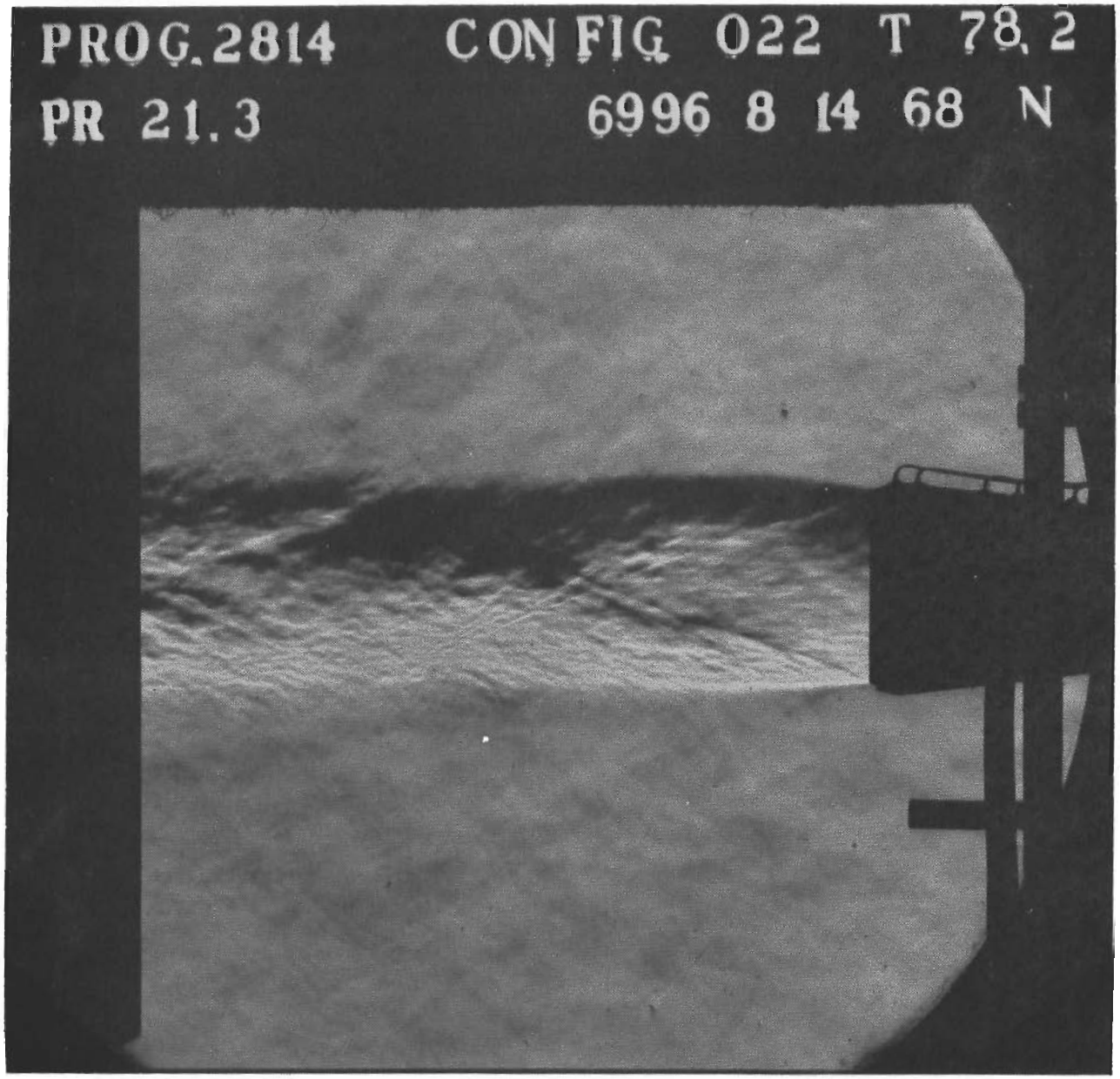


Figure 315. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Schlieren Photograph

Approved for Public Release

Contrails

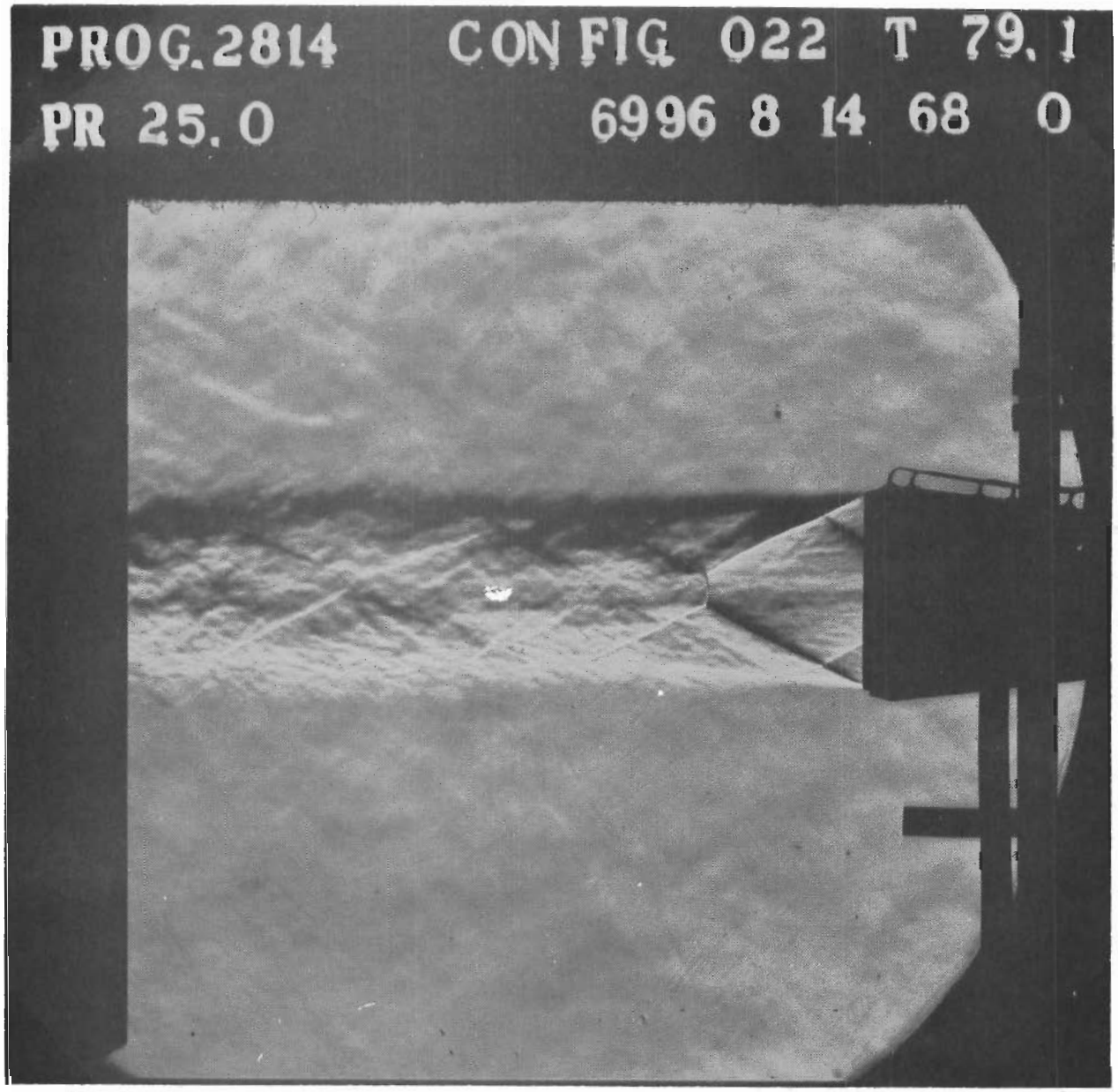


Figure 316. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Schlieren Photograph

Approved for Public Release

Contrails

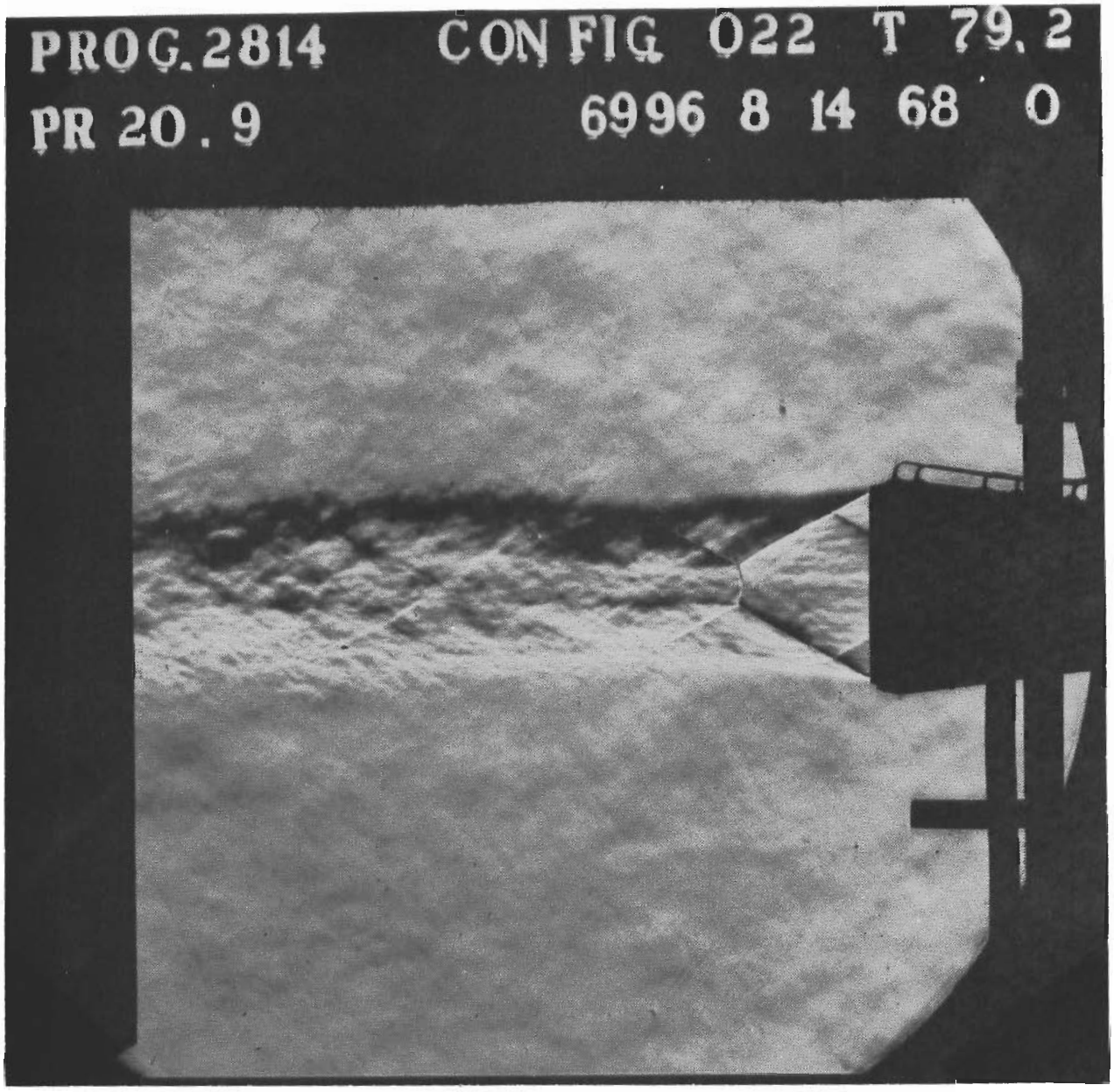


Figure 317. Shared Exit Ejector Nozzle Static Tests - Satellite Mode Schlieren Photograph

(The reverse of this page is blank)

Approved for Public Release

Contrails

Unclassified

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)*
Los Angeles Division of
North American Rockwell Corporation

2a. REPORT SECURITY CLASSIFICATION
Unclassified

2b. GROUP
—

3. REPORT TITLE
SHARED EXIT EJECTOR NOZZLE STATIC TESTS
PROPULSION SYSTEM INTEGRATION AND TEST PROGRAM (STEADY STATE)

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*
Phase II Phase End Technical Report (23 July 1968 through 5 September 1968)

5. AUTHOR(S) *(First name, middle initial, last name)*
David L. Alfano

6. REPORT DATE
June 1969

7a. TOTAL NO. OF PAGES
390 + i - viii

7b. NO. OF REFS
5

8a. CONTRACT OR GRANT NO.
F33615-67-C-1829

b. PROJECT NO.
3066

c.

d.

9a. ORIGINATOR'S REPORT NUMBER(S)
NA-68-939
Part II

9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*
AFAPL-TR-69-44, Pt II

10. DISTRIBUTION STATEMENT This document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of The Air Force Aero Propulsion Laboratory (APTA), Research and Technology Division, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio.

11. SUPPLEMENTARY NOTES
—

12. SPONSORING MILITARY ACTIVITY
Air Force Aero Propulsion Laboratory/APTA
Air Force Systems Command
Wright Patterson Air Force Base, Ohio 45433

13. ABSTRACT

A program for designing and conducting tests on a shared exit ejector nozzle was formulated to provide experimental verification of available analytic techniques, where applicable, and to provide data at those conditions where analytic techniques were not applicable so that this nozzle concept could be evaluated. The test plan was formulated around the complete spectrum of engine cycle data for an Integrated Propulsion System Tactical Fighter. Results from this test program indicate that the reliability of the available analytic techniques for predicting nozzle performance is dependent on an accurate estimate of the internal losses and aerodynamic flow areas involved. The model performance was generally better than predicted. Where analytic techniques are not available, model performance has been observed to be generally greater than 97 percent of ideal thrust.

DD FORM 1 NOV 65 1473

Unclassified

Security Classification

Approved for Public Release

Contrails

Unclassified
Security Classification

14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
Exhaust Nozzle						
Ejector						
Ejector Nozzle, Shared Exit						

Unclassified
Security Classification

Approved for Public Release