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(NASA-CR-159816) DATA ANALYSIS OF P SUB T/P SUB S NOSEBOOM PROBE TESTING ON F100 ENGINE P680072 AT NASA LEWIS RESEARCH CENTER Final Report (Pratt and Whitney Aircraft Group) 23 p HC A02/MF A01 CSCL 21E G3/07

N80-21334

Unclas 46831

NASA CR-159816

DATA ANALYSIS OF P_T/P_S NOSEBOOM PROBE TESTING ON F100 ENGINE P680072 AT NASA LEWIS RESEARCH CENTER

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Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Lewis Research Center
Cleveland, Ohio 44135

March 1980

Contract NAS3-19442

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INTRODUCTION

In July 1979, NASA-Lewis Research Center (LeRC) conducted a P_{S2} noseboom probe test on F100 engine P680072. Design of the testing provided an evaluation of the P_{S2} probe sensing ability in the control of the F100 engine utilizing an Engine Pressure Ratio (EPR) mode of control. Figure 1 shows the test configuration. The primary program objective was to verify P_{S2} noseboom measurements to P_{T2} correlation at altitude points for clean inlet and classical inlet distortion patterns. Follow-on tests are planned for an F-15 inlet correlation in the NASA F-15 aircraft. Additional objectives included verification of the altitude distortion rematch effects and correlation of measured Fan Pressure Ratio/Engine Pressure Ratio with the P6M engine production probe. The data was also intended to support Backup Control (BUC) schedules required for planned NASA F-15 DEEC flight testing and FADEC/INTERACT flight test programs.

The program utilized the following inlet configurations and operating conditions with the distortion support grate located 60 in. in front of the engine:

- Clean inlet (pre- and post-distortion testing)
- 180° circumferential (5.5 × 5.5 × 0.063 in.) located at 0° to 180° and 180°-0° positions
- OD radial (5.0 × 5.0 × 0.063 in.)
- 0.9/30k (Mach number/altitude) composite
- 90° circumferential (5.5 × 5.5 × 0.063 in.) located at 210 to 300°, 240 to 330°, and 330 to 360° positions
- Calibrations at 10 psia inlet pressure used T_{T2} = 30-45°F
- Calibrations at 2, 4, and 5.8 psia used T_{T2} = 20°F

Locked nozzle airflow calibrations were made at inlet pressure settings of 10, 4, and 2 psia with inlet total pressures recorded with a 34-probe instrumented inlet case. The prototype P_{S2} probe and backup control inlet case static ports were used for the PT/PS calibration.

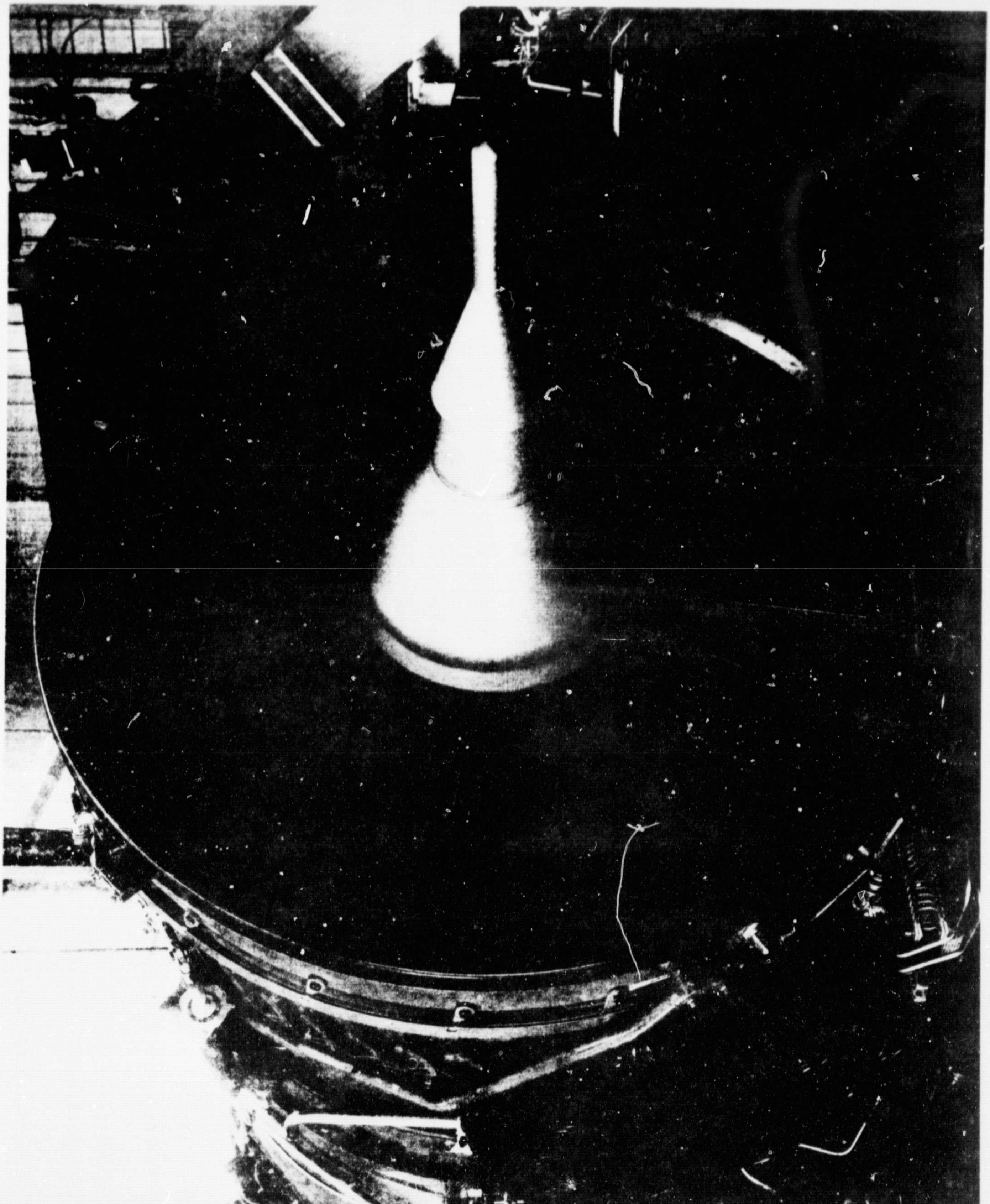

Figure 1. P_{S2} Noseboom Probe Test At NASA Lewis Research Center

DISCUSSION

PT/PS CORRELATION

The F100 engine P680072 clean inlet calibrations at near sea-level conditions agree identically with FX225 and FX227 tests at P&WA/Florida. These three tests show a lower PT/PS correlation than the current G04 schedule. Figure 2 details a comparison between the G04 schedule and current test results. The lower correlation results from the reduction in length of the DEEC P_{S2} probe and a difference between bellmouth and engine face P_{T2} measurements.

LOW-PRESSURE ALTITUDE SHIFT

A comparison of the calibrations at 10, 4, and 2 psia inlet pressure determined the low-pressure effects on the PT/PS correlation. The 2 psia calibration produced a maximum PT/PS shift of 0.5%. The 4 and 10 psia calibrations were identical. Figure 3 shows the low-pressure altitude shift in PT/PS for the clean inlet configuration.

The FX215-18 test at AEDC indicated at 1.5% increase for low inlet pressures, as indicated by comparison of intermediate points from several flight conditions through several test periods. However, the back-to-back P680072 calibrations are considered more reliable. This disagreement in low-pressure altitude shift should be resolved during the forthcoming FX227 testing at AEDC.

The distorted inlet configurations did not demonstrate an increase in the PT/PS correlation for low-pressures. Figure 4 presents the distorted inlet comparisons at inlet pressures of 10 and 2 psia. The difference between the clean and distorted inlet low-pressure shift may be the result of P_{T2} measurement uncertainty. Since the undistorted measurements are considered more reliable, the proposed DEEC schedule adjustment will include a low-pressure bias. Figure 5 illustrates the proposed G04 schedule.

DISTORTION SHIFT

The F100 engine P680072 test demonstrated PT/PS distortion shifts similar to previous sea-level tests with the same inlet distortion. Figure 6 plots the measured PT/PS shift for the distorted inlet configurations at an inlet pressure of 10 psia. Table 1 lists the agreement between the P680072 altitude test and sea-level tests at Government Products Division (GPD).

TABLE 1. PT/PS DISTORTION SHIFT COMPARISON (WAIC = 212 pps)

Distortion Pattern	*P044* GPD	*FX225* GPD	*P0072*[1] LeRC	P0072[2] LeRC
OD	0.5%	0.6%	0.6%	0
180°	2.5%	1.7%	3.3%	2.7%
0.9/30k	—	—	1.7%	2.0%

[1] P_{T2} = 10 psia
[2] P_{T2} = 2 psia

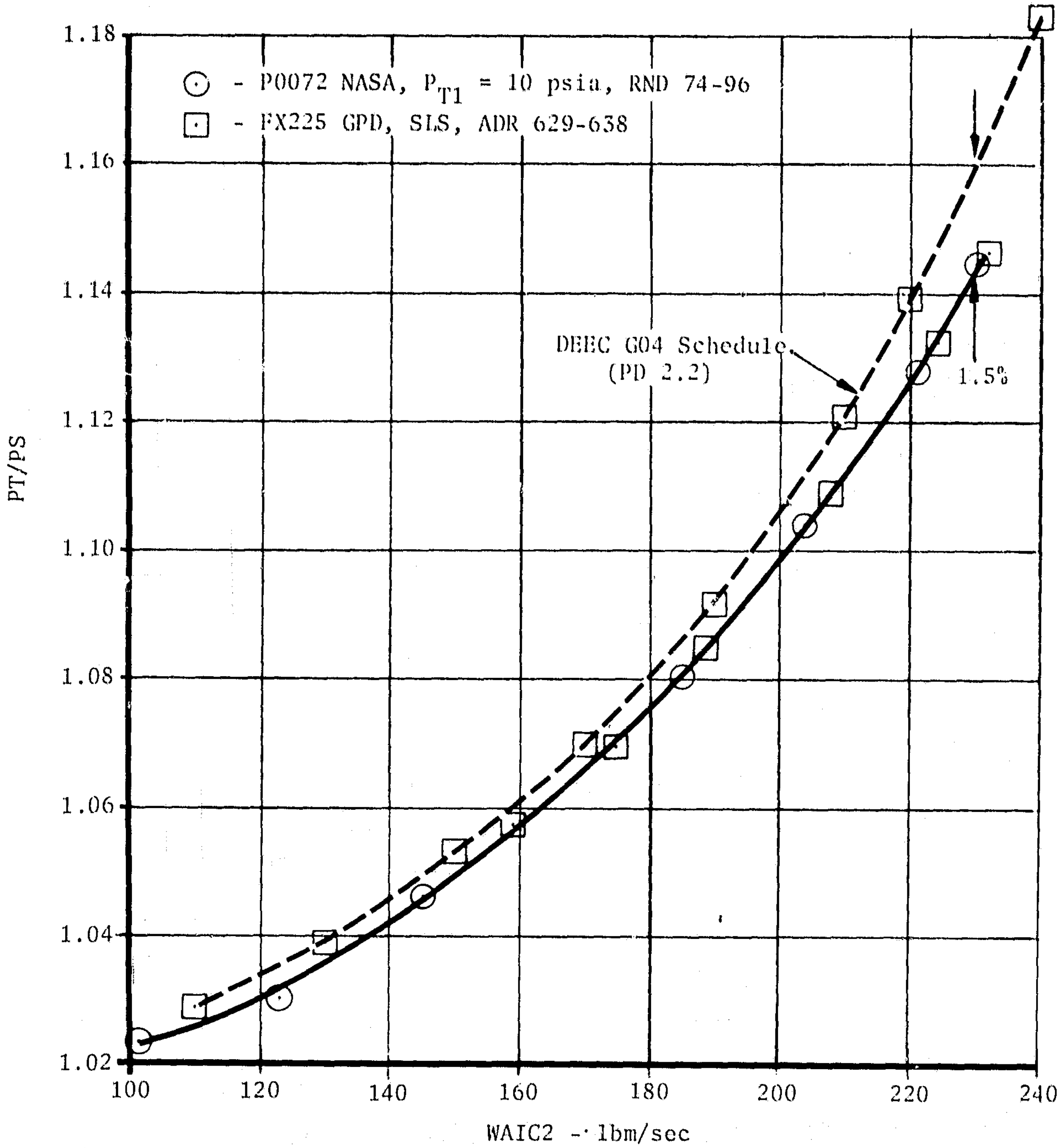

Figure 2. Current Test Results Show Lower PT/PS Correlation

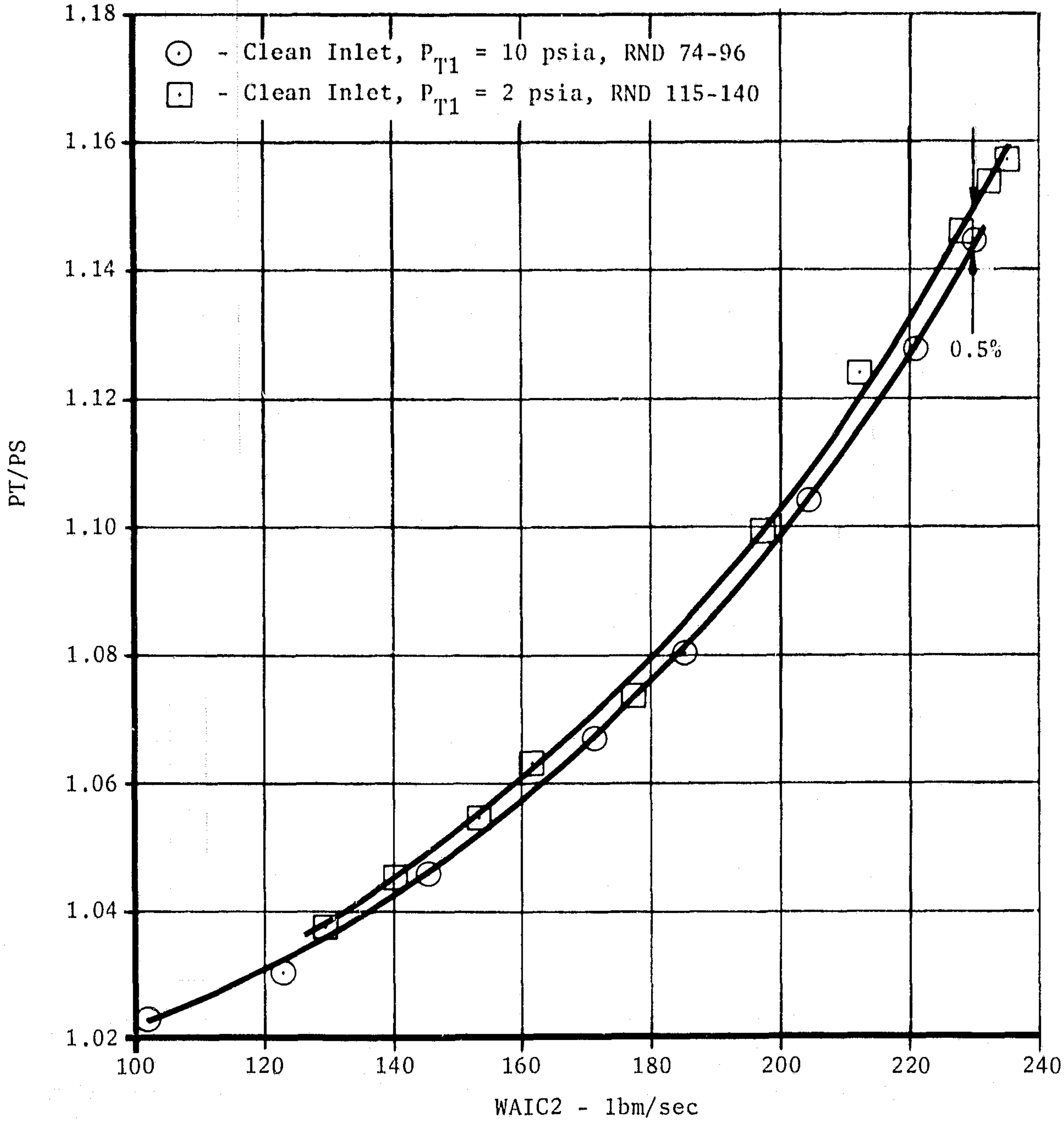

Figure 3. P0072 Shows Up to 0.5% Low Pressure Bias

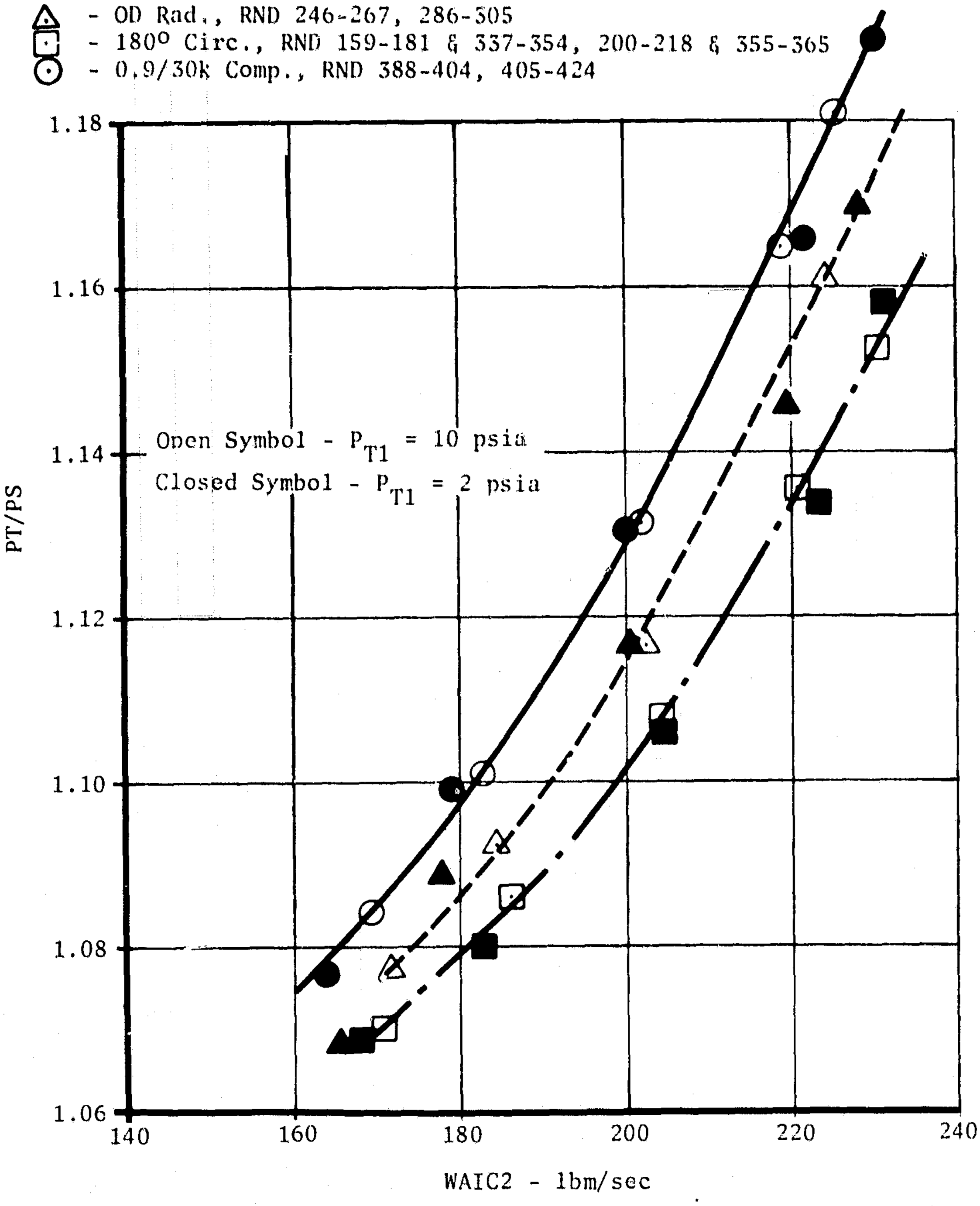

Figure 4. Distortion Calibrations Show No Shift in PT/PS For Low Pressures

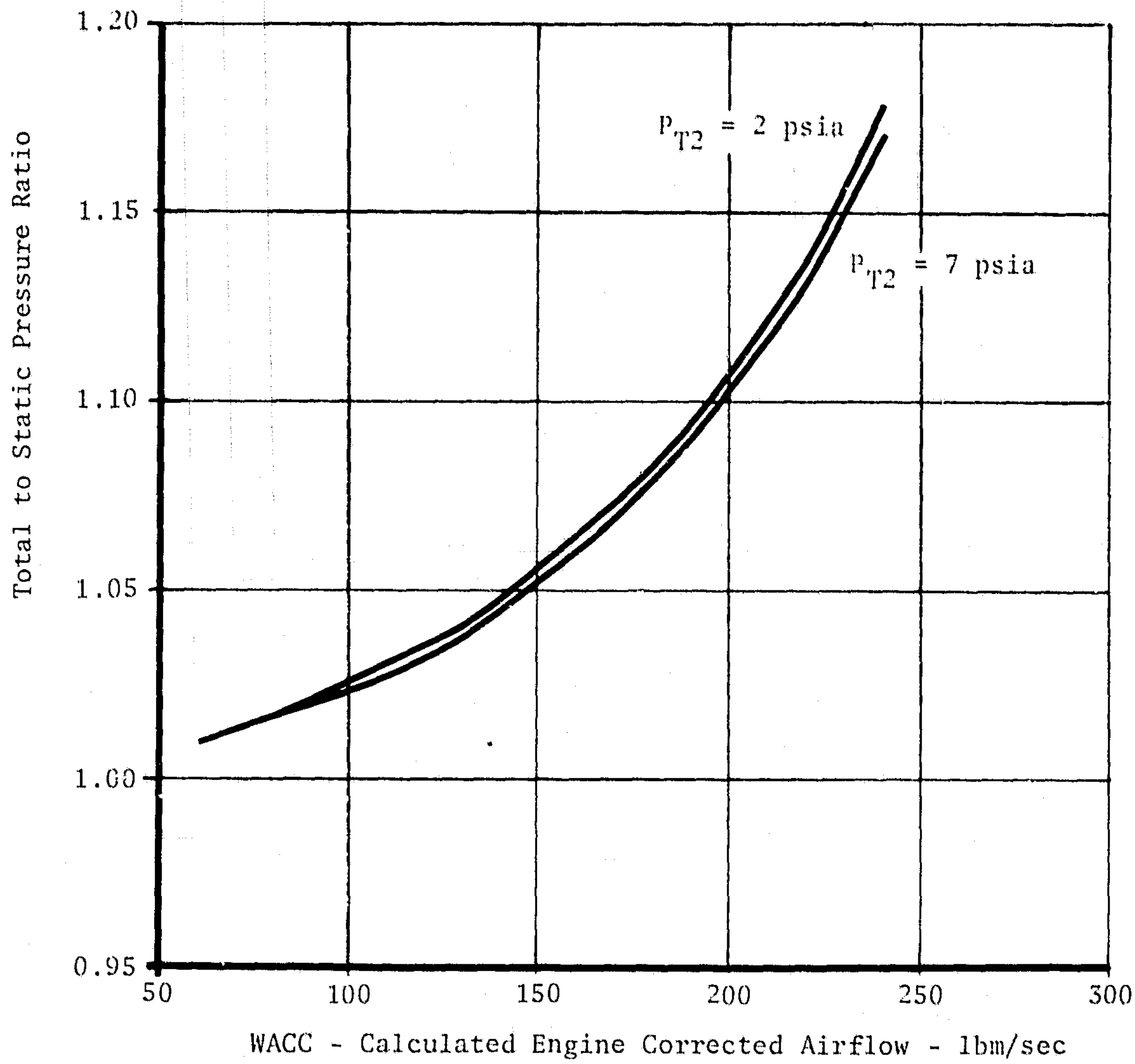

Figure 5. Digital Electronic Engine Control - G04 Engine Inlet Total to Static Pressure Ratio

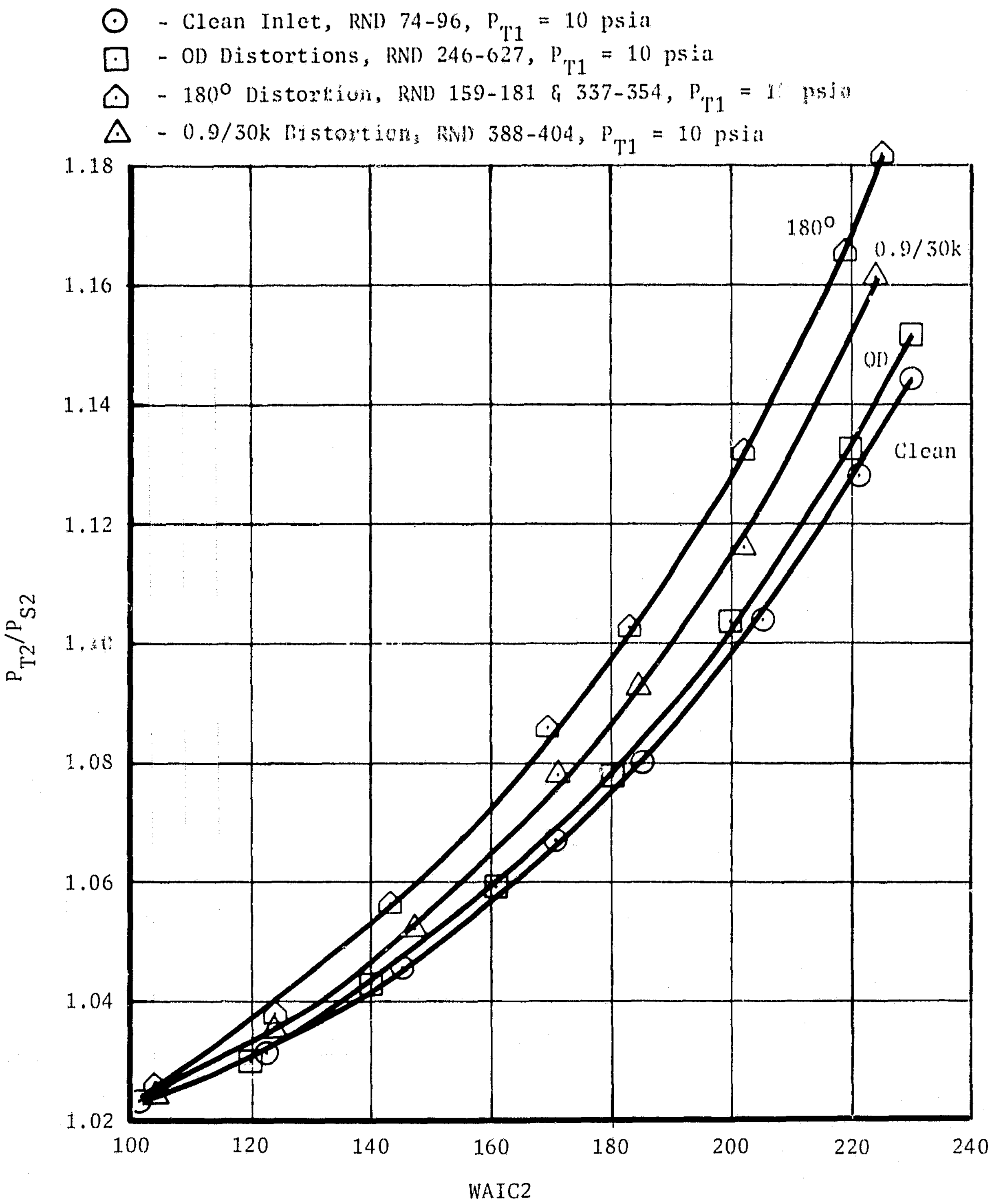

Figure 6. P0072 Demonstrates Distortion Rematch

BUC INLET CASE STATIC PRESSURE

A singular tap and three manifolded taps provided the means to record static pressures in the engine inlet case. These static pressure measurements were proposed as an independent P_{s2} source for the DEEC backup control. For distorted flow, sea-level tests show that the manifolded pressures more accurately represent P_{s2} than the singular pressure measurement. However, the locations of the pressure taps result in a lower P_{s2} measurement and a higher distortion shift when compared to the DEEC P_{s2} probe measurements. Figure 7 shows the difference between the BUC and P_{s2} DEEC measurements. The present BUC schedule allows operation with either P_{s2} source, but specification performance may require schedule adjustments.

A change in the orientation of a circumferential distortion pattern causes a change in distortion shift with BUC P_{s2}. This effect results from the location and number of taps in the inlet case. Figure 8 reproduces the variations for two different positions of the 180-deg pattern.

At an inlet pressure of 2 psia, the BUC P_{s2} shows an increase in altitude PT/PS shift when compared to the DEEC P_{s2} probe measurements. Figure 9 illustrates a 2.5% PT/PS increase for the clean inlet configuration. Other comparisons of BUC and DEEC P_{s2} show considerable data scatter for the manifolded inlet case P_{s2} measurements. The singular inlet case P_{s2} measurement appears to have less scatter than the manifolded P_{s2}. Figure 10 details both measurements compared to the DEEC P_{s2}. These results should be investigated further during the FX227 altitude test.

PRODUCTION P6M PROBE

Production P6M probe accuracy with inlet distortion was verified. The production probe measurements were compared to the 40-probe mass-weighted development rake P6M. Figure 11 plots the two measurements and shows that they agree within 0.5% for both clean and distorted inlet configurations.

AIRFLOW

The fan airflow measured at NASA-LeRC was 2% higher than GPD calibrations and 1% higher than nominal F100(3) speed flow. Figures 12 and 13 show the speed flow relationships. For correlations involving airflow, the NASA-measured airflow was adjusted down by 1% to provide an average of GPD and NASA calibrations.

At intermediate airflow, the NASA data does not indicate measurable Reynolds number effects at upper left-hand corner conditions. The part power settings at this condition show a 3 to 4% airflow reduction. Figure 14 shows this comparison.

The distorted speed flow shift for this test was 1.6% or less. The loss or gain in flow is shown in Table 2 with comparisons made for the calibrations at 10 psia inlet pressure.

TABLE 2. FAN SPEED FLOW SHIFT WITH DISTORTION

	Δ% WAT2C		
% N1C2	180°	OD	0.9/30k
106	−0.9	+0.1	−1.6
104	−0.9	0	0
98	−0.7	+0.6	−0.7
93	−0.5	+0.4	−0.3

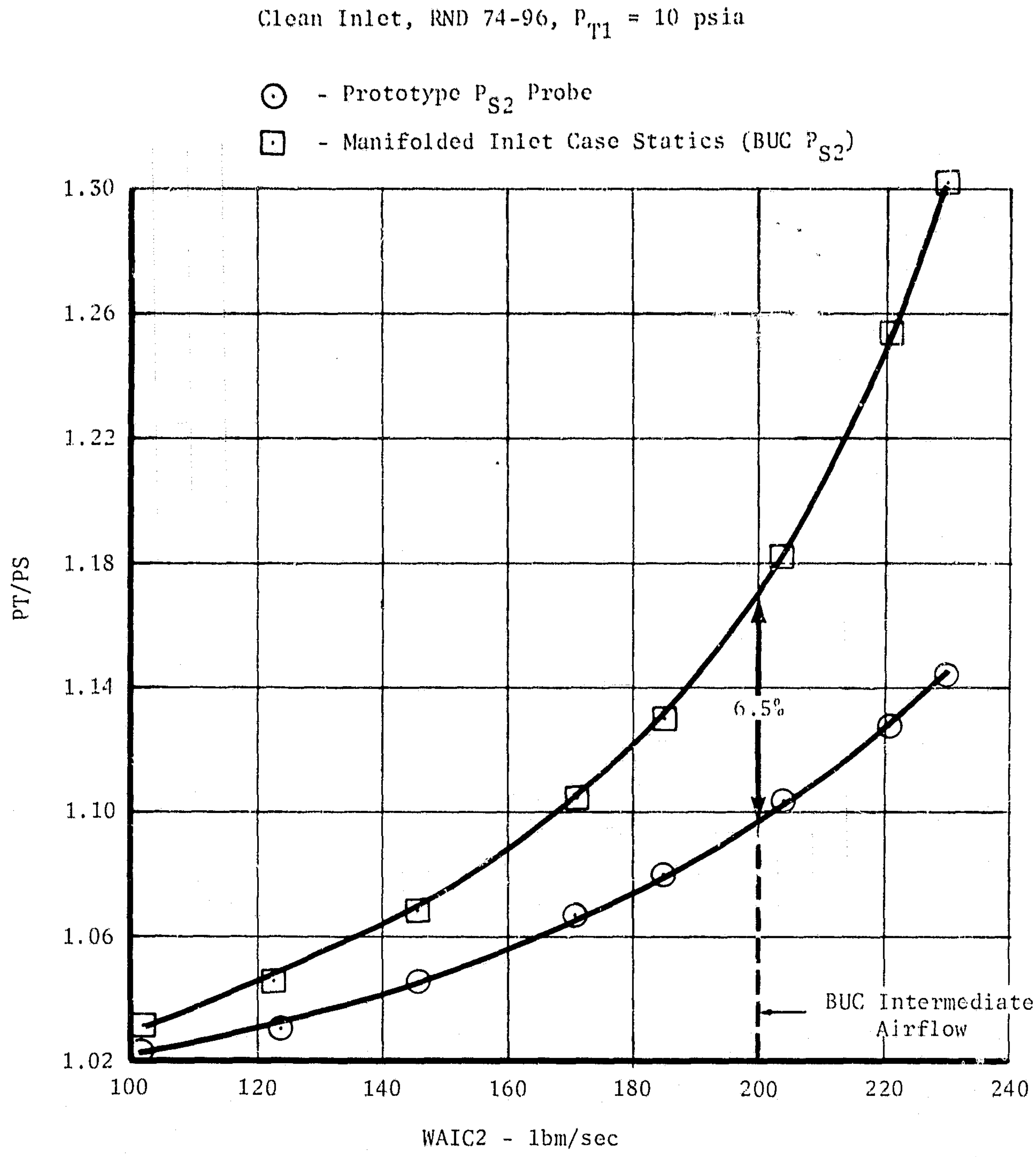

Figure 7. BUC P_{S2} 6.5% Lower than DEEC P_{S2}

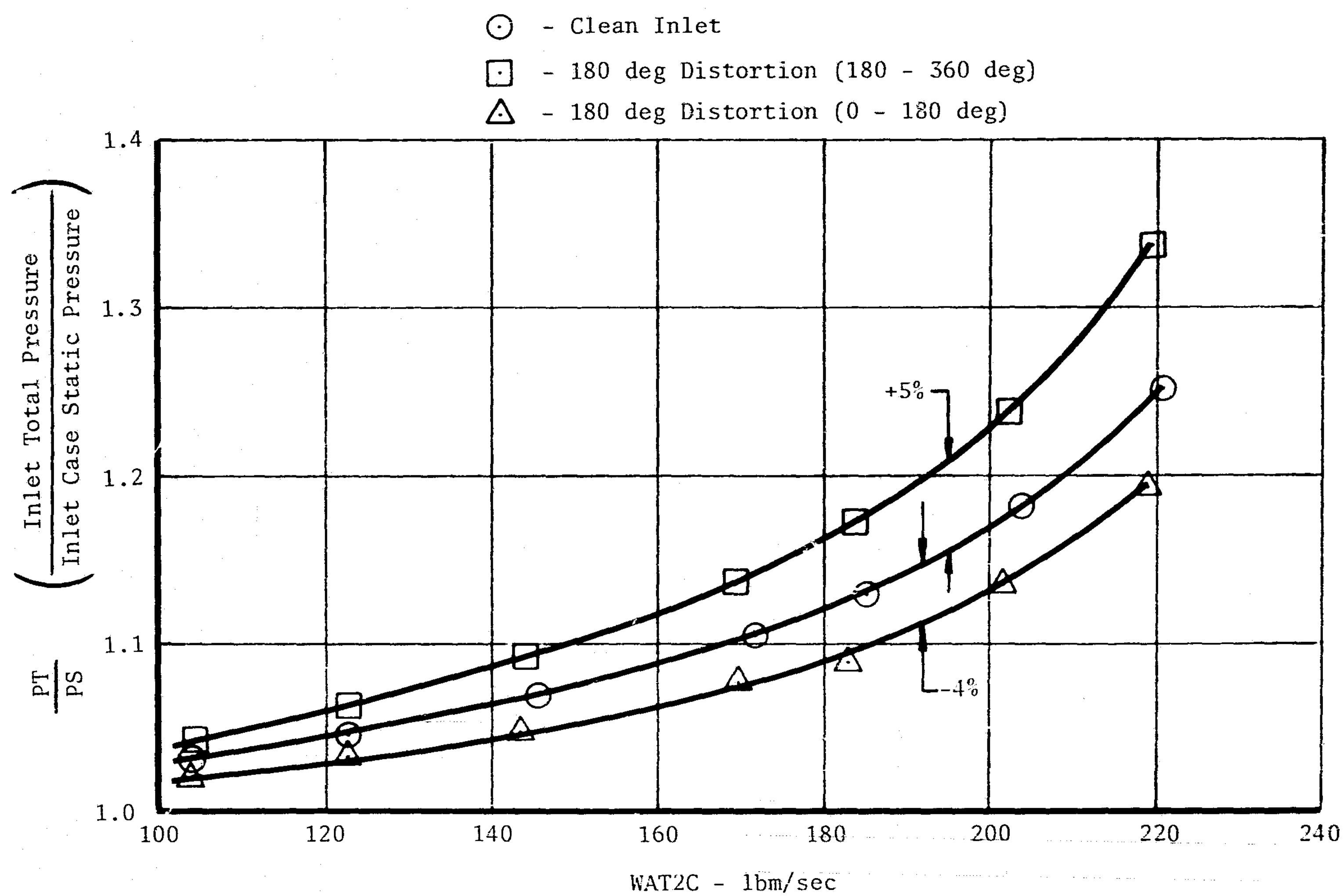

Figure 8. Variations for Two Different Positions of 180° Pattern

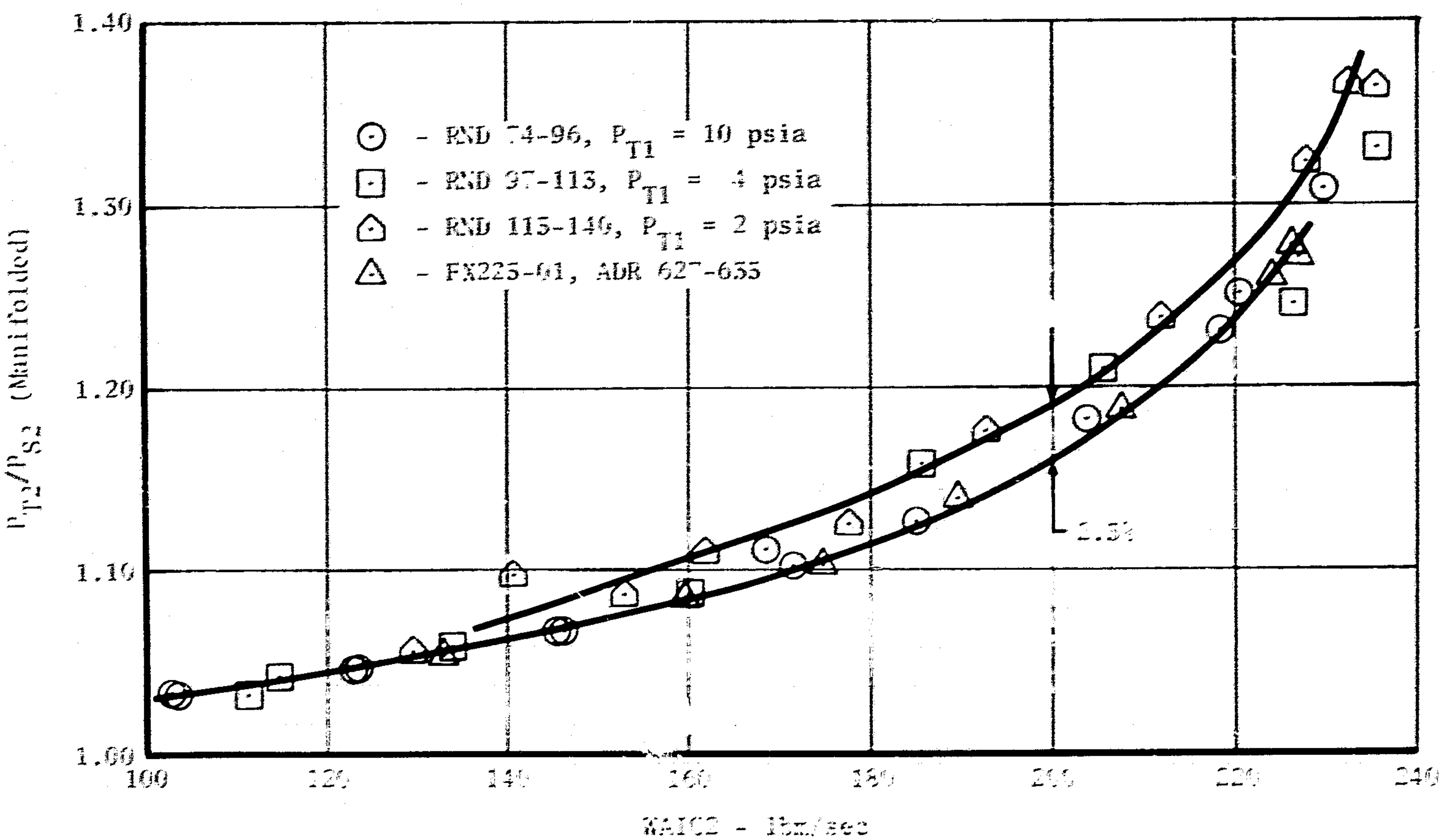

Figure 9. Altitude Variation in P_{T2}/P_{S2} Using BUC P_{S2}.

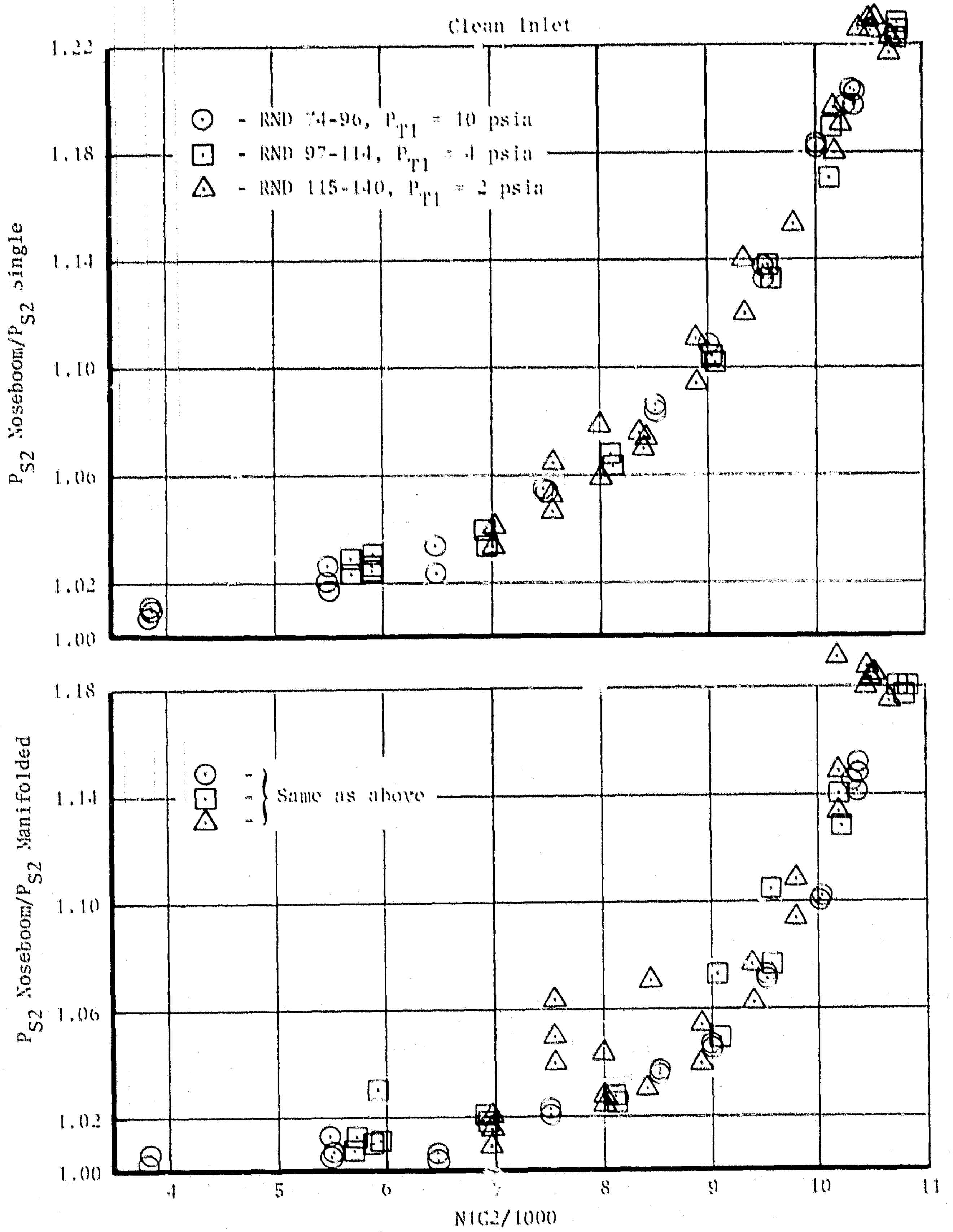

Figure 10. Comparison of BUC P_{S2} Single and Manifolded Pressure to DEEC Primary P_{S2}

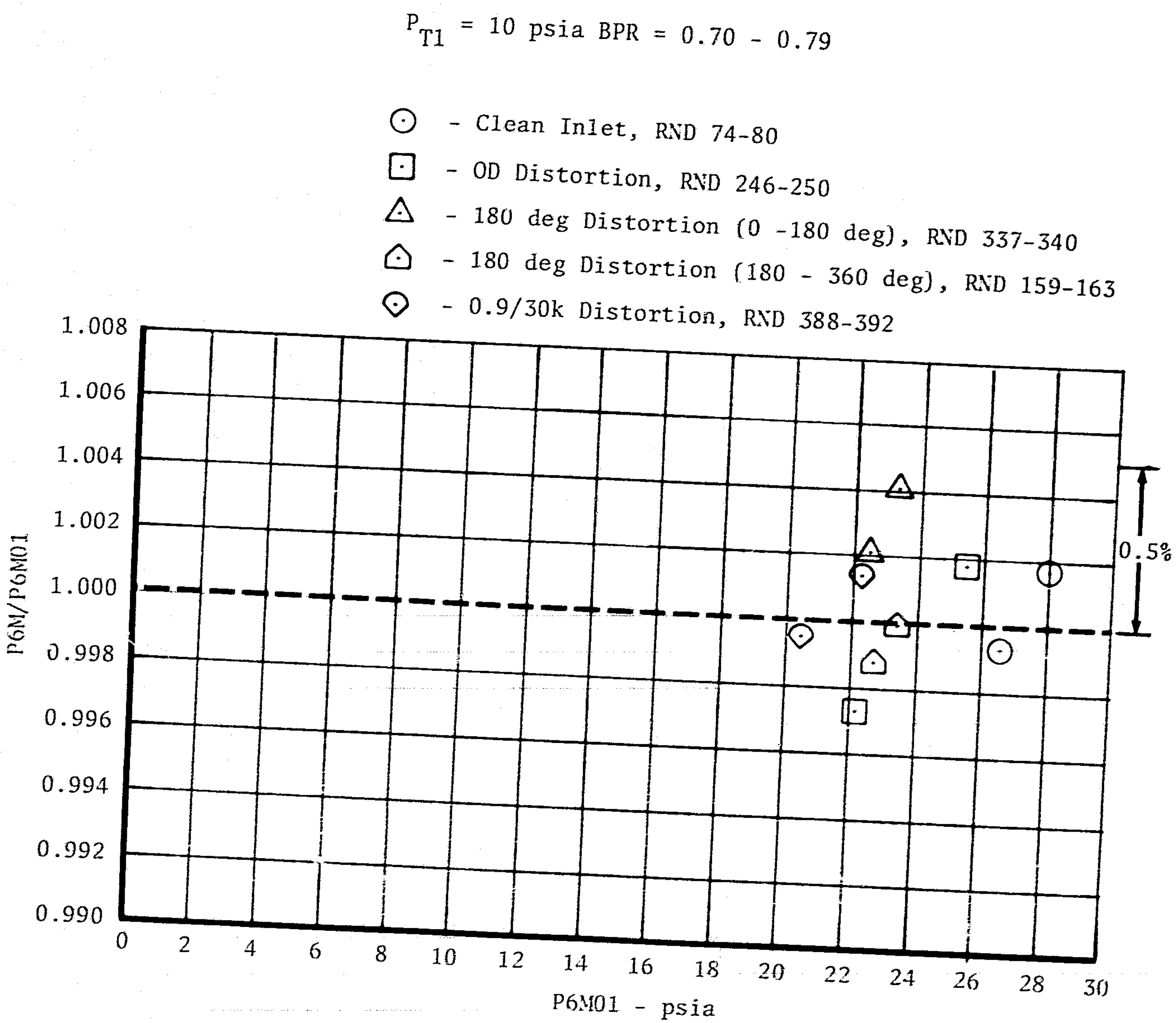

Figure 11. Station 6 Production Probe Indicates Mass Weighted Total Pressure With and Without Inlet Distortion

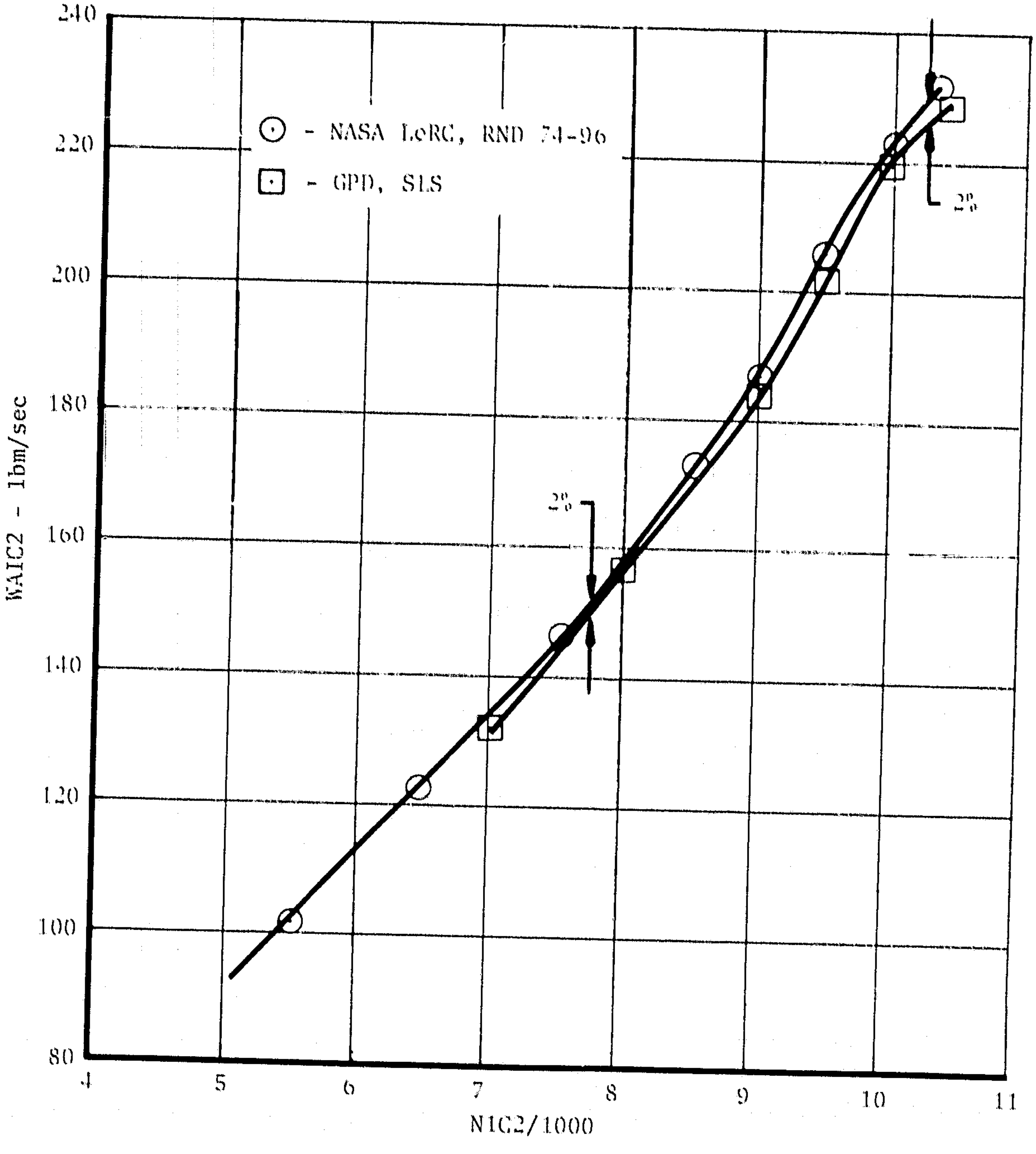

Figure 12. NASA LeRC Measured Airflow 2% Higher than GPD

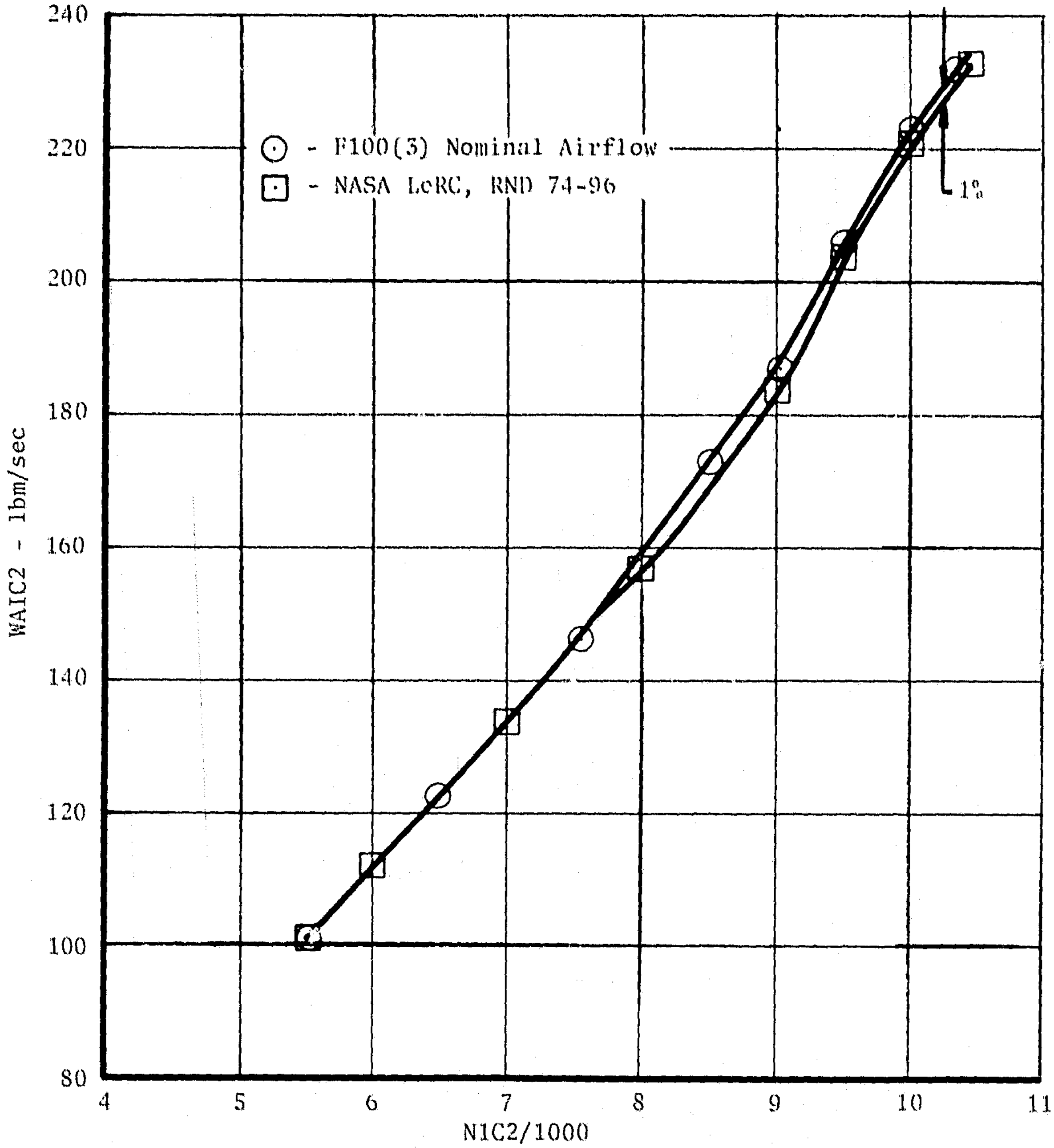

Figure 13. NASA LeRC Measured Airflow 1% Higher Than Nominal

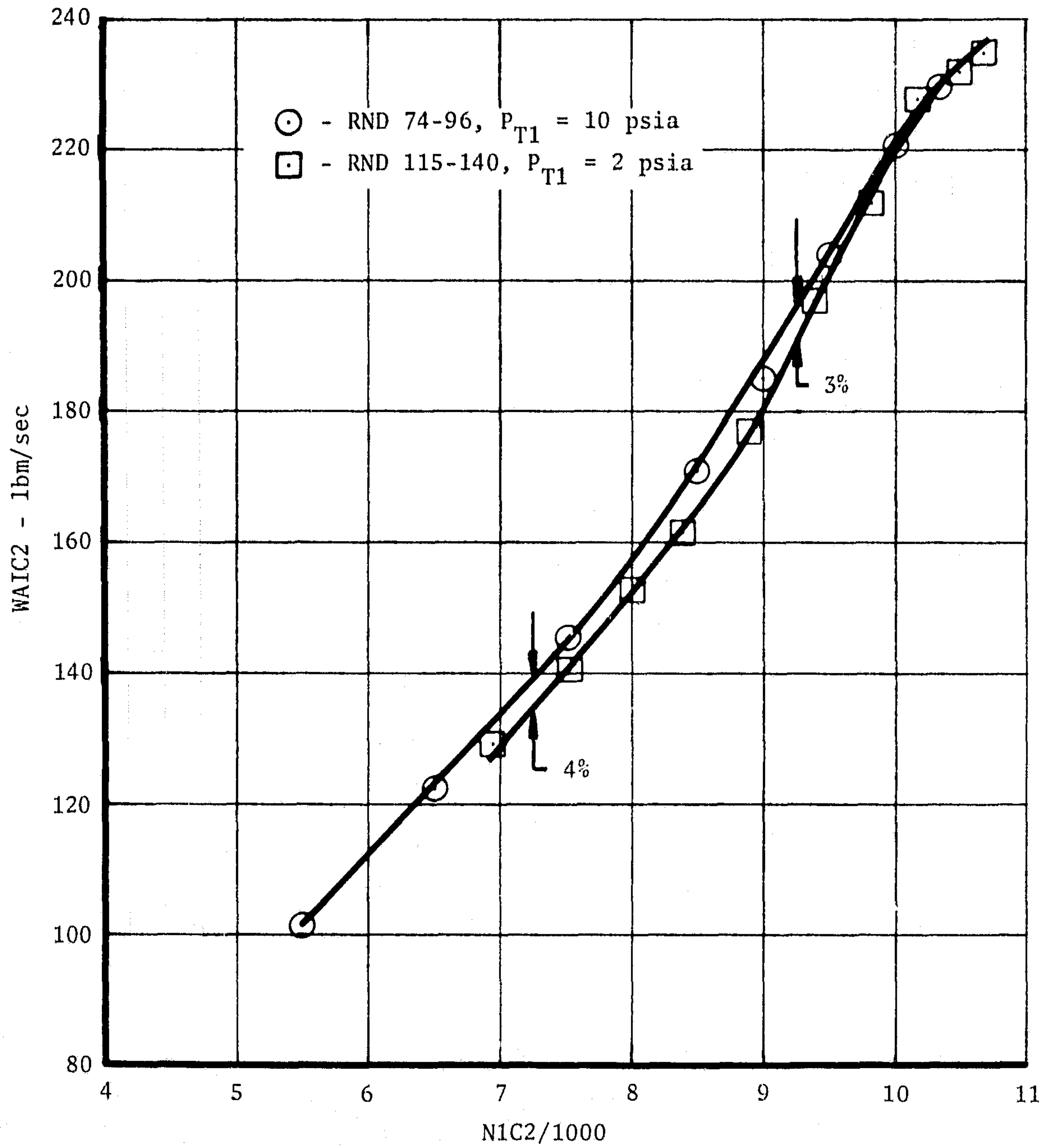

Figure 14. Reduction in Airflow at Low Reynolds Numbers

DATA ADJUSTMENTS

Several adjustments made to the recorded test data provided a more accurate representation of test results. These adjustments became necessary because of:

1. Unequal circumferential spacing of P_{T2} probes
2. Instrumentation calibration shifts at low pressure
3. Airflow calibration differences between GPD and NASA-LeRC
4. Leaking P_{T2} probes.

These adjustments, or correlations, resulted in closer agreement between the P680072 engine test and previous test results.

RESULTS

The following results were achieved during the P_{S2} noseboom testing conducted at NASA-LeRC in July 1979:

- The F100 engine P680072 PT/PS correlation agrees with sea-level tests with the same 17-in. probe
- Altitude low-pressure effects on the PT/PS correlation were 0.5% or less
- Distortion PT/PS shift was consistent between near sea-level and upper left-hand corner conditions
- The production P6 probe indicated mass-weighted within 0.5% for all inlet configurations at intermediate power and near sea-level conditions
- BUC manifolded inlet case static pressure indicated up to 2.5% low-pressure altitude shift
- BUC manifolded inlet case static pressure showed 5% shift with 180-deg moderate distortion.

RECOMMENDATIONS

As a result of the P_{S2} noseboom testing, the following recommendations are put forth:

- Adjust DEEC PT/PS schedule (G04) to reflect current test results
- Adjust pressure bias on DEEC PT/PS schedule to reflect the 0.5% increase at low inlet pressures
- Verify low-pressure shift in PT/PS schedule during FX227 engine testing at Arnold Engineering Development Center (AEDC)
- Adjust BUC WF/P_{S2} and RCVV schedules for P_{S2} measurements from the engine inlet case
- Obtain time variant recordings of BUC static pressures.