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VARIABLE STATOR RADIAL TURBINE

BY

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PREPARED FOR
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16. Abstract

An experimental investigation was conducted on a radial turbine stage with a variable area nozzle. A high work capacity turbine design (referred work = 89.4 kJ/kg, 38.4 B/lb) with a known high performance base was modified to accept a fixed vane stagger angle moveable sidewall nozzle. The nozzle area was varied by moving the forward and rearward sidewalls. Diffusing and accelerating rotor inlet ramps were also evaluated in combinations with hub and shroud rotor exit rings. Performance of contoured sidewalls and the location of the sidewall split line with respect to the rotor inlet was compared to the baseline. Testing was conducted at design rated speed and pressure ratio over a range of flow from 62 to 120 percent of design. Overall performance and rotor exit survey data are presented for thirty one (31) different geometries. Detail survey data at the nozzle exit are given in contour plot format for five (5) configurations. A data base is provided for a variable geometry concept that is a viable alternative to the more common pivoted vane variable geometry radial turbine.

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FOREWORD

The Variable Stator Radial Turbine Program is co-sponsored by the U. S. Army Research Technology Laboratories and National Aeronautics and Space Administration Lewis, Cleveland, Ohio, under Contract No. NAS3-23163. The program is in support of an effort to demonstrate a significant improvement in component performance of small gas turbine engines.

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SECTION 1.0

SUMMARY

The radial turbine with variable stator geometry has the potential of operating over a broad flow range at constant pressure ratio and speed. The design geometry, in particular the means of varying the stator flow area, must be selected so that acceptable turbine efficiency can be maintained over the desired flow range. The pivotable stator vane and the moveable stator sidewall are two prime candidates for varying the stator flow area. Before a preferred method can be identified both the mechanical and aerodynamic aspects of each method must be evaluated. Of the two methods there is much less experimental data on the moveable sidewall than the pivoting vane. An experimental investigation to establish a limited data base of several geometrical variations of the moveable stator sidewall was conducted on a turbine rig.

A high work capacity radial inflow turbine with a known performance base was modified to accept a combination of moveable nozzle sidewalls, diffusing or accelerating rotor inlet ramps and rotor exit restriction rings. The overall performance of this variable geometry turbine was measured at constant speed and pressure ratio for thirty-one (31) different test configurations. Data were obtained over a nozzle area range 62 to 125 percent of design.

The nozzle area was varied by moving either the forward and rearward sidewalls of the nozzle assembly. A performance fall off of less than 3.0 points in efficiency was demonstrated over the area range with a moveable hub wall configuration. A comparison of the overall performance of this concept with a variable stagger angle vane concept showed that the use of a moveable sidewall for area control is a viable alternative option.

Air leakage between the nozzle vane and moveable sidewall was found to affect performance significantly and is a factor to be minimized in any given practical application. The use of a simple "L" seal was demonstrated and recovered 2.5 points in efficiency and showed a peak stage efficiency of 87.0 percent.

Detail surveys were also conducted at the nozzle vane exit and immediately downstream of the rotor exducer and at a downstream mixed out plane. The results of the overall performance and survey of the experimental investigation are provided as an aerodynamic data base for a variable geometry radial turbine utilizing a moveable sidewall nozzle.

SECTION 2.0

INTRODUCTION

A number of alternate gas turbine cycles have been studies (Reference 1) for future use in military rotorcraft. One engine concept that offers the potential of reduced fuel consumption at off-design operating conditions is the variable-flow capacity engine. In this engine the gas generator and power turbine are operated at their optimum performance settings for the entire helicopter mission, while the power output is modulated by changing the engine air flow. Specifically, the engine is operated at a constant cycle pressure ratio, turbine inlet temperature, and rotative speed, and variable area components are used to vary the engine air flow. This variable flow-capacity engine concept was difficult to assess because of lack of data, particularly in the variable geometry components (Reference 1).

Two recent studies (Reference 2) and (Reference 3) have focused on the optimization of the high pressure turbine for a variable-flow capacity engine in the 5 lb/sec size class. For these studies only radial turbines, both cooled and uncooled, were considered for the gas generator. Two methods were considered to change the turbine nozzle area, pivotable stator vanes, and a moveable stator sidewall. To identify a preferred method, both mechanical and aerodynamic aspects of each method must be evaluated. Aerodynamic tests; i.e., (Reference 4); have been made with pivoting vanes in axial-flow turbines and the information obtained can be applied to radial turbines. On the other hand, there is little or no available test data for the moveable sidewall concept. To fill this gap, a government sponsored experimental investigation was made of the moveable sidewall radial turbine. The results of that investigation are included in this report.

2.1 OBJECTIVES

The objectives of this program are to experimentally determine effects of a moveable sidewall stator on a radial inflow turbine, to obtain aerodynamic loss data, and to establish an optimal geometry in the vaneless space within the tested configurations of known geometric constraints.

One result of moving the stator sidewall into the flow path to reduce the flow area is that a separated flow region is created at the rotor inlet and within the rotor, and the rotor reaction is reduced. Limited experimental data shows that the aerodynamic losses can be large where there is a significant separated region. It was unknown, however, if there was a loss difference depending on whether the separated region was located on the shroud or hub side of the meridional flow path. It was also unknown if the losses could be reduced by, (1)placing a diffusing or an accelerating ramp downstream of the closed down stator sidewall, and (2) reducing the rotor exit flow area to reduce the change in rotor reaction. The objective of this investigation was to provide answers to these questions and to provide a limited data base for a selected number of moveable sidewall radial turbine configurations.

Several variable geometry turbine configurations were investigated. These included moving the hub or shroud wall, changes in the vaneless space geometry, and geometric changes at the rotor exit to control the rotor reaction. This investigation included only the aerodynamic aspects of these geometry changes.

For each configuration, the turbine speed and pressure ratio were set at the design value and overall performance data taken. Tests were run in air at an inlet tempeature of 400K (260F) and a pressure of 170kPa (24.6 psia). In addition, five configurations were selected for detailed flow surveys to be taken at the stator exit, rotor trailing edge, and a downstream location where the rotor blade wakes were mixed-out. The results of these tests and the conclusions drawn are presented herein.

SECTION 3.0

TURBINE AND TEST RIG MODIFICATION

3.1 TEST TURBINE SELECTION

The radial turbine used in the experimental evaluation was an existing unit which was representative of a current or advanced design operating in a specific speed range of 68 to 82 with an equivalent specific work capability of 81.5 to 97.8kJ/kg (35 to 42 Btu/lb). Figure 1 shows a Teledyne CAE, thirteen bladed research turbine rotor, thirty vane turbine nozzle, and variable pivoted vane geometry actuator mechanism that had a data base that met the program requirements.

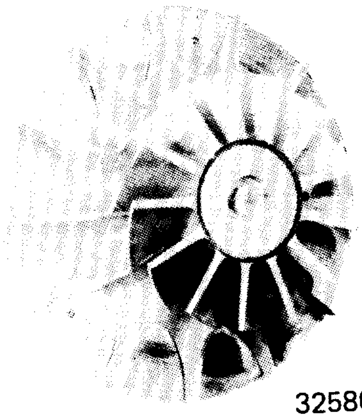
To properly evaluate the relative merits of the variable sidewall nozzle concept it was necessary to establish a baseline against which comparisons could be made. This research turbine demonstrated a high level of performance with pivoted vanes, (References 5 and 6), and the design was modified to accommodate moveable sidewall testing.

Figure 2 describes the research radial turbine flowpath geometry. Figure 3 shows typical performance test maps obtained as a function of pivoted nozzle area change. Figure 4 shows the tested overall performance with the nozzle in the nominal or design position. An efficiency change of only 0.5 percent (89.0 to 88.5 percent) is incurred over the program required equivalent specific work range 82 to 98 kJ/kg.

A comparison of the aerodynamic parameters of the selected variable area radial research turbine with those specified in the program requirements is given in Table I, which shows that specific speed, pressure ratio, equivalent specific work, efficiency, and work factor parameters are satisfied. Equivalent flow and speed which are a function of size could be satisfied by applying a scale factor.

3.1.1 Flow Range

Selection of the flow corresponding to the best efficiency point will strongly influence the geometry of the nozzle sidewall. The flowpath should be aerodynamically clean when designed to the best efficiency point. The choice of flow at best efficiency was based on the results of a recently completed NASA/ARTL study program for a rotor craft application, contract number NAS3-20005, Cooled Variable Area Radial Turbine Technology Program, Reference 2. Figure 5, from the study, shows the radial turbine predicted efficiency change as a function of engine flow. This curve, along



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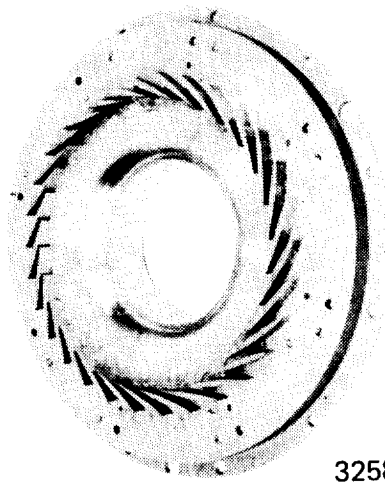
RADIAL FLOW
TURBINE ROTOR



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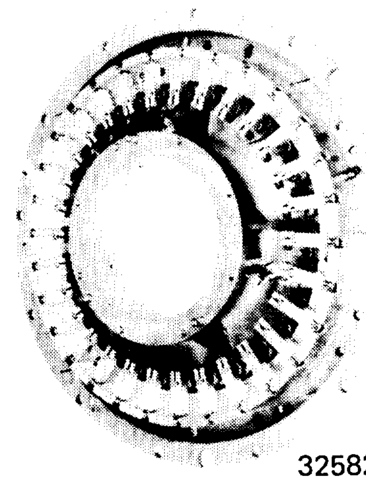
RADIAL FLOW TURBINE
INLET NOZZLE



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PIVOTED VANE ACTUATING
MECHANISM FOR ADJUSTING
RADIAL TURBINE FLOW

Figure 1. Teledyne CAE Variable Area Research Turbine.

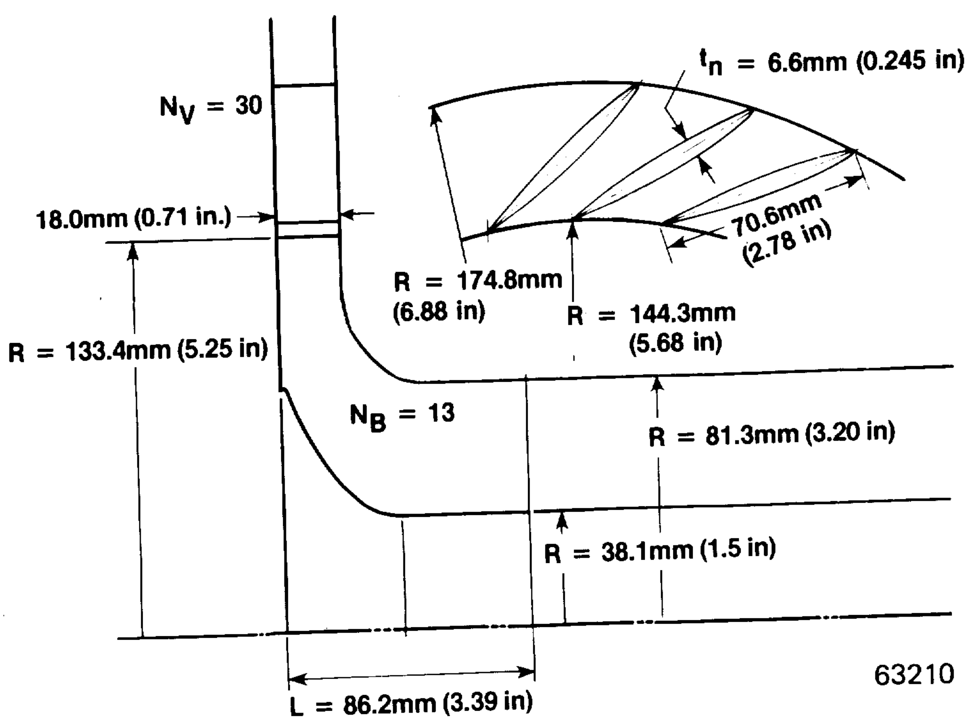

Figure 2. Research Turbine Flowpath Geometry.

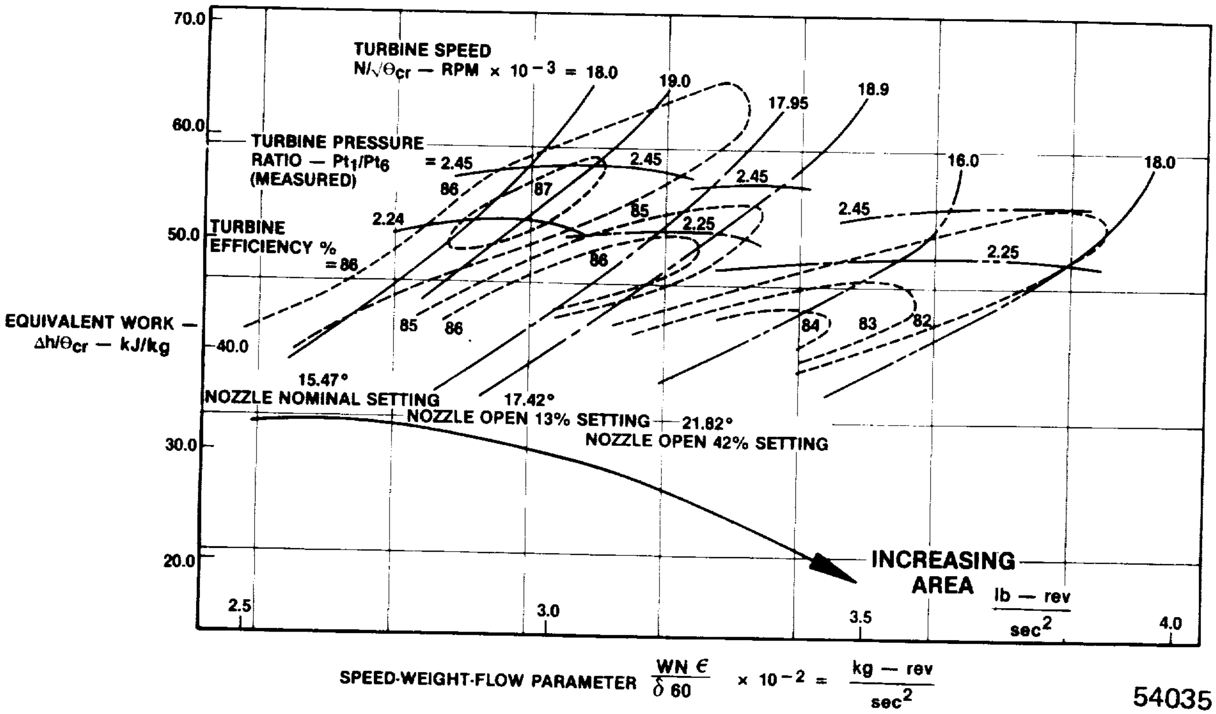

Figure 3. Turbine Stage Performance as A function of Pivoted Vane Area.

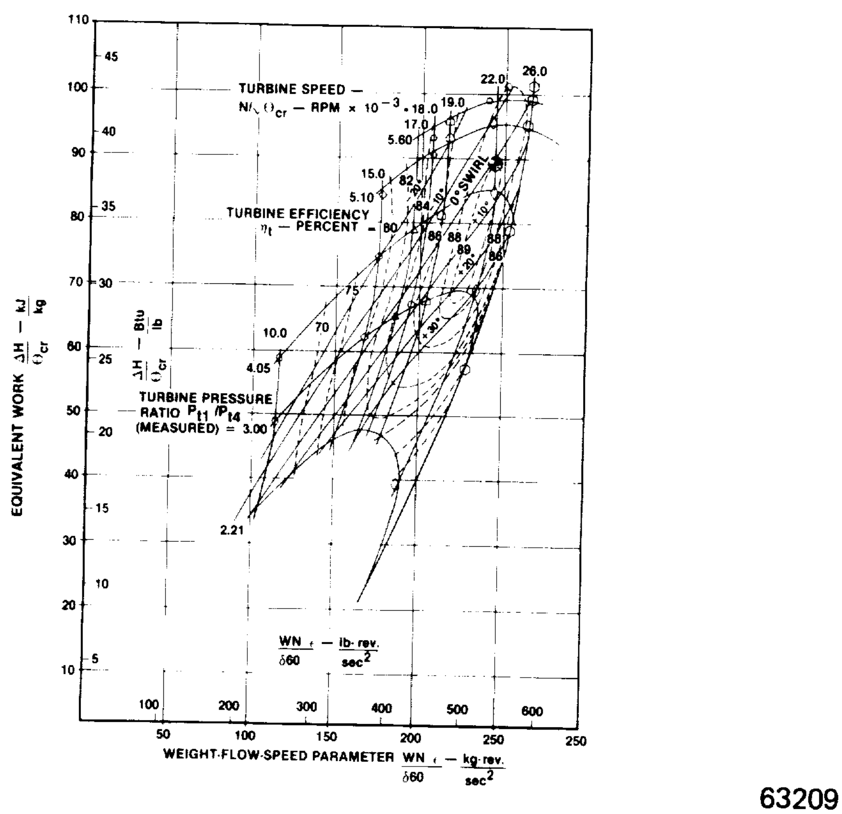

Figure 4. Overall Turbine Stage Performance.

TABLE I

COMPARISON OF PROGRAM REQUIREMENTS AND RESEARCH TURBINE PERFORMANCE

	PROGRAM REQUIREMENTS	RESEARCH TURBINE	TURBINE AT 1.333 SCALE
SPECIFIC SPEED, $\frac{N\sqrt{Q}}{H^{3/4}}$	68-82	70	70
EQUIVALENT WEIGHT FLOW, $\frac{W\sqrt{\Theta_{cr}}\,\epsilon}{\delta}$, $\frac{kg}{sec}$ $\left(\frac{lbs}{sec}\right)$	0.27-0.41 (0.6-0.9)	0.66 (1.45)	1.17 (2.58)
TIP DIA mm (in.)	—	266.7 (10.5)	355.5 (14.0)
PRESSURE RATIO, $\frac{P_{IN}}{P_{OUT}}$	4.0-5.0	3.8-5.4	3.8-5.4
EQUIVALENT SPEED $\frac{N}{\sqrt{\Theta_{cr}}}$, RPM	28500-35000	22000	16504
EQUIVALENT SPECIFIC WORK $\frac{\Delta H}{\Theta_{cr}}$ $\frac{kJ}{kg}$ $\left(\frac{BTU}{LB}\right)$	81.5-97.8 (35-42)	81.5-97.8 (35-42)	81.5-97.8 (35-42)
WORK FACTOR, $\frac{\Delta H}{u_t^2}$	0.9-1.1	0.86-1.03	0.86-1.03
PERFORMANCE TOTAL TO TOTAL EFFICIENCY	CURRENT OR ADVANCED DESIGN	89.0-88.5	89.0-88.5

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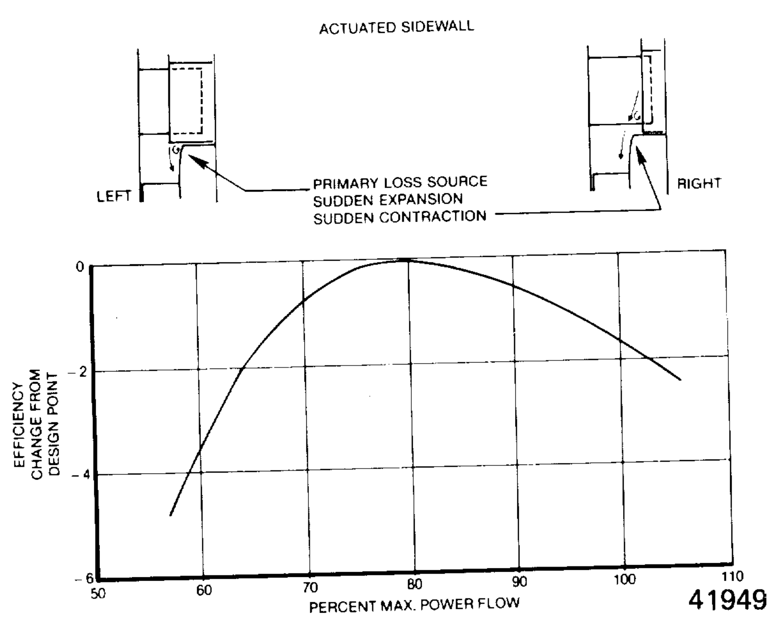

Figure 5. Radial Turbine Performance as a Function of Engine Flow.

with engine component off-design changes, was used to predict engine performance over the duty cycle of a turboshaft engine in a helicopter application. Integrations of fuel consumption over the duty cycle and subsequent iterations showed that it is desirable that the maximum efficiency occur at the 80 percent of maximum flow condition. The nominal or design setting of the turbine vane stagger angle was, therefore, set to maximum performance at 80 percent maximum flow. With the exception of the contoured sidewall concepts discussed in Section 3.3.2, all the geometries in the experimental investigation were configured around the best efficiency point; henceforth referred to as design or 100 percent flow condition. The test flow conditions that covered the range of interests were 62 percent, 81 percent, 100 percent, and 125 percent of the design nozzle throat area. Figure 6 shows the velocity vector diagrams for the best efficiency point for the hub, mean, and tip as obtained from the off-design computer program of Reference 7.

3.2 TEST TURBINE SIZE CONSIDERATIONS

A usual practice in warm flow rig testing is to gather data and subsequently correct to the Reynold's number representative of the engine environment. This requires testing at several inlet conditions to generate a change of efficiency curve versus Reynold's number. Rig performance is then extrapolated to the engine condition. These types of corrections were avoided in this program by selecting a radial turbine rotor size which actually gave engine Reynold's numbers under test rig conditions.

To be representative of engine Reynolds numbers of a practical application, an engine cycle was chosen which corresponded to that selected in a previous Army funded NASA study (Reference 2). This study was accomplished for a rotor-craft application with a maximum engine airflow of 2.27 kg/sec (5 lbs/sec). The high pressure turbine Reynolds numbers for that engine were 4.37×10^5 and 1.42×10^5 for the nozzle and rotor, respectively. To achieve those Reynolds numbers, within the limitation of the test facility, required the scaling of the selected research turbine listed in Table I by a factor of 1.33. The rig scaled turbine had a diameter of 35.6 cm (14 inches) and was tested at nominally 400K (260F) and 170 kPa (50 inches mercury) pressure.

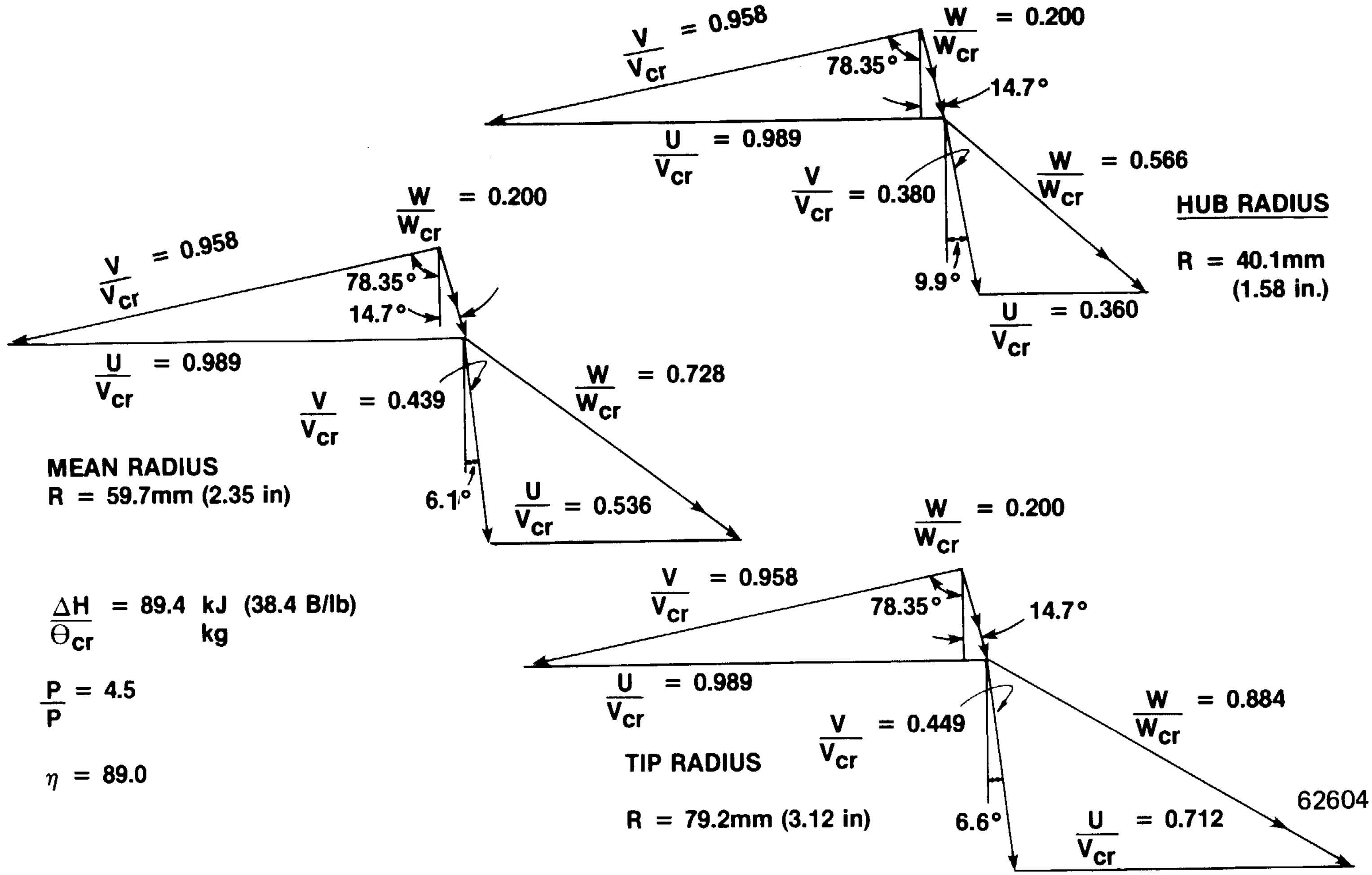

Figure 6. Stage Velocity Triangles at Design Point Flow.

In addition to the advantage of duplicating the main engine parameters in the turbine rig, a larger turbine wheel allowed a better quality of data reduction. This is attributable to instrumentation that is smaller in size relative to the larger nozzle/rotor which minimizes flow interferences. The turbine rig also rotates at slower speed and gives higher torque ratings subject to a smaller percentage of uncertainty. Operating clearances were also scaled to be representative of engine operation. The running clearance at the rotor backface and at the rotor tip shroud were set at 3.4 percent of the design rotor tip width. The radial clearance at the rotor exit was set at 1.0 percent of the exducer span height.

3.3 TEST RIG AND TURBINE CONFIGURATIONS

3.3.1 Test Rig Configuration/Operation

Figure 7 shows a cross section of the radial turbine rig, with its major component units indicated. Flow is supplied by ram compressors which raises the pressure to 172K Pa (25 PSIA). The ram air is then channeled through a series of steam bunkers and electric heaters to bring the rig supply conditions to a temperature of 394 K (250F). The flow then enters a large inlet supply plenum which acts as a settling chamber to reduce distortions. Two inlet screens are provided in the elbow preceeding the nozzle to further reduce flow distortion. The flow is then turned through a 90^{o} elbow at a Mach number less than 0.05 to the moveable nozzle wall assembly, through the rotor, and to the exhaust duct. The exhaust leads to a set of vacuum pumps which are adjusted to create the desired pressure ratio across the entire turbine stage.

A Kahn water brake dynamometer is used to absorb the shaft power generated by the radial turbine. The power is absorbed by flowing water through a series of perforated rotors and stators inside the water brake. The shaft speed is then controlled by varying the water flow rate through the brake by remote control inlet and exit valves. A Lebow torque sensing unit is installed between the water brake and the shafting of the turbine rotor. This torque sensor measures the output of the turbine by the use of a series of strain gages installed in the torque sensor shaft. The electrical signal produced by the stain gage deflection is picked up through a set of brushes on the shaft and led to the instrumentation panel. The Lebow unit also has a speed sensor which picks up instantaneous shaft speed. The measured torque and measured speed was one basis used to calculate the shaft power generated by the turbine.

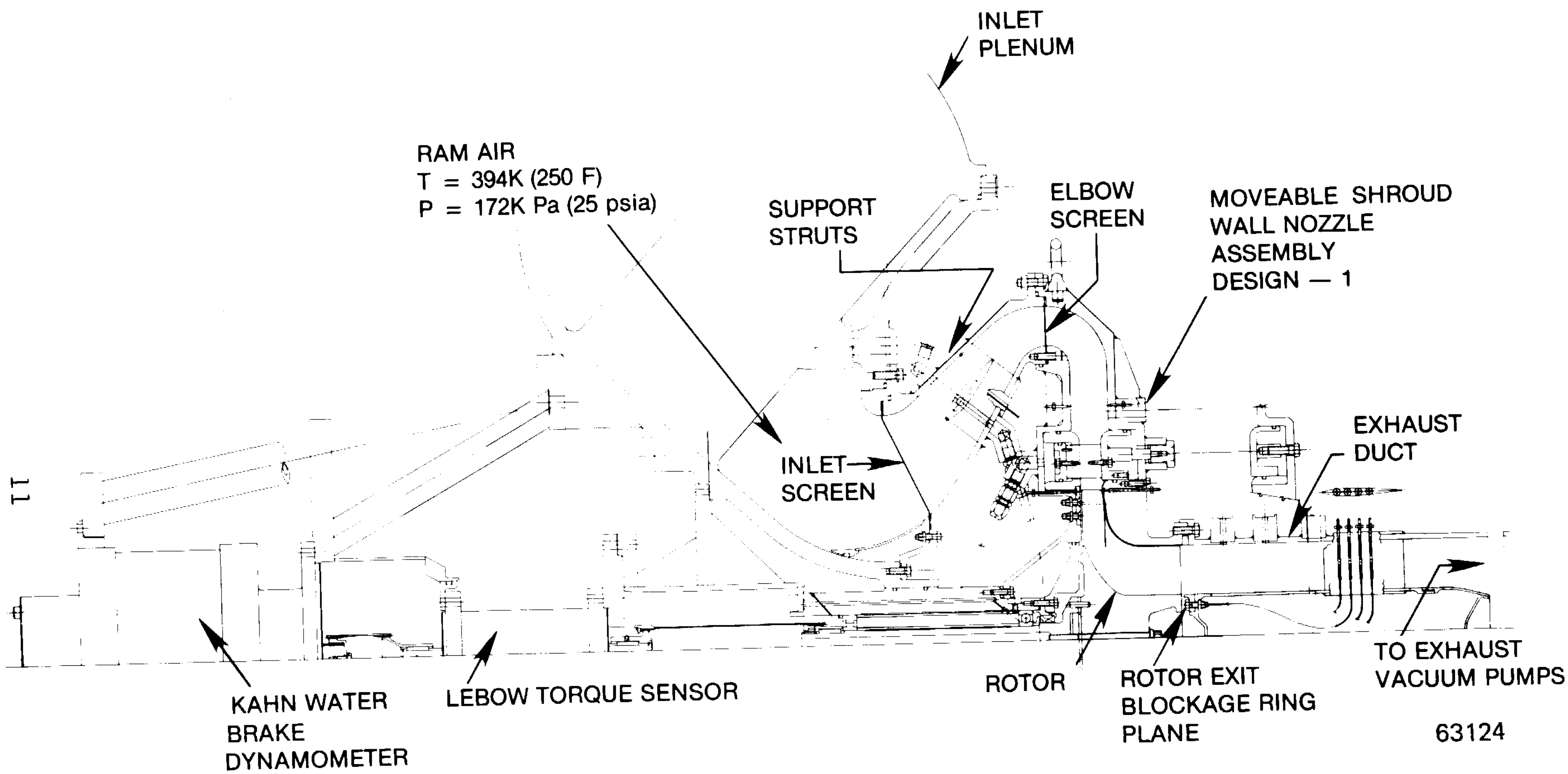

Figure 7. Turbine Rig Cross Section.

Figure 8 shows the moveable sidewall nozzle and turbine rotor assembly. This cross section shows the mechanism used to actuate the shroud side of the nozzle. The turbine inlet nozzle consists of an externally adjustable sliding piston assembly for positioning of the moveable stator sidewalls. The stator vanes are fixed to a sliding piston ring at each end. The stationary hub wall ring is trapped between the sliding guide piston (left) and the moveable shroud sidewall piston (right). The entire nozzle piston assembly, hub and shroud rings and vanes, is positioned by turning the threaded nozzle adjustment bolts. The nozzle throat width can be set by means of a depth gage inserted through one of the vane passages. The nozzle is designed to allow sidewall travel over a range to allow flow adjustment from 62% to 125% of design flow. Provision was also made to actuate the moveable wall by pneumatic means. High pressure air can be supplied to the enclosed cavity behind the piston sidewall, as shown in Figure 8. Pressure on the piston moves the wall assembly to the right. The wall can be repositioned by the threaded screws in the housing or the wall can be independently located by adjusting bolts threaded into turbine housing.

Insertable vaneless space hub adapter rings were provided for constant width, diffusing, and accelerating sidewall variations between the stator trailing edge and rotor leading edge. The rings are changed by removal of the exhaust duct and nozzle shroud housing. These changes can be accomplished without removing the variable stator test rig from the facility test stand, thereby minimizing configuration turn-around time.

A similar mechanism to the one described above is also used for the moveable hub wall configuration. In this case the hub adapter rings are provided with retainers which can be removed through the rotor disk web, Figure 9, and the rings can thus be replaced without disturbing the rotor assembly. Provision is made for rotor exit hub and shroud blockage rings, which can be easily inserted by unbolting the exhaust transition duct.

Figures 10 through 13 are photographs of the main parts comprising the nozzle assembly and rotor. Figure 10 is a photograph of a typical vane as viewed from the trailing edge, side and leading edge, from left to right, respectively. Figure 11 is the stationary hub sidewall ring showing the slots that were electron discharge machined (EDM) to the vane airfoil contour. The clearance gap between the vane and the sidewall was an average 0.4 mm (0.016 in.) around the entire airfoil. Figure 12 is a photograph of the assembled sidewall annular piston, stationary sidewall ring, nozzle vanes, and the moveable sidewall annular piston and Figure 13 shows this assembly installed in the test rig along with the turbine rotor.

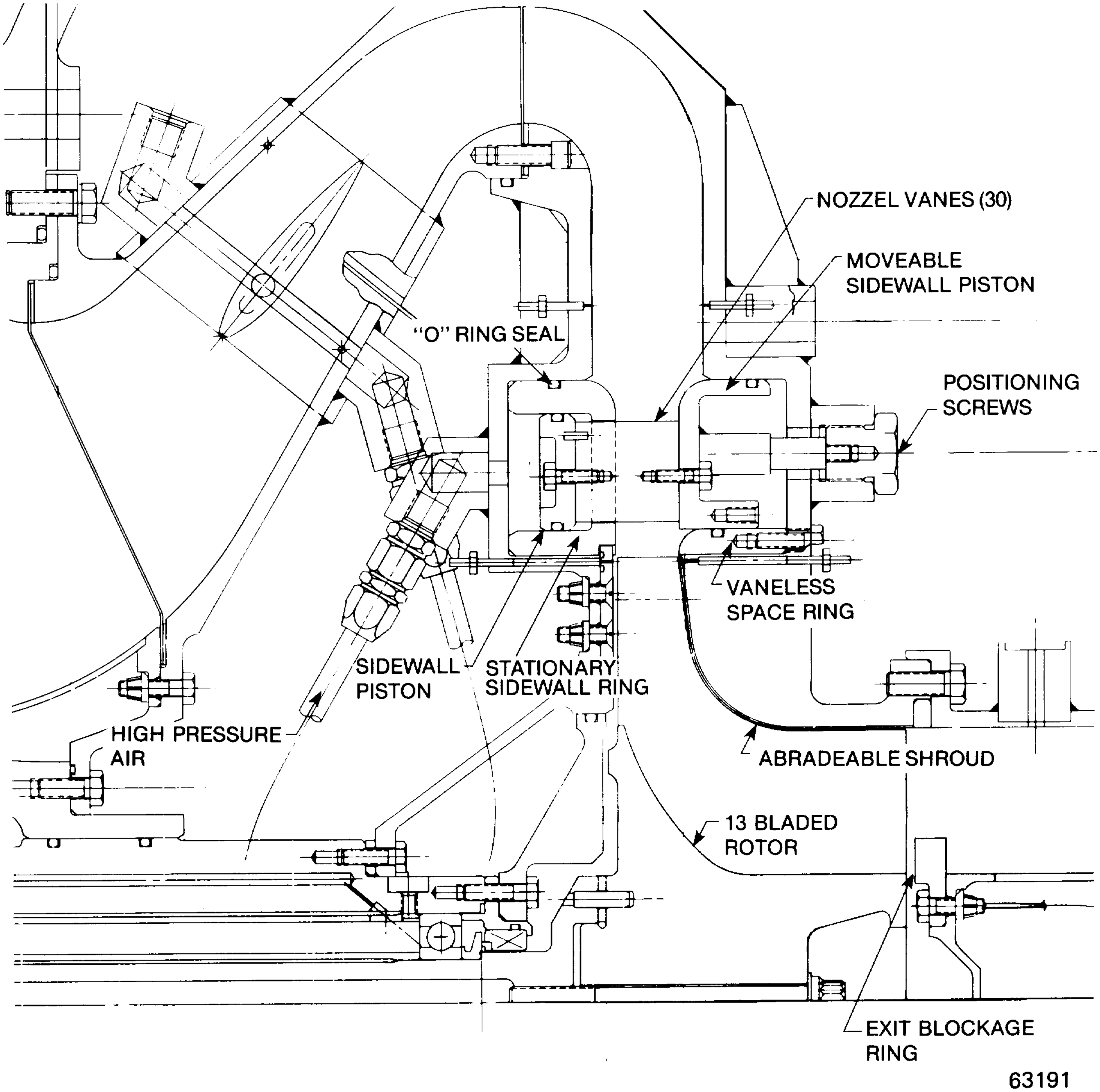

Figure 8. Moveable Shroud Sidewall Nozzle and Turbine Rotor Assembly.

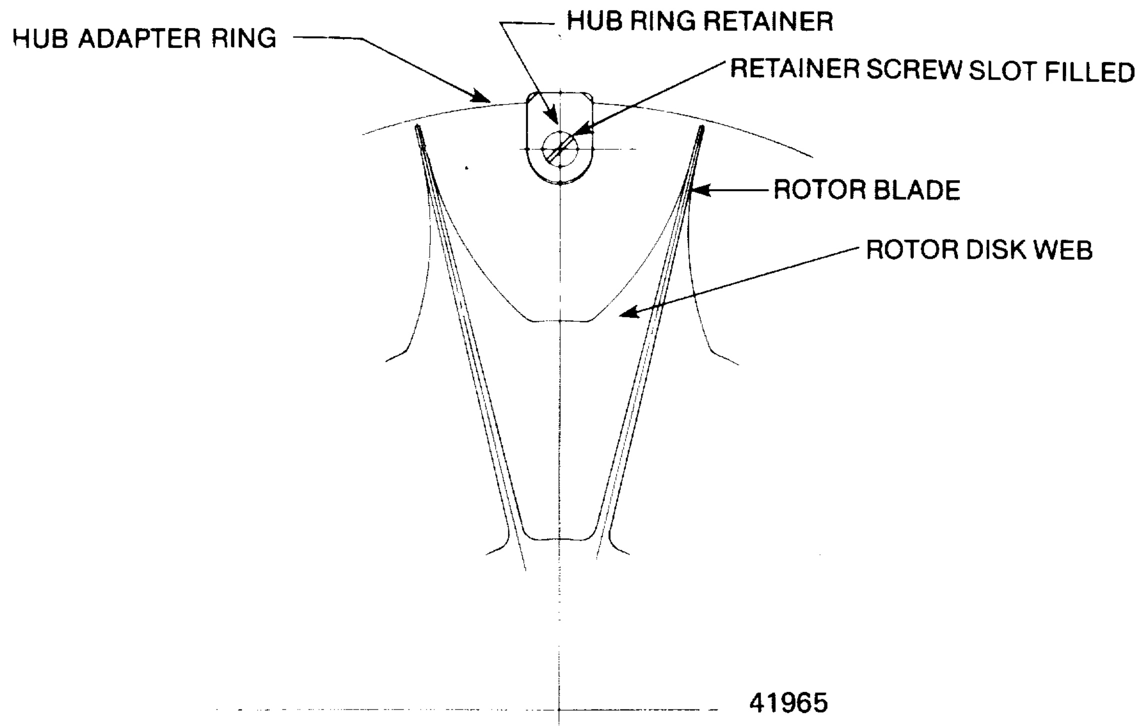

Figure 9. Hub Ring Retainer: Sidewall Adapter Ring Retainer Inserted Between Rotor Blades.

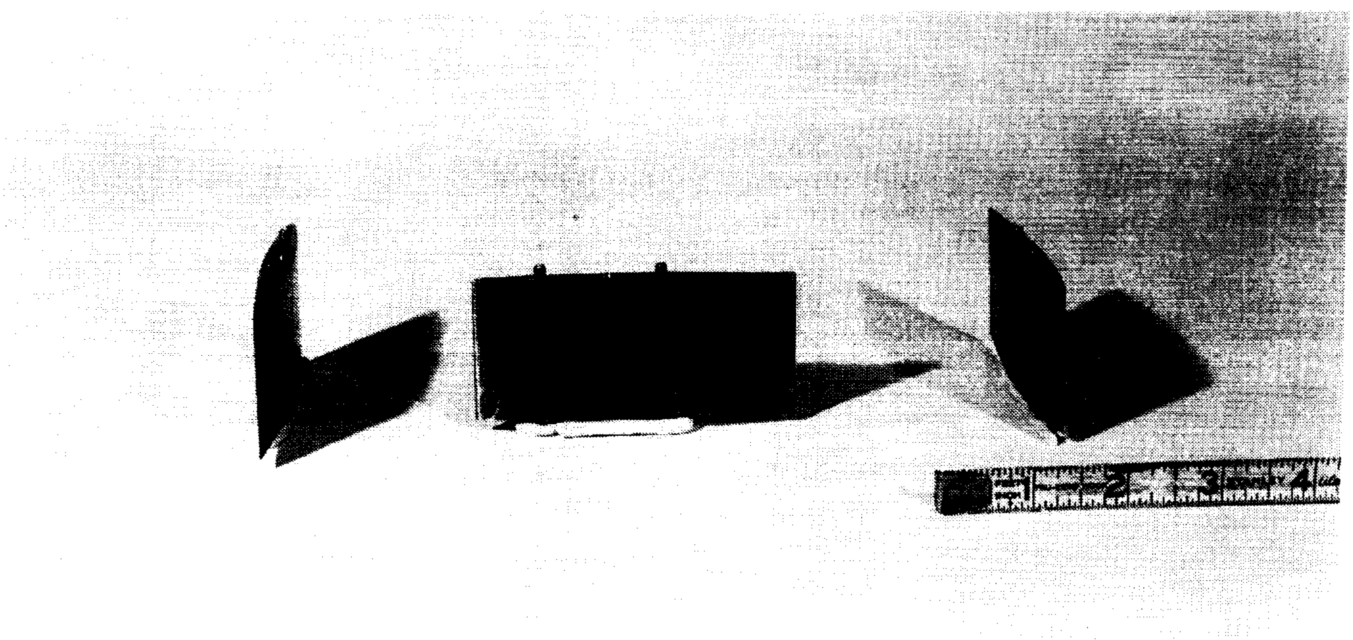

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Figure 10. Turbine Inlet Nozzle Vane.

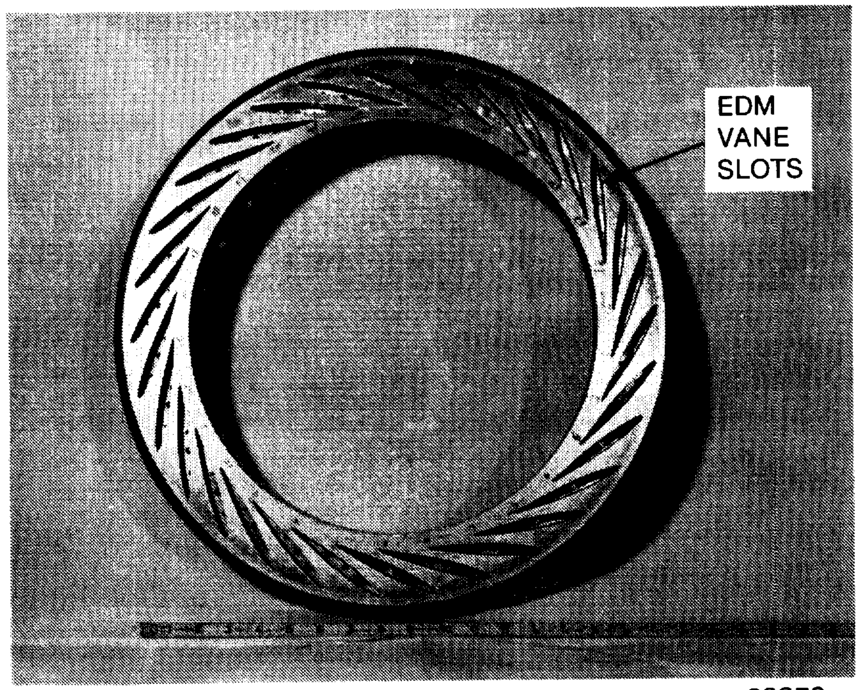

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Figure 11. Stationary Hub Sidewall Ring.

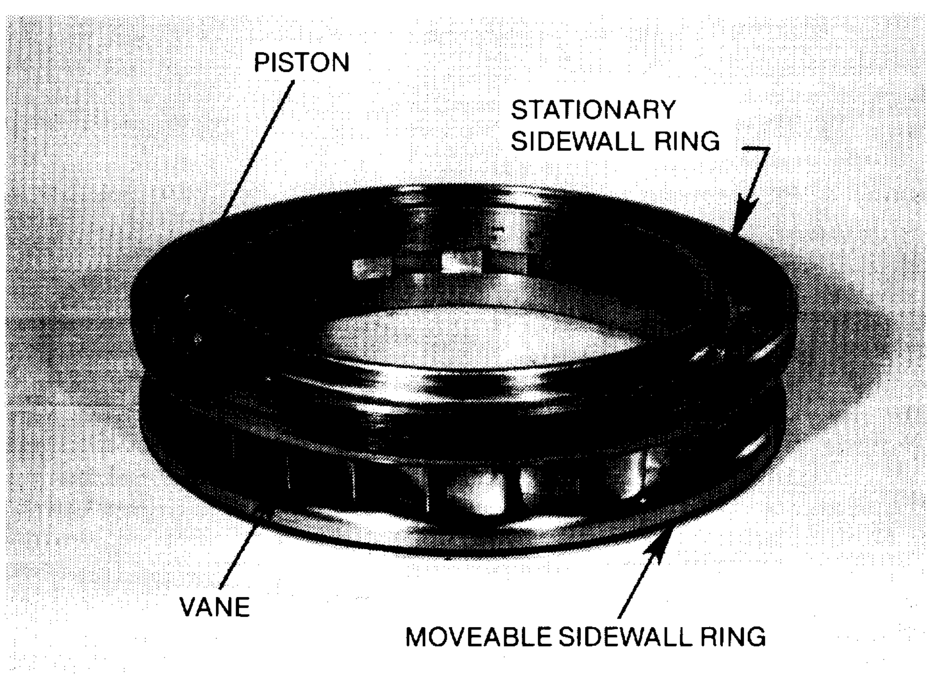

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Figure 12. Moveable Sidewall Nozzle Assembly.

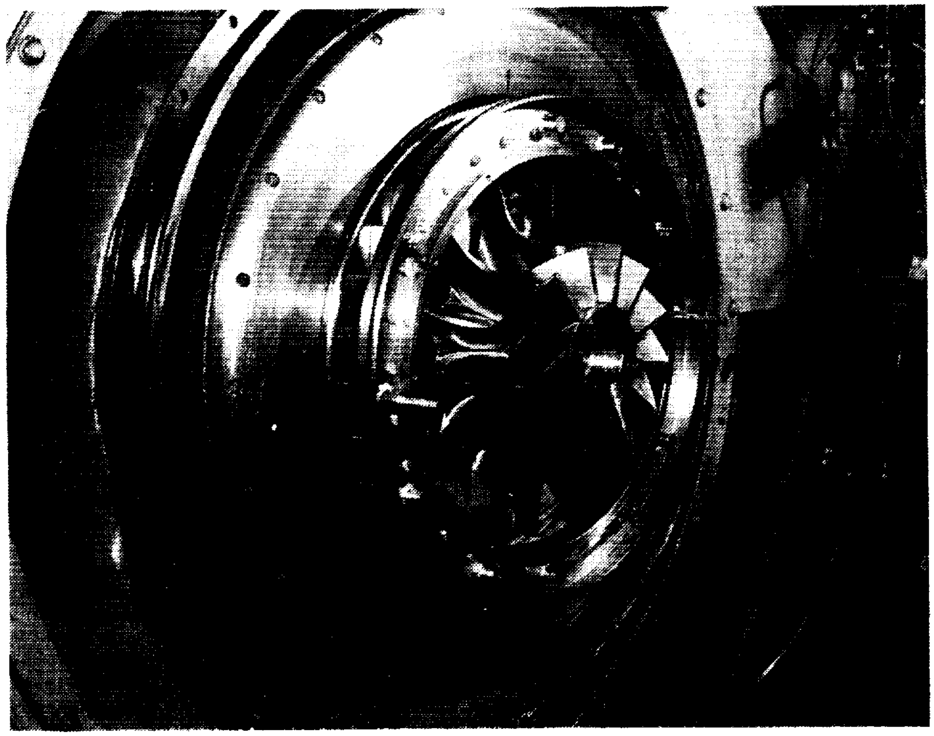

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Figure 13. Variable Area Nozzle and Rotor Installed in Turbine Rig.

3.3.2 Turbine Configurations

The overall performance of a variable capacity radial turbine stage with a moveable sidewall stator is expected to be adversely affected by changes in nozzle and rotor reaction, incidences, changes in rotor exit swirl and rotor exit duct mixing losses. Furthermore, in a real engine environment, losses can also be compounded by leakage flows around the nozzle vanes and the sliding sidewalls.

Several stator sidewall geometries and rotor exit area reducing rings were designed to evaluate as many as possible of the above losses within the limitations of the program funding. Figure 14 shows the turbine with the moveable sidewall in the design or flushwall position. Moving the stator sidewall into the flowpath, Figure 15, to reduce the flow creates a step discontinuity and sudden expansion loss at the rotor inlet. Removeable diffusing ramps, Figure 16, were tested with several wall positions to evaluate their effect on turbine performance.The diffusing ramp, shown in Figure 16, was at first throught of as an effective device for the minimum or 62% flow case. However, at 62% flow wall position, the effective diffuser angle, in the direction of flow, was well "beyond a separated flow value." Therefore, the ramp was sized for the 81% flow case and then simply translated to the 62% wall position. In this position the diffusing ramp does not smoothly connect the nozzle trailing edge with the rotor leading edge, as shown in Figure 16.

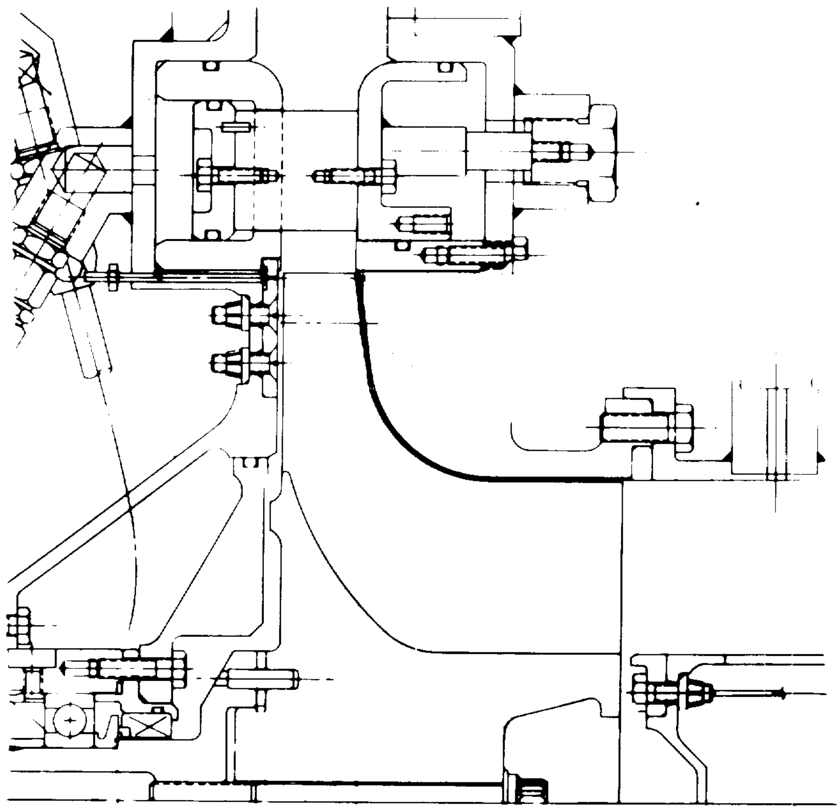

Figure 14. Moveable Sidewall Configuration - Baseline Geometry.

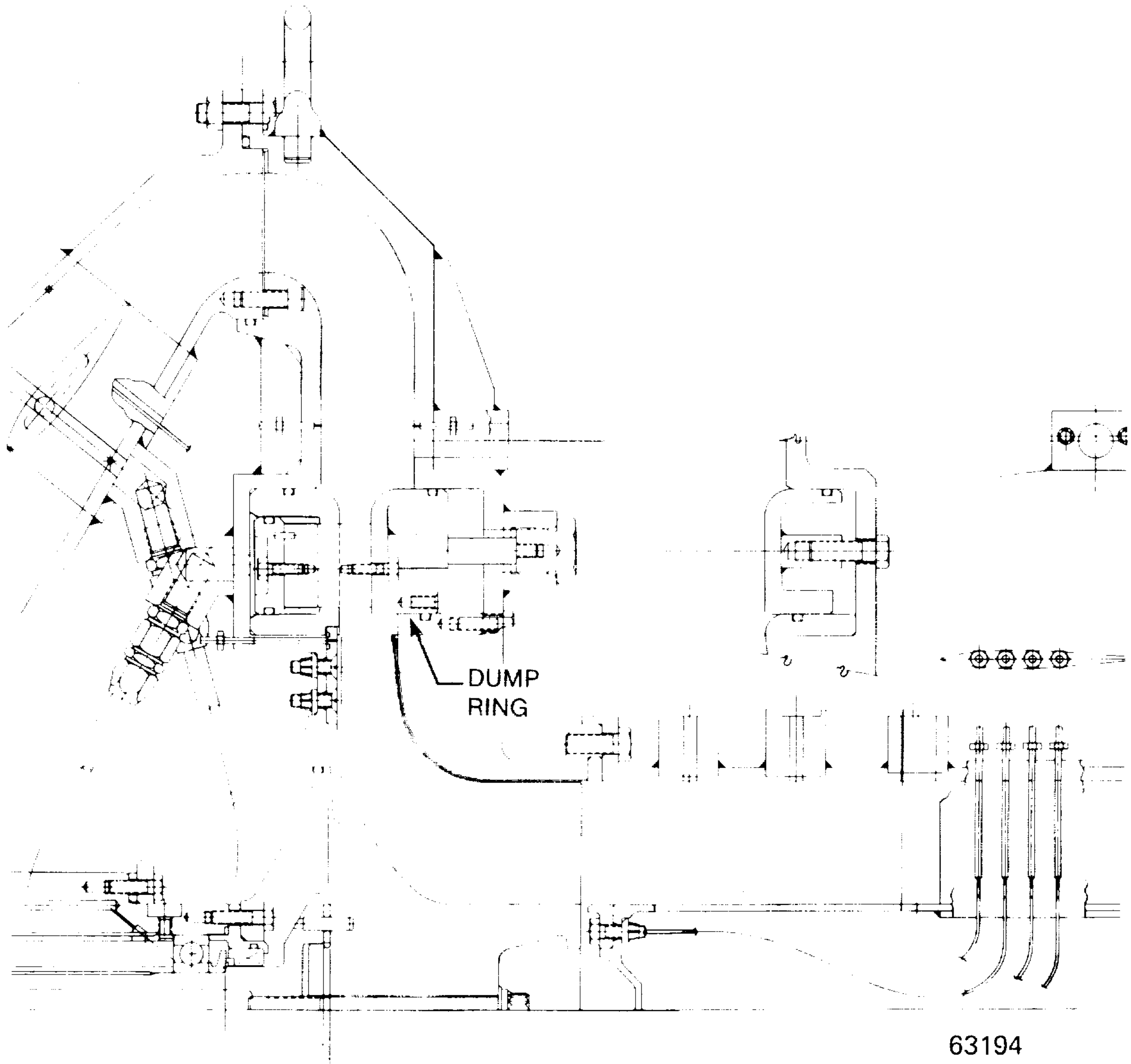

Figure 15. Moveable Sidewall in Closed Position - Simple Dump Vaneless Space Insert.

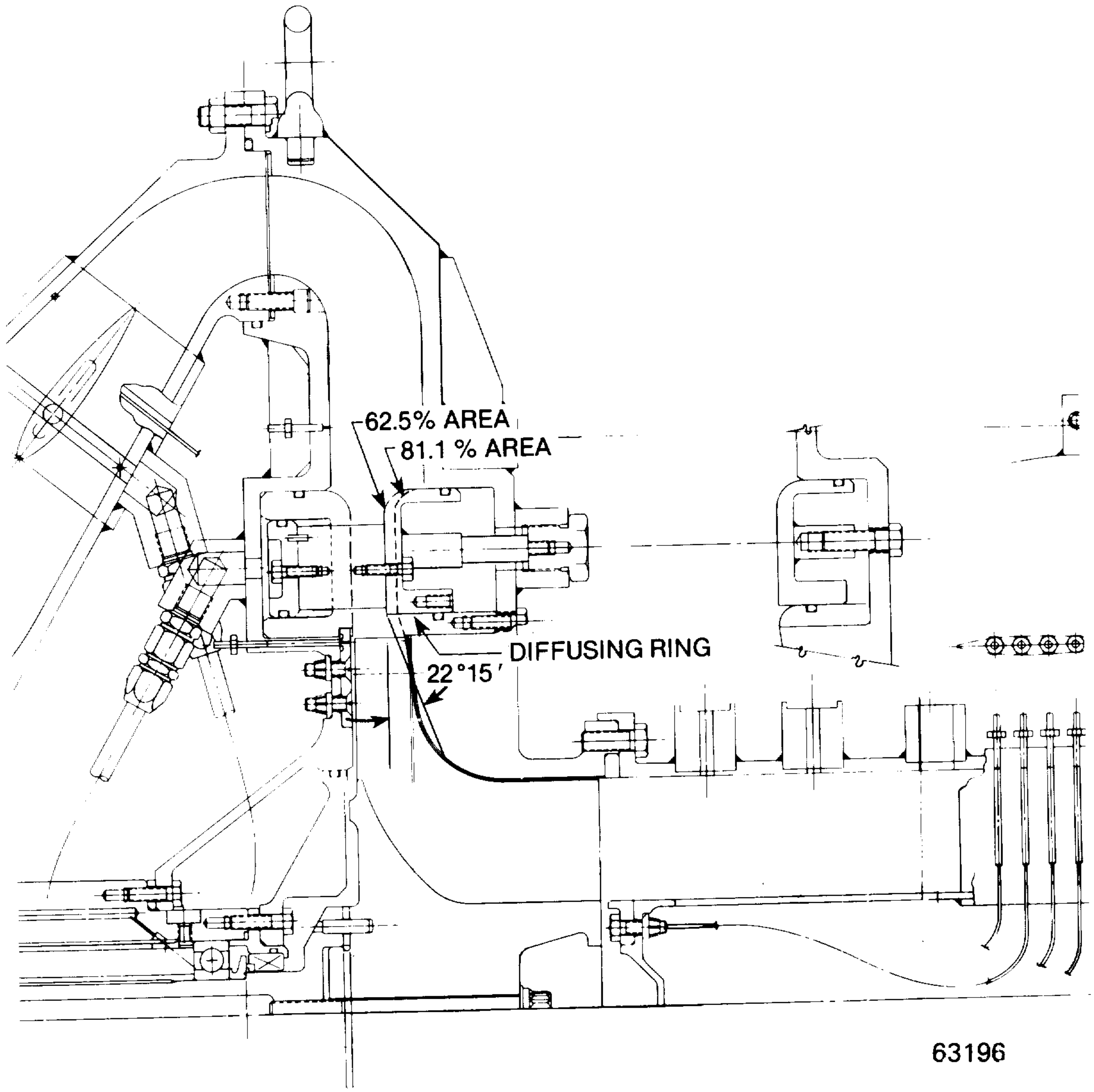

Figure 16. Moveable Sidewall in Closed Position With Diffusing Vaneless Space Insert.

Conversely opening the nozzle flow area beyond the nominal position (configuration where sidewalls are flush) creates a sudden contraction in the flowpath. Several of the sidewall geometries were tested at this setting.

Tests were conducted with a simple sudden contraction and also with an accelerating ramp ring as shown in Figure 17. Finally, rings that reduced the flow area at the rotor exit, thereby controlling rotor reaction as nozzle area was reduced, were evaluated with several of the sidewall geometries. For the reduced flow test points, it was thought that the turbine performance could be enhanced by preserving the stage reaction through the use of rotor exit blockage rings. As the nozzle endwall is closed down, the stage reaction is decreased due to the decrease in the nozzle throat area. The exit blockage rings, shown in Figure 18 were sized so that the effective rotor throat area would be reduced by the same percentage as the nozzle throat area, thus preserving reaction. A shroud ring was used with the moveable shroud wall nozzle and a hub ring was used with the moveable hub wall configurations, respectively.

The location of the moveable sidewall splitline, with respect to the rotor tip, was also considered to be an important variable. An alternate nozzle geometry was, therefore, configured with the moveable sidewall splitline located as near as practical to the rotor inlet. This concept, referred to as "a low radius dump", Figure 19, was added to the test series as a potentially high efficiency candidate. The vaneless space between the nozzle trailing edge and the rotor leading edge operates at transonic velocities and a dump in this critical region was expected to create substantial aerodynamic losses. Transferring the dump to the leading edge of the rotor could result in a different loss mechanism of lesser significance, since the dump would occur in the rotor tip relative plane where the Mach numbers are less than 0.3.

The aerodynamic benefits of shroud contouring on nozzles are well known in axial turbine technology (Reference 8-13), but this approach is not commonly applied to radial inflow turbine machinery. This feature also cannot be easily applied to a pivoted nozzle but for a moveable sidewall configuration it could result in a performance advantage.

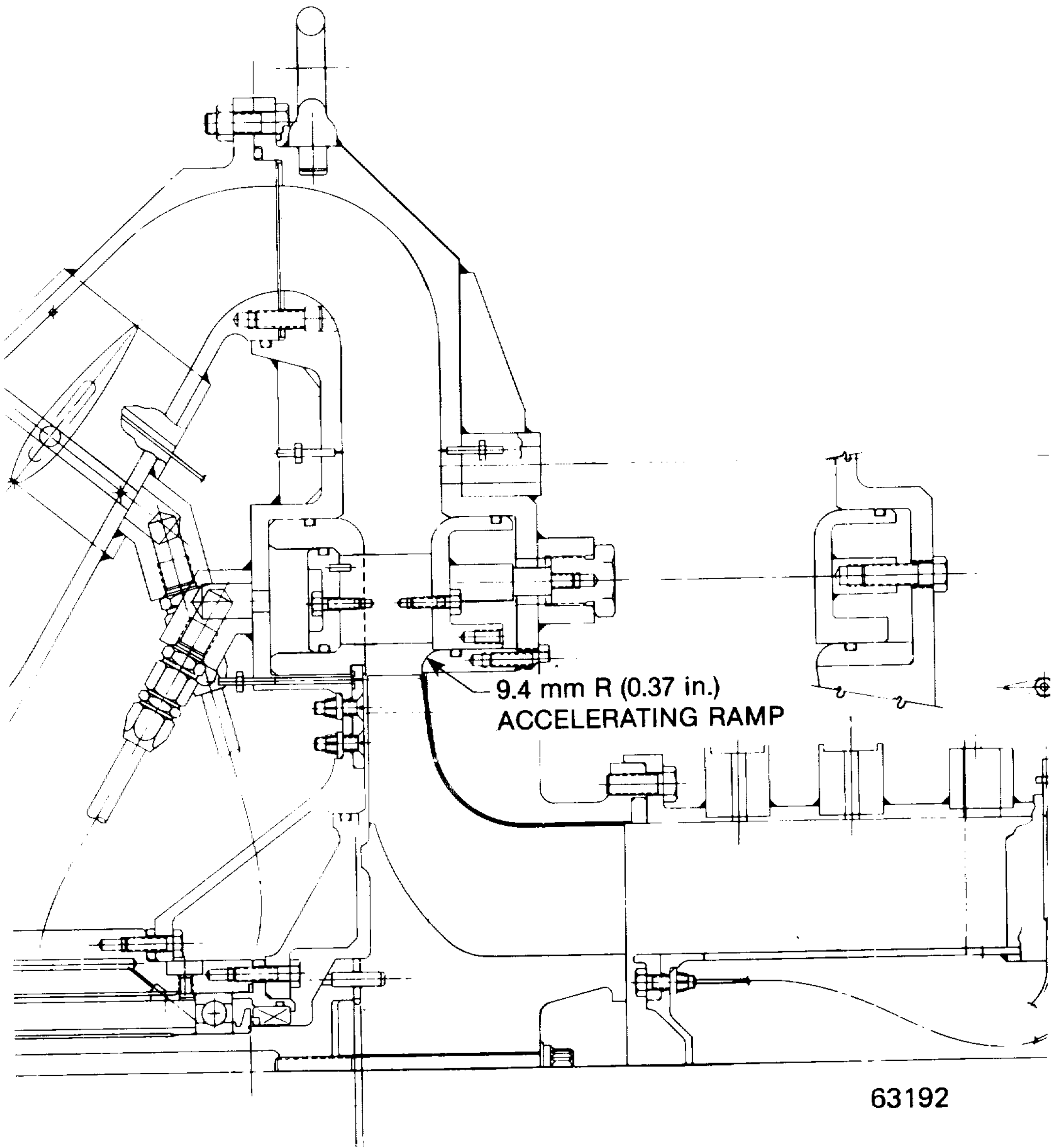

Figure 17. Moveable Sidewall in Wide Open Position With Accelerating Ramp Vaneless Space Insert.

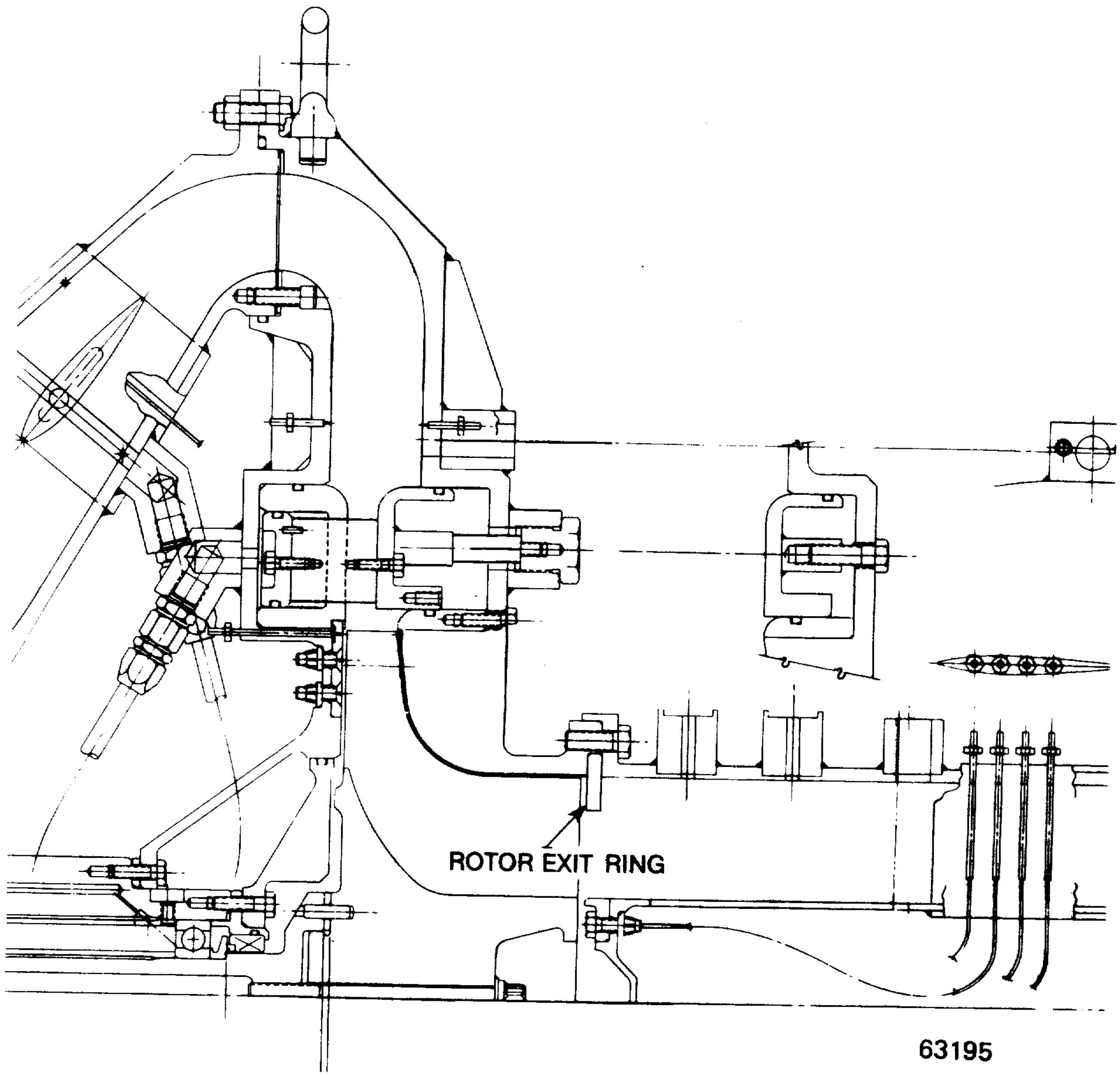

Figure 18. Moveable Sidewall in Closed Position With Reduced Rotor Exit Area Ring.

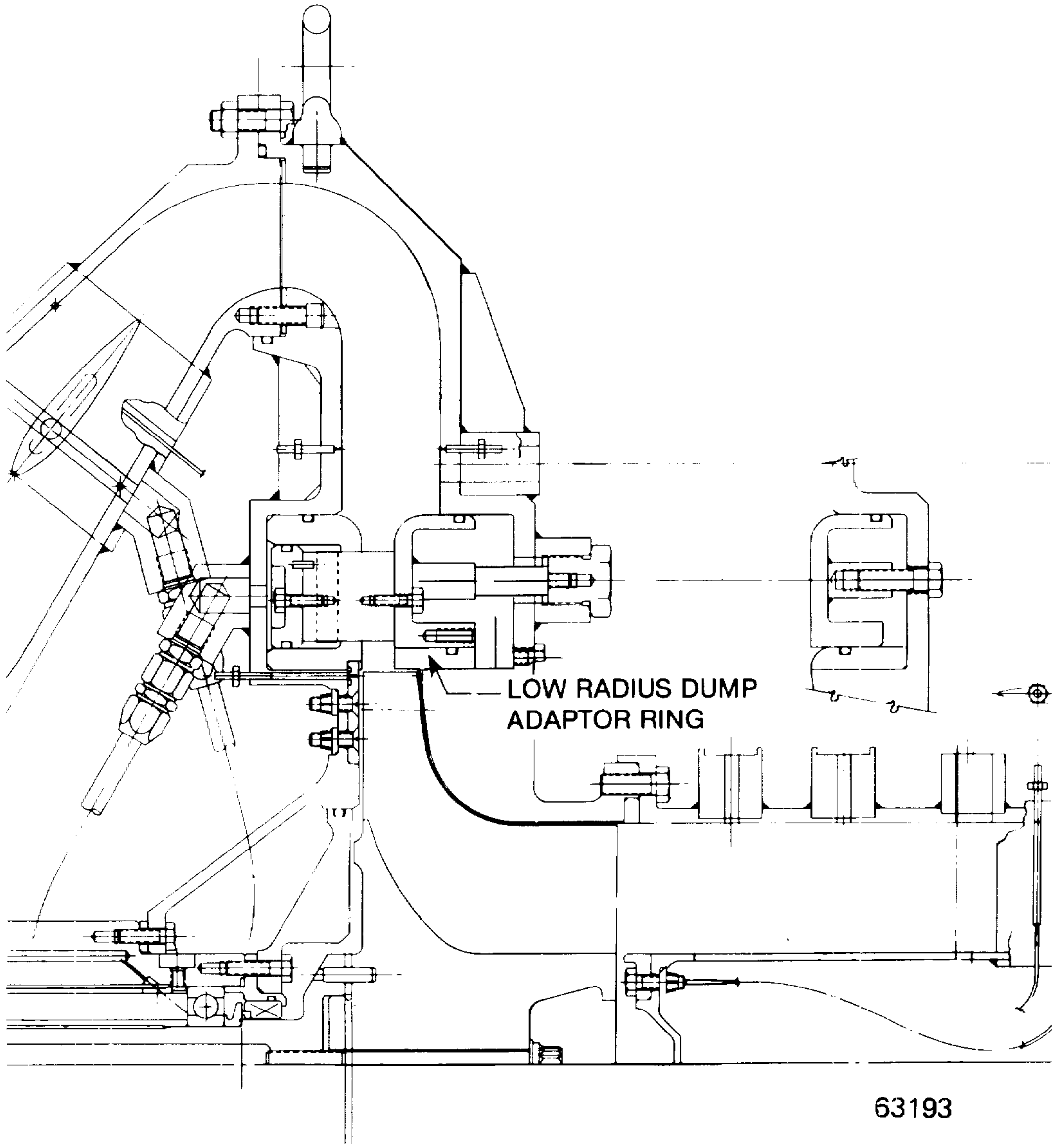

Figure 19. Moveable Sidewall in Closed Position With Low Radius Dump Ring.

The reduction of loss is due to two separate mechanisms. First, the secondary flows are decreased by reduced velocity levels in the region of highest turning; second, the airfoil loading can be redistributed to minimize suction surface diffusion boundary layer build up and its associated losses. Even though in this particular case, the nozzle vane shape was fixed (original TCAE research turbine geometry), it was thought that the turbine performance could benefit from the reduction of diffusion and secondary losses.

The potential reduction of nozzle losses, taken from Deich, et al references 9 and 13, is given in Figure 20. The constriction geometry with the sidewall exit positioned flush with the rotor, 103.5 percent design area, and closed down to 66 percent area is also shown on this figure. A compromised nozzle area increase in the throat of 3.5 percent was incurred as a result of using the same nozzle stagger angle as for the parallel or straight wall nozzle configuration. Ideally the geometries should be compared with the same throat areas, however, fabrication of a separate contoured wall nozzle assembly was beyond the scope of the program. The definition of the shape of the sidewall contouring is given in Figure 21. In this program, both the moveable hub and shroud configurations were designed with contoured sidewalls and evaluated experimentally.

Since the rotor geometry was fixed for all stator configurations, the contouring of the nozzle sidewalls resulted in a larger than optimum throat area and the nozzle to rotor reaction split was, therefore, non-optimum and test results for these configurations should be judged accordingly. To obtain a better area match between the contoured nozzle and the test rotor would have required building a second nozzle ring with the vanes closed down. This was outside the scope of the program.

3.3.3 Test Matrix

The test matricies are given in Table II for the moveable hub wall and Table III for the moveable shroud wall. Where rotor exit rings were used in the exducer plane they were sized to reduce that flow area by a percentage corresponding to nozzle flow area reduction. This was done to preserve the nozzle to rotor reaction ratio. The 100 percent flow condition (80 percent of maximum nozzle area) corresponded to flush walls, i.e. where there were no sudden contraction or expansion steps in the flowpath. In total, thirty-one (31) different configurations were tested for overall performance comparison. For each configuration, data was taken at the turbine design speed, $N/\sqrt{\theta_{cr}}$ = 16,540 rpm, and a design total-to-total pressure ratio of 4.38. Based on this series of tests, five geometries of interest were finally selected for detail surveys at the nozzle and rotor exit. They were test numbers 7, 17, 18, 19, and 29, shown in Table IV.

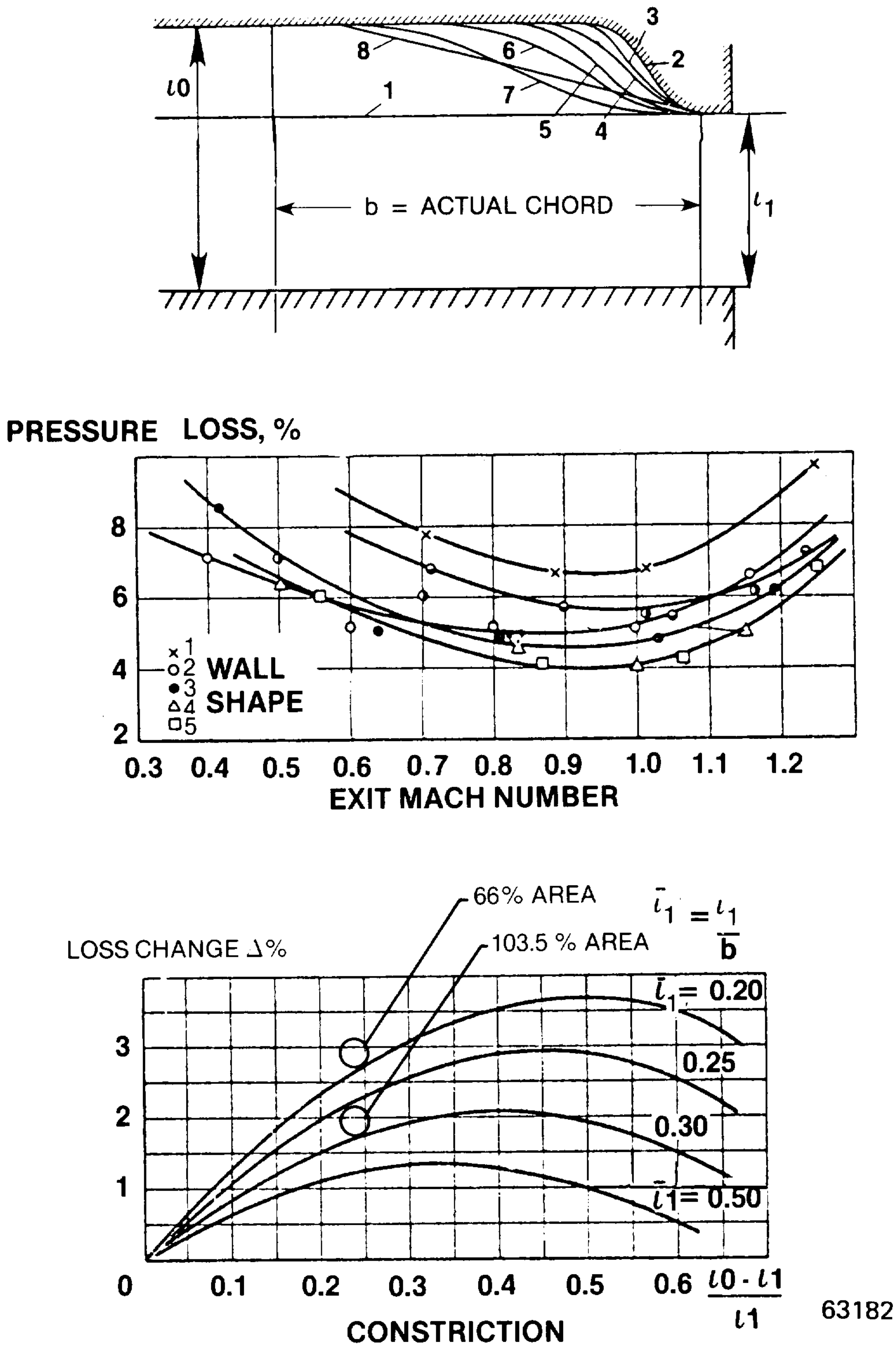

Figure 20. Nozzle Loss Reduction With Sidewall Contouring.

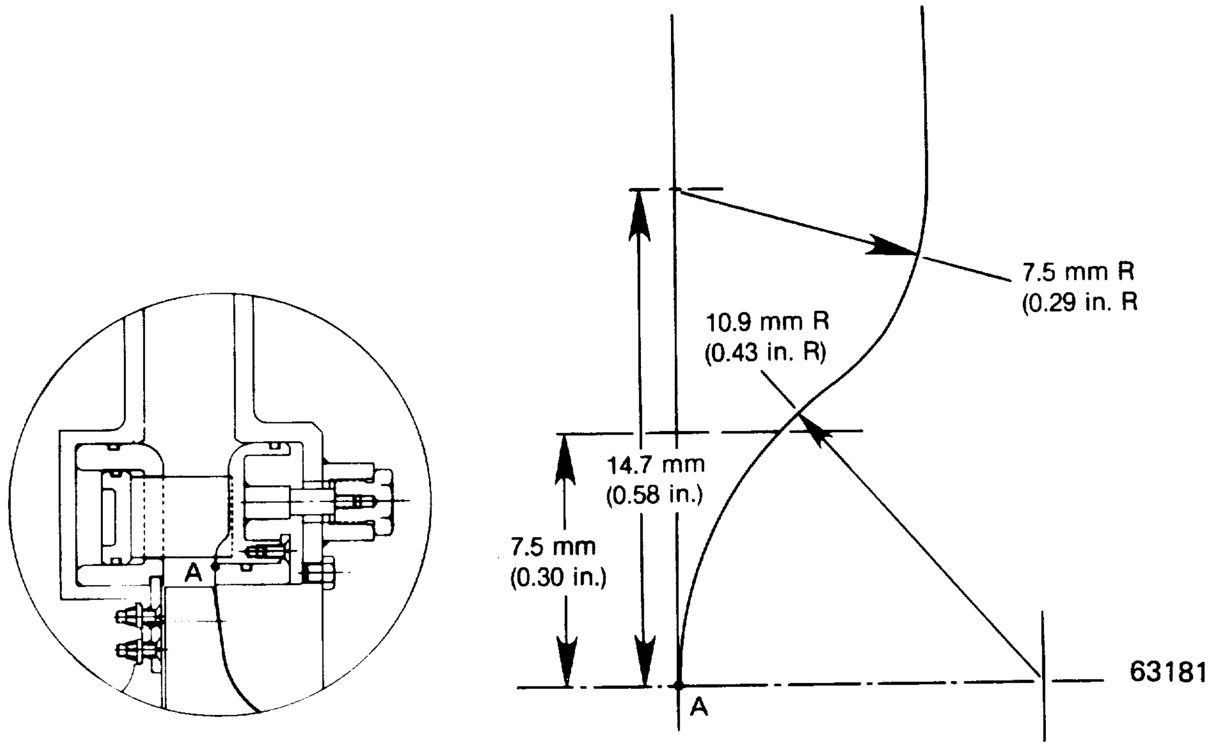

Figure 21. Moveable Sidewall Configuration - Contoured Sidewall Definition.

TABLE II

TEST CONFIGURATION MATRIX - MOVEABLE HUB WALL NOZZLE

TEST NO. (CONFIG.)	MOVEABLE WALL	WALL TYPE	PERCENT DESIGN NOZZ. AREA	VANELESS SPACE INSERT	ROTOR EXIT RING
A	HUB	STRAIGHT	100.0	ACCELERATING RAMP	(NO SEALS)
0	HUB	STRAIGHT	108.8	DUMP	—
1	HUB	STRAIGHT	100.0	DUMP	—
2	HUB	STRAIGHT	81.1	DUMP	—
3	HUB	STRAIGHT	62.2	DUMP	—
4	HUB	STRAIGHT	62.2	DUMP	HUB RING
5	HUB	STRAIGHT	108.8	ACCELERATING RAMP	—
6	HUB	STRAIGHT	100.0	ACCELERATING RAMP	—
7	HUB	STRAIGHT	81.1	ACCELERATING RAMP	—
8	HUB	STRAIGHT	81.1	DIFFUSING RAMP	—
9	HUB	STRAIGHT	62.2	DIFFUSING RAMP	—
10	HUB	STRAIGHT	62.2	DIFFUSING RAMP	HUB RING
11	HUB	CONTOURED	103.5	LOW RADIUS DUMP	—
12	HUB	CONTOURED	84.6	LOW RADIUS DUMP	—
13	HUB	CONTOURED	66.0	LOW RADIUS DUMP	—

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TABLE III

TEST CONFIGURATION MATRIX - MOVEABLE SHROUD WALL NOZZLE

TEST NO. (CONFIG.)	MOVEABLE WALL	WALL TYPE	PERCENT DESIGN NOZZ. AREA	VANELESS SPACE INSERT	ROTOR EXIT RING
14	SHROUD	STRAIGHT	81.1	DUMP	—
15	SHROUD	STRAIGHT	62.5	DUMP	—
16	SHROUD	STRAIGHT	62.5	DUMP	SHROUD RING
17	SHROUD	STRAIGHT	125.0	ACCELERATING RAMP	—
18	SHROUD	STRAIGHT	100.0	ACCELERATING RAMP	—
19	SHROUD	STRAIGHT	81.1	ACCELERATING RAMP	—
20	SHROUD	STRAIGHT	81.1	DIFFUSING RAMP	—
21	SHROUD	STRAIGHT	62.5	DIFFUSING RAMP	—
22	SHROUD	STRAIGHT	62.5	DIFFUSING RAMP	SHROUD RING
23	SHROUD	STRAIGHT	81.1	LOW RADIUS DUMP	—
24	SHROUD	STRAIGHT	62.5	LOW RADIUS DUMP	—
25	SHROUD	STRAIGHT	62.5	LOW RADIUS DUMP	SHROUD RING
26	SHROUD	CONTOURED	103.5	DUMP	—
27	SHROUD	CONTOURED	84.6	DUMP	—
28	SHROUD	CONTOURED	66.0	DUMP	—
29	SHROUD	STRAIGHT	62.2	ACCELERATING RAMP	—

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TABLE IV

NOZZLE CONFIGURATIONS SELECTED FOR DETAIL SURVEYS

TEST CONFIG. NO.	MOVEABLE WALL	PERCENT DESIGN AREA	PERCENT DES. FLOW	NOZZLE RING	ROTOR RING	
17	SHROUD	125	120.0	ACCEL. RAMP	NONE	COMPLETES OVERALL PERF. TEST SERIES AND TEST BEST CONFIGURATION AT MAX. FLOW.
18	SHROUD	100	100.0	ACCEL. RAMP	NONE	GIVES BASELINE DATA FOR NOZZLE ROTOR SPLITS, VEL. TRIANGLES, ETC.
19	SHROUD	81.1	84.0	ACCEL. RAMP	NONE	COMPLETES SERIES WITH ACCEL. RAMP TO 81.1% DESIGN AREA
7	HUB	81.1	85.5	ACCEL. RAMP	NONE	DIRECT COMPARISON DATA TO 19 ABOVE WITH OPPOSITE SIDEWALL MOVEMENT
29	SHROUD	62.2	64.8	ACCEL. RAMP	NONE	COMPLETES SERIES WITH ACCEL. RAMP TO 62.2% DESIGN AREA

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SECTION 4.0

DATA ACQUISITION

4.1 INSTRUMENTATION

Instrumentation was selectively placed in the turbine flowpath to evaluate overall performance and to separate nozzle and turbine rotor losses. Figure 21 shows the instrumentation planes in the rig cross sectional view. Figures 22 to 25 show the circumferential location of the instrumentation in the respective planes and consist of the following:

<u>Plane 1 - Turbine Stator Inlet</u>

3 total temperature rakes (4 elements each)
3 total pressure rakes (4 elements each)
2 total pressure, total temperature and flow angle survey probes
4 static pressure taps - inner wall
4 static pressure taps - outer wall

The turbine stator inlet instrumentation plane was located upstream of the vane leading edges a distance corresponding to 47% of the stator vane chord. The rake sensing elements were located at centers of equal areas and spaced in equal circumferential sectors.

<u>Plane 2 - Vaneless Space and Rotor Shroud</u>

4 static pressure taps - inner wall
4 static pressure taps - outer wall
1 Cobra type survey probe for angle and total pressure measurement
8 static pressure taps - rotor shroud
The Cobra survey probe was capable of traversing the entire channel height during normal rig operation and also traversing through an arc of 25° circumferentially to cover the distance of 1 1/2 stator pitches. The eight static pressure taps in the rotor shroud were positioned at equal meridional increments.

<u>Plane 3 - Turbine Rotor Exit</u>

4 static pressure taps - inner wall
4 static pressure taps - outer wall
1 Cobra type survey probe for angle, total pressure and total temperature measurement

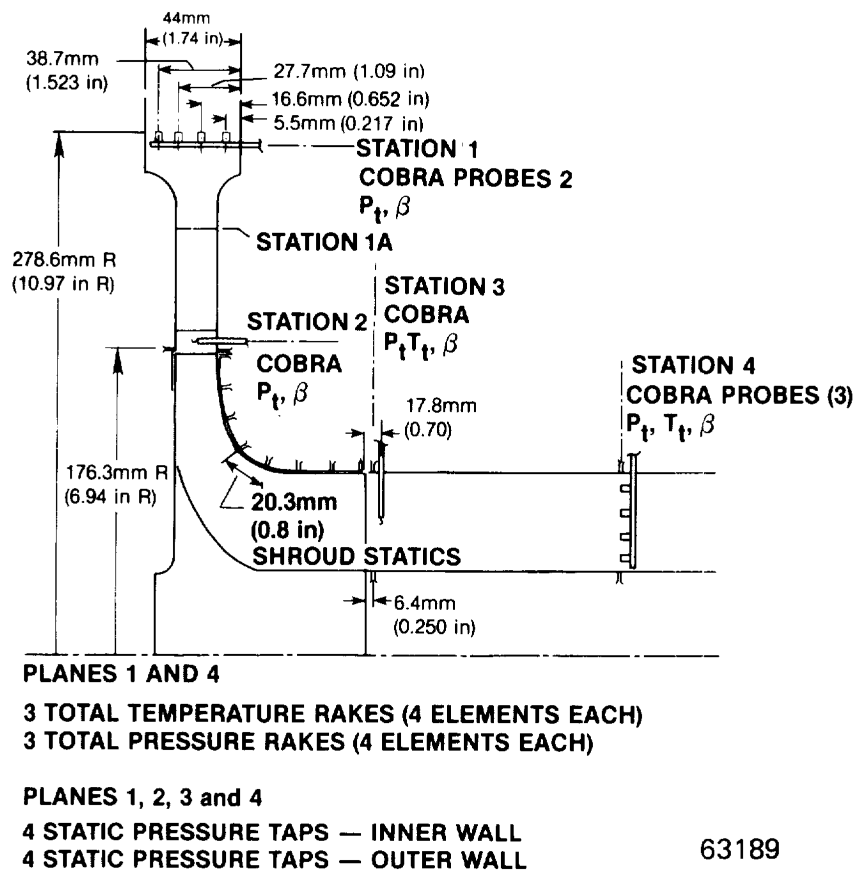

Figure 22. Radial Turbine Rig Instrumentation Planes.

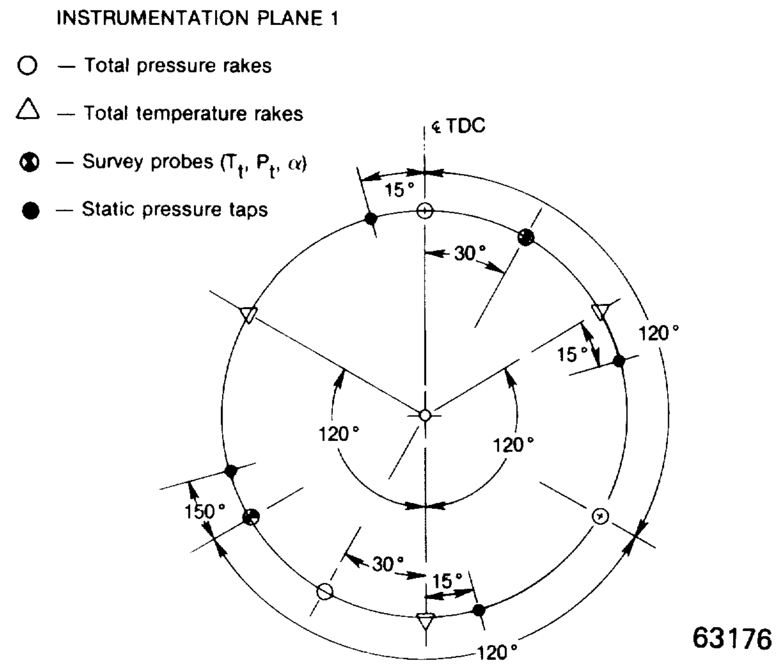

Figure 23. Stator Inlet (Plane 1) Circumferential Instrumentation Location.

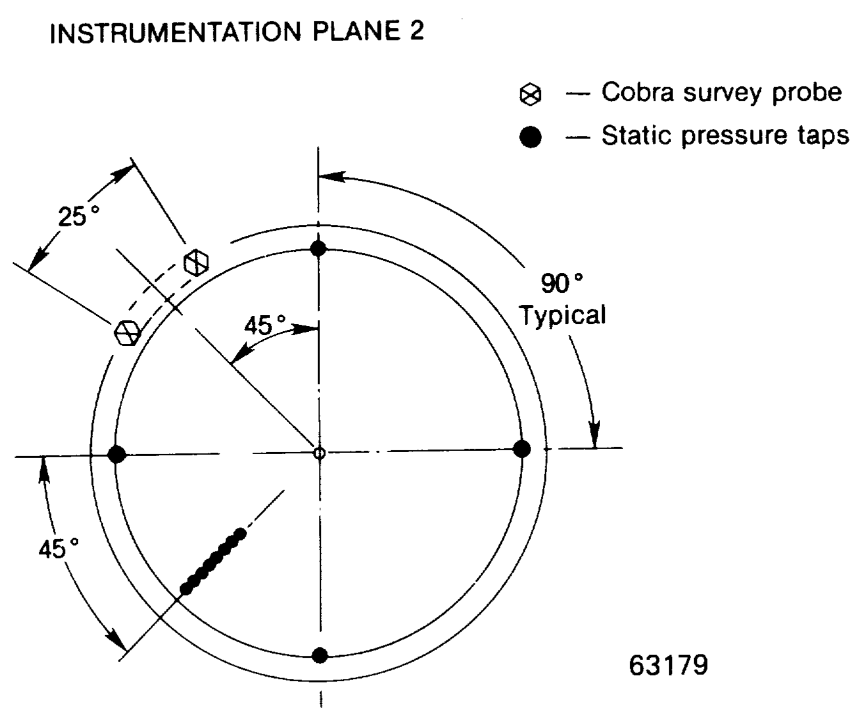

Figure 24. Vaneless Space (Plane 2) Circumferential Instrumentation Location.

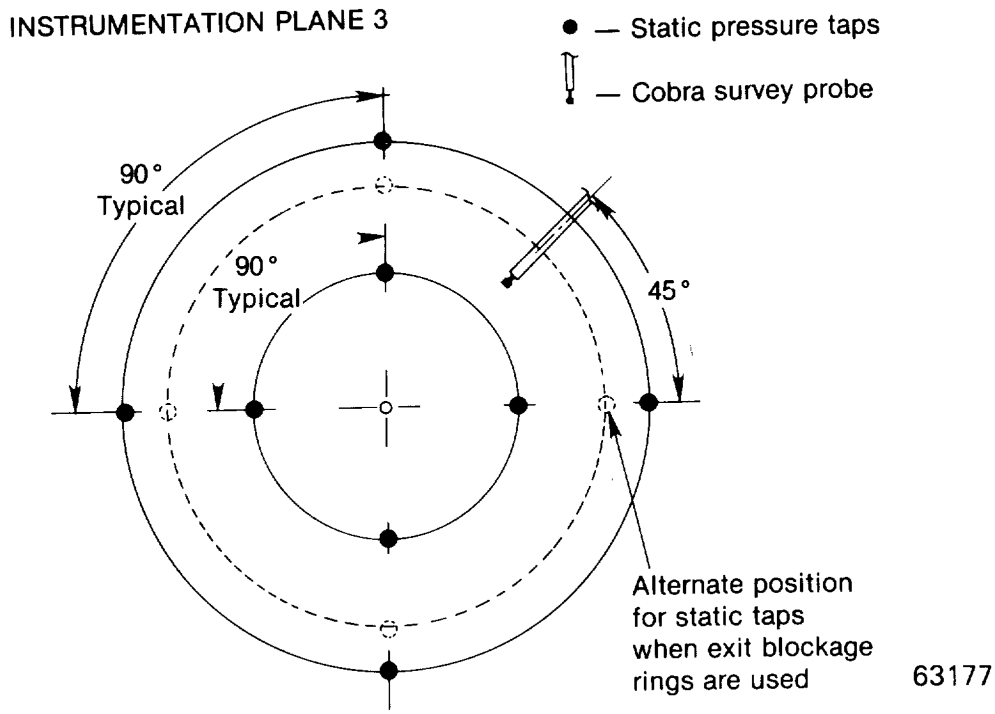

Figure 25. Exducer Exit Instrumentation (Plane 3) Circumferential Instrumentation Location.

The static pressure taps and the plane of the Cobra survey probe were located 6.4 mm (0.25 in) and 17.8 mm (0.70 in) downstream of the rotor exit respectively. When blocking rings were inserted, the static pressure was also measured on the ring surface. The Cobra probe had a traversing capability only in the radial direction at this location.

Plane 4 - Exhaust Duct

3 total temperature rakes (4 elements each)
3 total pressure rakes (4 elements each)
3 total pressure, total temperature and flow angle survey probes

Miscellaneous Instrumentation

total pressure - main flow orifice
total temperature - main flow orifice
static pressure differential - main flow orifice
turbine shaft torque via a "Lebow" inline torque measurement
turbine shaft mechanical speed

Figure 27 shows a 4-element, shielded total temperature rake used in planes 1 and 4. The shielded thermocouple was employed because it required much smaller Mach number correction in comparison to an exposed thermocouple and also because of its insensitivity to angle changes. Figure 28 depicts a 4-element total pressure rake also used in planes 1 and 4. The total pressure rake was designed to minimize its sensitivity to flow angle variation. Conventional self nulling cobra type survey probes, shown in Figure 29, were utilized in each of the instrumentation planes 1, 2, 3, and 4. The cobra probe was designed for simultaneous measurement of total temperature, total pressure, and flow angle during surveys.

4.2 DATA REDUCTION

An Interdata 7/32 computer was linked for data acquisition and test support. All the probe readings and the processed performance data were stored in the computer disk and also printed by a deckwriter for online review. Data stored in the computer disk were then transferred to a magnetic tape for additional data reduction and storage.

A data reduction program was loaded on the Interdata 7/32 to process the performance data while the rig was running. A data point was reduced every 2.5 seconds and the average of ten values was printed for any given test point configuration. These data include corrected flow ($W\sqrt{\theta cr}\,\epsilon/\delta$), flow speed parameter ($WN\epsilon/60\delta$), equivalent speed ($N/\sqrt{\theta cr}$), equivalent work ($\Delta H/\theta cr$), total-to-total pressure ratio (PT1/PT4), and total-to-total efficiency. The reduced overall performance data for all the configurations tested are included in Appendix A.

Two other data reduction programs were developed to reduce the survey data. One is for the survey at the exducer exit and mixed out plane and one for the survey data at the nozzle exit. The computer program for reducing the survey data at the exducer exit and mixed out plane plots the data as a function of radial span. Values of swirl angle, total pressure, total temperature, streamline efficiency, and local to critical velocity ratio are plotted. The mass average value of each of the parameters is also calculated. These plots for each of the configuration test points are given in Appendicies B and C. The computer program for reducing the survey data at the nozzle exit plots two dimensional contours for the flow angle, total pressure loss, nozzle efficiency, and pressure loss coefficient. These plots are shown in Appendix D.

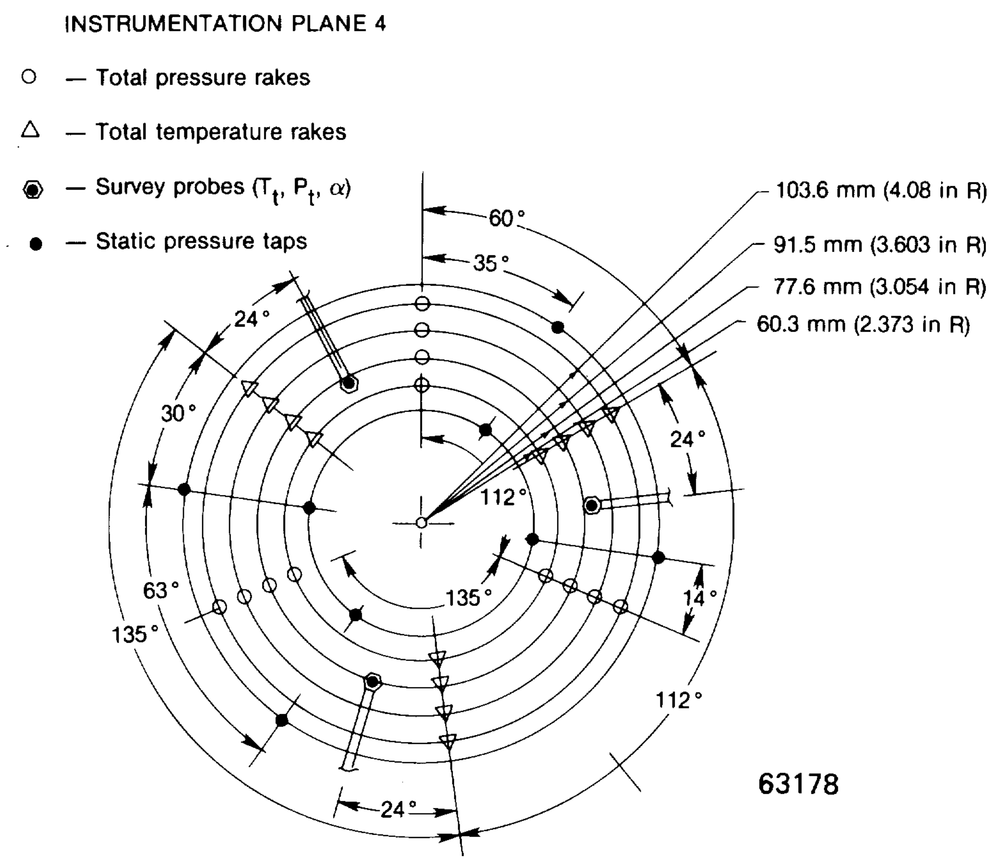

Figure 26. Exhaust Duct Mixed Out Station (Plane 4) Circumferential Instrumentation Location.

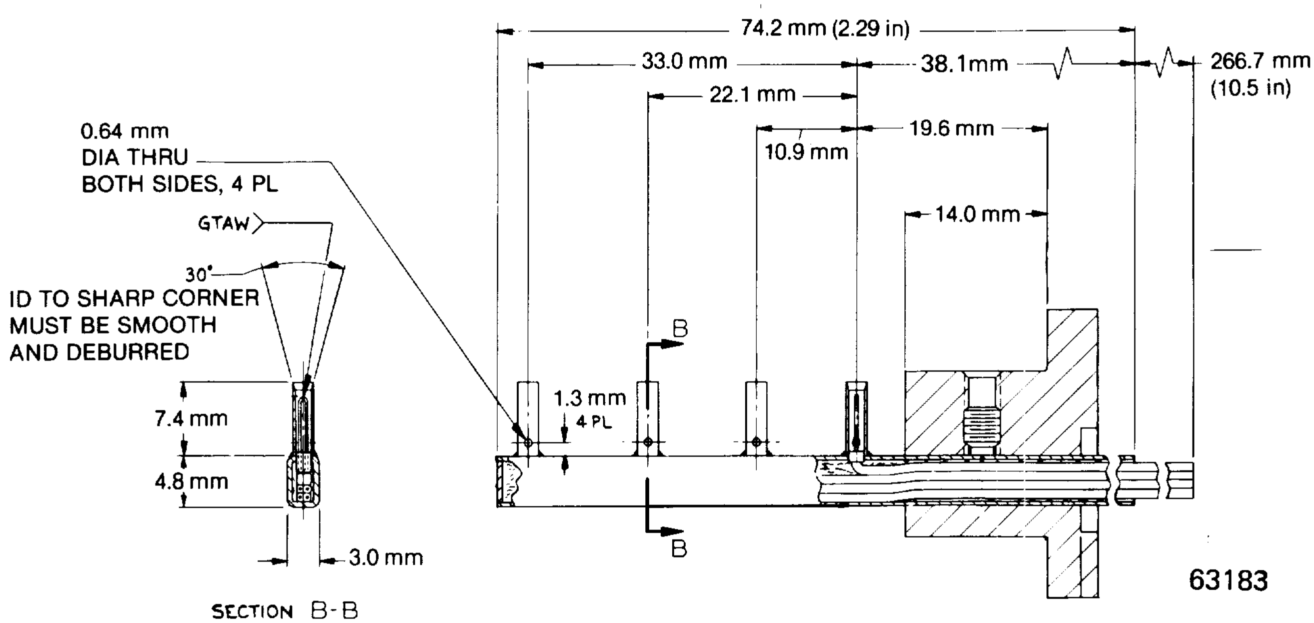

Figure 27. Multi-Element Total Temperature Rake.

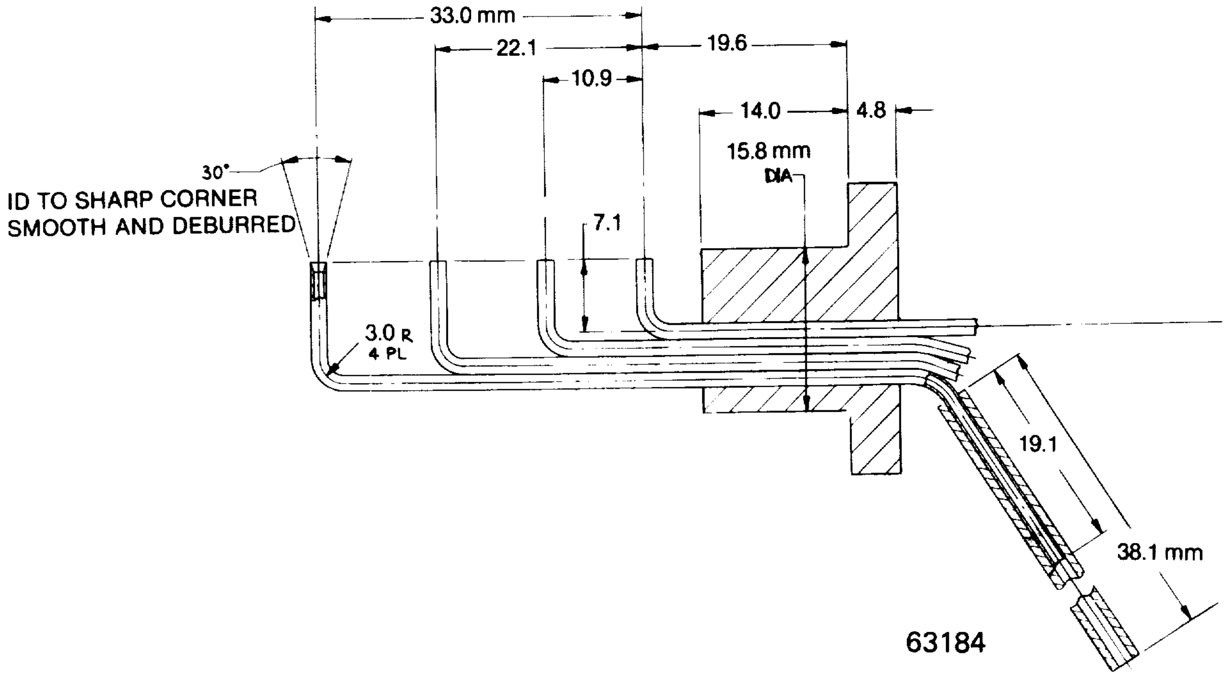

Figure 28. Multi-Element Total Pressure Rake.

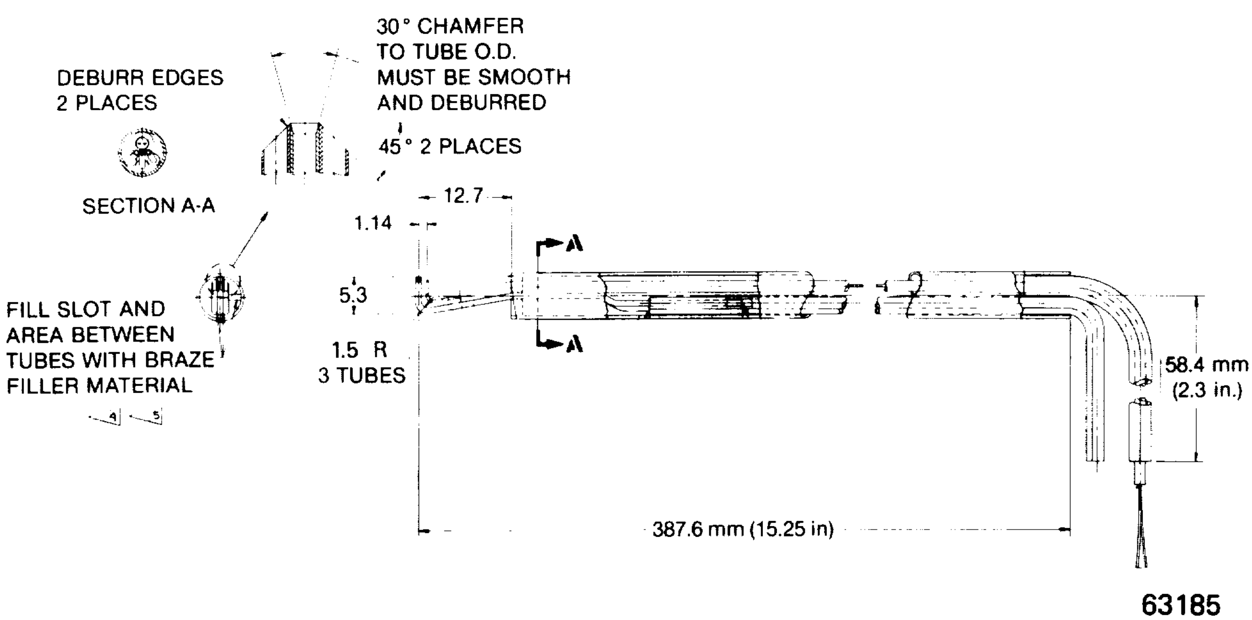

Figure 29. Multi-Element Total Pressure, Total Temperature and Flow Angle Survey Probe.

4.3 DATA ACCURACY

Overall performance of the turbine stage was evaluated on the basis of total temperature/pressure rake data, torque/air flow measurements, and mass averaged survey data. In tests of some of the configurations, severe flow gradients at the rotor exit impacted the accuracy of efficiency values obtained from rake measurements. These gradients were found to be most severe when rotor shroud rings were placed in the exducer exit plane. In these few select cases, the performance based on rake data was considered less accurate.

Tables V and VI summarize the overall performance testing results for the thirty-one (31) geometries. Where torque, rake and survey data is available for comparison, the greatest differences in efficiencies are evident in geometries using exducer shroud rings and near the end of the test series when torque measurements became erratic due to worn electrical pickup brushes. A statistical summary of the performance data is given in Table VII, using mass averaged efficiencies determined from flow surveys as a baseline. Statistical sampling was conducted based on all readings, a case where the last two erratic torque data samples were removed, and a case where the exducer rings distorted the rake readings and were also removed. In the latter case it may be seen that standard deviation values are 1.07 and 0.54 points, for torque efficiency and temperature efficiency respectively, compared to the baseline survey mass-averaged efficiency which was considered the most accurate.

TABLE V

SUMMARY OF OVERALL PERFORMANCE TESTING
WITH MOVEABLE HUB WALL

TEST NO. CONFIG.	MOVABLE SIDEWALL	NOZZLE RING	ROTOR RING	PERCENT DESIGN AREA	$W\sqrt{\Theta_{cr}}\,\epsilon/\delta$ kg/s	EFF TORQUE, η_T	EFF RAKE η_A	EFF SURVEY, η_S	$\Delta\eta$ $\eta S - \eta T$	$\Delta\eta$ $\eta S - \eta A$
A	HUB/STRAIGHT	ACCEL DUMP	—	100.0	1.375	83.77	84.48	—	—	—
0.	HUB/STRAIGHT	DUMP	—	108.8	1.369	88.30	86.60	—	—	—
1.	HUB/STRAIGHT	DUMP	—	100.0	1.280	88.00	87.01	—	—	—
2.	HUB/STRAIGHT	DUMP	—	81.1	1.088	86.97	86.32	—	—	—
3.	HUB/STRAIGHT	DUMP	—	62.2	0.855	85.12	84.63	—	—	—
4.	HUB/STRAIGHT	DUMP	HUB RING	62.2	0.849	77.10	78.08	77.68	0.58	−0.40
5.	HUB/STRAIGHT	ACCEL RAMP	—	108.8	1.389	87.64	86.94	86.32	−1.32	−0.62
6.	HUB/STRAIGHT	ACCEL RAMP	—	100.0	1.300	87.72	86.93	86.37	−1.35	−0.56
7.	HUB/STRAIGHT	ACCEL RAMP	—	81.1	1.095	86.71	86.37	85.01	−1.70	−1.36
8.	HUB/STRAIGHT	DIFF. RAMP	—	81.1	1.103	86.11	86.11	84.89	−1.22	−1.22
9.	HUB/STRAIGHT	DIFF. RAMP	—	62.2	0.860	86.10	84.29	82.65	−3.45	−1.64
10.	HUB/STRAIGHT	DIFF. RAMP	HUB RING	62.2	0.850	79.49	79.33	79.92	0.43	0.59
11.	HUB/CONTOUR	LOW R DUMP	—	103.5	1.332	84.85	86.46	85.14	0.29	−1.32
12.	HUB/CONTOUR	LOW R DUMP	—	84.6	1.134	86.30	85.98	84.64	−1.66	−1.34
13.	HUB/CONTOUR	LOW R DUMP	—	66.0	0.898	84.07	83.50	81.87	−2.20	−1.63

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TABLE VI

SUMMARY OF OVERALL PERFORMANCE TESTING
WITH MOVEABLE SHROUD WALL

TEST NO. CONFIGURATION	MOVABLE SIDEWALL	NOZZLE RING	ROTOR RING	PERCENT DESIGN AREA	$W\sqrt{\Theta_{cr}}\epsilon/\delta$ kg/s	EFF TORQUE, η_T	EFF RAKE η_A	EFF SURVEY, η_S	$\Delta\eta$ $\eta S - \eta T$	$\Delta\eta$ $\eta S - \eta A$
14.	SHRD/STRAIGHT	DUMP	—	81.1	1.072	87.92	86.77	86.22	−1.70	−0.55
15.	SHRD/STRAIGHT	DUMP	—	62.5	0.841	85.21	83.76	83.20	−2.01	−0.56
16.	SHRD/STRAIGHT	DUMP	SHRD RING	62.5	0.815	76.71	74.01	77.67	0.96	3.66
17.	SHRD/STRAIGHT	ACCEL RAMP	—	125.0	1.536	—	84.95	—	—	—
18.	SHRD/STRAIGHT	ACCEL RAMP	—	100.0	1.280	88.76	87.33	86.53	−2.23	−0.80
19.	SHRD/STRAIGHT	ACCEL RAMP	—	81.1	1.075	87.46	86.81	85.83	−1.63	−0.98
20.	SHRD/STRAIGHT	DIFF. RAMP	—	81.1	1.063	88.34	86.66	85.92	−2.42	−0.74
21.	SHRD/STRAIGHT	DIFF. RAMP	—	62.5	0.836	85.04	83.54	82.42	−2.62	−1.12
22.	SHRD/STRAIGHT	DIFF. RAMP	SHRD RING	62.5	0.821	75.21	74.68	79.48	4.27	4.8
23.	SHRD/STRAIGHT	LOW R DUMP	—	81.1	1.066	87.58	86.34	85.38	−2.20	−0.96
24.	SHRD/STRAIGHT	LOW R DUMP	—	62.5	0.837	84.32	82.61	82.11	−2.21	−0.50
25.	SHRD/STRAIGHT	LOW R DUMP	SHRD RING	62.5	0.809	76.08	73.23	77.17	1.09	3.94
26.	SHRD/CONTOUR	DUMP	—	103.5	1.362	89.49	86.06	85.01	−4.48	−1.05
27.	SHRD/CONTOUR	DUMP	—	84.6	1.188	88.31	86.07	85.37	−2.94	−0.70
28.	SHRD/CONTOUR	DUMP	—	66.0	0.975	—	84.31	83.03	—	−1.28
29.	SHRD/STRAIGHT	ACCEL RAMP	—	62.2	0.829	—	83.16	—	—	—

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TABLE VII

STATISTICAL EVALUATION OF MEASURED EFFICIENCIES

	TORQUE EFFICIENCY, η_T			RAKE EFFICIENCY, η_A		
NO. OF SAMPLES, n	23	21	18	23	21	18
SAMPLES REMOVED, Δn	NONE	LAST (2)	2 + SHRD RING DATA = (5)	NONE	LAST (2)	2 + SHRD RING DATA = (5)
AVERAGE, $\frac{\Sigma \Delta \eta}{n}$	−1.29	−1.06	−1.59	−0.22	−0.16	−0.87
SUM OF EFF. DIFFERENCES, $\Sigma \Delta \eta$	−29.12	−22.3	−28.62	−5.06	−3.37	−15.71
SUM OF (DIFF.)^2, $\Sigma \Delta \eta$	114.0	85.39	65.05	72.17	70.58	18.62
POPULATION STD. DEV., $\sigma_n = \sqrt{\frac{\Sigma \Delta \eta^2 - \frac{(\Sigma \Delta \eta)^2}{n}}{n}}$	1.81	1.71	1.04	1.76	1.83	0.52
STANDARD DEV., $\sigma_{n-1} = \sqrt{\frac{\Sigma \Delta \eta^2 - \frac{(\Sigma \Delta \eta)^2}{n}}{n}}$	1.86	1.76	1.07	1.80	1.81	0.54

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SECTION 5.0

TEST RESULTS

5.1 BASELINE OVERALL PERFORMANCE

Initial testing on the turbine stage was conducted with a clearance between the nozzle vane profile and the sidewall of 0.406 mm (0.016 in). This value was considered as a representative minimum practical value required in an engine application. However, substantial stage losses were incurred due to leakage flows in this clearance gap. Figure 30 shows the performance of the moveable hub shroud nozzle geometry, with a vaneless space simple dump, as a function of total flow. Test configuration numbers A and 1 were conducted with the same geometry but with the clearances first open, Test A, and then with the gaps sealed with a room temperature vulcanized silicone, Test No. 1, respectively. Leakage flow bypassing the nozzle throat with no sealant was measured to be eight percent which corresponds approximately to a choke condition in the gap area downstream of the throat. With the clearance space filled in with the sealant, two and one half points in efficiency were recovered and design flow was achieved. Subsequently metal "L" seals, Figure 31 were installed in the nozzle throat region. These seals effectively reduced the by-pass flow and allowed the turbine to operate at the same performance level as with the positive silicone seal. The "L" seal, which is typical of what could be used in actual engine application was used throughout the remainder of test series.

The most complete data set for the remaining test configurations was taken with rake measured performance. Since this data was shown to be reasonably accurate (within 0.5 points of survey data) most of the following performance comparisons are based on rake measurements, Section 4.3, Data Accuracy.

5.2 MOVEABLE HUB WALL - EFFECTS OF NOZZLE GEOMETRY AND ROTOR EXIT RESTRICTION

Figure 32 summarizes the overall performance testing of the moveable hub wall configurations with straight sidewalls, based on rake data. The stage efficiency peaked out at the design or nominal flow area point (100 percent nominal flow = 1.28 kg/sec (2.823 lbs/sec) achieving a total/total efficiency value of 87.0 percent with flush walls. A second flush wall position. Test number 6, a configuration with an accelerating ramp closely duplicated performance at an efficiency of 86.9 percent.

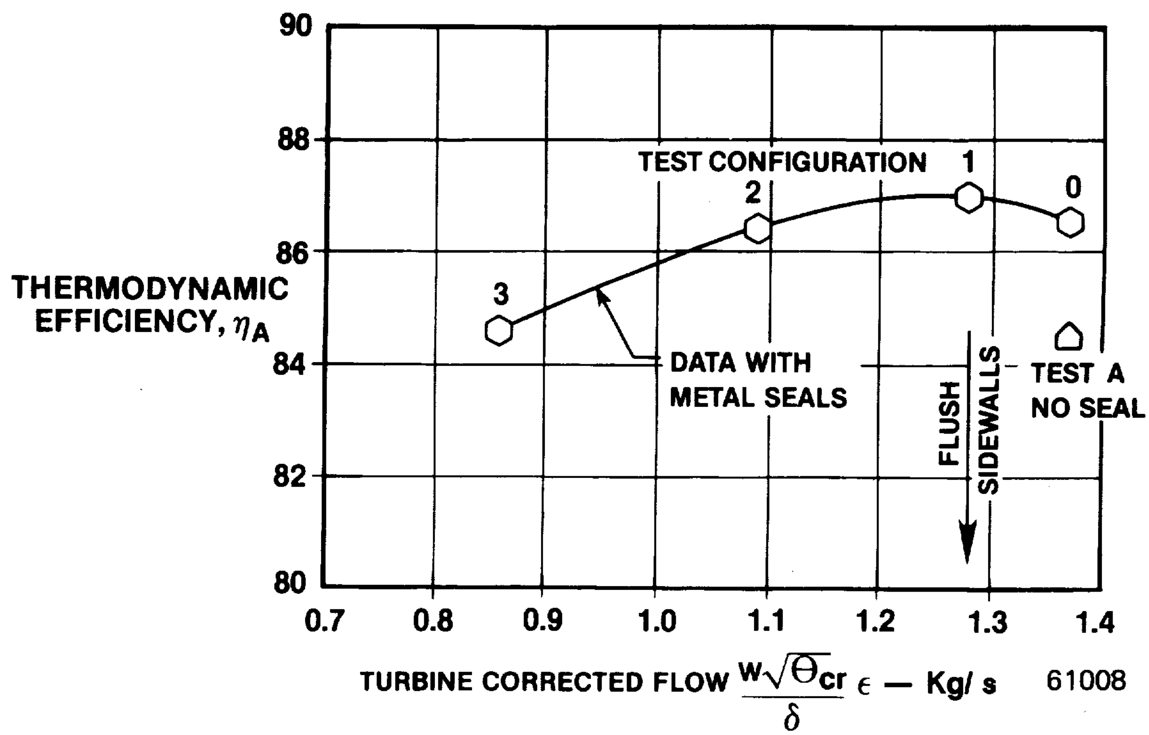


Figure 30. Nozzle Leakage Effect on Stage Performance.

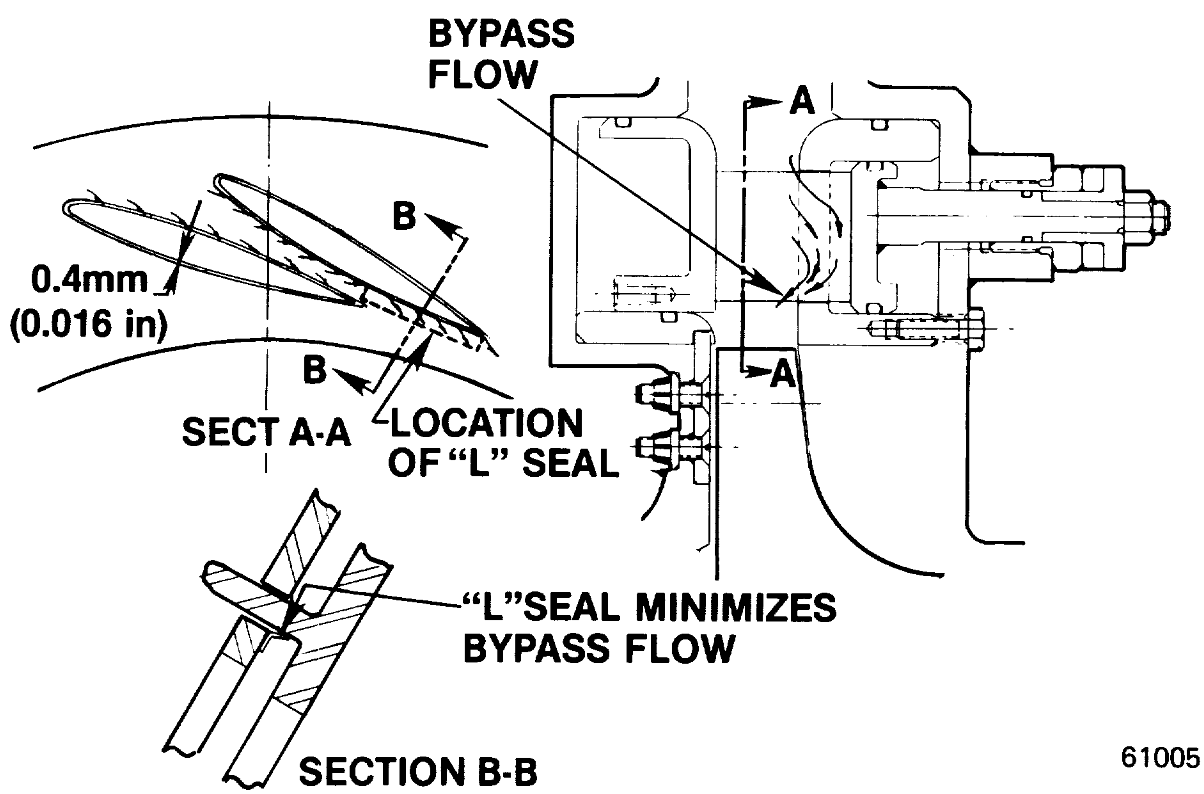


Figure 31. Nozzle Sidewall Leakage and Throat Bypass Flows.

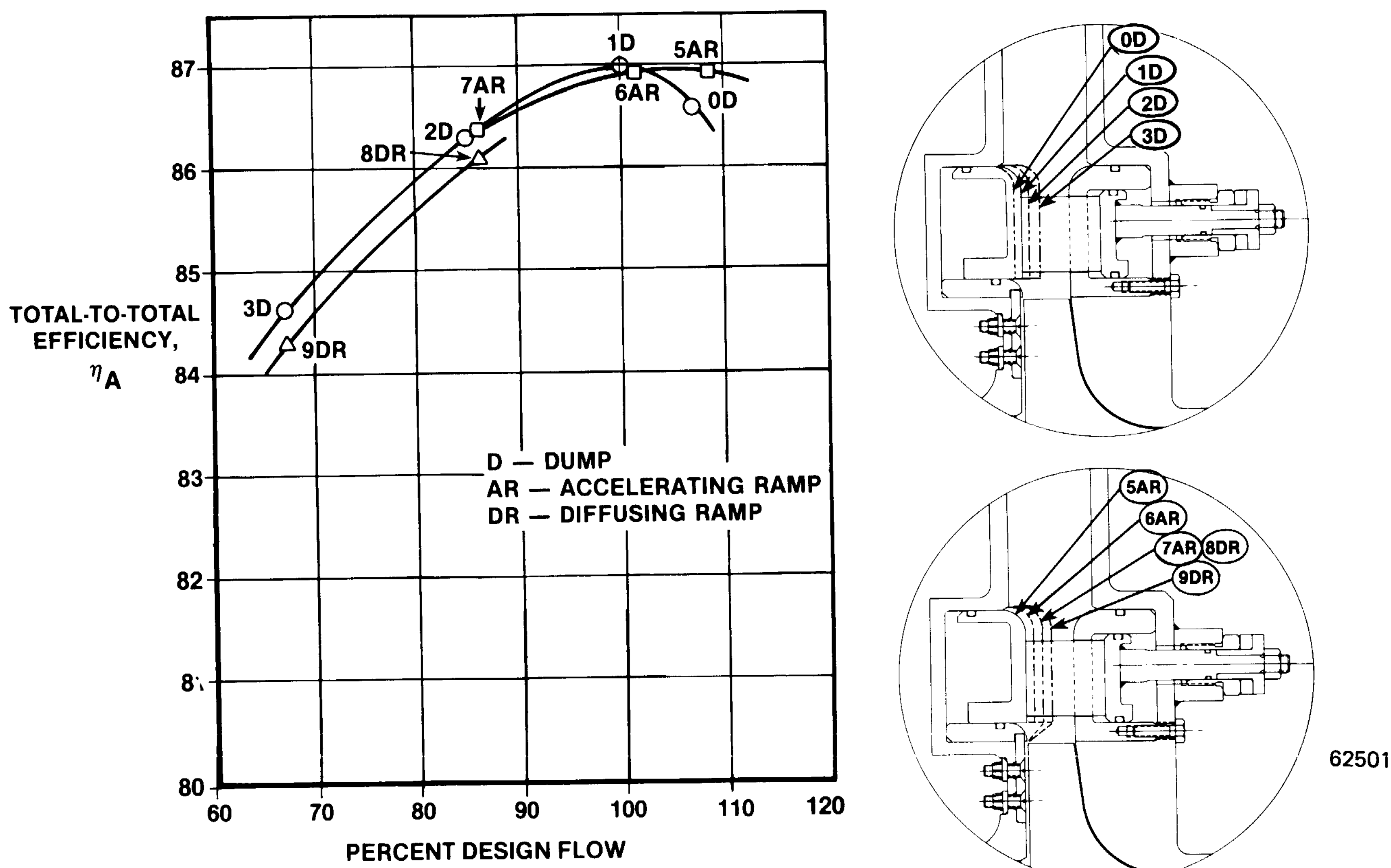


Figure 32. Moveable Hub Wall Performance Comparison for Straight Walls.

The use of a diffusing ramp at 50 percent nominal flow area, Test number 9, showed only little improvement in performance of the straight dump configuration, Test number 3. Conversly, an accelerating ramp, Test number 5, improved performance by 0.4 points over a step area change geometry, Test number 0, at the maximum flow area position. The penalty associated with the use of an accelerating ramp at reduced flow areas was found to be the same as the straight dump configuration.

Tests 11, 12 and 13 were conducted with low radius dump and a contoured sidewall. This configuration resulted in a performance penalty at all nozzle area settings, Figure 33. Although some of this loss could be due to the low radius dump ring, the reduced contoured wall performance trend was also confirmed with shroud wall area variation testing, Section 5.3.

Rotor exducer hub constriction rings were added that reduced the exhaust duct area corresponding to an amount equal to the nozzle area reduction to balance the rotor reaction with the change in stator area. Any gain in the rotor performance was significantly offset by downstream sudden expansion losses occuring in the downstream ducting. Figure 33 shows that the addition of exducer rings reduced the stage efficiency at the mixed out plane by six to ten points.

5.3 Moveable Shroud Wall - Effects of Nozzle Geometry and Rotor Exit Restriction

The overall turbine performance when the shroud sidewall is moved is shown in Figures 34 and 35.

In general, the results with the moveable shroud sidewall are similar to those for the moveable hub sidewall. The accelerating ramp with the 100 percent nozzle area (Test 18) had the highest efficiency (87.3 percent) of all configurations tested. The accelerating ramp, dump and diffusing ramp had nearly the same efficiency for the common nozzle areas tested. The low radius dump configurations (Tests 23 and 24) were about one-half point lower. Another significant finding was that the location of the nozzle exit wall split line at a higher radius (away from the rotor leading edge) resulted in, up to one point efficiency improvement over a low radius location (comparison of Test points 15 and 24. This was also confirmed in the exducer shroud ring Tests 16 and 25, Figure 35.

Figure 35 also shows the results of the contoured sidewall effect, Tests 26, 27 and 28. As with the moveable hub sidewall tests, contouring resulted in lower performance than with straight sidewalls. Contouring showed the lowest efficiency in all

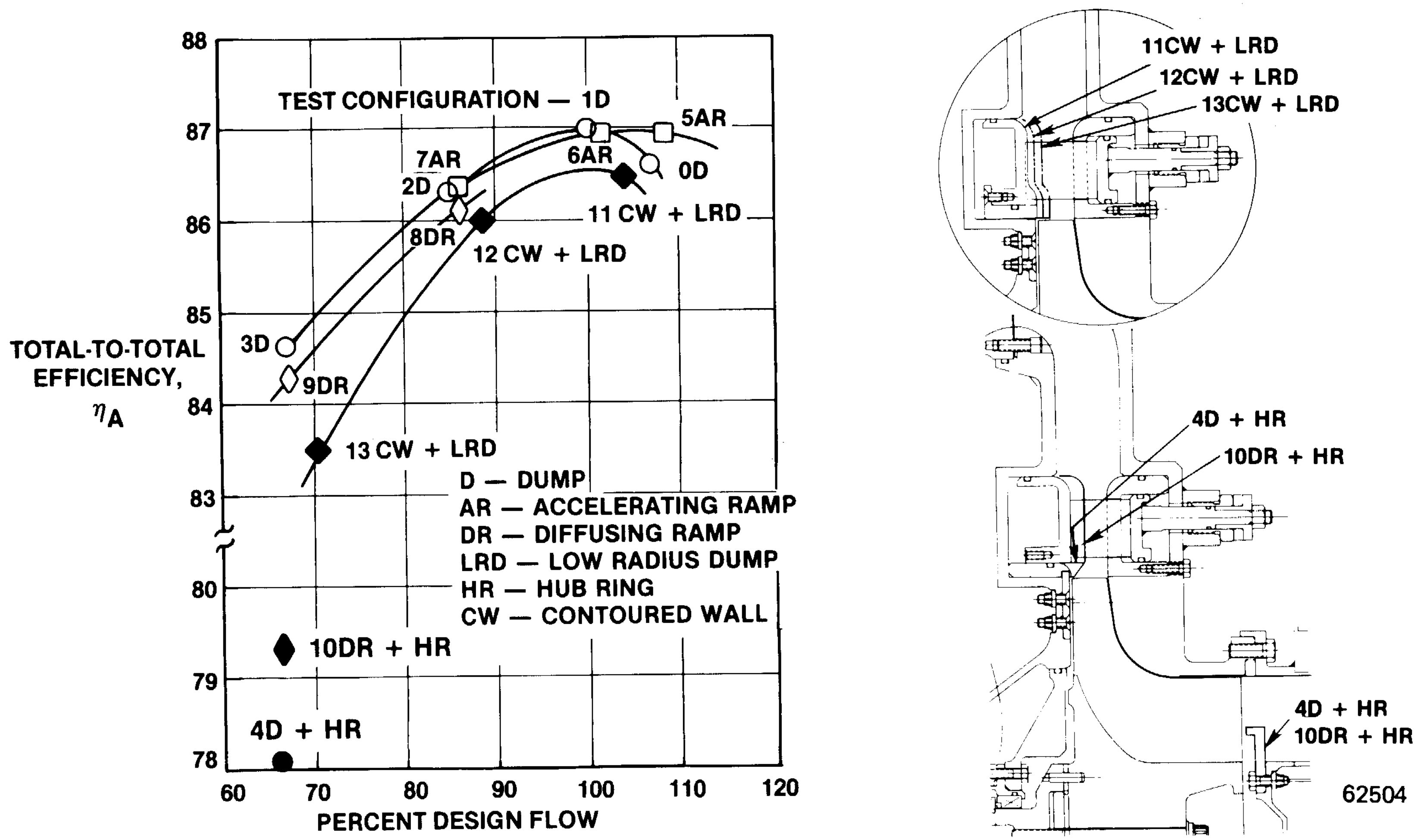


Figure 33. Moveable Hub Wall Performance Comparison for Contour Wall and Hub Ring.

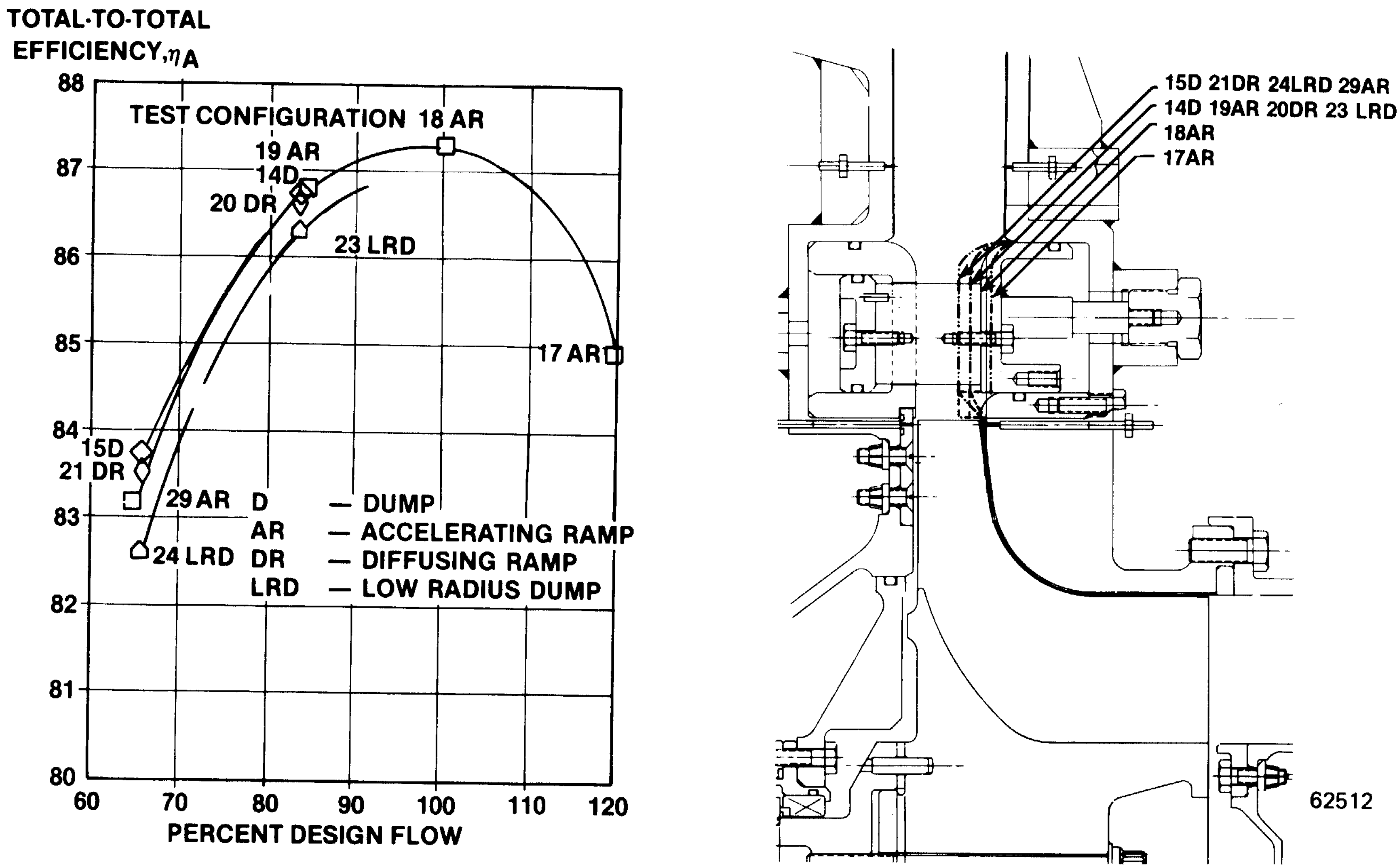


Figure 34. Moveable Shroud Wall Performance Comparison for Straight Walls.

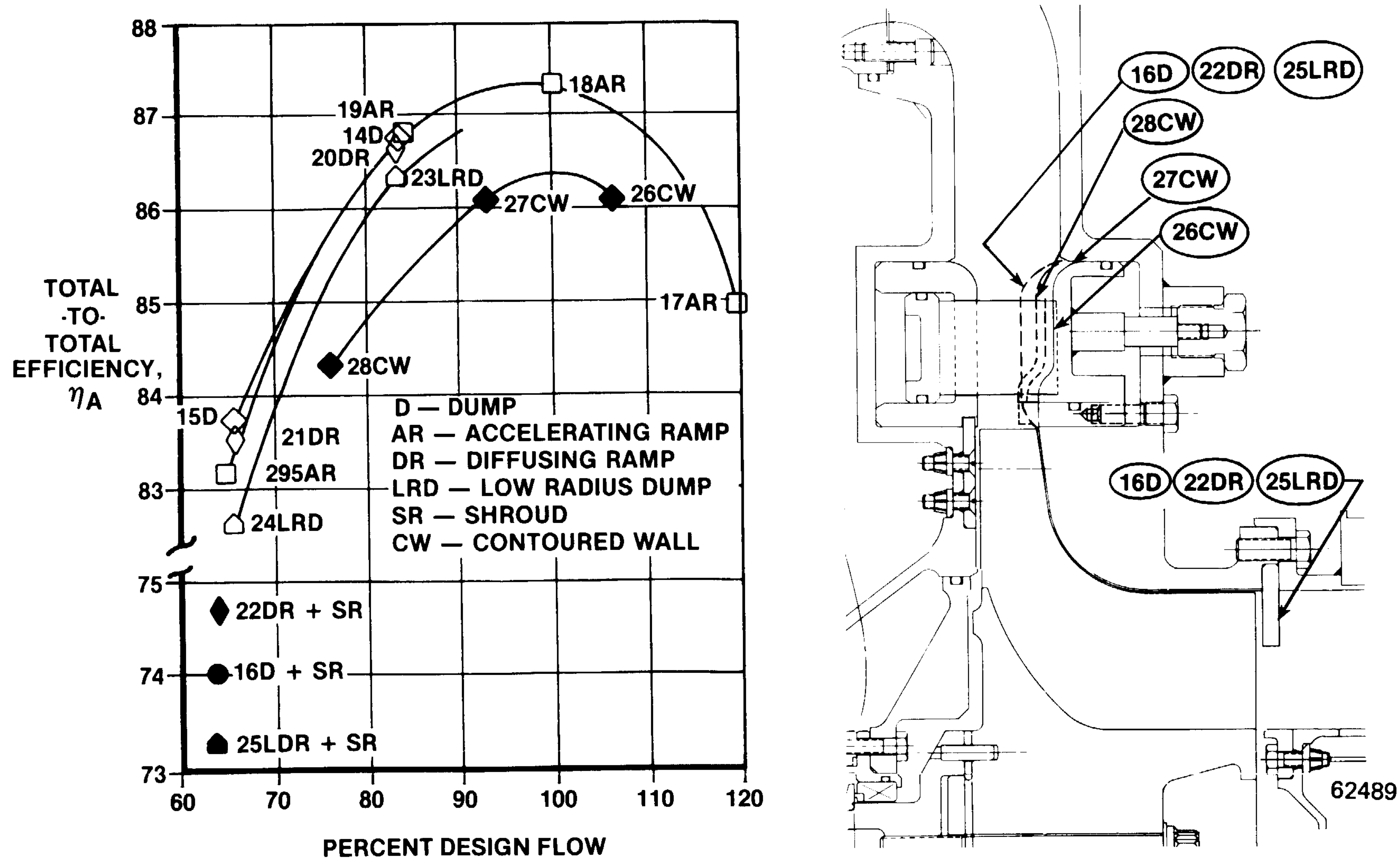


Figure 35. Moveable Shroud Wall Performance Comparison for Contour Wall and Shroud Ring.

configurations tested. However, this should not be construed as non-beneficial since the nozzle to rotor reaction was compromised in the implementation of this concept. The data results showing that performance is significantly affected, by this geometry change alone, suggests that this concept should be further investigated.

Figure 36 is a comparison of total to total efficiency moveable hub wall tests and moveable shroud wall tests. The dashed curves in the figure are moveable hub Tests 5, 6 and 7 with an accelerating ramp; Tests 0, 1, 2 and 3 with a simple dump; and Tests 8 and 9 with a diffusing ramp.

The experimental data show that the shroud side area variation is marginally better than the hub side over the flow range investigated. However, the slope of the fall off of efficiency with hub side actuation is lower than with shroud side actuation. Consequently, at flows lower than 65 percent design, changing the flow capacity by hub side wall movement showed higher efficiency capabilities.

Figure 37 shows a similar comparison but efficiency based on exit static pressure at the mixed out plane is also included. This performance is more representative of a turbine using a dump type diffuser. The efficiency based on total to static pressures peaks out at a lower flow (70-80 percent).

5.4 Flow and Exit Swirl Characteristics

Figure 38 shows measured nozzle flow characteristics of the moveable sidewall nozzle. Percent design flow is plotted against percent design nozzle area. A 45° slope line (dotted) is also shown for comparison. This 45° slope line represents a fully choked nozzle flow characteristics where flow capacity would be directly proportional to the nozzle area. Figure 38 shows a higher flow capacity as compared to the fully choked line when the design nozzle area is decreased. This could be attributed to the nozzle flow not being fully choked at the design condition. The turbine was operated at constant stage pressure ratio and constant referred speed. A higher pressure ratio across the nozzle would be observed for a smaller nozzle area because the rotor relatively presents less of a restriction at lower flows. Figure 39 presents the average measured rotor exit swirl versus measured equivalent flow. A correlation curve between rotor exit swirl and equivalent flow at the design speed was established with minimum data scatter. The rotor exit swirl for design nozzle area was 11 degrees against rotation, 21 degrees against rotation for 125 percent design nozzle area, and 23 degrees with rotation for 62 percent design nozzle area.

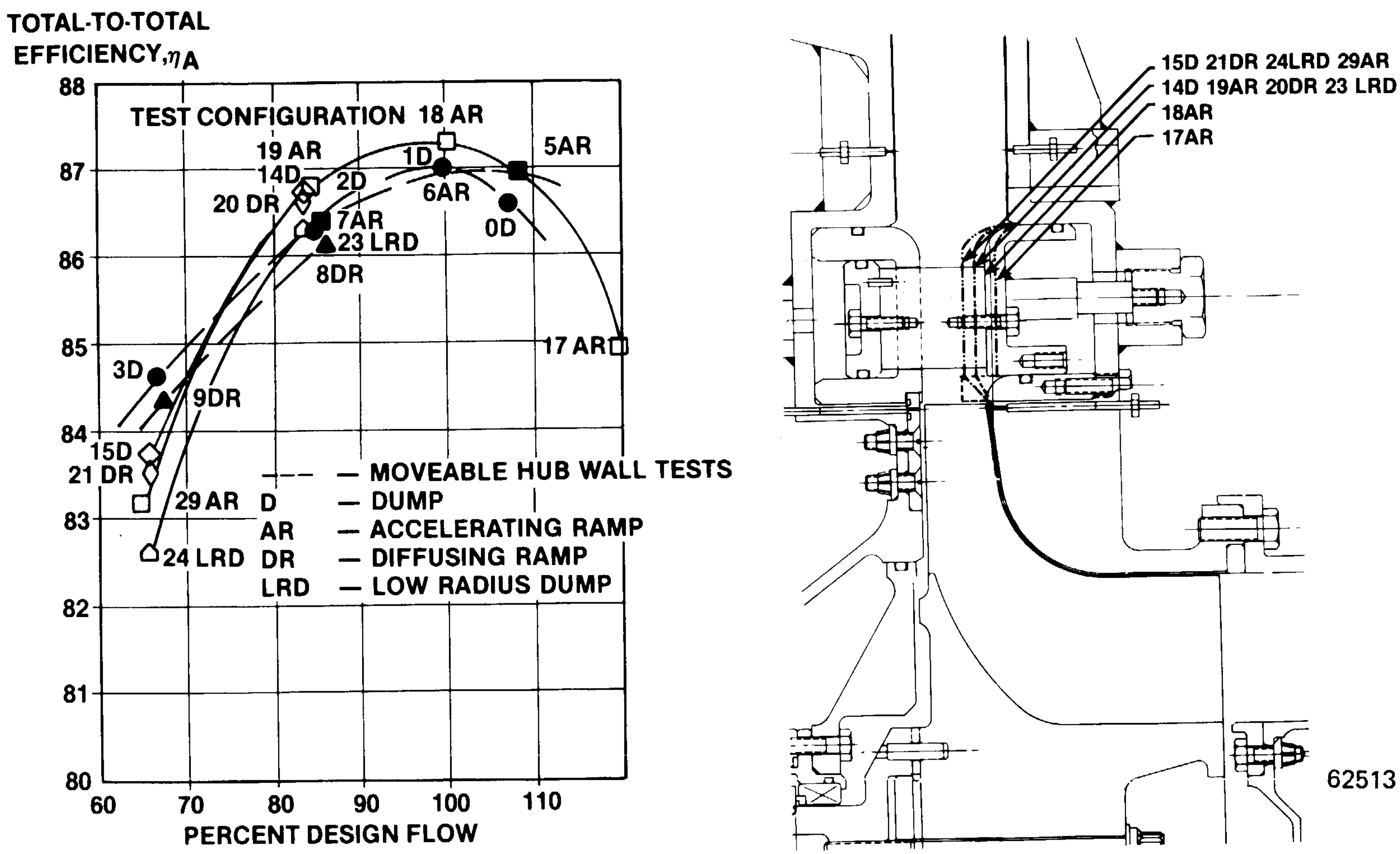


Figure 36. Moveable Hub Wall Vs. Shroud Wall Performance Comparison.

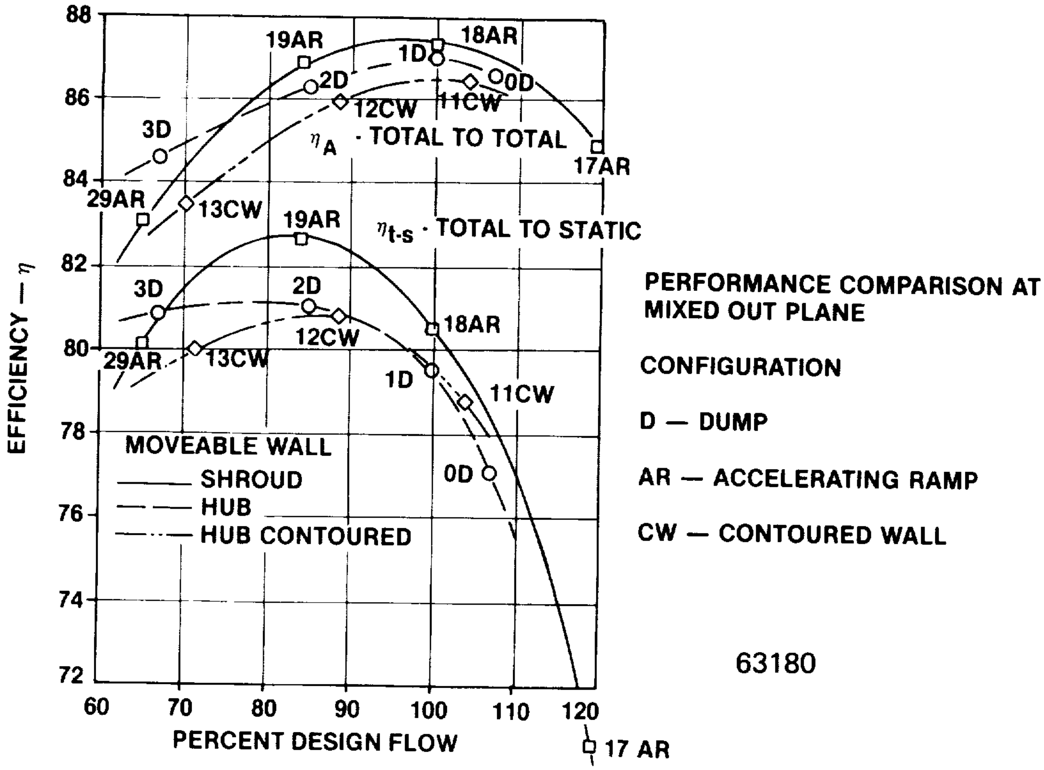
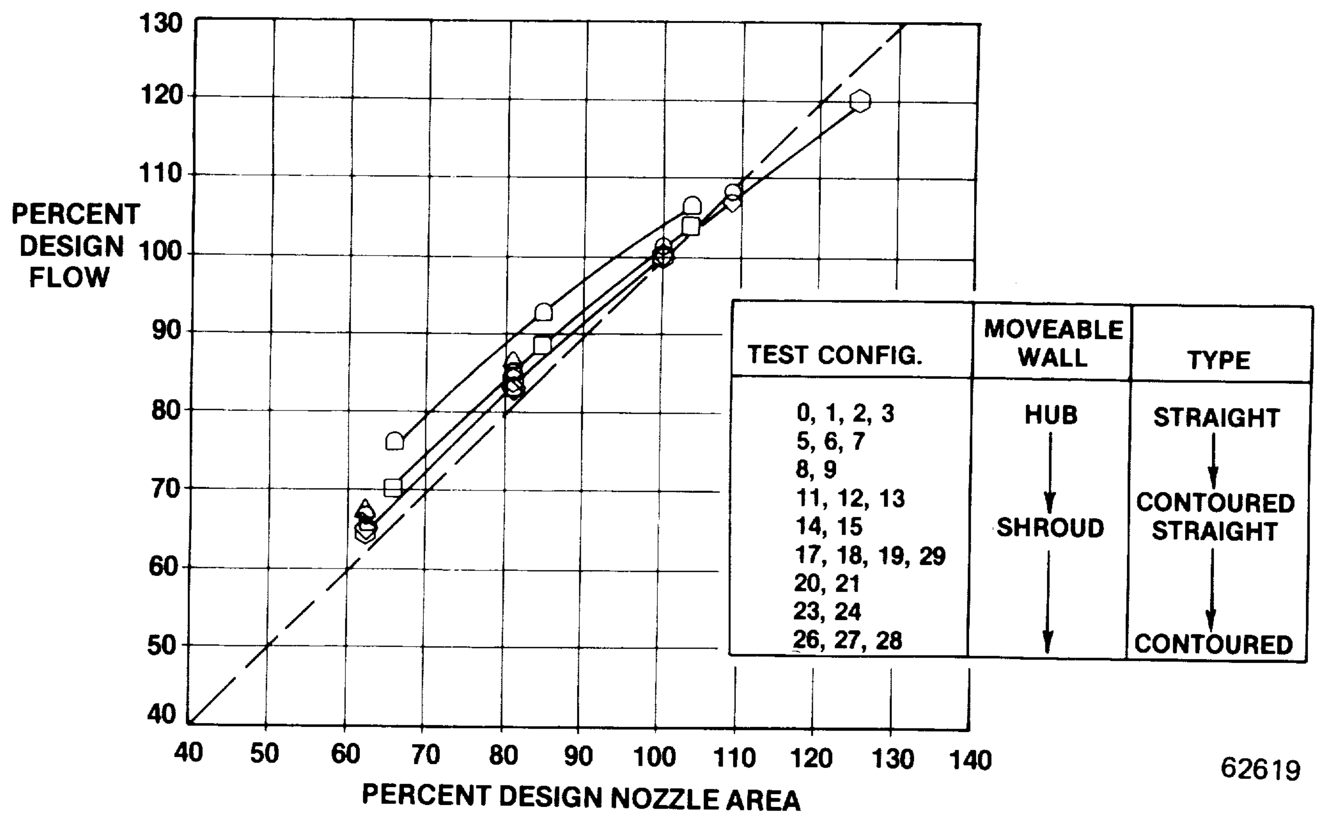


Figure 37. Total to Total and Total to Static Efficiency Comparison With Moveable Hub and Shroud Wall Configurations.



TEST CONFIG.	MOVEABLE WALL	TYPE
0, 1, 2, 3	HUB	STRAIGHT
5, 6, 7		
8, 9		
11, 12, 13		CONTOURED
14, 15	SHROUD	STRAIGHT
17, 18, 19, 29		
20, 21		
23, 24		
26, 27, 28		CONTOURED

Figure 38. Moveable Sidewall Nozzle Measured Flow Characteristics.

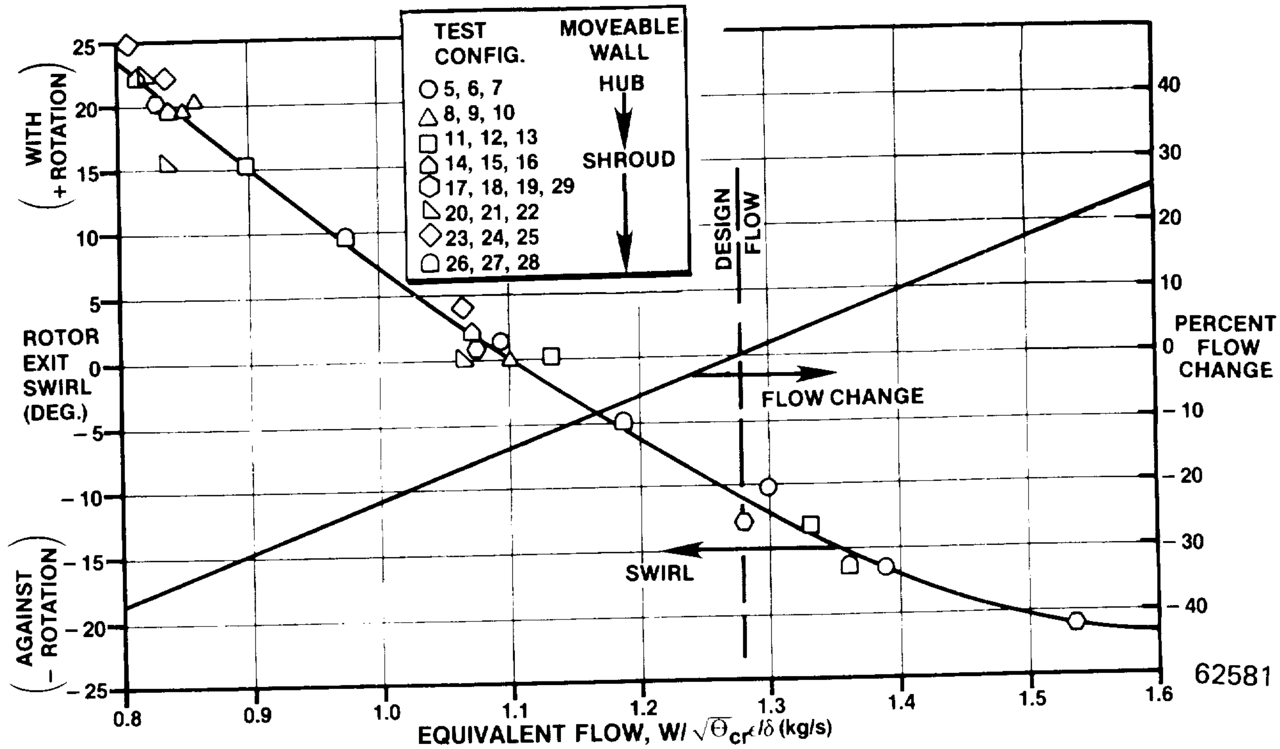


Figure 39. Measured Turbine Exit Swirl Vs. Measured Flow for Constant Speed and Pressure Ratio.

5.5 Survey Data

Detailed channel surveys have been performed in three critical areas of the turbine , i.e., at the nozzle exit, exducer exit, and the turbine exit mixed out plane. These survey data reveal some of the flow characteristics of the radial inflow turbine as affected by nozzle sidewall geometry changes. A limited data analysis has been completed and included herein to sum up the general flow phenomenon observed. A further indepth data analysis is needed to understand the test data to its full potential.

5.5.1 Mixed Out Plane Surveys

Surveys were conducted 16 cm (6.3 in) downstream of the rotor exit. This plane is 2.7 exducer span lengths downstream of the rotor where the trailing edge wakes are essentially mixed out. Detailed surveys at this rotor exit mixed out plane were performed for Test No. 1 through Test No. 29 employing three Cobra type survey probes. Flow angle, total pressure and temperature were measured using these survey probes. Data were taken at 13 radial locations. These survey data were plotted against percent radial span for swirl angle, total pressure, total temperature, streamline efficiency, and local to critical velocity ratio. A complete set of these plots at the rotor exit mixed out plane for Tests No. 4 through 29 is included in Appendix B.

The mass averaged efficiencies obtained from detail surveys at the rotor exit mixed out plane compare, in most cases, well with the efficiencies calculated from exit performance test data, Tables V & VI. These surveys, conducted well downstream of the exducer exit, include the rotor wake mixing and duct losses that existed up to this measurement plane.

Surveys were also conducted for configurations 1-3, however, these surveys were made before the "L" seal leakage fix was made to the sidewall. The data for these three tests, only, were corrected for the efficiency improvement measured when the "L" seals were put into the build. This allows a comparison to be made with the remaining tests.

Typical performance data of efficiency and exit swirl vs. percent exducer span for the moveable hub wall nozzle is shown in Figure 40. The efficiency for each configuration is normalized to its respective mass averaged efficiency for comparison purposes. Configurations 1-3 with a simple dump show the highest efficiency in the hub region. As may be expected, Figure 40 also shows that the rotor exit swirl angle increased in the direction of wheel rotation as the nozzle area was reduced. The hub blockage ring, Test 4, smoothed the streamline efficiency and made it uniform from hub to tip. The swirl angle also became more uniform. The penalty incurred by the hub ring was 6.6 points. The data for the accelerating ramp nozzle configuration was also included in Figure 40 for comparison. The difference between dump configuration and accelerating ramp was very small for the design nozzle area (flush walls).

Figure 41 depicts the efficiency and swirl for the moveable hub with an accelerating ramp configuration. Similar characteristics to the simple dump are shown as the nozzle area is decreased. Opening the nozzle area to 108.8 percent of design, however, resulted in no change in efficiency. These surveys confirmed the beneficial effect of the accelerating ramp when the nozzle is opened beyond the flush sidewall position. Figure 42 presents the data for the diffusing ramp nozzle configurations 8-10 and includes the accelerating ramp, Test 10, for comparison. Again, the efficiency and swirl distributions were similar. The effect of adding the hub blockage ring was repeated. The efficiency distribution becomes more uniform and the exit swirl is more nearly constant.

Figures 43 to 47 present a typical set of data that show the effects of a shroud ring as measured at the mixed out plane - Test Nos. 15 and 16. Nozzle test configuration 15 had a moveable shroud with a straight dump and a 62.5 percent design

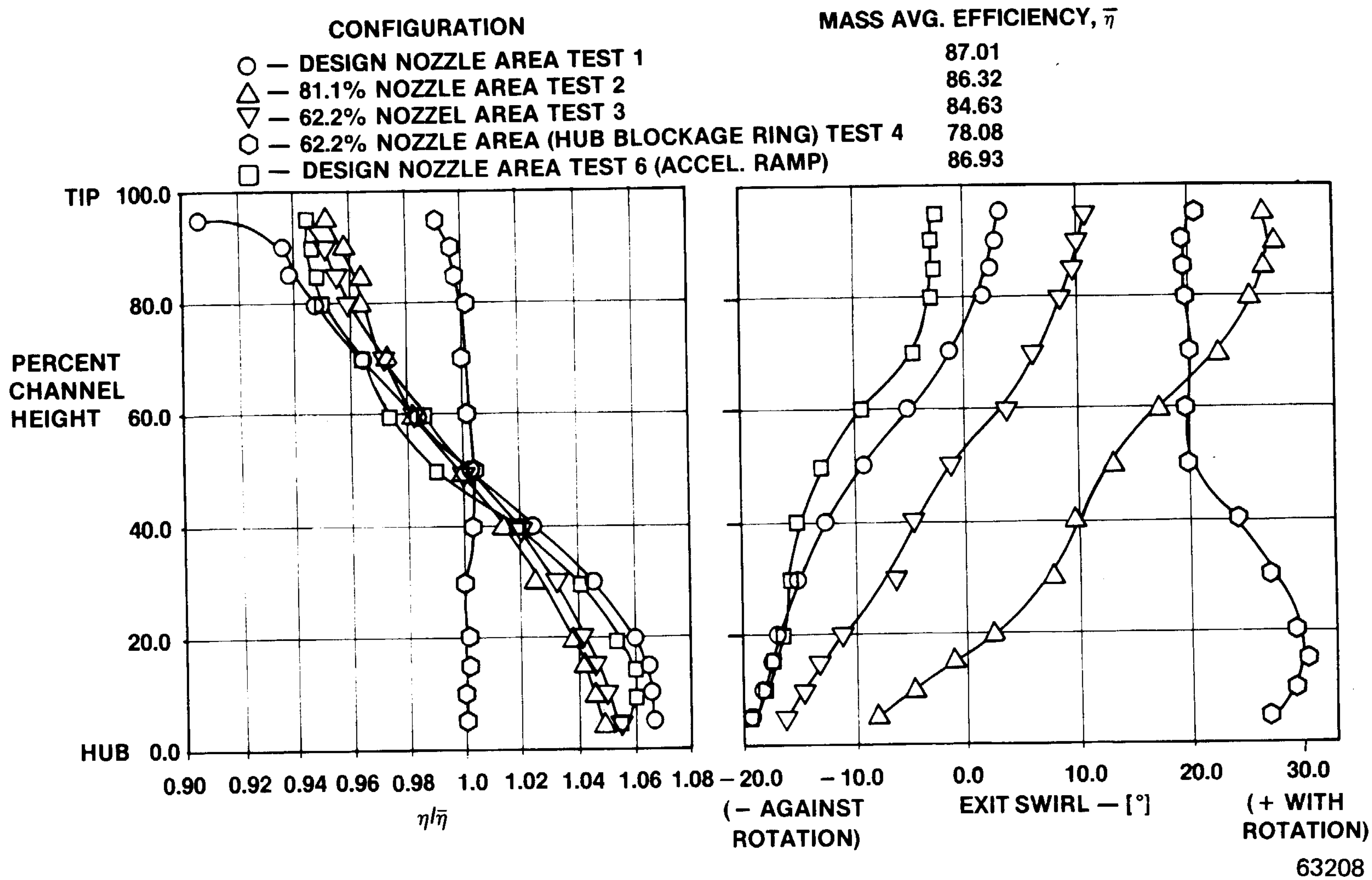


Figure 40. Turbine Exit Mixed Out Plane Surveys - Moveable Hub Wall Nozzle Dump Configuration.

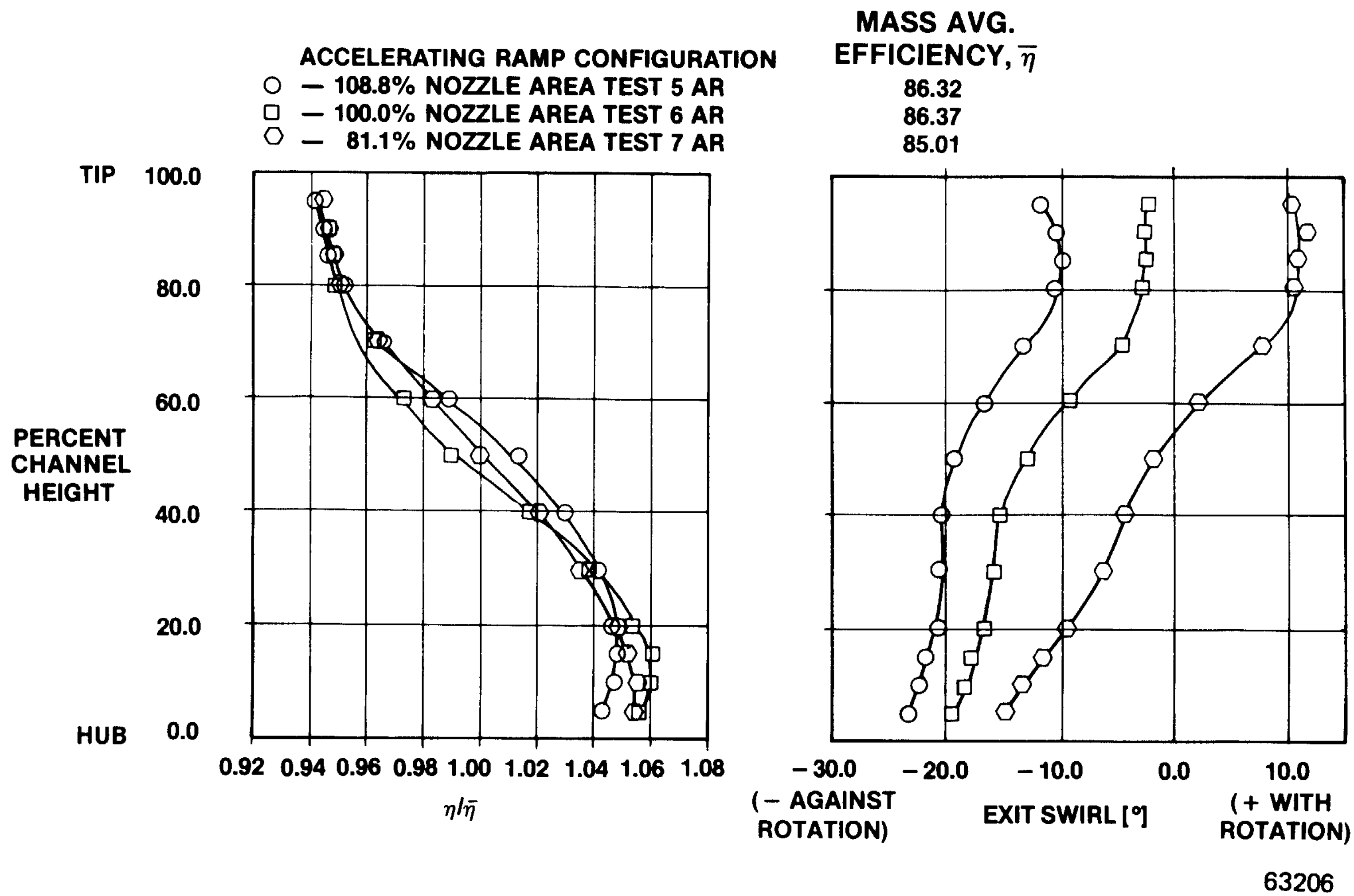


Figure 41. Turbine Exit Mixed Out Plane Surveys - Moveable Hub Wall Nozzle Accelerating ramp Configuration.

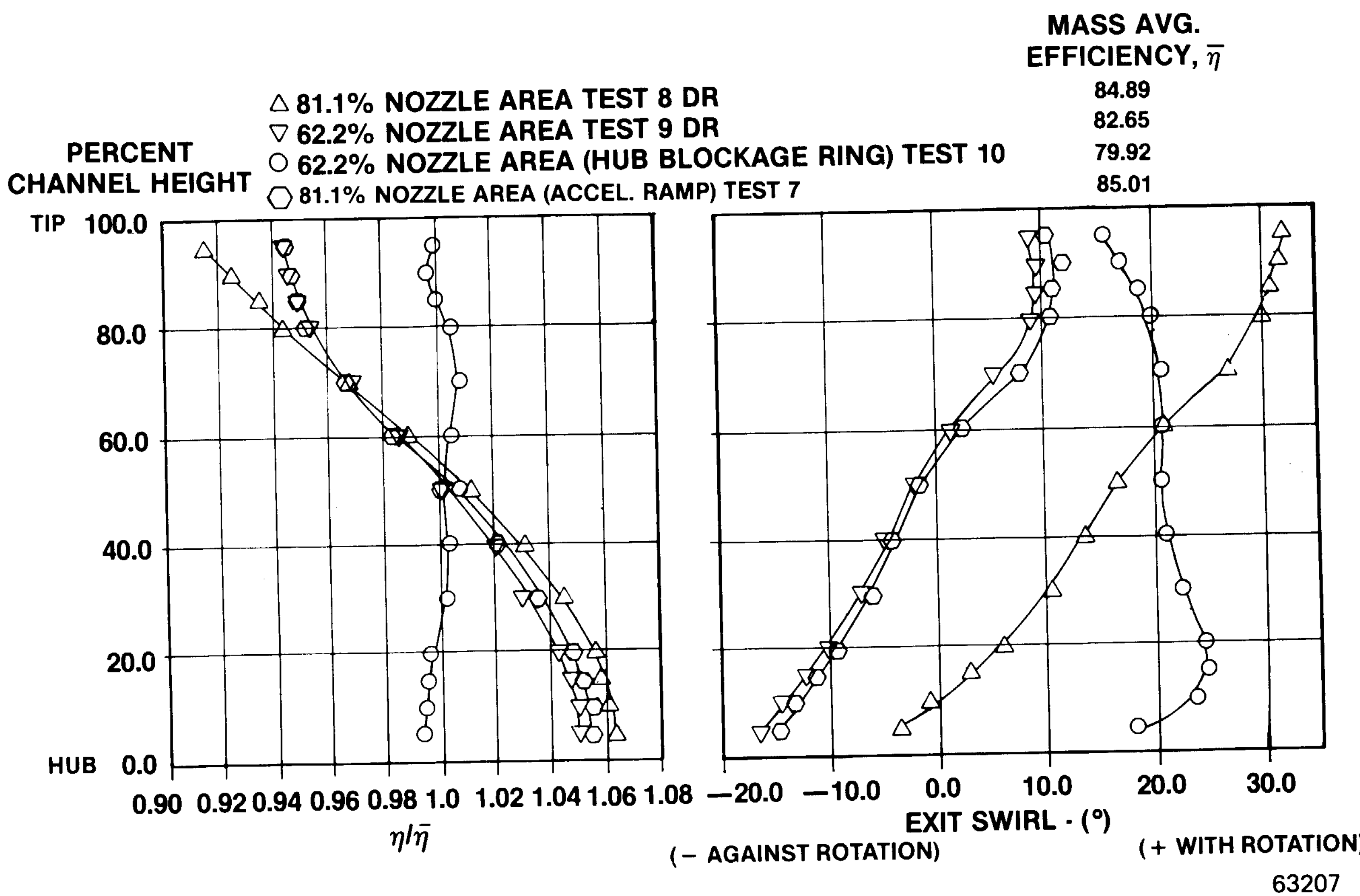


Figure 42. Turbine Exit Mixed Out Plane Surveys - Moveable Hub Wall Nozzle Diffusing Ramp Configuration.

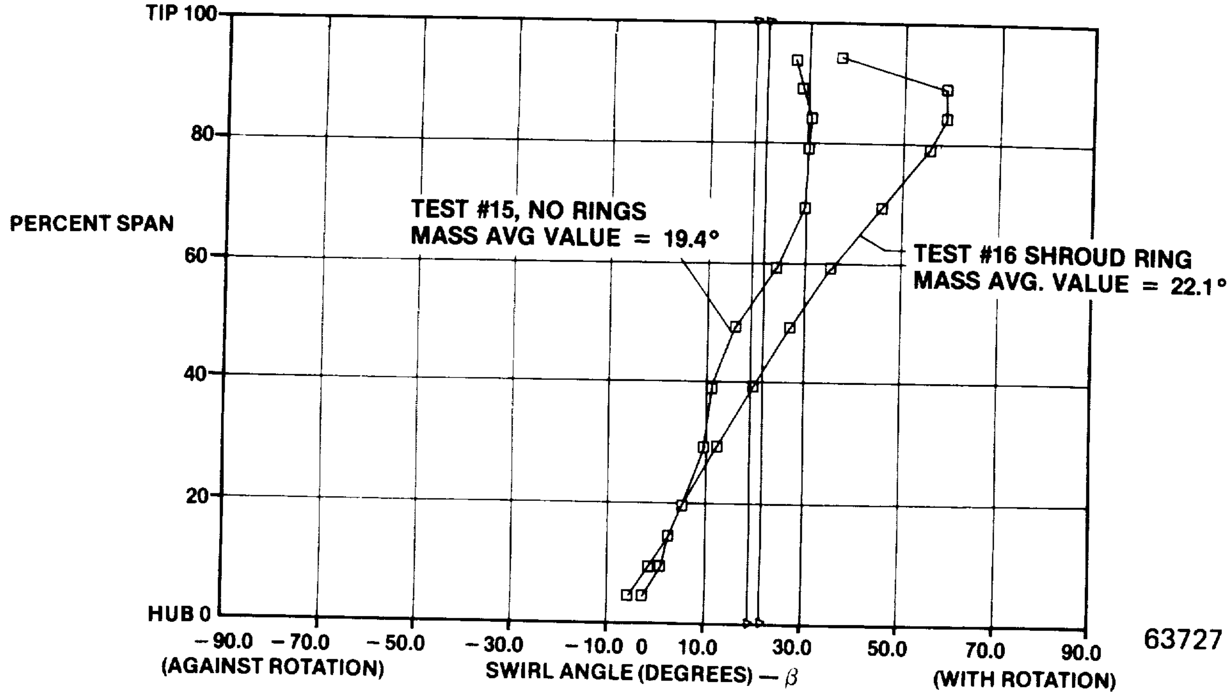


Figure 43. Turbine Exit Mixed Out Plane Surveys - Swirl Angle for a Moveable Shroud Wall Nozzle.

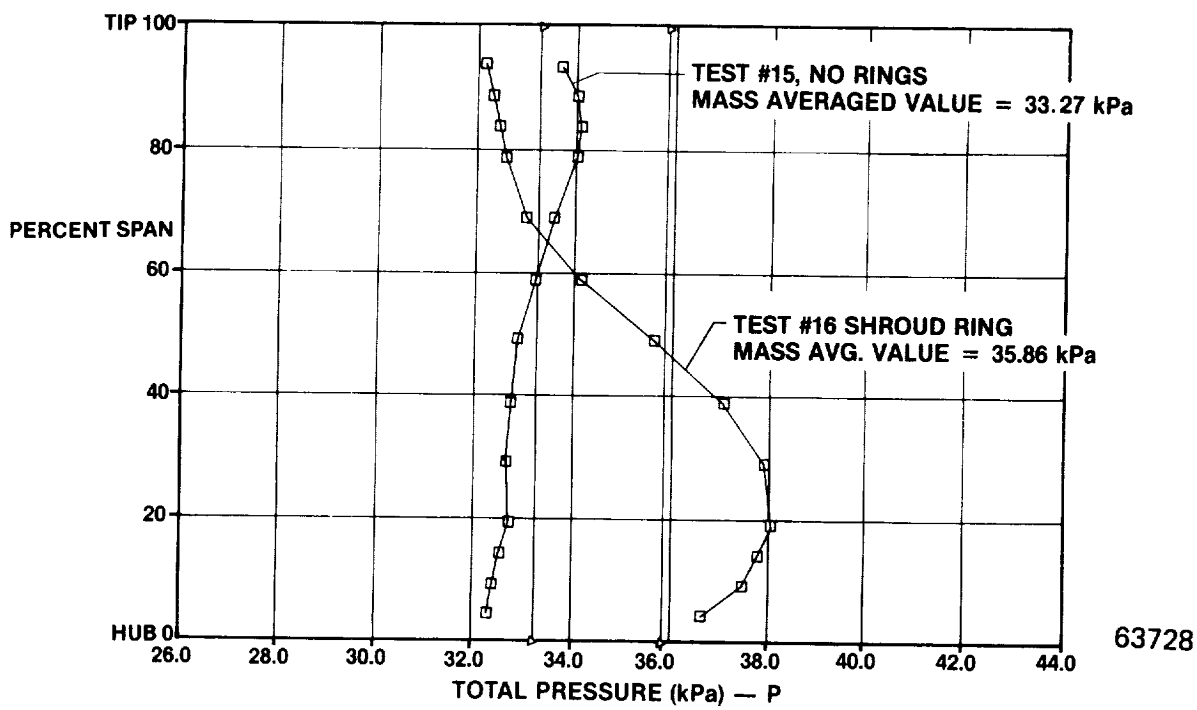


Figure 44. Turbine Exit Mixed Out Plane Surveys - Total Pressure for a Moveable Shroud Wall Nozzle.

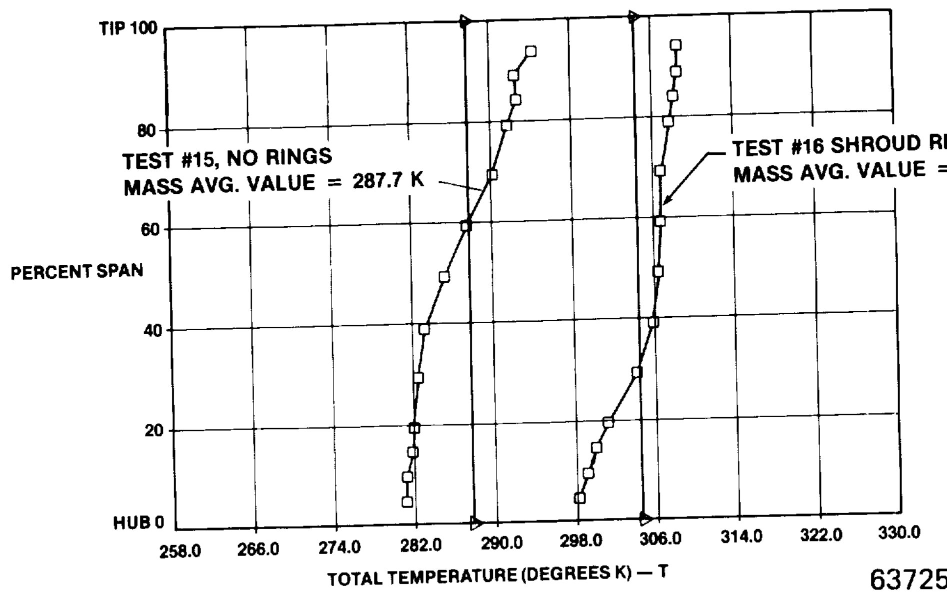


Figure 45. Turbine Exit Mixed Out Plane Surveys - Total Temperature for a Moveable Shroud Wall Nozzle.

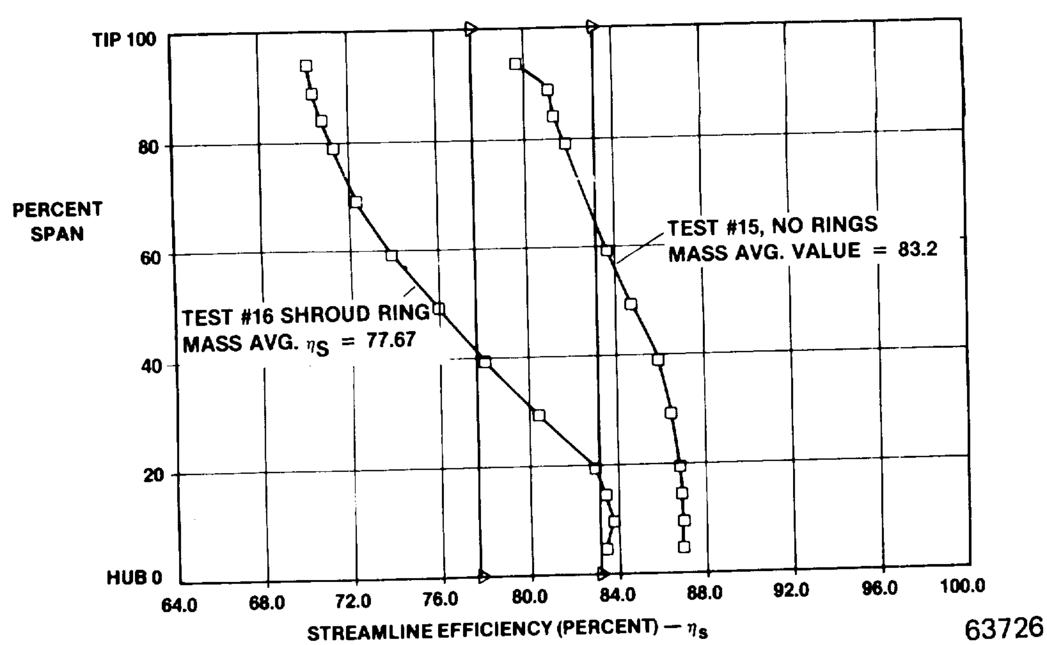


Figure 46. Turbine Exit Mixed Out Plane Surveys - Streamline Efficiency for a Moveable Shroud Wall Nozzle.

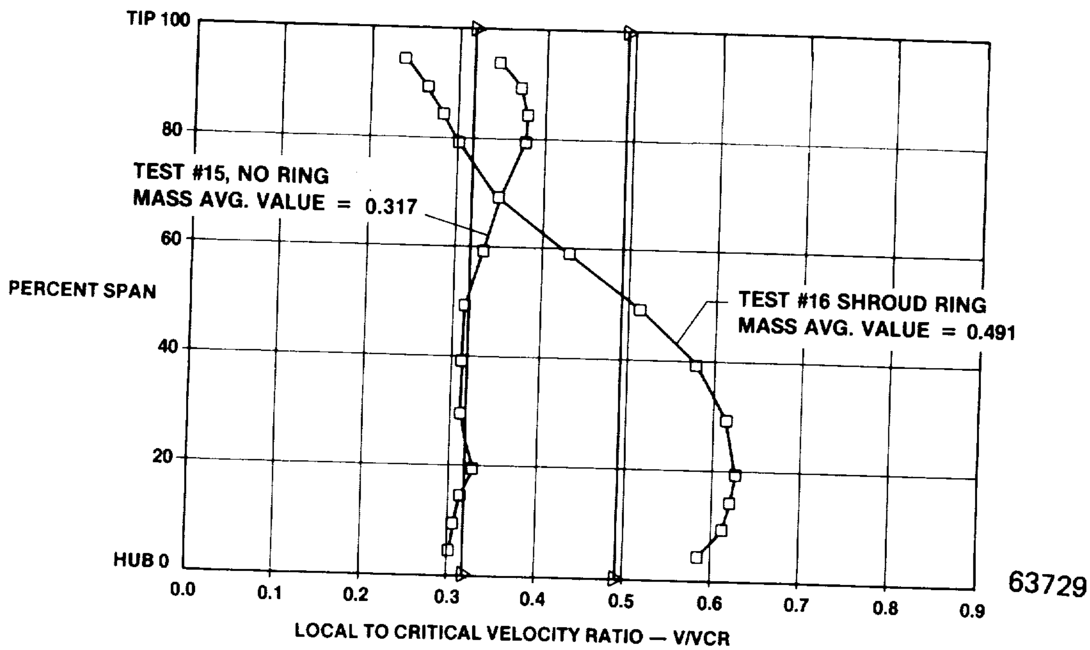


Figure 47. Turbine Exit Mixed Out Plane Surveys - Velocity Ratio for a Moveable Shroud Wall Nozzle.

nozzle width. A shroud ring was added for Test No. 16. Figure 43 shows the effect of the shroud ring on exit swirl. The swirl angle increased with rotation by 2.7 degrees with most of the increase occurring in the tip region. The total pressure and total temperature distributions are shown in Figures 44 and 45 respectively. The shroud ring forced the flow to the hub and increased the total pressure in this hub region. The total temperature increased uniformly. The combined effect of changes in total pressure and temperature translates to in an efficiency penalty in the tip region as shown in Figure 46. The net effect of the shroud ring is a loss in efficiency of 5.53 points. Figure 47 shows the comparison of velocity distributions for the two configurations. Velocity distribution is given as a ratio of local velocity to the critical velocity. The flow shift to the hub is evidenced as an increase in critical velocity ratio in this region. The mass averaged value increases from 0.317 to 0.491, and is also an indication of performance penalty.

5.5.2 Exducer Exit Surveys

Five accelerating ramp configurations (Table IV), Test No. 7, 17, 18, 19, and 29 were chosen to perform exducer exit surveys. One Cobra type survey was used to measure flow angle, total pressure and temperature. These survey data were also plotted versus percent radial span for swirl angle, total pressure, total temperature, streamline efficiency, and local to critical velocity ratio and are included in Appendix C.

Typical data obtained immediately downstream of the exducer is compared to the data at the mixed out plane, 15 cm (6.3 in) downstream and is shown in Figure 48 for Test No. 18. The mixing taking place in the annular duct tends to smooth out the gradients shown in the exducer plane. The wake mixing and duct losses reduced the mass averaged efficiency by 0.7 points and resulted in a decrease in the average critical velocity ratio from 0.515 to 0.491.

The comparison of stage efficiencies for the exducer exit and mixed out planes for the other four cases shows that wake mixing and duct losses account for loss in efficiency of 1.04 points for Test No. 7, 2.85 points for Test No. 17, 1.43 points for Test No. 19, and 0.47 points for Test No. 29. Details on the distributions may be found in Appendix B and C.

5.5.3 Detailed Nozzle Exit Surveys

Five accelerating ramp configurations (Table IV), Test No. 7, 17, 18, 19, and 29 were also selected to perform detailed nozzle exit surveys. Four surveys (Test No. 17, 18, 19 and 29) were made with a moveable shroud sidewall and one survey (Test No. 7) was made with a closed down hub sidewall. The detailed surveys were conducted in the vaneless space between nozzle exit and rotor inlet about 7.4mm (0.29 inches) away from nozzle trailing edge. One Cobra type survey probe was employed to measure flow angle and total pressure. The Cobra type survey probe was mounted against a protractor and could be indexed in one degree increments. The center of the protractor was lined up with the midpitch of a nozzle passage.

A midpitch survey at 13 span positions from the shroud wall to the hub wall was initially taken for each of the five test configurations when the radial turbine rig was running at the design speed and stage pressure ratio. Figure 49 shows the total pressure losses as measured by the midpitch surveys. In all cases the entire width of the rotor tip was surveyed and data are presented in the form of total pressure loss versus percent passage width of the rotor tip. The physical location of the nozzle sidewall with respect to the rotor is also indicated in the figure. High losses are indicated in the probable separation regions immediately downstream of the wall step. These losses also increased as the magnitude of the flowpath step increased. The stationary hub wall region for this test series also shows indications of high losses and possible flow reversal. One source of the high loss on this wall could be from cross leakage flows.

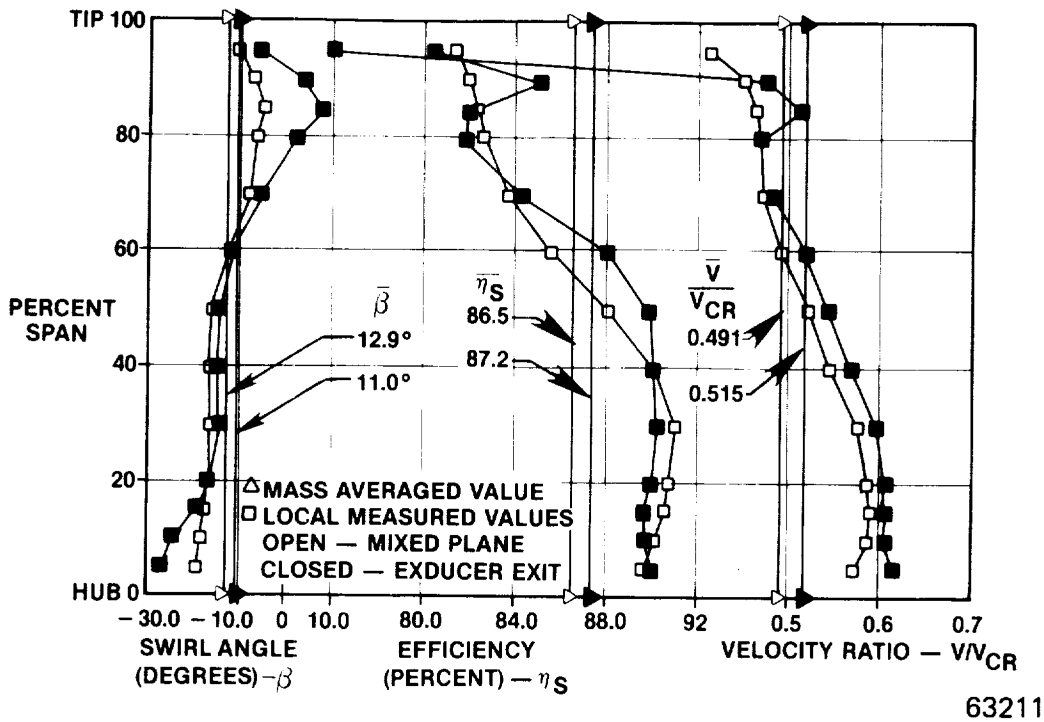


Figure 48. Exducer Exit and Mixed Out Plane Survey Data Comparison for Test No. 18.

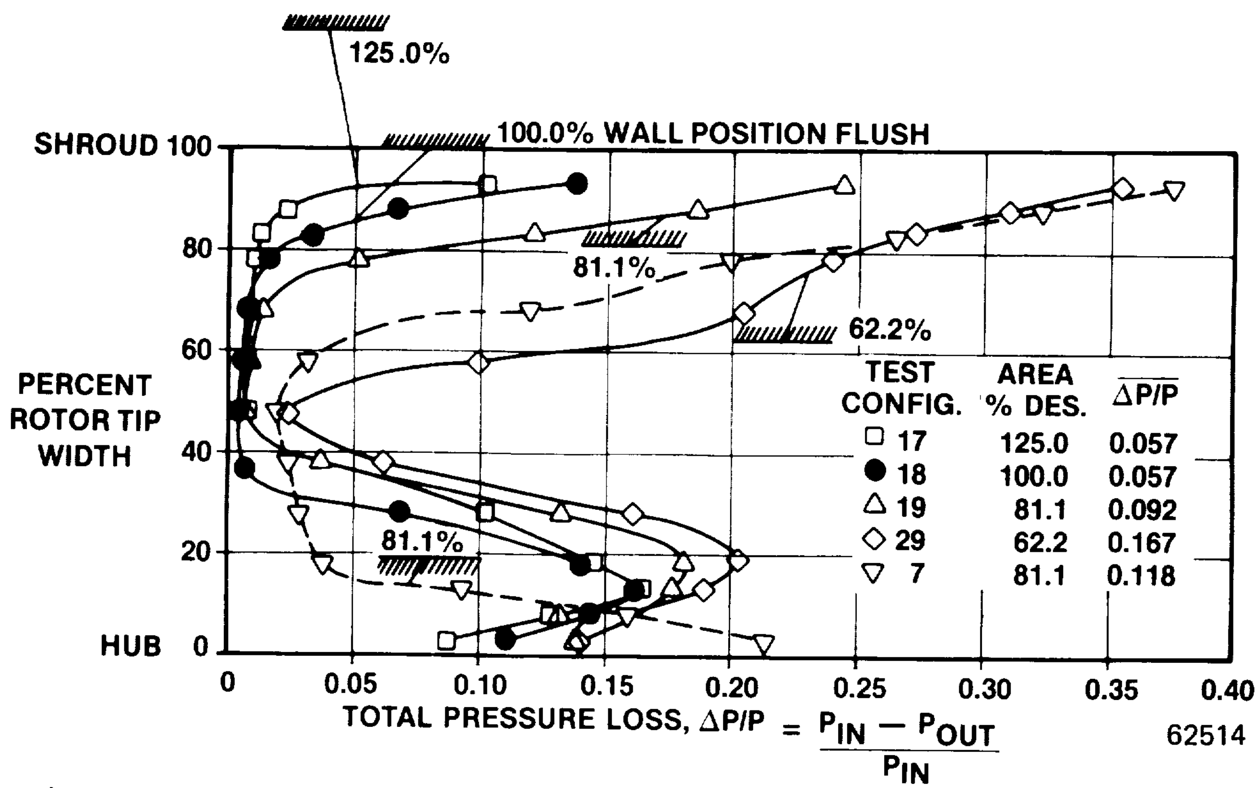


Figure 49. Nozzle Total Pressure Loss as a Function of Sidewall Position.

Flow from the main channel can leak into the clearance space between the sliding vane profile and the fixed hub sidewall and then into the vaneless space as depicted in Figure 50. Closing down the nozzle area by moving the hub wall, Test No. 7, resulted in improved flow conditions and reduced losses on the hub. This decrease in pressure loss along the hub sidewall in Test 7, would be expected if the previously measured pressure loss in this region was caused by hub leakage as postulated above. Pressure loss in the shroud wall region for Test No. 7 is higher as compared to Test No. 18 (moveable shroud wall) where the shroud walls were flush. This could be attributed to a similar leakage flow that now occurs along the shroud wall. There may also be a recirculation loss in the cutout slot where the survey probe enters the flowpath. This slot alters the local flow pattern near the wall where the measurement was made.

Figure 51 shows the plots of nozzle discharge angle as functions of percent nozzle width. As the shroud wall is moved in, the flow angle is most affected close to the shroud and least affected in the one third rotor width next to the hub. The nozzle exit angle increases in the tangential direction from an average value of 78.1 degrees at the extreme open position, Test No. 17; 125 percent design area, to 81.9 degrees at 62.2 percent of design area, Test No. 29. Movement of the opposite sidewall Test No. 7, 81.1 percent design area, however, resulted in a slight decrease in nozzle flow angle. Figure 52 shows the distribution of rotor incidence angle, as a function of sidewall position as calculated from the nozzle discharge data as obtained from midpitch surveys.

More detailed nozzle exit data were then obtained by surveying over a ten degree sector of circumference on each side of the midpitch in increments of one degree. These detailed surveys were performed at a lower rig speed so that the probe could be manually moved in the circumferential direction while the rig was running. This avoided the many rig shut downs that would otherwise be necessary to move the probe circumferentially. Low speed conditions were set so that the midpitch total pressure losses and pressure ratio at low speed matched the total pressure loss surveys taken at the design conditions. Five depth locations were surveyed for each of the nozzle circumferential positions except the midpitch position where thirteen nozzle depth locations were surveyed. The results of the detailed surveys are presented as two dimensional contours of flow angle, total pressure loss, local nozzle efficiency, and total pressure loss coefficient. These parameters are defined in the nomenclature. These results are included in Appendix D, and the calculated mass flow average values across one pitch distance are presented in Table VIII.

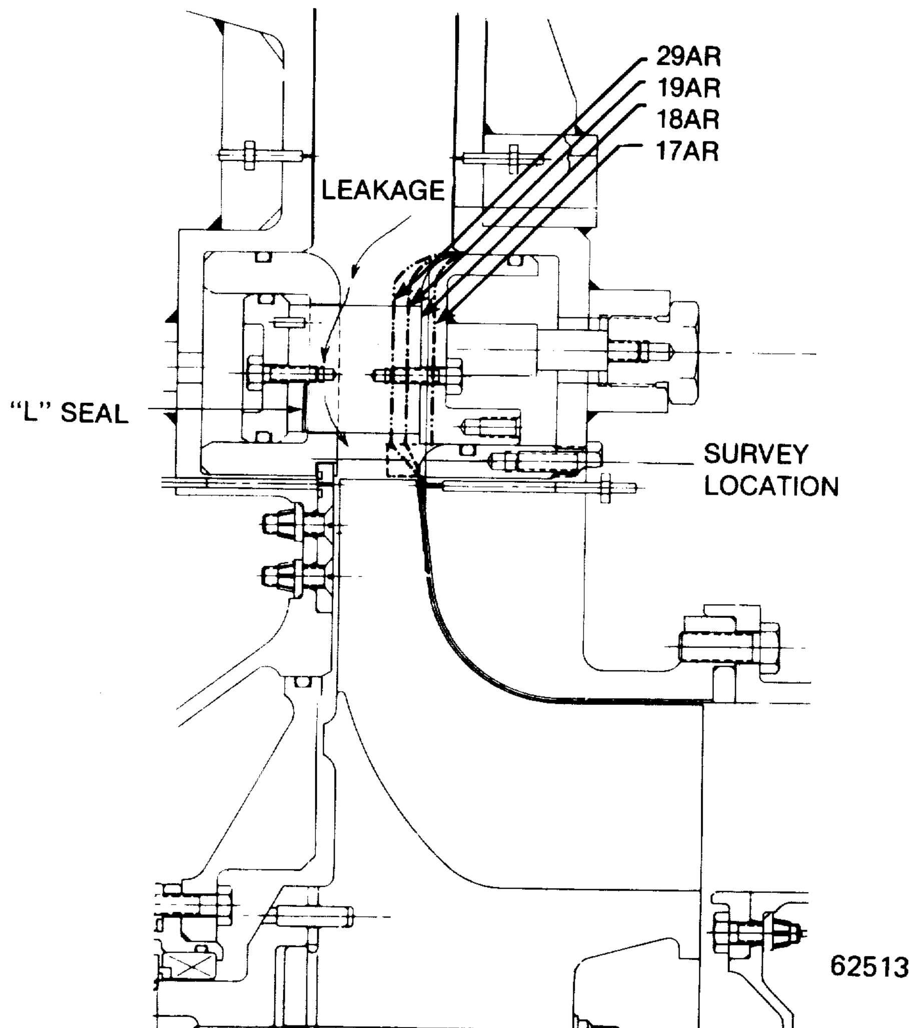


Figure 50   Illustration of Probable Leakage Along Hubwall

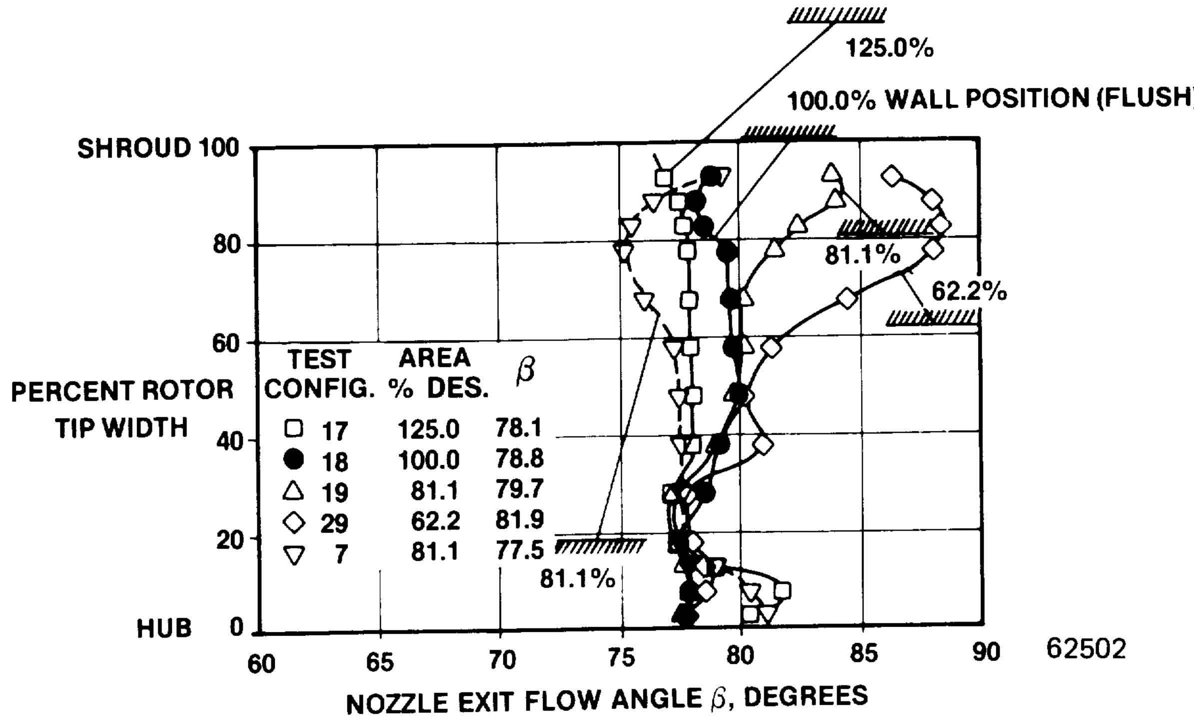


Figure 51. Nozzle Exit Flow Angle Distribution.

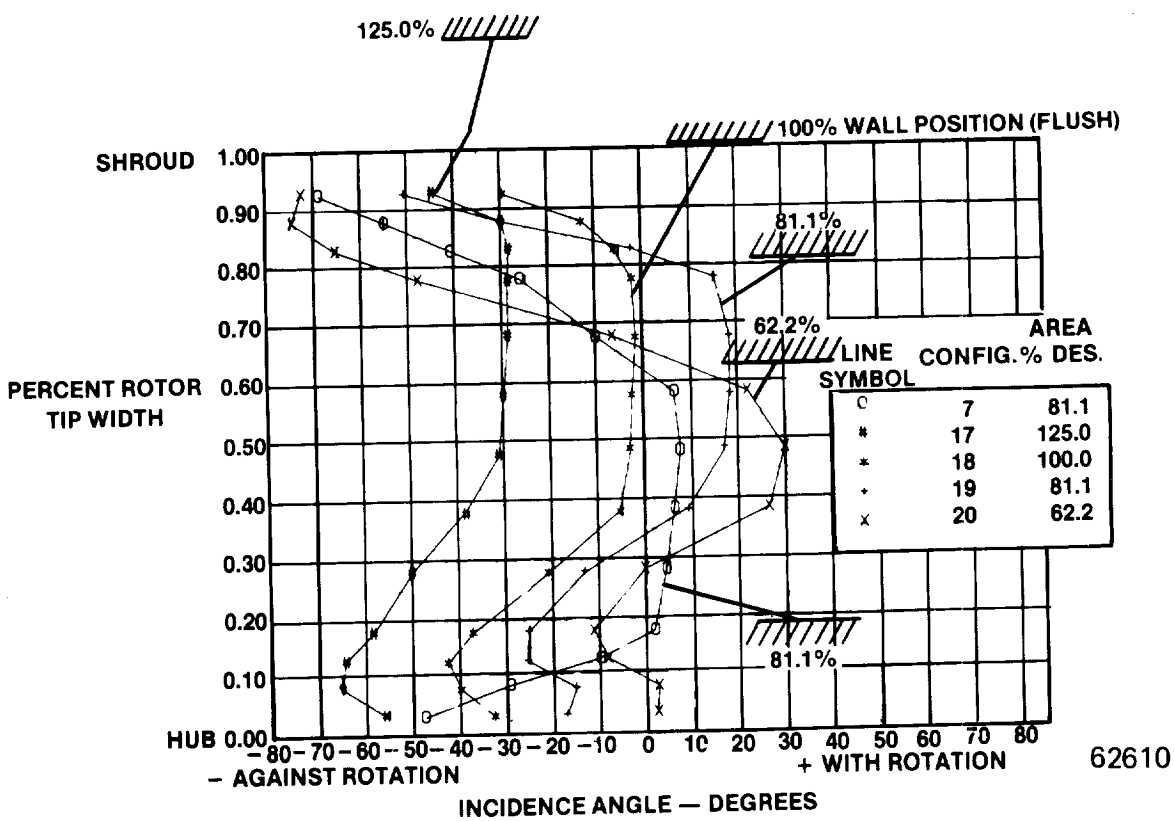


Figure 52. Effect of Nozzle Sidewall Position on Rotor Incidence.

TABLE VIII

NOZZLE EXIT SURVEY RESULTS - MASS AVERAGED
DATA REDUCED ACROSS ONE PITCH

PARAMETER	CONFIGURATION TEST NUMBER				
	7	17	18	19	29
MASS AVERAGE FLOW ANGLE (DEGREES)	77.08	76.95	77.19	77.53	78.23
MASS AVERAGE TOTAL PRESSURE LOSS	0.135	0.061	0.069	0.106	0.164
MASS AVERAGE NOZZLE EFFICIENCY	0.811	0.882	0.897	0.860	0.795
MASS AVERAGE PRESSURE LOSS COEFFICIENT	0.758	0.153	0.144	0.200	0.290

63297

Figure 53 shows a typical nozzle exit flow angle contour for moveable hub wall of 81.1% design nozzle area (Test No. 7). The nozzle wall position and nozzle vane circumferential positions are also depicted in Figure 53. The zero circumferential location on the rig was lined up mechanically with an upstream vane passage mid-channel point. The loss data, Figure 54, showed that the upstream zero circumferential location coincided with a downstream nozzle trailing edge maximum loss region. The location of the downstream trailing edge was confirmed by a calculation of a logarithmic spiral trajectory which reasonably described the radial flow in the vaneless space. All the contour plots shown in Appendix D are shown with the zero position aligned with the nozzle trailing edge calculated wake position. Figure 54 also reveals high loss regions along both hub and tip walls, and a low loss region in the mid span. The high loss region along the hub wall could be due to the upstream nozzle wall step discontinuity. The high loss region along the tip wall could be attributed to instrumentaiton cutout as discussed in the previous paragraph and also due to leakages around the vane seals. It should be noted that a high loss region normally associated with a trailing edge wake is not prevalent. Most of the wake loss is smeared by the high loss regions along both sidewalls.

Figure 55 compares total pressure loss contours for Test Nos. 7 and 19 which have the same area setting, 81.1 percent, but with opposite sidewalls moved. The loss contours are similar near the wall that was moved however, the mass flow averaged total pressure loss for the moveable shroud wall (Test No. 19) of 0.106 was 27% lower than that of the moveable hub wall (Test No. 7). This might be attributed to the cutout for instrumentation in the shroud wall. The instrumentation slot effect on configuration 19 could have been masked by the wall step which covers this slot when the wall is moved from the shroud side.

In addition to the surveys in the flow stream, static pressure taps were installed in the shroud wall along the turbine flowpath. Figures 56 and 57 show typical static pressure distributions as functions of percent shroud distance with the turbine flowpath shown along side for reference. The meridional distance from the nozzle inlet (Station 1) to the exducer exit (Station 3) was used as a reference shroud distance. The inlet total to local static pressure ratios were plotted against the shroud distance to indicate the reaction changes along the flowpath for Test Nos. 3, 17, 18 and 29.

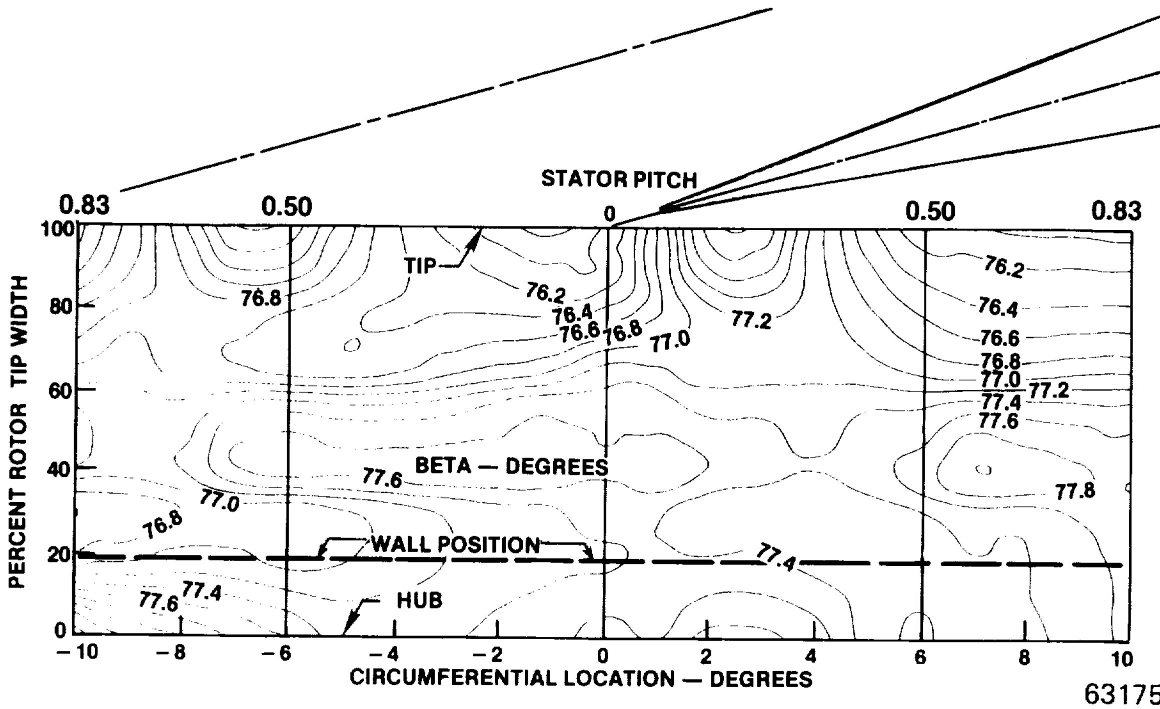
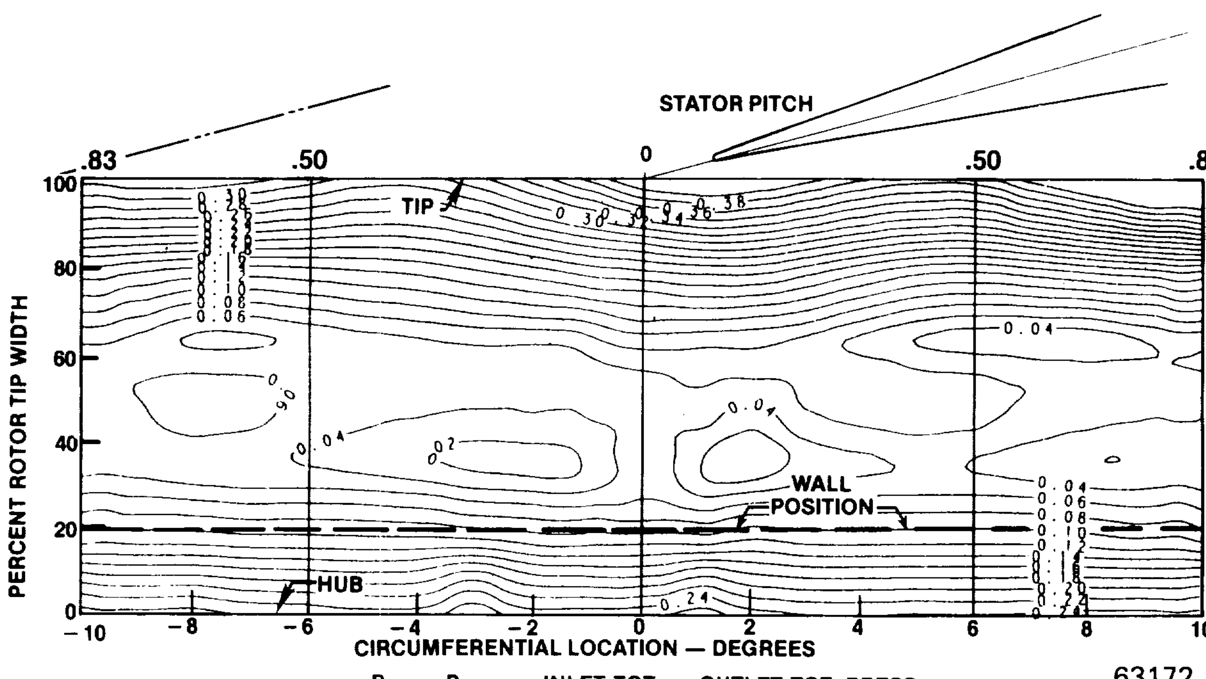


Figure 53. Nozzle Exit Flow Angle Contour for Moveable Hub Wall Nozzle - Test No. 7.



$$\Delta P/P = \frac{P_{IN} - P_{OUT}}{P_{IN}} = \frac{\text{INLET TOT. — OUTLET TOT. PRESS.}}{\text{INLET TOTAL PRESS.}}$$

Figure 54. Total Pressure Loss Contour for Moveable Hub Wall Nozzle - Test No. 7.

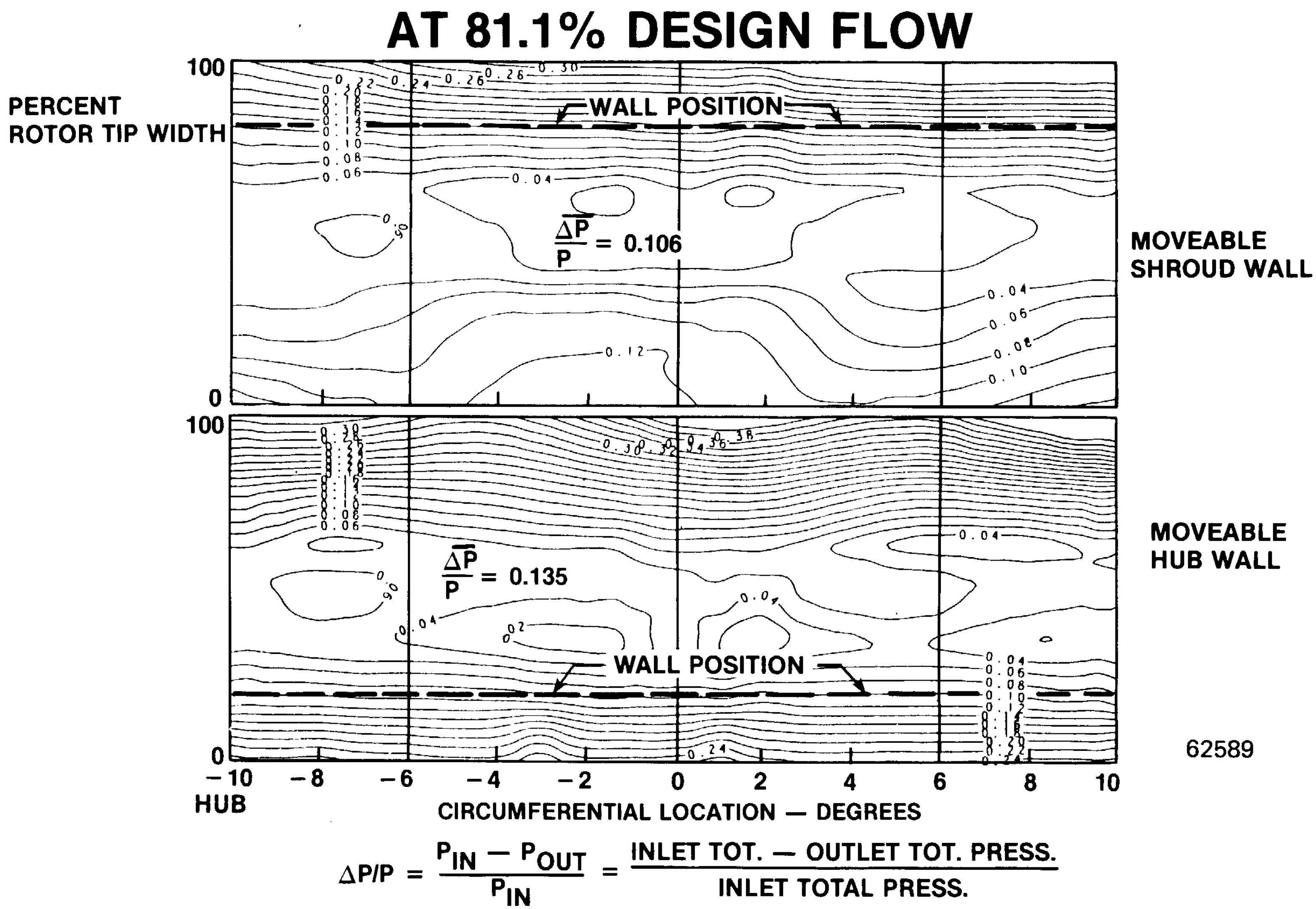
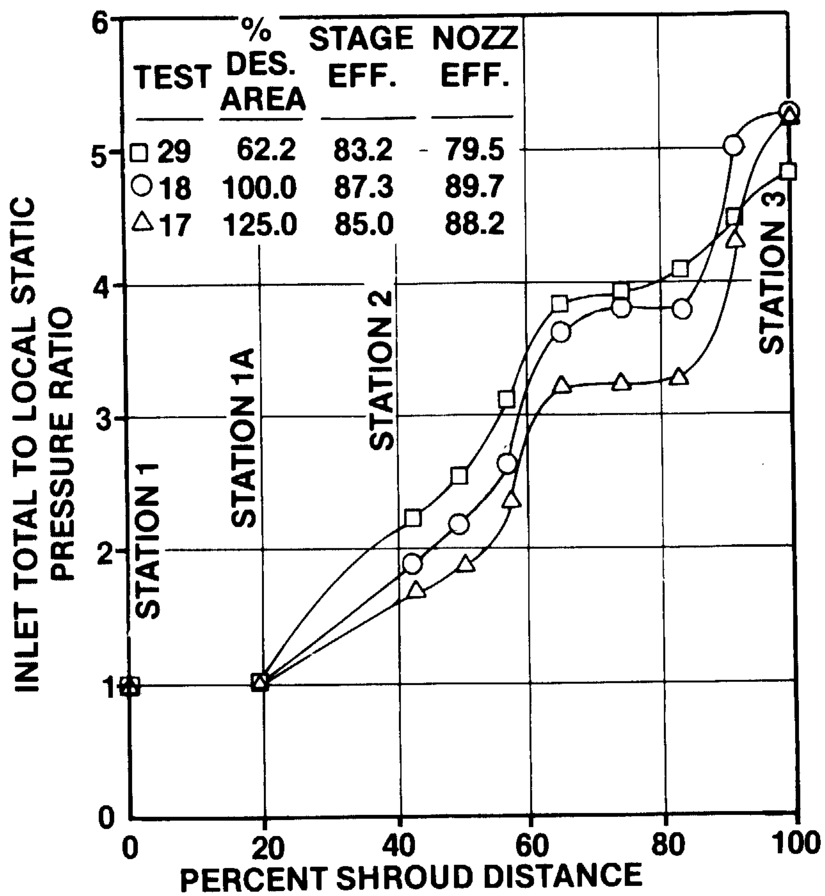


Figure 55. Comparison of Total Pressure Loss Contours - Moveable Shroud Wall vs. Hub Wall.



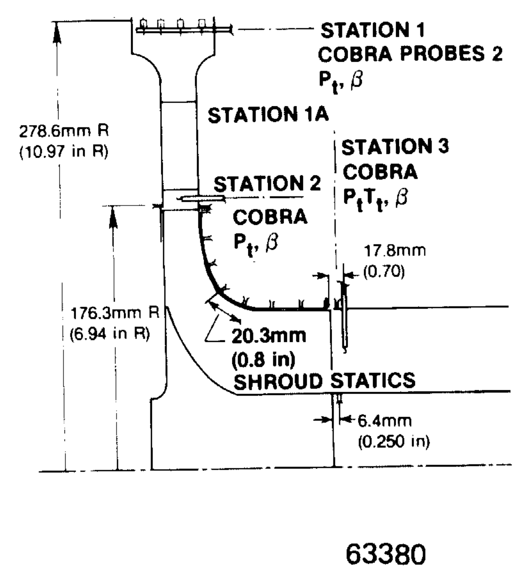


Figure 56. Shroud Wall Static Pressure Distribution - Effects of Shroud Wall Position.

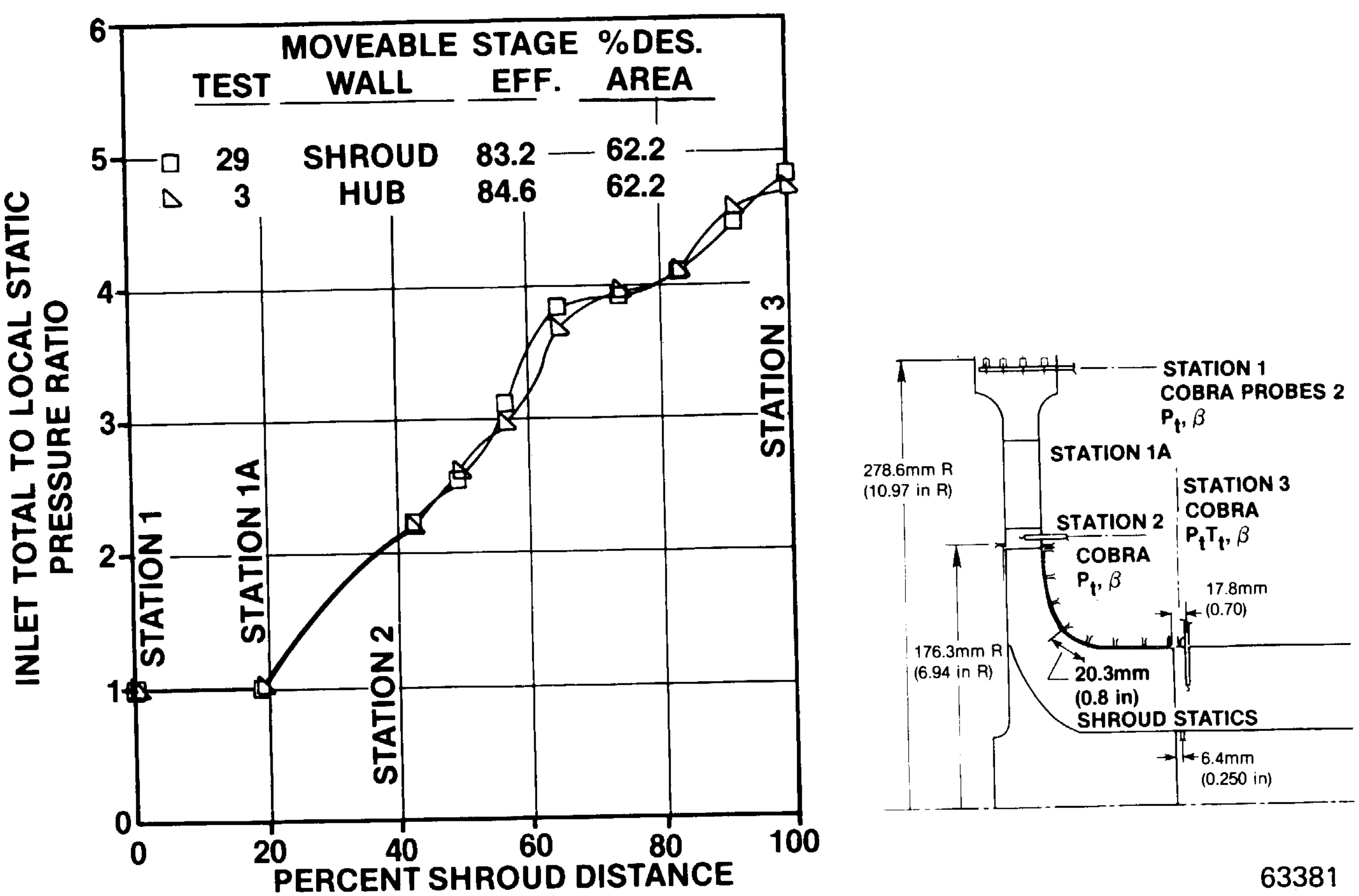


Figure 57. Shroud Wall Static Pressure Distribution - Effects of Opposite Wall Area Change.

Figure 56 shows the effect of shroud wall movement on static pressure distribution and compares 125, 100 and 62.2 percent design area wall positions, Tests 17, 18 and 29 respectively. With respect to the flush walls Test 18, opening the nozzle to 125 percent area decreases the pressure ratio across the nozzle and increases the rotor pressure ratio. The nozzle Mach numbers were reduced and the calculated nozzle efficiency from survey data shows a small decrease of 1.5 points from 89.7 to 88.2 percent efficiency. The stage overall performance, decreased from 87.3 percent to 85.0 or 2.3 points. Conversly closing the nozzle to 62.2 percent area increased the pressure ratio across the nozzle and reduced the rotor pressure ratio. Mach numbers in the nozzle (especially downstream of the throat) are increased resulting in higher losses. The nozzle efficiency calculated from survey data shows a substantial decrease of 10.2 points from 89.7 to 79.5 percent. The overall stage efficiency decreased from 87.3 percent to 83.2 or 4.1 points.

Figure 57 shows a comparison of stage pressure distribution as obtained from a moveable hub sidewall (Test 3), vs. a moveable shroud sidewall (Test 29). Both tests were conducted at a nozzle area of 62.2 percent of design. These two tests had different vaneless space inserts i.e. Test 3 had a simple dump ring whereas Test 29 had an accelerating ramp ring. However, at this setting the rings are deep in the sudden expansion region where they would be expected to have a minor impact on performance. Little or no change in static pressure distribution is shown in Figure 57. However, the stage efficiency was measured as 1.4 points higher with a hub area change as compared to a shroud area change.

5.6 Comparison to Pivoted Vane Performance

An exact direct comparison to a pivoted vane configuration could not be made because of limited data availability, differences of geometry, work levels, and leakage effects. However, a preliminary relative measure was made on a qualitative basis.

Three reference turbines with a known data base were selected for comparison. The first was the in-house research turbine design that was modified for the current program testing. This turbine was tested with pivoted vanes in five different positions and typical data is given in Figure 3. These tests were conducted with the sidewalls clamped in place and had zero leakage around the vanes.

The second reference turbine, a NASA stage, NASA TN D-3742, Reference 14, with a design specific speed of 95.6 was tested with a given rotor and fixed vanes (no leakage) at different stagger angles. The vane solidity and airfoil shape at each area was also optimized for the respective area test. With no leakage, this turbine test data series would be optimistic with respect to a practical pivotable vane turbine stage. The third reference turbine, NASA TN D-6605 Reference 15, was also tested in a similar manner except the same vane airfoil shape was used in the series.

Figure 58 shows a comparison of performance of the three reference turbines with the moveable sidewall data. The latter test data was taken with a 0.41 mm (0.016 in) leakage gap around the airfoil except at the downstream throat region where a "L" seal was used (Section 5, Test Results). The data are presented as a ratio of the measured efficiency to the peak efficiency achieved by each configurtion. The NASA turbines were tested with a combination of fixed geometry nozzle vane stagger angles and solidity (vane nos. given on figure). Fixed solidity and pivoting leakages would have probably resulted in additional efficiency reduction. The TCAE pivoted vane data (with zero leakage) also shows substantially higher fall-off of performance than the moveable sidewall (leakage included).

With respect to the pivoted vane area variation, the moveable sidewall variable geometry shows less fall off in performance at all the low off-design flow conditions. At higher flows the moveable sidewall fall off is comparable to the turbine of Reference 15, but less than, the more directly comparable research turbine, pivoted vane data.

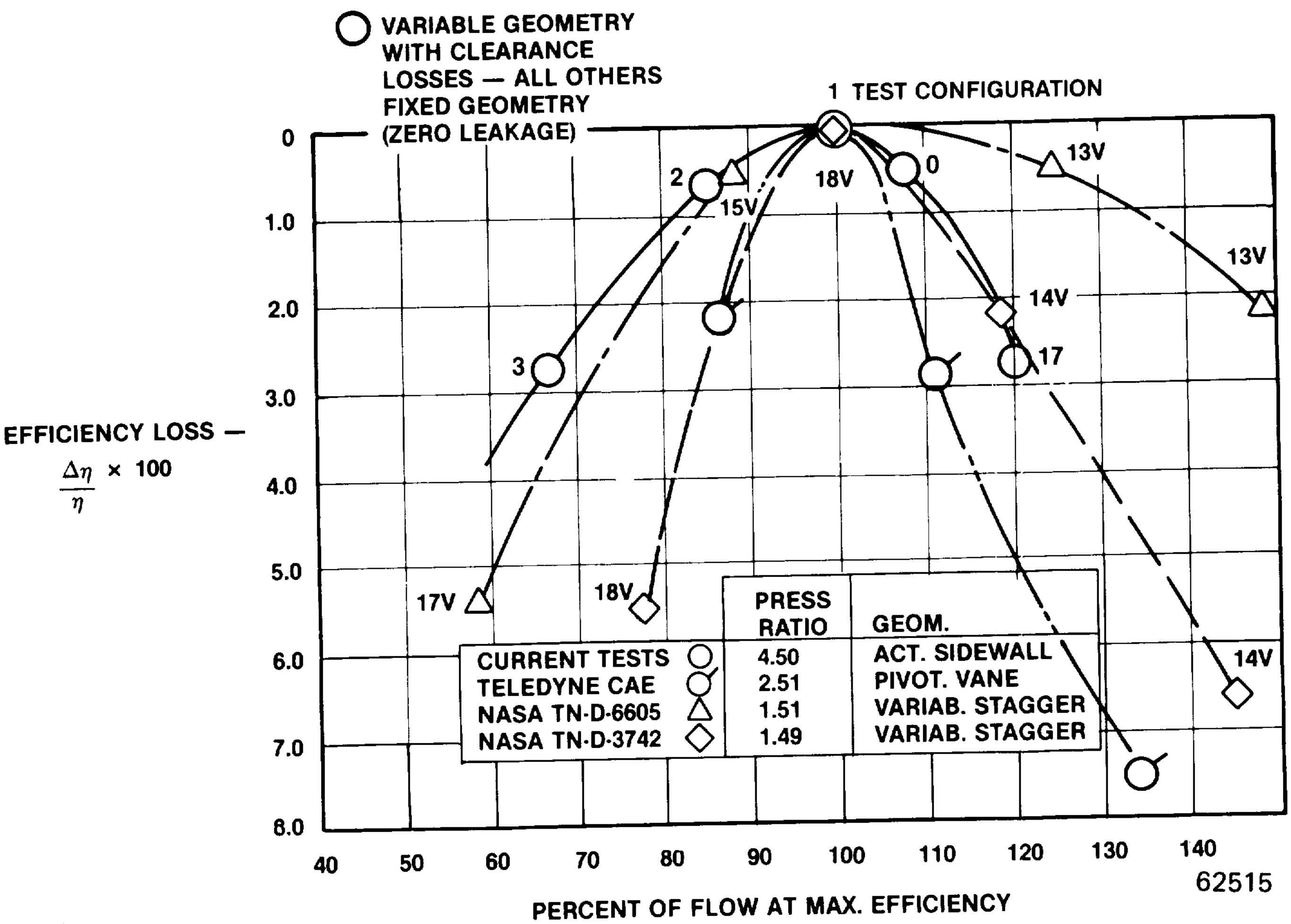


Figure 58. Performance Comparison - Moveable Sidewall and Pivoted Vane - Efficiency Loss vs. Flow.

SECTION 6.0

CONCLUSIONS AND RECOMMENDATIONS

A test data base was established for a variable nozzle area radial turbine using the moveable sidewall concepts. Thirty one (31) different flow area configurations were evaluated. The test results indicate that this variable geometry concept is efficient and competitive with the pivoted vane method. Leakage in the area of sidewall/vane protrusion is a significant factor and must be addressed in a practical application of the concept.

For the turbine stage tested, the addition of diffusing ramps downstream of a closed down stator sidewall or the use of meridional constriction did not improve performance as compared to a simple dump. However, this investigation used an existing turbine design which was modified for the experimental evaluation and, therefore, these geometries may have been non-optimum. Evaluation with a tailored design might show additional improvements.

Variable area losses were found to be different with hub and shroud wall movement. The use of an accelerating ramp at the nozzle exit was found to be beneficial at openings greater than the nominal or flush wall position.

Detailed survey measurements at the exducer exit and mixed out planes show that the rotor exit wake mixing and duct losses account for loss in efficiency ranging from 0.47 to 2.85 points for the five configurations tested.

Detailed surveys at the nozzle exit, for five selected configurations, showed how the nozzle loss and flow characteristics were affected by the nozzle sidewall positions. The results of the detail nozzle surveys indicate that nozzle losses are strongly influenced by which sidewall is moved and the position of the sidewall. For all five configurations surveyed, the pattern of a low loss region in the mid section and higher losses along the walls was encountered. A high loss region behind the vane trailing edge did not appear in the loss measurement which could have been obscured by the much higher nozzle sidewall wall losses.

Over 280 hours of testing were accumulated on the radial turbine stage and over 3000 survey points recorded and reduced. A comprehensive data base has been provided and general analyses were conducted on several configurations of interest. Complete analysis of this volumonous amount of data, however, was beyond the scope of the program.

It is recommended that further data analysis and studies be conducted. The turbine component and stage performance can be analytically modeled with the program test results. Semi-emperical correlations and off-design performance predictions can then be made for more in depth examination of the moveable sidewall concept and comparisons made to available alternate variable geometry methods.

The detail surveys in the nozzle vaneless space were conducted with a Cobra type probe. While meaningful data was acquired, the in depth analysis of the flowfield requires the use of non-intrusive data acquisition. A full understanding of the stage performance and component loss mechanism would also require knowledge of the rotor flowfield which can only be measured accurately by non-intrusive instrumentation such as laser doppler velocimitry (LDV). Detail LDV survey measurements at select flowpath stations complimented by the current program results would provide a benchmark data base for three-dimensional viscous compressible modeling of the flowfield and future improvements in turbine stage performance.

SECTION 7.0

NOMENCLATURE

SYMBOLS	DEFINITION
ΔH	enthalpy, kJ/kg; B/lb
H_{ad}	total to static adiabatic head, m; ft
L	rotor axial blade length, m; in
N	rotational speed, rev/sec
N_B	blade number
N_S	specific speed = $\dfrac{N\sqrt{Q}}{H_{ad}^{3/4}}$
NV	vane number
P	stagnation pressure, kPa; psia
Pin/Pout	total pressure ratio
ΔP	total pressure loss kPa; psia
Q	volume flow from exit of turbine, m^3/sec; ft^3/sec
R	radius, m; in
T	stagnation temperature, K; ^{o}R
tn	normal thickness, m; in
TORQ	measured torque corrected for bearing and windage, cm-kg/in-lb
U	blade velocity, m/sec; ft/sec

V	absolute gas velocity, m/sec; ft/sec
V_{cr}	critical velocity, m/sec; ft/sec
W	mass flow, kg/sec; lbs/sec
γ	ratio of specific heats
δ	ratio of inlet stagnation pressure to sea level standard
ϵ	function of γ defined as $\frac{\gamma st}{\gamma}\left[\left(\frac{\gamma+1}{2}\right)^{\frac{\gamma-1}{\gamma}}\left(\frac{\gamma st+1}{2}\right)^{\frac{\gamma st}{\gamma st-1}}\right]$
η_A	total-to-total adiabatic efficiency, based on temperature $\frac{\left(\frac{\gamma}{\gamma-1}\right)(TT1-TT4)}{\left(\frac{\gamma'}{\gamma'-1}\right)(TT1)\left[1-\left(\frac{PT4}{PT1}\right)^{(\gamma'-1)/\gamma'}\right]}$ γ, γ', based on actual and ideal expansions, respectively
$\eta_{t\text{-}s}$	total-to-static adiabatic efficiency based on temperature $\frac{\left(\frac{\gamma}{\gamma-1}\right)(TT1-TT4)}{\left(\frac{\gamma'}{\gamma'-1}\right)(TT1)\left[1-\left(\frac{PS4}{PT1}\right)^{(\gamma'-1)/\gamma'}\right]}$
η_T	total-to-total adiabatic efficiency based on torque $\frac{\left(\frac{2\pi}{60}\right)(N)(TORQ)}{W\left(\frac{\gamma'}{\gamma'-1}\right)(R)(TT1)\left[1-\left(\frac{PT4}{PT1}\right)^{(\gamma'-1)/\gamma'}\right]}$
$\Delta\eta$	change in total-to-total efficiency
θ_{cr}	squared ratio of critical velocity at turbine inlet tempeature to critical velocity at standard sea level temperature
ρ	density, kg/m^3; slugs/ft^3

DATA SUMMARY SHEET NOMENCLATURE - APPENDIX A

SYMBOL		DEFINITION
TIME	-	real time in hour:minute:second
PT1	-	turbine nozzle inlet total pressure, psia
TT1	-	turbine nozzle inlet total temperature, degree Rankine
SPEED	-	equivalent rotative speed ($N/\sqrt{\theta_{cr}}$), rpm
PT3	-	N/A
TT3	-	N/A
PNHCOR	-	percent of design equivalent speed (16540 rpm)
PT4	-	turbine rotor exit total pressure, psia
TT4	-	turbine rotor exit total temperature, degree Rankine
WORK	-	equivalent work ($\Delta H/\theta_{cr}$) calculated from rake measurement, Btu/lbm
PR1	-	stage pressure ratio (PT1/PT4)
PR2	-	N/A
TORQH	-	equivalent work ($\Delta H/\theta_{cr}$) calculated from dynamometer measurement, Btu/lbm
PR3	-	N/A
PRBD	-	N/A
TORQ	-	N/A
WA/C	-	equivalent flow ($W\sqrt{\theta_{cr}}\ \epsilon/\delta$), lbm/sec
WABD	-	N/A
FSP	-	flow speed parameter ($WN\epsilon/60\delta$), lbm rev/sec^2
WAM	-	measured flow rate (W), lbm/sec
WLAB	-	N/A
TUMX	-	N/A
WAN	-	N/A
WAR	-	N/A
PRAT	-	N/A
WPU	-	N/A
WPL	-	N/A
UV01	-	N/A
WAFT	-	N/A
RAD	-	N/A
E-AB	-	adiabatic efficiency (ηA) defined above
E-PR	-	primary efficiency (ηPR) defined above
YAW	-	N/A
E-TORQ	-	thermodynamic efficiency (ηTORQ) defined above
E-TH	-	N/A
LOC	-	N/A
TREF1	-	temperature of reference thermocouple, degree Rankine
E-EB	-	N/A
BLDN	-	N/A
TREF2	-	temperature of reference thermocouple, degree Rankine
PS2AV	-	N/A
BLDR	-	N/A

Appendix D - Vaneless Space Survey Nomenclature

Flow Angle - measured flow angle, degree

Total Pressure Loss - $\frac{\Delta P}{P} = \frac{PT1 - PT2}{PT1}$

Nozzle Efficiency - $$\frac{1 - \left[\left(\frac{PS2}{PT2} \right) \right]^{\frac{\gamma - 1}{\gamma}}}{1 - \left[\frac{PS2}{PT1} \right]^{\frac{\gamma - 1}{\gamma}}}$$

Pressure Loss Coefficient - $\frac{PT1 - PT2}{PT1 - PS2}$

PT1 - total pressure measured at turbine nozzle inlet

PT2 - total pressure measured at turbine nozzle exit

PS2 - static pressure measured at turbine nozzle exit

SECTION 8.0

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SECTION 9.0

TEST - SUMMARY

This section contains a summary of test data and data reduction of the NASA/ARTL Variable Stator Radial Turbine Program. It includes four appendixes which present data in four categories. In total, thirty-one (31) nozzle configurations were tested in this program. A test number is assigned to each of the 31 configurations and is used as reference for all the figures in all of the four appendixes. The first 15 tests, Test numbers A-13, were conducted with a moveable hub wall nozzle and the remaining 16 tests, Test numbers 14-29 were completed with a moveable shroud wall nozzle. Figures 58 and 59 respectively identify the test number and the geometry associated with each of the configurations.

The data is grouped into four appendixes A-D. Appendix A presents the overall performance data for all 31 configurations tested. This data was obtained and reduced on line as the rig test was being conducted. The nomenclature for the computer listing is defined in Section 7. Overall performance is based on fixed rake instrumentation located in the rotor mixed out plane. Stage data such as flow, corrected flow, pressure ratios, temperature, torque, speed is given at each of ten (10) individual test points as well as averaged values for the configuration test.

Appendix B presents the results of surveys conducted at the rotor mixed out plane. The data is presented as a plots of local angle, pressure, temperature, calculated streamline efficiency and calculated local to critical velocity ratio versus percent of flowpath span. Values are given as the average of three circumferential probe measurements taken at each radial station. A computed streamline continuity mass averaged value for the entire flowpath span is also given on each plot. Five figures were plotted for each of the twenty-six configurations reduced (Tests 4 through 29).

Five configurations were selected for detailed surveys immediately downstream of the nozzle and also immediately downstream of the rotor exducer. These surveys were completed for five selected configurations (Test Nos. 7, 17, 18, 19, and 29). Again, swirl angle, total pressure, total temperature, streamline efficiency, and local to critical velocity ratio were presented for each of selected configurations. These data are given in Appendix C for the rotor exducer survey plane.

Appendix D presents the survey data performed in the vaneless space behind the turbine nozzle for the same five selected configurations. These surveys covered a range of 20 degrees in the circumferential direction and across the entire rotor tip width.

Survey points were taken in one degree increments and at 5, 25, 50, 75 and 95 percent rotor tip width. These data were plotted for local flow angle, total pressure loss, nozzle efficiency, and pressure loss coefficient. Continuity mass average calculations were also made on each of the parameters and are given in Table VIII for a one vane pitch by full rotor width window.

TEST NO. (CONFIG.)	MOVEABLE WALL	WALL TYPE	PERCENT DESIGN NOZZ. AREA	VANELESS SPACE INSERT	ROTOR EXIT RING
A	HUB	STRAIGHT	100.0	ACCELERATING RAMP	(NO SEALS)
0	HUB	STRAIGHT	108.8	DUMP	—
1	HUB	STRAIGHT	100.0	DUMP	—
2	HUB	STRAIGHT	81.1	DUMP	—
3	HUB	STRAIGHT	62.2	DUMP	—
4	HUB	STRAIGHT	62.2	DUMP	HUB RING
5	HUB	STRAIGHT	108.8	ACCELERATING RAMP	—
6	HUB	STRAIGHT	100.0	ACCELERATING RAMP	—
7	HUB	STRAIGHT	81.1	ACCELERATING RAMP	—
8	HUB	STRAIGHT	81.1	DIFFUSING RAMP	—
9	HUB	STRAIGHT	62.2	DIFFUSING RAMP	—
10	HUB	STRAIGHT	62.2	DIFFUSING RAMP	HUB RING
11	HUB	CONTOURED	103.5	LOW RADIUS DUMP	—
12	HUB	CONTOURED	84.6	LOW RADIUS DUMP	—
13	HUB	CONTOURED	66.0	LOW RADIUS DUMP	—

62503

Figure 59. Test Number and Geometry Identification - Moveable Hub Wall Configurations.

TEST NO. (CONFIG.)	MOVEABLE WALL	WALL TYPE	PERCENT DESIGN NOZZ. AREA	VANELESS SPACE INSERT	ROTOR EXIT RING
14	SHROUD	STRAIGHT	81.1	DUMP	—
15	SHROUD	STRAIGHT	62.5	DUMP	—
16	SHROUD	STRAIGHT	62.5	DUMP	SHROUD RING
17	SHROUD	STRAIGHT	125.0	ACCELERATING RAMP	—
18	SHROUD	STRAIGHT	100.0	ACCELERATING RAMP	—
19	SHROUD	STRAIGHT	81.1	ACCELERATING RAMP	—
20	SHROUD	STRAIGHT	81.1	DIFFUSING RAMP	—
21	SHROUD	STRAIGHT	62.5	DIFFUSING RAMP	—
22	SHROUD	STRAIGHT	62.5	DIFFUSING RAMP	SHROUD RING
23	SHROUD	STRAIGHT	81.1	LOW RADIUS DUMP	—
24	SHROUD	STRAIGHT	62.5	LOW RADIUS DUMP	—
25	SHROUD	STRAIGHT	62.5	LOW RADIUS DUMP	SHROUD RING
26	SHROUD	CONTOURED	103.5	DUMP	—
27	SHROUD	CONTOURED	84.6	DUMP	—
28	SHROUD	CONTOURED	66.0	DUMP	—
29	SHROUD	STRAIGHT	62.2	ACCELERATING RAMP	—

61019

Figure 60. Test Number and Geometry Identification - Moveable Shroud Wall Configurations.

APPENDIX A

OVERALL STAGE PERFORMANCE DATA

Pressures Temperatures
Total to Total Efficiency
Work and Equivalent Work
Pressure Ratio
Speed

UNCLAS' 'IED

COMPONENT TEST - CT1637 - DATE 14/12/82

N.A.S.A. TURBINE DATA REDUCTION POINT # 10

TIME	SPEED	PNHCOR	WORK	TORQH	TORQ	FSP	TUMX	PRAT	UV01	E-AR	E-TORQ	TREF1	TREF2
PT1	PT3	PT4	PR1	PR3	WA/C	WAM	WAN	WPU	WAFT	E-PR	E-TH	E-EB	PS2AV
TT1	TT3	TT4	PR2	PRBD	WABD	WLAB	WAR	WPL	RAD	YAW	LOC	BLDN	BLDR
3:53:18	16490	100.28	36.73	36.02	49.12	831.66	51.93	-0.00	0.99	84.58	82.95	491.7	491.7
24.03	0.00	5.37	4.477	5.462	3.026	4.180	0.000	0.000	-0.000	82.95	0.00	0.00	13.20
724.8	0.0	511.6	5.021	1.820	5.508	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
3:53:24	16530	100.52	36.78	36.11	49.11	833.51	51.64	-0.00	0.99	84.66	83.12	491.7	491.7
24.03	0.00	5.36	4.481	5.465	3.025	4.180	0.000	0.000	-0.000	83.12	0.00	0.00	13.26
724.8	0.0	511.3	5.022	1.813	5.487	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
3:53:27	16513	100.42	36.78	36.70	49.63	827.30	51.71	-0.00	0.98	84.64	84.43	491.7	491.7
24.04	0.00	5.36	4.484	5.466	3.006	4.154	0.000	0.000	-0.000	84.43	0.00	0.00	13.28
724.9	0.0	511.4	5.024	1.811	5.445	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
3:53:28	16474	100.18	36.76	36.40	49.67	830.62	51.78	-0.00	0.98	84.58	83.75	491.7	491.7
24.04	0.00	5.36	4.485	5.467	3.025	4.181	0.000	0.000	-0.000	83.75	0.00	0.00	13.28
724.9	0.0	511.5	5.025	1.810	5.477	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
3:53:31	16402	99.74	36.76	36.48	50.05	827.85	51.93	-0.00	0.97	84.55	83.91	491.7	491.7
24.04	0.00	5.36	4.487	5.469	3.028	4.185	0.000	0.000	-0.000	83.91	0.00	0.00	13.29
725.0	0.0	511.6	5.026	1.809	5.479	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
3:53:33	16317	99.22	36.73	36.40	50.27	824.69	52.07	-0.00	0.97	84.49	83.73	491.7	491.7
24.04	0.00	5.36	4.486	5.469	3.033	4.191	0.000	0.000	-0.000	83.73	0.00	0.00	13.29
725.0	0.0	511.8	5.025	1.809	5.487	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
3:53:36	16222	98.65	36.67	36.48	50.63	819.07	52.36	-0.00	0.96	84.36	83.92	491.7	491.7
24.04	0.00	5.36	4.486	5.468	3.029	4.187	0.000	0.000	-0.000	83.92	0.00	0.00	13.29
724.9	0.0	512.1	5.025	1.809	5.483	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
3:53:39	16202	98.52	36.67	36.55	50.77	817.77	52.36	-0.00	0.96	84.37	84.09	491.7	491.7
24.04	0.00	5.36	4.485	5.468	3.028	4.185	0.000	0.000	-0.000	84.09	0.00	0.00	13.27
724.9	0.0	512.1	5.026	1.811	5.487	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
3:53:40	16169	98.33	36.65	36.50	50.85	817.05	52.64	-0.00	0.96	84.32	83.96	491.7	491.7
24.04	0.00	5.36	4.485	5.468	3.032	4.189	0.000	0.000	-0.000	83.96	0.00	0.00	13.27
725.2	0.0	512.3	5.026	1.812	5.494	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
3:53:43	16172	98.35	36.62	36.42	50.82	818.53	52.64	-0.00	0.96	84.26	83.81	491.7	491.7
24.04	0.00	5.36	4.484	5.468	3.037	4.196	0.000	0.000	-0.000	83.81	0.00	0.00	13.25
724.9	0.0	512.3	5.025	1.814	5.511	-0.000	0.000	0.000	0.00	0	0	0.00	0.00

AVERAGED DATA REDUCTION VALUES

3:53:45	16349	99.42	36.72	36.41	50.09	824.80	52.11	-0.00	0.97	84.48	83.77	491.7	491.7
24.04	0.00	5.36	4.484	5.467	3.027	4.183	0.000	0.000	-0.000	83.77	0.00	0.00	13.24
724.9	0.0	511.8	5.025	1.812	5.486	-0.000	0.000	0.000	0.00	0	0	0.00	0.00

Figure A-1 Overall Performance, Test No. A, Moveable Hub 100.0 Percent Area

COMPONENT TEST - CT1637 - DATE 7/ 1/83

N.A.S.A. TURBINE DATA REDUCTION POINT # 36

TIME	SPEED	FNHCOR	WORK	TORQH	TORQ	FSP	TUMX	PRAT	UV01	E-AB	E-TORQ	TREF1	TREF2
PT1	PT3	PT4	PR1	PR3	WA/C	WAM	WAN	WPU	WAFT	E-FK	E-TH	E-EB	PS2AV
TT1	TT3	TT4	PR2	PRBD	WABD	WLAB	WAR	WPL	RAD	YAW	LOC	BLDN	BLDR
5: 2:35	16408	99.78	37.65	38.18	52.61	832.19	48.88	-0.00	0.96	86.57	87.79	491.7	490.7
19.44	0.00	4.33	4.489	5.639	3.043	3.393	0.000	0.000	-0.000	87.79	0.00	0.00	10.86
728.1	0.0	508.6	5.369	1.790	5.449	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
5: 2:39	16485	100.25	37.73	39.37	52.58	814.06	48.31	-0.00	0.95	86.72	90.49	491.7	490.7
19.45	0.00	4.33	4.492	5.644	2.963	3.307	0.000	0.000	-0.000	90.49	0.00	0.00	10.86
727.9	0.0	508.0	5.373	1.791	5.309	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
5: 2:42	16550	100.64	37.75	39.44	52.37	815.89	47.88	-0.00	0.96	86.72	90.59	491.7	490.7
19.48	0.00	4.33	4.497	5.651	2.958	3.306	0.000	0.000	-0.000	90.59	0.00	0.00	10.87
727.5	0.0	507.6	5.378	1.792	5.302	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
5: 2:46	16544	100.61	37.73	38.63	52.06	827.33	48.02	-0.00	0.97	86.59	88.66	491.7	490.7
19.52	0.00	4.33	4.506	5.662	3.000	3.360	0.000	0.000	-0.000	88.66	0.00	0.00	10.89
727.5	0.0	507.7	5.390	1.793	5.380	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
5: 2:47	16493	100.30	37.67	38.22	52.13	832.18	48.45	-0.00	0.97	86.47	87.74	491.7	490.7
19.51	0.00	4.33	4.504	5.659	3.027	3.389	0.000	0.000	-0.000	87.74	0.00	0.00	10.89
727.6	0.0	508.2	5.388	1.792	5.425	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
5: 2:50	16378	99.60	37.67	38.10	52.46	828.51	49.10	-0.00	0.96	86.51	87.50	491.7	490.7
19.49	0.00	4.33	4.499	5.652	3.035	3.391	0.000	0.000	-0.000	87.50	0.00	0.00	10.89
728.5	0.0	508.8	5.381	1.790	5.433	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
5: 2:52	16393	99.69	37.65	37.98	52.34	830.70	49.17	-0.00	0.96	86.50	87.24	491.7	490.7
19.48	0.00	4.33	4.497	5.650	3.040	3.396	0.000	0.000	-0.000	87.24	0.00	0.00	10.88
728.5	0.0	508.9	5.378	1.789	5.442	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
5: 2:55	16484	100.24	37.65	38.10	52.14	834.16	48.53	-0.00	0.97	86.51	87.55	491.7	490.7
19.47	0.00	4.33	4.494	5.647	3.036	3.392	0.000	0.000	-0.000	87.55	0.00	0.00	10.88
727.5	0.0	508.2	5.375	1.789	5.433	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
5: 2:56	16466	100.13	37.66	38.05	52.22	834.76	48.60	-0.00	0.97	86.55	87.43	491.7	490.7
19.47	0.00	4.33	4.494	5.646	3.042	3.397	0.000	0.000	-0.000	87.43	0.00	0.00	10.88
727.8	0.0	508.3	5.374	1.789	5.443	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
5: 3: 0	16453	100.05	37.70	38.06	52.26	833.61	48.95	-0.00	0.97	86.63	87.47	491.7	490.7
19.46	0.00	4.33	4.494	5.645	3.040	3.392	0.000	0.000	-0.000	87.47	0.00	0.00	10.88
728.6	0.0	508.7	5.373	1.789	5.438	-0.000	0.000	0.000	0.00	0	0	0.00	0.00

AVERAGED DATA REDUCTION VALUES

5: 3: 1	16465	100.13	37.69	38.41	52.32	828.34	48.59	-0.00	0.96	86.58	88.25	491.7	490.7
19.48	0.00	4.33	4.497	5.649	3.018	3.372	0.000	0.000	-0.000	88.25	0.00	0.00	10.88
727.9	0.0	508.3	5.378	1.790	5.406	-0.000	0.000	0.000	0.00	0	0	0.00	0.00

Figure A-2 Overall Performance, Test No. 0, Moveable Hub 108.8 Percent Area

UNCLASSIFIED

COMPONENT TEST - CT1637 - DATE 5/ 1/83

N.A.S.A. TURBINE DATA REDUCTION POINT # 28

TIME / PT1 / TT1	SPEED / PT3 / TT3	PNHCOR / PT4 / TT4	WORK / PR1 / PR2	TORQH / PR3 / PRBD	TORQ / WA/C / WABD	FSP / WAM / WLAB	TUMX / WAN / WAR	PRAT / WPU / WPL	UV01 / WAFT / RAD	E-AB / E-PR / YAW	E-TORQ / E-TH / LOC	TREF1 / E-EB / BLDN	TREF2 / PS2AV / BLDR
1:31:12	16442	99.99	37.78	38.62	49.38	775.34	46.89	-0.00	0.96	86.97	88.90	491.7	491.7
22.23	0.00	4.96	4.480	5.317	2.829	3.612	0.000	0.000	-0.000	88.90	0.00	0.00	11.89
726.3	0.0	506.6	5.078	1.869	5.290	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
1:31:18	16493	100.30	37.78	38.16	48.64	777.70	46.82	-0.00	0.97	86.99	87.86	491.7	491.7
22.23	0.00	4.96	4.479	5.315	2.829	3.612	0.000	0.000	-0.000	87.86	0.00	0.00	11.89
726.3	0.0	506.5	5.077	1.870	5.291	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
1:31:19	16437	99.96	37.76	38.24	48.83	773.89	47.03	-0.00	0.97	86.93	88.04	491.7	491.7
22.23	0.00	4.96	4.479	5.314	2.825	3.606	0.000	0.000	-0.000	88.04	0.00	0.00	11.89
726.3	0.0	506.7	5.077	1.869	5.282	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
1:31:23	16471	100.16	37.81	38.16	48.62	775.14	46.82	-0.00	0.97	87.05	87.86	491.7	491.7
22.23	0.00	4.96	4.479	5.314	2.824	3.605	0.000	0.000	-0.000	87.86	0.00	0.00	11.89
726.5	0.0	506.5	5.076	1.869	5.280	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
1:31:24	16526	100.50	37.77	38.08	48.42	778.90	46.74	-0.00	0.97	86.96	87.67	491.7	491.7
22.23	0.00	4.96	4.479	5.313	2.828	3.611	0.000	0.000	-0.000	87.67	0.00	0.00	11.89
726.0	0.0	506.4	5.075	1.869	5.288	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
1:31:27	16487	100.26	37.81	38.10	48.52	776.52	46.74	-0.00	0.97	87.05	87.71	491.7	491.7
22.23	0.00	4.96	4.479	5.313	2.826	3.608	0.000	0.000	-0.000	87.71	0.00	0.00	11.90
726.4	0.0	506.4	5.076	1.869	5.282	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
1:31:29	16488	100.26	37.77	38.08	48.50	776.63	46.96	-0.00	0.97	86.95	87.68	491.7	491.7
22.23	0.00	4.96	4.479	5.313	2.826	3.608	0.000	0.000	-0.000	87.68	0.00	0.00	11.90
726.3	0.0	506.7	5.076	1.868	5.281	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
1:31:32	16511	100.41	37.77	38.05	48.42	778.17	47.39	-0.00	0.97	86.95	87.60	491.7	491.7
22.23	0.00	4.96	4.479	5.313	2.828	3.609	0.000	0.000	-0.000	87.60	0.00	0.00	11.90
726.9	0.0	507.1	5.076	1.868	5.283	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
1:31:34	16520	100.46	37.81	38.13	48.37	776.47	47.24	-0.00	0.97	87.04	87.79	491.7	491.7
22.23	0.00	4.96	4.479	5.313	2.820	3.599	0.000	0.000	-0.000	87.79	0.00	0.00	11.90
727.1	0.0	506.9	5.076	1.868	5.269	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
1:31:37	16694	101.52	37.90	38.63	48.04	777.39	46.46	-0.00	0.98	87.24	88.92	491.7	491.7
22.24	0.00	4.96	4.480	5.315	2.794	3.568	0.000	0.000	-0.000	88.92	0.00	0.00	11.91
726.7	0.0	506.2	5.077	1.867	5.217	-0.000	0.000	0.000	0.00	0	0	0.00	0.00

AVERAGED DATA REDUCTION VALUES

1:31:38	16507	100.38	37.80	38.23	48.57	776.62	46.91	-0.00	0.97	87.01	88.00	491.7	491.7
22.23	0.00	4.96	4.479	5.314	2.823	3.604	0.000	0.000	-0.000	88.00	0.00	0.00	11.92
726.5	0.0	506.6	5.076	1.869	5.276	-0.000	0.000	0.000	0.00	0	0	0.00	0.00

Figure A-3 Overall Performance, Test No. 1, Moveable Hub 100.0 Percent Area

COMPONENT TEST - CT1637 - DATE 7/1/83

N.A.S.A. TURBINE DATA REDUCTION POINT # 31

TIME PT1 TT1	SPEED PT3 TT3	PNHCOR PT4 TT4	WORK PR1 PR2	TORQH PR3 PRBD	TORQ WA/C WABD	FSP WAM WLAB	TUMX WAN WAR	PRAT WPU WPL	UV01 WAFT RAD	E-AB E-PK YAW	E-TORQ E-TH LOC	TREF1 E-EB BLDN	TREF2 PS2AV BLDR
0: 7:35	16424	99.87	37.51	37.93	41.20	657.17	51.25	-0.00	0.97	86.27	87.23	491.7	491.7
22.32	0.00	4.97	4.487	5.033	2.401	3.069	0.000	0.000	-0.000	87.23	0.00	0.00	11.04
730.2	0.0	510.9	4.867	2.022	4.855	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
0: 7:41	16427	99.90	37.50	37.77	41.07	658.18	51.39	-0.00	0.97	86.25	86.86	491.7	491.7
22.32	0.00	4.97	4.487	5.033	2.404	3.073	0.000	0.000	-0.000	86.86	0.00	0.00	11.04
730.4	0.0	511.1	4.867	2.023	4.864	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
0: 7:43	16436	99.95	37.56	37.79	41.02	657.78	51.18	-0.00	0.97	86.37	86.91	491.7	491.7
22.32	0.00	4.97	4.487	5.033	2.401	3.069	0.000	0.000	-0.000	86.91	0.00	0.00	11.03
730.5	0.0	510.9	4.867	2.023	4.860	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
0: 7:46	16438	99.96	37.56	37.75	41.00	658.31	51.32	-0.00	0.97	86.38	86.82	491.7	491.7
22.32	0.00	4.97	4.487	5.033	2.403	3.071	0.000	0.000	-0.000	86.82	0.00	0.00	11.03
730.7	0.0	511.0	4.868	2.023	4.863	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
0: 7:48	16456	100.07	37.54	37.81	40.96	657.97	51.25	-0.00	0.97	86.35	86.96	491.7	491.7
22.32	0.00	4.97	4.487	5.033	2.399	3.066	0.000	0.000	-0.000	86.96	0.00	0.00	11.04
730.5	0.0	510.9	4.867	2.023	4.854	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
0: 7:51	16452	100.05	37.54	37.74	40.94	658.50	51.18	-0.00	0.97	86.33	86.80	491.7	491.7
22.32	0.00	4.97	4.487	5.033	2.401	3.070	0.000	0.000	-0.000	86.80	0.00	0.00	11.04
730.4	0.0	510.9	4.868	2.023	4.859	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
0: 7:52	16431	99.92	37.52	37.83	41.02	656.59	51.11	-0.00	0.97	86.28	87.00	491.7	491.7
22.32	0.00	4.97	4.487	5.033	2.398	3.066	0.000	0.000	-0.000	87.00	0.00	0.00	11.04
730.1	0.0	510.8	4.867	2.023	4.851	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
0: 7:56	16430	99.91	37.52	37.78	41.00	657.14	51.46	-0.00	0.97	86.28	86.89	491.7	491.7
22.32	0.00	4.97	4.487	5.033	2.400	3.067	0.000	0.000	-0.000	86.89	0.00	0.00	11.03
730.6	0.0	511.2	4.867	2.023	4.856	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
0: 7:57	16432	99.92	37.53	37.68	40.98	658.62	51.61	-0.00	0.97	86.31	86.67	491.7	491.7
22.32	0.00	4.98	4.486	5.033	2.405	3.073	0.000	0.000	-0.000	86.67	0.00	0.00	11.03
730.9	0.0	511.3	4.867	2.023	4.866	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
0: 8: 0	16481	100.22	37.57	38.05	40.87	654.37	50.75	-0.00	0.97	86.40	87.52	491.7	491.7
22.32	0.00	4.97	4.487	5.033	2.382	3.046	0.000	0.000	-0.000	87.52	0.00	0.00	11.04
730.0	0.0	510.4	4.867	2.022	4.819	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
AVERAGED DATA REDUCTION VALUES													
0: 8: 2	16441	99.98	37.53	37.81	41.01	657.46	51.25	-0.00	0.97	86.32	86.97	491.7	491.7
22.32	0.00	4.97	4.487	5.033	2.399	3.067	0.000	0.000	-0.000	86.97	0.00	0.00	11.04
730.4	0.0	510.9	4.867	2.023	4.855	-0.000	0.000	0.000	0.00	0	0	0.00	0.00

Figure A-4 Overall Performance, Test No. 2, Moveable Hub 81.1 Percent Area

UNCLASSIFIED

COMPONENT TEST - CT1637 - DATE 7/ 1/83

N.A.S.A. TURBINE DATA REDUCTION POINT # 33

TIME PT1 TT1	SPEED PT3 TT3	PNHCOR PT4 TT4	WORK PR1 PR2	TORQH PR3 PRBD	TORQ WA/C WABD	FSP WAM WLAB	TUMX WAN WAR	PRAT WPU WPL	UV01 WAFT RAD	E-AB E-PR YAW	E-TORQ E-TH LOC	TREF1 E-EB BLDN	TREF2 PS2AV BLDR
2:32: 7	16446	100.01	36.78	36.63	31.24	517.37	56.34	-0.00	0.97	84.62	84.26	492.5	491.7
22.42	0.00	5.00	4.484	4.845	1.887	2.422	0.000	0.000	-0.000	84.26	0.00	0.00	10.09
731.4	0.0	516.0	4.672	2.222	4.196	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
2:32:13	16443	99.99	36.85	37.28	31.79	517.12	55.55	-0.00	0.97	84.75	85.75	492.5	491.7
22.43	0.00	5.00	4.486	4.845	1.887	2.423	0.000	0.000	-0.000	85.75	0.00	0.00	10.09
730.8	0.0	515.3	4.673	2.222	4.193	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
2:32:15	16426	99.89	36.78	37.07	31.66	516.92	56.05	-0.00	0.97	84.60	85.26	492.5	491.7
22.43	0.00	5.00	4.486	4.845	1.888	2.424	0.000	0.000	-0.000	85.26	0.00	0.00	10.10
730.9	0.0	515.8	4.673	2.221	4.195	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
2:32:18	16443	99.99	36.79	36.86	31.45	517.44	56.20	-0.00	0.97	84.62	84.77	492.5	491.7
22.42	0.00	5.00	4.486	4.846	1.888	2.423	0.000	0.000	-0.000	84.77	0.00	0.00	10.10
731.2	0.0	515.9	4.673	2.221	4.194	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
2:32:19	16447	100.01	36.78	36.83	31.45	517.99	55.98	-0.00	0.97	84.60	84.72	492.5	491.7
22.42	0.00	5.00	4.486	4.846	1.890	2.426	0.000	0.000	-0.000	84.72	0.00	0.00	10.10
730.9	0.0	515.7	4.673	2.221	4.197	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
2:32:22	16412	99.80	36.84	36.85	31.51	516.66	56.27	-0.00	0.97	84.74	84.75	492.5	491.7
22.42	0.00	5.00	4.486	4.845	1.889	2.423	0.000	0.000	-0.000	84.75	0.00	0.00	10.10
731.7	0.0	516.0	4.673	2.220	4.194	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
2:32:24	16427	99.89	36.78	36.81	31.47	517.38	56.34	-0.00	0.97	84.59	84.67	492.5	491.7
22.42	0.00	5.00	4.486	4.845	1.890	2.425	0.000	0.000	-0.000	84.67	0.00	0.00	10.10
731.3	0.0	516.0	4.674	2.220	4.196	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
2:32:27	16420	99.85	36.75	36.93	31.51	516.08	56.27	-0.00	0.97	84.53	84.93	492.5	491.7
22.43	0.00	5.00	4.486	4.845	1.886	2.421	0.000	0.000	-0.000	84.93	0.00	0.00	10.10
731.0	0.0	516.0	4.673	2.220	4.187	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
2:32:28	16461	100.10	36.83	37.56	31.37	507.63	55.77	-0.00	0.96	84.69	86.37	492.5	491.7
22.43	0.00	5.00	4.488	4.847	1.850	2.376	0.000	0.000	-0.000	86.37	0.00	0.00	10.10
730.9	0.0	515.5	4.676	2.221	4.110	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
2:32:32	16448	100.02	36.79	37.28	31.78	517.32	55.84	-0.00	0.97	84.60	85.72	492.5	491.7
22.44	0.00	5.00	4.488	4.848	1.887	2.424	0.000	0.000	-0.000	85.72	0.00	0.00	10.10
730.7	0.0	515.5	4.676	2.221	4.191	-0.000	0.000	0.000	0.00	0	0	0.00	0.00

AVERAGED DATA REDUCTION VALUES

2:32:35	16437	99.96	36.80	37.01	31.52	516.19	56.06	-0.00	0.97	84.63	85.12	492.5	491.7
22.43	0.00	5.00	4.486	4.846	1.884	2.419	0.000	0.000	-0.000	85.12	0.00	0.00	10.10
731.1	0.0	515.8	4.674	2.221	4.186	-0.000	0.000	0.000	0.00	0	0	0.00	0.00

Figure A-5 Overall Performance, Test No. 3, Moveable Hub 62.2 Percent Area

UNCLASSIFIED

COMPONENT TEST - CT1637 - DATE 13/ 1/83

N.A.S.A. TURBINE DATA REDUCTION POINT # 48

TIME	SPEED	PNHCOR	WORK	TORQH	TORQ	FSP	TUMX	PRAT	UV01	E-AB	E-TORQ	TREF1	TREF2
PT1	PT3	PT4	PR1	PR3	WA/C	WAM	WAN	WPU	WAFT	E-PR	E-TH	E-EB	PS2AV
TT1	TT3	TT4	PR2	PRBD	WABD	WLAB	WAR	WPL	RAD	YAW	LOC	BLDN	BLDR
0: 2:29	16462	100.11	33.94	33.61	28.33	512.36	73.00	-0.00	0.98	78.17	77.39	490.7	489.8
23.62	0.00	5.28	4.475	4.559	1.867	2.524	0.000	0.000	-0.000	77.39	0.00	0.00	11.97
731.3	0.0	532.7	5.143	1.973	3.685	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
(1 0: 2:34	16473	100.18	33.90	33.60	28.28	512.39	73.86	-0.00	0.98	78.06	77.37	490.7	489.8
23.62	0.00	5.28	4.476	4.560	1.866	2.522	0.000	0.000	-0.000	77.37	0.00	0.00	11.98
732.1	0.0	533.6	5.143	1.971	3.679	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
0: 2:37	16497	100.32	33.91	33.46	28.20	514.50	73.57	-0.00	0.98	78.09	77.05	490.7	489.8
23.62	0.00	5.28	4.476	4.560	1.871	2.529	0.000	0.000	-0.000	77.05	0.00	0.00	11.99
731.8	0.0	533.3	5.143	1.971	3.688	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
0: 2:40	16488	100.27	33.88	33.56	28.24	513.10	73.93	-0.00	0.98	78.03	77.29	490.7	489.8
23.62	0.00	5.28	4.476	4.560	1.867	2.523	0.000	0.000	-0.000	77.29	0.00	0.00	11.99
732.1	0.0	533.6	5.143	1.970	3.679	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
0: 2:41	16496	100.31	33.96	33.42	28.18	514.57	73.65	-0.00	0.98	78.20	76.96	490.7	489.8
23.62	0.00	5.28	4.476	4.561	1.872	2.529	0.000	0.000	-0.000	76.96	0.00	0.00	11.99
732.3	0.0	533.3	5.143	1.970	3.688	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
0: 2:44	16488	100.27	33.88	33.47	28.24	514.62	73.93	-0.00	0.98	78.03	77.06	490.7	489.8
23.62	0.00	5.28	4.476	4.560	1.873	2.530	0.000	0.000	-0.000	77.06	0.00	0.00	12.00
732.1	0.0	533.6	5.143	1.969	3.687	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
0: 2:46	16482	100.23	33.86	33.43	28.22	514.48	73.79	-0.00	0.98	77.98	76.98	490.7	489.8
23.62	0.00	5.28	4.476	4.560	1.873	2.531	0.000	0.000	-0.000	76.98	0.00	0.00	12.00
731.7	0.0	533.5	5.143	1.968	3.687	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
0: 2:49	16451	100.04	33.90	33.42	28.29	513.73	74.00	-0.00	0.98	78.07	76.97	490.7	489.8
23.62	0.00	5.28	4.476	4.559	1.874	2.531	0.000	0.000	-0.000	76.97	0.00	0.00	12.00
732.3	0.0	533.7	5.142	1.968	3.688	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
0: 2:51	16452	100.04	33.96	33.36	28.25	514.02	73.93	-0.00	0.98	78.20	76.82	490.7	489.8
23.62	0.00	5.28	4.476	4.559	1.875	2.531	0.000	0.000	-0.000	76.82	0.00	0.00	12.00
732.7	0.0	533.6	5.142	1.968	3.690	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
0: 2:54	16472	100.17	33.86	33.47	28.22	513.21	73.79	-0.00	0.98	77.98	77.08	490.7	489.8
23.62	0.00	5.28	4.476	4.560	1.869	2.526	0.000	0.000	-0.000	77.08	0.00	0.00	12.00
731.7	0.0	533.5	5.143	1.968	3.680	-0.000	0.000	0.000	0.00	0	0	0.00	0.00

AVERAGED DATA REDUCTION VALUES

0: 2:55	16476	100.19	33.91	33.48	28.24	513.70	73.75	-0.00	0.98	78.08	77.10	490.7	489.8
23.62	0.00	5.28	4.476	4.560	1.871	2.527	0.000	0.000	-0.000	77.10	0.00	0.00	12.00
732.0	0.0	533.4	5.143	1.969	3.685	-0.000	0.000	0.000	0.00	0	0	0.00	0.00

Figure A-6 Overall Performance, Test No. 4, Moveable Hub 62.2 Percent Area

UNCLASSIFIED

COMPONENT TEST - CT1637 - DATE 10/ 1/83

N.A.S.A. TURBINE DATA REDUCTION POINT # 39

TIME PT1 TT1	SPEED PT3 TT3	PNHCOR PT4 TT4	WORK PR1 PR2	TORQH PR3 PRBD	TORQ WA/C WABD	FSP WAM WLAB	TUMX WAN WAR	PRAT WPU WPL	UV01 WAFT RAD	E-AB E-PR YAW	E-TORQ E-TH LOC	TREF1 E-EB BLDN	TREF2 PS2AV BLDR
0:19:59	16421	99.86	37.81	38.07	52.76	838.36	47.45	-0.00	0.97	86.96	87.56	490.7	490.7
20.10	0.00	4.48	4.486	5.274	3.063	3.533	0.000	0.000	-0.000	87.56	0.00	0.00	11.13
727.3	0.0	507.1	5.403	1.806	5.532	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
0:20: 5	16353	99.44	37.77	38.01	52.88	834.61	47.88	-0.00	0.96	86.86	87.41	490.7	490.7
20.10	0.00	4.48	4.487	5.276	3.062	3.531	0.000	0.000	-0.000	87.41	0.00	0.00	11.13
727.6	0.0	507.6	5.405	1.806	5.531	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
0:20: 7	16395	99.70	37.79	38.08	52.86	836.97	47.95	-0.00	0.97	86.91	87.58	490.7	490.7
20.10	0.00	4.48	4.487	5.276	3.063	3.532	0.000	0.000	-0.000	87.58	0.00	0.00	11.13
727.9	0.0	507.6	5.405	1.806	5.533	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
0:20:10	16477	100.20	37.84	38.42	53.06	840.97	47.52	-0.00	0.97	87.02	88.36	490.7	490.7
20.10	0.00	4.48	4.488	5.276	3.062	3.531	0.000	0.000	-0.000	88.36	0.00	0.00	11.13
727.7	0.0	507.2	5.405	1.806	5.530	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
0:20:12	16430	99.91	37.85	38.17	52.91	839.38	47.59	-0.00	0.97	87.05	87.77	490.7	490.7
20.10	0.00	4.48	4.488	5.276	3.065	3.534	0.000	0.000	-0.000	87.77	0.00	0.00	11.13
727.9	0.0	507.3	5.405	1.805	5.534	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
0:20:15	16408	99.78	37.79	38.09	52.86	838.00	47.74	-0.00	0.97	86.91	87.60	490.7	490.7
20.10	0.00	4.48	4.488	5.276	3.064	3.534	0.000	0.000	-0.000	87.60	0.00	0.00	11.14
727.6	0.0	507.4	5.405	1.805	5.531	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
0:20:16	16380	99.61	37.81	38.10	52.88	835.24	47.52	-0.00	0.96	86.94	87.61	490.7	490.7
20.10	0.00	4.48	4.489	5.277	3.059	3.529	0.000	0.000	-0.000	87.61	0.00	0.00	11.15
727.5	0.0	507.2	5.407	1.803	5.519	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
0:20:19	16400	99.73	37.80	38.11	52.78	835.56	47.52	-0.00	0.97	86.92	87.62	490.7	490.7
20.10	0.00	4.48	4.489	5.278	3.057	3.526	0.000	0.000	-0.000	87.62	0.00	0.00	11.15
727.4	0.0	507.2	5.406	1.804	5.515	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
0:20:21	16380	99.61	37.81	38.04	52.82	835.64	47.45	-0.00	0.97	86.94	87.47	490.7	490.7
20.10	0.00	4.48	4.490	5.279	3.061	3.531	0.000	0.000	-0.000	87.47	0.00	0.00	11.15
727.4	0.0	507.1	5.409	1.804	5.523	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
0:20:24	16348	99.41	37.80	38.02	52.97	835.18	47.66	-0.00	0.96	86.92	87.41	490.7	490.7
20.10	0.00	4.48	4.489	5.278	3.065	3.536	0.000	0.000	-0.000	87.41	0.00	0.00	11.14
727.6	0.0	507.4	5.408	1.804	5.531	-0.000	0.000	0.000	0.00	0	0	0.00	0.00

AVERAGED DATA REDUCTION VALUES

0:20:27	16399	99.72	37.81	38.11	52.88	836.99	47.63	-0.00	0.97	86.94	87.64	490.7	490.7
20.10	0.00	4.48	4.488	5.277	3.062	3.532	0.000	0.000	-0.000	87.64	0.00	0.00	11.14
727.6	0.0	507.3	5.406	1.805	5.528	-0.000	0.000	0.000	0.00	0	0	0.00	0.00

Figure A-7 Overall Performance, Test No. 5, Moveable Hub 108.8 Percent Area

COMPONENT TEST - CT1637 - DATE 10/ 1/83

N.A.S.A. TURBINE DATA REDUCTION POINT # 41

TIME PT1 TT1	SPEED PT3 TT3	PNHCOR PT4 TT4	WORK PR1 PR2	TORQH PR3 PRBD	TORQ WA/C WABD	FSP WAM WLAB	TUMX WAN WAR	PRAT WPU WPL	UV01 WAFT RAD	E-AB E-PR YAW	E-TORQ E-TH LOC	TREF1 E-EB BLDN	TREF2 PS2AV BLDR
4:47:31	16391	99.68	37.81	38.18	49.67	783.94	48.72	-0.00	0.96	86.92	87.78	491.7	491.7
22.41	0.00	4.99	4.490	4.949	2.870	3.686	0.000	0.000	-0.000	87.78	0.00	0.00	12.01
729.1	0.0	508.4	5.151	1.867	5.358	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
4:47:35	16469	100.15	37.86	38.17	49.40	787.40	48.58	-0.00	0.97	87.03	87.75	491.7	491.7
22.42	0.00	4.99	4.491	4.951	2.869	3.685	0.000	0.000	-0.000	87.75	0.00	0.00	12.00
729.3	0.0	508.3	5.153	1.867	5.358	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
4:47:38	16503	100.36	37.81	38.19	49.27	788.17	48.58	-0.00	0.97	86.92	87.77	491.7	491.7
22.42	0.00	4.99	4.492	4.951	2.865	3.682	0.000	0.000	-0.000	87.77	0.00	0.00	12.01
729.0	0.0	508.3	5.154	1.867	5.352	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
4:47:40	16422	99.86	37.81	38.16	49.51	784.72	48.93	-0.00	0.97	86.92	87.72	491.7	491.7
22.42	0.00	4.99	4.492	4.951	2.867	3.683	0.000	0.000	-0.000	87.72	0.00	0.00	12.01
729.5	0.0	508.6	5.154	1.867	5.354	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
4:47:43	16405	99.76	37.82	38.11	49.53	784.49	49.01	-0.00	0.97	86.93	87.61	491.7	491.7
22.42	0.00	4.99	4.492	4.951	2.869	3.685	0.000	0.000	-0.000	87.61	0.00	0.00	12.01
729.6	0.0	508.7	5.154	1.867	5.358	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
4:47:45	16422	99.86	37.80	38.49	49.50	777.91	48.36	-0.00	0.96	86.89	88.47	491.7	491.7
22.42	0.00	4.99	4.492	4.952	2.842	3.654	0.000	0.000	-0.000	88.47	0.00	0.00	12.01
728.6	0.0	508.1	5.155	1.867	5.308	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
4:47:48	16397	99.71	37.81	38.11	49.51	783.40	48.65	-0.00	0.97	86.90	87.60	491.7	491.7
22.42	0.00	4.99	4.493	4.953	2.867	3.684	0.000	0.000	-0.000	87.60	0.00	0.00	12.01
729.1	0.0	508.3	5.156	1.868	5.355	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
4:47:50	16426	99.89	37.81	38.04	49.40	785.90	49.36	-0.00	0.97	86.91	87.43	491.7	491.7
22.42	0.00	4.99	4.492	4.952	2.871	3.686	0.000	0.000	-0.000	87.43	0.00	0.00	12.01
730.1	0.0	509.1	5.155	1.867	5.362	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
4:47:53	16353	99.44	37.82	38.09	49.65	781.84	49.15	-0.00	0.96	86.93	87.55	491.7	491.7
22.42	0.00	4.99	4.492	4.952	2.869	3.684	0.000	0.000	-0.000	87.55	0.00	0.00	12.01
729.9	0.0	508.8	5.155	1.867	5.358	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
4:47:56	16391	99.68	37.84	38.06	49.53	784.39	48.86	-0.00	0.97	86.97	87.48	491.7	491.7
22.41	0.00	4.99	4.491	4.951	2.871	3.688	0.000	0.000	-0.000	87.48	0.00	0.00	12.00
729.6	0.0	508.6	5.155	1.868	5.364	-0.000	0.000	0.000	0.00	0	0	0.00	0.00

AVERAGED DATA REDUCTION VALUES

4:47:57	16418	99.84	37.82	38.16	49.50	784.21	48.82	-0.00	0.97	86.93	87.72	491.7	491.7
22.42	0.00	4.99	4.492	4.951	2.866	3.682	0.000	0.000	-0.000	87.72	0.00	0.00	12.00
729.4	0.0	508.5	5.154	1.867	5.353	-0.000	0.000	0.000	0.00	0	0	0.00	0.00

Figure A-8 Overall Performance, Test No. 6, Moveable Hub 100.0 Percent Area

UNCLASSIFIED

COMPONENT TEST - CT1637 - DATE 12/ 1/83

N.A.S.A. TURBINE DATA REDUCTION POINT # 46

TIME FT1 TT1	SPEED FT3 TT3	FNHCOR FT4 TT4	WORK PR1 PR2	TORQH PR3 PRBD	TORQ WA/C WABD	FSP WAM WLAB	TUMX WAN WAR	PRAT WPU WPL	UV01 WAFT RAD	E-AB E-FR YAW	E-TORQ E-TH LOC	TREF1 E-EB BLDN	TREF2 PS2AV BLDR
3: 8:42	16428	99.90	37.56	37.79	41.23	660.43	50.98	-0.00	0.97	86.44	86.96	491.7	491.7
22.52	0.00	5.02	4.482	4.676	2.412	3.110	0.000	0.000	-0.000	86.96	0.00	0.00	11.12
730.3	0.0	510.7	4.893	2.025	4.885	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
(1 3: 8:47	16465	100.13	37.58	37.77	41.10	661.57	50.76	-0.00	0.97	86.46	86.90	491.7	491.7
22.52	0.00	5.02	4.484	4.677	2.411	3.109	0.000	0.000	-0.000	86.90	0.00	0.00	11.12
730.1	0.0	510.5	4.895	2.025	4.883	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
3: 8:50	16403	99.75	37.57	37.69	41.29	661.12	50.90	-0.00	0.97	86.44	86.71	491.7	491.7
22.52	0.00	5.02	4.485	4.677	2.418	3.118	0.000	0.000	-0.000	86.71	0.00	0.00	11.12
730.3	0.0	510.6	4.895	2.025	4.898	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
3: 8:52	16392	99.68	37.55	37.85	41.33	658.14	50.76	-0.00	0.97	86.39	87.07	491.7	491.7
22.52	0.00	5.02	4.485	4.678	2.409	3.107	0.000	0.000	-0.000	87.07	0.00	0.00	11.12
729.9	0.0	510.5	4.896	2.025	4.879	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
3: 8:55	16384	99.63	37.52	37.75	41.28	658.36	50.83	-0.00	0.97	86.31	86.84	491.7	491.7
22.52	0.00	5.02	4.486	4.679	2.411	3.111	0.000	0.000	-0.000	86.84	0.00	0.00	11.11
729.8	0.0	510.5	4.898	2.027	4.887	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
3: 8:57	16358	99.48	37.57	37.64	41.32	658.86	50.90	-0.00	0.97	86.42	86.58	491.7	491.7
22.52	0.00	5.02	4.486	4.680	2.417	3.117	0.000	0.000	-0.000	86.58	0.00	0.00	11.11
730.3	0.0	510.6	4.898	2.027	4.899	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
3: 9: 0	16397	99.71	37.55	37.54	41.18	661.54	50.76	-0.00	0.97	86.38	86.35	491.7	491.7
22.52	0.00	5.02	4.486	4.680	2.421	3.122	0.000	0.000	-0.000	86.35	0.00	0.00	11.11
729.9	0.0	510.5	4.898	2.027	4.908	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
3: 9: 1	16388	99.66	37.52	37.65	41.22	659.67	50.90	-0.00	0.97	86.30	86.59	491.7	491.7
22.52	0.00	5.02	4.486	4.679	2.415	3.115	0.000	0.000	-0.000	86.59	0.00	0.00	11.11
729.8	0.0	510.6	4.897	2.027	4.896	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
3: 9: 3	16381	99.61	37.52	37.65	41.22	659.02	50.76	-0.00	0.97	86.30	86.59	491.7	491.7
22.52	0.00	5.02	4.486	4.680	2.414	3.114	0.000	0.000	-0.000	86.59	0.00	0.00	11.10
729.6	0.0	510.5	4.899	2.028	4.897	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
3: 9: 6	16418	99.84	37.52	37.61	41.12	660.98	50.98	-0.00	0.97	86.29	86.51	491.7	491.7
22.52	0.00	5.02	4.486	4.680	2.416	3.116	0.000	0.000	-0.000	86.51	0.00	0.00	11.10
729.9	0.0	510.7	4.899	2.028	4.901	-0.000	0.000	0.000	0.00	0	0	0.00	0.00

AVERAGED DATA REDUCTION VALUES

3: 9: 8	16402	99.74	37.55	37.69	41.23	659.97	50.85	-0.00	0.97	86.37	86.71	491.7	491.7
22.52	0.00	5.02	4.485	4.679	2.414	3.114	0.000	0.000	-0.000	86.71	0.00	0.00	11.10
730.0	0.0	510.6	4.897	2.026	4.893	-0.000	0.000	0.000	0.00	0	0	0.00	0.00

Figure A-9 Overall Performance, Test No. 7, Moveable Hub 81.1 Percent Area

UNCLASSIFIED

COMPONENT TEST - CT1637 - DATE 15/ 1/83

N.A.S.A. TURBINE DATA REDUCTION POINT # 55

TIME	SPEED	PNHCOR	WORK	TORQH	TORQ	FSP	TUMX	FRAT	UV01	E-AB	E-TORQ	TREF1	TREF2
PT1	PT3	PT4	PR1	PR3	WA/C	WAM	WAN	WPU	WAFT	E-PR	E-TH	E-ER	PS2AV
TT1	TT3	TT4	PR2	PRBD	WABD	WLAB	WAR	WPL	RAD	YAW	LOC	BLDN	BLDR
4:39:49	16332	99.32	37.45	38.19	42.21	661.32	50.09	-0.00	0.96	86.11	87.82	490.7	490.7
22.49	0.00	5.01	4.488	4.777	2.429	3.134	0.000	0.000	-0.000	87.82	0.00	0.00	11.08
728.1	0.0	509.8	4.815	2.030	4.933	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
4:39:55	16332	99.31	37.38	37.52	41.52	662.13	50.52	-0.00	0.96	86.00	86.31	490.7	490.7
22.49	0.00	5.01	4.485	4.773	2.432	3.138	0.000	0.000	-0.000	86.31	0.00	0.00	11.08
728.2	0.0	510.2	4.811	2.030	4.940	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
4:39:58	16326	99.28	37.44	37.39	41.38	661.64	49.95	-0.00	0.97	86.14	86.03	490.7	490.7
22.49	0.00	5.02	4.483	4.771	2.432	3.137	0.000	0.000	-0.000	86.03	0.00	0.00	11.08
727.8	0.0	509.6	4.809	2.030	4.938	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
4:40: 0	16350	99.43	37.41	37.33	41.29	663.19	50.16	-0.00	0.97	86.09	85.91	490.7	490.7
22.49	0.00	5.02	4.482	4.769	2.434	3.140	0.000	0.000	-0.000	85.91	0.00	0.00	11.08
727.9	0.0	509.9	4.808	2.031	4.943	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
4:40: 3	16352	99.43	37.39	37.28	41.25	663.55	50.16	-0.00	0.97	86.07	85.82	490.7	490.7
22.49	0.00	5.02	4.480	4.767	2.435	3.142	0.000	0.000	-0.000	85.82	0.00	0.00	11.07
727.7	0.0	509.9	4.806	2.031	4.946	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
4:40: 4	16343	99.38	37.40	37.34	41.29	662.45	50.02	-0.00	0.97	86.10	85.98	490.7	490.7
22.49	0.00	5.02	4.478	4.765	2.432	3.138	0.000	0.000	-0.000	85.98	0.00	0.00	11.08
727.6	0.0	509.7	4.804	2.030	4.939	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
4:40: 7	16373	99.56	37.37	37.31	41.18	663.75	50.52	-0.00	0.97	86.05	85.89	490.7	490.7
22.49	0.00	5.02	4.478	4.765	2.432	3.138	0.000	0.000	-0.000	85.89	0.00	0.00	11.08
728.1	0.0	510.2	4.804	2.030	4.940	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
4:40:10	16400	99.73	37.41	37.24	41.08	665.42	50.16	-0.00	0.97	86.14	85.75	490.7	490.7
22.49	0.00	5.02	4.477	4.764	2.434	3.141	0.000	0.000	-0.000	85.75	0.00	0.00	11.08
727.9	0.0	509.9	4.803	2.030	4.944	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
4:40:12	16400	99.73	37.42	37.29	41.05	664.26	50.37	-0.00	0.97	86.19	85.87	490.7	490.7
22.49	0.00	5.02	4.476	4.763	2.430	3.135	0.000	0.000	-0.000	85.87	0.00	0.00	11.08
728.3	0.0	510.1	4.803	2.030	4.935	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
4:40:15	16377	99.59	37.42	37.23	41.12	664.35	50.02	-0.00	0.97	86.18	85.76	490.7	490.7
22.49	0.00	5.03	4.474	4.761	2.434	3.141	0.000	0.000	-0.000	85.76	0.00	0.00	11.08
727.7	0.0	509.7	4.800	2.030	4.941	-0.000	0.000	0.000	0.00	0	0	0.00	0.00

AVERAGED DATA REDUCTION VALUES

4:40:16	16358	99.48	37.41	37.41	41.34	663.20	50.20	-0.00	0.97	86.11	86.11	490.7	490.7
22.49	0.00	5.02	4.480	4.767	2.432	3.138	0.000	0.000	-0.000	86.11	0.00	0.00	11.08
727.9	0.0	509.9	4.806	2.030	4.940	-0.000	0.000	0.000	0.00	0	0	0.00	0.00

Figure A-10 Overall Performance, Test No. 8, Moveable Hub 81.1 Percent Area

UNCLASSIFIED

COMPONENT TEST - CT1637 - DATE 15/ 1/83

N.A.S.A. TURBINE DATA REDUCTION POINT # 53

TIME / PT1 / TT1	SPEED / PT3 / TT3	PNHCOR / PT4 / TT4	WORK / PR1 / PR2	TORQH / PR3 / PRBD	TORQ / WA/C / WABD	FSP / WAM / WLAB	TUMX / WAN / WAR	PRAT / WPU / WPL	UV01 / WAFT / RAD	E-AB / E-PR / YAW	E-TORQ / E-TH / LOC	TREF1 / E-EB / BLDN	TREF2 / PS2AV / BLDR
0:29:59	16396	99.70	36.61	36.95	31.79	518.76	55.80	-0.00	0.97	84.20	85.00	490.7	490.7
23.29	0.00	5.19	4.486	4.608	1.898	2.534	0.000	0.000	-0.000	85.00	0.00	0.00	10.41
729.2	0.0	515.5	4.655	2.238	4.249	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
0:30: 5	16444	100.00	36.62	37.49	32.13	519.81	55.51	-0.00	0.96	84.23	86.23	491.7	490.7
23.29	0.00	5.19	4.486	4.609	1.897	2.532	0.000	0.000	-0.000	86.23	0.00	0.00	10.40
728.9	0.0	515.2	4.655	2.239	4.248	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
0:30: 6	16435	99.94	36.68	36.84	31.66	520.55	55.73	-0.00	0.97	84.38	84.75	491.7	490.7
23.28	0.00	5.19	4.485	4.609	1.900	2.535	0.000	0.000	-0.000	84.75	0.00	0.00	10.40
729.7	0.0	515.4	4.655	2.238	4.255	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
0:30: 9	16428	99.90	36.70	37.45	32.17	520.10	55.73	-0.00	0.96	84.42	86.14	490.7	490.7
23.28	0.00	5.19	4.485	4.609	1.899	2.534	0.000	0.000	-0.000	86.14	0.00	0.00	10.40
729.8	0.0	515.4	4.656	2.238	4.253	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
0:30:12	16432	99.93	36.64	37.64	32.28	519.30	55.80	-0.00	0.96	84.28	86.59	491.7	490.7
23.28	0.00	5.19	4.486	4.610	1.896	2.530	0.000	0.000	-0.000	86.59	0.00	0.00	10.40
729.5	0.0	515.5	4.656	2.238	4.245	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
0:30:14	16432	99.93	36.66	38.23	32.73	518.59	55.73	-0.00	0.95	84.30	87.91	490.7	490.7
23.29	0.00	5.19	4.487	4.610	1.893	2.527	0.000	0.000	-0.000	87.91	0.00	0.00	10.40
729.5	0.0	515.4	4.657	2.239	4.240	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
0:30:17	16453	100.05	36.68	38.38	32.90	520.39	55.23	-0.00	0.95	84.36	88.28	491.7	490.7
23.29	0.00	5.19	4.487	4.611	1.898	2.533	0.000	0.000	-0.000	88.28	0.00	0.00	10.40
729.0	0.0	514.9	4.658	2.239	4.250	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
0:30:19	16492	100.29	36.64	37.75	32.25	521.24	55.51	-0.00	0.96	84.26	86.82	491.7	490.7
23.29	0.00	5.19	4.487	4.611	1.896	2.531	0.000	0.000	-0.000	86.82	0.00	0.00	10.40
729.0	0.0	515.2	4.658	2.239	4.217	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
0:30:22	16476	100.19	36.63	36.80	31.51	521.28	55.65	-0.00	0.97	84.24	84.62	491.7	490.7
23.29	0.00	5.19	4.488	4.611	1.898	2.534	0.000	0.000	-0.000	84.62	0.00	0.00	10.40
729.2	0.0	515.4	4.659	2.238	4.250	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
0:30:23	16462	100.11	36.61	36.79	31.44	519.47	55.66	-0.00	0.97	84.20	84.61	491.7	490.7
23.29	0.00	5.19	4.488	4.611	1.893	2.527	0.000	0.000	-0.000	84.61	0.00	0.00	10.41
729.0	0.0	515.4	4.659	2.238	4.238	-0.000	0.000	0.000	0.00	0	0	0.00	0.00

AVERAGED DATA REDUCTION VALUES

TIME / PT1 / TT1	SPEED / PT3 / TT3	PNHCOR / PT4 / TT4	WORK / PR1 / PR2	TORQH / PR3 / PRBD	TORQ / WA/C / WABD	FSP / WAM / WLAB	TUMX / WAN / WAR	PRAT / WPU / WPL	UV01 / WAFT / RAD	E-AB / E-PR / YAW	E-TORQ / E-TH / LOC	TREF1 / E-EB / BLDN	TREF2 / PS2AV / BLDR
0:30:26	16445	100.00	36.65	37.43	32.09	519.95	55.63	-0.00	0.96	84.29	86.10	490.7	490.7
23.29	0.00	5.19	4.487	4.610	1.897	2.532	0.000	0.000	-0.000	86.10	0.00	0.00	10.41
729.3	0.0	515.3	4.657	2.238	4.248	-0.000	0.000	0.000	0.00	0	0	0.00	0.00

Figure A-11 Overall Performance, Test No. 9, Moveable Hub 62.2 Percent Area

UNCLASSIFIED

COMPONENT TEST - CT1637 - DATE 15/ 1/83

N.A.S.A. TURBINE DATA REDUCTION POINT # 51

TIME PT1 TT1	SPEED PT3 TT3	PNHCOR PT4 TT4	WORK PR1 PR2	TORQH PR3 PRBD	TORQ WA/C WABD	FSP WAM WLAB	TUMX WAN WAR	PRAT WPU WPL	UV01 WAFT RAD	E-AB E-PR YAW	E-TORQ E-TH LOC	TREF1 E-ER BLDN	TREF2 PS2AV BLDR
1:53:14	16461	100.10	34.47	35.12	29.65	513.11	68.64	-0.00	0.97	79.39	80.86	490.7	490.7
23.49	0.00	5.25	4.476	4.555	1.870	2.518	0.000	0.000	-0.000	80.86	0.00	0.00	11.48
729.6	0.0	528.3	5.064	2.047	3.829	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
1:53:15	16434	99.94	34.41	34.75	29.46	513.51	68.78	-0.00	0.97	79.25	80.03	490.7	490.7
23.49	0.00	5.25	4.476	4.554	1.875	2.524	0.000	0.000	-0.000	80.03	0.00	0.00	11.48
729.3	0.0	528.5	5.064	2.047	3.838	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
1:53:18	16419	99.85	34.47	34.55	29.23	511.73	68.78	-0.00	0.97	79.37	79.55	490.7	490.7
23.49	0.00	5.25	4.476	4.554	1.870	2.517	0.000	0.000	-0.000	79.55	0.00	0.00	11.48
729.8	0.0	528.5	5.063	2.047	3.829	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
1:53:20	16419	99.84	34.41	34.42	29.17	512.53	68.78	-0.00	0.97	79.25	79.26	490.7	490.7
23.49	0.00	5.25	4.476	4.555	1.873	2.522	0.000	0.000	-0.000	79.26	0.00	0.00	11.48
729.3	0.0	528.5	5.064	2.047	3.835	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
1:53:23	16412	99.80	34.49	34.19	29.07	513.70	68.49	-0.00	0.98	79.42	78.72	490.7	490.7
23.49	0.00	5.25	4.476	4.555	1.878	2.528	0.000	0.000	-0.000	78.72	0.00	0.00	11.48
729.5	0.0	528.2	5.064	2.047	3.846	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
1:53:25	16407	99.77	34.44	34.26	29.07	512.35	68.71	-0.00	0.97	79.32	78.89	490.7	490.7
23.49	0.00	5.25	4.476	4.555	1.874	2.522	0.000	0.000	-0.000	78.89	0.00	0.00	11.48
729.5	0.0	528.4	5.064	2.047	3.837	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
1:53:28	16436	99.95	34.41	34.05	28.95	515.13	68.64	-0.00	0.98	79.24	78.41	490.7	490.7
23.49	0.00	5.25	4.476	4.555	1.880	2.532	0.000	0.000	-0.000	78.41	0.00	0.00	11.47
729.1	0.0	528.3	5.064	2.048	3.852	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
1:53:30	16442	99.98	34.47	34.16	28.93	513.44	68.64	-0.00	0.98	79.36	78.66	490.7	490.7
23.49	0.00	5.25	4.476	4.555	1.874	2.522	0.000	0.000	-0.000	78.66	0.00	0.00	11.47
729.5	0.0	528.3	5.064	2.048	3.838	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
1:53:31	16436	99.95	34.44	34.13	28.95	513.93	68.49	-0.00	0.98	79.31	78.58	490.7	490.7
23.49	0.00	5.25	4.477	4.555	1.876	2.526	0.000	0.000	-0.000	78.58	0.00	0.00	11.48
729.2	0.0	528.2	5.064	2.047	3.842	-0.000	0.000	0.000	0.00	0	0	0.00	0.00

AVERAGED DATA REDUCTION VALUES

1:53:34	16435	99.94	34.45	34.52	29.25	513.45	68.66	-0.00	0.97	79.33	79.49	490.7	490.7
23.49	0.00	5.25	4.476	4.555	1.874	2.524	0.000	0.000	-0.000	79.49	0.00	0.00	11.48
729.4	0.0	528.4	5.063	2.047	3.839	-0.000	0.000	0.000	0.00	0	0	0.00	0.00

Figure A-12 Overall Performance, Test No. 10, Moveable Hub 62.2 Percent Area

UNCLASSIFIED

COMPONENT TEST - CT1637 - DATE 28/ 2/83

N.A.S.A. TURBINE DATA REDUCTION POINT # 57

TIME	SPEED	PNHCOR	WORK	TORQH	TORQ	FSP	TUMX	PRAT	UV01	E-AB	E-TORQ	TREF1	TREF2
PT1	PT3	PT4	PR1	PR3	WA/C	WAM	WAN	WPU	WAFT	E-FR	E-TH	E-EB	FS2AV
TT1	TT3	TT4	PR2	PRBD	WABD	WLAB	WAR	WPL	RAD	YAW	LOC	BLDN	BLDR
13:21:49	16433	99.93	37.58	38.02	50.53	805.11	45.91	-0.00	0.97	86.52	87.52	490.7	491.7
21.60	0.00	4.82	4.480	5.420	2.940	3.655	0.000	0.000	-0.000	87.52	0.00	0.00	11.58
723.3	0.0	505.6	4.967	1.865	5.485	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
13:21:55	16420	99.85	37.57	35.32	46.88	802.70	45.84	-0.00	1.00	86.47	81.30	490.7	491.7
21.61	0.00	4.82	4.481	5.421	2.933	3.648	0.000	0.000	-0.000	81.30	0.00	0.00	11.58
723.1	0.0	505.5	4.968	1.866	5.474	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
13:21:57	16354	99.45	37.56	36.71	48.96	800.11	46.27	-0.00	0.98	86.44	84.49	490.7	491.7
21.61	0.00	4.82	4.481	5.421	2.935	3.649	0.000	0.000	-0.000	84.49	0.00	0.00	11.58
723.6	0.0	506.0	4.968	1.866	5.478	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
13:22: 0	16333	99.32	37.53	37.50	50.14	800.19	46.12	-0.00	0.97	86.38	86.30	490.7	491.7
21.61	0.00	4.82	4.482	5.422	2.939	3.655	0.000	0.000	-0.000	86.30	0.00	0.00	11.58
723.2	0.0	505.8	4.968	1.866	5.487	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
13:22: 2	16436	99.95	37.52	37.63	50.01	805.32	46.05	-0.00	0.97	86.37	86.61	490.7	491.7
21.61	0.00	4.82	4.481	5.422	2.940	3.657	0.000	0.000	-0.000	86.61	0.00	0.00	11.58
723.0	0.0	505.8	4.968	1.866	5.488	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
13:22: 5	16460	100.09	37.57	37.77	50.05	805.33	45.91	-0.00	0.97	86.46	86.93	490.7	491.7
21.61	0.00	4.82	4.482	5.422	2.936	3.651	0.000	0.000	-0.000	86.93	0.00	0.00	11.58
723.2	0.0	505.6	4.968	1.867	5.481	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
13:22: 6	16457	100.08	37.59	35.03	46.45	805.61	45.91	-0.00	1.01	86.52	80.62	490.7	491.7
21.61	0.00	4.82	4.482	5.422	2.937	3.652	0.000	0.000	-0.000	80.62	0.00	0.00	11.58
723.4	0.0	505.6	4.969	1.866	5.482	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
13:22: 9	16422	99.87	37.55	36.72	48.78	803.44	45.77	-0.00	0.98	86.43	84.52	490.7	491.7
21.61	0.00	4.82	4.482	5.422	2.935	3.652	0.000	0.000	-0.000	84.52	0.00	0.00	11.59
722.9	0.0	505.5	4.969	1.865	5.476	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
13:22:13	16432	99.92	37.59	37.05	49.19	804.18	45.62	-0.00	0.98	86.50	85.26	490.7	491.7
21.61	0.00	4.82	4.483	5.423	2.936	3.653	0.000	0.000	-0.000	85.26	0.00	0.00	11.57
723.0	0.0	505.3	4.970	1.865	5.478	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
13:22:14	16457	100.08	37.58	36.91	48.87	804.29	45.69	-0.00	0.98	86.47	84.94	490.7	491.7
21.62	0.00	4.82	4.484	5.424	2.932	3.649	0.000	0.000	-0.000	84.94	0.00	0.00	11.59
723.0	0.0	505.4	4.971	1.865	5.471	-0.000	0.000	0.000	0.00	0	0	0.00	0.00

AVERAGED DATA REDUCTION VALUES

13:22:17	16420	99.85	37.56	36.87	48.99	803.63	45.91	-0.00	0.98	86.46	84.85	490.7	491.7
21.61	0.00	4.82	4.482	5.422	2.936	3.652	0.000	0.000	-0.000	84.85	0.00	0.00	11.60
723.2	0.0	505.6	4.969	1.866	5.480	-0.000	0.000	0.000	0.00	0	0	0.00	0.00

Figure A-13 Overall Performance, Test No. 11, Moveable Hub 103.5 Percent Area

UNCLASSIFIED

COMPONENT TEST - CT1637 - DATE 1/ 3/83

N.A.S.A. TURBINE DATA REDUCTION POINT # 60

TIME PT1 TT1	SPEED PT3 TT3	FNHCOR PT4 TT4	WORK PR1 PR2	TORQH PR3 PRBD	TORQ WA/C WABD	FSF WAM WLAB	TUMX WAN WAR	PRAT WFU WFL	UV01 WAFT RAD	E-AB E-FR YAW	E-TORQ E-TH LOC	TREF1 E-EB BLDN	TREF2 FS2AV BLDR
9:24: 5	16463	100.12	37.38	37.55	42.35	685.56	48.97	-0.00	0.97	86.05	86.45	490.7	490.7
21.57	0.00	4.82	4.480	5.056	2.498	3.096	0.000	0.000	-0.000	86.45	0.00	0.00	10.53
726.0	0.0	508.7	4.742	2.048	5.118	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
9:24:11	16450	100.03	37.35	37.52	42.32	684.65	49.04	-0.00	0.97	85.98	86.36	490.7	490.7
21.57	0.00	4.82	4.480	5.056	2.497	3.095	0.000	0.000	-0.000	86.36	0.00	0.00	10.53
725.8	0.0	508.7	4.741	2.048	5.116	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
9:24:14	16327	99.29	37.31	37.54	42.70	680.19	49.40	-0.00	0.96	85.88	86.41	490.7	490.7
21.57	0.00	4.82	4.480	5.054	2.499	3.097	0.000	0.000	-0.000	86.41	0.00	0.00	10.53
726.0	0.0	509.1	4.741	2.048	5.121	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
9:24:16	16381	99.61	37.36	37.39	42.41	682.72	49.54	-0.00	0.97	86.01	86.07	490.7	490.7
21.57	0.00	4.82	4.480	5.054	2.501	3.097	0.000	0.000	-0.000	86.07	0.00	0.00	10.53
726.6	0.0	509.2	4.740	2.049	5.125	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
9:24:19	16532	100.53	37.41	37.51	42.10	688.18	48.90	-0.00	0.98	86.13	86.35	490.7	490.7
21.57	0.00	4.82	4.479	5.053	2.497	3.095	0.000	0.000	-0.000	86.35	0.00	0.00	10.53
726.1	0.0	508.6	4.739	2.049	5.118	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
9:24:21	16543	100.60	37.42	37.46	42.06	689.21	49.11	-0.00	0.98	86.14	86.24	490.7	490.7
21.57	0.00	4.82	4.480	5.054	2.500	3.096	0.000	0.000	-0.000	86.24	0.00	0.00	10.53
726.5	0.0	508.8	4.740	2.048	5.121	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
9:24:24	16353	99.44	37.32	37.67	42.70	679.81	49.33	-0.00	0.96	85.91	86.72	490.7	490.7
21.57	0.00	4.82	4.480	5.054	2.494	3.091	0.000	0.000	-0.000	86.72	0.00	0.00	10.54
726.0	0.0	509.0	4.741	2.046	5.106	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
9:24:25	16334	99.33	37.29	37.51	42.67	680.87	49.40	-0.00	0.96	85.84	86.34	490.7	490.7
21.57	0.00	4.82	4.480	5.055	2.501	3.100	0.000	0.000	-0.000	86.34	0.00	0.00	10.54
725.8	0.0	509.1	4.741	2.047	5.121	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
9:24:28	16379	99.60	37.27	37.35	42.43	683.62	49.53	-0.00	0.97	85.79	85.97	490.7	490.7
21.57	0.00	4.82	4.480	5.054	2.504	3.103	0.000	0.000	-0.000	85.97	0.00	0.00	10.53
726.3	0.0	509.6	4.740	2.049	5.132	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
9:24:30	16382	99.62	37.38	37.41	42.41	682.39	49.33	-0.00	0.97	86.06	86.13	490.7	490.7
21.57	0.00	4.82	4.479	5.053	2.499	3.096	0.000	0.000	-0.000	86.13	0.00	0.00	10.53
[illegible]	0.0	509.0	4.740	2.049	5.122	-0.000	0.000	0.000	0.00	0	0	0.00	0.00

AVERAGED DATA REDUCTION VALUES

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	42.4[illegible]	[illegible]	[illegible]	[illegible]	0.97	[illegible]	86.30	490.7	490.7
[illegible]	[illegible]	4.82	4.480	5.054	2.499	3.097	0.000	0.000	-0.000	86.30	0.00	0.00	10.53
[illegible]	0.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-0.000	[illegible]	[illegible]	0.00	0	[illegible]	0.00	0.00

Figure A-14 Overall Performance, Test No. 12, Moveable Hub 84.6 Percent Area

UNCLASSIFIED

COMPONENT TEST - CT1637 - DATE 1/ 3/83

N.A.S.A. TURBINE DATA REDUCTION POINT # 63

TIME FT1 TT1	SPEED FT3 TT3	FNHCOR FT4 TT4	WORK FR1 FR2	TORQH FR3 FRBD	TORQ WA,C WABD	FSP WAM WLAB	TUMX WAN WAR	FRAT WFU WPL	UVO1 WAFT RAD	E-AB E-FR YAW	E-TORQ E-TH LOC	TREF1 E-EB BLDN	TREF2 ES2AV BLDR
13:55:49	16518	100.44	36.28	36.61	32.60	544.89	61.34	-0.00	0.97	83.43	84.20	495.1	495.1
21.54	0.00	4.80	4.486	4.840	1.979	2.435	0.000	0.000	-0.000	84.20	0.00	0.00	10.26
734.2	0.0	521.0	4.592	2.099	4.156	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
13:55:54	16466	100.13	36.21	36.58	32.69	543.42	61.84	-0.00	0.97	83.28	84.14	495.1	495.1
21.54	0.00	4.80	4.486	4.840	1.980	2.436	0.000	0.000	-0.000	84.14	0.00	0.00	10.26
734.3	0.0	521.5	4.592	2.099	4.158	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
13:55:56	16443	99.99	36.25	36.64	32.73	541.72	62.13	-0.00	0.97	83.37	84.28	495.1	495.1
21.54	0.00	4.80	4.486	4.840	1.977	2.430	0.000	0.000	-0.000	84.28	0.00	0.00	10.25
735.0	0.0	521.8	4.593	2.100	4.153	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
13:55:59	16474	100.18	36.32	36.44	32.60	544.55	61.99	-0.00	0.97	83.53	83.82	495.1	495.1
21.54	0.00	4.80	4.486	4.841	1.983	2.437	0.000	0.000	-0.000	83.82	0.00	0.00	10.25
735.4	0.0	521.7	4.592	2.101	4.168	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
13:56: 1	16520	100.46	36.32	36.49	32.54	545.80	61.91	-0.00	0.97	83.54	83.93	495.1	495.1
21.53	0.00	4.80	4.485	4.840	1.982	2.436	0.000	0.000	-0.000	83.93	0.00	0.00	10.25
735.3	0.0	521.6	4.592	2.101	4.166	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
13:56: 3	16640	101.19	36.33	36.75	32.21	550.16	61.56	-0.00	0.98	83.55	83.61	495.1	495.1
21.53	0.00	4.80	4.486	4.840	1.984	2.439	0.000	0.000	-0.000	83.61	0.00	0.00	10.25
734.9	0.0	521.3	4.592	2.101	4.168	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
13:56: 5	16617	101.05	36.30	36.57	32.38	548.48	61.27	-0.00	0.98	83.48	84.11	495.1	495.1
21.53	0.00	4.80	4.486	4.840	1.980	2.436	0.000	0.000	-0.000	84.11	0.00	0.00	10.25
734.2	0.0	521.0	4.592	2.100	4.161	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
13:56: 8	16568	100.75	36.34	36.75	32.52	544.77	61.27	-0.00	0.97	83.58	84.52	495.1	495.1
21.53	0.00	4.80	4.486	4.841	1.973	2.426	0.000	0.000	-0.000	84.52	0.00	0.00	10.26
734.6	0.0	521.0	4.593	2.099	4.143	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
13:56:10	16646	101.23	36.37	36.46	32.24	549.39	61.20	-0.00	0.98	83.63	83.87	495.1	495.1
21.54	0.00	4.80	4.488	4.842	1.980	2.435	0.000	0.000	-0.000	83.87	0.00	0.00	10.26
734.7	0.0	520.9	4.593	2.099	4.158	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
13:56:13	16638	101.18	36.34	36.63	32.33	548.05	61.27	-0.00	0.98	83.56	84.22	495.1	495.1
21.54	0.00	4.80	4.488	4.842	1.976	2.431	0.000	0.000	-0.000	84.22	0.00	0.00	10.27
734.6	0.0	521.0	4.594	2.098	4.118	-0.000	0.000	0.000	0.00	0	0	0.00	0.00

AVERAGED DATA REDUCTION VALUES

13:56:15	16553	100.66	36.31	36.55	32.48	546.12	61.58	-0.00	0.98	83.50	84.07	495.1	495.1
21.54	0.00	4.80	4.488	4.841	1.979	2.434	0.000	0.000	-0.000	84.07	0.00	0.00	10.27
734.7	0.0	521.3	4.592	2.100	4.158	-0.000	0.000	0.000	0.00	0	0	0.00	0.00

Figure A-15 Overall Performance, Test No. 13, Moveable Hub 66.0 Percent Area

[redacted]SIFIED

COMPONENT TEST - CT1632 - DATE 9/ 3/83

N.A.S.A. TURBINE DATA REDUCTION POINT # [illegible]

TIME PT1 TT1	SPEED PT3 TT3	PNHCOR PT4 TT4	WORK PR1 PR2	TORQH PR3 PRRD	TORQ WA/C WABD	FSP WAM WLAB	TUMX WAN WAR	FRAT WFU WFL	HVOL WAFT RAD	E-AB E-FR YAW	E-TORQ E-TH LOC	TREF1 E-EB BLDN	TREF2 PS2AV BLDR
9:39: 7	16405	99.76	37.72	38.09	40.82	646.92	43.00	-0.00	0.97	86.76	87.60	489.8	490.7
21.57	0.00	4.81	4.488	4.944	2.366	2.943	0.000	0.000	-0.000	87.60	0.00	0.00	10.56
720.4	0.0	502.7	4.565	2.044	4.837	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
9:39:12	16431	99.92	37.72	38.33	40.88	645.82	42.64	-0.00	0.96	86.75	88.15	489.8	490.7
21.57	0.00	4.81	4.489	4.947	2.358	2.935	0.000	0.000	-0.000	88.15	0.00	0.00	10.56
719.9	0.0	502.3	4.565	2.043	4.820	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
9:39:15	16435	99.94	37.78	38.17	40.83	647.93	42.43	-0.00	0.97	86.87	87.78	489.8	490.7
21.58	0.00	4.81	4.490	4.948	2.365	2.944	0.000	0.000	-0.000	87.78	0.00	0.00	10.56
720.0	0.0	502.1	4.567	2.044	4.836	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
9:39:16	16450	100.04	37.73	38.09	40.75	649.48	42.35	-0.00	0.97	86.74	87.57	489.8	490.7
21.58	0.00	4.81	4.491	4.949	2.369	2.950	0.000	0.000	-0.000	87.57	0.00	0.00	10.56
719.5	0.0	502.1	4.569	2.044	4.842	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
9:39:19	16442	99.98	37.74	38.12	40.75	648.17	42.21	-0.00	0.97	86.75	87.63	490.2	490.2
21.59	0.00	4.81	4.492	4.949	2.365	2.947	0.000	0.000	-0.000	87.63	0.00	0.00	10.57
719.4	0.0	501.9	4.569	2.043	4.833	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
9:39:21	16392	99.68	37.75	38.83	41.57	645.22	42.42	-0.00	0.96	86.79	89.26	489.8	490.7
21.59	0.00	4.81	4.492	4.949	2.362	2.941	0.000	0.000	-0.000	89.26	0.00	0.00	10.57
719.8	0.0	502.1	4.570	2.043	4.825	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
9:39:24	16366	99.64	37.71	38.40	41.10	644.65	42.71	-0.00	0.96	86.[illegible]	88.27	489.8	490.7
21.59	0.00	4.81	4.492	4.949	2.360	2.940	0.000	0.000	-0.000	88.27	0.00	0.00	10.56
719.9	0.0	502.4	4.569	2.043	4.825	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
9:39:26	16398	99.72	37.71	38.11	40.85	646.50	42.85	-0.00	0.96	86.72	87.63	489.8	490.7
21.58	0.00	4.81	4.491	4.947	2.365	2.944	0.000	0.000	-0.000	87.63	0.00	0.00	10.56
720.1	0.0	502.6	4.567	2.043	4.834	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
9:39:29	16452	100.05	37.72	38.13	40.74	648.58	42.93	-0.00	0.97	86.73	87.68	489.8	490.7
21.58	0.00	4.81	4.491	4.948	2.365	2.944	0.000	0.000	-0.000	87.68	0.00	0.00	10.56
720.2	0.0	502.6	4.567	2.044	4.835	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
9:39:30	16507	100.38	37.76	38.12	40.51	649.42	42.71	-0.00	0.97	86.85	87.67	489.8	490.7
21.57	0.00	4.81	4.489	4.945	2.360	2.937	0.000	0.000	-0.000	87.67	0.00	0.00	10.56
720.3	0.0	502.4	4.565	2.042	4.822	-0.000	0.000	0.000	0.00	0	0	0.00	0.00

AVERAGED DATA REDUCTION VALUES

9:39:34	16430	99.91	37.74	38.24	40.88	647.27	42.63	-0.00	0.97	86.77	87.92	489.8	490.7
21.58	0.00	4.81	4.491	4.947	2.364	2.943	0.000	0.000	-0.000	87.92	0.00	0.00	10.56
720.0	0.0	502.3	4.567	2.043	4.831	-0.000	0.000	0.000	0.00	0	0	0.00	0.00

Figure A-16 Overall Performance, Test No. 14, Moveable Shroud 81.1 Percent Area

UNCLASSIFIED

COMPONENT TEST - CT1537 - DATE 9/ 3/83

N.A.S.A. TURBINE DATA REDUCTION POINT # 69

TIME	SPEED	FNHCOR	WORK	TORQH	TORQ	FSP	TUMX	PRAT	UV01	E-AB	E-TORQ	IREF1	IREF2
PT1	PT3	PT4	PR1	PR3	WA/C	WAM	WAN	WFU	WAFT	E-FR	E-TH	E-ER	PS2AV
TT1	TT3	TT4	PR2	PRBD	WABD	WLAB	WAR	WFL	RAD	YAW	LOC	BLDN	BLDR
13:56:55	16461	100.10	36.41	37.15	31.06	508.11	56.45	-0.00	0.96	83.80	85.51	490.7	490.7
21.39	-0.00	4.77	4.480	4.754	1.852	2.272	0.000	0.000	-0.000	85.51	0.00	0.00	9.81
728.4	0.0	516.1	4.411	2.180	4.039	-0.000	0.000	0.000	-0.00	0	1	0.00	0.00
13:57: 2	16466	100.13	36.44	37.14	31.05	508.41	56.33	-0.00	0.96	83.86	85.46	490.7	490.7
21.39	-0.00	4.77	4.483	4.757	1.853	2.273	0.000	0.000	-0.000	85.46	0.00	0.00	9.81
728.4	0.0	515.9	4.412	2.180	4.039	-0.000	0.000	0.000	-0.00	0	1	0.00	0.00
13:57: 4	16494	100.30	36.38	37.01	30.91	509.58	55.45	-0.00	0.97	83.71	85.17	490.7	490.7
21.40	-0.00	4.77	4.483	4.757	1.854	2.277	0.000	0.000	-0.000	85.17	0.00	0.00	9.82
726.8	0.0	515.1	4.413	2.180	4.041	-0.000	0.000	0.000	-0.00	0	1	0.00	0.00
13:57: 5	16490	100.28	36.34	37.16	31.00	508.84	56.23	-0.00	0.96	83.63	85.50	490.7	490.7
21.40	-0.00	4.77	4.483	4.757	1.851	2.273	0.000	0.000	-0.000	85.50	0.00	0.00	9.82
727.6	0.0	515.9	4.413	2.180	4.037	-0.000	0.000	0.000	-0.00	0	1	0.00	0.00
13:57: 8	16455	100.07	36.40	37.02	31.00	508.45	56.52	-0.00	0.97	83.75	85.19	490.7	490.7
21.40	-0.00	4.77	4.484	4.758	1.854	2.275	0.000	0.000	-0.000	85.19	0.00	0.00	9.82
728.5	0.0	516.2	4.413	2.180	4.042	-0.000	0.000	0.000	-0.00	0	1	0.00	0.00
13:57:10	16437	99.96	36.40	37.18	31.15	507.82	55.73	-0.00	0.96	83.76	85.54	490.7	490.7
21.40	-0.00	4.77	4.484	4.758	1.854	2.276	0.000	0.000	-0.000	85.54	0.00	0.00	9.82
727.4	0.0	515.4	4.413	2.179	4.041	-0.000	0.000	0.000	-0.00	0	1	0.00	0.00
13:57:13	16454	100.06	36.40	37.00	30.99	508.73	56.66	-0.00	0.97	83.73	85.11	490.7	490.7
21.40	-0.00	4.77	4.485	4.759	1.855	2.276	0.000	0.000	-0.000	85.11	0.00	0.00	9.82
728.7	0.0	516.4	4.413	2.180	4.045	-0.000	0.000	0.000	-0.00	0	1	0.00	0.00
13:57:15	16445	100.00	36.41	36.81	30.93	509.67	55.45	-0.00	0.97	83.78	84.70	490.7	490.7
21.40	-0.00	4.77	4.484	4.759	1.859	2.282	0.000	0.000	-0.000	84.70	0.00	0.00	9.82
728.5	0.0	516.1	4.413	2.180	4.054	-0.000	0.000	0.000	-0.00	0	1	0.00	0.00
13:57:18	16458	100.08	36.42	36.84	30.82	508.24	56.59	-0.00	0.97	83.79	84.76	490.7	490.7
21.40	-0.00	4.77	4.484	4.759	1.853	2.273	0.000	0.000	-0.000	84.76	0.00	0.00	9.82
728.7	0.0	516.3	4.413	2.180	4.040	-0.000	0.000	0.000	-0.00	0	1	0.00	0.00
13:57:20	16465	100.13	36.41	37.00	30.93	508.35	56.16	-0.00	0.97	83.77	85.12	490.7	490.7
21.40	-0.00	4.77	4.484	4.759	1.852	2.274	0.000	0.000	-0.000	85.12	0.00	0.00	9.82
728.1	0.0	515.9	4.413	2.179	4.038	-0.000	0.000	0.000	-0.00	0	1	0.00	0.00

AVERAGED DATA REDUCTION VALUES

13:57:22	16463	100.11	36.40	37.03	30.98	508.62	56.25	-0.00	0.97	83.76	85.21	490.7	490.7
21.40	-0.00	4.77	4.483	4.758	1.854	2.275	0.000	0.000	-0.000	85.21	0.00	0.00	9.82
728.1	0.0	515.9	4.413	2.180	4.042	-0.000	0.000	0.000	-0.00	0	1	0.00	0.00

Figure A-17 Overall Performance, Test No. 15, Moveable Shroud 62.5 Percent Area

COMPONENT TEST - CT1637 - DATE 15/ 3/83

N.A.S.A. TURBINE DATA REDUCTION POINT # 72

TIME PT1 TT1	SPEED PT3 TT3	ENHCOF PT4 TT4	WORK PR1 PR2	TORQH PR3 PRBD	TORQ WA/C WABD	FSP WAM WLAB	TUMX WAN WAR	FRAT WFU WFL	[illegible] WAFT RAD	F-AP E FF YAW	F TURO E-TH LOC	TREF1 E-EB BLDN	TREF2 PS2AV BLDR
9: 6:49	16412	99.80	32.19	33.47	27.37	494.03	84.46	-0.00	0.95	74.08	77.04	490.7	490.7
21.57	0.00	4.81	4.480	4.883	1.806	2.227	0.000	0.000	-0.000	77.04	0.00	0.00	12.13
732.8	0.0	544.2	4.548	1.778	3.212	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
9: 6:55	16444	100.00	32.18	34.42	27.13	478.08	83.39	-0.00	0.94	74.02	79.17	490.7	490.7
21.59	0.00	4.81	4.484	4.887	1.744	2.155	0.000	0.000	-0.000	79.17	0.00	0.00	12.13
231.3	0.0	543.1	4.552	1.779	3.104	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
9: 6:56	16453	100.05	32.13	33.21	26.83	490.53	83.39	-0.00	0.96	[illegible]	75.39	490.7	490.7
21.59	0.00	4.81	4.485	4.888	1.789	2.211	0.000	0.000	-0.000	75.39	0.00	0.00	12.13
730.9	0.0	543.1	4.552	1.779	3.184	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
9: 6:59	16428	99.90	32.15	33.70	27.40	492.07	83.96	-0.00	0.95	73.97	77.54	490.7	490.7
21.58	0.00	4.81	4.484	4.886	1.797	2.219	0.000	0.000	-0.000	77.54	0.00	0.00	12.13
731.9	0.0	543.7	4.550	1.779	3.198	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
9: 7: 1	16416	99.83	32.14	33.08	26.97	492.84	84.17	-0.00	0.96	73.93	76.11	490.7	490.7
21.58	0.00	4.81	4.484	4.886	1.801	2.224	0.000	0.000	-0.000	76.11	0.00	0.00	12.13
732.0	0.0	543.9	4.550	1.779	3.205	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
9: 7: 4	16429	99.91	32.16	32.77	26.76	494.32	84.53	-0.00	0.96	73.99	75.40	490.7	490.7
21.58	0.00	4.81	4.483	4.885	1.805	2.227	0.000	0.000	-0.000	75.40	0.00	0.00	12.13
732.7	0.0	544.2	4.549	1.778	3.211	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
9: 7: 6	16421	99.86	32.18	32.79	26.78	494.06	84.25	-0.00	0.96	74.04	75.44	490.7	490.7
21.57	0.00	4.81	4.483	4.884	1.805	2.227	0.000	0.000	-0.000	75.44	0.00	0.00	12.13
732.4	0.0	543.9	4.549	1.778	3.211	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
9: 7: 9	16458	100.08	32.18	34.18	27.77	493.64	84.46	-0.00	0.94	74.04	78.64	490.7	490.7
21.57	0.00	4.81	4.483	4.884	1.800	2.220	0.000	0.000	-0.000	78.64	0.00	0.00	12.13
732.7	0.0	544.2	4.548	1.778	3.201	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
9: 7:10	16427	99.90	32.18	32.95	26.90	494.09	84.53	-0.00	0.95	74.04	75.81	490.7	490.7
21.57	0.00	4.81	4.482	4.884	1.805	2.226	0.000	0.000	-0.000	75.81	0.00	0.00	12.13
732.8	0.0	544.2	4.548	1.778	3.210	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
9: 7:13	16394	99.69	32.21	32.82	26.85	493.23	84.25	-0.00	0.96	74.11	75.52	490.7	490.7
21.57	0.00	4.81	4.482	4.883	1.805	2.226	0.000	0.000	-0.000	75.52	0.00	0.00	12.13
732.7	0.0	543.9	4.547	1.778	3.210	-0.000	0.000	0.000	0.00	0	0	0.00	0.00

AVERAGED DATA REDUCTION VALUES

9: 7:15	16428	99.90	32.17	33.34	27.08	491.69	84.14	-0.00	0.95	74.01	76.71	490.7	490.7
21.58	0.00	4.81	4.483	4.885	1.796	2.216	0.000	0.000	-0.000	76.71	0.00	0.00	12.13
732.2	0.0	543.8	4.549	1.778	3.194	-0.000	0.000	0.000	0.00	0	0	0.00	0.00

Figure A-18 Overall Performance, Test No. 16, Moveable Shroud 62.5 Percent Area

UNCLASSIFIED

COMPONENT TEST - CT1637 - DATE 83/ 7/22

N.A.S.A. TURBINE DATA REDUCTION POINT # 3

TIME PT1 TT1	SPEED PT3 TT3	PNHCOR PT4 TT4	WORK PR1 PR2	TORQH PR3 PRBD	TORQ WA/C WABD	FSP WAM WLAB	TUMX WAN WAR	PRAT WFU WPL	UV01 WAFT RAD	E-AB E-PR YAW	E-TORQ E-TH LOC	TREF1 E-EB BLDN	TREF2 FS2AV BLDR
21:24:42	16400	99.73	36.55	0.35	0.54	922.09	49.88	0.00	9.89	84.89	0.82	491.7	491.7
21.37	0.00	4.85	4.407	6.437	3.373	4.156	0.000	0.000	0.000	0.82	0.00	0.00	12.99
720.5	0.0	509.6	6.499	1.645	5.550	0.000	0.000	0.000	0.00	0	0	0.00	0.00
21:24:47	16517	100.44	36.59	0.36	0.55	932.88	50.24	0.00	9.91	85.07	0.83	491.7	491.7
21.32	0.00	4.85	4.399	6.424	3.389	4.164	0.000	0.000	0.000	0.83	0.00	0.00	12.97
721.3	0.0	509.9	6.488	1.643	5.570	0.000	0.000	0.000	0.00	0	0	0.00	0.00
21:24:49	16609	101.00	36.66	0.37	0.55	911.83	49.17	0.00	9.79	85.18	0.87	491.7	491.7
21.35	0.00	4.85	4.404	6.431	3.294	4.057	0.000	0.000	0.000	0.87	0.00	0.00	12.99
720.4	0.0	508.9	6.498	1.643	5.415	0.000	0.000	0.000	0.00	0	0	0.00	0.00
21:24:52	16612	101.02	36.65	0.37	0.55	916.94	48.74	0.00	9.82	85.07	0.86	491.7	491.7
21.39	0.00	4.85	4.412	6.442	3.312	4.088	0.000	0.000	0.000	0.86	0.00	0.00	13.02
719.7	0.0	508.4	6.510	1.643	5.443	0.000	0.000	0.000	0.00	0	0	0.00	0.00
21:24:54	16464	100.12	36.66	0.36	0.54	928.60	49.74	0.00	9.92	85.10	0.83	491.7	491.7
21.37	0.00	4.85	4.410	6.437	3.384	4.169	0.000	0.000	0.000	0.83	0.00	0.00	13.02
721.1	0.0	509.4	6.504	1.641	5.554	0.000	0.000	0.000	0.00	0	0	0.00	0.00
21:24:57	16337	99.34	36.57	0.35	0.54	922.34	50.24	0.00	9.91	84.96	0.82	491.7	491.7
21.35	0.00	4.85	4.406	6.431	3.387	4.168	0.000	0.000	0.000	0.82	0.00	0.00	13.01
721.2	0.0	509.9	6.498	1.640	5.558	0.000	0.000	0.000	0.00	0	0	0.00	0.00
21:25: 0	16195	98.48	36.49	0.34	0.54	918.96	50.74	0.00	9.92	84.81	0.80	491.7	491.7
21.33	0.00	4.85	4.402	6.425	3.405	4.185	0.000	0.000	0.000	0.80	0.00	0.00	12.99
721.2	0.0	510.4	6.492	1.641	5.589	0.000	0.000	0.000	0.00	0	0	0.00	0.00
21:25: 2	16176	98.37	36.46	0.34	0.54	920.18	51.17	0.00	9.92	84.78	0.80	491.7	491.7
21.31	0.00	4.85	4.397	6.420	3.413	4.191	0.000	0.000	0.000	0.80	0.00	0.00	12.97
721.5	0.0	510.9	6.486	1.643	5.608	0.000	0.000	0.000	0.00	0	0	0.00	0.00
21:25: 5	16155	98.24	36.44	0.34	0.54	919.15	51.31	0.00	9.92	84.79	0.80	491.7	491.7
21.29	0.00	4.85	4.392	6.412	3.414	4.188	0.000	0.000	0.000	0.80	0.00	0.00	12.95
721.6	0.0	511.0	6.479	1.644	5.615	0.000	0.000	0.000	0.00	0	0	0.00	0.00
21:25: 7	16143	98.17	36.45	0.34	0.54	919.06	51.03	0.00	9.92	84.86	0.79	491.7	491.7
21.28	0.00	4.85	4.388	6.408	3.416	4.190	0.000	0.000	0.000	0.79	0.00	0.00	12.92
721.3	0.0	510.7	6.475	1.647	5.626	0.000	0.000	0.000	0.00	0	0	0.00	0.00

AVERAGED DATA REDUCTION VALUES

21:25:10	16361	99.49	36.55	0.35	0.54	921.20	50.23	0.00	9.89	84.95	0.82	491.7	491.7
21.34	0.00	4.85	4.402	6.427	3.379	4.156	0.000	0.000	0.000	0.82	0.00	0.00	12.91
721.0	0.0	509.9	6.493	1.643	5.553	0.000	0.000	0.000	0.00	0	0	0.00	0.00

Figure A-19 Overall Performance, Test No. 17, Moveable Shroud 125.0 Percent Area

UNCLASSIFIED

COMPONENT TEST - CT1637 - DATE 4/ 5/83

N.A.S.A. TURBINE DATA REDUCTION POINT # 80

TIME PT1 TT1	SPEED PT3 TT3	PNHCOR PT4 TT4	WORK PR1 PR2	TORQH PR3 PRBD	TORQ WA/C WABD	FSP WAM WLAB	TUMX WAN WAR	PRAT WPU WPL	UV01 WAFT RAD	E-AB E-PR YAW	E-TORQ E-TH LOC	TREF1 E-EB BLDN	TREF2 PS2AV BLDR
10:20:47	16361	99.49	38.11	38.63	49.77	773.56	38.52	-0.00	0.96	87.69	88.87	490.7	490.7
21.84	0.00	4.87	4.485	5.222	2.837	3.580	0.000	0.000	-0.000	88.87	0.00	0.00	11.54
717.2	0.0	498.2	4.768	1.892	5.370	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
10:20:53	16401	99.74	38.06	38.53	49.55	775.87	38.23	-0.00	0.96	87.57	88.66	490.7	490.7
21.84	0.00	4.87	4.485	5.223	2.838	3.584	0.000	0.000	-0.000	88.66	0.00	0.00	11.54
716.4	0.0	497.9	4.769	1.893	5.373	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
10:20:55	16422	99.86	38.10	38.57	49.57	777.48	37.94	-0.00	0.97	87.67	88.74	490.7	490.7
21.84	0.00	4.87	4.485	5.223	2.841	3.587	0.000	0.000	-0.000	88.74	0.00	0.00	11.54
716.3	0.0	497.6	4.769	1.893	5.377	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
10:20:58	16540	100.58	38.16	39.90	49.29	757.96	37.22	-0.00	0.96	87.75	91.75	490.7	490.7
21.87	0.00	4.87	4.491	5.231	2.750	3.478	0.000	0.000	-0.000	91.75	0.00	0.00	11.55
715.8	0.0	496.9	4.775	1.893	5.206	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
10:21: 0	16529	100.51	38.22	39.56	49.30	763.55	36.63	-0.00	0.96	87.85	90.93	490.7	490.7
21.88	0.00	4.87	4.494	5.234	2.772	3.510	0.000	0.000	-0.000	90.93	0.00	0.00	11.56
715.4	0.0	496.3	4.779	1.893	5.248	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
10:21: 3	16460	100.10	38.10	38.61	49.31	776.15	38.09	-0.00	0.97	87.57	88.74	490.7	490.7
21.88	0.00	4.87	4.495	5.235	2.829	3.580	0.000	0.000	-0.000	88.74	0.00	0.00	11.57
716.5	0.0	497.8	4.779	1.892	5.353	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
10:21: 4	16468	100.14	38.15	38.50	49.24	777.95	37.94	-0.00	0.97	87.70	88.51	490.7	490.7
21.88	0.00	4.87	4.493	5.233	2.834	3.585	0.000	0.000	-0.000	88.51	0.00	0.00	11.57
716.7	0.0	497.6	4.778	1.891	5.361	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
10:21: 7	16454	100.06	38.17	38.47	49.29	778.05	38.09	-0.00	0.97	87.76	88.44	490.7	490.7
21.86	0.00	4.87	4.492	5.231	2.837	3.586	0.000	0.000	-0.000	88.44	0.00	0.00	11.57
717.1	0.0	497.8	4.775	1.890	5.363	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
10:21: 9	16468	100.14	38.16	38.48	49.26	778.60	38.23	-0.00	0.97	87.73	88.49	490.7	490.7
21.86	0.00	4.87	4.491	5.229	2.837	3.584	0.000	0.000	-0.000	88.49	0.00	0.00	11.57
717.2	0.0	497.9	4.774	1.889	5.360	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
10:21:12	16516	100.44	38.18	38.44	49.08	781.32	37.94	-0.00	0.97	87.79	88.38	490.7	490.7
21.86	0.00	4.87	4.491	5.229	2.838	3.587	0.000	0.000	-0.000	88.38	0.00	0.00	11.57
717.0	0.0	497.6	4.774	1.889	5.363	-0.000	0.000	0.000	0.00	0	0	0.00	0.00

AVERAGED DATA REDUCTION VALUES

10:21:15	16462	100.11	38.14	38.77	49.36	774.05	37.88	-0.00	0.97	87.71	89.15	490.7	490.7
21.86	0.00	4.87	4.490	5.229	2.821	3.566	0.000	0.000	-0.000	89.15	0.00	0.00	11.58
716.6	0.0	497.6	4.774	1.891	5.337	-0.000	0.000	0.000	0.00	0	0	0.00	0.00

Figure A-20 Overall Performance, Test No. 18, Moveable Shroud 100.0 Percent Area

UNCLASSIFIED

COMPONENT TEST - CT1637 - DATE 3/ 5/83

N.A.S.A. TURBINE DATA REDUCTION POINT # 77

TIME PT1 TT1	SPEED PT3 TT3	PNHCOR PT4 TT4	WORK PR1 PR2	TORQH PR3 PRBD	TORQ WA/C WABD	FSP WAM WLAB	TUMX WAN WAR	PRAT WPU WPL	UV01 WAFT RAD	E-AB E-PR YAW	E-TORQ E-TH LOC	TREF1 E-EB BLDN	TREF2 PS2AV BLDR
13:42:32	16299	99.12	37.64	38.19	41.04	640.28	42.26	-0.00	0.96	86.69	87.96	490.7	490.7
22.66	0.00	5.06	4.477	4.879	2.357	3.084	0.000	0.000	-0.000	87.96	0.00	0.00	11.00
718.7	0.0	502.0	4.528	2.060	4.857	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
13:42:37	16249	98.81	37.61	38.05	41.13	640.27	42.77	-0.00	0.96	86.65	87.66	490.7	490.7
22.64	0.00	5.06	4.474	4.875	2.364	3.090	0.000	0.000	-0.000	87.66	0.00	0.00	10.99
719.1	0.0	502.5	4.524	2.060	4.873	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
13:42:39	16305	99.15	37.63	37.91	40.94	644.08	42.91	-0.00	0.96	86.72	87.38	490.7	490.7
22.63	0.00	5.06	4.470	4.873	2.370	3.095	0.000	0.000	-0.000	87.38	0.00	0.00	10.98
719.5	0.0	502.6	4.522	2.062	4.888	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
13:42:42	16369	99.54	37.67	37.91	40.76	646.13	42.48	-0.00	0.97	86.82	87.39	490.7	490.7
22.63	0.00	5.06	4.470	4.872	2.368	3.093	0.000	0.000	-0.000	87.39	0.00	0.00	10.97
719.2	0.0	502.2	4.521	2.062	4.885	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
13:42:44	16335	99.33	37.67	37.93	40.95	646.25	42.41	-0.00	0.96	86.83	87.43	490.7	490.7
22.63	0.00	5.06	4.470	4.872	2.374	3.100	0.000	0.000	-0.000	87.43	0.00	0.00	10.98
719.1	0.0	502.1	4.521	2.061	4.893	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
13:42:46	16314	99.21	37.66	37.94	40.98	644.77	42.48	-0.00	0.96	86.82	87.45	490.7	490.7
22.63	0.00	5.06	4.470	4.872	2.371	3.097	0.000	0.000	-0.000	87.45	0.00	0.00	10.98
719.2	0.0	502.2	4.521	2.061	4.888	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
13:42:49	16260	98.88	37.64	37.86	41.11	643.87	42.84	-0.00	0.96	86.77	87.29	490.7	490.7
22.62	0.00	5.06	4.469	4.870	2.376	3.101	0.000	0.000	-0.000	87.29	0.00	0.00	10.98
719.5	0.0	502.5	4.520	2.061	4.898	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
13:42:51	16340	99.37	37.66	37.84	40.82	646.01	43.05	-0.00	0.97	86.82	87.23	490.7	490.7
22.62	0.00	5.06	4.469	4.871	2.372	3.095	0.000	0.000	-0.000	87.23	0.00	0.00	10.97
720.0	0.0	502.8	4.519	2.061	4.891	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
13:42:53	16315	99.21	37.75	37.92	40.94	644.68	42.55	-0.00	0.96	87.02	87.41	490.7	490.7
22.62	0.00	5.06	4.469	4.870	2.371	3.094	0.000	0.000	-0.000	87.41	0.00	0.00	10.97
720.0	0.0	502.3	4.520	2.061	4.888	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
13:42:56	16316	99.22	37.70	37.92	40.96	645.02	42.48	-0.00	0.96	86.91	87.42	490.7	490.7
22.62	0.00	5.06	4.469	4.871	2.372	3.096	0.000	0.000	-0.000	87.42	0.00	0.00	10.97
719.5	0.0	502.2	4.520	2.061	4.891	-0.000	0.000	0.000	0.00	0	0	0.00	0.00

AVERAGED DATA REDUCTION VALUES

13:42:58	16310	99.18	37.66	37.95	40.96	644.14	42.62	-0.00	0.96	86.81	87.46	490.7	490.7
22.63	0.00	5.06	4.471	4.873	2.369	3.095	0.000	0.000	-0.000	87.46	0.00	0.00	10.98
719.4	0.0	502.3	4.521	2.061	4.885	-0.000	0.000	0.000	0.00	0	0	0.00	0.00

Figure A-21 Overall Performance, Test No. 19, Moveable Shroud
81.1 Percent Area

UNCLASSIFIED

COMPONENT TEST - CT1637 - DATE 13/ 5/83

N.A.S.A. TURBINE DATA REDUCTION POINT # 82

TIME / PT1 / TT1	SPEED / PT3 / TT3	PNHCOR / PT4 / TT4	WORK / PR1 / PR2	TORQH / PR3 / PRBD	TORQ / WA/C / WABD	FSP / WAM / WLAB	TUMX / WAN / WAR	PRAT / WPU / WPL	UVO1 / WAFT / RAD	E-AB / E-PR / YAW	E-TORQ / E-TH / LOC	TREF1 / E-EB / BLDN	TREF2 / PS2AV / BLDR
10:33:54	16506	100.37	37.69	38.44	40.57	644.91	52.27	-0.00	0.97	86.67	88.40	490.7	490.7
21.75	0.00	4.85	4.486	4.883	2.344	2.914	0.000	0.000	-0.000	88.40	0.00	0.00	10.63
733.1	0.0	512.0	4.542	2.045	4.797	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
10:33:59	16476	100.19	37.70	38.38	40.61	644.43	52.42	-0.00	0.97	86.72	88.26	490.7	490.7
21.75	0.00	4.85	4.486	4.883	2.347	2.916	0.000	0.000	-0.000	88.26	0.00	0.00	10.63
733.5	0.0	512.1	4.542	2.045	4.800	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
10:34: 2	16510	100.40	37.74	38.42	40.53	645.03	51.99	-0.00	0.97	86.82	88.37	490.7	490.7
21.74	0.00	4.85	4.485	4.882	2.344	2.913	0.000	0.000	-0.000	88.37	0.00	0.00	10.63
733.2	0.0	511.7	4.541	2.045	4.796	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
10:34: 4	16508	100.39	37.68	38.41	40.51	644.63	52.49	-0.00	0.97	86.65	88.34	490.7	490.7
21.74	0.00	4.85	4.486	4.882	2.343	2.911	0.000	0.000	-0.000	88.34	0.00	0.00	10.63
733.3	0.0	512.2	4.541	2.045	4.792	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
10:34: 8	16489	100.27	37.67	38.45	40.58	643.54	52.13	-0.00	0.97	86.66	88.45	490.7	490.7
21.74	0.00	4.85	4.485	4.882	2.342	2.910	0.000	0.000	-0.000	88.45	0.00	0.00	10.63
732.8	0.0	511.8	4.541	2.045	4.790	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
10:34:10	16472	100.17	37.65	38.50	40.60	641.86	52.70	-0.00	0.96	86.59	88.54	490.7	490.7
21.74	0.00	4.85	4.486	4.882	2.338	2.905	0.000	0.000	-0.000	88.55	0.00	0.00	10.63
733.4	0.0	512.4	4.541	2.045	4.782	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
10:34:13	16491	100.28	37.69	38.48	40.60	643.71	52.20	-0.00	0.97	86.68	88.49	490.7	490.7
21.74	0.00	4.85	4.486	4.882	2.342	2.910	0.000	0.000	-0.000	88.49	0.00	0.00	10.63
733.0	0.0	511.9	4.541	2.046	4.793	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
10:34:17	16499	100.33	37.64	38.37	40.52	644.86	52.27	-0.00	0.97	86.56	88.24	490.7	490.7
21.75	0.00	4.85	4.488	4.884	2.345	2.916	0.000	0.000	-0.000	88.24	0.00	0.00	10.63
732.8	0.0	512.0	4.543	2.046	4.800	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
10:34:19	16558	100.69	37.68	38.33	40.32	646.93	52.13	-0.00	0.97	86.65	88.15	490.7	490.7
21.75	0.00	4.85	4.488	4.884	2.344	2.914	0.000	0.000	-0.000	88.15	0.00	0.00	10.63
732.9	0.0	511.8	4.543	2.046	4.798	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
10:34:22	16538	100.57	37.64	38.31	40.47	648.02	52.06	-0.00	0.97	86.62	88.17	490.7	490.7
21.72	0.00	4.85	4.482	4.877	2.351	2.919	0.000	0.000	-0.000	88.17	0.00	0.00	10.64
732.4	0.0	511.8	4.537	2.042	4.801	-0.000	0.000	0.000	0.00	0	0	0.00	0.00

AVERAGED DATA REDUCTION VALUES

TIME / PT1 / TT1	SPEED / PT3 / TT3	PNHCOR / PT4 / TT4	WORK / PR1 / PR2	TORQH / PR3 / PRBD	TORQ / WA/C / WABD	FSP / WAM / WLAB	TUMX / WAN / WAR	PRAT / WPU / WPL	UVO1 / WAFT / RAD	E-AB / E-PR / YAW	E-TORQ / E-TH / LOC	TREF1 / E-EB / BLDN	TREF2 / PS2AV / BLDR
10:34:25	16505	100.37	37.68	38.41	40.53	644.79	52.27	-0.00	0.97	86.66	88.34	490.7	490.7
21.74	0.00	4.85	4.486	4.882	2.344	2.913	0.000	0.000	-0.000	88.34	0.00	0.00	10.64
733.1	0.0	512.0	4.541	2.045	4.795	-0.000	0.000	0.000	0.00	0	0	0.00	0.00

Figure A-22 Overall Performance, Test No. 20, Moveable Shroud 81.1 Percent Area

UNCLASSIFIED

COMPONENT TEST - CT1637 - DATE 16/ 5/83

N.A.S.A. TURBINE DATA REDUCTION POINT # 84

TIME	SPEED	PNHCOR	WORK	TORQH	TORQ	FSP	TUMX	PRAT	UV01	E-AB	E-TORQ	TREF1	TREF2
PT1	PT3	PT4	PR1	PR3	WA/C	WAM	WAN	WPU	WAFT	E-PR	E-TH	E-EB	PS2AV
TT1	TT3	TT4	PR2	PRBD	WABD	WLAB	WAR	WPL	RAD	YAW	LOC	BLDN	BLDR
10:17:25	16454	100.06	36.35	36.74	30.76	508.38	57.92	-0.00	0.97	83.75	84.65	491.7	490.7
22.32	0.00	4.99	4.472	4.686	1.854	2.370	0.000	0.000	-0.000	84.65	0.00	0.00	10.77
730.0	0.0	517.6	4.417	2.074	3.845	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
10:17:31	16464	100.12	36.23	36.68	30.59	508.80	57.99	-0.00	0.97	83.48	84.51	491.7	489.8
22.32	0.00	4.99	4.472	4.686	1.854	2.372	0.000	0.000	-0.000	84.51	0.00	0.00	10.77
729.2	0.0	517.7	4.416	2.073	3.845	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
10:17:33	16510	100.40	36.27	36.77	30.59	508.62	57.42	-0.00	0.97	83.55	84.71	491.7	490.7
22.32	0.00	4.99	4.473	4.686	1.848	2.366	0.000	0.000	-0.000	84.71	0.00	0.00	10.77
728.7	0.0	517.1	4.416	2.072	3.832	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
10:17:36	16528	100.51	36.22	36.85	30.56	508.19	57.49	-0.00	0.97	83.44	84.90	491.7	489.8
22.33	0.00	4.99	4.473	4.687	1.845	2.362	0.000	0.000	-0.000	84.90	0.00	0.00	10.77
728.4	0.0	517.2	4.417	2.072	3.823	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
10:17:38	16503	100.35	36.24	36.86	30.65	507.87	58.07	-0.00	0.97	83.48	84.92	491.7	490.7
22.33	0.00	4.99	4.473	4.687	1.846	2.363	0.000	0.000	-0.000	84.92	0.00	0.00	10.78
729.3	0.0	517.8	4.418	2.071	3.825	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
10:17:42	16499	100.33	36.25	36.76	30.63	508.71	57.56	-0.00	0.97	83.51	84.69	491.7	490.7
22.33	0.00	4.99	4.474	4.687	1.850	2.368	0.000	0.000	-0.000	84.69	0.00	0.00	10.78
728.7	0.0	517.3	4.417	2.070	3.831	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
10:17:45	16468	100.14	36.25	36.70	30.67	508.37	57.92	-0.00	0.97	83.52	84.55	491.7	489.8
22.33	0.00	4.99	4.473	4.686	1.852	2.370	0.000	0.000	-0.000	84.55	0.00	0.00	10.79
729.3	0.0	517.6	4.417	2.070	3.834	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
10:17:47	16447	100.01	36.26	36.81	30.69	505.89	57.99	-0.00	0.97	83.53	84.79	491.7	489.8
22.33	0.00	4.99	4.474	4.686	1.846	2.361	0.000	0.000	-0.000	84.79	0.00	0.00	10.79
729.4	0.0	517.7	4.418	2.070	3.821	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
10:17:50	16439	99.97	36.28	36.78	30.71	506.19	57.71	-0.00	0.97	83.58	84.73	491.7	489.8
22.32	0.00	4.99	4.473	4.686	1.847	2.364	0.000	0.000	-0.000	84.73	0.00	0.00	10.79
729.2	0.0	517.4	4.417	2.070	3.825	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
10:17:54	16470	100.15	36.29	38.18	30.74	489.81	56.99	-0.00	0.95	83.58	87.94	491.7	489.8
22.34	0.00	4.99	4.475	4.688	1.784	2.286	0.000	0.000	-0.000	87.94	0.00	0.00	10.78
728.2	0.0	516.7	4.420	2.072	3.698	-0.000	0.000	0.000	0.00	0	0	0.00	0.00

AVERAGED DATA REDUCTION VALUES

10:17:56	16478	100.21	36.27	36.91	30.67	506.08	57.71	-0.00	0.97	83.54	85.04	491.7	490.7
22.33	0.00	4.99	4.473	4.686	1.843	2.358	0.000	0.000	-0.000	85.04	0.00	0.00	10.78
729.0	0.0	517.4	4.417	2.071	3.818	-0.000	0.000	0.000	0.00	0	0	0.00	0.00

Figure A-23 Overall Performance, Test No. 21, Moveable Shroud 62.5 Percent Area

COMPONENT TEST - CT1637 - DATE 18/ 5/83

N.A.S.A. TURBINE DATA REDUCTION POINT # 86

TIME PT1 TT1	SPEED PT3 TT3	PNHCOR PT4 TT4	WORK PR1 PR2	TORQH PR3 PRBD	TORQ WA/C WABD	FSP WAM WLAB	TUMX WAN WAR	PRAT WPU WPL	UV01 WAFT RAD	E-AB E-FR YAW	E-TORQ E-TH LOC	TREF1 E-EB BLDN	TREF2 PS2AV BLDR
9: 0:45	16439	99.97	32.48	32.73	26.73	494.99	77.98	-0.00	0.97	74.76	75.34	490.7	489.8
21.97	0.00	4.90	4.481	4.770	1.807	2.279	0.000	0.000	-0.000	75.34	0.00	0.00	11.90
726.5	0.0	537.7	4.506	1.846	3.335	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
9: 0:50	16408	99.78	32.42	32.76	26.75	492.98	77.69	-0.00	0.97	74.61	75.40	490.7	489.8
21.97	0.00	4.90	4.482	4.770	1.803	2.276	0.000	0.000	-0.000	75.40	0.00	0.00	11.91
725.6	0.0	537.4	4.507	1.845	3.327	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
9: 0:52	16369	99.54	32.43	32.75	26.85	492.80	77.91	-0.00	0.96	74.64	75.37	490.7	489.8
21.97	0.00	4.90	4.482	4.769	1.806	2.280	0.000	0.000	-0.000	75.37	0.00	0.00	11.91
726.0	0.0	537.6	4.507	1.845	3.334	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
9: 0:56	16386	99.65	32.42	32.69	26.83	494.25	77.12	-0.00	0.97	74.68	75.30	490.7	489.8
21.94	0.00	4.90	4.474	4.762	1.810	2.283	0.000	0.000	-0.000	75.30	0.00	0.00	11.91
724.9	0.0	536.8	4.500	1.843	3.335	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
9: 0:59	16398	99.72	32.40	32.59	26.77	495.49	77.76	-0.00	0.97	74.62	75.05	490.7	489.8
21.95	0.00	4.90	4.477	4.764	1.813	2.287	0.000	0.000	-0.000	75.05	0.00	0.00	11.91
725.6	0.0	537.5	4.501	1.843	3.343	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
9: 1: 1	16406	99.77	32.42	32.66	26.75	494.55	77.84	-0.00	0.97	74.65	75.22	490.7	489.8
21.95	0.00	4.90	4.476	4.763	1.809	2.281	0.000	0.000	-0.000	75.22	0.00	0.00	11.91
725.8	0.0	537.5	4.500	1.843	3.334	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
9: 1: 5	16388	99.66	32.47	32.63	26.81	494.95	78.05	-0.00	0.97	74.80	75.17	490.7	489.8
21.94	0.00	4.90	4.474	4.761	1.812	2.283	0.000	0.000	-0.000	75.17	0.00	0.00	11.91
726.5	0.0	537.7	4.498	1.842	3.340	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
9: 1: 7	16398	99.71	32.45	32.62	26.77	494.96	77.55	-0.00	0.97	74.76	75.14	490.7	489.8
21.94	0.00	4.90	4.473	4.761	1.811	2.283	0.000	0.000	-0.000	75.14	0.00	0.00	11.90
725.7	0.0	537.2	4.498	1.843	3.338	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
9: 1:10	16408	99.78	32.43	32.55	26.72	495.78	77.62	-0.00	0.97	74.71	74.98	490.7	489.8
21.94	0.00	4.90	4.474	4.761	1.813	2.285	0.000	0.000	-0.000	74.98	0.00	0.00	11.90
725.6	0.0	537.3	4.498	1.843	3.342	-0.000	0.000	0.000	0.00	0	0	0.00	0.00
9: 1:14	16390	99.67	32.41	32.65	26.73	493.24	77.62	-0.00	0.97	74.58	75.14	490.7	489.8
21.99	0.00	4.90	4.483	4.770	1.806	2.281	0.000	0.000	-0.000	75.14	0.00	0.00	11.90
725.4	0.0	537.3	4.507	1.847	3.336	-0.000	0.000	0.000	0.00	0	0	0.00	0.00

AVERAGED DATA REDUCTION VALUES

TIME PT1 TT1	SPEED PT3 TT3	PNHCOR PT4 TT4	WORK PR1 PR2	TORQH PR3 PRBD	TORQ WA/C WABD	FSP WAM WLAB	TUMX WAN WAR	PRAT WPU WPL	UV01 WAFT RAD	E-AB E-FR YAW	E-TORQ E-TH LOC	TREF1 E-EB BLDN	TREF2 PS2AV BLDR
9: 1:16	16399	99.72	32.43	32.66	26.77	494.40	77.71	-0.00	0.97	74.68	75.21	490.7	489.8
21.96	0.00	4.90	4.478	4.765	1.809	2.282	0.000	0.000	-0.000	75.21	0.00	0.00	11.90
725.8	0.0	537.4	4.502	1.844	3.336	-0.000	0.000	0.000	0.00	0	0	0.00	0.00

Figure A-24 Overall Performance, Test No. 22, Moveable Shroud 62.5 Percent Area

COMPONENT TEST - CT1637 - DATE 83/ 5/27

N.A.S.A. TURBINE DATA REDUCTION POINT # 92

TIME	SPEED	PNHCOR	WORK	TORQH	TORQ	FSP	TUMX	PRAT	UV01	E-AR	E-TORQ	TREF1	TREF2
PT1	PT3	PT4	PR1	PR3	WA/C	WAM	WAN	WPU	WAFT	E-FR	E-TH	E-ER	PS2AV
TT1	TT3	TT4	PR2	PRBD	WABD	WLAB	WAR	WPL	RAD	YAW	LOC	BLDN	BLDR
11:36:57	16448	100.02	37.48	38.41	40.72	643.43	46.91	0.00	0.96	86.22	88.36	491.7	490.7
21.55	0.00	4.80	4.485	4.882	2.347	2.910	0.000	0.000	0.000	88.36	0.00	0.00	10.31
723.9	0.0	506.6	4.520	2.090	4.908	0.000	0.000	0.000	0.00	0	0	0.00	0.00
11:37: 2	16419	99.84	37.51	38.14	40.63	644.15	46.98	0.00	0.96	86.28	87.73	491.7	490.7
21.55	0.00	4.80	4.486	4.883	2.354	2.918	0.000	0.000	0.000	87.73	0.00	0.00	10.31
724.2	0.0	506.7	4.522	2.090	4.920	0.000	0.000	0.000	0.00	0	0	0.00	0.00
11:37: 5	16424	99.87	37.53	38.09	40.52	643.59	46.84	0.00	0.96	86.34	87.62	491.7	490.7
21.55	0.00	4.80	4.486	4.883	2.351	2.915	0.000	0.000	0.000	87.62	0.00	0.00	10.31
724.2	0.0	506.5	4.522	2.090	4.915	0.000	0.000	0.000	0.00	0	0	0.00	0.00
11:37: 8	16414	99.81	37.54	38.07	40.47	642.33	47.13	0.00	0.96	86.35	87.58	491.7	490.7
21.55	0.00	4.80	4.486	4.883	2.348	2.910	0.000	0.000	0.000	87.58	0.00	0.00	10.31
724.7	0.0	506.8	4.522	2.090	4.908	0.000	0.000	0.000	0.00	0	0	0.00	0.00
11:37:10	16389	99.66	37.51	38.10	40.56	641.40	46.91	0.00	0.96	86.30	87.65	491.7	490.7
21.55	0.00	4.80	4.486	4.883	2.348	2.911	0.000	0.000	0.000	87.65	0.00	0.00	10.31
724.2	0.0	506.6	4.522	2.090	4.908	0.000	0.000	0.000	0.00	0	0	0.00	0.00
11:37:13	16376	99.58	37.47	37.98	40.54	642.04	47.05	0.00	0.96	86.21	87.39	491.7	490.7
21.55	0.00	4.80	4.485	4.882	2.352	2.916	0.000	0.000	0.000	87.39	0.00	0.00	10.31
724.0	0.0	506.8	4.521	2.091	4.919	0.000	0.000	0.000	0.00	0	0	0.00	0.00
11:37:15	16420	99.85	37.51	37.94	40.39	643.89	46.91	0.00	0.97	86.31	87.28	491.7	490.7
21.55	0.00	4.80	4.485	4.882	2.353	2.916	0.000	0.000	0.000	87.28	0.00	0.00	10.31
724.2	0.0	506.6	4.521	2.090	4.920	0.000	0.000	0.000	0.00	0	0	0.00	0.00
11:37:18	16460	100.09	37.57	38.02	40.33	644.67	46.91	0.00	0.97	86.43	87.46	491.7	490.7
21.55	0.00	4.80	4.485	4.882	2.350	2.911	0.000	0.000	0.000	87.46	0.00	0.00	10.31
724.6	0.0	506.6	4.521	2.090	4.914	0.000	0.000	0.000	0.00	0	0	0.00	0.00
11:37:20	16460	100.10	37.57	38.02	40.33	644.66	47.20	0.00	0.97	86.44	87.47	491.7	490.7
21.55	0.00	4.80	4.435	4.882	2.350	2.910	0.000	0.000	0.000	87.47	0.00	0.00	10.31
725.0	0.0	506.9	4.521	2.090	4.912	0.000	0.000	0.000	0.00	0	0	0.00	0.00
11:37:21	16473	100.17	37.62	37.94	40.28	646.16	46.77	0.00	0.97	86.55	87.30	491.7	490.7
21.55	0.00	4.80	4.485	4.882	2.353	2.916	0.000	0.000	0.000	87.30	0.00	0.00	10.31
724.8	0.0	506.5	4.521	2.090	4.919	0.000	0.000	0.000	0.00	0	0	0.00	0.00

AVERAGED DATA REDUCTION VALUES

11:37:24	16428	99.90	37.53	38.07	40.48	643.63	46.96	0.00	0.96	86.34	87.58	491.7	490.7
21.55	0.00	4.80	4.485	4.882	2.351	2.913	0.000	0.000	0.000	87.58	0.00	0.00	10.32
724.4	0.0	506.7	4.521	2.090	4.914	0.000	0.000	0.000	0.00	0	0	0.00	0.00

Figure A-25 Overall Performance, Test No. 23, Moveable Shroud 81.1 Percent Area

COMPONENT TEST - CT1637 - DATE 83/ 5/27

N.A.S.A. TURBINE DATA REDUCTION POINT # 90

TIME PT1 TT1	SPEED PT3 TT3	PNHCOR PT4 TT4	WORK PR1 PR2	TORQH PR3 PRBD	TORQ WA/C WABD	FSP WAM WLAB	TUMX WAN WAR	PRAT WPU WPL	UV01 WAFT RAD	E-AB E-FR YAW	E-TORQ E-TH LOC	TREF1 E-EB BLDN	TREF2 PS2AV BLDR
8:44:41 22.13 723.0	16478 0.00 0.0	100.20 4.93 515.3	35.89 4.489 4.374	36.67 4.710 2.225	30.57 1.848 4.113	507.58 2.354 0.000	55.57 0.000 0.000	0.00 0.000 0.000	0.96 0.000 0.00	82.53 84.34 0	84.34 0.00 0	490.7 0.00 0.00	490.7 9.95 0.00
8:44:45 22.13 724.5	16461 0.00 0.0	100.10 4.93 516.0	35.94 4.489 4.375	36.66 4.711 2.225	30.57 1.847 4.110	506.74 2.350 0.000	56.28 0.000 0.000	0.00 0.000 0.000	0.96 0.000 0.00	82.65 84.31 0	84.31 0.00 0	490.7 0.00 0.00	489.8 9.95 0.00
8:44:47 22.13 723.4	16489 0.00 0.0	100.27 4.93 515.4	35.91 4.490 4.375	36.71 4.711 2.225	30.55 1.847 4.110	507.47 2.352 0.000	55.71 0.000 0.000	0.00 0.000 0.000	0.96 0.000 0.00	82.57 84.40 0	84.40 0.00 0	490.7 0.00 0.00	489.8 9.95 0.00
8:44:50 22.13 724.0	16497 0.00 0.0	100.32 4.93 515.6	35.96 4.490 4.375	36.66 4.711 2.225	30.48 1.846 4.108	507.52 2.350 0.000	55.85 0.000 0.000	0.00 0.000 0.000	0.97 0.000 0.00	82.67 84.30 0	84.30 0.00 0	490.7 0.00 0.00	490.7 9.95 0.00
8:44:52 22.13 723.8	16484 0.00 0.0	100.24 4.93 515.6	35.93 4.491 4.375	36.74 4.712 2.225	30.57 1.846 4.107	507.05 2.350 0.000	55.92 0.000 0.000	0.00 0.000 0.000	0.96 0.000 0.00	82.59 84.47 0	84.47 0.00 0	490.7 0.00 0.00	489.8 9.95 0.00
8:44:55 22.13 724.2	16439 0.00 0.0	99.97 4.93 516.1	35.90 4.492 4.375	36.66 4.712 2.225	30.59 1.846 4.108	505.80 2.350 0.000	56.35 0.000 0.000	0.00 0.000 0.000	0.96 0.000 0.00	82.52 84.27 0	84.27 0.00 0	490.7 0.00 0.00	489.8 9.95 0.00
8:44:57 22.13 724.0	16471 0.00 0.0	100.16 4.93 515.9	35.90 4.492 4.376	36.58 4.712 2.226	30.48 1.847 4.112	507.03 2.351 0.000	56.21 0.000 0.000	0.00 0.000 0.000	0.96 0.000 0.00	82.53 84.09 0	84.09 0.00 0	490.7 0.00 0.00	490.7 9.94 0.00
8:45: 0 22.13 724.0	16482 0.00 0.0	100.23 4.93 515.3	36.00 4.492 4.378	36.88 4.713 2.227	30.46 1.832 4.081	503.25 2.332 0.000	55.57 0.000 0.000	0.00 0.000 0.000	0.96 0.000 0.00	82.76 84.77 0	84.77 0.00 0	490.7 0.00 0.00	490.7 9.94 0.00
8:45: 2 22.13 723.3	16520 0.00 0.0	100.46 4.93 515.1	35.96 4.493 4.378	36.61 4.714 2.226	30.35 1.843 4.103	507.33 2.347 0.000	55.35 0.000 0.000	0.00 0.000 0.000	0.97 0.000 0.00	82.65 84.16 0	84.16 0.00 0	490.7 0.00 0.00	490.7 9.94 0.00
8:45: 5 22.13 724.0	16487 0.00 0.0	100.26 4.93 515.6	35.94 4.493 4.378	36.57 4.714 2.225	30.46 1.848 4.113	507.75 2.352 0.000	55.92 0.000 0.000	0.00 0.000 0.000	0.97 0.000 0.00	82.62 84.07 0	84.07 0.00 0	490.7 0.00 0.00	490.7 9.94 0.00

AVERAGED DATA REDUCTION VALUES

8:45: 7 22.13 723.8	16481 0.00 0.0	100.22 4.93 515.6	35.93 4.491 4.376	36.68 4.712 2.225	30.51 1.845 4.107	506.75 2.349 0.000	55.87 0.000 0.000	0.00 0.000 0.000	0.96 0.000 0.00	82.61 84.32 0	84.32 0.00 0	490.7 0.00 0.00	489.8 9.95 0.00

Figure A-26 Overall Performance, Test No. 24, Moveable Shroud 62.5 Percent Area

UNCLASSIFIED

COMPONENT TEST - CT1637 - DATE 5/83/23

N.A.S.A. TURBINE DATA REDUCTION POINT # 88

TIME PT1 TT1	SPEED PT3 TT3	PNHCOR PT4 TT4	WORK PR1 PR2	TORQH PR3 PRBD	TORQ WA/C WABD	FSP WAM WLAB	TUMX WAN WAR	PRAT WPU WPL	UV01 WAFT RAD	E-AB E-PR YAW	E-TORQ E-TH LOC	TREF1 E-EB BLDN	TREF2 PS2AV BLDR
13: 0:58	16298	99.11	31.79	33.32	27.14	485.18	85.48	0.00	0.94	73.19	76.73	493.4	492.5
22.39	0.00	5.00	4.477	4.749	1.786	2.289	0.000	0.000	0.000	76.73	0.00	0.00	11.84
731.0	0.0	545.2	3.906	1.891	3.379	0.000	0.000	0.000	0.00	0	0	0.00	0.00
13: 1: 3	16368	99.54	31.76	33.03	26.79	487.54	85.27	0.00	0.95	73.14	76.04	493.4	492.5
22.39	0.00	5.00	4.477	4.751	1.787	2.291	0.000	0.000	0.000	76.04	0.00	0.00	11.83
730.6	0.0	545.0	3.908	1.892	3.382	0.000	0.000	0.000	0.00	0	0	0.00	0.00
13: 1: 6	16413	99.81	31.85	33.05	26.71	488.29	84.77	0.00	0.95	73.34	76.10	492.5	492.5
22.39	0.00	5.00	4.477	4.752	1.785	2.288	0.000	0.000	0.000	76.10	0.00	0.00	11.83
730.6	0.0	544.5	3.909	1.892	3.378	0.000	0.000	0.000	0.00	0	0	0.00	0.00
13: 1: 8	16421	99.86	31.84	33.04	26.66	488.14	84.62	0.00	0.95	73.31	76.07	493.4	492.5
22.39	0.00	5.00	4.478	4.752	1.784	2.287	0.000	0.000	0.000	76.07	0.00	0.00	11.84
730.3	0.0	544.3	3.908	1.891	3.374	0.000	0.000	0.000	0.00	0	0	0.00	0.00
13: 1:11	16378	99.59	31.84	33.03	26.77	487.61	84.84	0.00	0.95	73.28	76.02	492.5	491.7
22.39	0.00	5.00	4.481	4.753	1.786	2.290	0.000	0.000	0.000	76.02	0.00	0.00	11.84
730.6	0.0	544.5	3.909	1.891	3.379	0.000	0.000	0.000	0.00	0	0	0.00	0.00
13: 1:14	16408	99.78	31.83	32.96	26.62	487.63	84.91	0.00	0.95	73.26	75.86	492.5	491.7
22.39	0.00	5.00	4.481	4.753	1.783	2.286	0.000	0.000	0.000	75.86	0.00	0.00	11.84
730.6	0.0	544.6	3.910	1.891	3.373	0.000	0.000	0.000	0.00	0	0	0.00	0.00
13: 1:16	16376	99.58	31.84	33.08	26.75	486.29	84.62	0.00	0.95	73.27	76.14	493.4	491.7
22.39	0.00	5.00	4.482	4.753	1.782	2.285	0.000	0.000	0.000	76.14	0.00	0.00	11.84
730.3	0.0	544.3	3.910	1.891	3.369	0.000	0.000	0.000	0.00	0	0	0.00	0.00
13: 1:19	16367	99.53	31.85	33.00	26.72	486.56	84.84	0.00	0.95	73.28	75.94	493.4	491.7
22.39	0.00	5.00	4.482	4.754	1.784	2.287	0.000	0.000	0.000	75.94	0.00	0.00	11.84
730.6	0.0	544.5	3.910	1.891	3.373	0.000	0.000	0.000	0.00	0	0	0.00	0.00
13: 1:21	16365	99.52	31.79	33.05	26.72	485.65	84.98	0.00	0.95	73.15	76.05	493.4	492.5
22.39	0.00	4.99	4.483	4.755	1.781	2.283	0.000	0.000	0.000	76.05	0.00	0.00	11.84
730.4	0.0	544.7	3.911	1.891	3.367	0.000	0.000	0.000	0.00	0	0	0.00	0.00
13: 1:24	16364	99.51	31.77	32.97	26.71	486.67	84.48	0.00	0.95	73.09	75.86	493.4	492.5
22.40	0.00	5.00	4.484	4.757	1.784	2.290	0.000	0.000	0.000	75.86	0.00	0.00	11.84
729.5	0.0	544.2	3.912	1.891	3.376	0.000	0.000	0.000	0.00	0	0	0.00	0.00

AVERAGED DATA REDUCTION VALUES

13: 1:26	16376	99.58	31.82	33.05	26.76	486.96	84.88	0.00	0.95	73.23	76.08	493.4	492.5
22.39	0.00	5.00	4.480	4.753	1.784	2.287	0.000	0.000	0.000	76.08	0.00	0.00	11.84
730.5	0.0	544.6	3.909	1.891	3.375	0.000	0.000	0.000	0.00	0	0	0.00	0.00

Figure A-27 Overall Performance, Test No. 25, Moveable Shroud
62.5 Percent Area

N.A.S.A. TURBINE DATA REDUCTION POINT # 95

TIME	SPEED	PNHCOR	WORK	TORQH	TORQ	FSP	TUMX	PRAT	UV01	E-AB	E-TORQ	TREF1	TREF2
PT1	PT3	PT4	PR1	PR3	WA/C	WAM	WAN	WPU	WAFT	E-PR	E-TH	E-EB	FS2AV
TT1	TT3	TT4	PR2	PRBD	WABD	WLAB	WAR	WPL	RAD	YAW	LOC	BLDN	BLDR
10:37:20	16444	99.99	37.33	38.75	52.57	822.73	44.56	0.00	0.96	86.08	89.37	491.7	490.7
21.70	0.00	4.86	4.466	5.432	3.002	3.760	0.000	0.000	0.000	89.37	0.00	0.00	12.18
719.3	0.0	504.3	5.027	1.782	5.350	0.000	0.000	0.000	0.00	0	0	0.00	0.00
10:37:25	16517	100.44	37.33	38.78	52.38	826.56	44.98	0.00	0.96	86.08	89.41	491.7	490.7
21.71	0.00	4.86	4.467	5.434	3.002	3.760	0.000	0.000	0.000	89.41	0.00	0.00	12.19
720.0	0.0	504.7	5.029	1.781	5.349	0.000	0.000	0.000	0.00	0	0	0.00	0.00
10:37:27	16497	100.32	37.38	38.84	52.51	825.21	44.41	0.00	0.96	86.17	89.55	491.7	490.7
21.71	0.00	4.86	4.468	5.436	3.001	3.760	0.000	0.000	0.000	89.55	0.00	0.00	12.20
719.6	0.0	504.1	5.029	1.779	5.342	0.000	0.000	0.000	0.00	0	0	0.00	0.00
10:37:30	16482	100.23	37.34	38.86	52.57	824.45	44.56	0.00	0.96	86.10	89.59	491.7	490.7
21.71	0.00	4.86	4.468	5.435	3.001	3.760	0.000	0.000	0.000	89.58	0.00	0.00	12.21
719.5	0.0	504.3	5.029	1.779	5.340	0.000	0.000	0.000	0.00	0	0	0.00	0.00
10:37:32	16465	100.12	37.32	38.86	52.64	823.69	44.84	0.00	0.96	86.04	89.58	491.7	491.7
21.71	0.00	4.86	4.469	5.434	3.002	3.760	0.000	0.000	0.000	89.58	0.00	0.00	12.21
719.7	0.0	504.5	5.029	1.778	5.339	0.000	0.000	0.000	0.00	0	0	0.00	0.00
10:37:35	16447	100.02	37.37	38.87	52.70	822.64	44.41	0.00	0.95	86.14	89.61	491.7	491.7
21.71	0.00	4.86	4.469	5.436	3.001	3.760	0.000	0.000	0.000	89.61	0.00	0.00	12.21
719.5	0.0	504.1	5.029	1.778	5.338	0.000	0.000	0.000	0.00	0	0	0.00	0.00
10:37:37	16431	99.92	37.33	38.79	52.66	822.10	44.98	0.00	0.95	66.06	89.41	491.7	490.7
21.71	0.00	4.86	4.470	5.436	3.002	3.760	0.000	0.000	0.000	89.41	0.00	0.00	12.21
720.0	0.0	504.7	5.030	1.778	5.339	0.000	0.000	0.000	0.00	0	0	0.00	0.00
10:37:40	16458	100.08	37.33	38.77	52.53	823.19	44.91	0.00	0.76	86.05	89.36	491.7	490.7
21.71	0.00	4.86	4.470	5.436	3.001	3.759	0.000	0.000	0.000	89.36	0.00	0.00	12.21
719.8	0.0	504.6	5.029	1.778	5.338	0.000	0.000	0.000	0.00	0	0	0.00	0.00
10:37:42	16431	99.92	37.29	38.80	52.66	821.92	44.91	0.00	0.95	85.97	89.44	491.7	490.7
21.71	0.00	4.86	4.469	5.436	3.001	3.760	0.000	0.000	0.000	89.44	0.00	0.00	12.21
719.6	0.0	504.6	5.029	1.779	5.339	0.000	0.000	0.000	0.00	0	0	0.00	0.00
10:37:45	16468	100.14	37.29	38.77	52.51	823.99	45.13	0.00	0.96	85.96	89.36	491.7	490.7
21.71	0.00	4.86	4.469	5.435	3.002	3.760	0.000	0.000	0.000	89.36	0.00	0.00	12.21
719.8	0.0	504.8	5.029	1.779	5.341	0.000	0.000	0.000	0.00	0	0	0.00	0.00

AVERAGED DATA REDUCTION VALUES

10:37:47	16464	100.12	37.33	38.81	52.57	823.65	44.77	0.00	0.96	86.06	89.47	491.7	490.7
21.71	0.00	4.86	4.469	5.435	3.002	3.760	0.000	0.000	0.000	89.47	0.00	0.00	12.21
719.7	0.0	504.5	5.029	1.779	5.342	0.000	0.000	0.000	0.00	0	0	0.00	0.00

Figure A-28 Overall Performance, Test No. 26, Moveable Shroud 103.5 Percent Area

UNCLASSIFIED

COMPONENT TEST - CT1637 - DATE 83/ 6/15

N.A.S.A. TURBINE DATA REDUCTION POINT # 97

TIME PT1 TT1	SPEED PT3 TT3	PNHCOR PT4 TT4	WORK PR1 PR2	TORQH PR3 PRBD	TORQ WA/C WABD	FSP WAM WLAB	TUMX WAN WAR	PRAT WPU WPL	UV01 WAFT RAD	E-AB E-PR YAW	E-TORQ E-TH LOC	TREF1 E-EB BLDN	TREF2 FS2AV BLDR
15: 4: 8	16465	100.12	37.37	38.13	45.39	723.96	46.51	0.00	0.96	85.97	87.71	492.5	491.7
21.85	0.00	4.87	4.485	5.077	2.638	3.320	0.000	0.000	0.000	87.71	0.00	0.00	11.18
722.4	0.0	506.2	4.689	1.955	5.159	0.000	0.000	0.000	0.00	0	0	0.00	0.00
15: 4:13	16460	100.10	37.34	38.15	45.48	724.46	46.93	0.00	0.96	85.91	87.79	492.5	491.7
21.85	0.00	4.87	4.484	5.076	2.641	3.322	0.000	0.000	0.000	87.79	0.00	0.00	11.17
722.8	0.0	506.6	4.688	1.956	5.166	0.000	0.000	0.000	0.00	0	0	0.00	0.00
15: 4:15	16436	99.95	37.40	38.18	45.59	723.54	46.50	0.00	0.96	86.07	87.86	492.5	491.7
21.85	0.00	4.87	4.484	5.075	2.641	3.323	0.000	0.000	0.000	87.86	0.00	0.00	11.17
722.7	0.0	506.2	4.688	1.956	5.168	0.000	0.000	0.000	0.00	0	0	0.00	0.00
15: 4:18	16539	100.57	37.49	39.47	45.47	706.69	45.90	0.00	0.95	86.24	90.81	492.5	491.7
21.86	0.00	4.87	4.486	5.077	2.564	3.227	0.000	0.000	0.000	90.81	0.00	0.00	11.17
722.6	0.0	505.6	4.690	1.957	5.019	0.000	0.000	0.000	0.00	0	0	0.00	0.00
15: 4:20	16555	100.67	37.50	39.49	45.21	703.94	45.11	0.00	0.95	86.21	90.77	492.5	491.7
21.90	0.00	4.87	4.492	5.085	2.551	3.219	0.000	0.000	0.000	90.77	0.00	0.00	11.18
721.5	0.0	504.8	4.698	1.959	4.999	0.000	0.000	0.000	0.00	0	0	0.00	0.00
15: 4:22	16571	100.77	37.38	38.24	45.02	725.17	46.43	0.00	0.97	85.91	87.89	492.5	491.7
21.90	0.00	4.87	4.494	5.086	2.626	3.312	0.000	0.000	0.000	87.89	0.00	0.00	11.19
722.4	0.0	506.1	4.700	1.958	5.142	0.000	0.000	0.000	0.00	0	0	0.00	0.00
15: 4:24	16569	100.76	37.39	38.06	45.01	728.10	46.18	0.00	0.97	85.96	87.52	492.5	491.7
21.89	0.00	4.87	4.491	5.082	2.637	3.324	0.000	0.000	0.000	87.52	0.00	0.00	11.19
722.1	0.0	505.9	4.695	1.956	5.158	0.000	0.000	0.000	0.00	0	0	0.00	0.00
15: 4:27	16593	100.90	37.44	37.99	44.87	729.22	46.29	0.00	0.97	86.10	87.38	492.5	491.7
21.89	0.00	4.88	4.489	5.081	2.637	3.323	0.000	0.000	0.000	87.38	0.00	0.00	11.20
722.7	0.0	506.0	4.693	1.955	5.155	0.000	0.000	0.000	0.00	0	0	0.00	0.00
15: 4:29	16565	100.73	37.46	38.08	44.86	725.08	46.04	0.00	0.97	86.16	87.59	492.5	491.7
21.88	0.00	4.88	4.486	5.078	2.626	3.309	0.000	0.000	0.000	87.59	0.00	0.00	11.21
722.5	0.0	505.7	4.692	1.952	5.128	0.000	0.000	0.000	0.00	0	0	0.00	0.00
15: 4:32	16520	100.46	37.43	38.15	45.08	723.30	46.43	0.00	0.97	86.11	87.76	492.5	491.7
21.88	0.00	4.88	4.486	5.077	2.627	3.309	0.000	0.000	0.000	87.76	0.00	0.00	11.21
722.8	0.0	506.1	4.691	1.952	5.128	0.000	0.000	0.000	0.00	0	0	0.00	0.00

AVERAGED DATA REDUCTION VALUES

15: 4:34	16527	100.50	37.42	38.39	45.20	721.35	46.23	0.00	0.97	86.07	88.31	492.5	491.7
21.87	0.00	4.87	4.488	5.079	2.619	3.299	0.000	0.000	0.000	88.31	0.00	0.00	11.21
722.5	0.0	505.9	4.693	1.955	5.122	0.000	0.000	0.000	0.00	0	0	0.00	0.00

Figure A-29 Overall Performance, Test No. 27, Moveable Shroud 84.6 Percent Area

COMPONENT TEST - CT1637 - DATE 83/ 6/21

N.A.S.A. TURBINE DATA REDUCTION POINT # 99

TIME PT1 TT1	SPEED PT3 TT3	PNHCOR PT4 TT4	WORK PR1 PR2	TORQH PR3 PRBD	TORQ WA/C WARD	FSP WAM WLAB	TUMX WAN WAR	PRAT WFU WFL	UV01 WAFT RAD	E-AB E-PR YAW	E-TORQ E-TH LOC	TREF1 E-EB BLDN	TREF2 PS2AV BLDR
9:30:24	16433	99.93	36.66	93.71	90.97	587.96	47.52	0.00	0.61	84.43	215.84	492.5	491.7
21.85	0.00	4.88	4.477	4.771	2.147	2.710	0.000	0.000	0.000	215.83	0.00	0.00	10.27
718.1	0.0	507.2	4.619	2.127	4.567	0.000	0.000	0.000	0.00	0	0	0.00	0.00
9:30:29	16390	99.67	36.65	93.41	90.99	586.92	47.73	0.00	0.61	84.41	215.16	492.5	491.7
21.85	0.00	4.88	4.476	4.771	2.149	2.711	0.000	0.000	0.000	215.16	0.00	0.00	10.28
718.3	0.0	507.4	4.619	2.125	4.567	0.000	0.000	0.000	0.00	0	0	0.00	0.00
9:30:32	16354	99.45	36.58	93.10	90.99	586.32	47.80	0.00	0.61	84.25	214.41	492.5	491.7
21.85	0.00	4.88	4.477	4.771	2.151	2.715	0.000	0.000	0.000	214.41	0.00	0.00	10.28
717.8	0.0	507.5	4.619	2.125	4.571	0.000	0.000	0.000	0.00	0	0	0.00	0.00
9:30:34	16367	99.53	36.65	93.10	90.99	587.27	47.88	0.00	0.61	84.41	214.41	492.5	491.7
21.85	0.00	4.88	4.477	4.772	2.153	2.716	0.000	0.000	0.000	214.41	0.00	0.00	10.28
718.5	0.0	507.6	4.619	2.125	4.576	0.000	0.000	0.000	0.00	0	0	0.00	0.00
9:30:37	16391	99.68	36.66	93.37	90.99	587.28	47.59	0.00	0.61	84.41	215.02	492.5	491.7
21.85	0.00	4.88	4.478	4.772	2.150	2.713	0.000	0.000	0.000	215.02	0.00	0.00	10.28
718.1	0.0	507.3	4.620	2.125	4.570	0.000	0.000	0.000	0.00	0	0	0.00	0.00
9:30:39	16404	99.75	36.56	93.47	90.99	587.55	47.66	0.00	0.61	84.20	215.25	492.5	491.7
21.85	0.00	4.88	4.478	4.772	2.149	2.713	0.000	0.000	0.000	215.25	0.00	0.00	10.28
717.5	0.0	507.4	4.620	2.125	4.568	0.000	0.000	0.000	0.00	0	0	0.00	0.00
9:30:42	16351	99.43	36.61	92.87	90.98	587.42	47.52	0.00	0.61	84.31	213.86	492.5	491.7
21.85	0.00	4.88	4.479	4.773	2.156	2.721	0.000	0.000	0.000	213.86	0.00	0.00	10.28
717.7	0.0	507.2	4.621	2.124	4.581	0.000	0.000	0.000	0.00	0	0	0.00	0.00
9:30:44	16358	99.47	36.59	93.41	90.96	584.47	47.52	0.00	0.61	84.24	215.05	492.5	491.7
21.85	0.00	4.88	4.480	4.774	2.144	2.707	0.000	0.000	0.000	215.05	0.00	0.00	10.28
717.5	0.0	507.2	4.622	2.126	4.559	0.000	0.000	0.000	0.00	0	0	0.00	0.00
9:30:48	16382	99.62	36.59	93.45	90.96	585.96	47.59	0.00	0.61	84.23	215.14	492.5	491.7
21.85	0.00	4.88	4.481	4.775	2.146	2.710	0.000	0.000	0.000	215.14	0.00	0.00	10.28
717.6	0.0	507.3	4.623	2.126	4.564	0.000	0.000	0.000	0.00	0	0	0.00	0.00
9:30:49	16338	99.35	36.59	92.90	90.95	586.14	47.80	0.00	0.61	84.23	213.86	492.5	491.7
21.86	0.00	4.88	4.481	4.776	2.153	2.718	0.000	0.000	0.000	213.86	0.00	0.00	10.28
717.9	0.0	507.5	4.623	2.126	4.578	0.000	0.000	0.000	0.00	0	0	0.00	0.00

AVERAGED DATA REDUCTION VALUES

TIME PT1 TT1	SPEED PT3 TT3	PNHCOR PT4 TT4	WORK PR1 PR2	TORQH PR3 PRBD	TORQ WA/C WARD	FSP WAM WLAB	TUMX WAN WAR	PRAT WFU WFL	UV01 WAFT RAD	E-AB E-PR YAW	E-TORQ E-TH LOC	TREF1 E-EB BLDN	TREF2 PS2AV BLDR
9:30:53	16377	99.59	36.61	93.28	90.98	586.73	47.66	0.00	0.61	84.31	214.80	492.5	491.7
21.85	0.00	4.88	4.478	4.773	2.150	2.713	0.000	0.000	0.000	214.80	0.00	0.00	10.28
717.9	0.0	507.4	4.621	2.125	4.570	0.000	0.000	0.000	0.00	0	0	0.00	0.00

Figure A-30 Overall Performance, Test No. 28, Moveable Shroud 66.0 Percent Area

UNCLASSIFIED

COMPONENT TEST - CT1637 - DATE 83/ 8/ 2

N.A.S.A. TURBINE DATA REDUCTION POINT # 46

TIME PT1 TT1	SPEED PT3 TT3	PNHCOR PT4 TT4	WORK PR1 PR2	TORQH PR3 PRBD	TORQ WA/C WABD	FSP WAM WLAB	TUMX WAN WAR	PRAT WPU WPL	BV01 WAFT RAD	E-AB E-PR YAW	E-TORQ E-TH LOC	TREF1 E-EB BLDN	TREF2 PB2AV BLDR
18:54: 3 22.16 723.8	16494 0.00 0.0	100.30 4.95 514.3	36.15 4.479 4.742	0.64 4.769 2.240	0.53 1.825 4.090	501.83 2.327 0.000	54.60 0.000 0.000	0.00 0.000 0.000	7.33 0.000 0.00	83.22 1.48 0	1.48 0.00 0	491.7 0.00 0.00	491.7 9.89 0.00
18:54: 8 22.16 724.2	16455 0.00 0.0	100.06 4.95 514.7	36.12 4.481 4.743	0.64 4.770 2.240	0.53 1.827 4.093	501.07 2.329 0.000	55.02 0.000 0.000	0.00 0.000 0.000	7.33 0.000 0.00	83.14 1.47 0	1.47 0.00 0	491.7 0.00 0.00	491.7 9.89 0.00
18:54:11 22.16 723.9	16408 0.00 0.0	99.78 4.95 514.5	36.12 4.481 4.743	0.66 4.770 2.240	0.55 1.827 4.093	499.67 2.329 0.000	54.81 0.000 0.000	0.00 0.000 0.000	7.18 0.000 0.00	83.14 1.52 0	1.52 0.00 0	491.7 0.00 0.00	491.7 9.89 0.00
18:54:13 22.16 723.6	16420 0.00 0.0	99.85 4.95 514.9	36.03 4.482 4.743	0.66 4.771 2.240	0.55 1.827 4.094	500.04 2.330 0.000	55.17 0.000 0.000	0.00 0.000 0.000	7.17 0.000 0.00	82.93 1.52 0	1.52 0.00 0	491.7 0.00 0.00	491.7 9.89 0.00
18:54:16 22.16 723.8	16429 0.00 0.0	99.90 4.95 514.7	36.09 4.480 4.743	0.66 4.770 2.240	0.55 1.823 4.083	499.07 2.324 0.000	54.95 0.000 0.000	0.00 0.000 0.000	7.17 0.000 0.00	83.07 1.53 0	1.53 0.00 0	491.7 0.00 0.00	491.7 9.89 0.00
18:54:19 22.16 723.9	16427 0.00 0.0	99.90 4.95 514.5	36.13 4.481 4.743	0.64 4.771 2.240	0.52 1.827 4.092	500.09 2.329 0.000	54.81 0.000 0.000	0.00 0.000 0.000	7.33 0.000 0.00	83.16 1.46 0	1.46 0.00 0	491.7 0.00 0.00	491.7 9.89 0.00
18:54:21 22.16 724.6	16435 0.00 0.0	99.94 4.95 515.0	36.12 4.481 4.743	0.64 4.771 2.240	0.53 1.828 4.097	500.82 2.330 0.000	55.31 0.000 0.000	0.00 0.000 0.000	7.33 0.000 0.00	83.15 1.46 0	1.46 0.00 0	491.7 0.00 0.00	491.7 9.89 0.00
18:54:24 22.16 724.2	16490 0.00 0.0	100.27 4.95 514.5	36.17 4.481 4.744	0.64 4.771 2.240	0.53 1.830 4.100	502.84 2.332 0.000	54.81 0.000 0.000	0.00 0.000 0.000	7.34 0.000 0.00	83.24 1.47 0	1.47 0.00 0	491.7 0.00 0.00	491.7 9.89 0.00
18:54:26 22.16 724.7	16469 0.00 0.0	100.15 4.95 514.9	36.15 4.481 4.744	0.64 4.771 2.240	0.53 1.827 4.095	501.60 2.329 0.000	55.24 0.000 0.000	0.00 0.000 0.000	7.33 0.000 0.00	83.22 1.47 0	1.47 0.00 0	491.7 0.00 0.00	491.7 9.89 0.00
18:54:29 22.16 724.6	16470 0.00 0.0	100.15 4.95 514.7	36.18 4.481 4.743	0.66 4.771 2.239	0.55 1.828 4.095	501.90 2.330 0.000	55.02 0.000 0.000	0.00 0.000 0.000	7.19 0.000 0.00	83.28 1.53 0	1.53 0.00 0	491.7 0.00 0.00	491.7 9.90 0.00

AVERAGED DATA REDUCTION VALUES

TIME PT1 TT1	SPEED PT3 TT3	PNHCOR PT4 TT4	WORK PR1 PR2	TORQH PR3 PRBD	TORQ WA/C WABD	FSP WAM WLAB	TUMX WAN WAR	PRAT WPU WPL	BV01 WAFT RAD	E-AB E-PR YAW	E-TORQ E-TH LOC	TREF1 E-EB BLDN	TREF2 PB2AV BLDR
18:54:31 22.16 724.1	16450 0.00 0.0	100.03 4.95 514.7	36.13 4.481 4.743	0.65 4.771 2.240	0.53 1.827 4.093	500.89 2.329 0.000	54.97 0.000 0.000	0.00 0.000 0.000	7.27 0.000 0.00	83.16 1.49 0	1.49 0.00 0	491.7 0.00 0.00	491.7 9.90 0.00

Figure A-31 Overall Performance, Test No. 29, Moveable Shroud 62.2 Percent Area

APPENDIX B

ROTOR EXIT MIXED OUT PLANE SURVEY DATA

Swirl Angle
Total Pressure
Total Temperature
Streamline Efficiency
Local to Critical Velocity Ratio

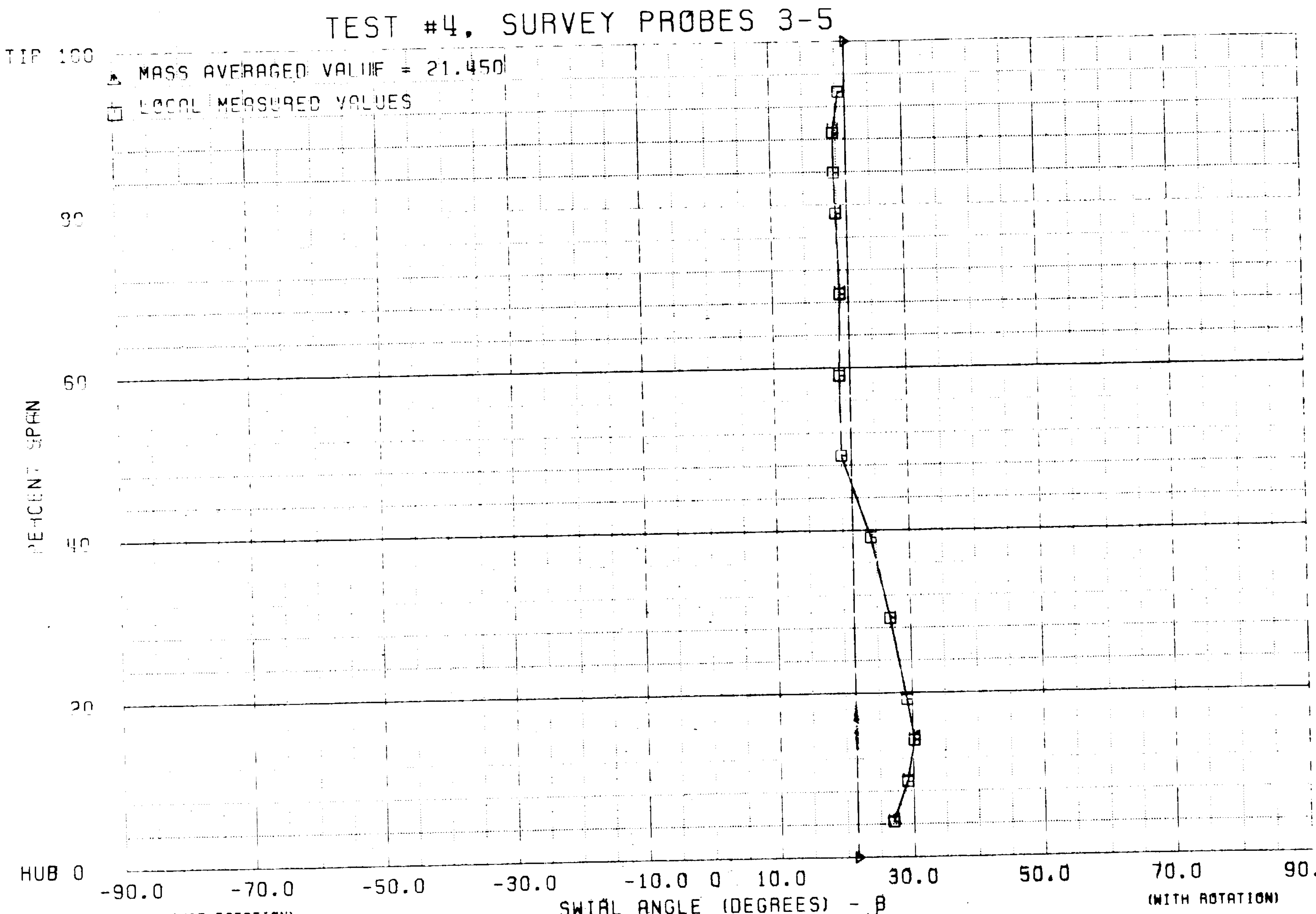

Figure B-1 Mixed Out Plane Survey - Swirl Angle vs. Percent Rotor Exit Span, Test No. 4, Moveable Hub 62.2 Percent Area

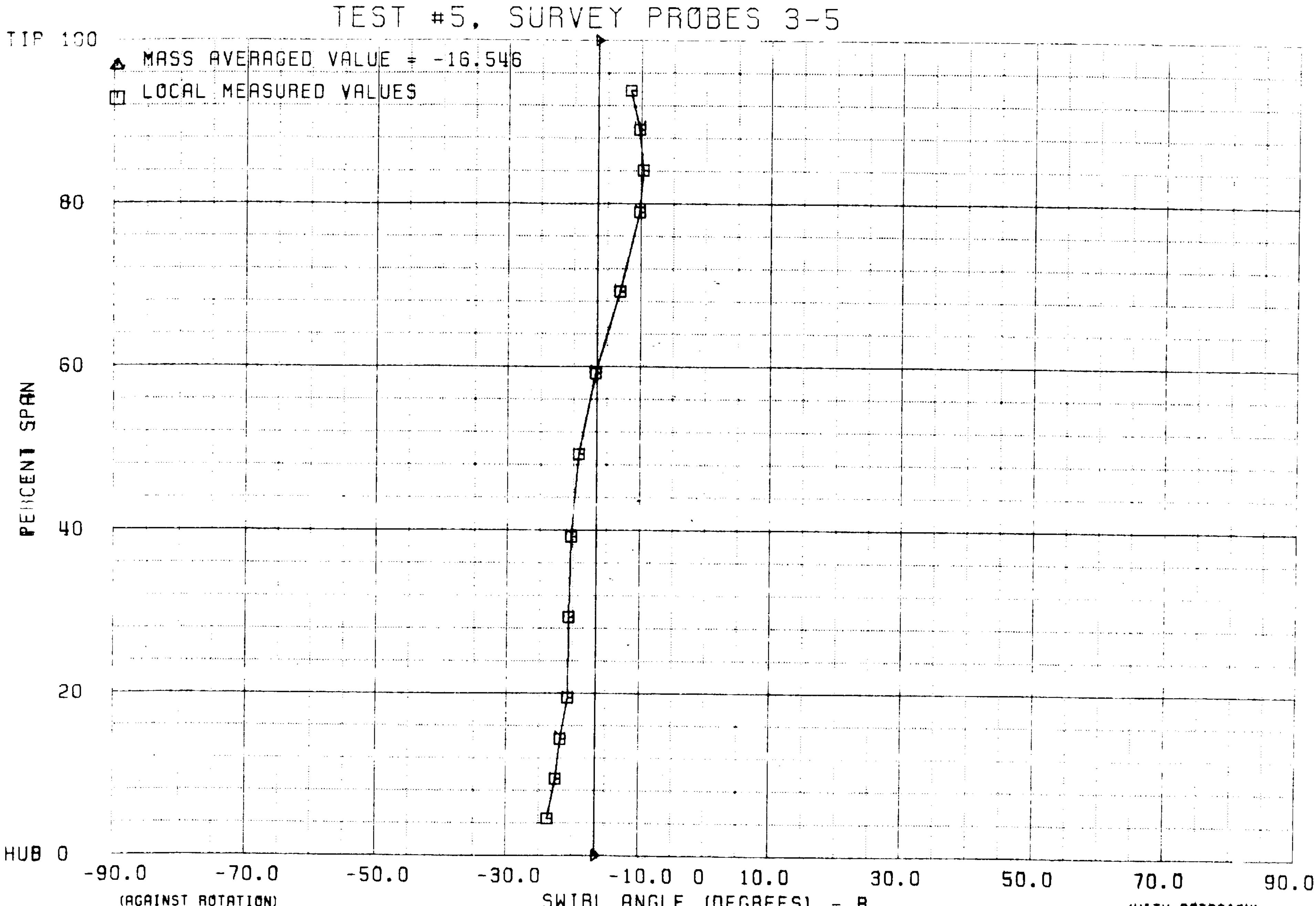

Figure B-2 Mixed Out Plane Survey - Swirl Angle vs. Percent Rotor Exit Span Test No. 5, Moveable Hub, 108.8 Percent Area

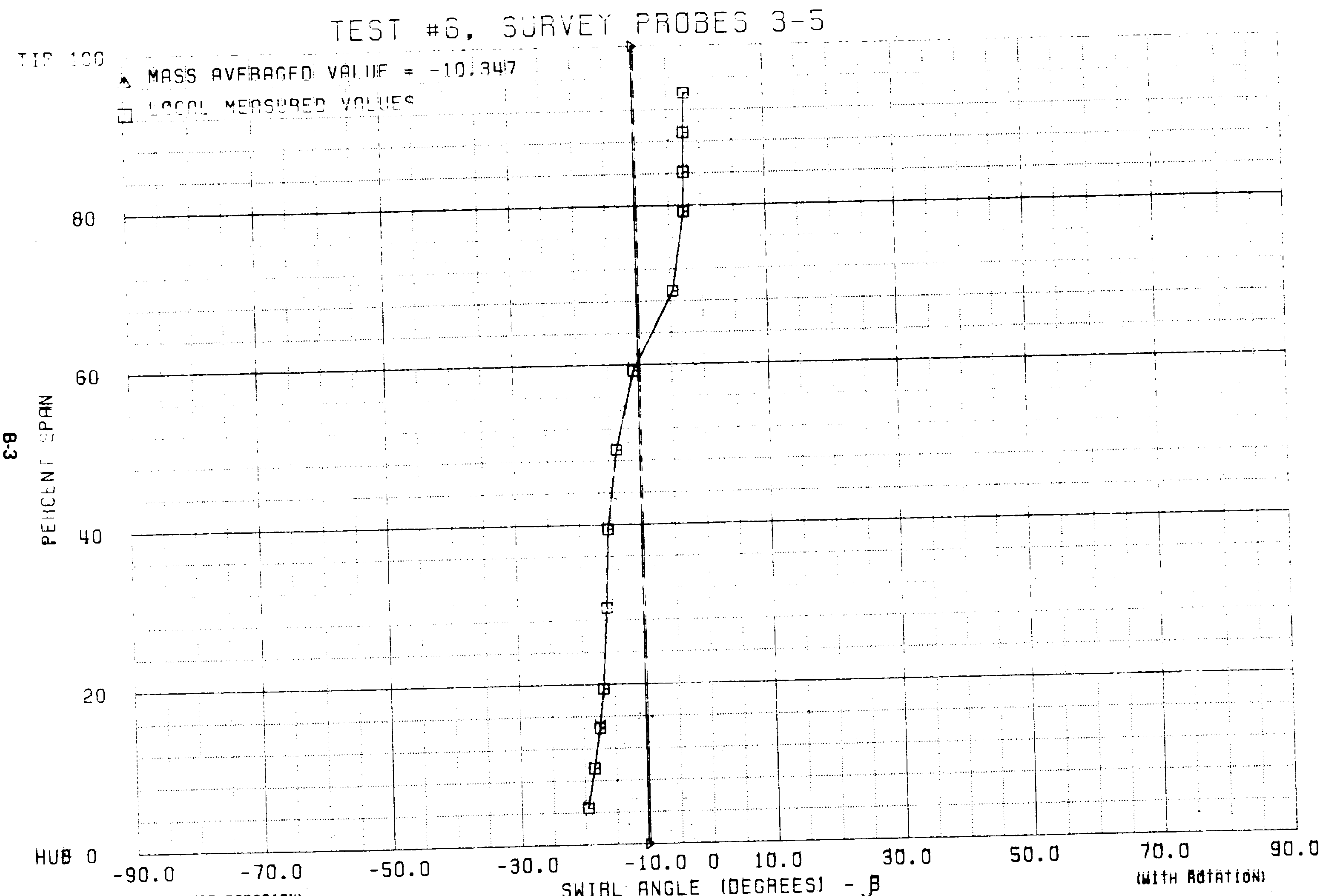

Figure B-3 Mixed Out Plane Survey - Swirl Angle vs. Percent Rotor Exit Span, Test No. 6, Moveable Hub, 100.0 Percent Area

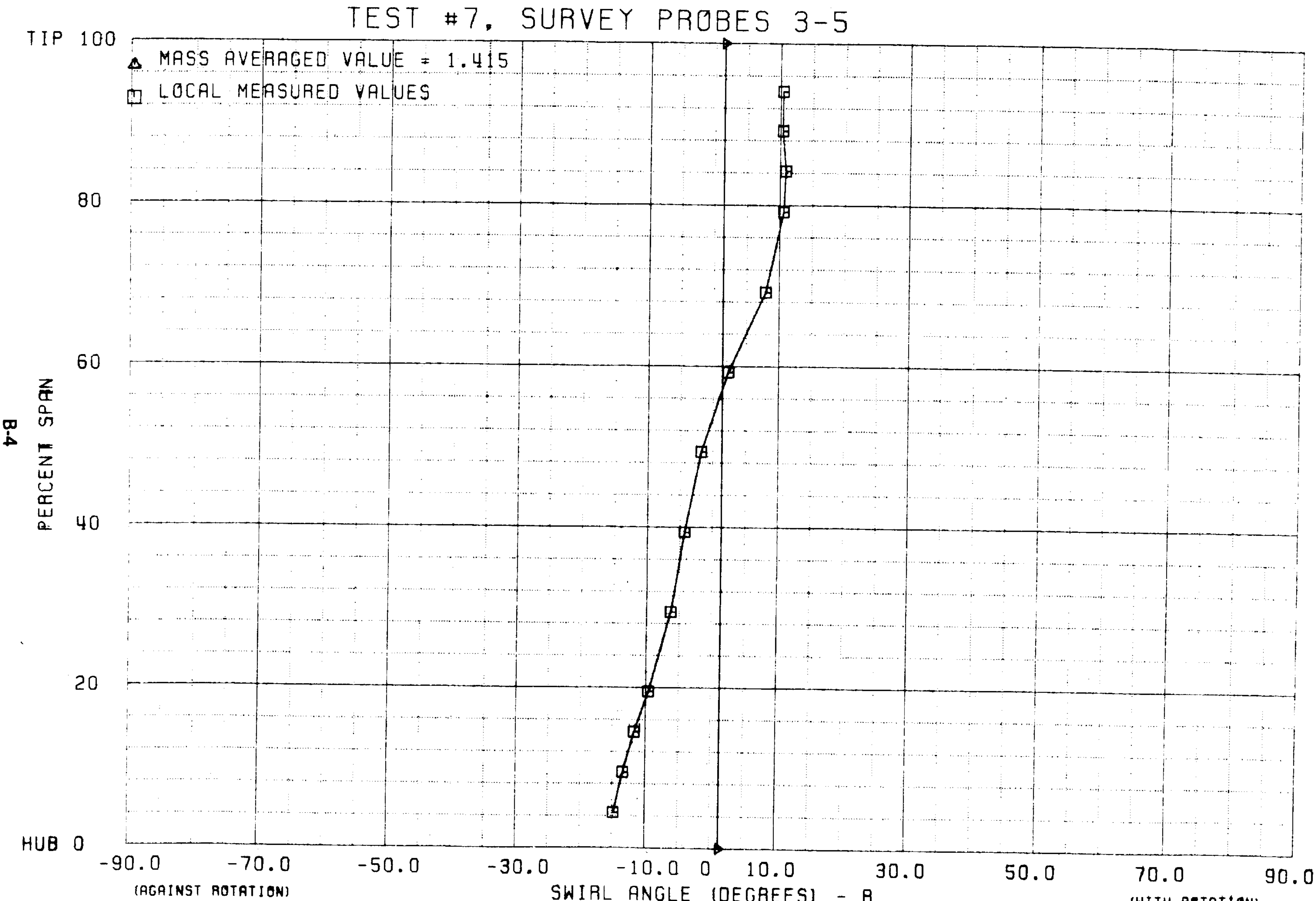

Figure B-4 Mixed Out Plane Survey - Swirl Angle vs. Percent Rotor Exit Span, Test No. 7, Moveable Hub, 81.1 Percent Area

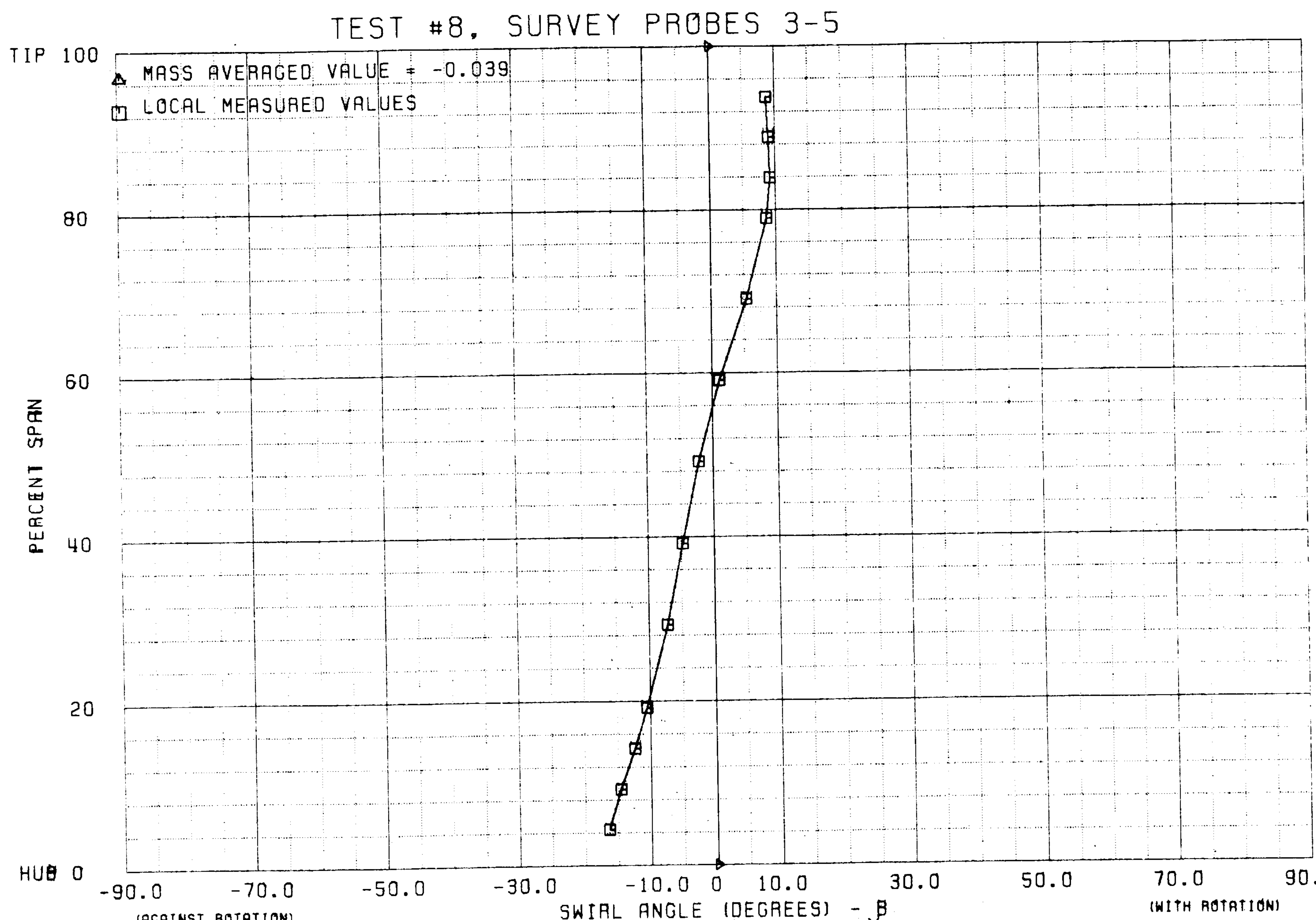

Figure B-5 Mixed Out Plane Survey - Swirl Angle vs. Percent Rotor Exit Span, Test No. 8, Moveable Hub, 81.1 Percent Area

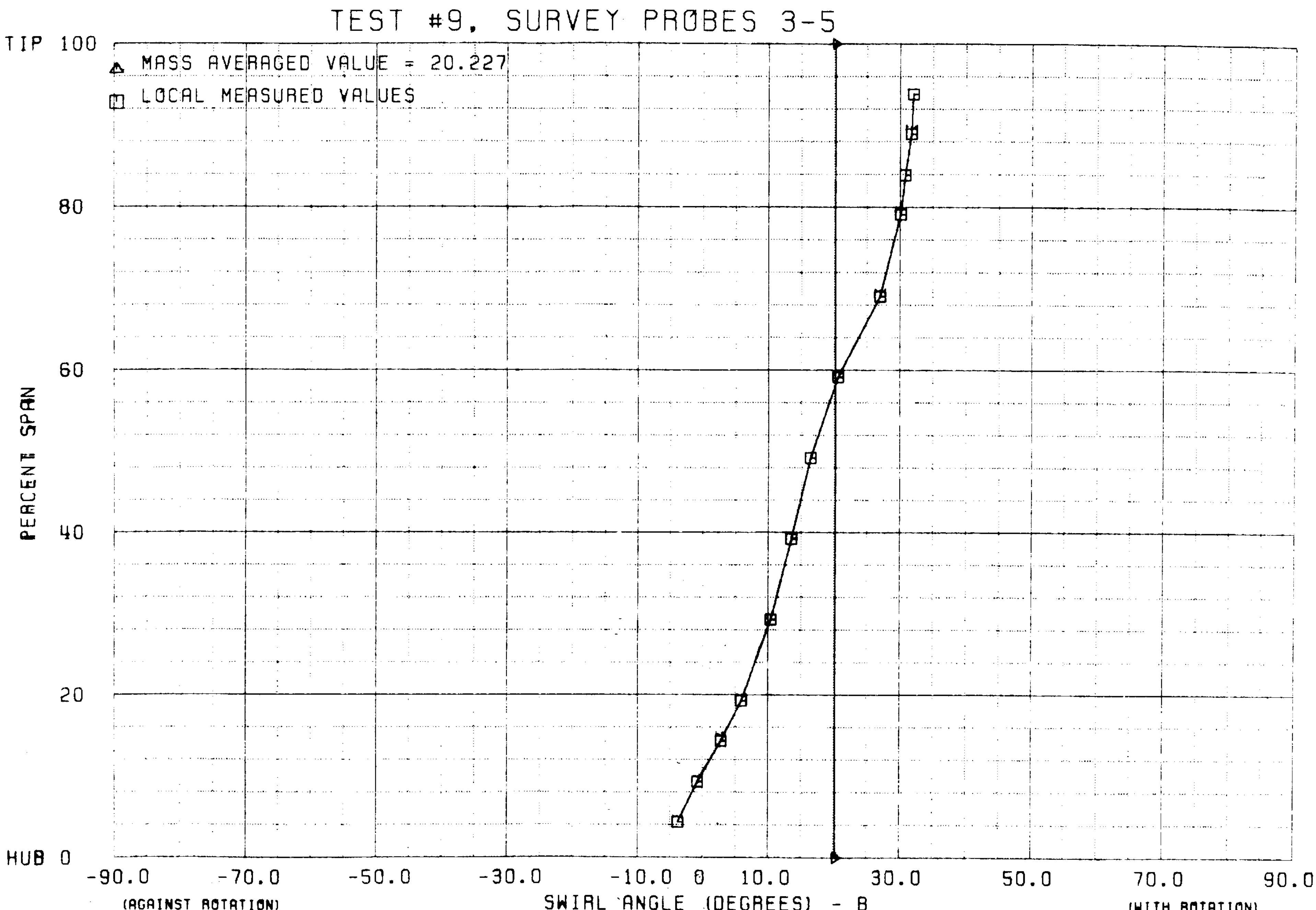

Figure B-6 Mixed Out Plane Survey - Swirl Angle vs. Percent Rotor Exit Span, Test No. 9, Moveable Hub, 62.2 Percent Area

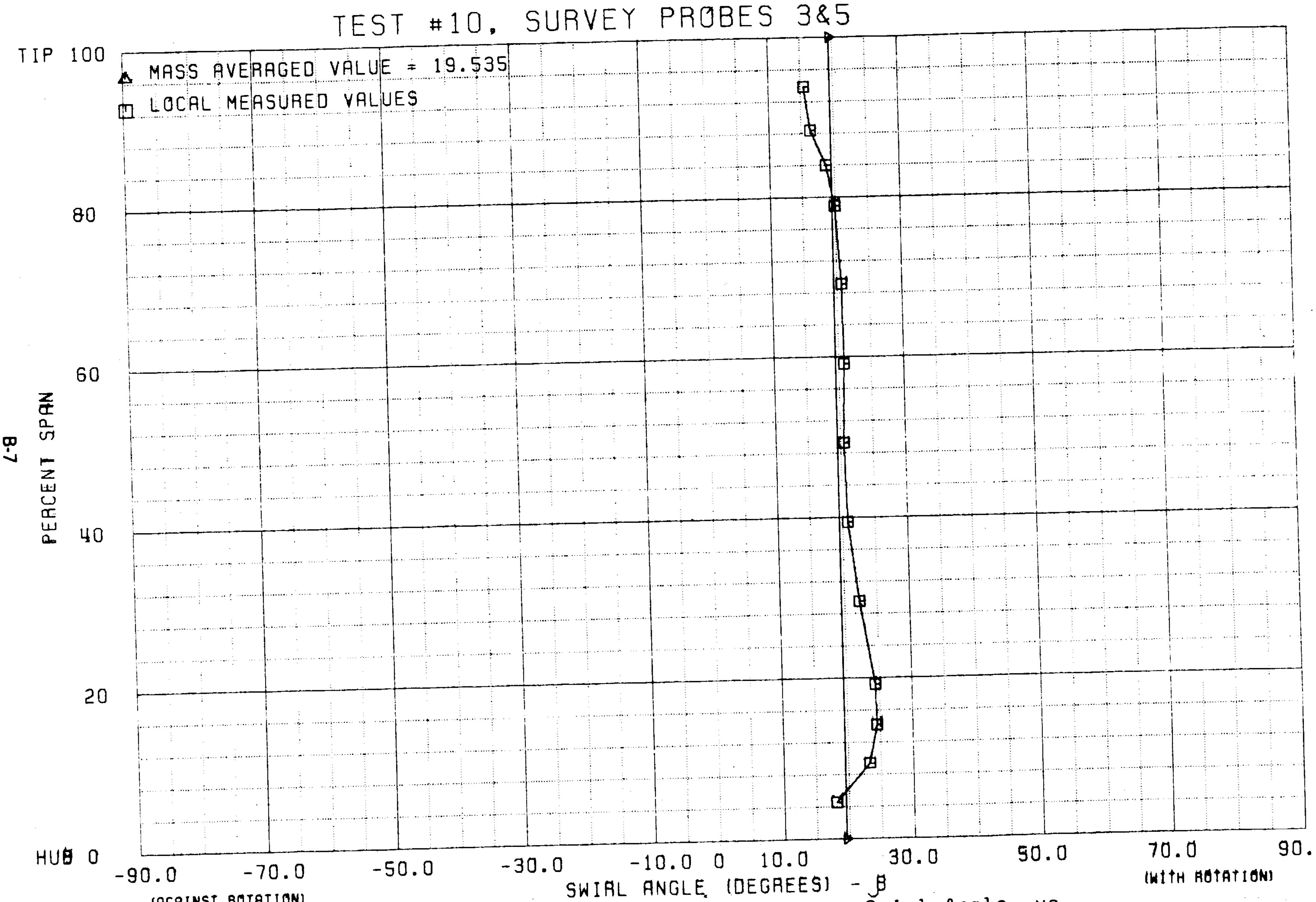

Figure B-7 Mixed Out Plane Survey - Swirl Angle vs. Percent Rotor Exit Span, Test No. 10, Moveable Hub, 62.2 Percent Area

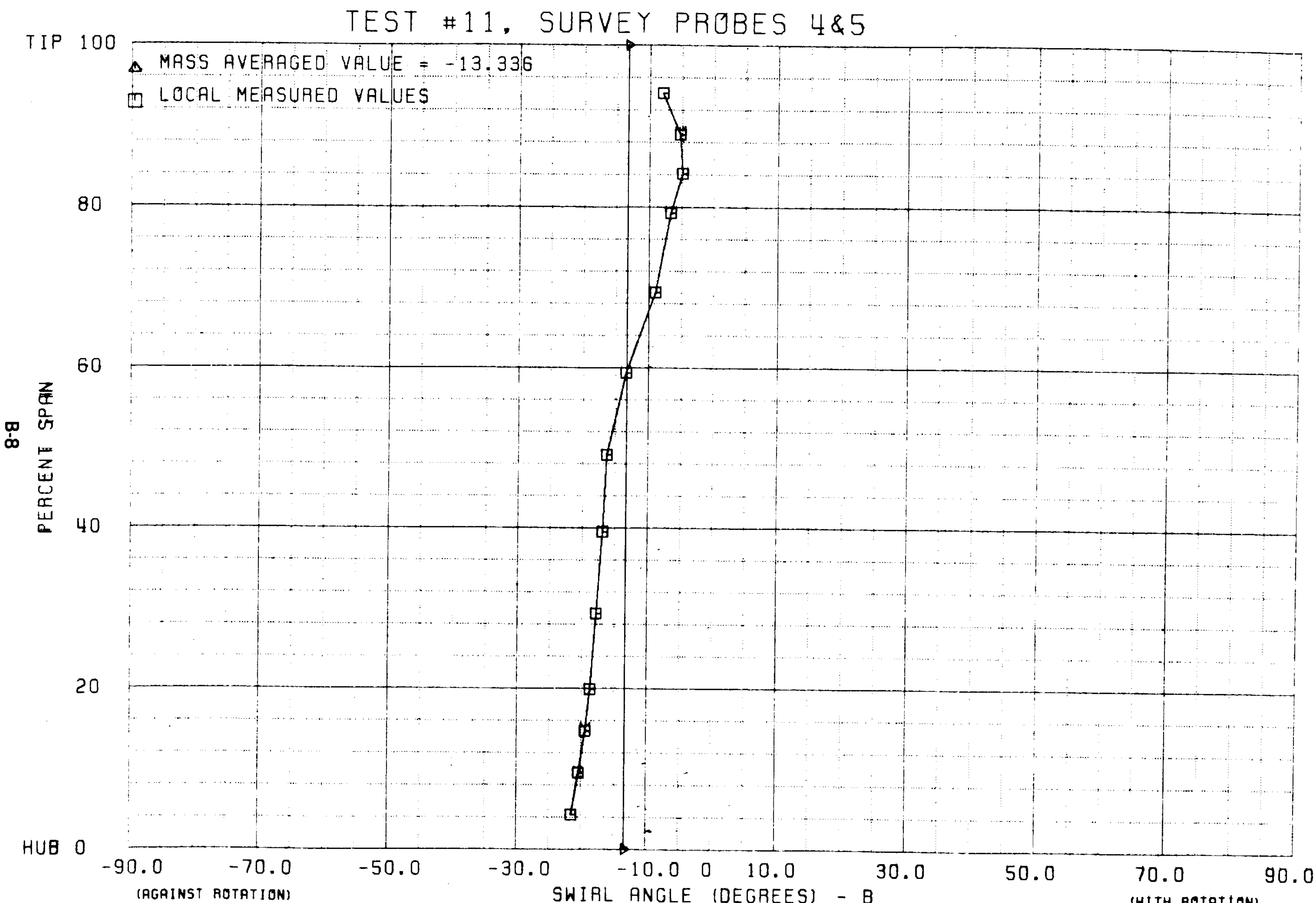

Figure B-8 Mixed Out Plane Survey - Swirl Angle vs. Percent Rotor Exit Span, Test No. 11, Moveable Hub, 103.5 Percent Area

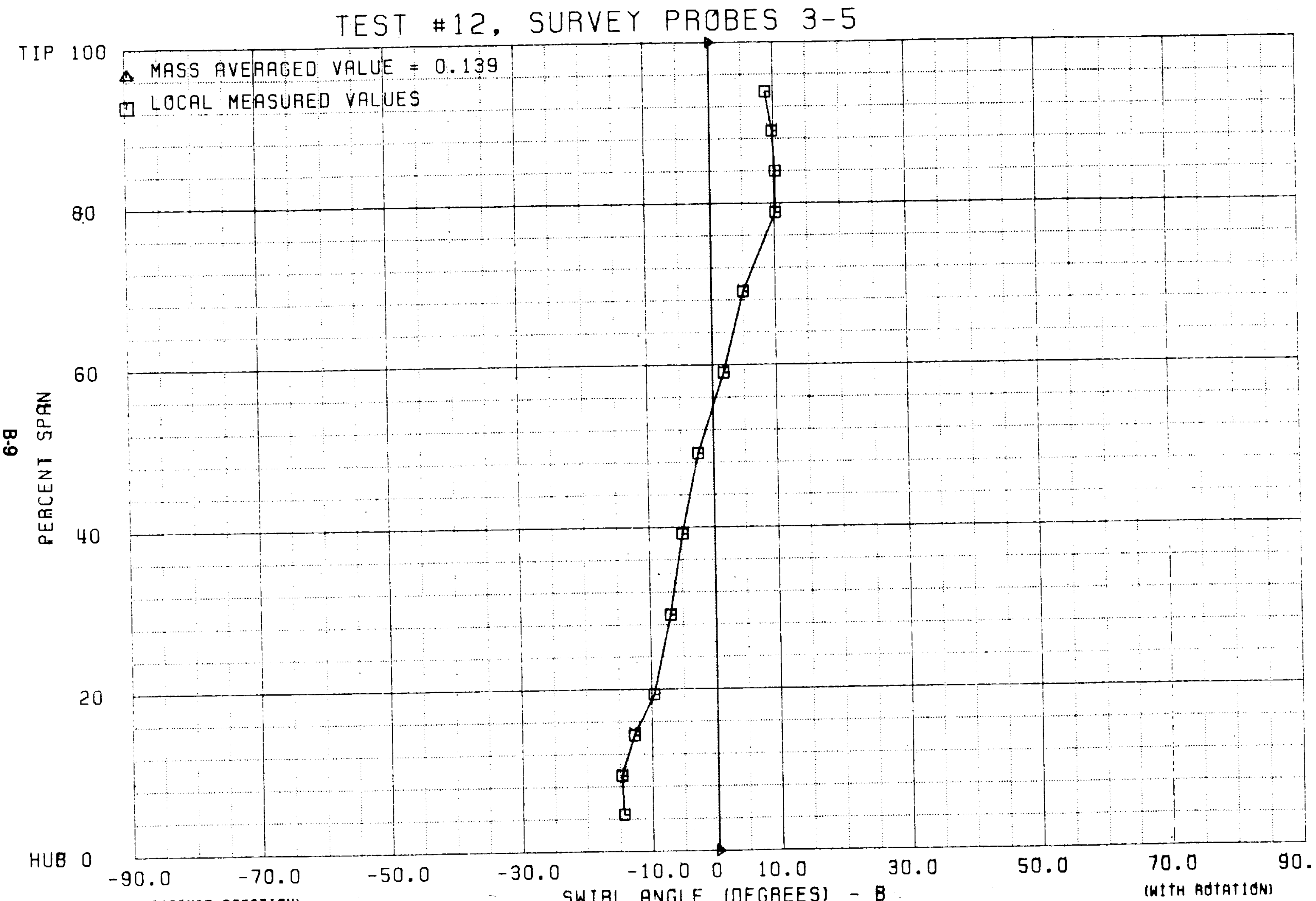

Figure B-9 Mixed Out Plane Survey - Swirl Angle vs. Percent Rotor Exit Span, Test No. 12, Moveable Hub, 84.6 Percent Area

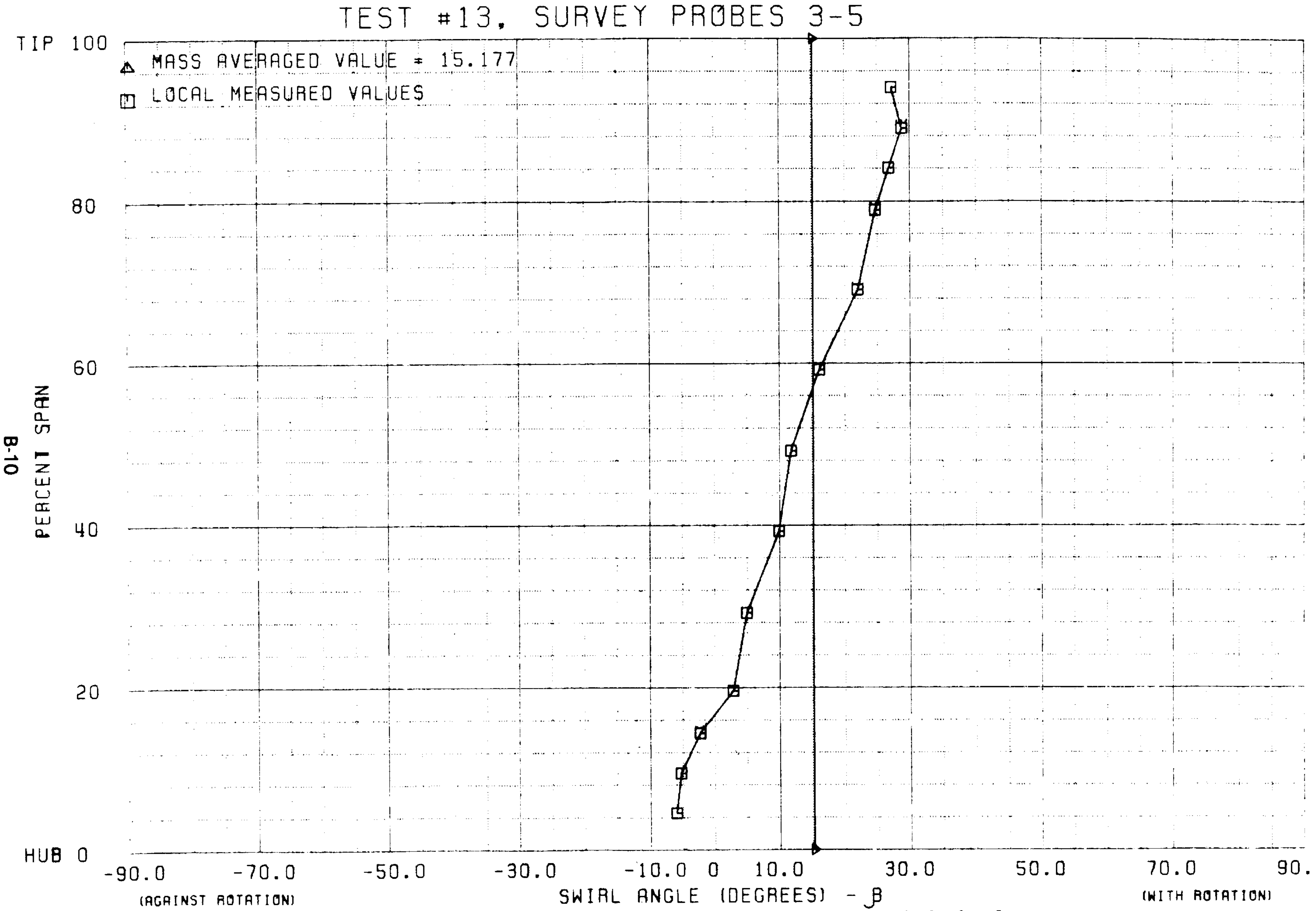

Figure B-10 Mixed Out Plane Survey - Swirl Angle vs. Percent Rotor Exit Span, Test No. 13, Moveable Hub, 66.0 Percent Area

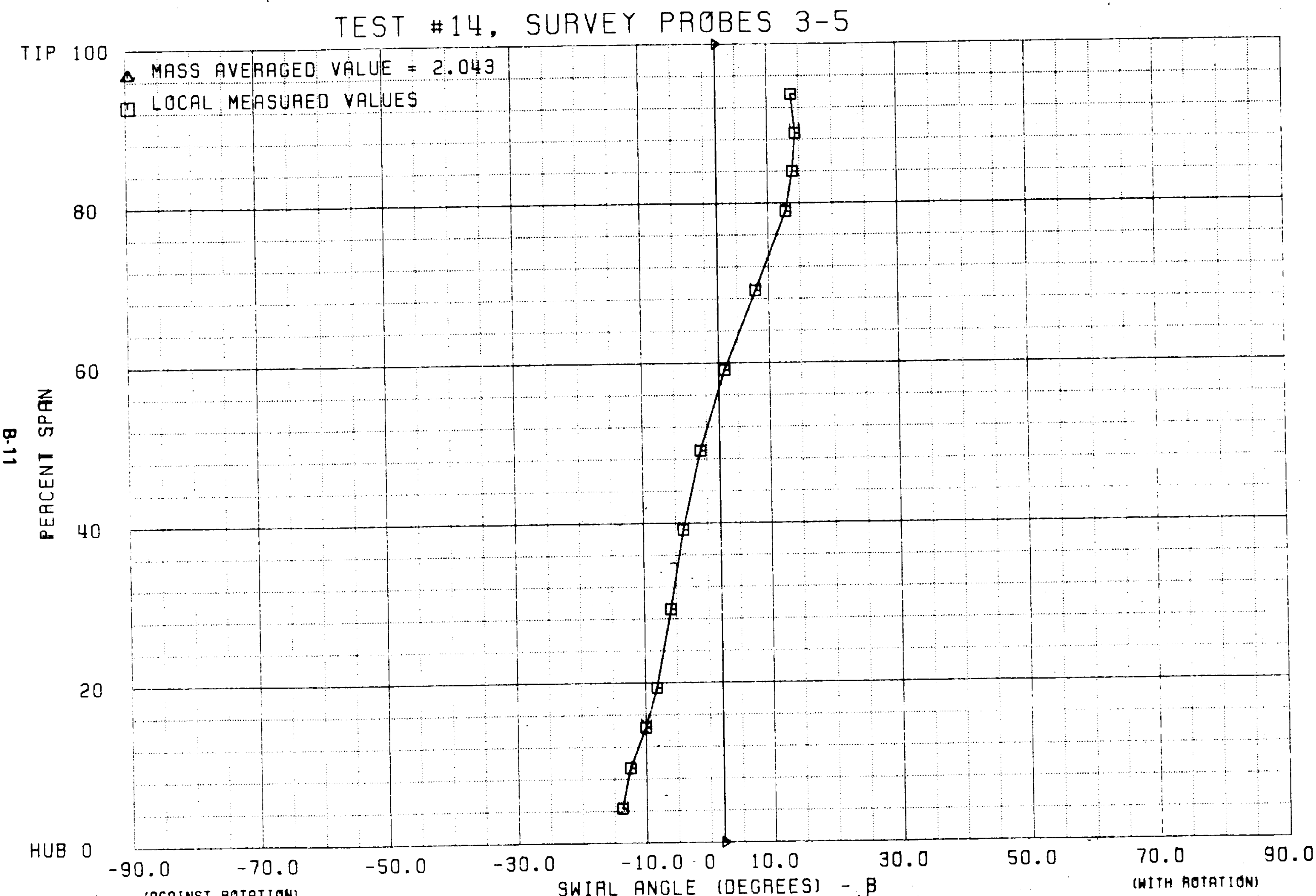

Figure B-11 Mixed Out Plane Survey - Swirl Angle vs. Percent Rotor Exit Span, Test No. 14, Moveable Shroud, 81.1 Percent Area

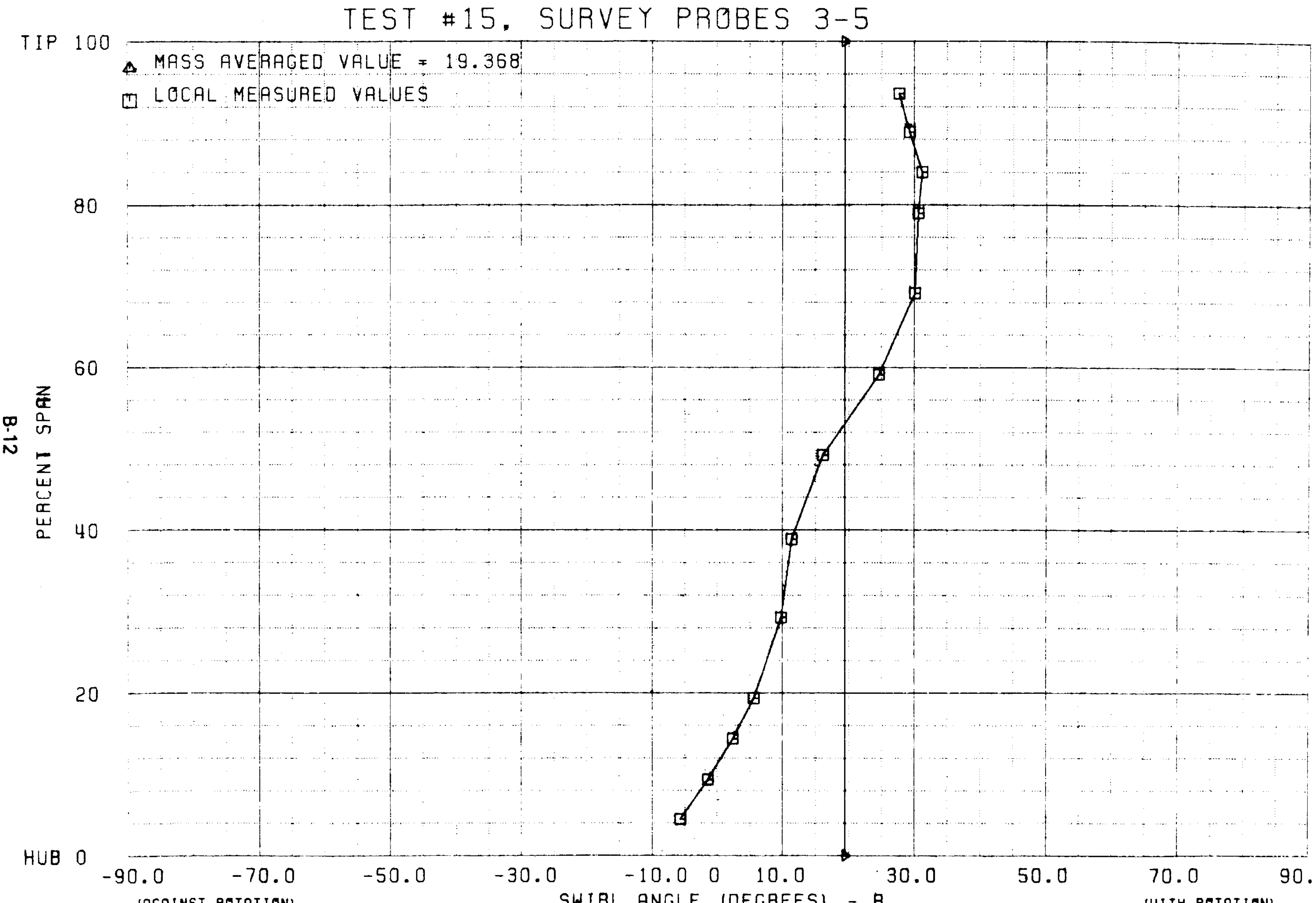

Figure B-12 Mixed Out Plane Survey - Swirl Angle vs. Percent Rotor Exit Span, Test No. 15, Moveable Shroud, 62.5 Percent Area

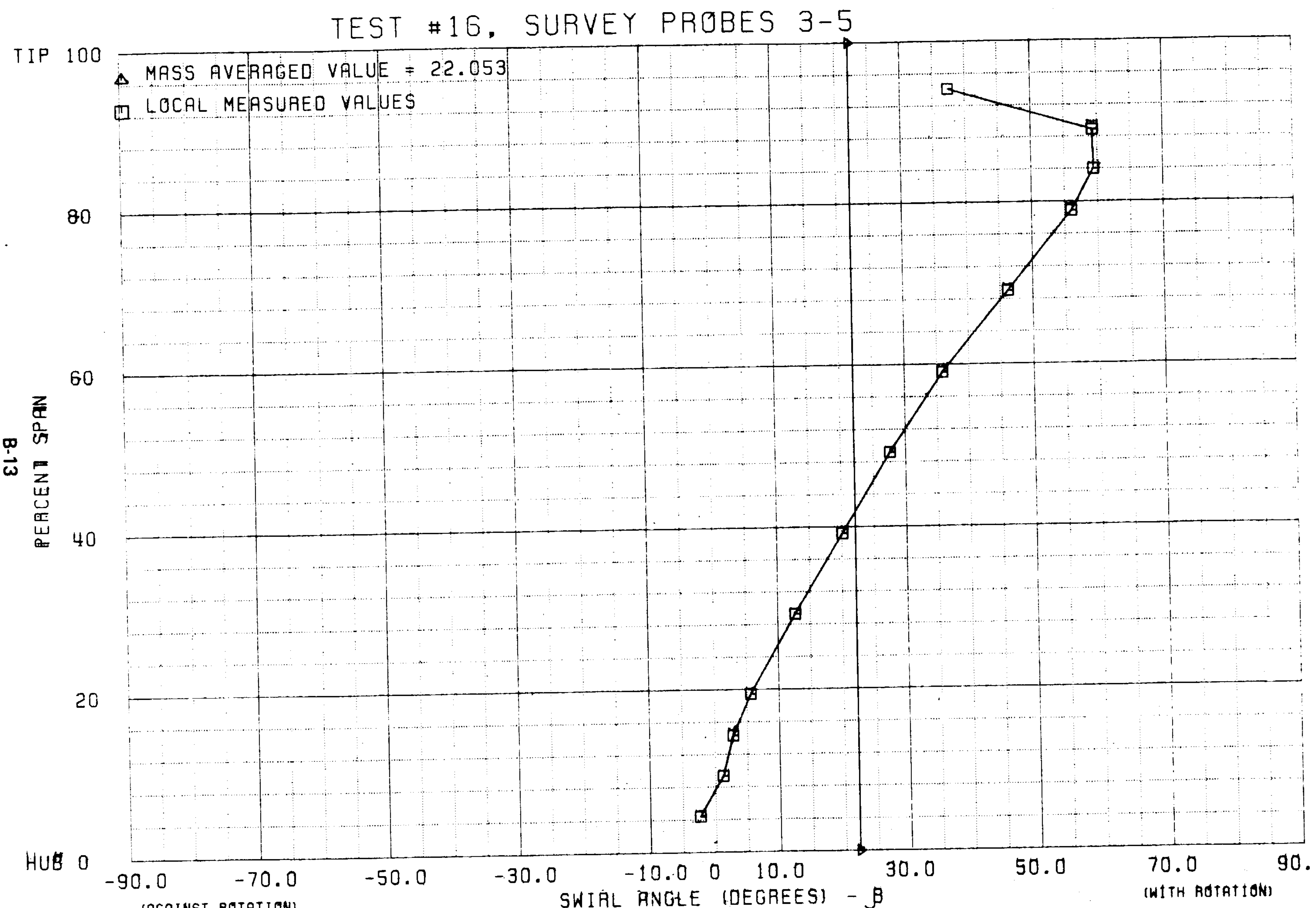

Figure B-13 Mixed Out Plane Survey - Swirl Angle vs. Percent Rotor Exit Span, Test No. 16, Moveable Shroud, 62.5 Percent Area

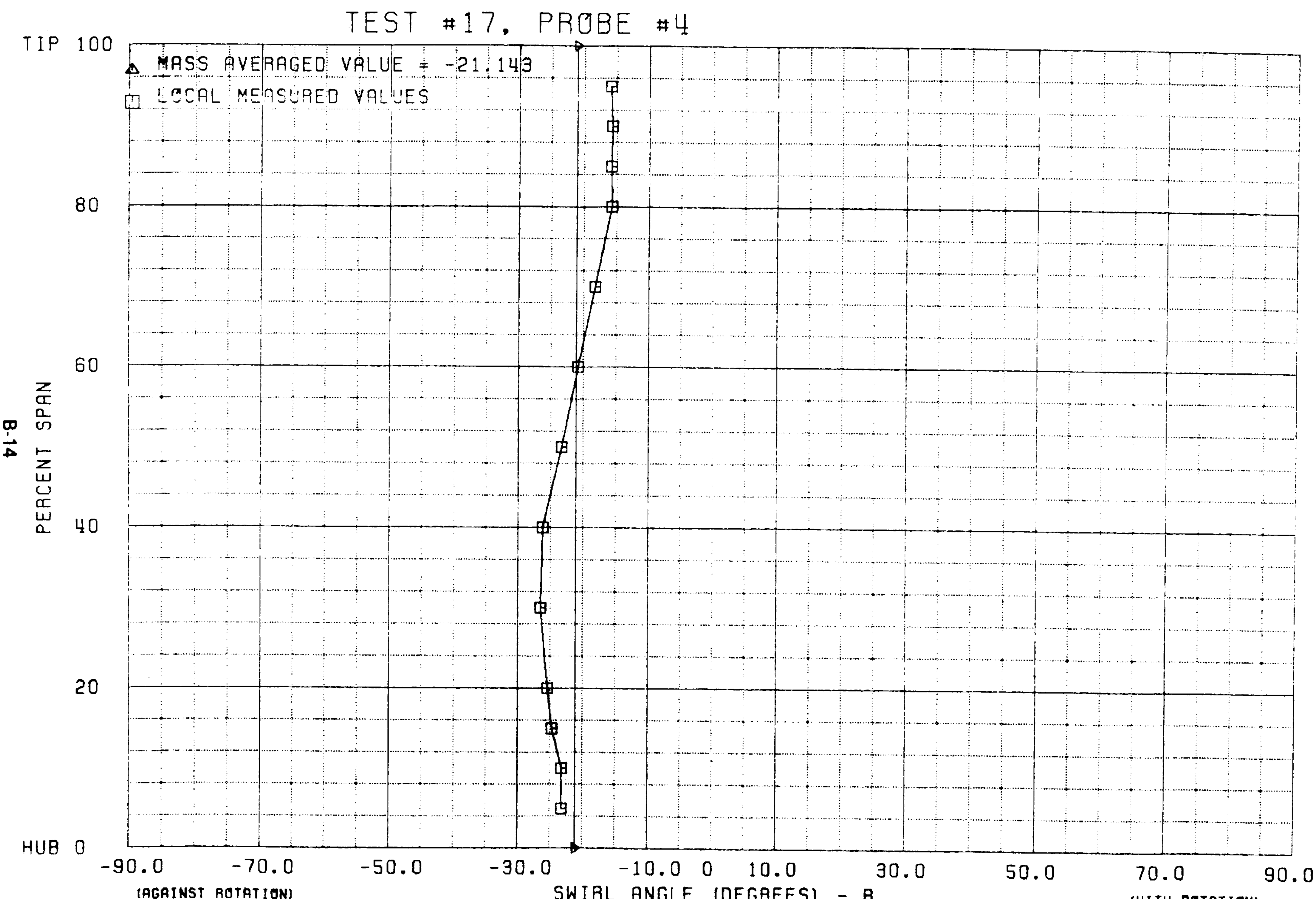

Figure B-14 Mixed Out Plane Survey - Swirl Angle vs. Percent Rotor Exit Span, Test No. 17, Moveable Shroud, 125.0 Percent Area

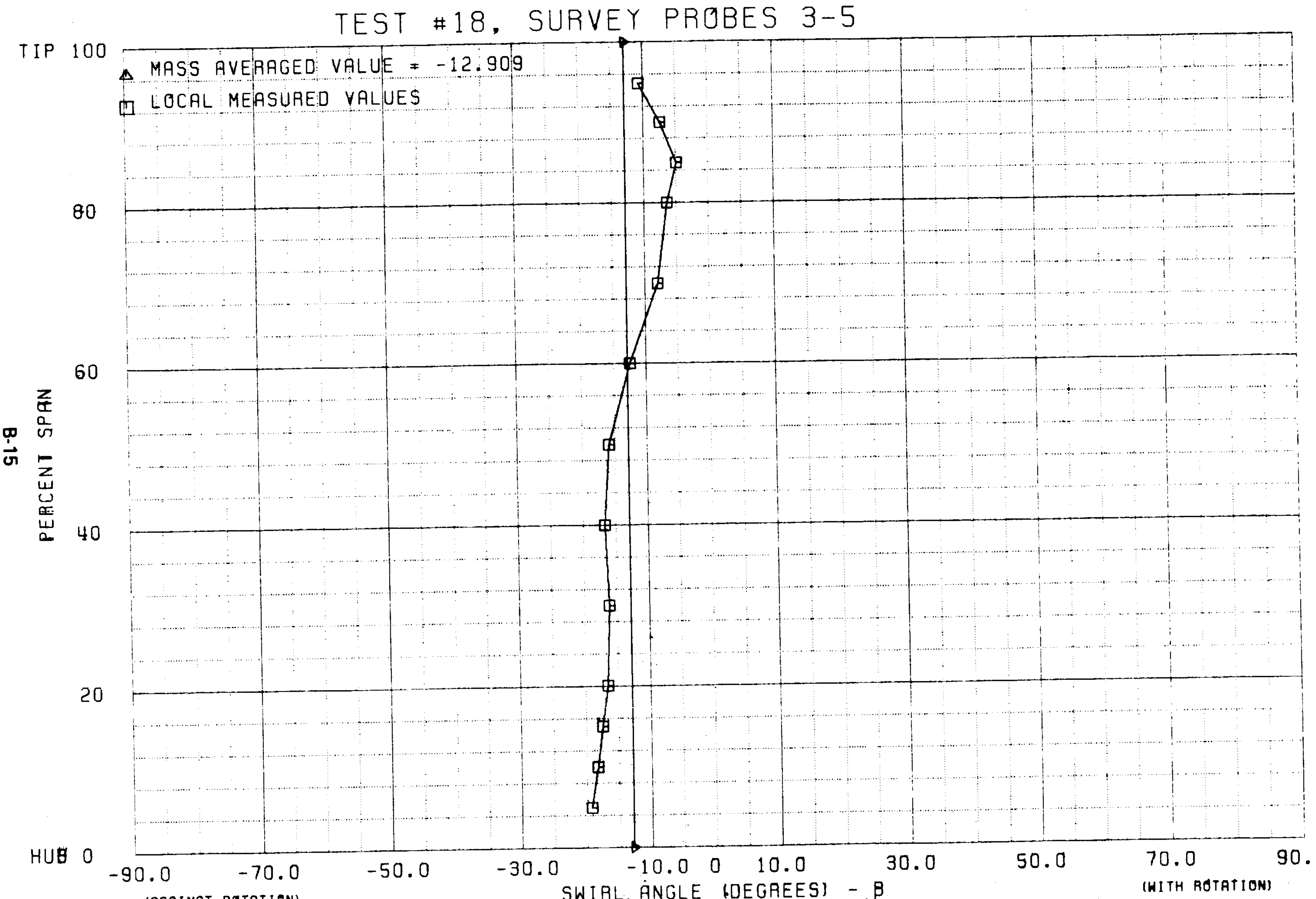

Figure B-15 Mixed Out Plane Survey - Swirl Angle vs. Percent Rotor Exit Span, Test No. 18, Moveable Shroud, 100.0 Percent Area

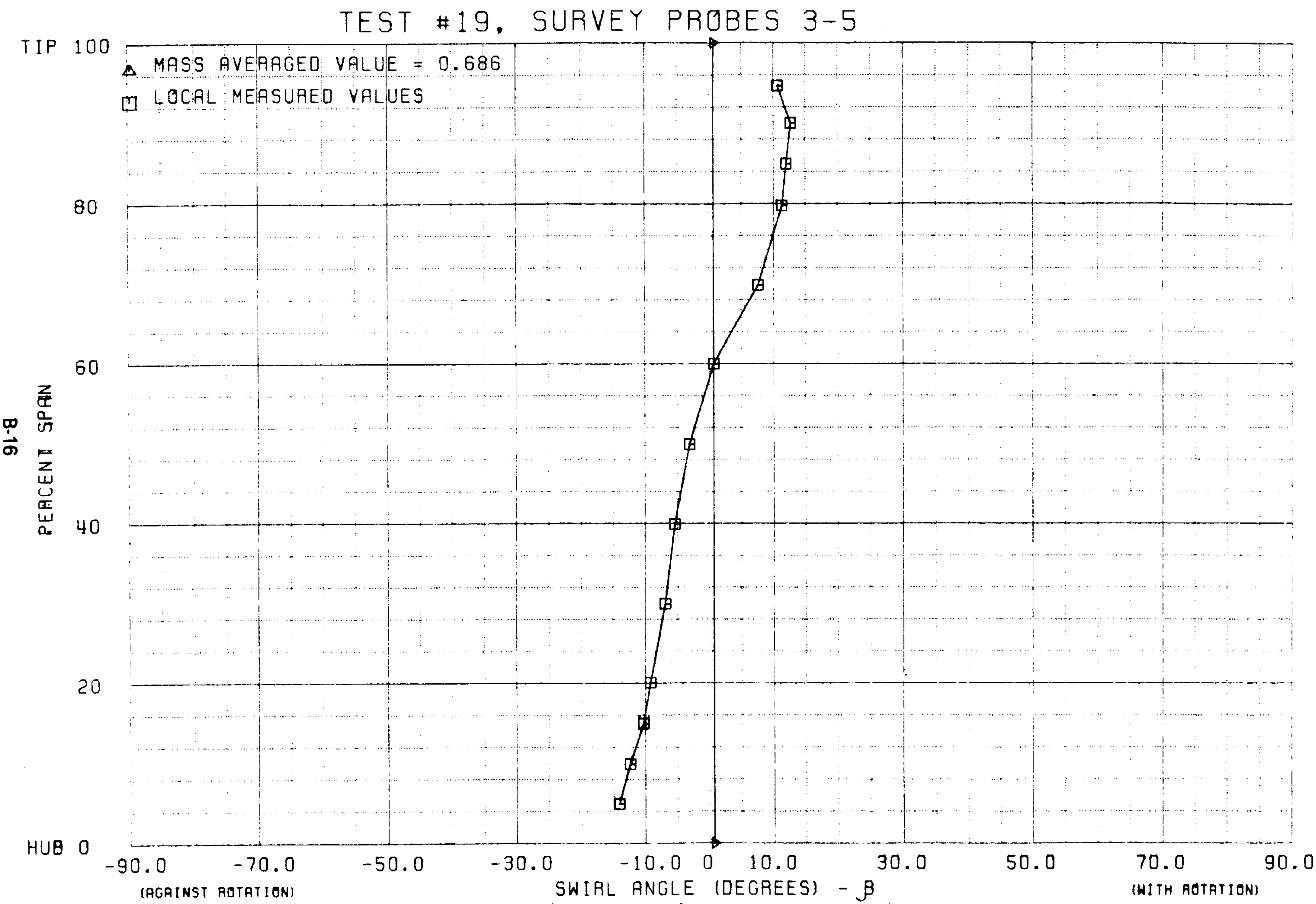

Figure B-16 Mixed Out Plane Survey - Swirl Angle vs. Percent Rotor Exit Span, Test No. 19, Moveable Shroud, 81.1 Percent Area

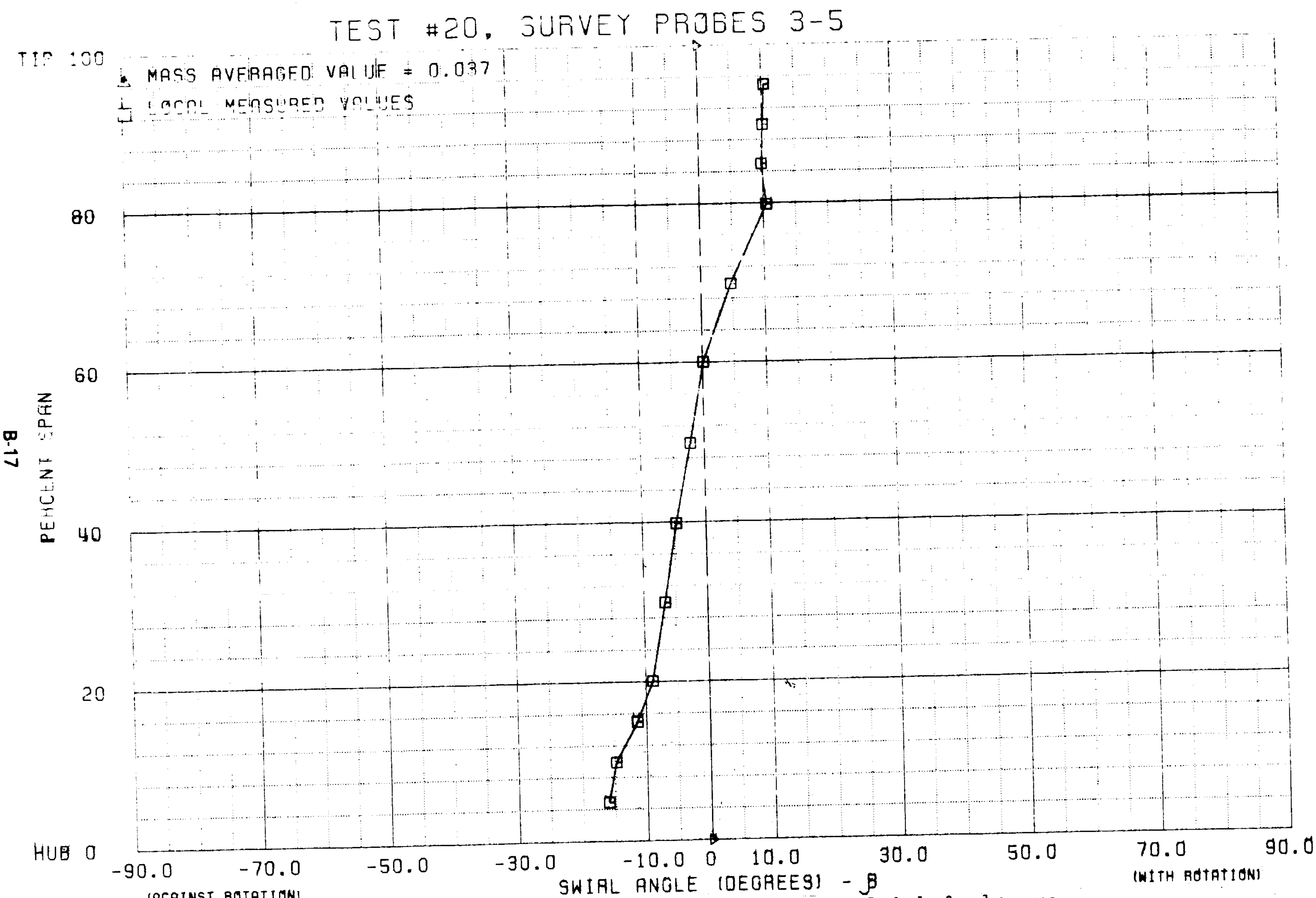

Figure B-17 Mixed Out Plane Survey - Swirl Angle vs. Percent Rotor Exit Span, Test No. 20, Moveable Shroud, 81.1 Percent Area

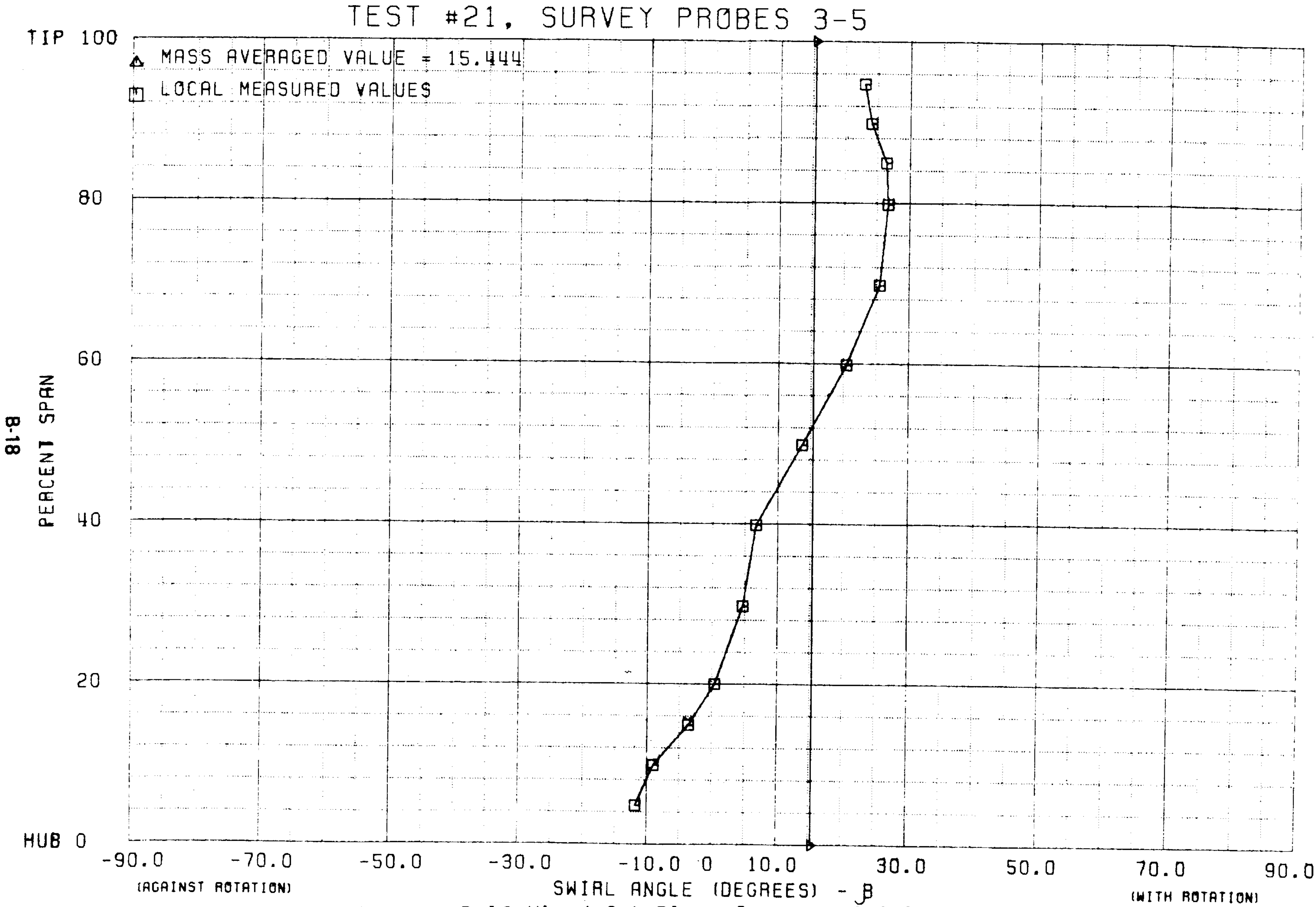

Figure B-18 Mixed Out Plane Survey - Swirl Angle vs. Percent Rotor Exit Span, Test No. 21, Moveable Shroud, 62.5 Percent Area

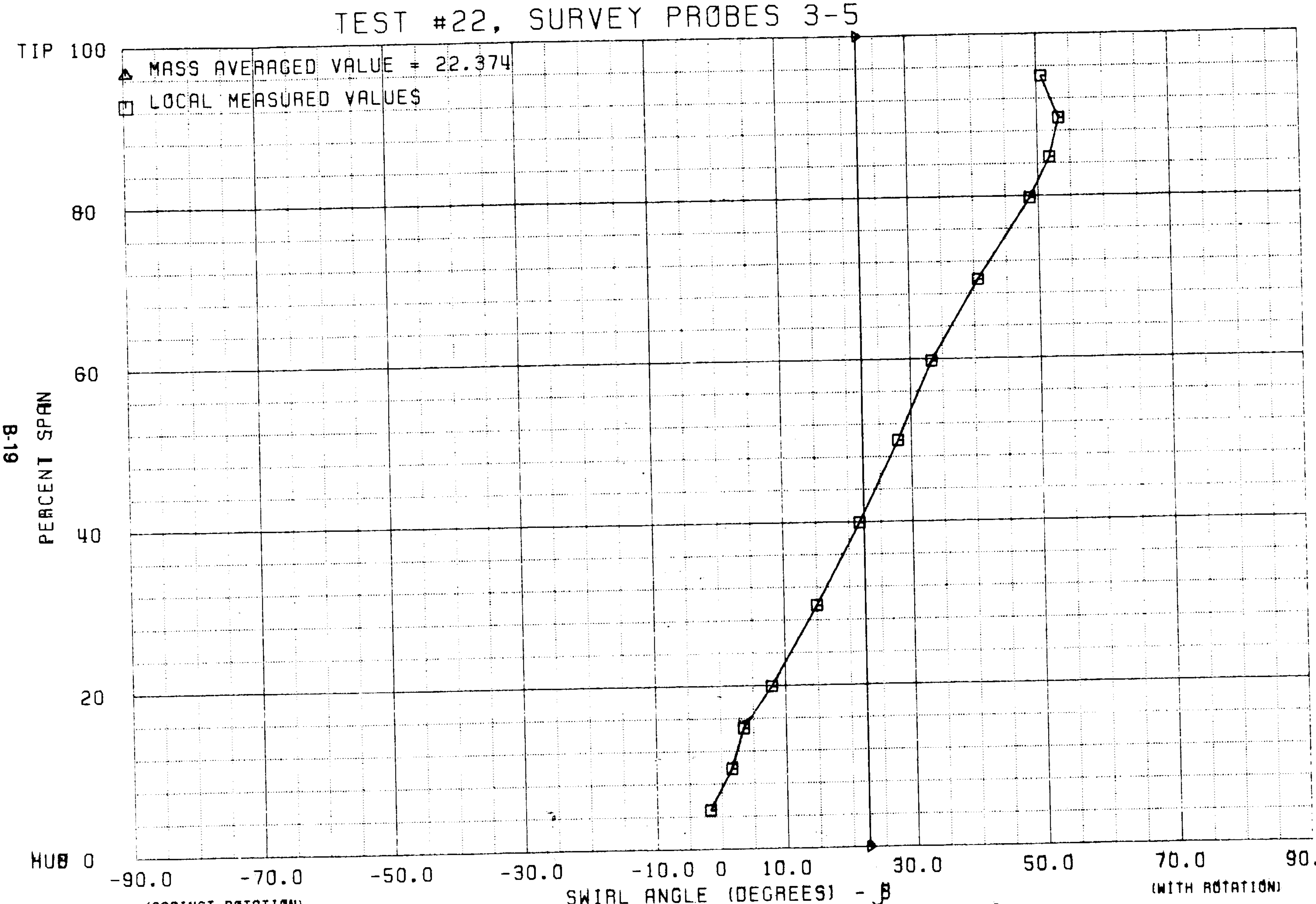

Figure B-19 Mixed Out Plane Survey - Swirl Angle vs. Percent Rotor Exit Span, Test No. 22, Moveable Shroud, 62.5 Percent Area

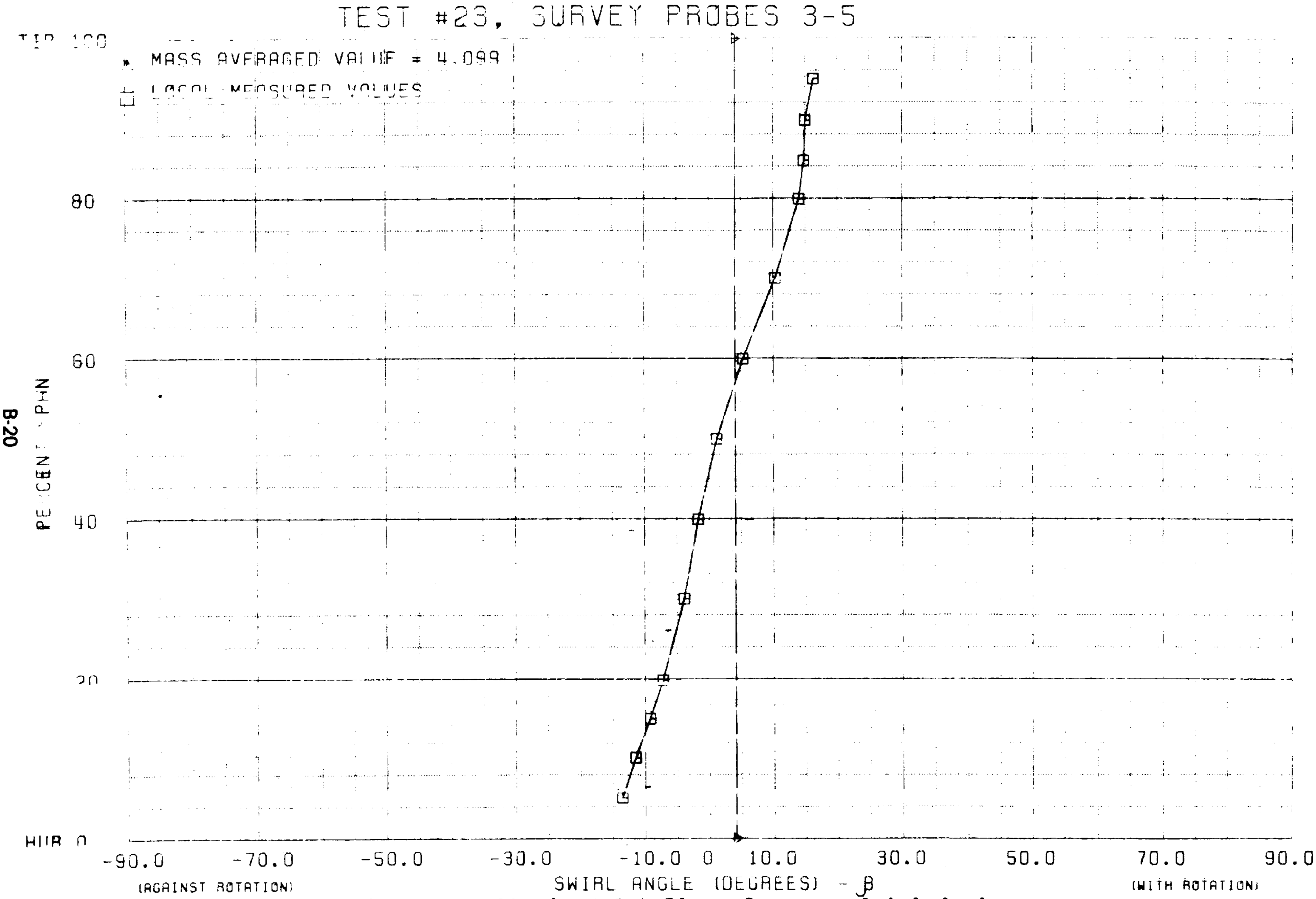

Figure B-20 Mixed Out Plane Survey - Swirl Angle vs. Percent Rotor Exit Span, Test No. 23, Moveable Shroud, 81.1 Percent Area

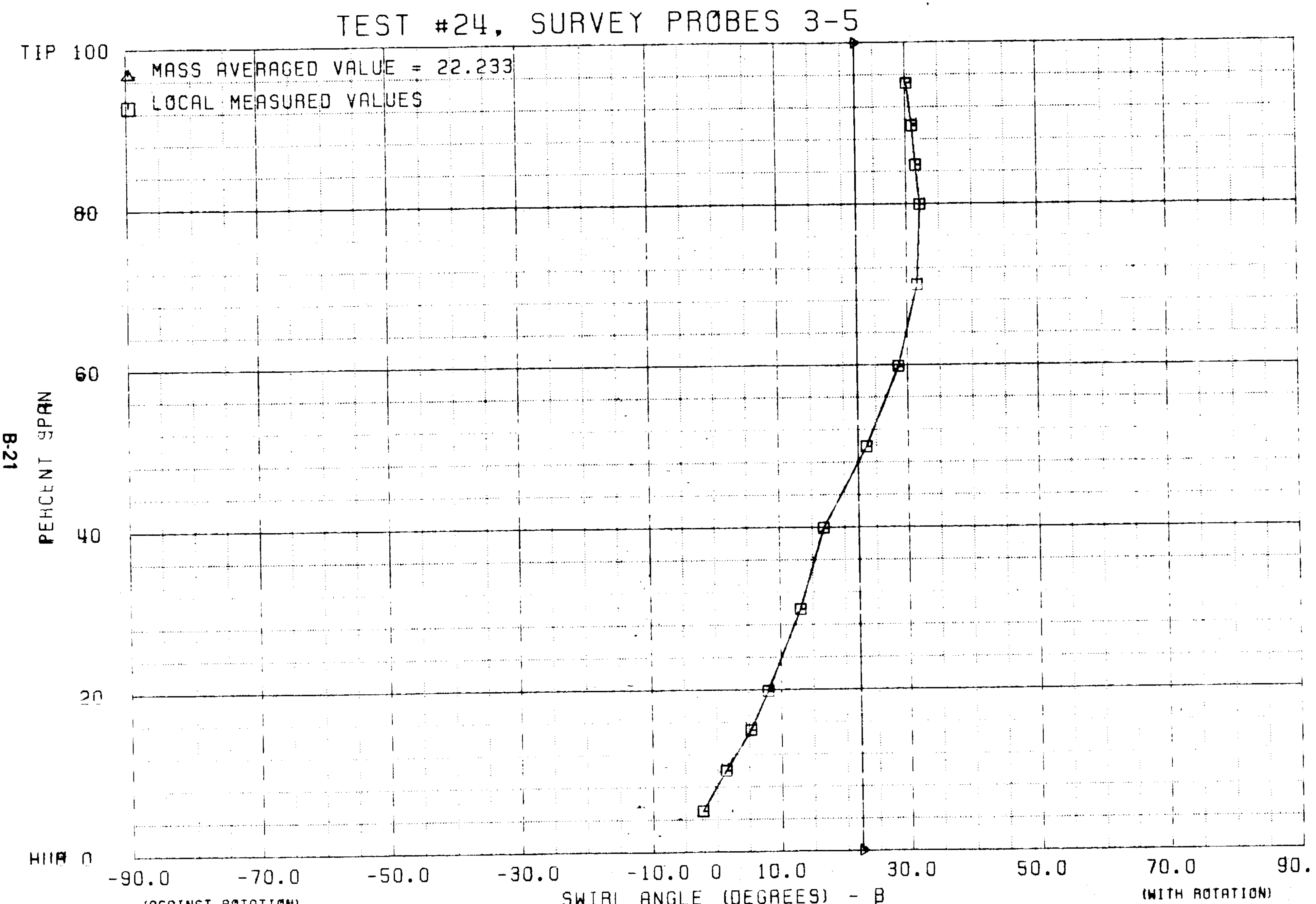

Figure B-21 Mixed Out Plane Survey - Swirl Angle vs. Percent Rotor Exit Span, Test No. 24, Moveable Shroud, 62.5 Percent Area

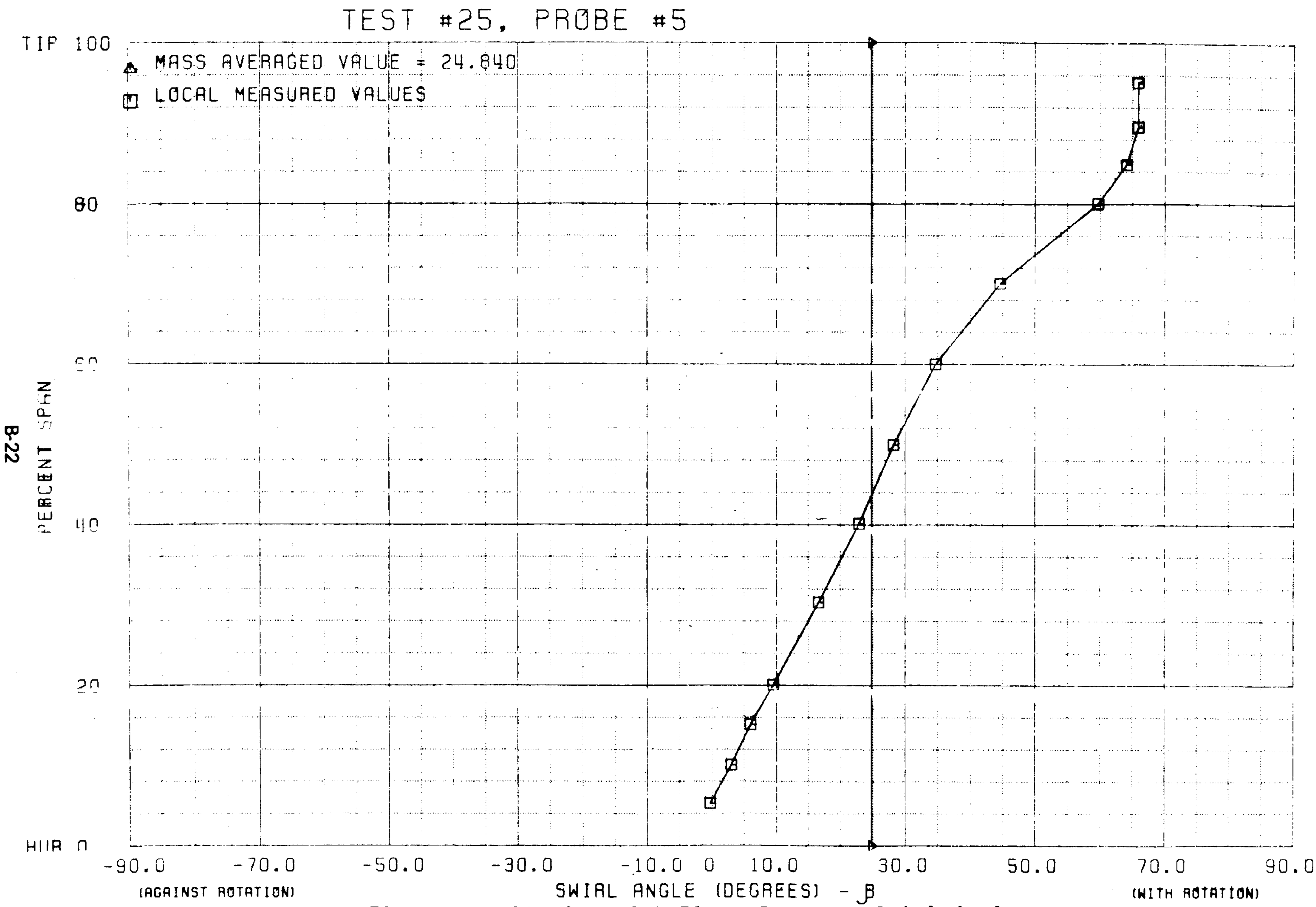

Figure B-22 Mixed Out Plane Survey - Swirl Angle vs. Percent Rotor Exit Span, Test No. 25, Moveable Shroud, 62.5 Percent Area

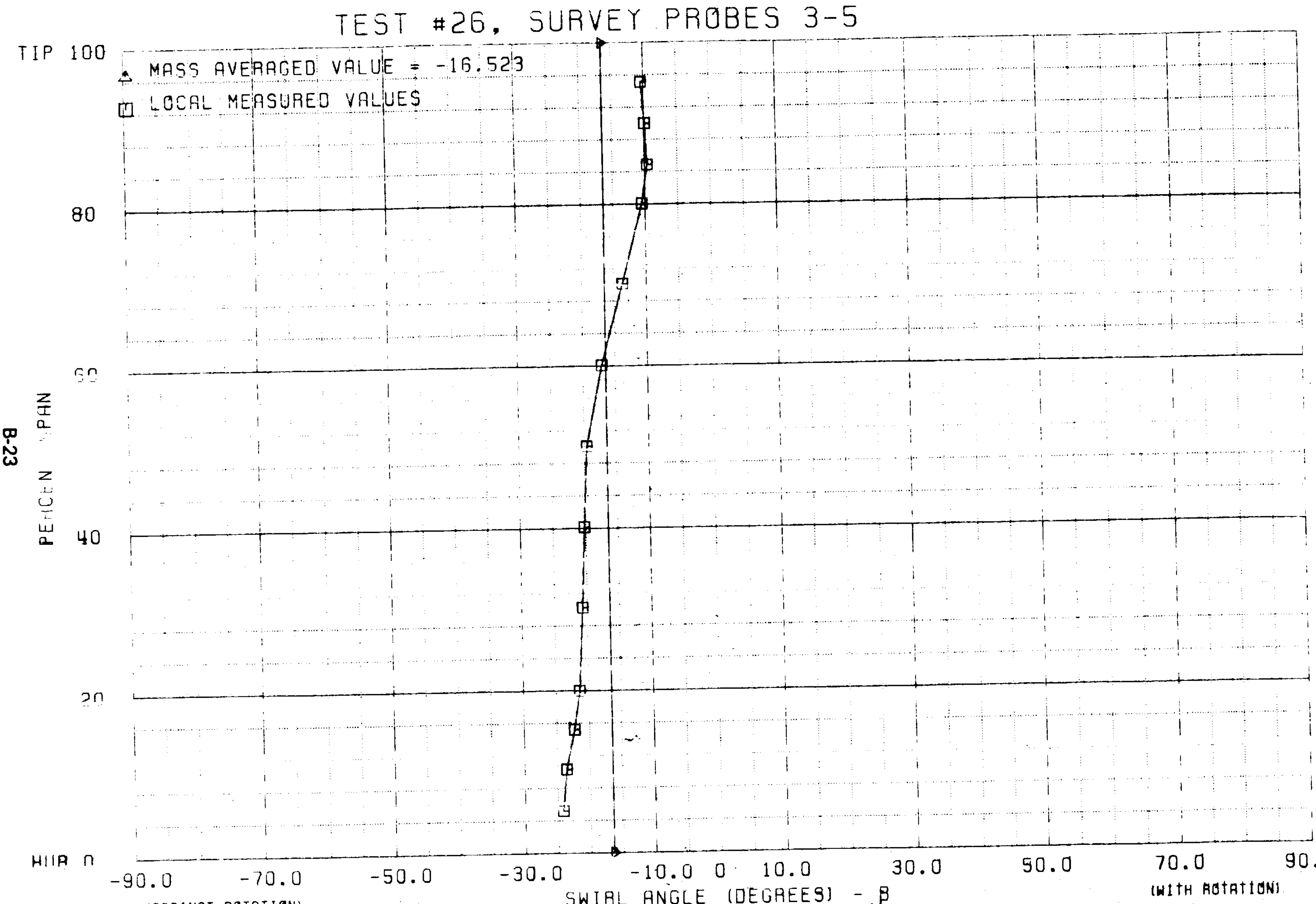

Figure B-23 Mixed Out Plane Survey - Swirl Angle vs. Percent Rotor Exit Span, Test No. 26, Moveable Shroud, 103.5 Percent Area

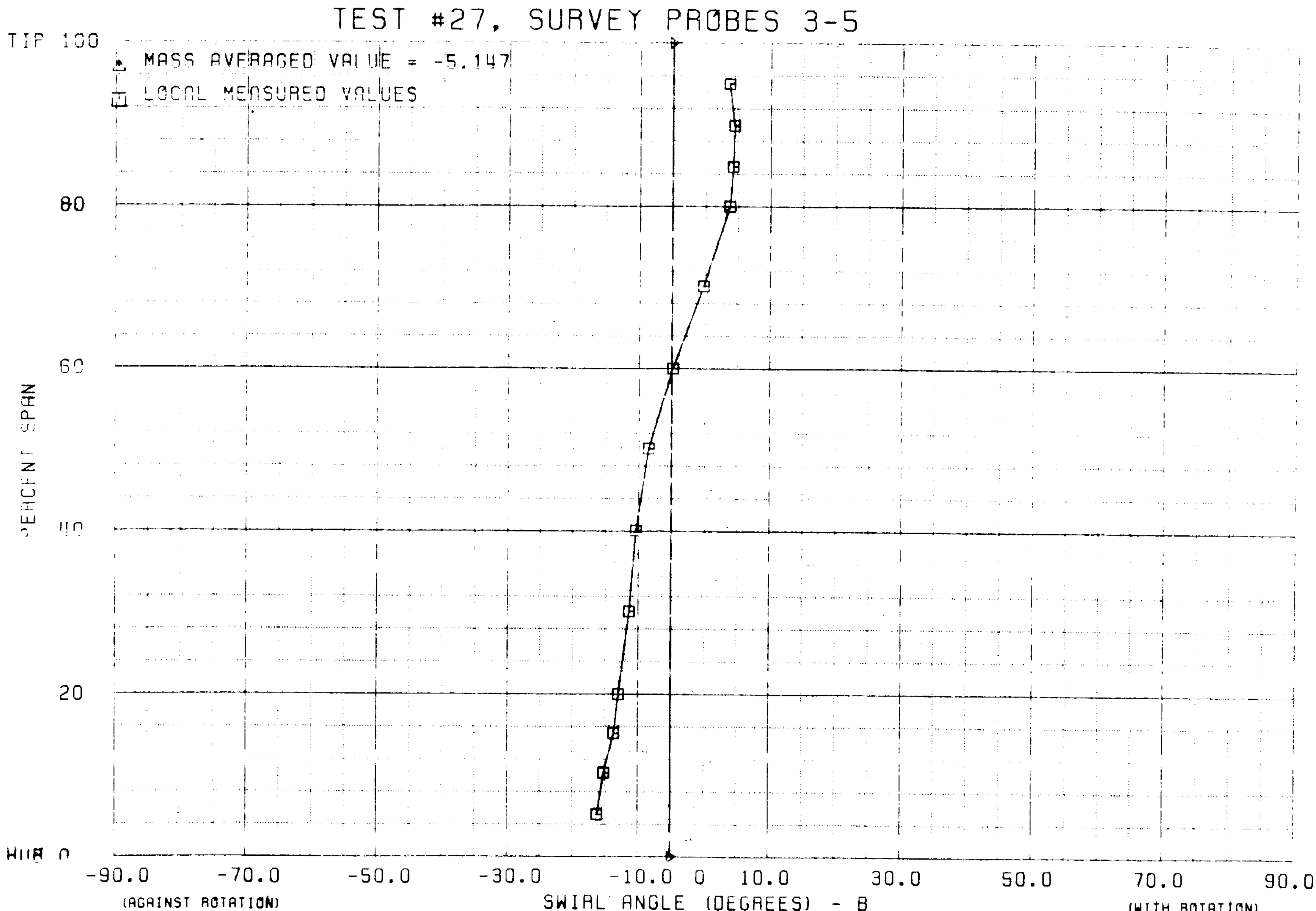

Figure B-24 Mixed Out Plane Survey - Swirl Angle vs. Percent Rotor Exit Span, Test No. 27, Moveable Shroud, 84.6 Percent Area

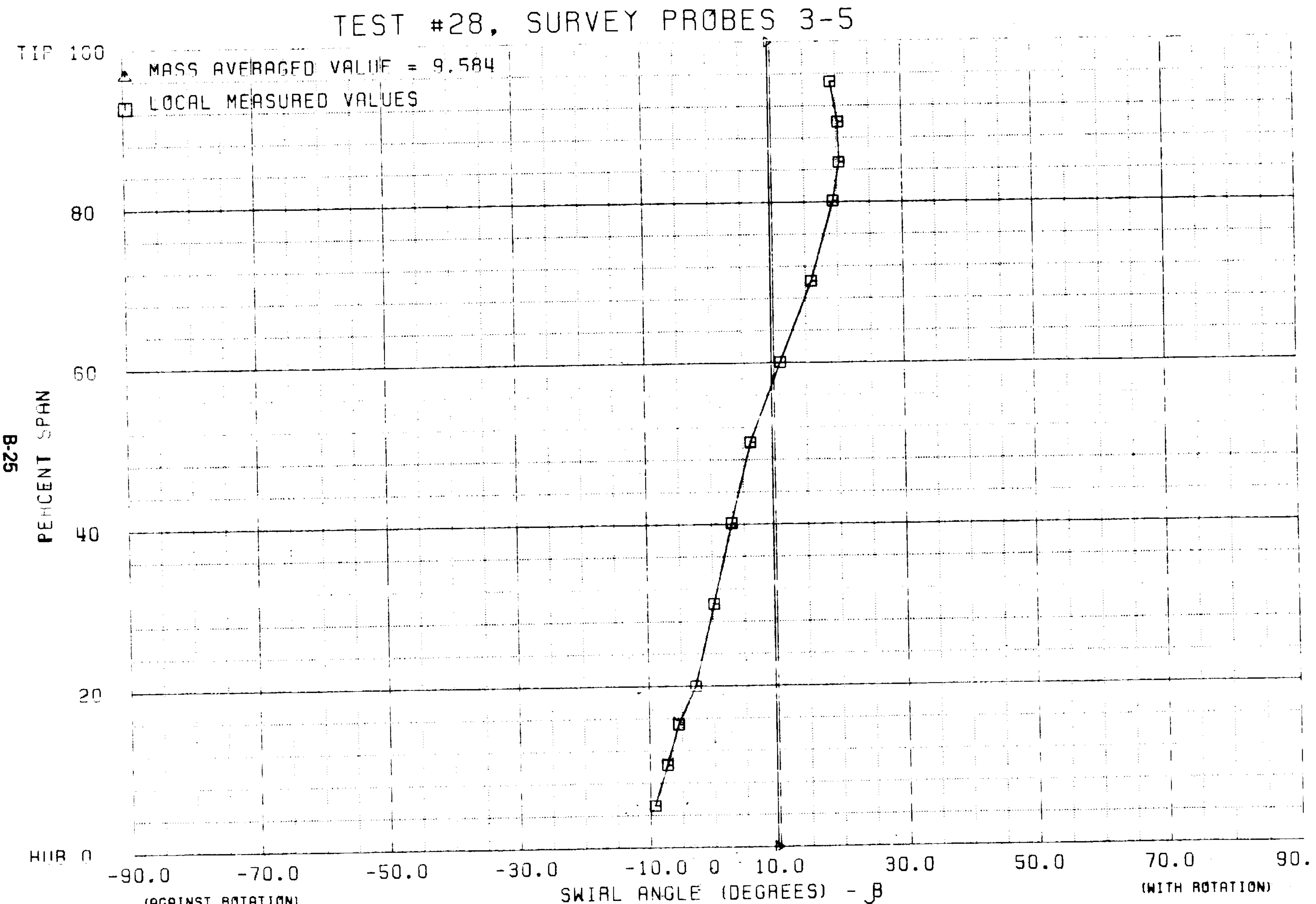

Figure B-25 Mixed Out Plane Survey - Swirl Angle vs. Percent Rotor Exit Span, Test No. 28, Moveable Shroud, 66.0 Percent Area

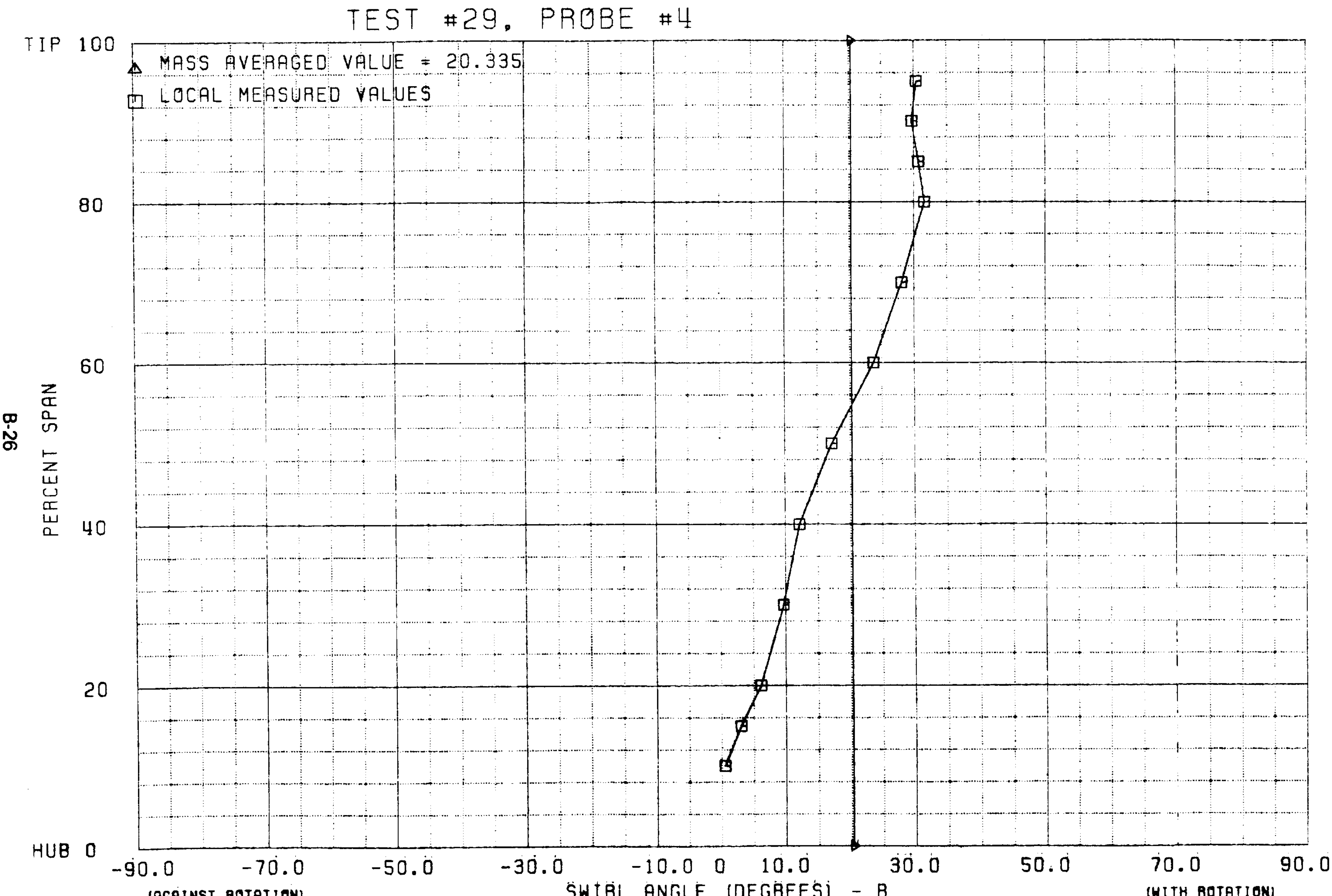

Figure B-26 Mixed Out Plane Survey - Swirl Angle vs. Percent Rotor Exit Span, Test No. 29, Moveable Shroud, 62.2 Percent Area

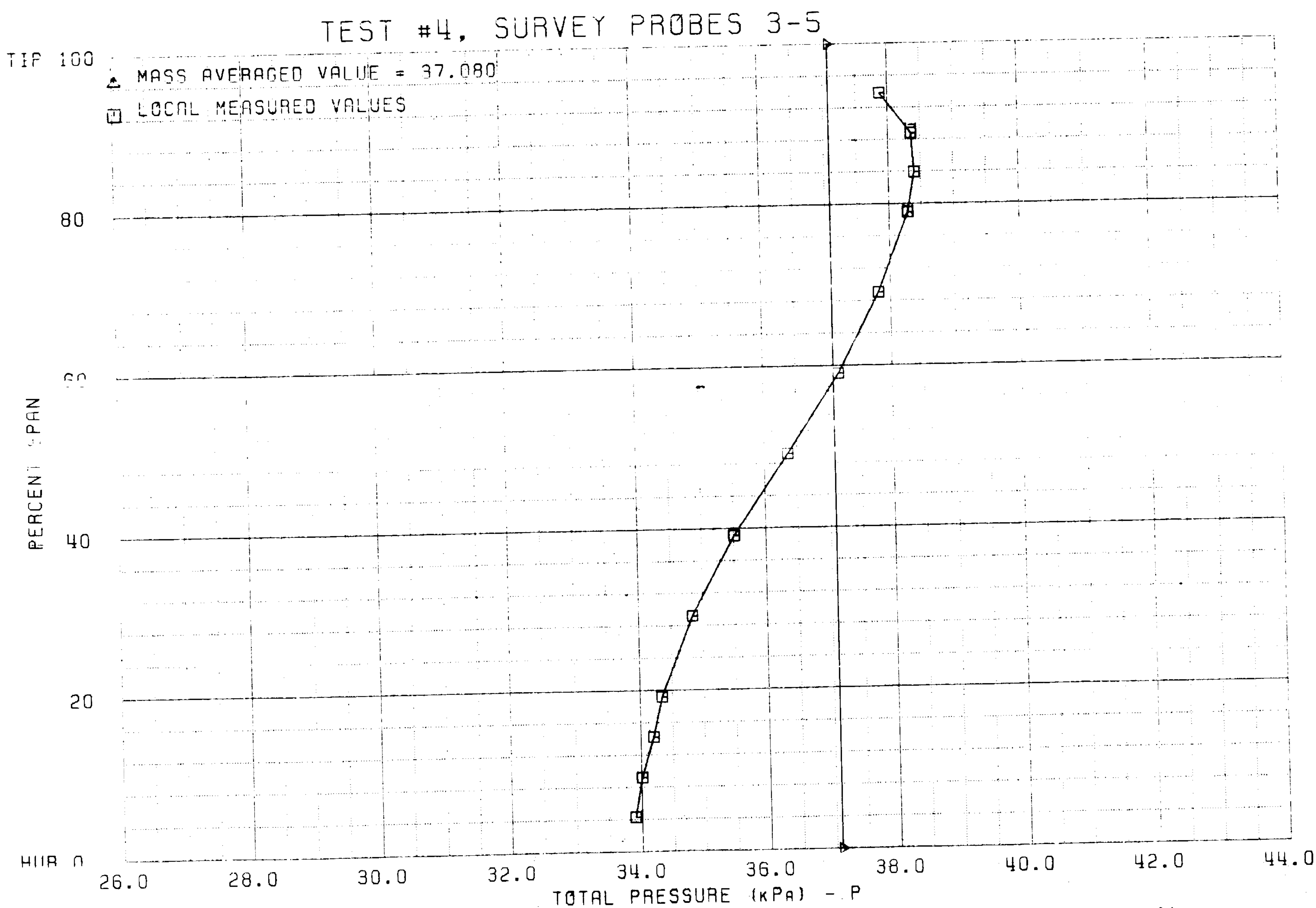

Figure B-27 Mixed Out Plane Survey - Total Pressure vs. Percent Rotor Exit

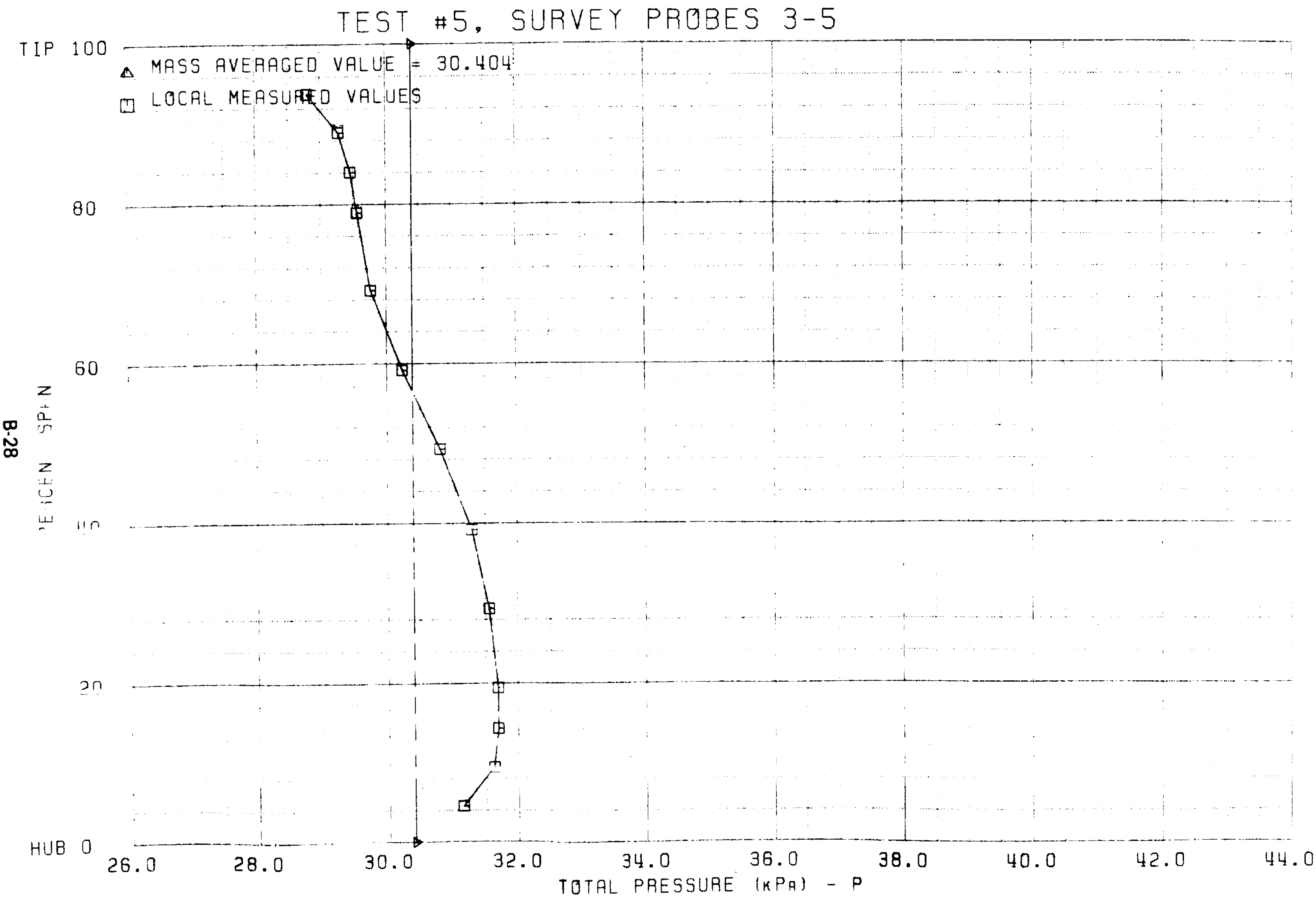

Figure B-28 Mixed Out Plane Survey - Total Pressure vs. Percent Rotor Exit Span, Test No. 5, Moveable Hub, 108.8 Percent Area

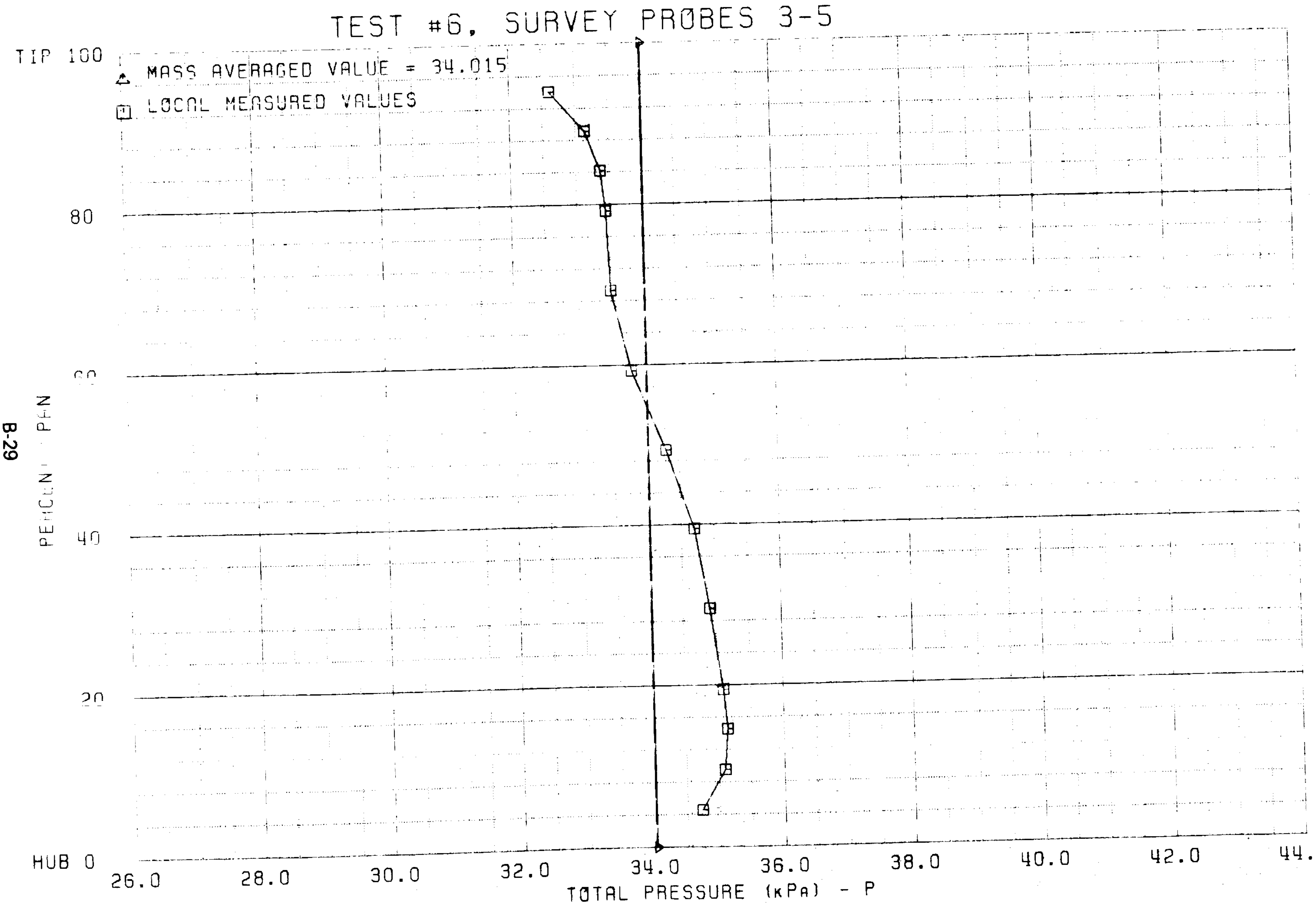

Figure B-29 Mixed Out Plane Survey - Total Pressure vs. Percent Rotor Exit

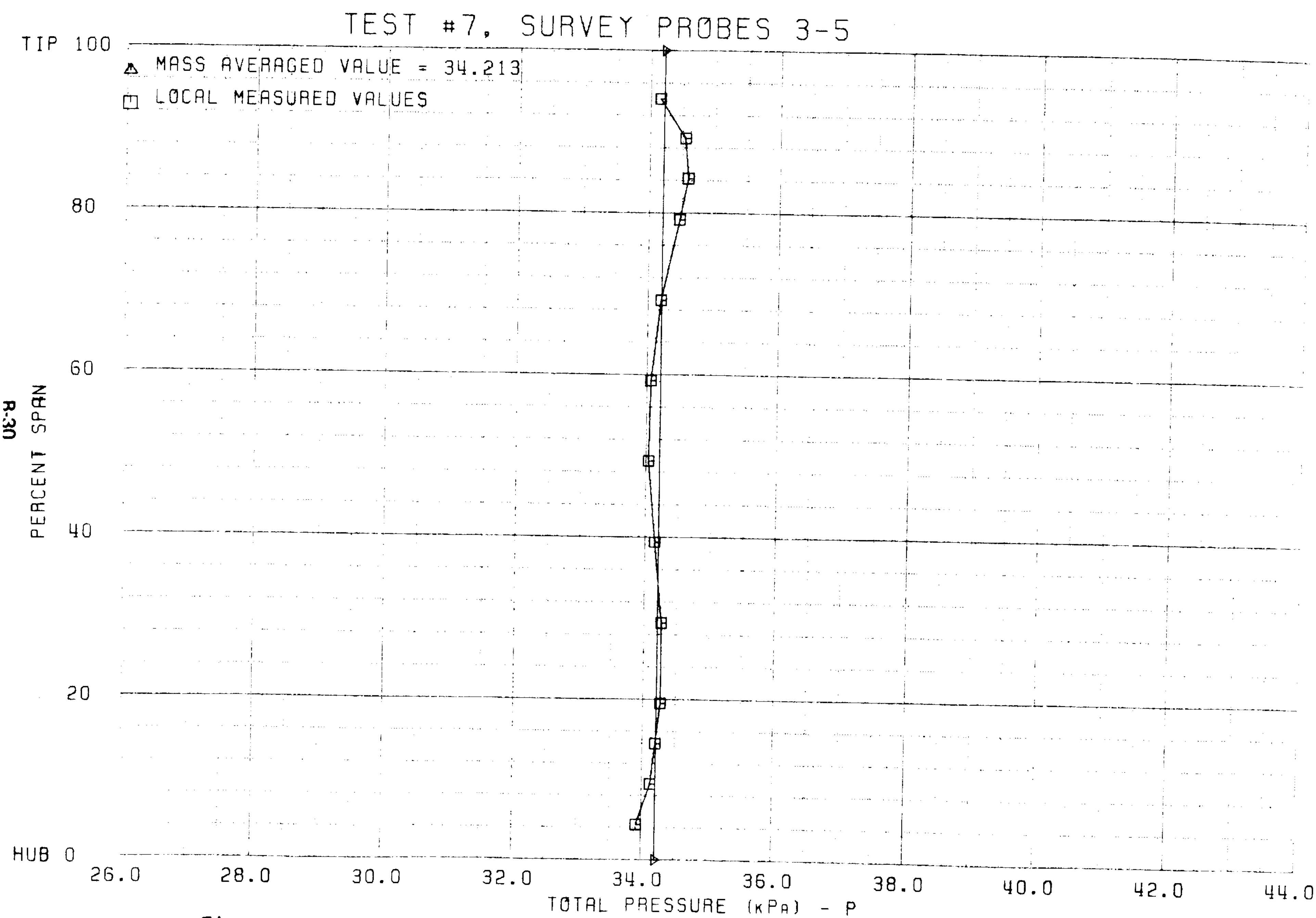

Figure B-30 Mixed Out Plane Survey - Total Pressure vs. Percent Rotor Exit Span, Test No. 7, Moveable Hub, 81.1 Percent Area

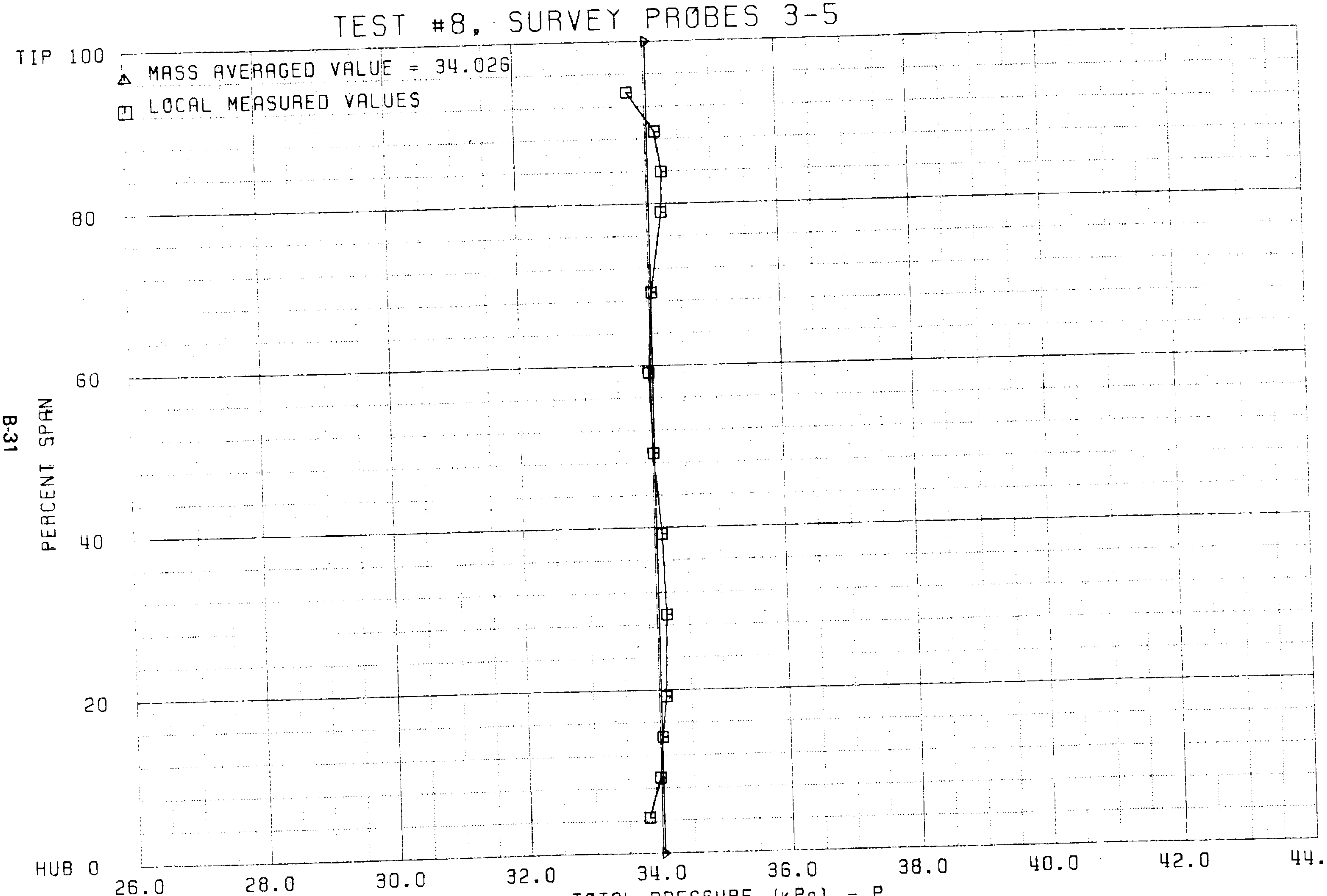

Figure B-31 Mixed Out Plane Survey - Total Pressure vs. Percent Rotor Exit

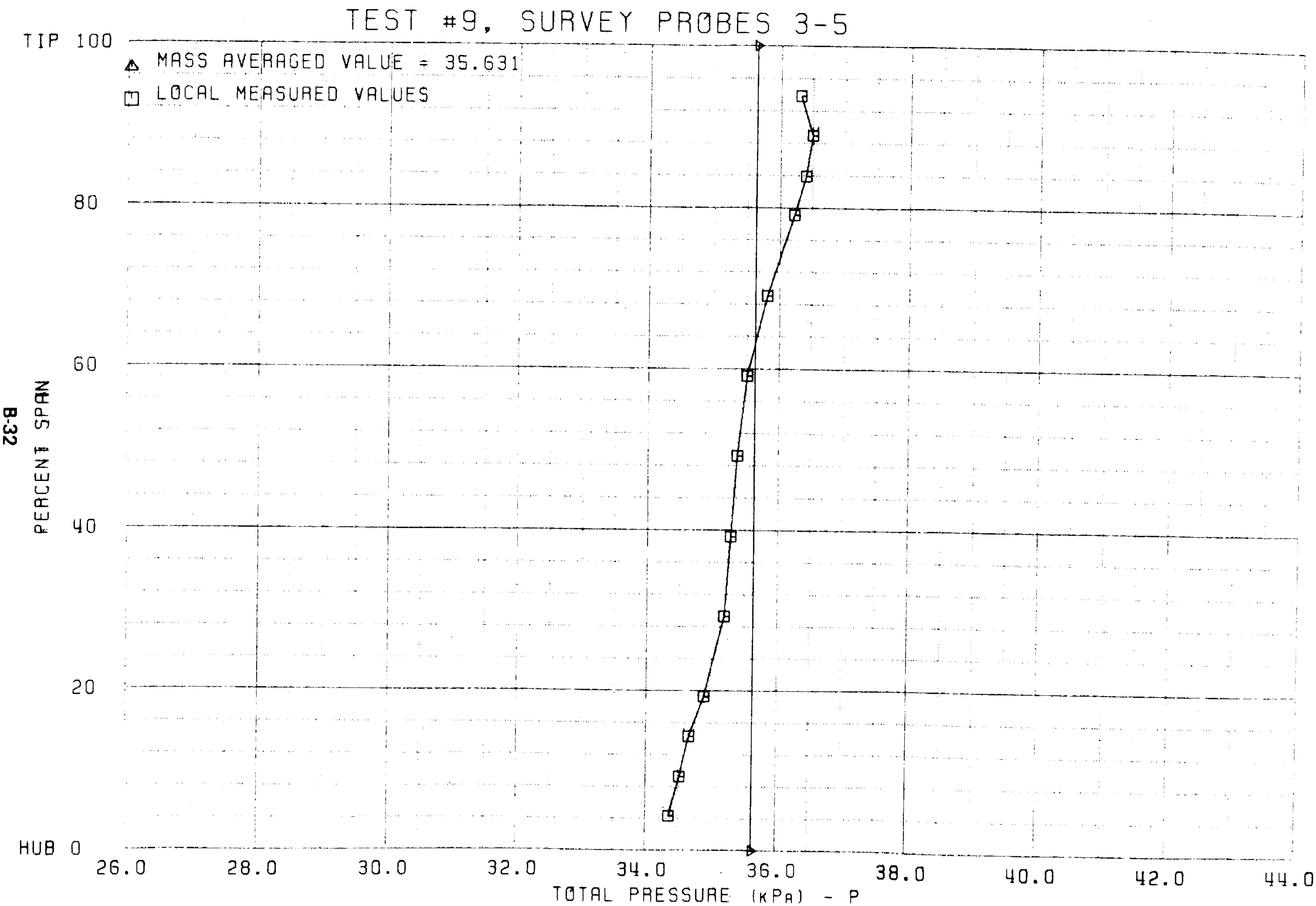

Figure B-32 Mixed Out Plane Survey - Total Pressure vs. Percent Rotor Exit Span, Test No. 9, Moveable Hub, 62.2 Percent Area

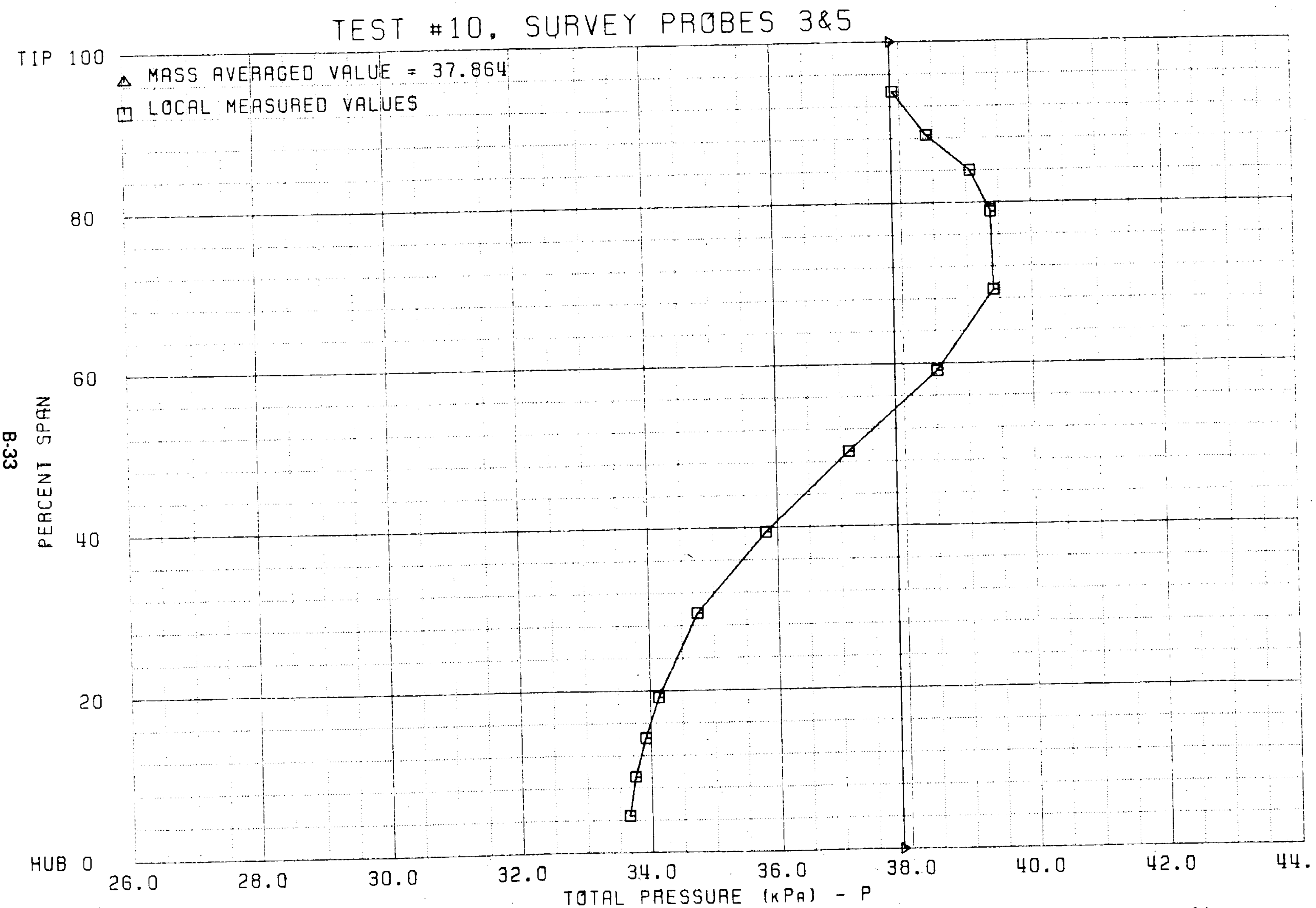

Figure B-33 Mixed Out Plane Survey - Total Pressure vs. Percent Rotor Exit

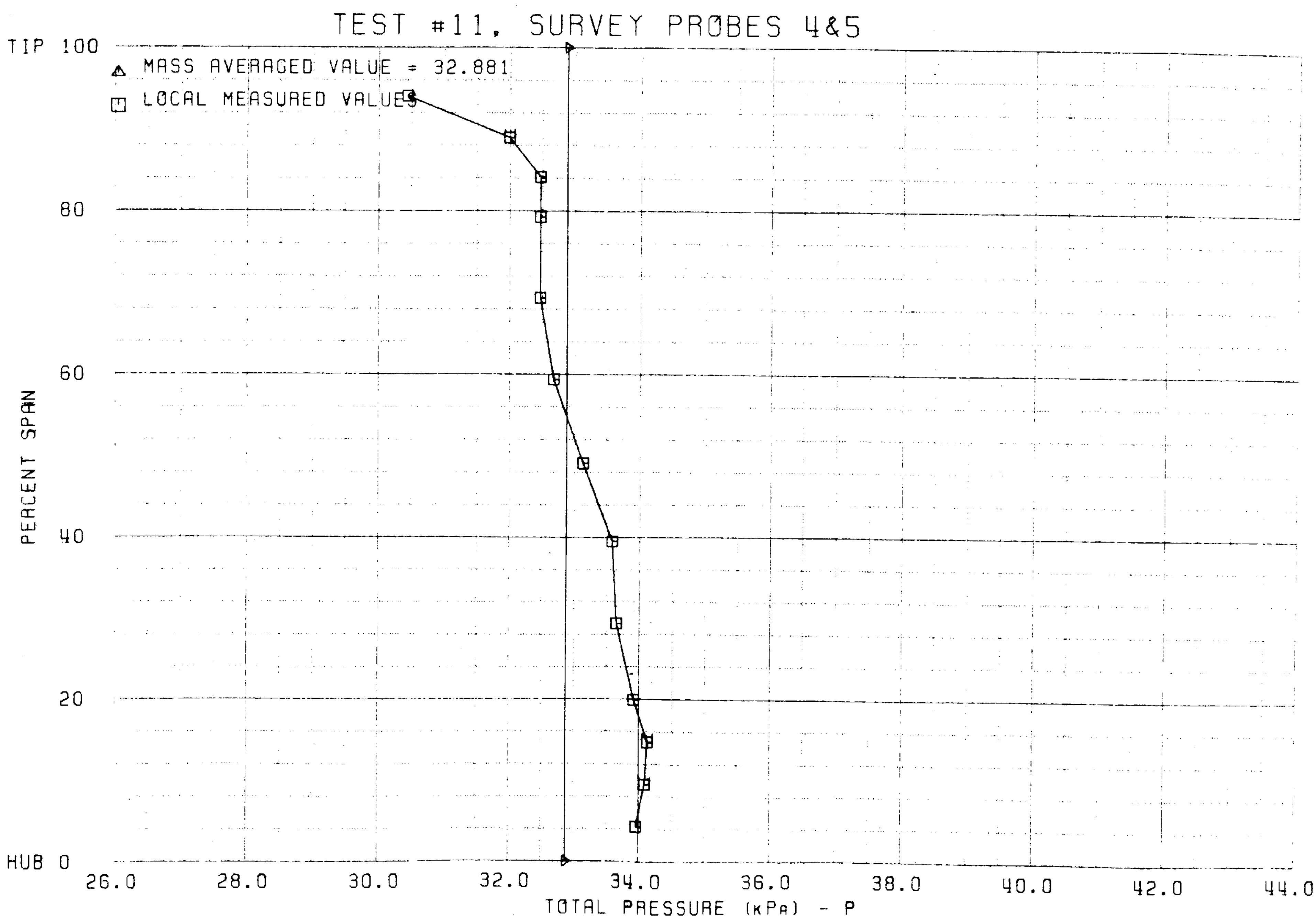

Figure B-34 Mixed Out Plane Survey - Total Pressure vs. Percent Rotor Exit Span, Test No. 11, Moveable Hub, 103.5 Percent Area

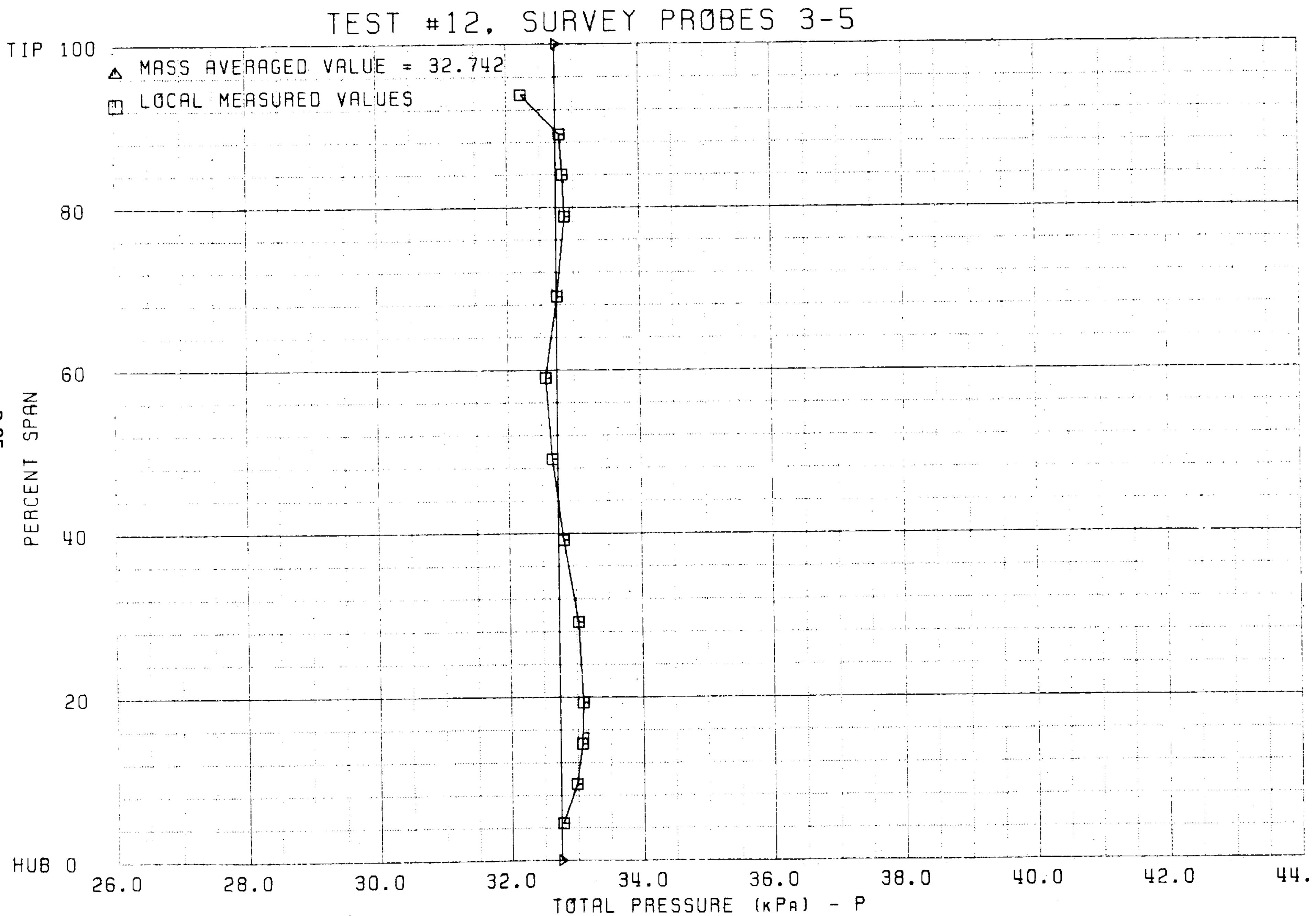

Figure B-35 Mixed Out Plane Survey - Total Pressure vs. Percent Rotor Exit

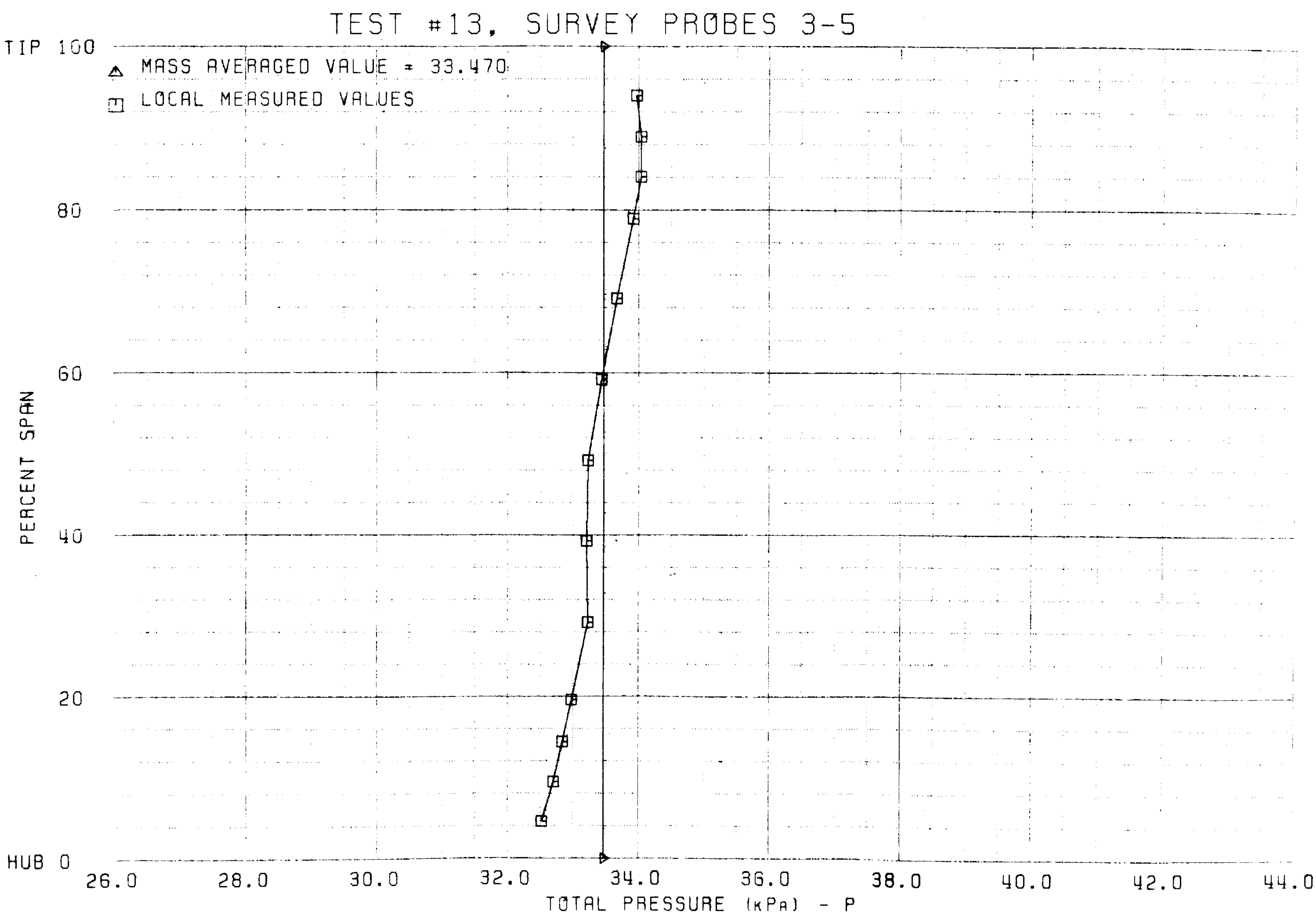

Figure B-36 Mixed Out Plane Survey - Total Pressure vs. Percent Rotor Exit Span, Test No. 13, Moveable Hub, 66.0 Percent Area

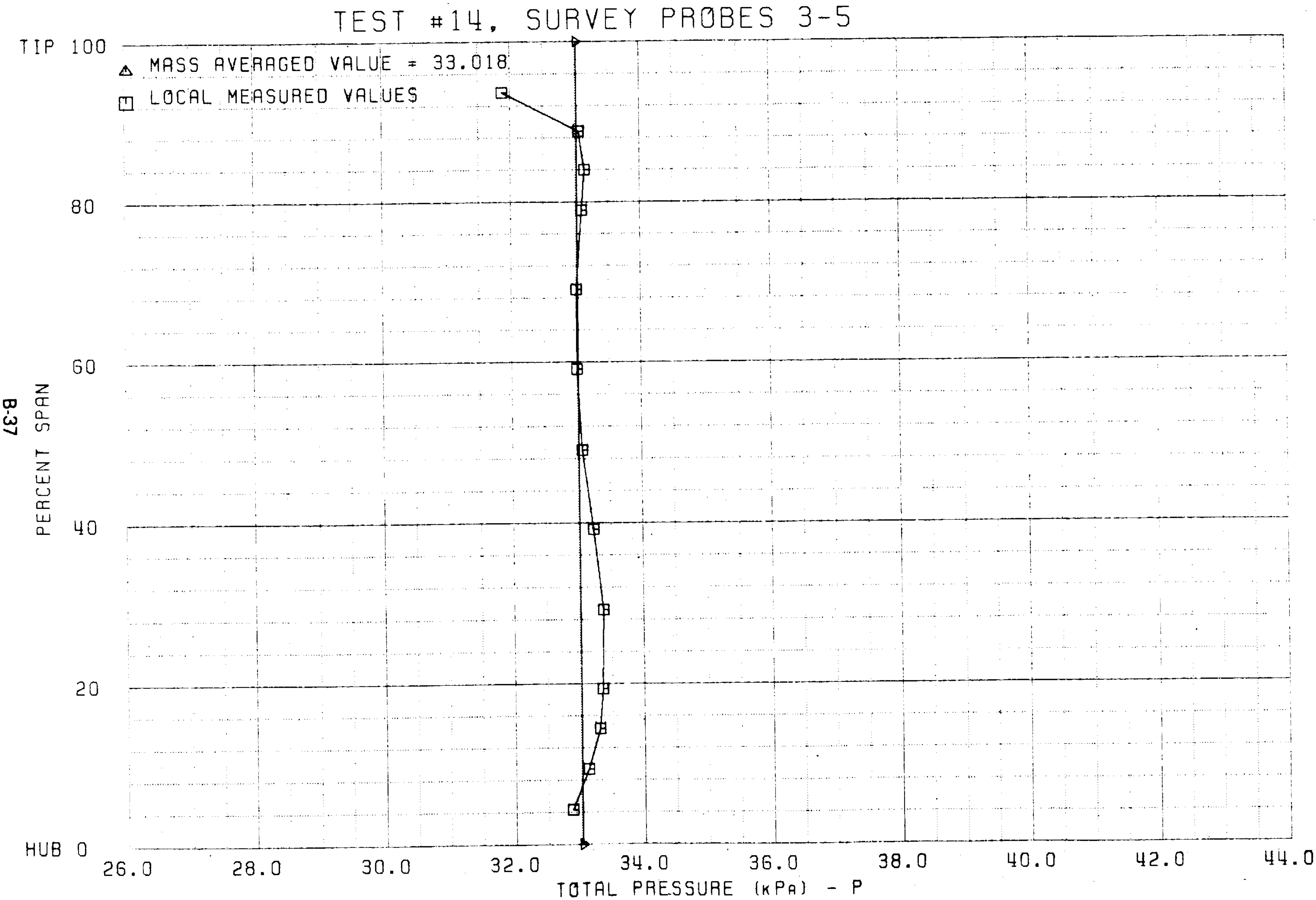

Figure B-37 Mixed Out Plane Survey - Total Pressure vs. Percent Rotor Exit
Survey, Test No. 14, Moveable Shroud, 81.1 Percent Area

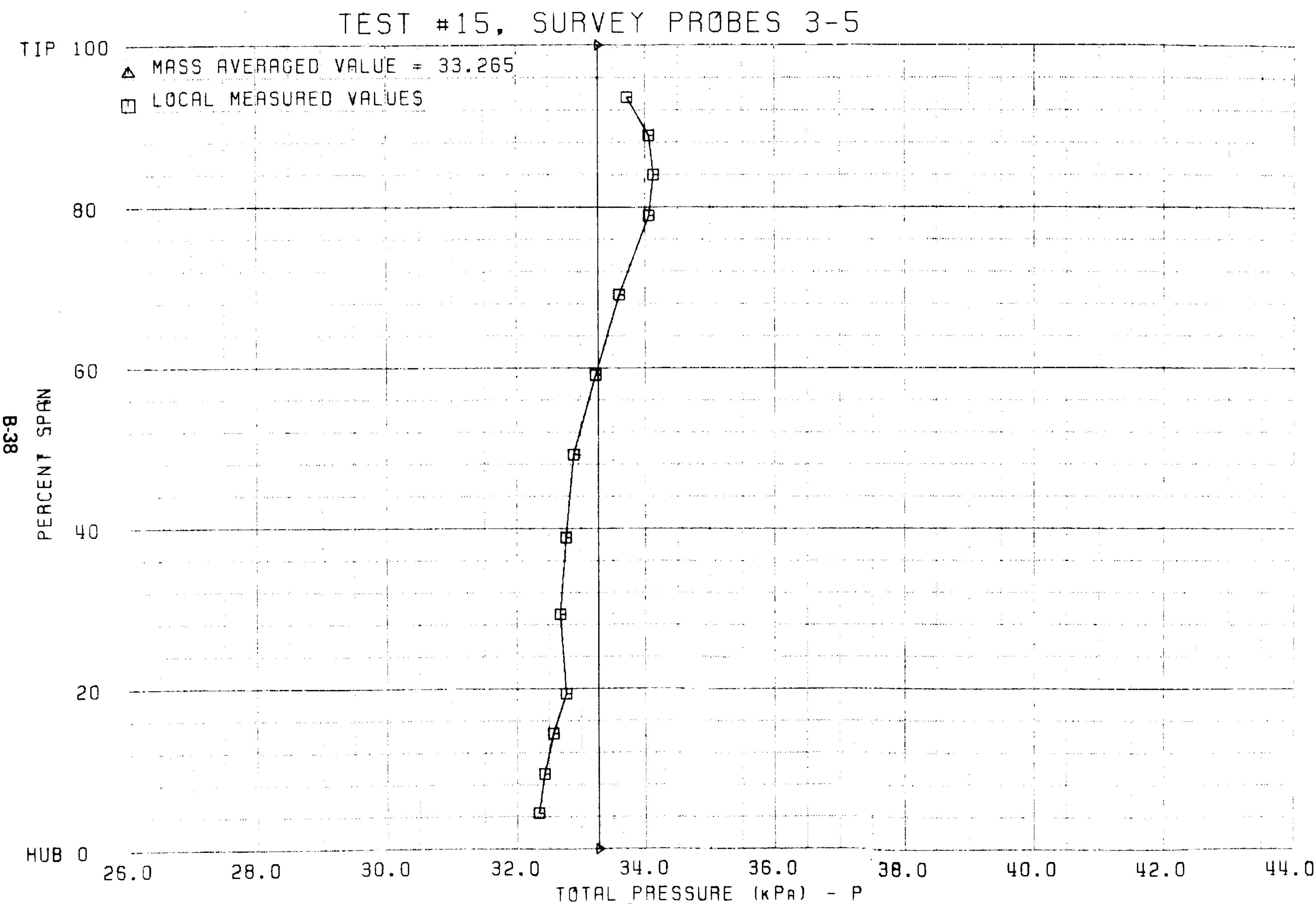

Figure B-38 Mixed Out Plane Survey - Total Pressure vs. Percent Rotor Exit Span, Test No. 15, Moveable Shroud, 62.5 Percent Area

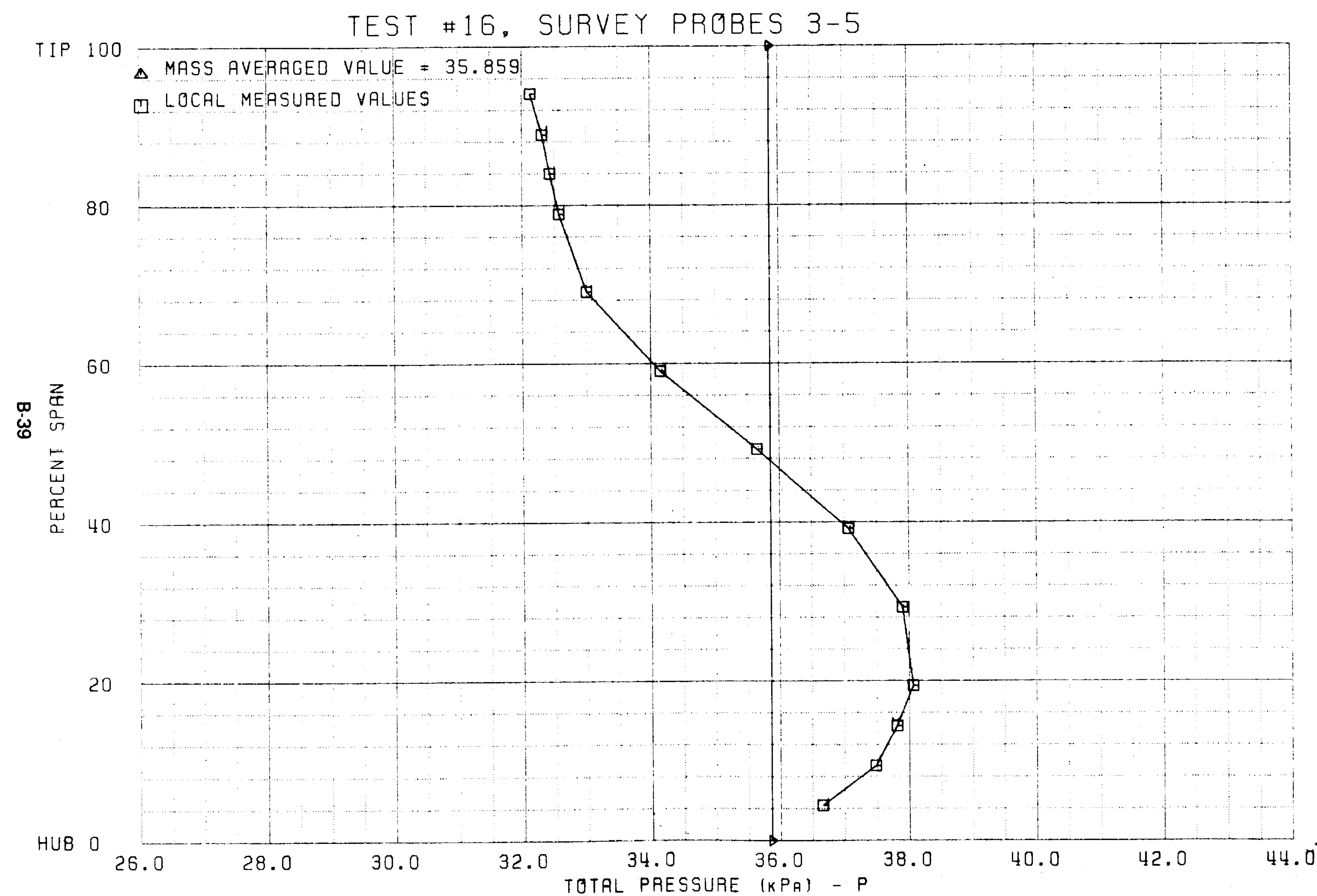

Figure B-39 Mixed Out Plane Survey - Total Pressure vs. Percent Rotor Exit Span, Test No. 16, Moveable Shroud, 62.5 Percent Area

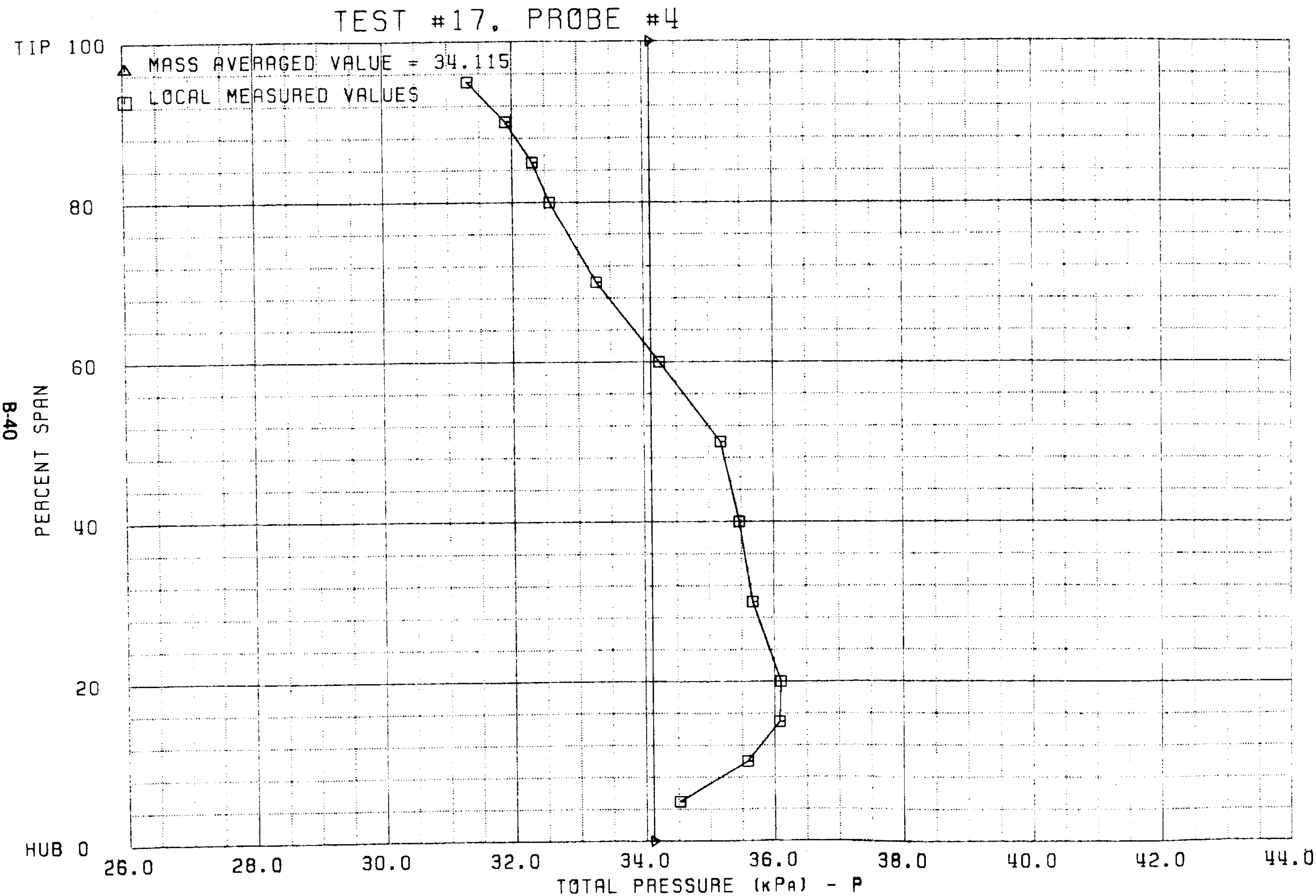

Figure B-40 Mixed Out Plane Survey - Total Pressure vs. Percent Rotor Exit Span, Test No. 17, Moveable Shroud, 125.0 Percent Area

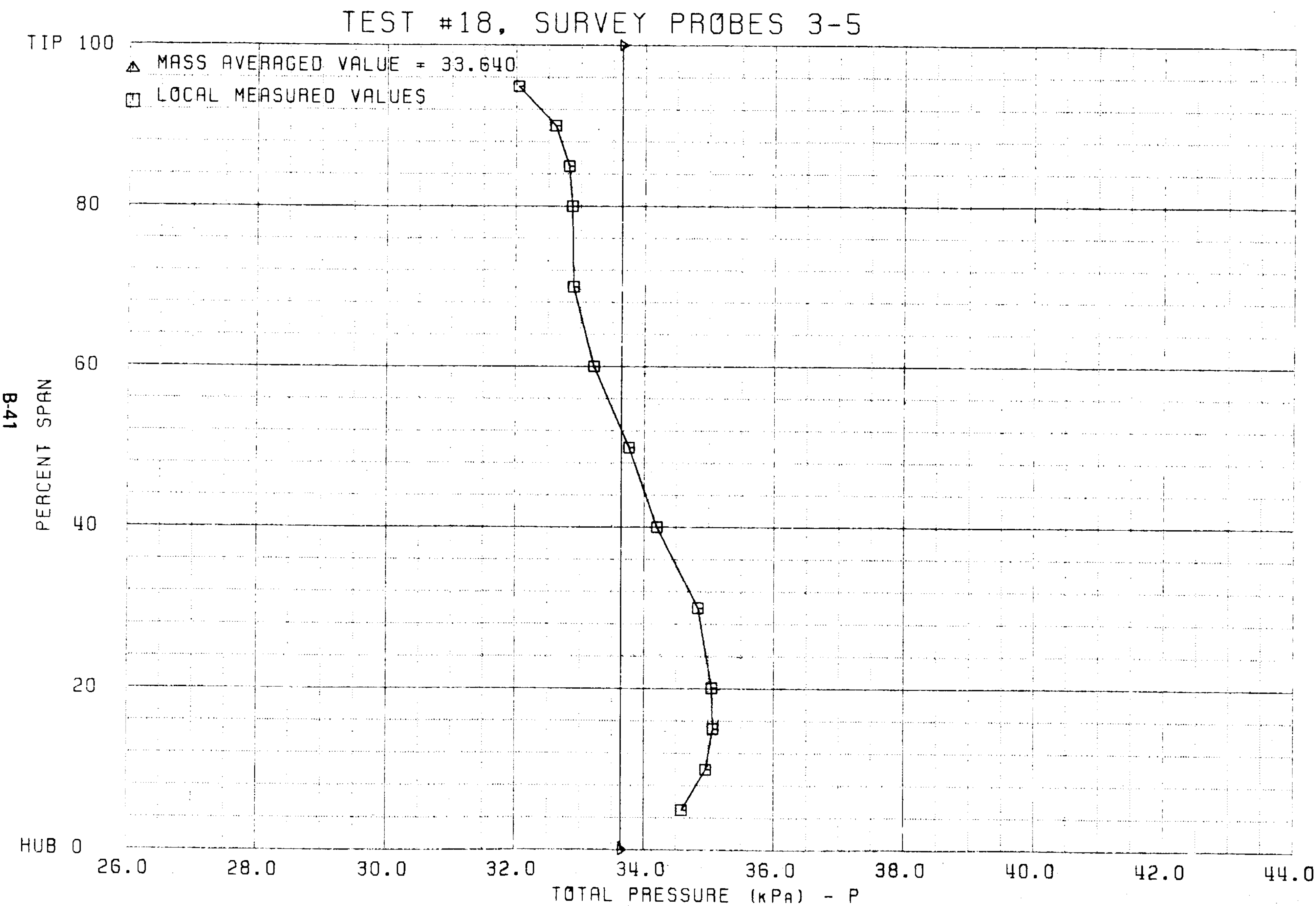

Figure B-41 Mixed Out Plane Survey - Total Pressure vs. Percent Rotor Exit Span, Test No. 18, Moveable Shroud, 100.0 Percent Area

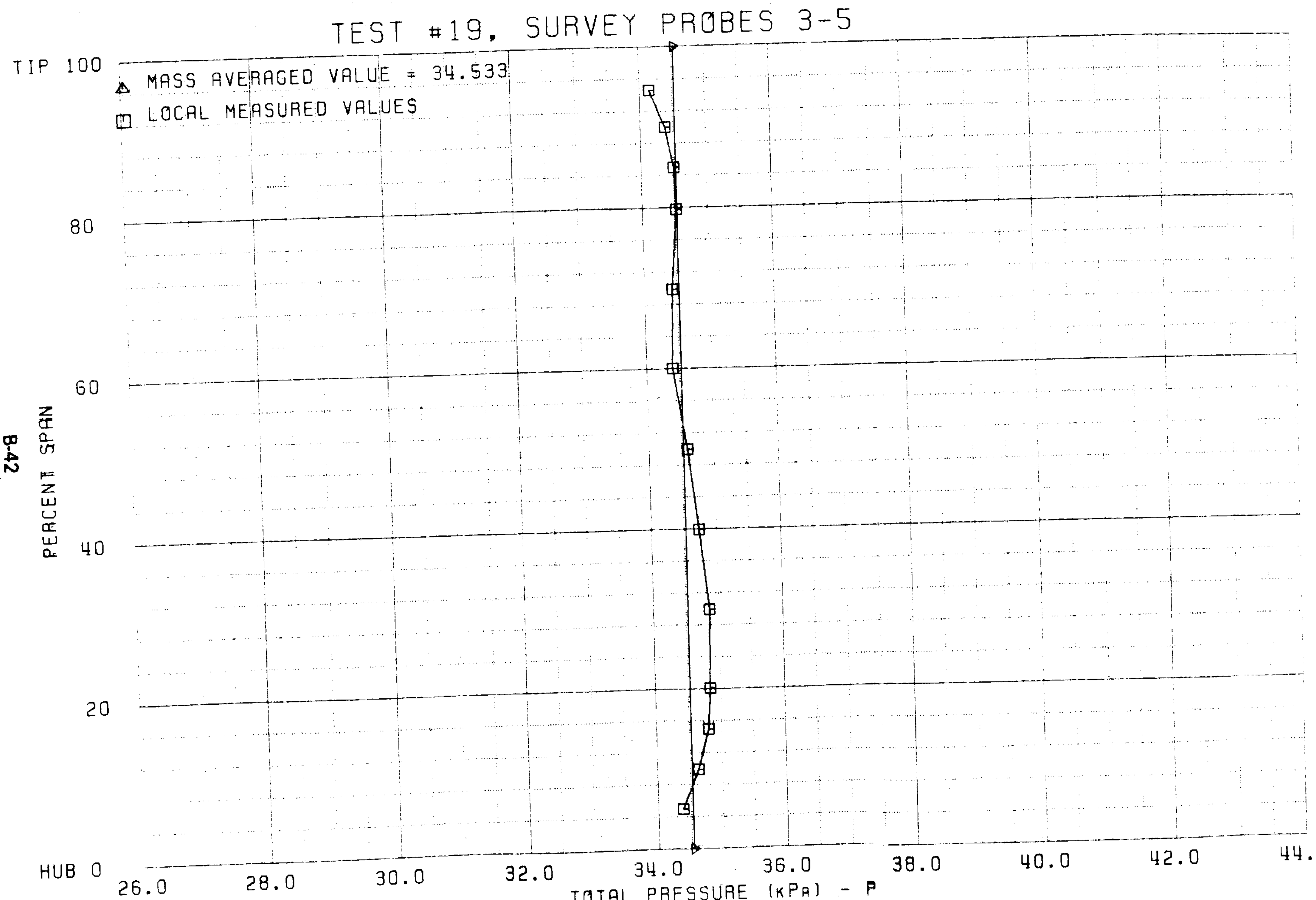

Figure B-42 Mixed Out Plane Survey - Total Pressure vs. Percent Rotor Exit Span, Test No. 19, Moveable Shroud, 81.1 Percent Area

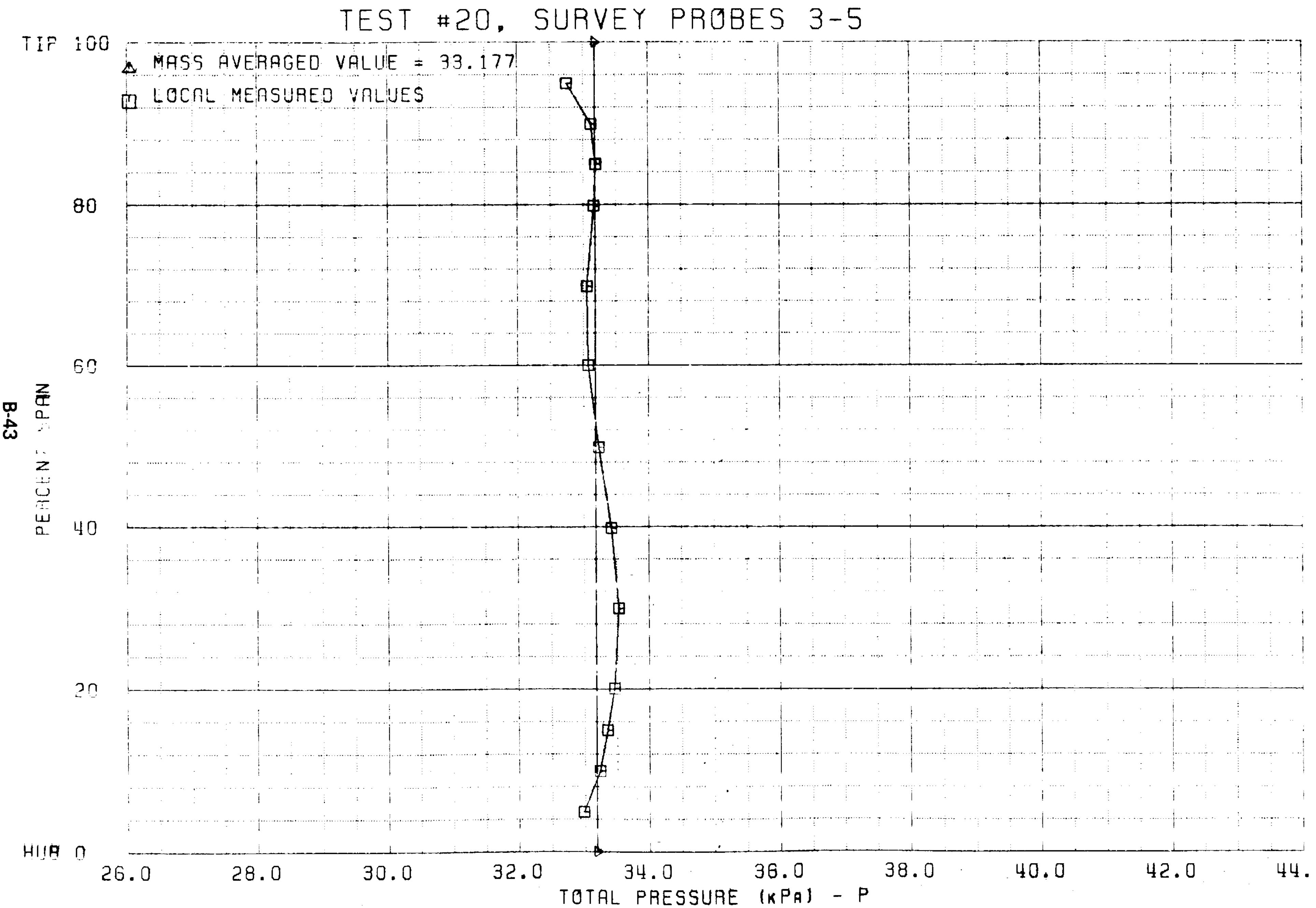

Figure B-43 Mixed Out Plane Survey - Total Pressure vs. Percent Rotor Exit Span, Test No. 20, Moveable Shroud, 81.1 Percent Area

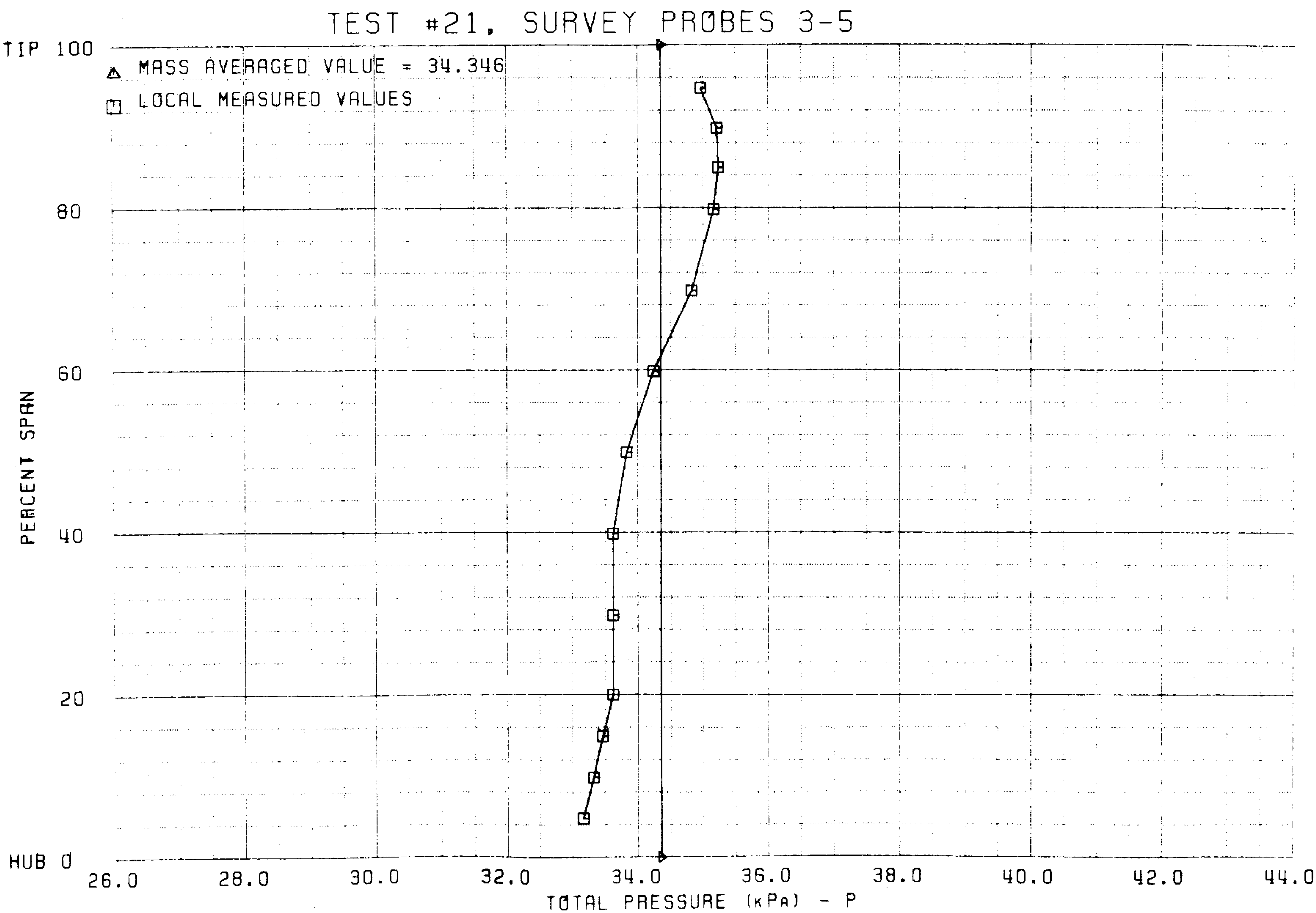

Figure B-44 Mixed Out Plane Survey - Total Pressure vs. Percent Rotor Exit Span, Test No. 21, Moveable Shroud, 62.5 Percent Area

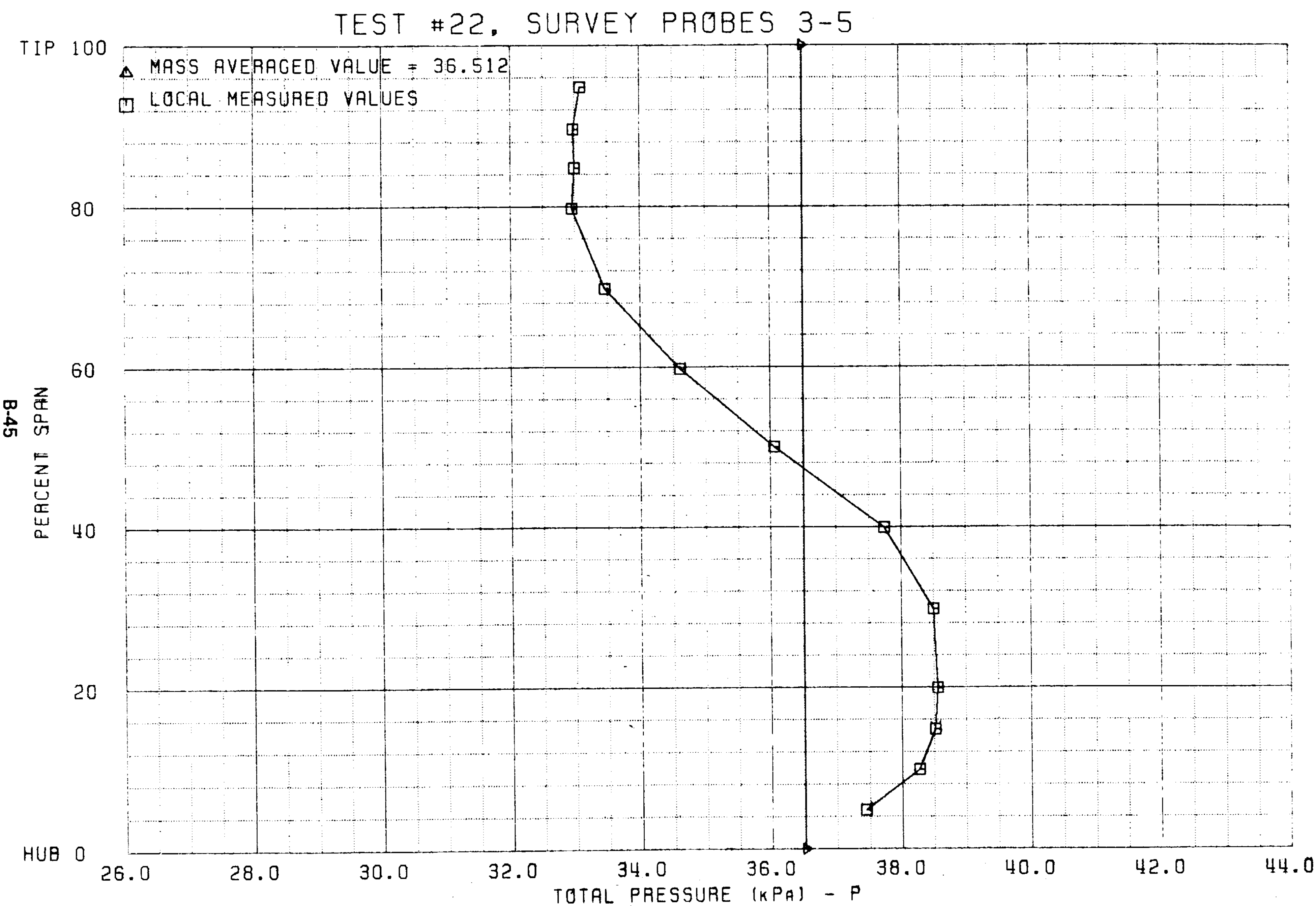

Figure B-45 Mixed Out Plane Survey - Total Pressure vs. Percent Rotor Exit Span, Test No. 22, Moveable Shroud, 62.5 Percent Area

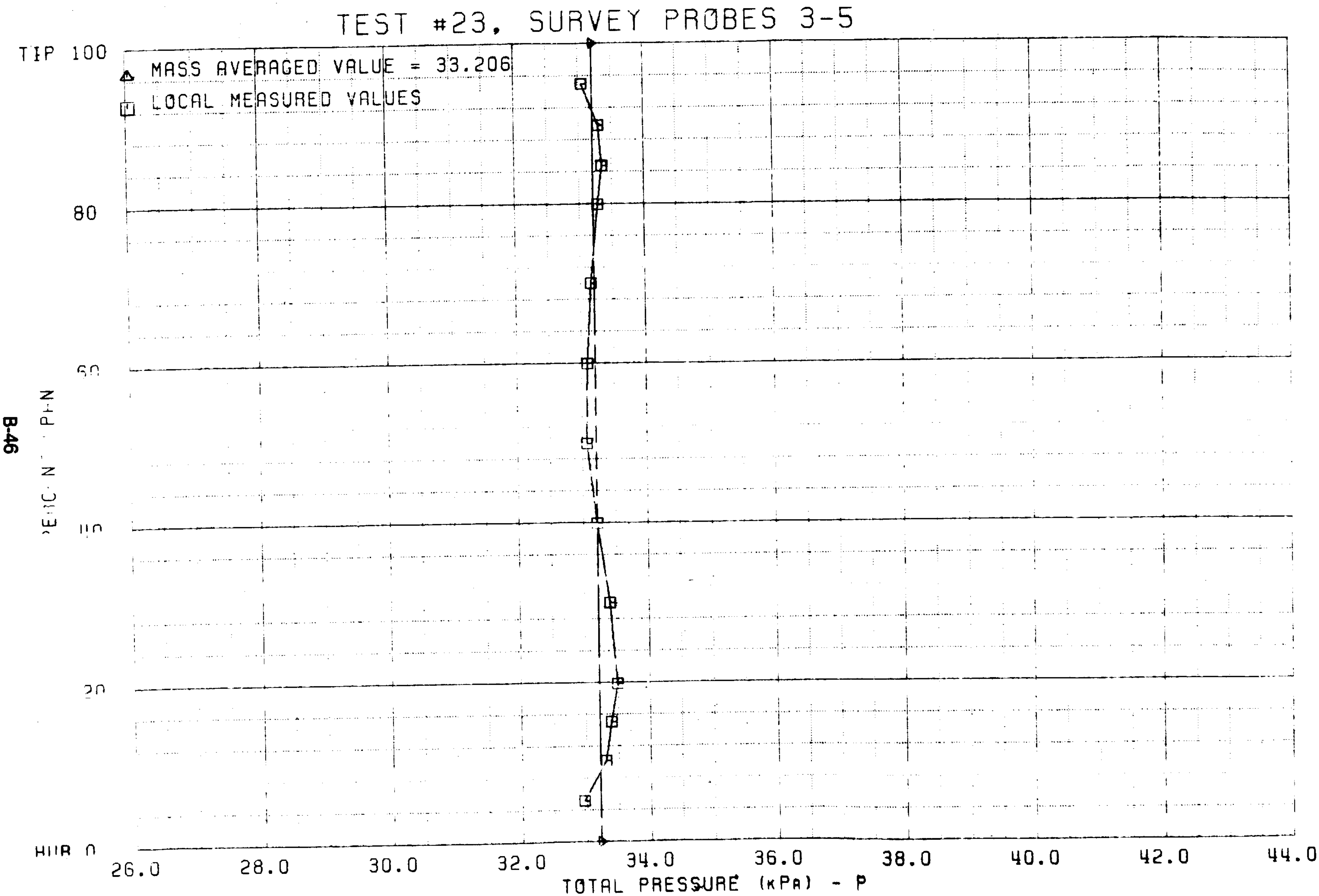

Figure B-46 Mixed Out Plane Survey - Total Pressure vs. Percent Rotor Exit Span, Test No. 23, Moveable Shroud, 81.1 Percent Area

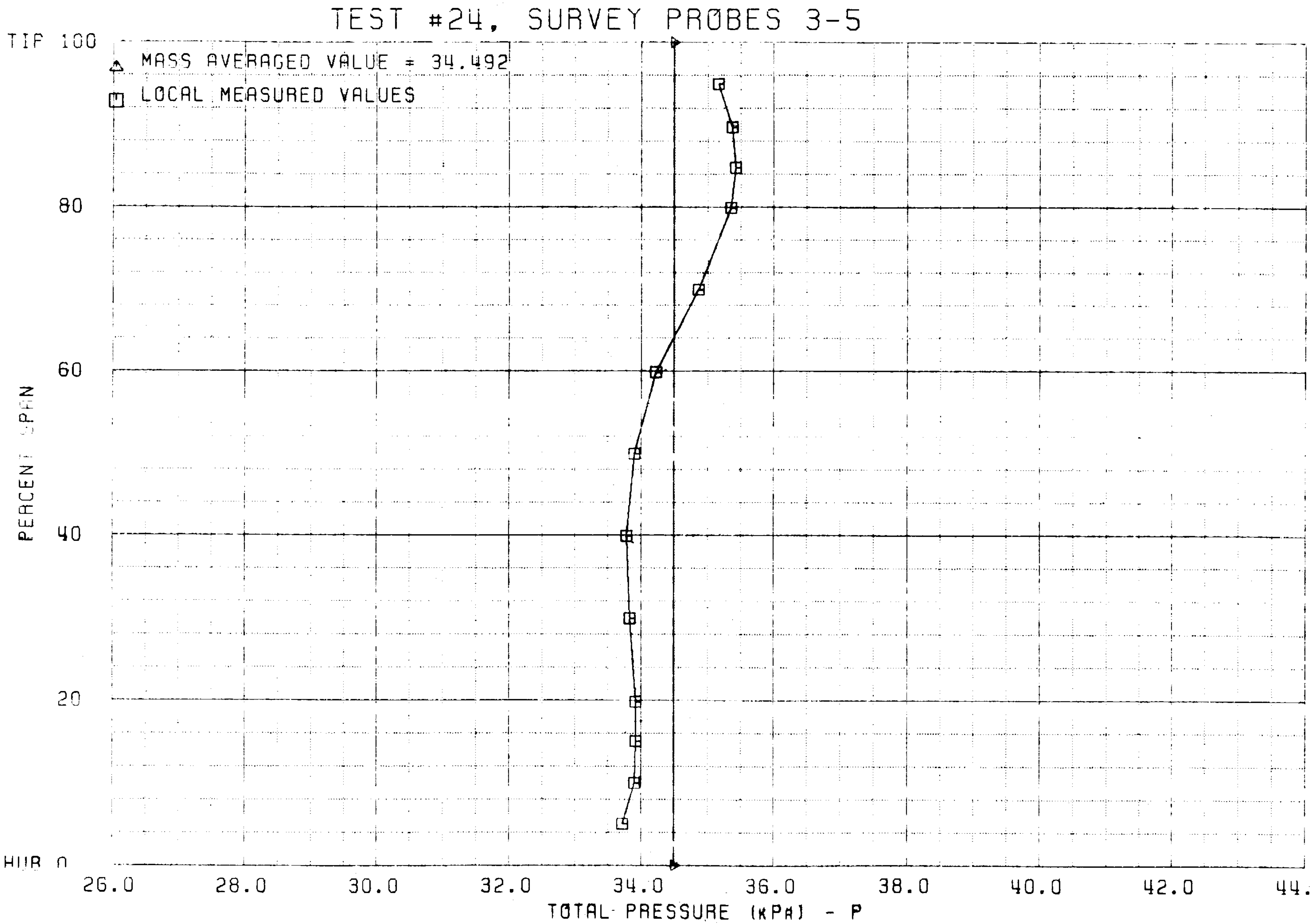

Figure B-47 Mixed Out Plane Survey - Total Pressure vs. Percent Rotor Exit Span, Test No. 24, Moveable Shroud, 62.5 Percent Area

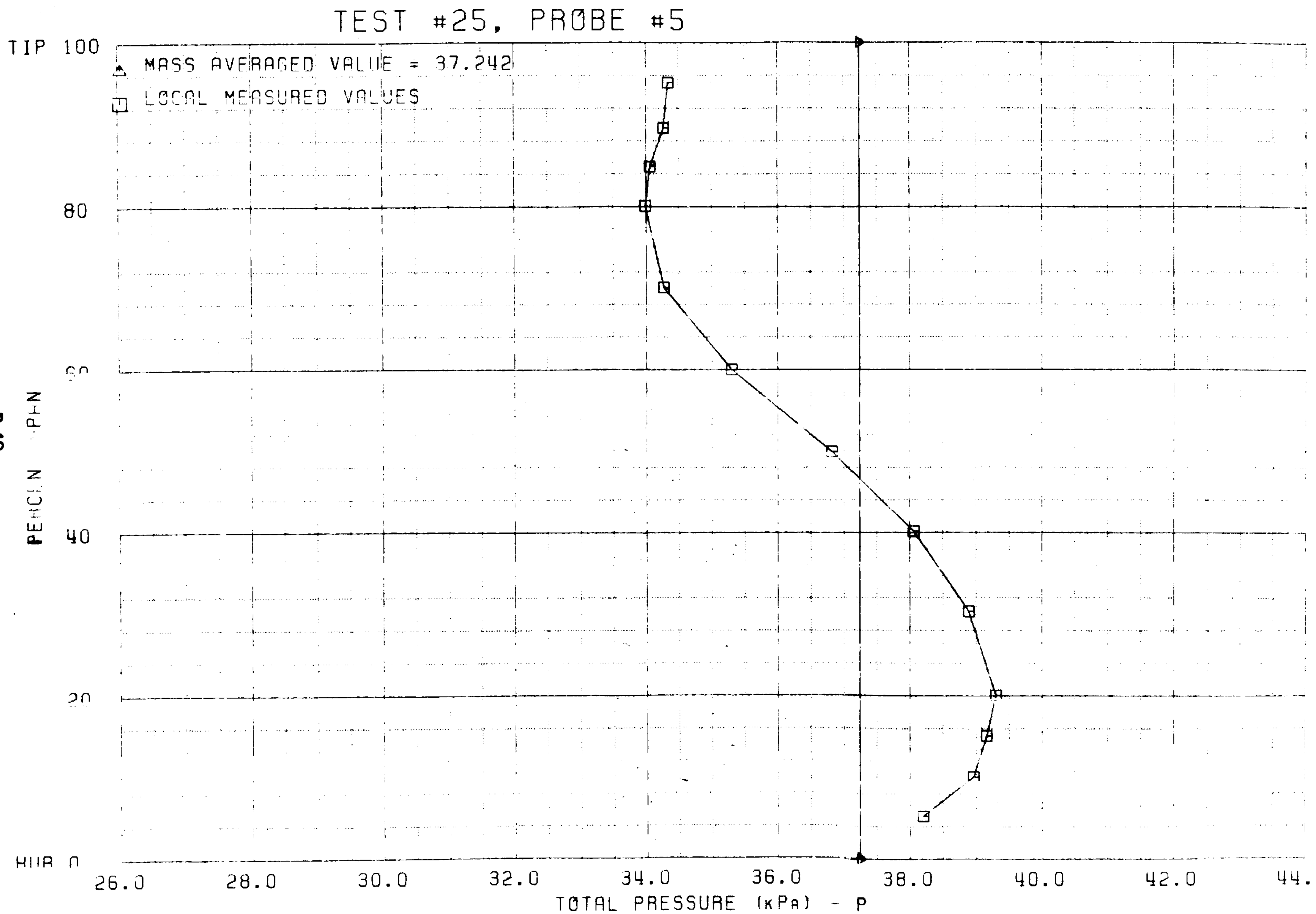

Figure B-48 Mixed Out Plane Survey - Total Pressure vs. Percent Rotor Exit Span, Test No. 25, Moveable Shroud, 62.5 Percent Area

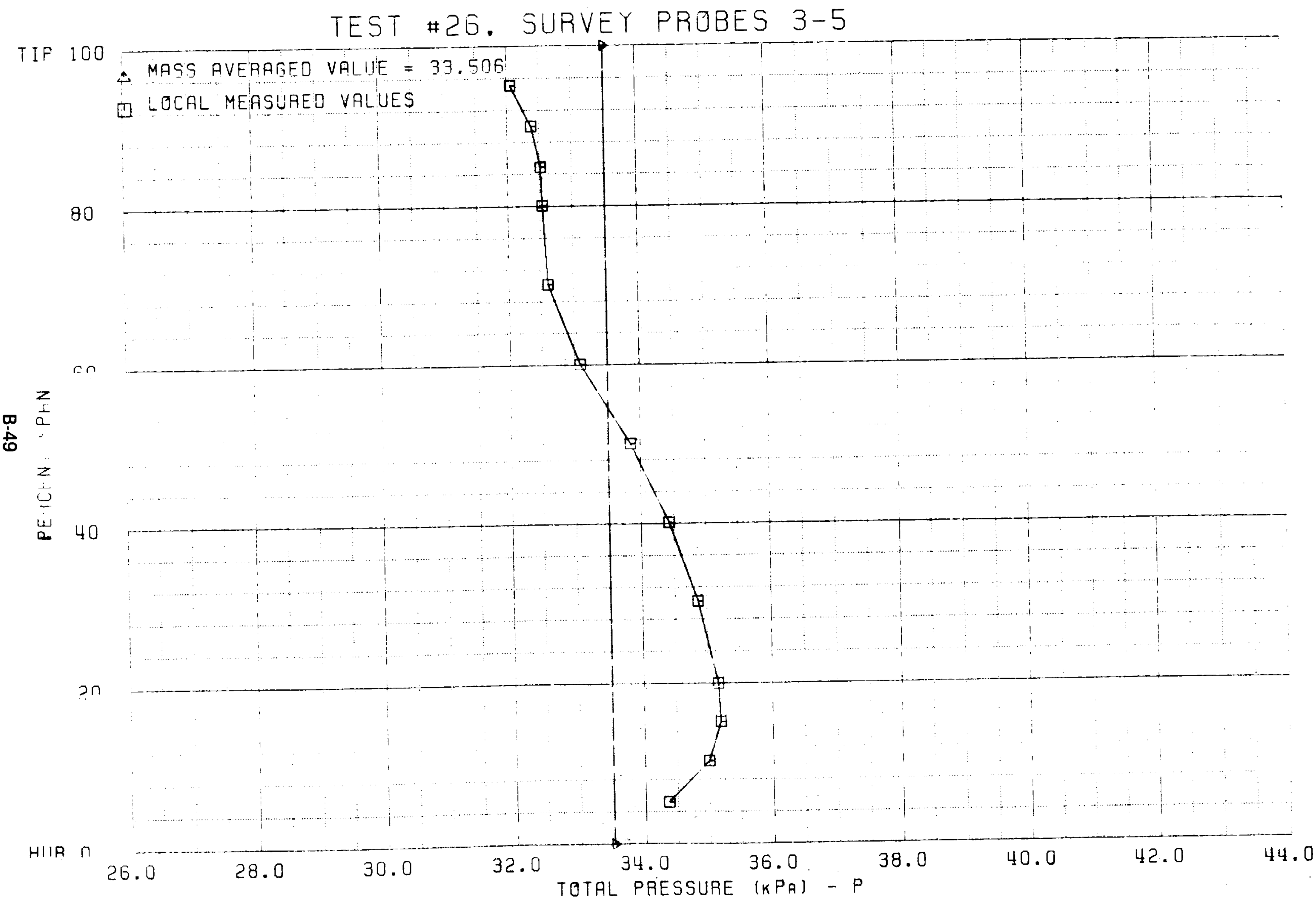

Figure B-49 Mixed Out Plane Survey - Total Pressure vs. Percent Rotor Exit Span, Test No. 26, Moveable Shroud, 103.5 Percent Area

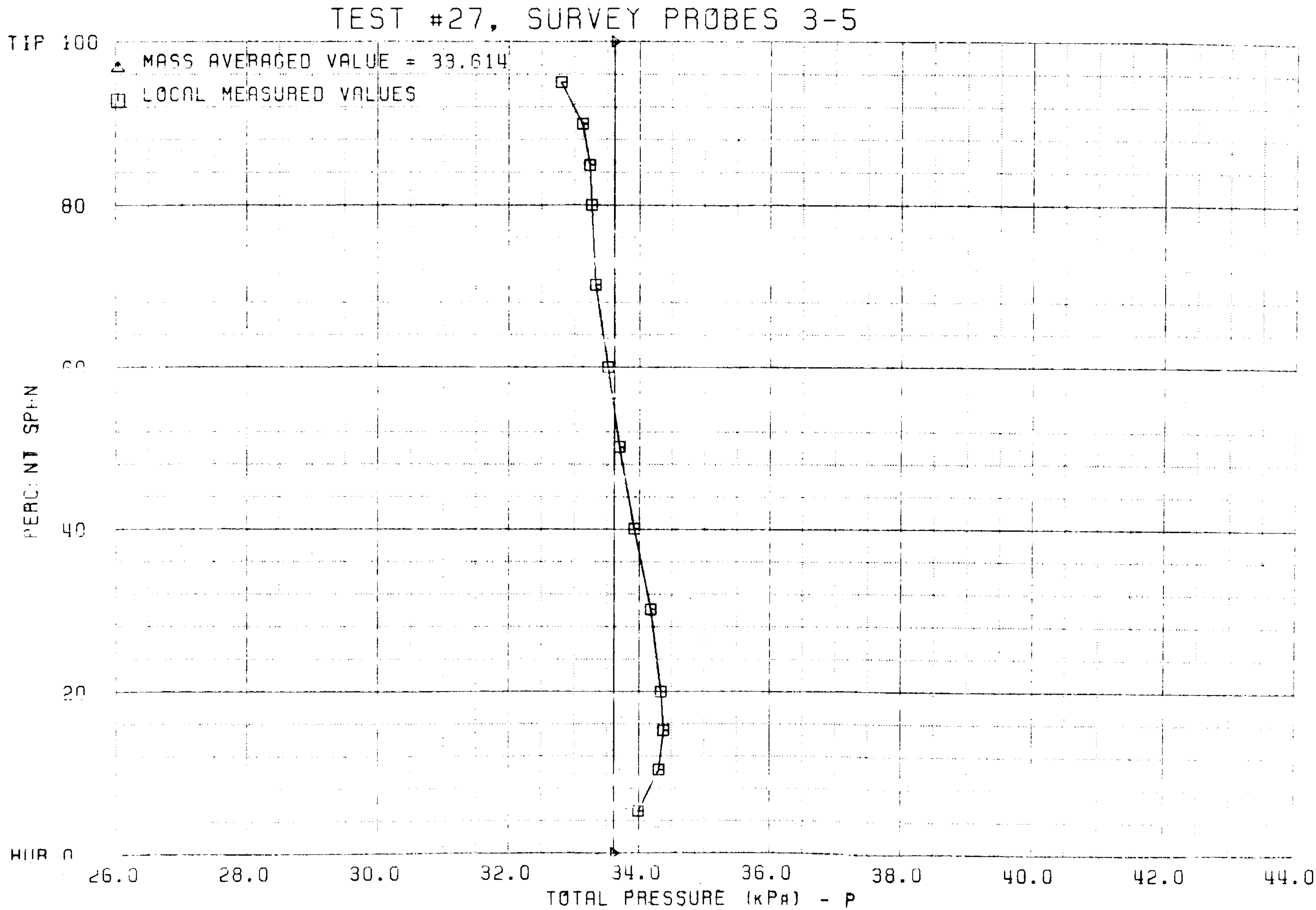

Figure B-50 Mixed Out Plane Survey - Total Pressure vs. Percent Rotor Exit Span, Test No. 27, Moveable Shroud, 84.6 Percent Area

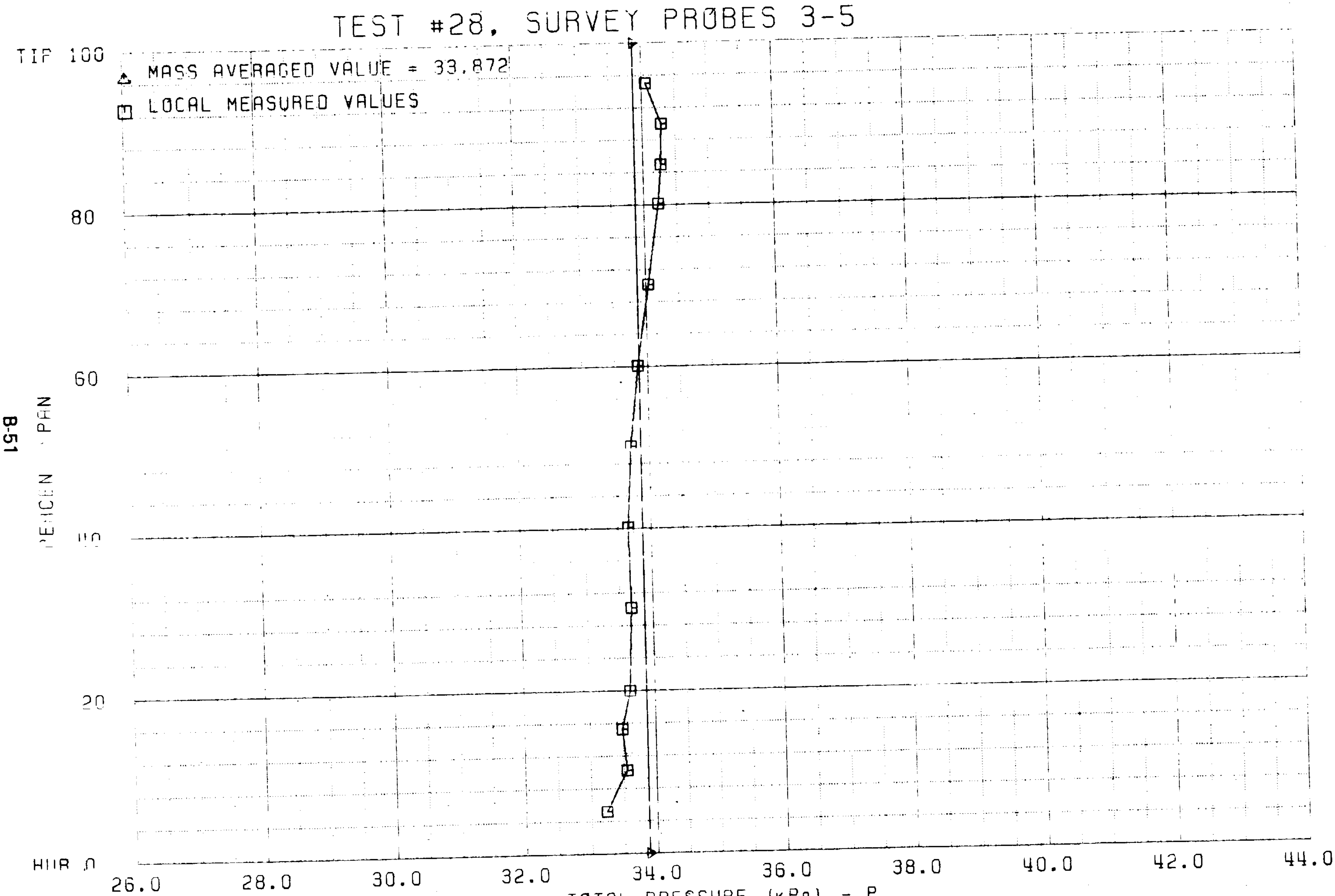

Figure B-51 Mixed Out Plane Survey - Total Pressure vs. Percent Rotor Exit Span, Test No. 28, Moveable Shroud, 66.0 Percent Area

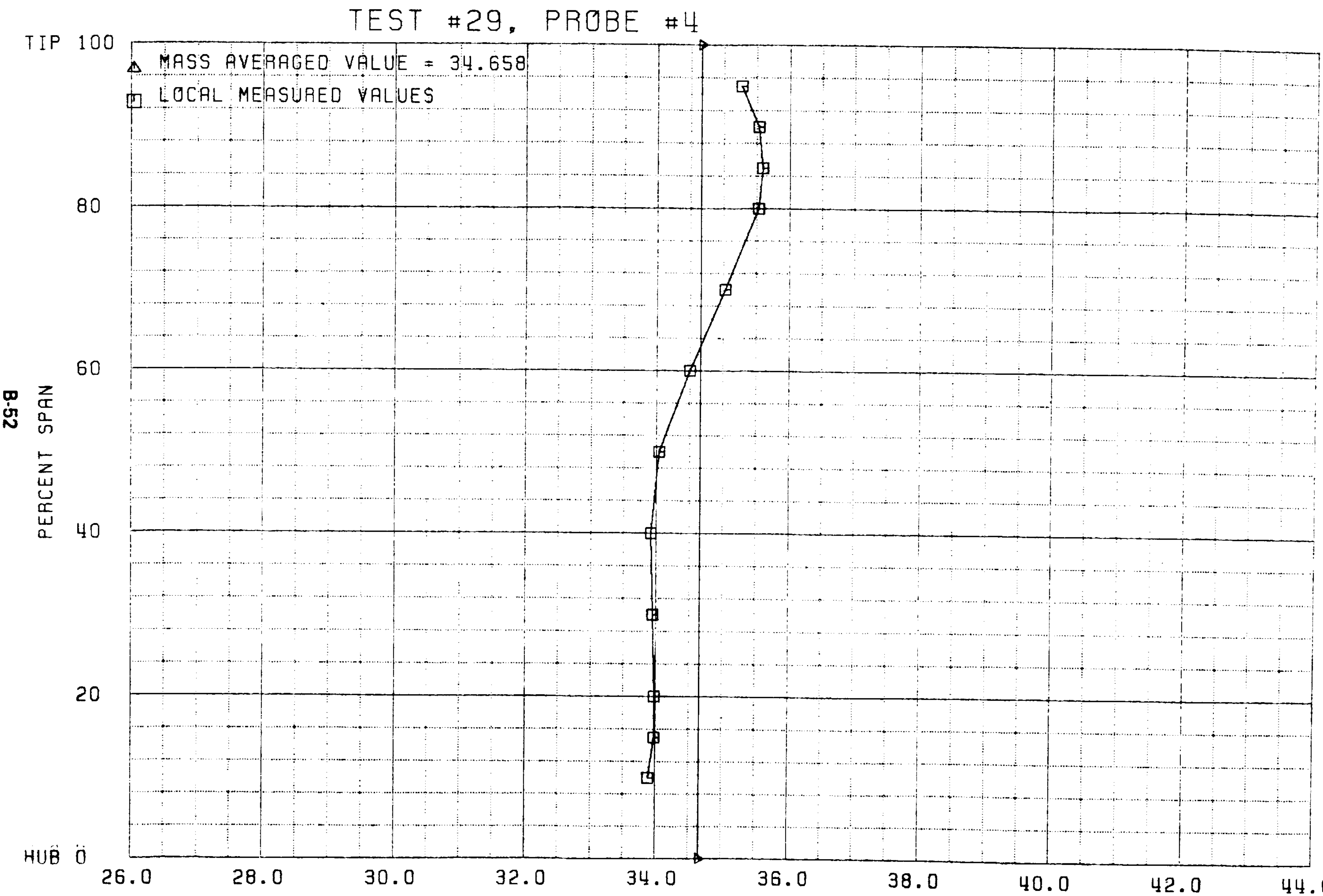

Figure B-52 Mixed Out Plane Survey - Total Pressure vs. Percent Rotor Exit Span, Test No. 29, Moveable Shroud, 62.2 Percent Area

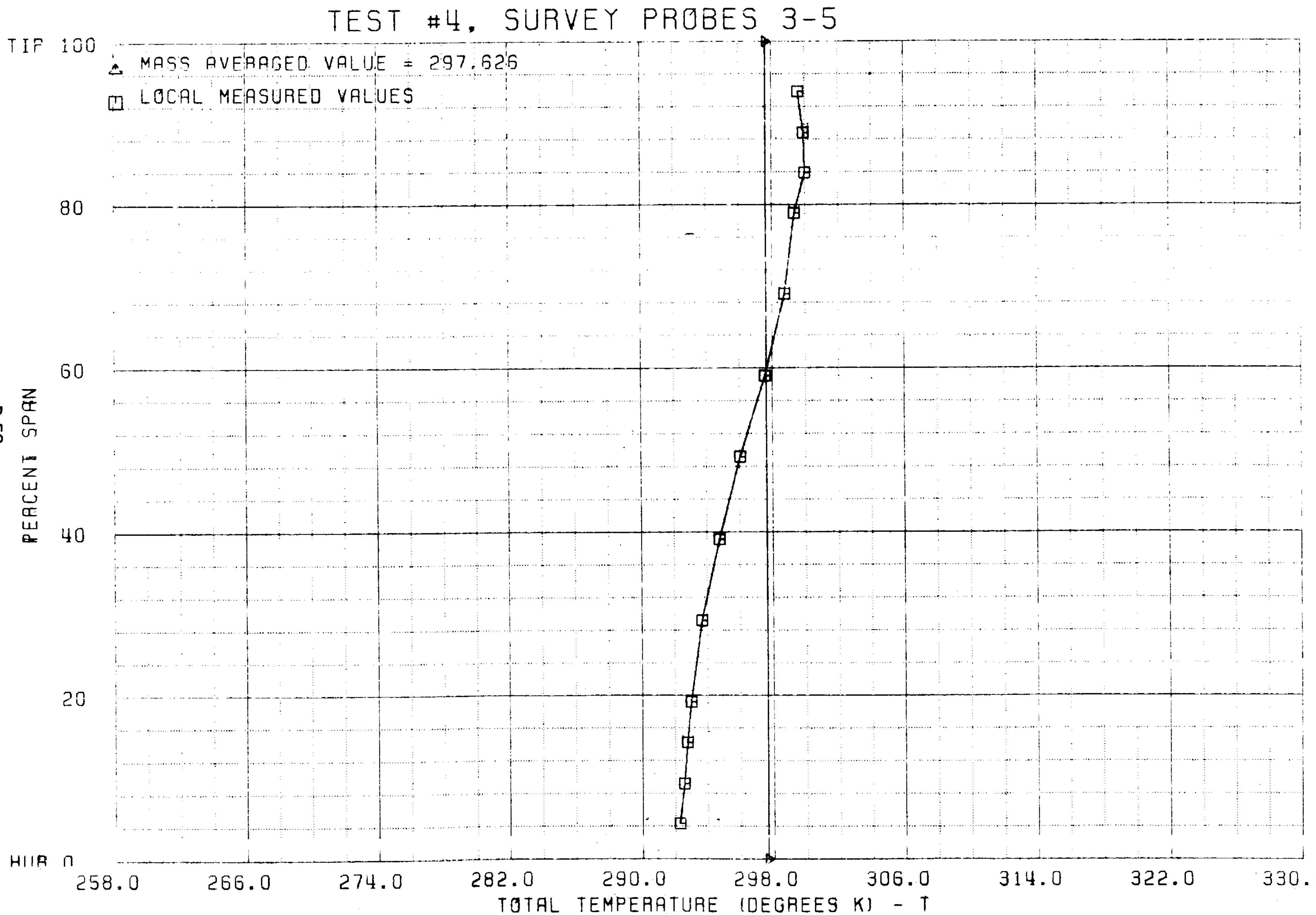

Figure B-53 Mixed Out Plane Survey - Total Temperature vs. Percent Rotor Exit Span, Test No. 4, Moveable Hub, 62.2 Percent Area

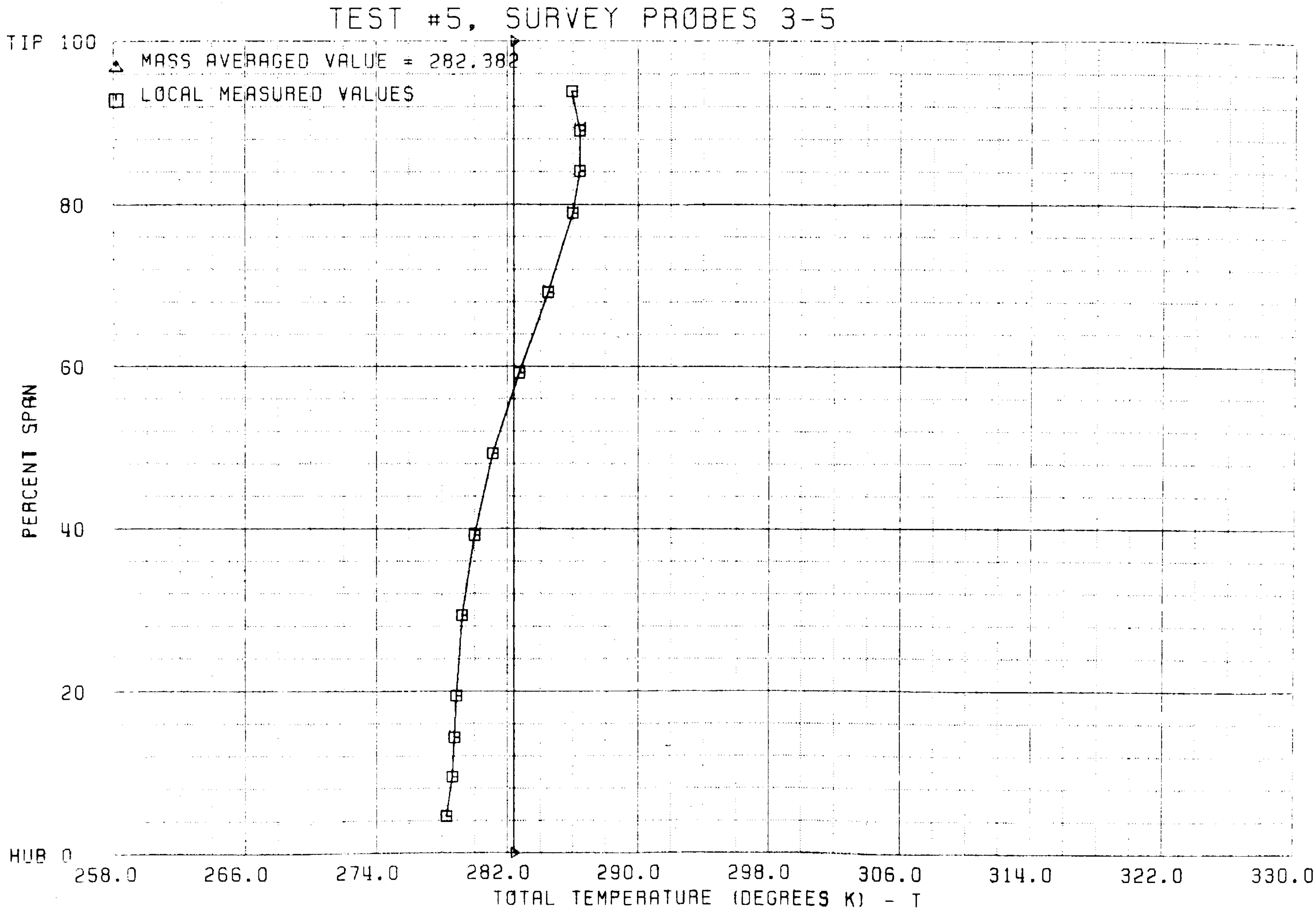

Figure B-54 Mixed Out Plane Survey - Total Temperature vs. Percent Rotor Exit Span, Test No. 5, Moveable Hub, 108.8 Percent Area

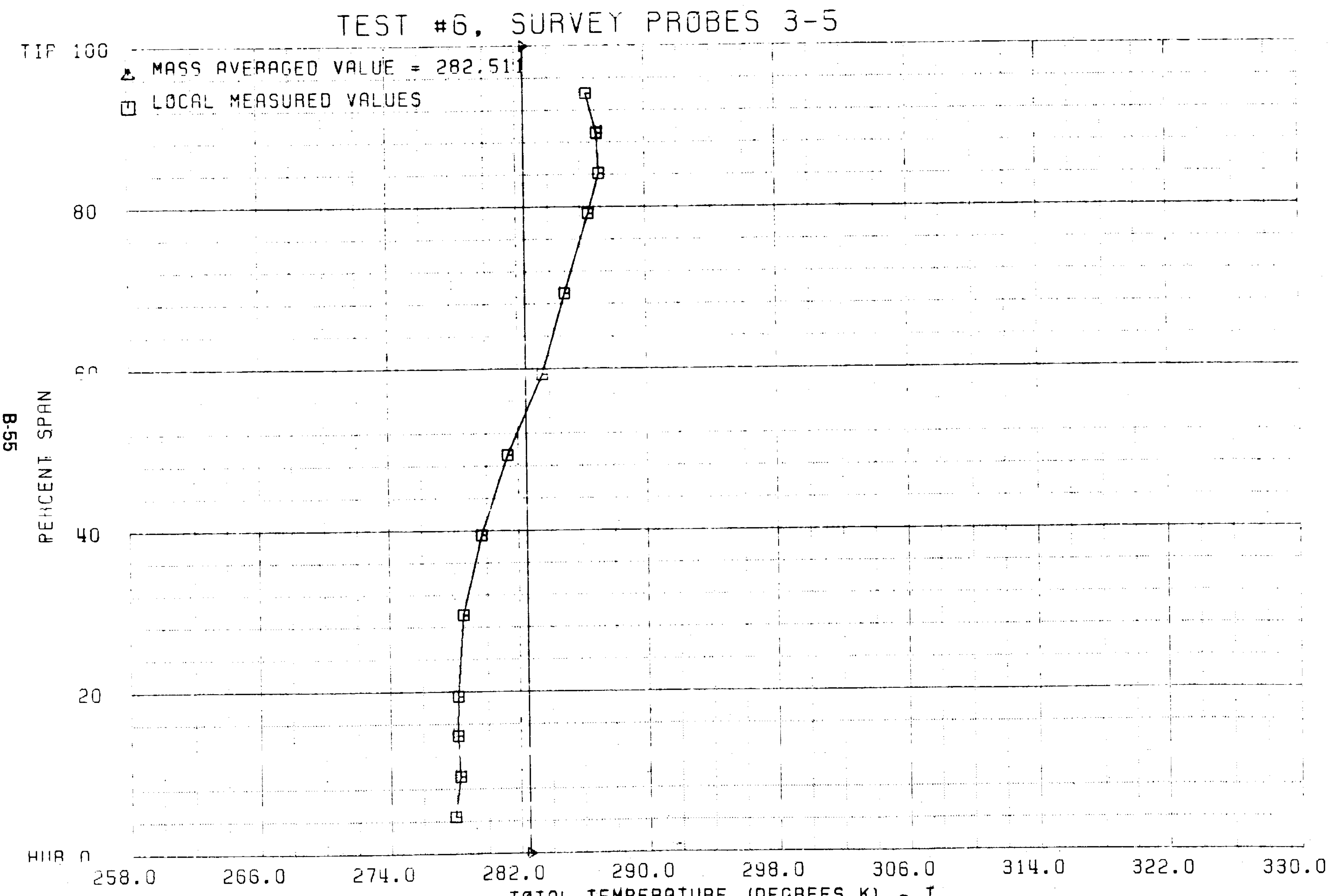

Figure B-55 Mixed Out Plane Survey - Total Temperature vs. Percent Rotor Exit Span, Test No. 6, Moveable Hub, 100.0 Percent Area

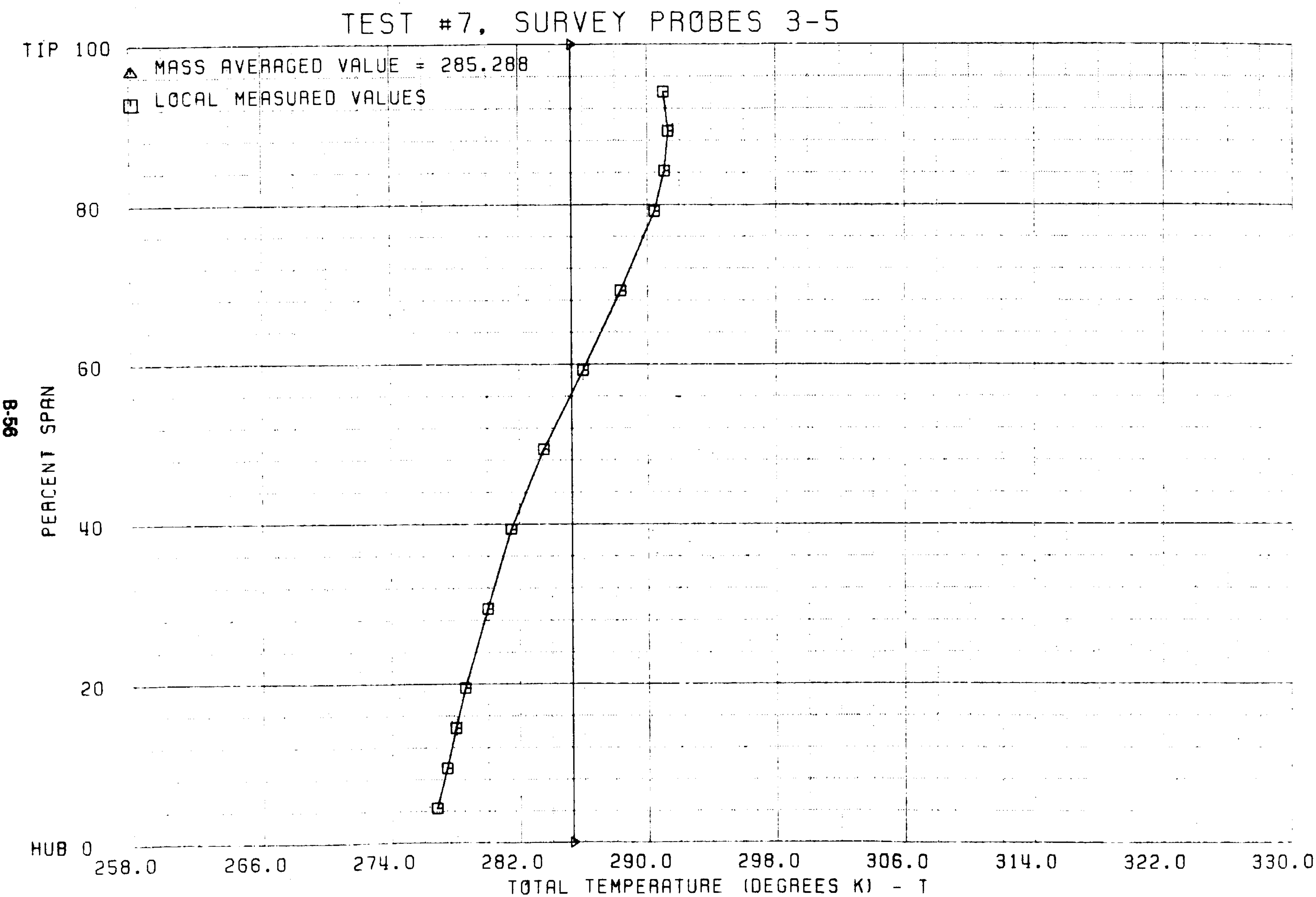

Figure B-56 Mixed Out Plane Survey - Total Temperature vs. Percent Rotor Exit Span, Test No. 7, Moveable Hub, 81.1 Percent Area

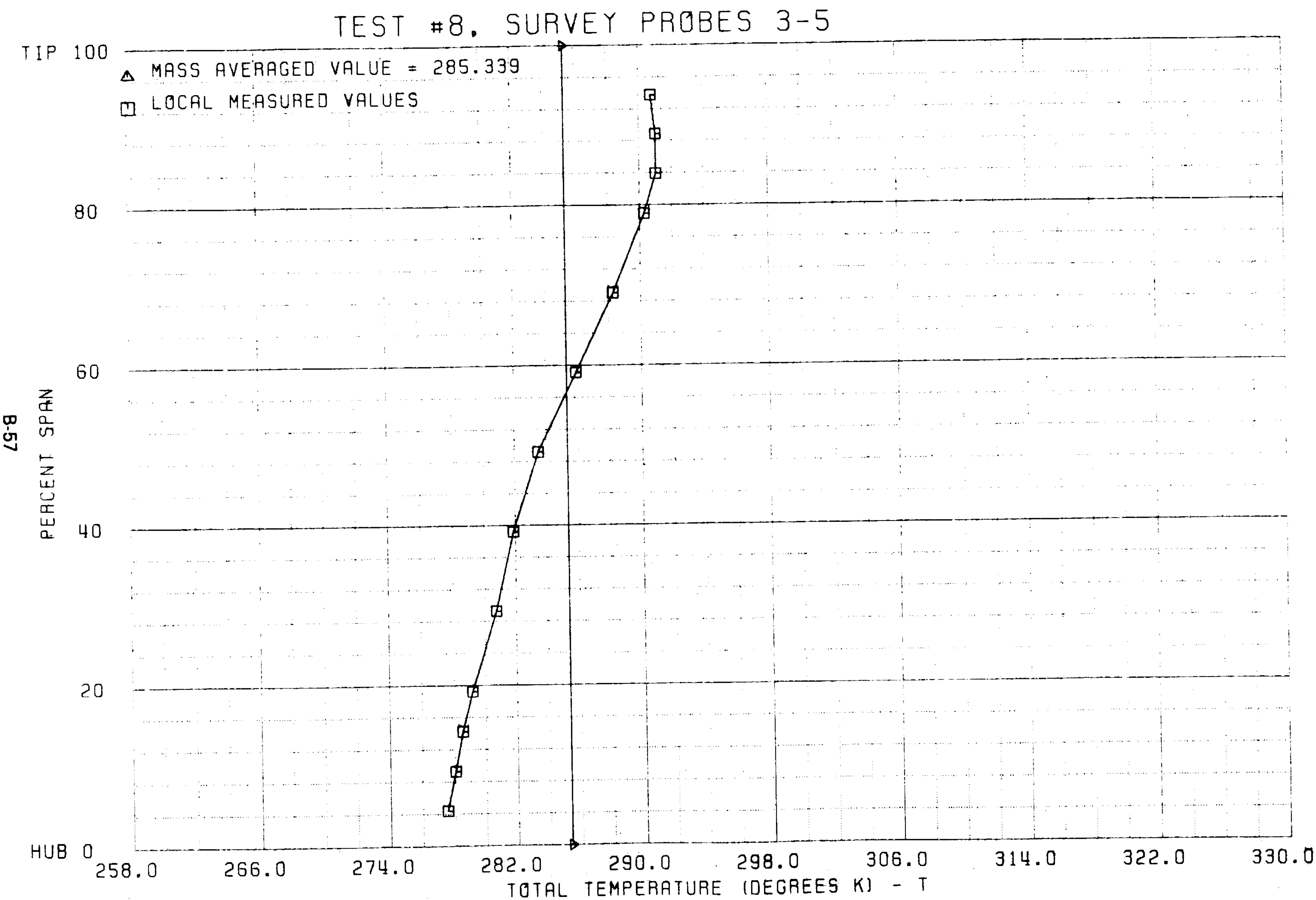

Figure B-57 Mixed Out Plane Survey - Total Temperature vs. Percent Rotor Exit Span, Test No. 8, Moveable Hub, 81.1 Percent Area

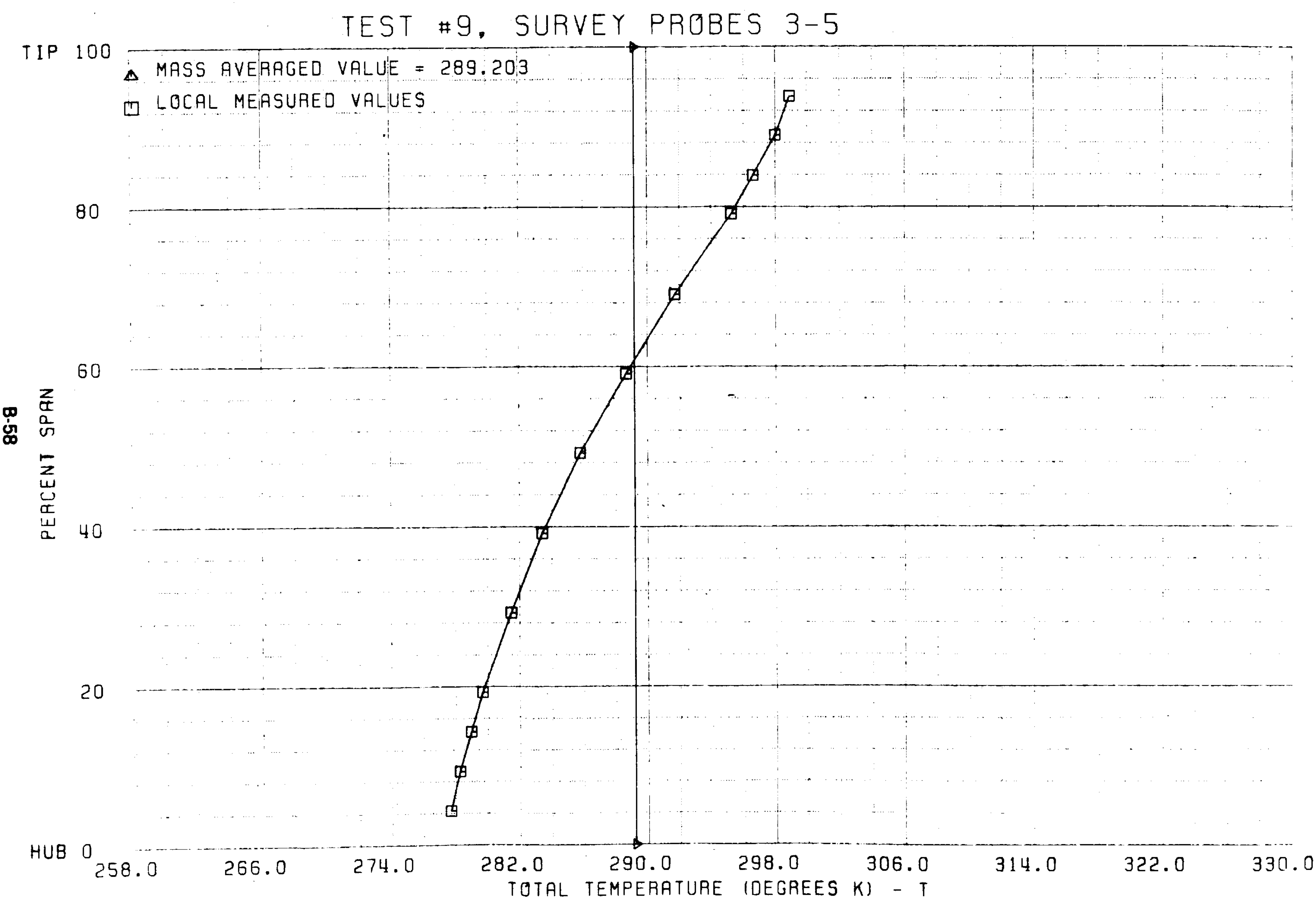

Figure B-58 Mixed Out Plane Survey - Total Temperature vs. Percent Rotor Exit Span, Test No. 9, Moveable Hub, 62.2 Percent Area

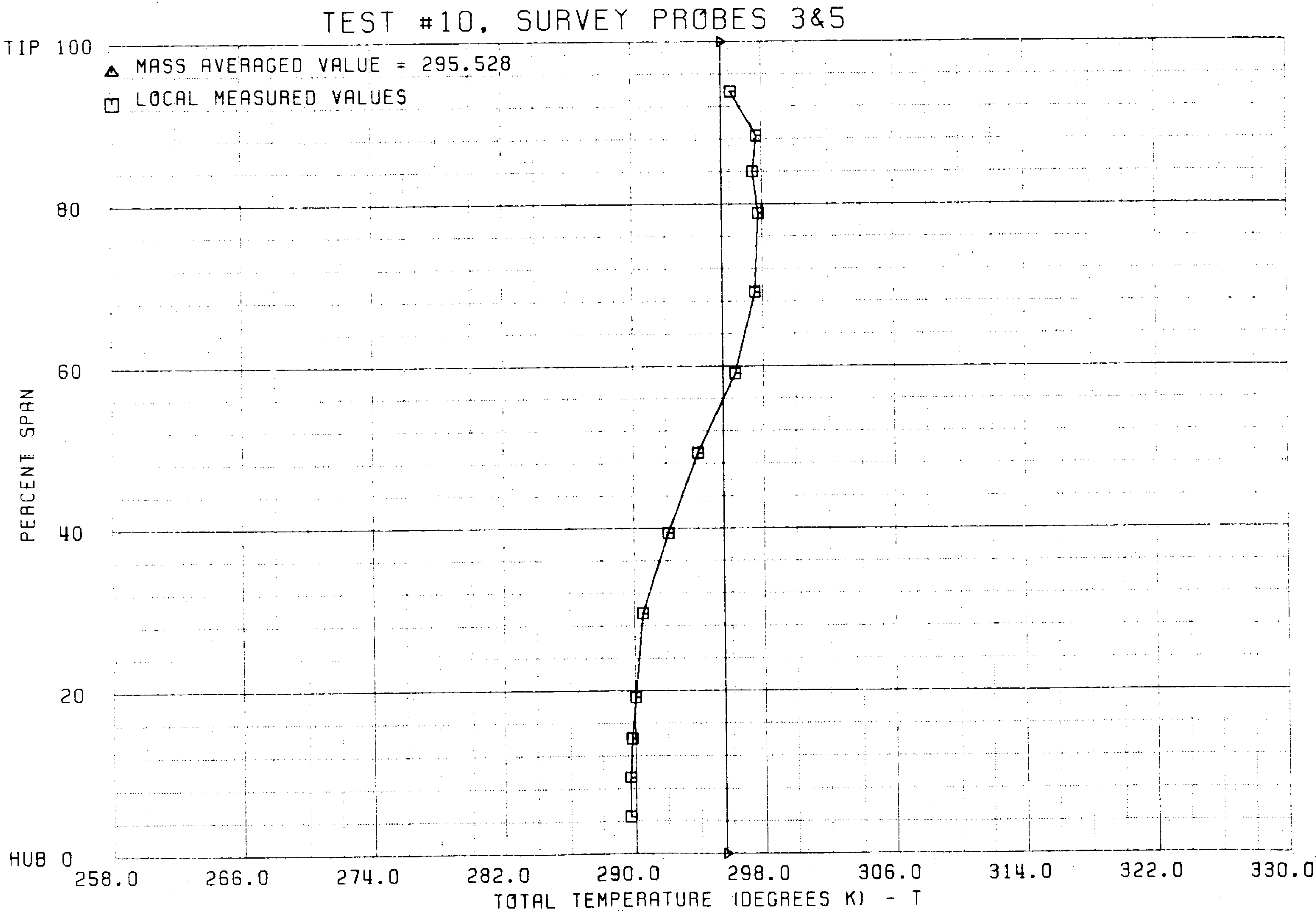

Figure B-59 Mixed Out Plane Survey - Total Temperature vs. Percent Rotor Exit Span, Test No. 10, Moveable Hub, 62.2 Percent Area

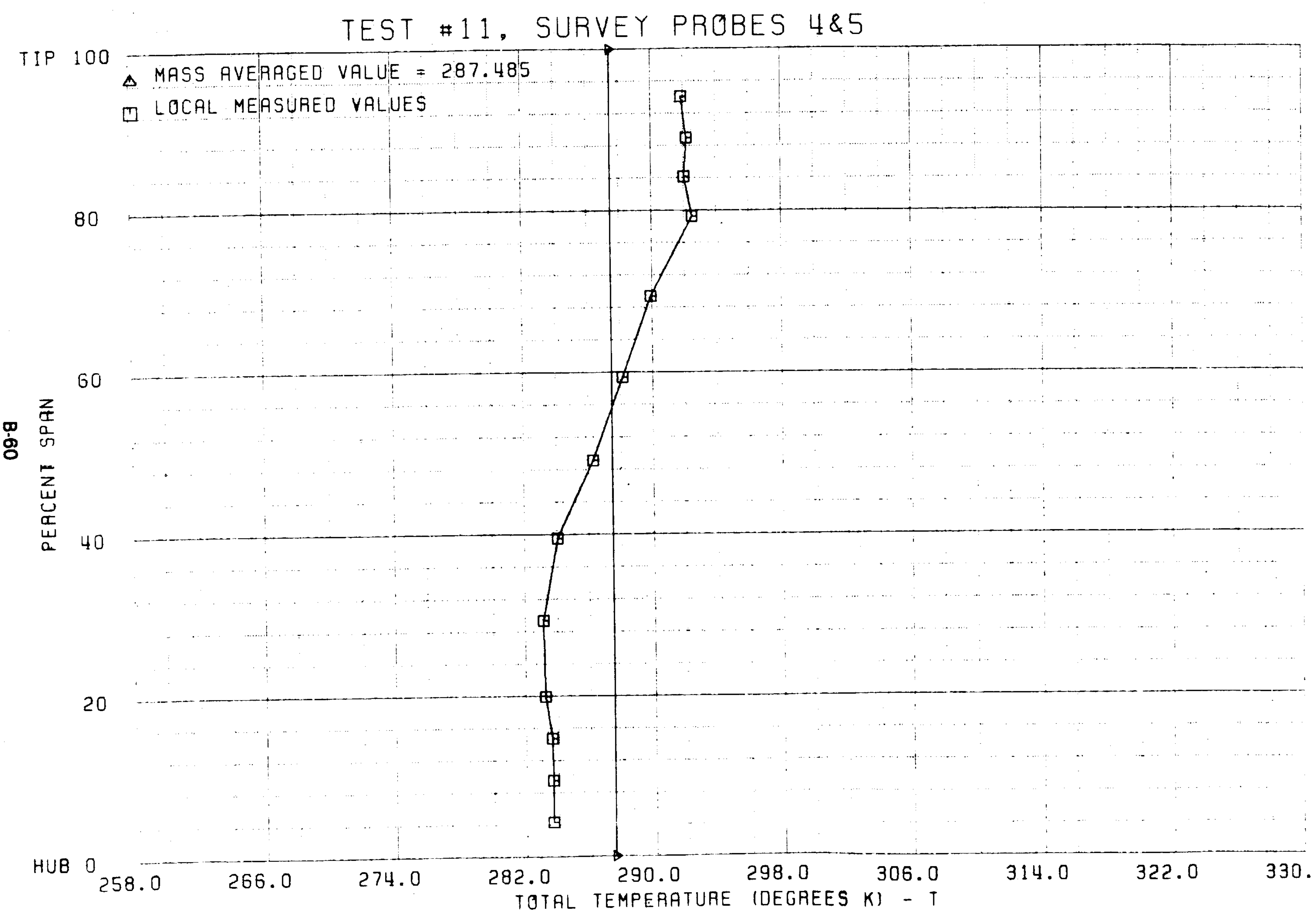

Figure B-60 Mixed Out Plane Survey - Total Temperature vs. Percent Rotor Exit Span, Test No. 11, Moveable Hub, 103.5 Percent Area

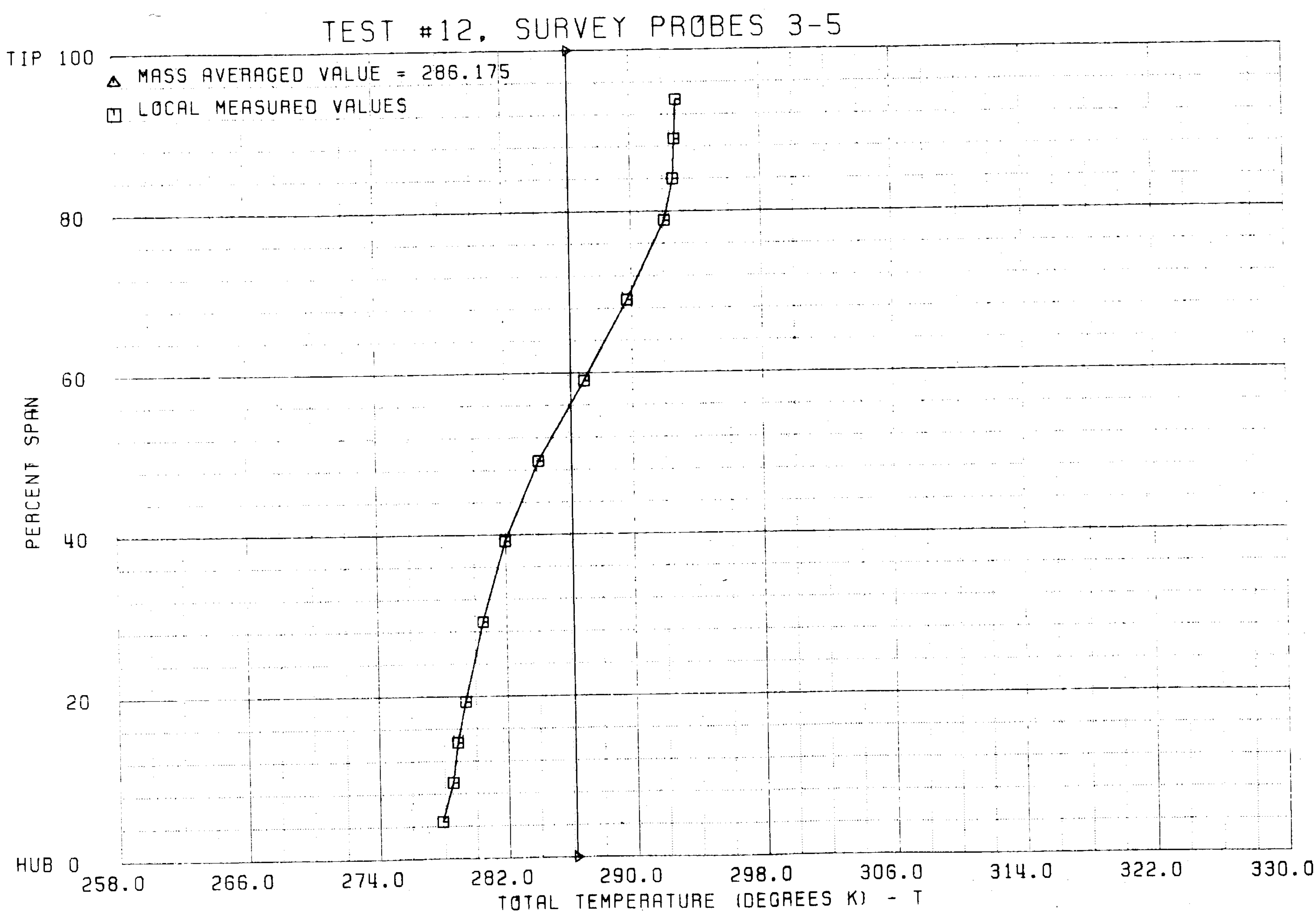

Figure B-61 Mixed Out Plane Survey - Total Temperature vs. Percent Rotor Exit Span, Test No. 12, Moveable Hub, 84.6 Percent Area

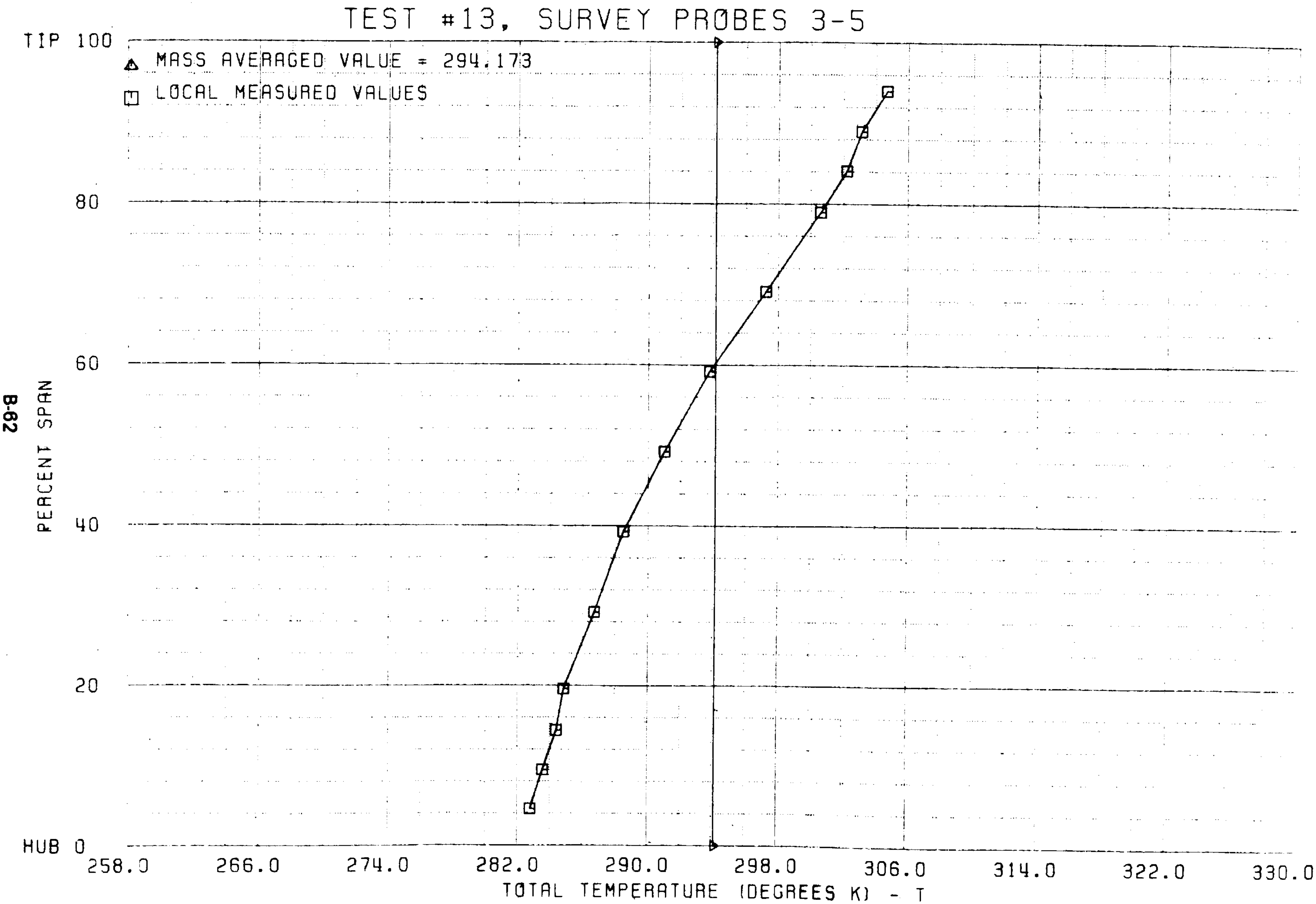

Figure B-62 Mixed Out Plane Survey - Total Temperature vs. Percent Rotor Exit Span, Test No. 13, Moveable Hub, 66.0 Percent Area

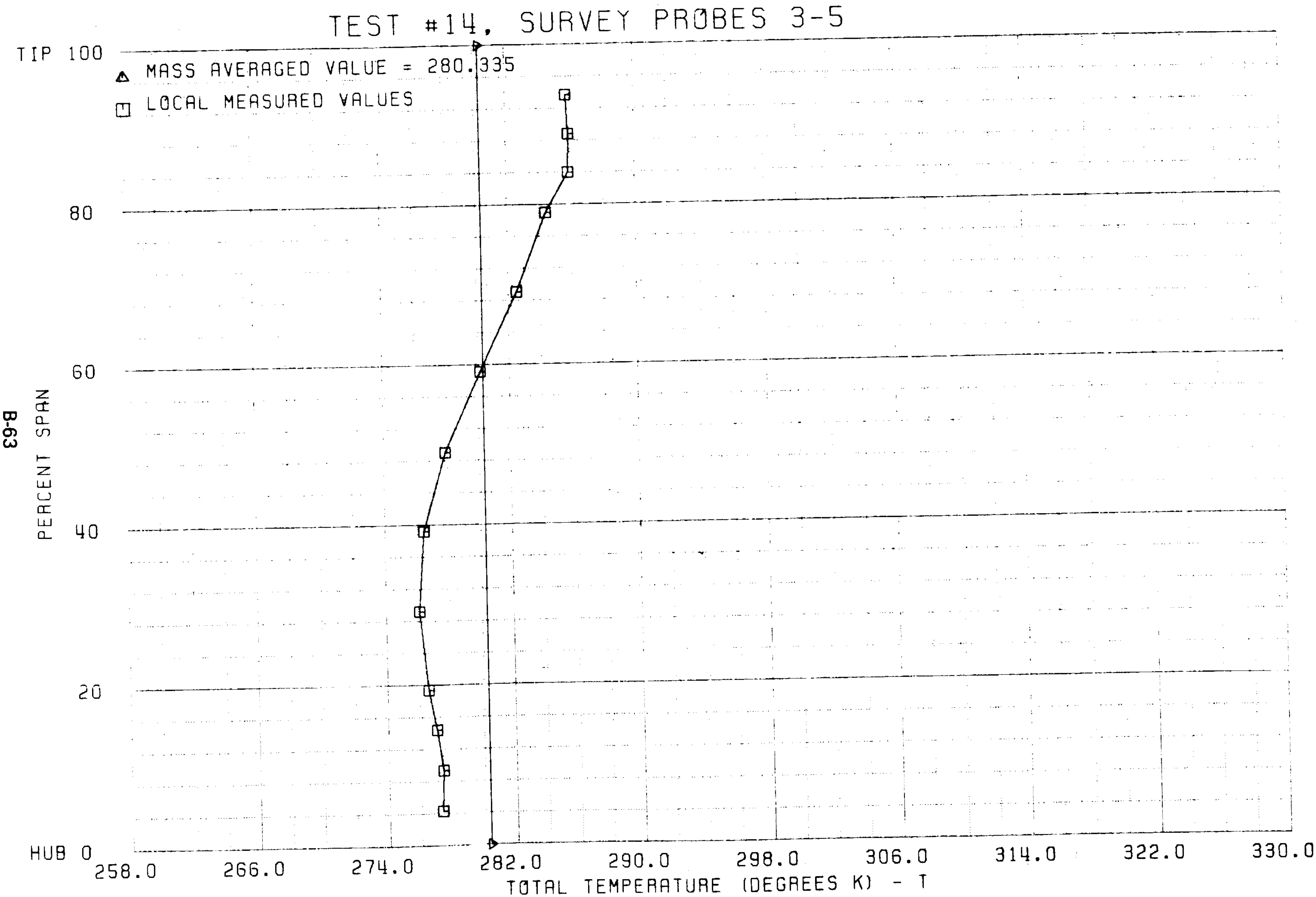

Figure B-63 Mixed Out Plane Survey - Total Temperature vs. Percent Rotor Exit Span, Test No. 14, Moveable Shroud, 81.1 Percent Area

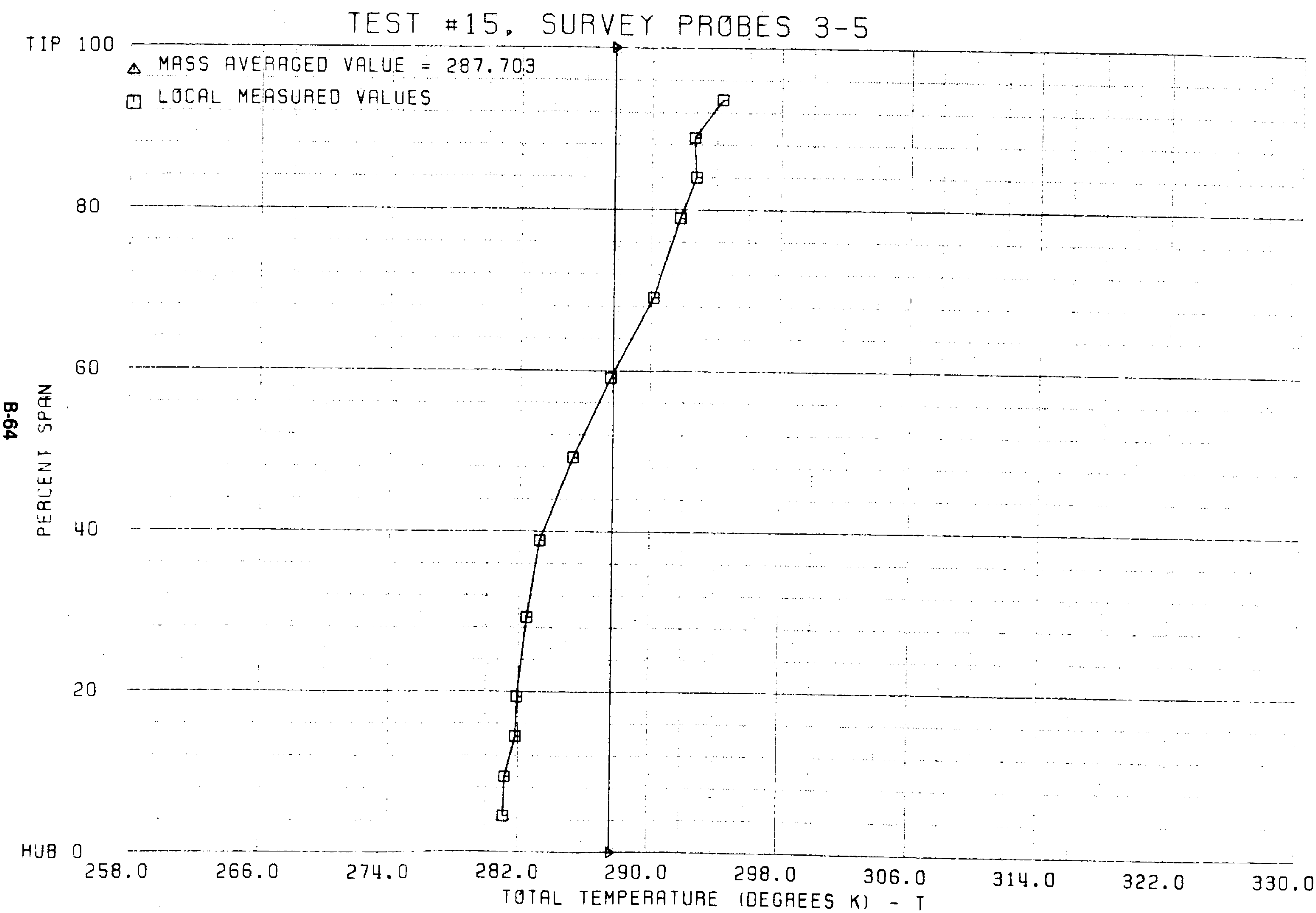

Figure B-64 Mixed Out Plane Survey - Total Temperature vs. Percent Rotor Exit Span, Test No. 15, Moveable Shroud, 62.5 Percent Area

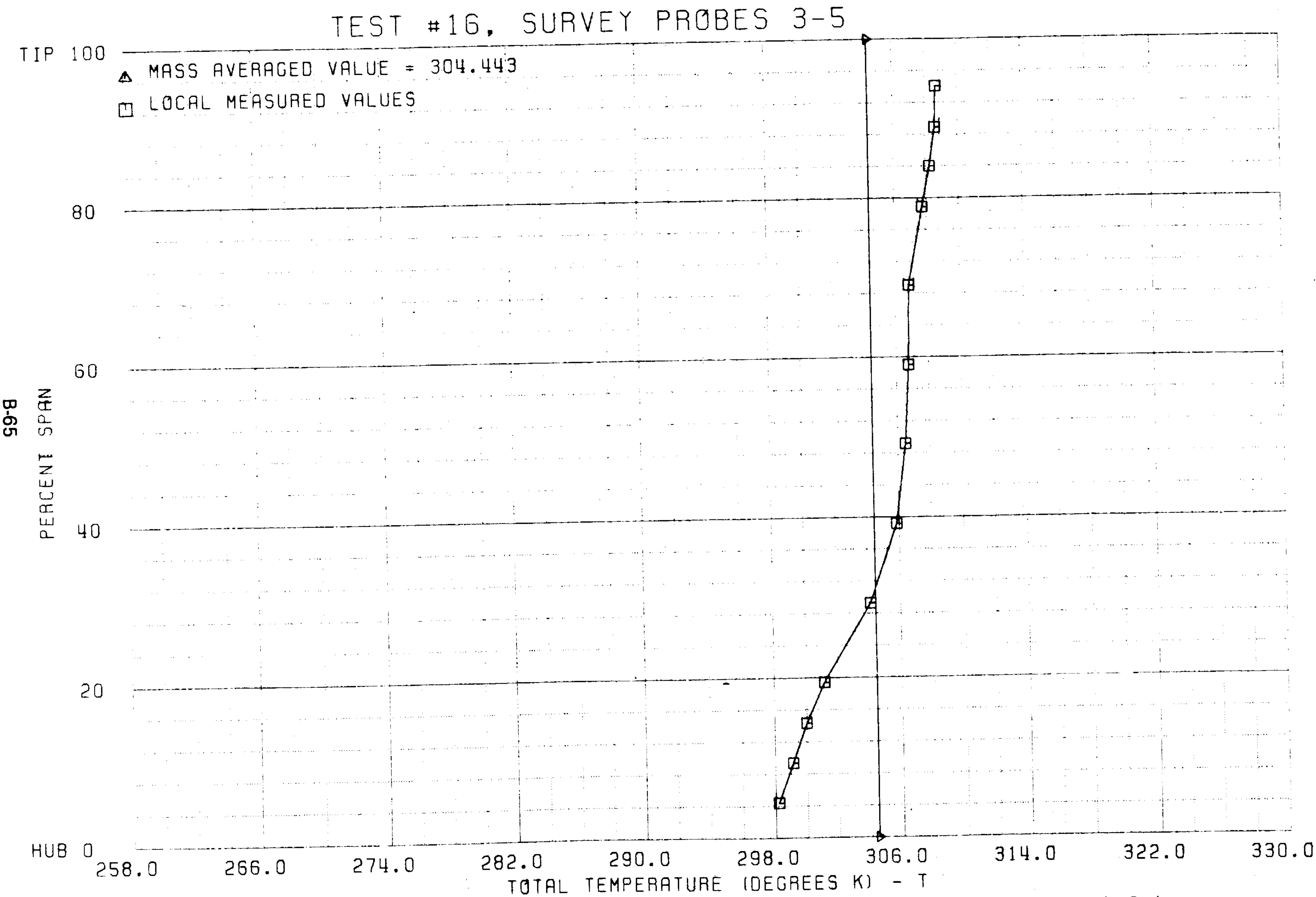

Figure B-65 Mixed Out Plane Survey - Total Temperature vs. Percent Rotor Exit Span, Test No. 16, Moveable Shroud, 62.5 Percent Area

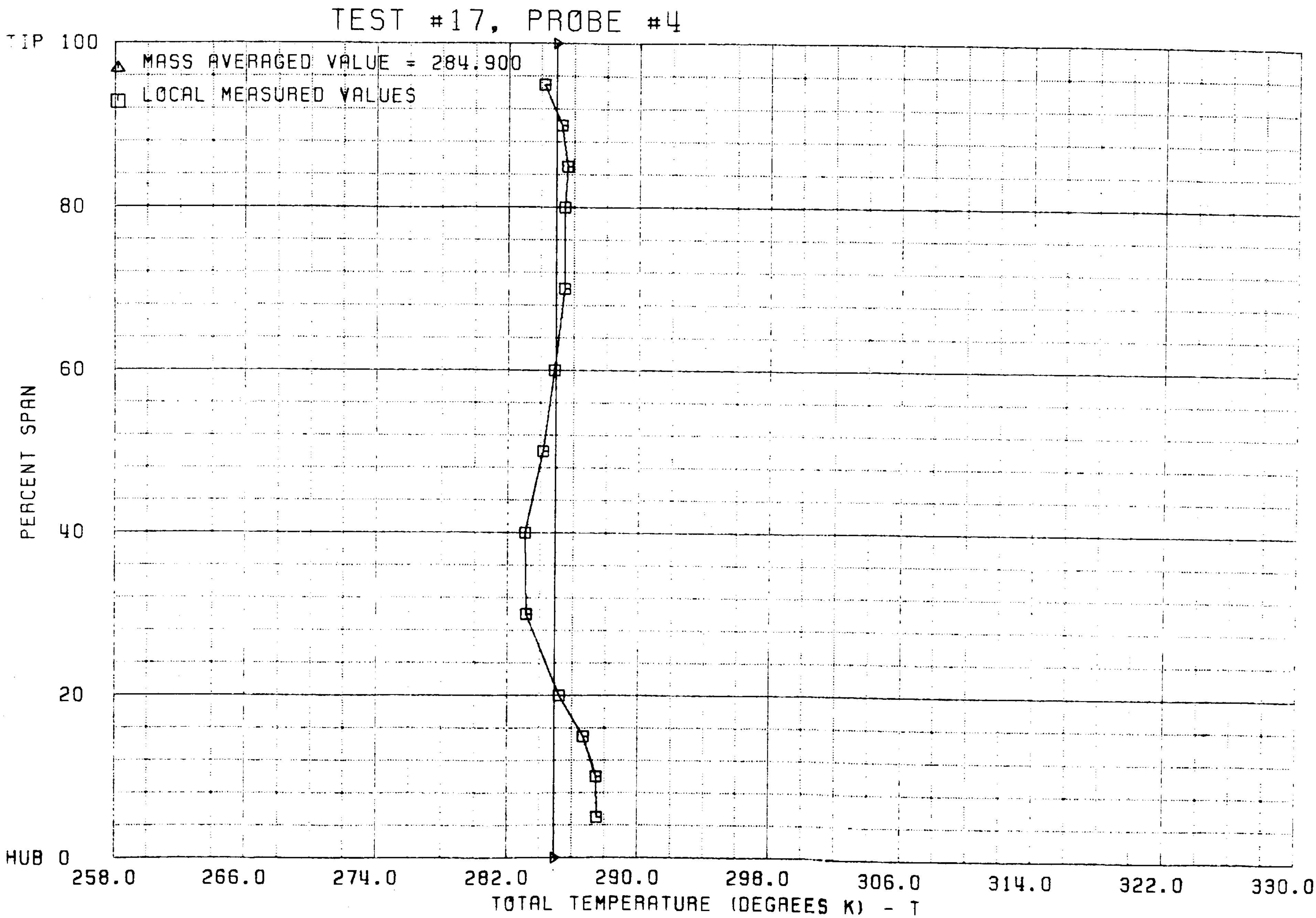

Figure B-66 Mixed Out Plane Survey - Total Temperature vs. Percent Rotor Exit Span, Test No. 17, Moveable Shroud, 125.0 Percent Area

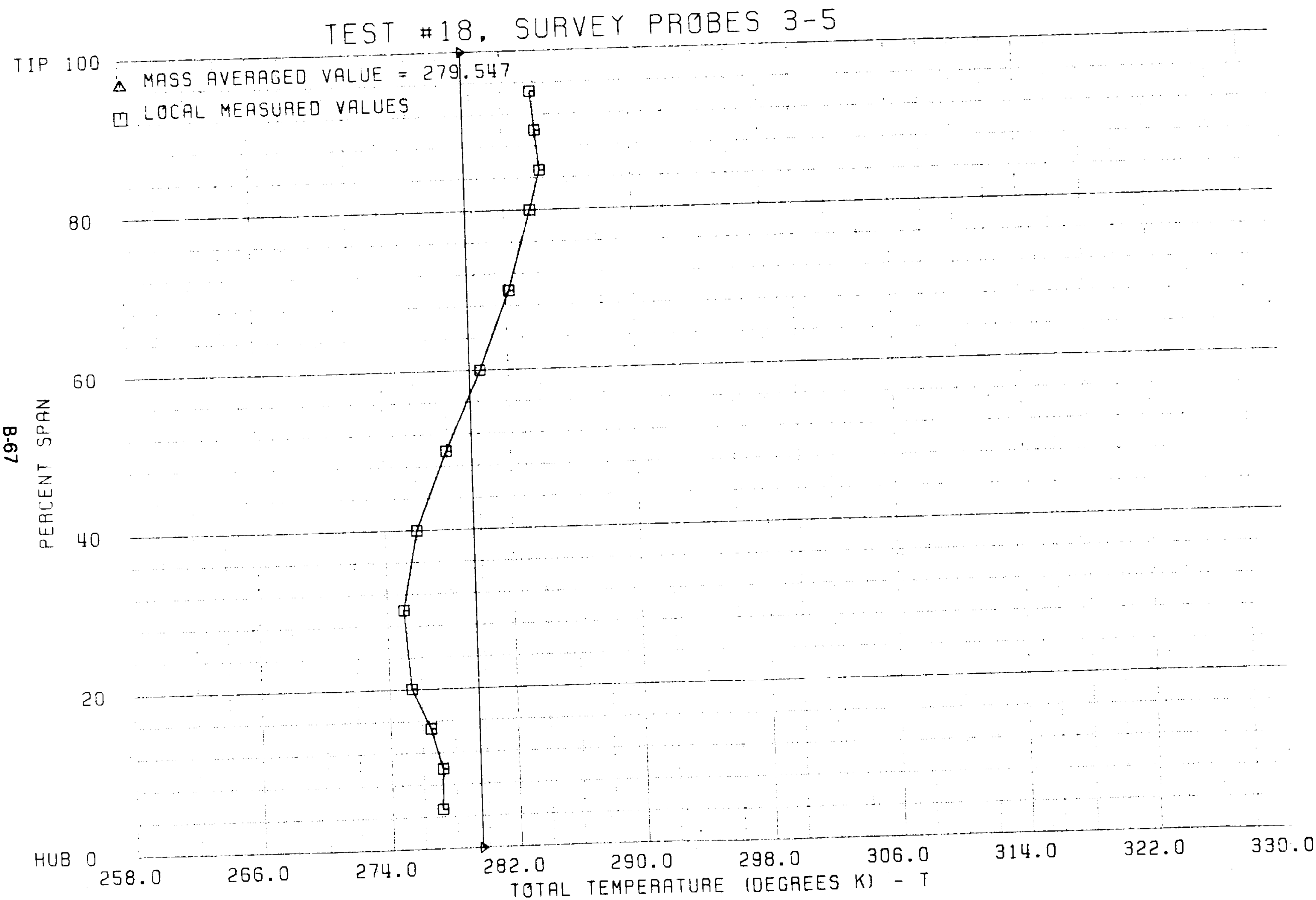

Figure B-67 Mixed Out Plane Survey - Total Temperature vs. Percent Rotor
Test No. 18, Moveable Shroud, 100.0 Percent Area

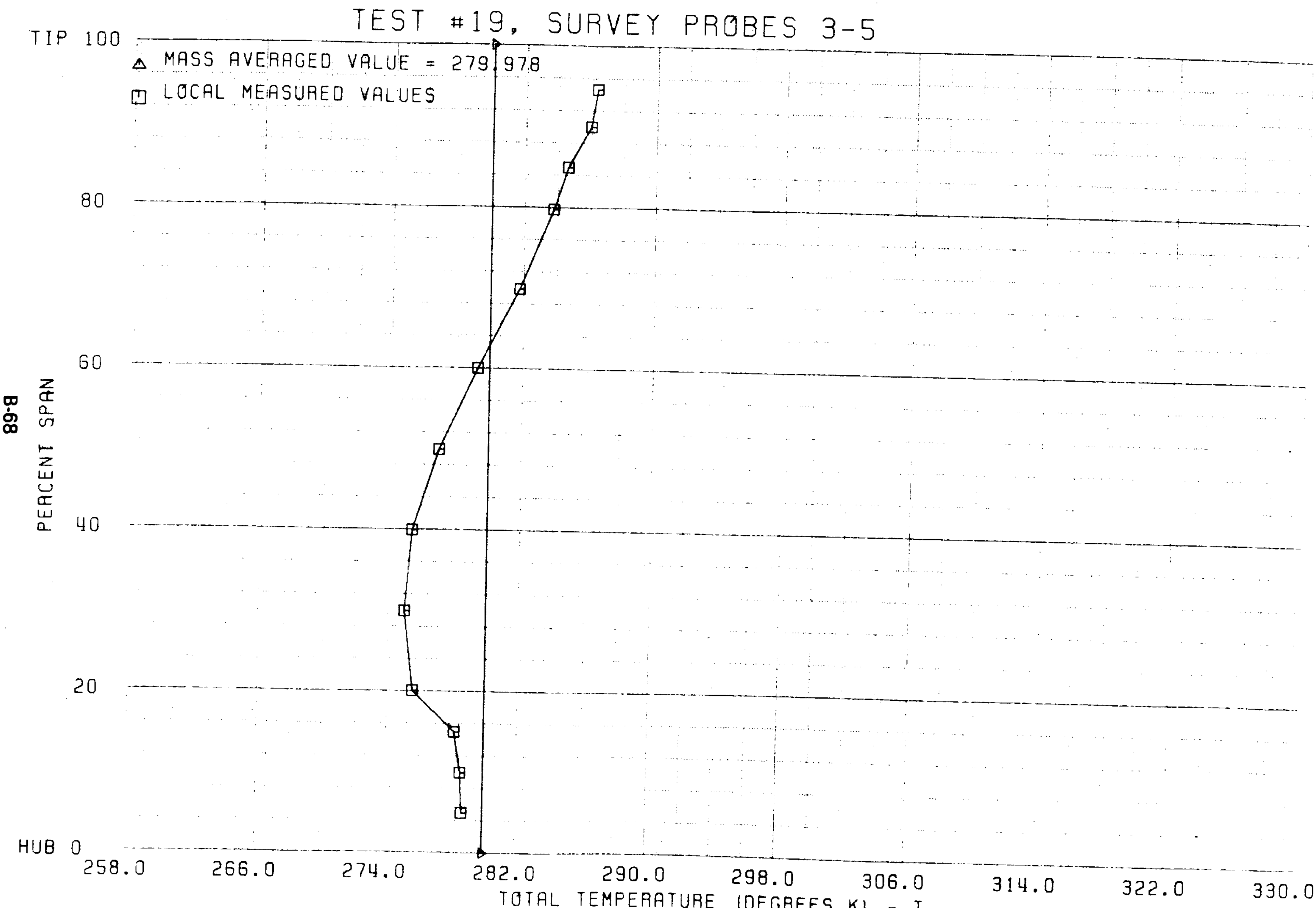

Figure B-68 Mixed Out Plane Survey - Total Temperature vs. Percent Rotor Exit Span, Test No. 19, Moveable Shroud, 81.1 Percent Area

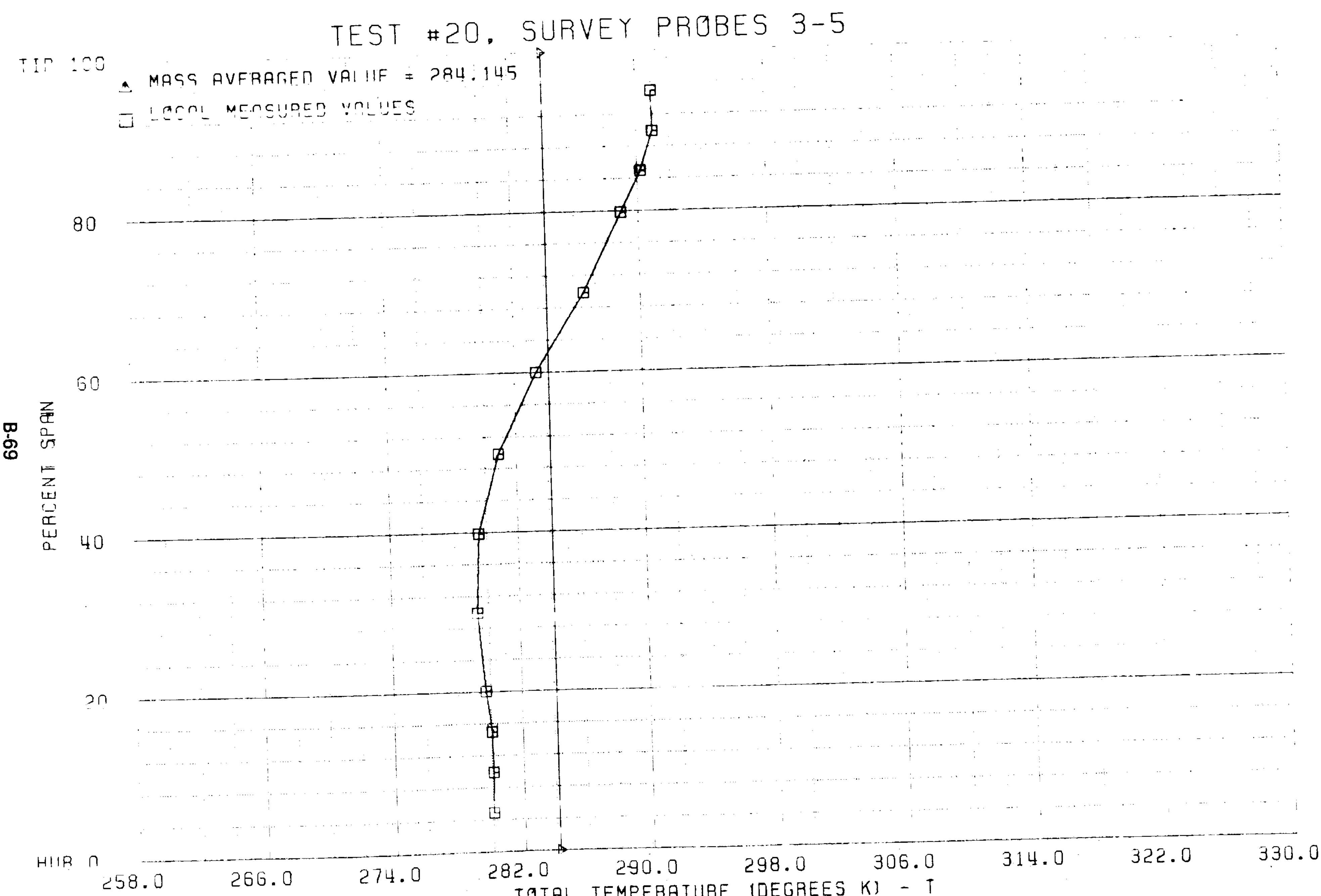

Figure B-69 Mixed Out Plane Survey - Total Temperature vs. Percent Rotor Exit Span, Test No. 20, Moveable Shroud, 81.1 Percent Area

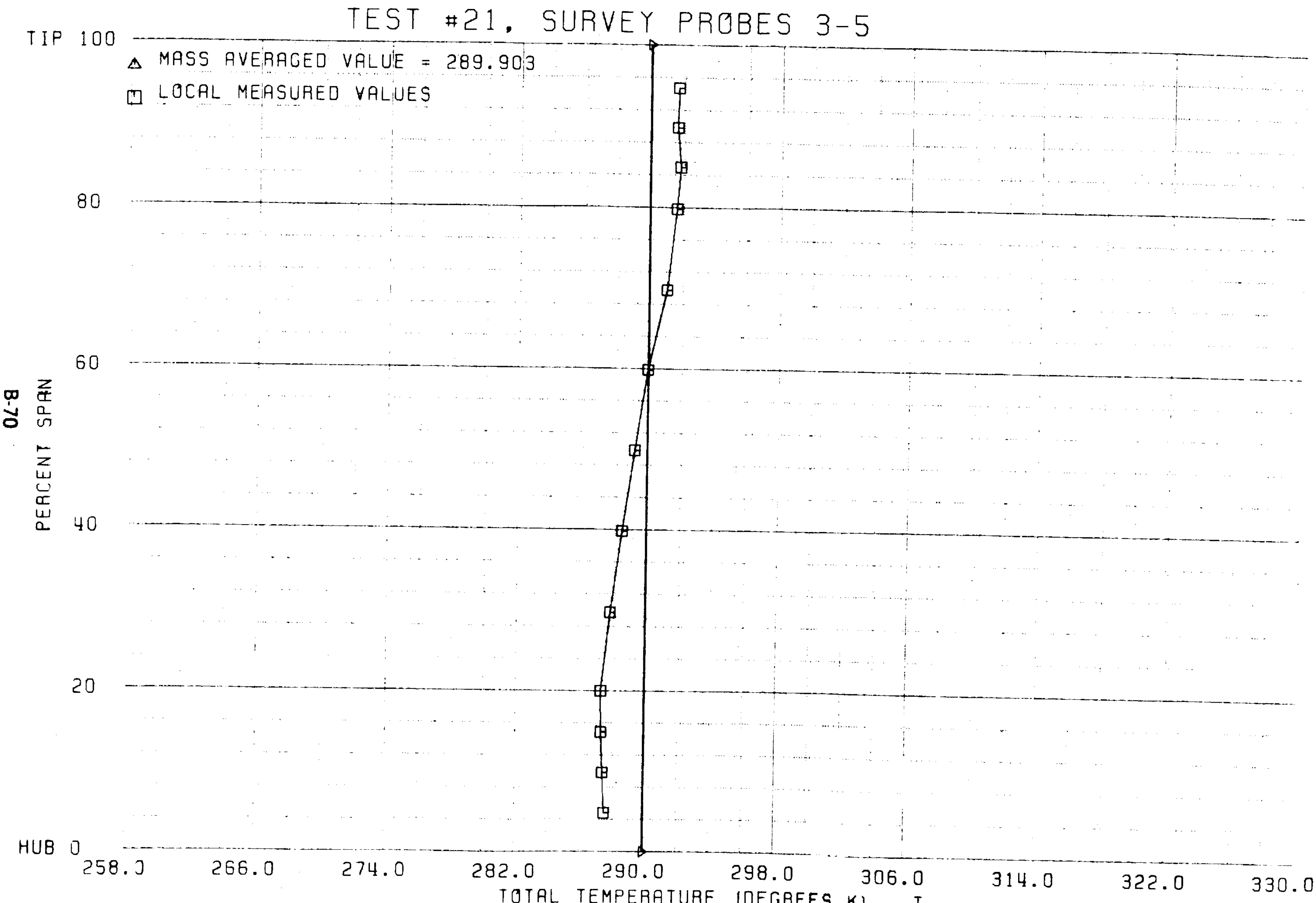

Figure B-70 Mixed Out Plane Survey - Total Temperature vs. Percent Rotor Exit Span, Test No. 21, Moveable Shroud, 62.5 Percent Area

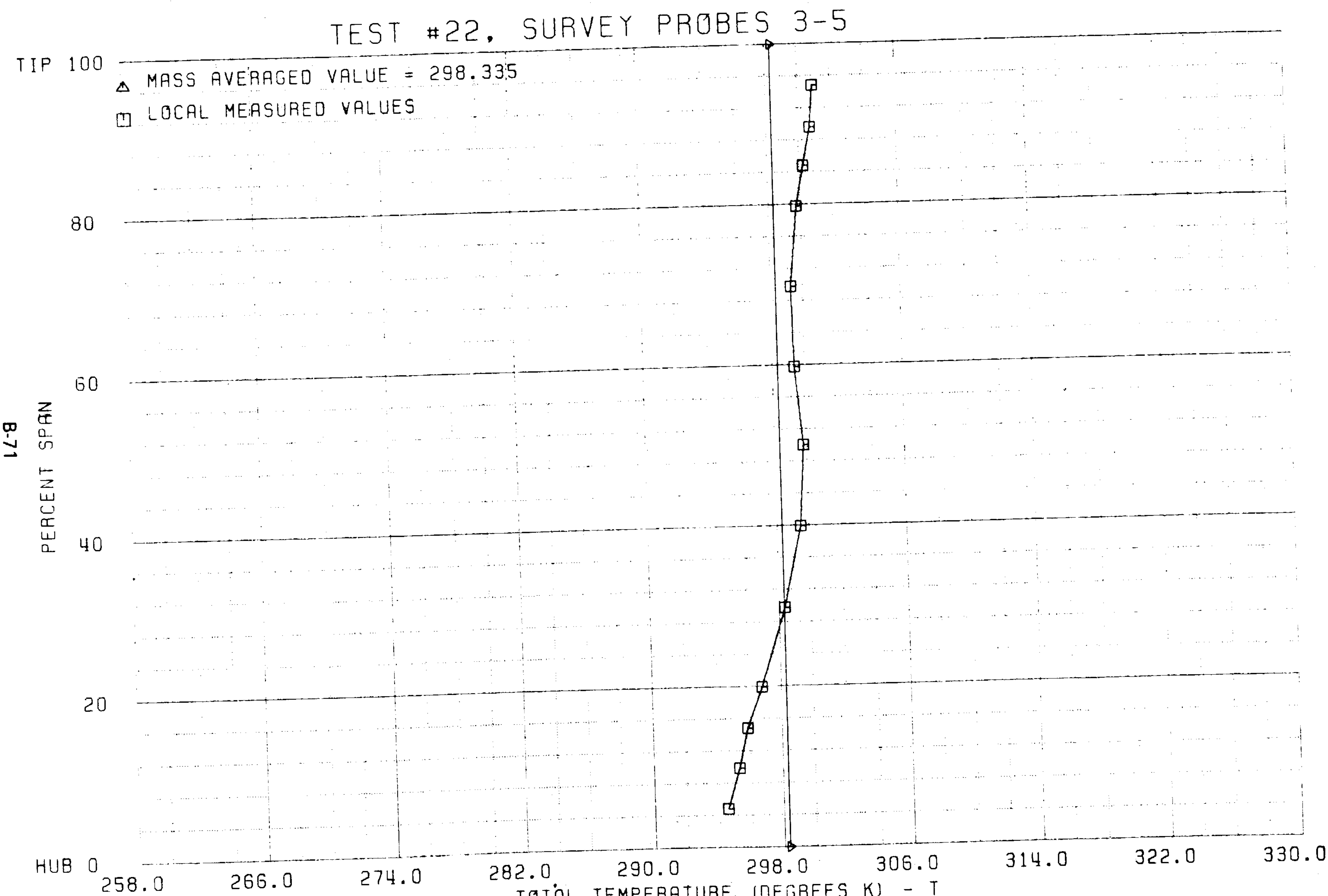

Figure B-71 Mixed Out Plane Survey - Total Temperature vs. Percent Rotor Exit Span, Test No. 22, Moveable Shroud, 62.5 Percent Area

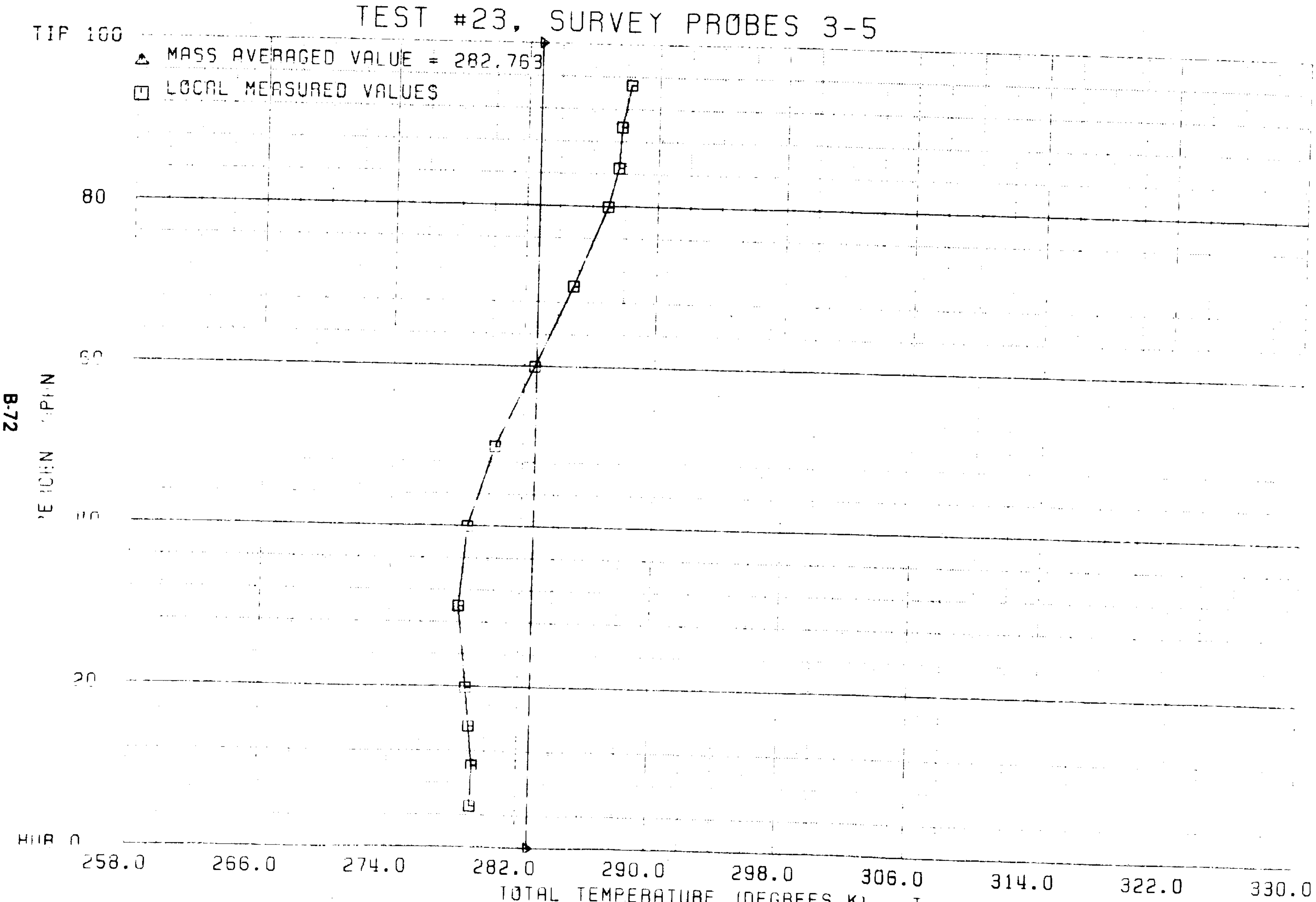

Figure B-72 Mixed Out Plane Survey - Total Temperature vs. Percent Rotor Exit Span, Test No. 23, Moveable Shroud, 81.1 Percent Area

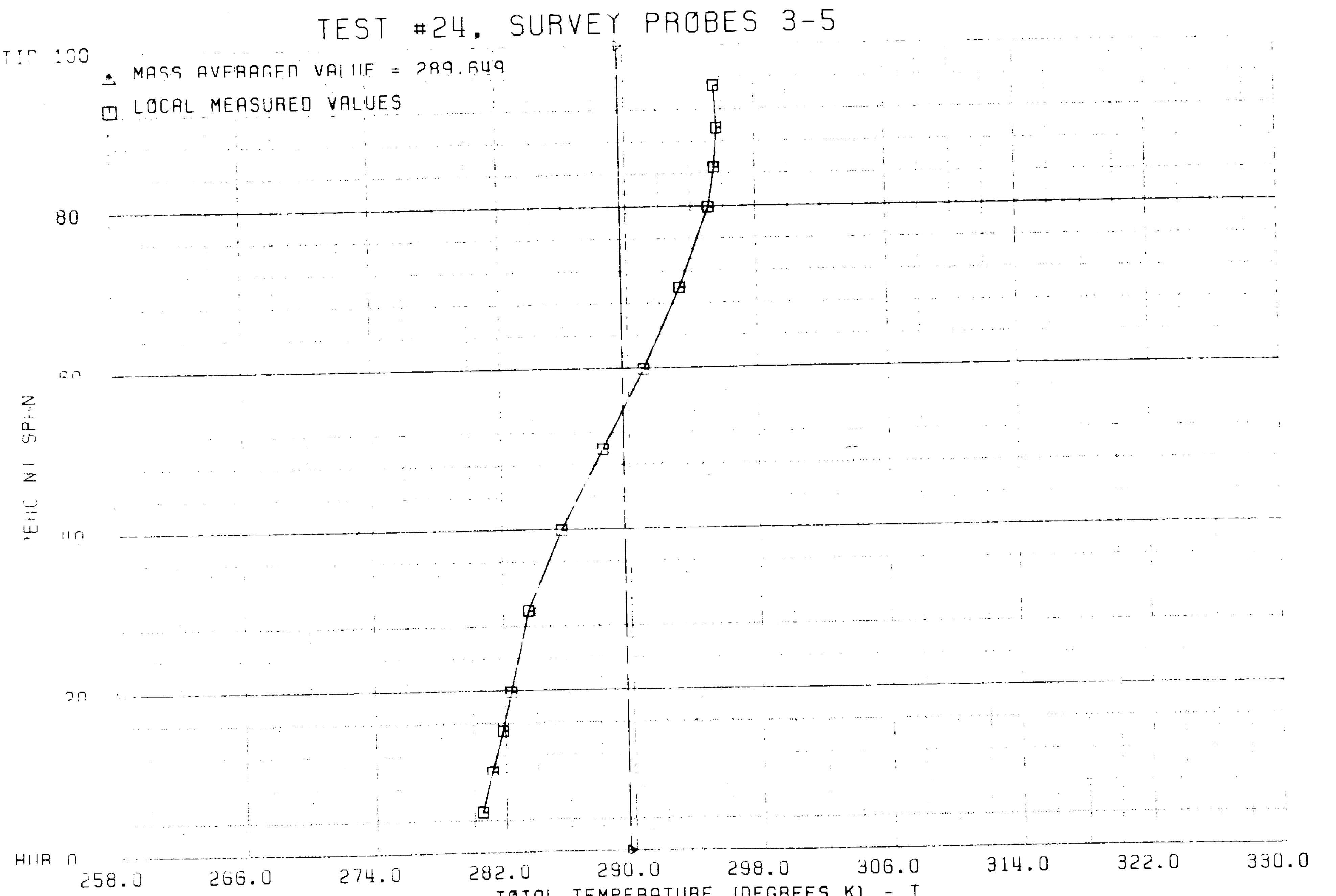

Figure B-73 Mixed Out Plane Survey - Total Temperature vs. Percent Rotor Exit Span, Test No. 24, Moveable Shroud, 62.5 Percent Area

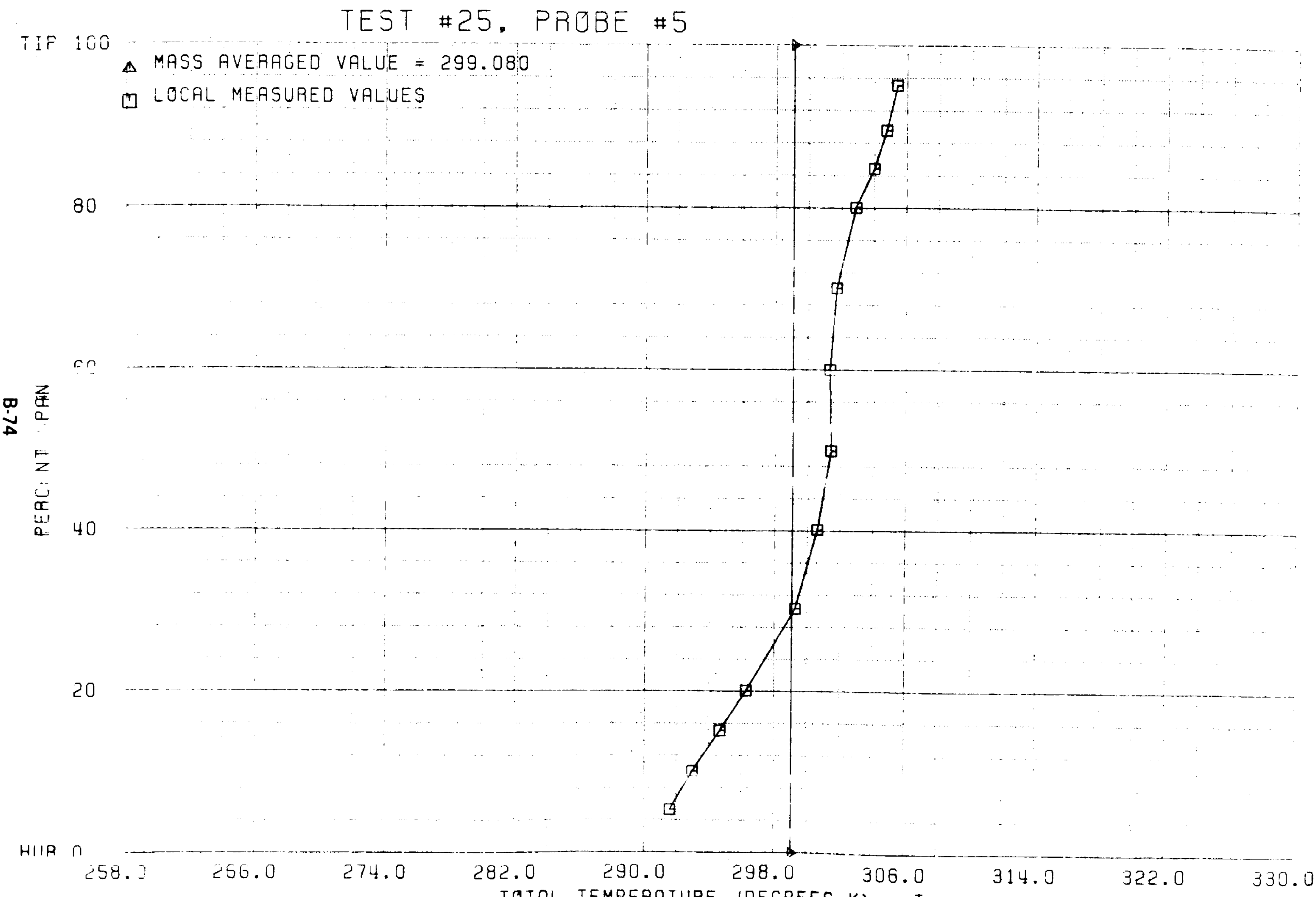

Figure B-74 Mixed Out Plane Survey - Total Temperature vs. Percent Rotor Exit Span, Test No. 25, Moveable Shroud, 62.5 Percent Area

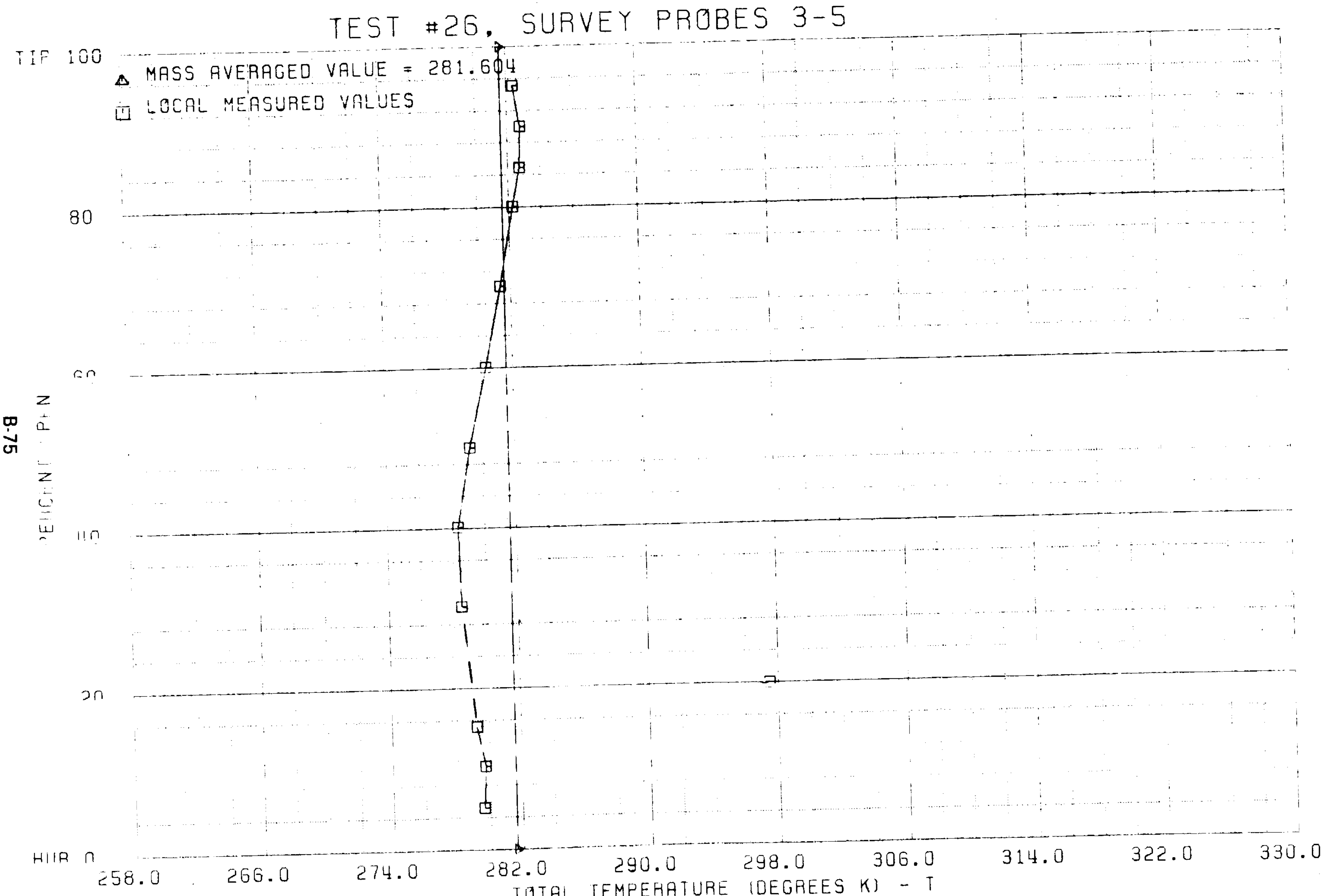

Figure B-75 Mixed Out Plane Survey - Total Temperature vs. Percent Rotor Exit Span, Test No. 26, Moveable Shroud, 103.5 Percent Area

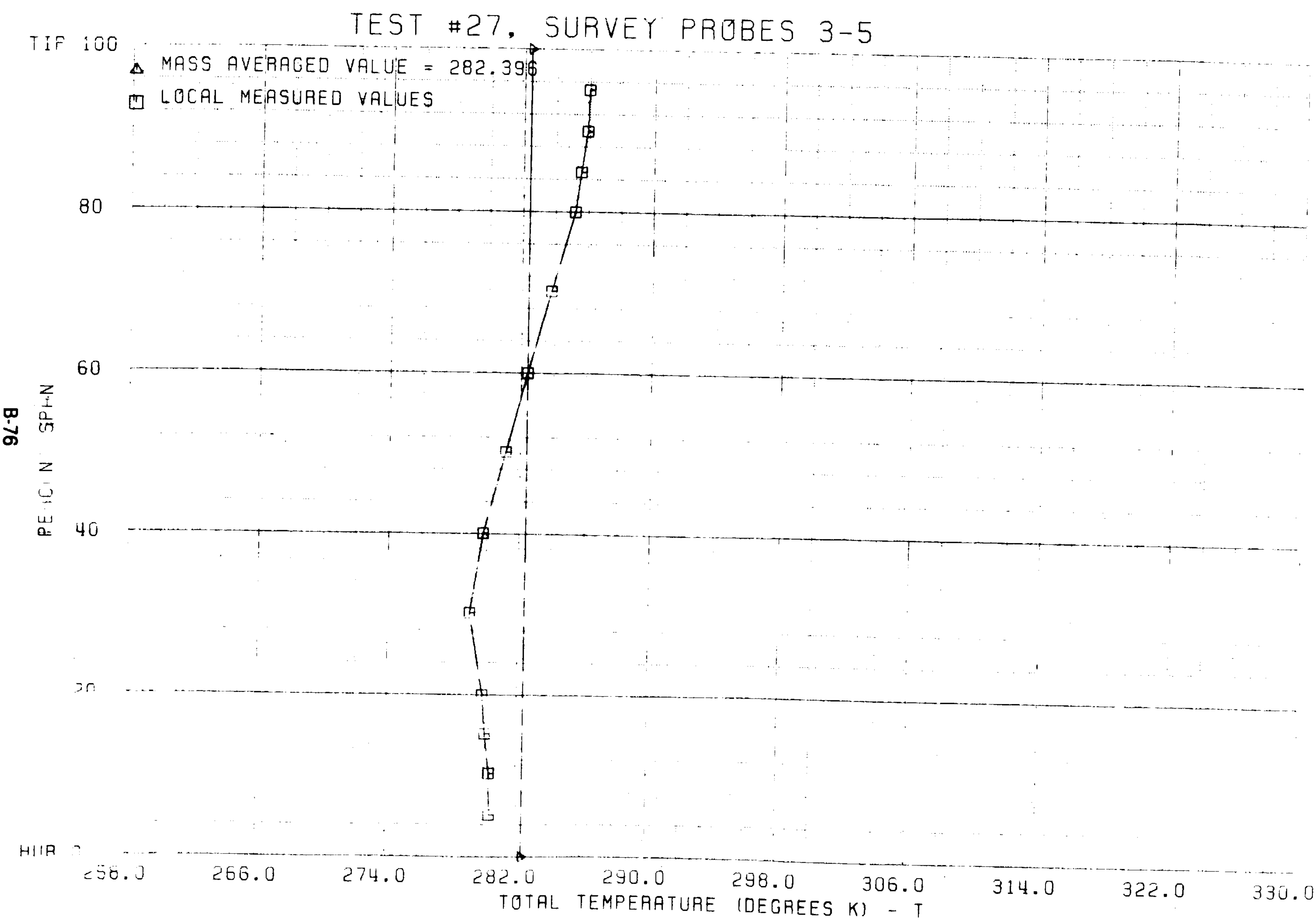

Figure B-76 Mixed Out Plane Survey - Total Temperature vs. Percent Rotor Exit Span, Test No. 27, Moveable Shroud, 84.6 Percent Area

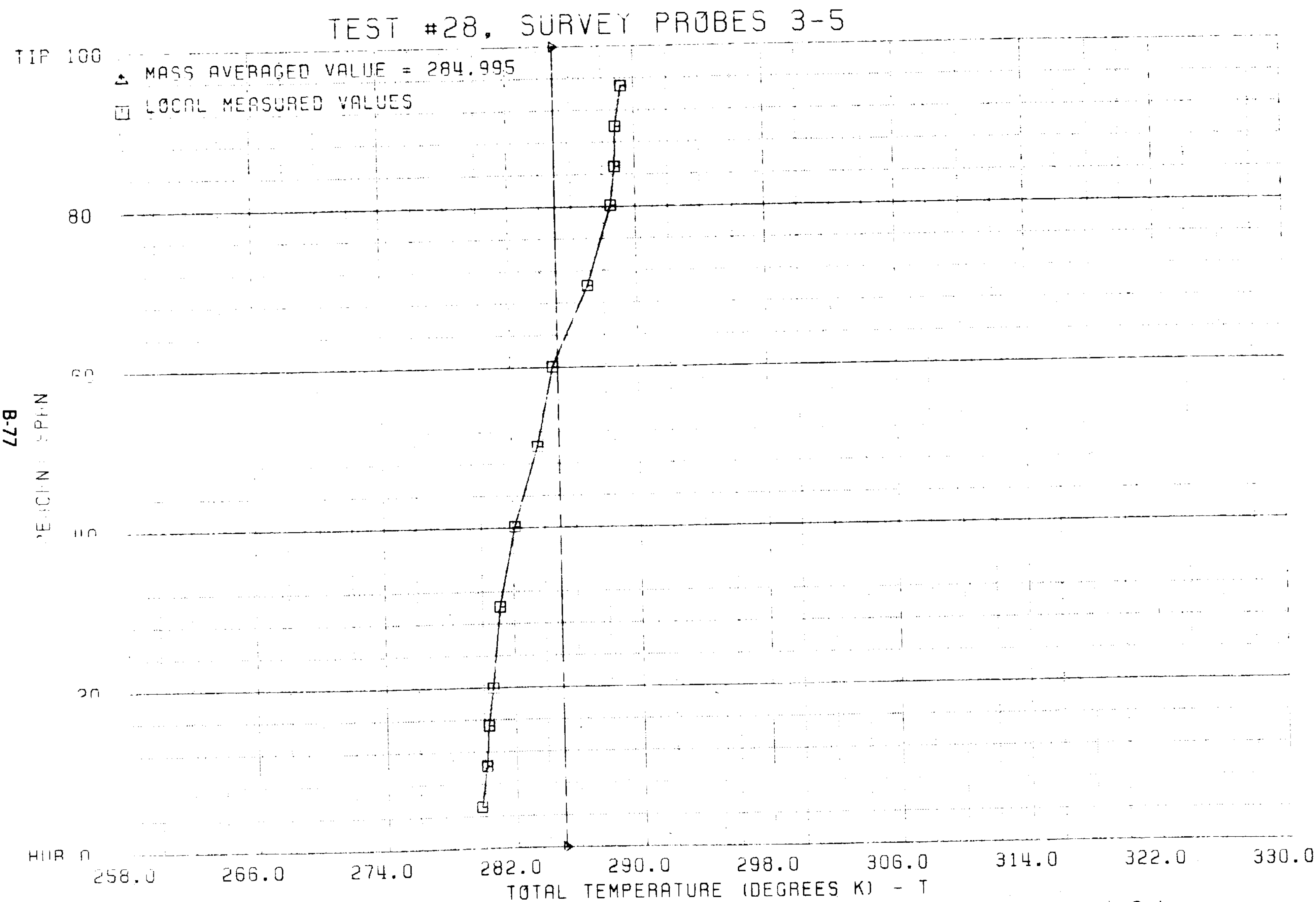

Figure B-77 Mixed Out Plane Survey - Total Temperature vs. Percent Rotor Exit Span, Test No. 28, Moveable Shroud, 66.0 Percent Area

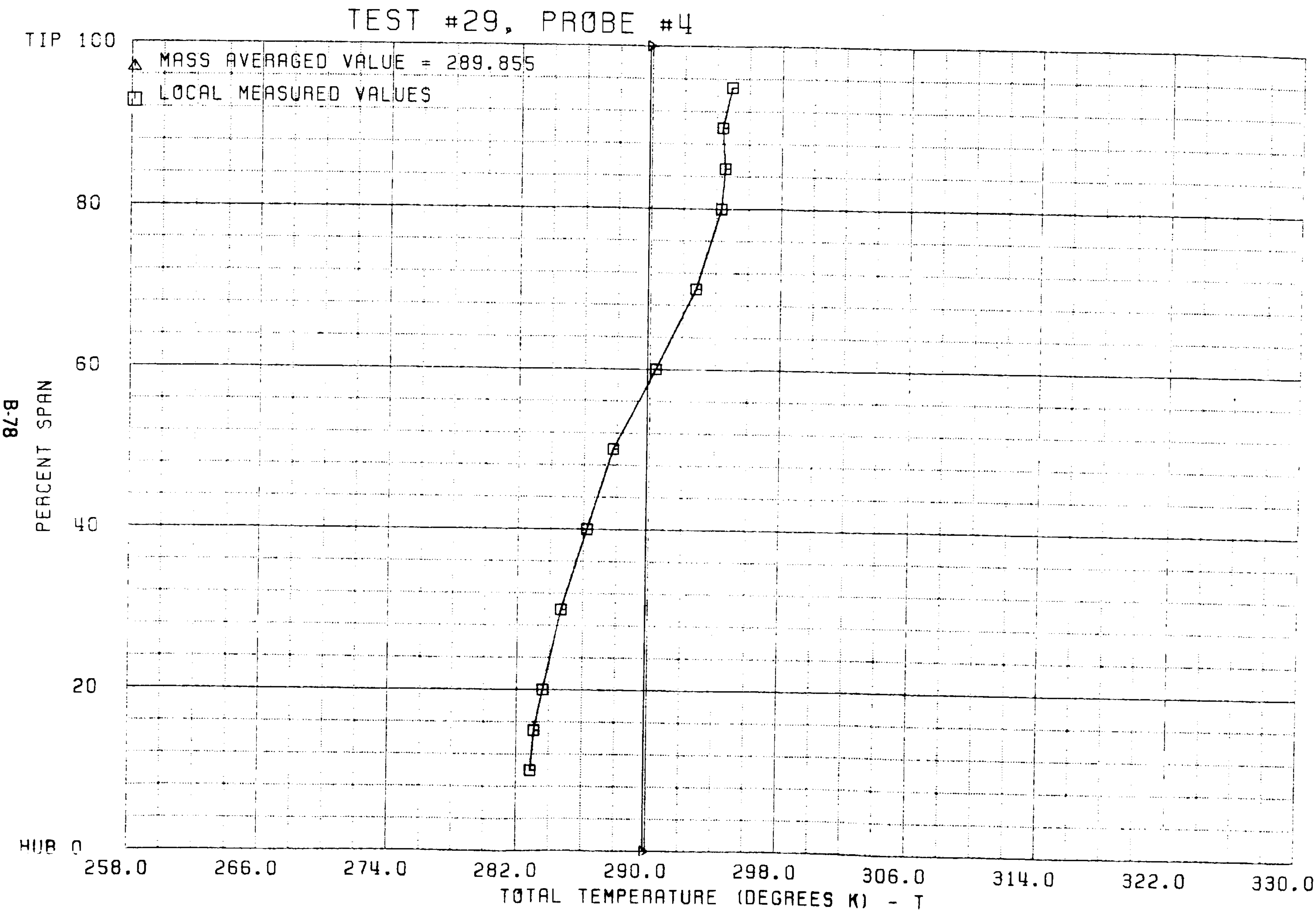

Figure B-78 Mixed Out Plane Survey - Total Temperature vs. Percent Rotor Exit Span, Test No. 29, Moveable Shroud, 62.2 Percent Area

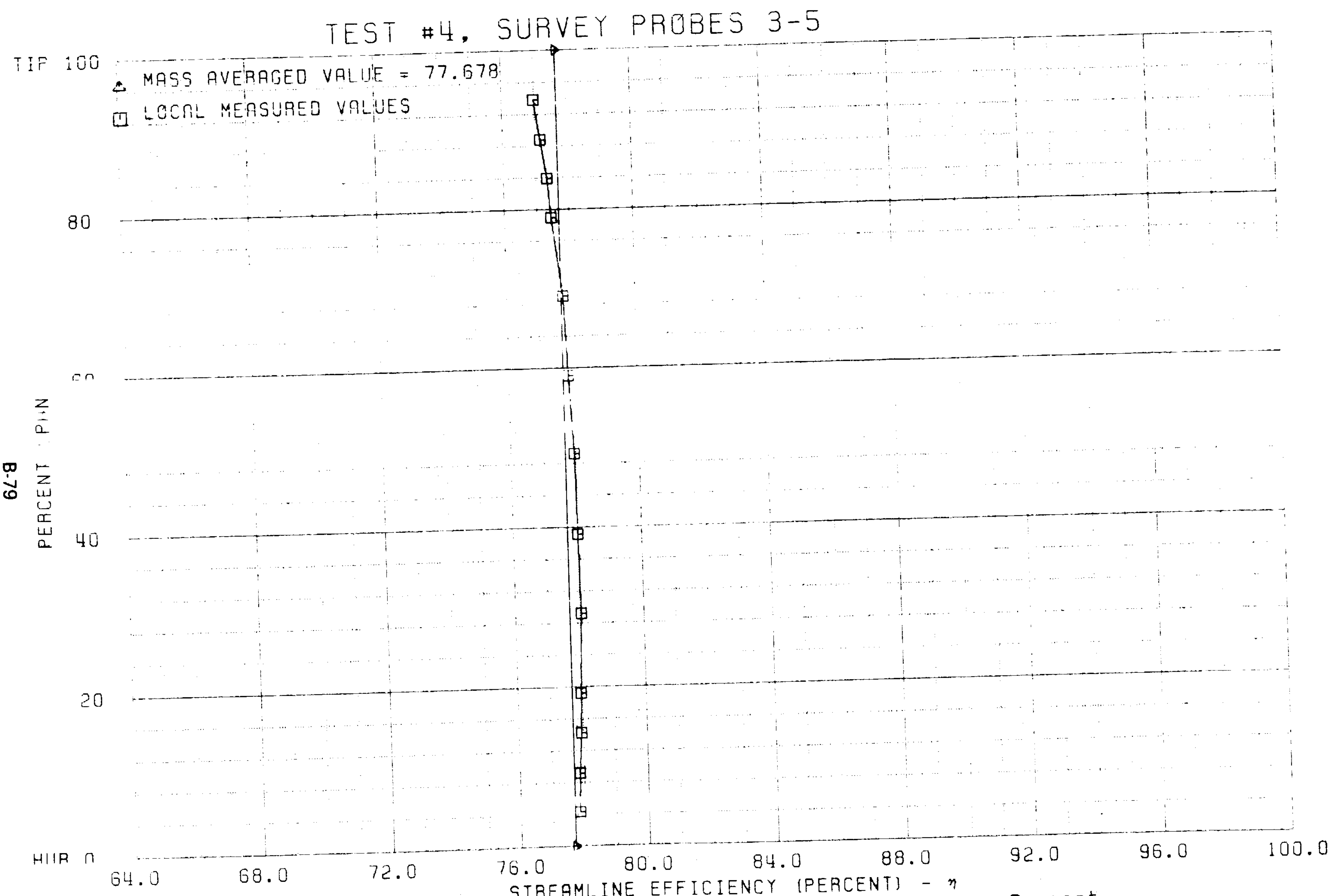

Figure B-79 Mixed Out Plane Survey - Streamline Efficiency vs. Percent Rotor Exit Span, Test No. 4, Moveable Hub, 62.2 Percent Area

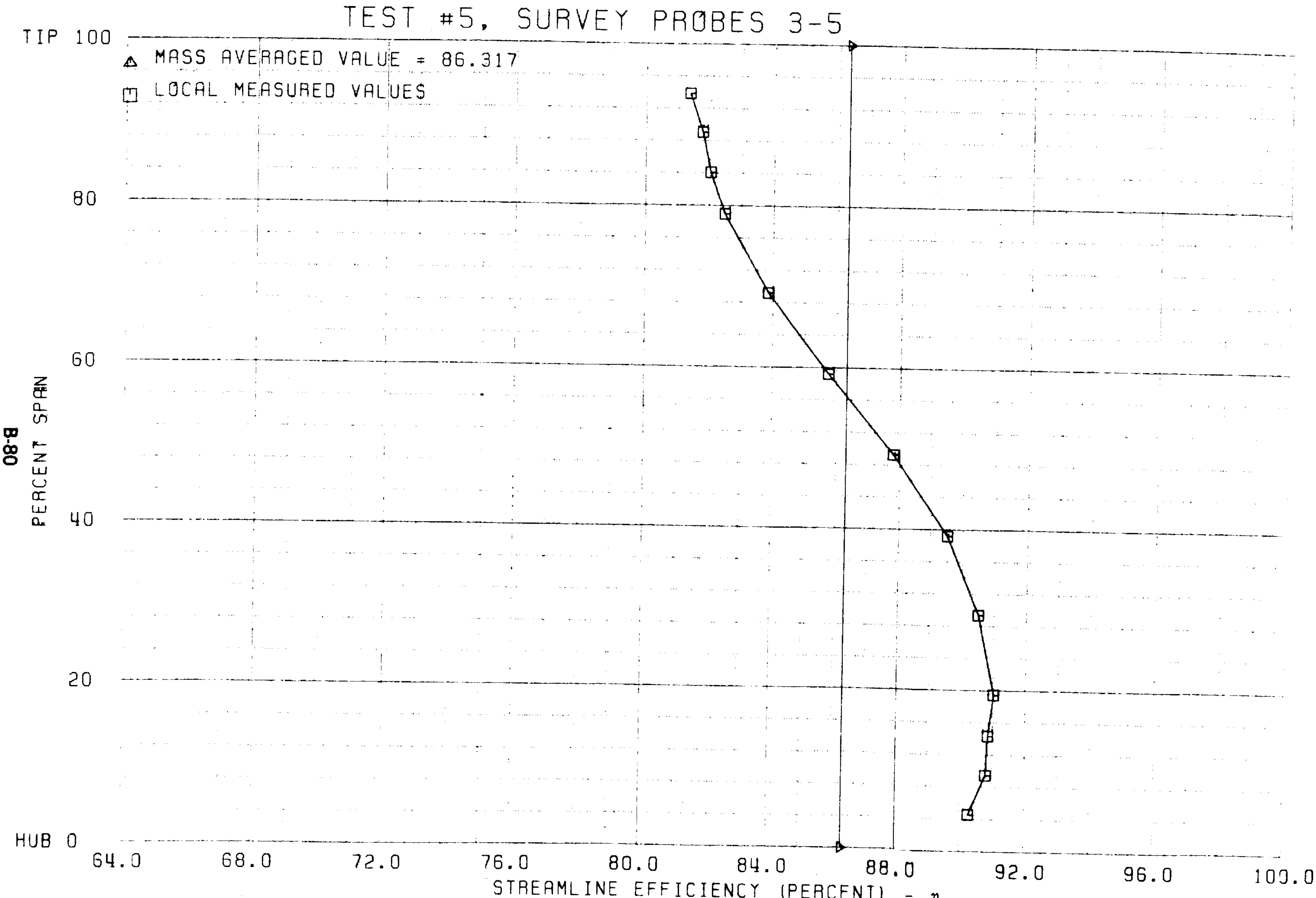

Figure B-80 Mixed Out Plane Survey - Streamline Efficiency vs. Percent Rotor Exit Span, Test No. 5, Moveable Hub, 108.8 Percent Area

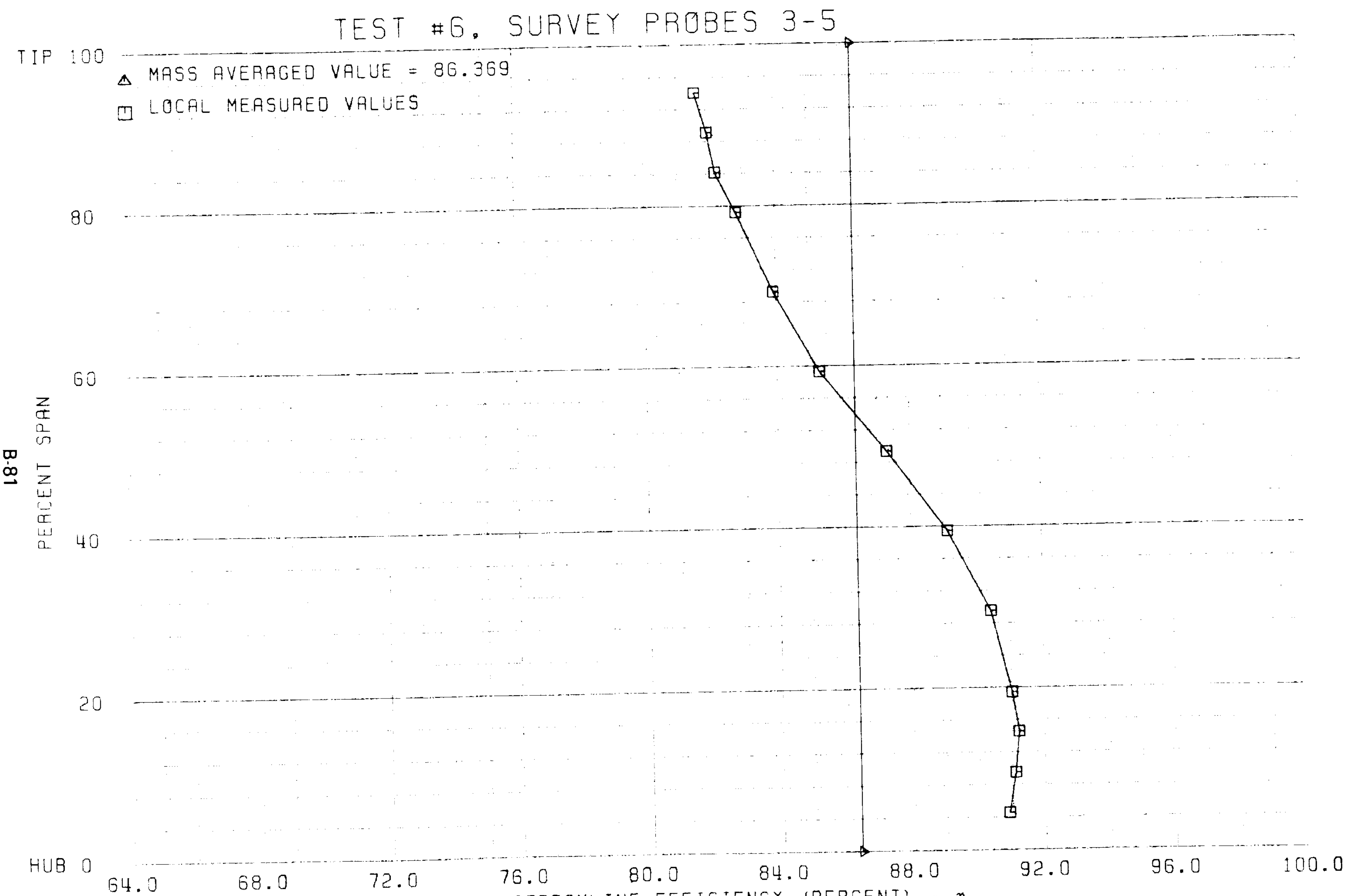

Figure B-81 Mixed Out Plane Survey - Streamline Efficiency vs. Percent Rotor Exit Span, Test No. 6, Moveable Hub, 100.0 Percent Area

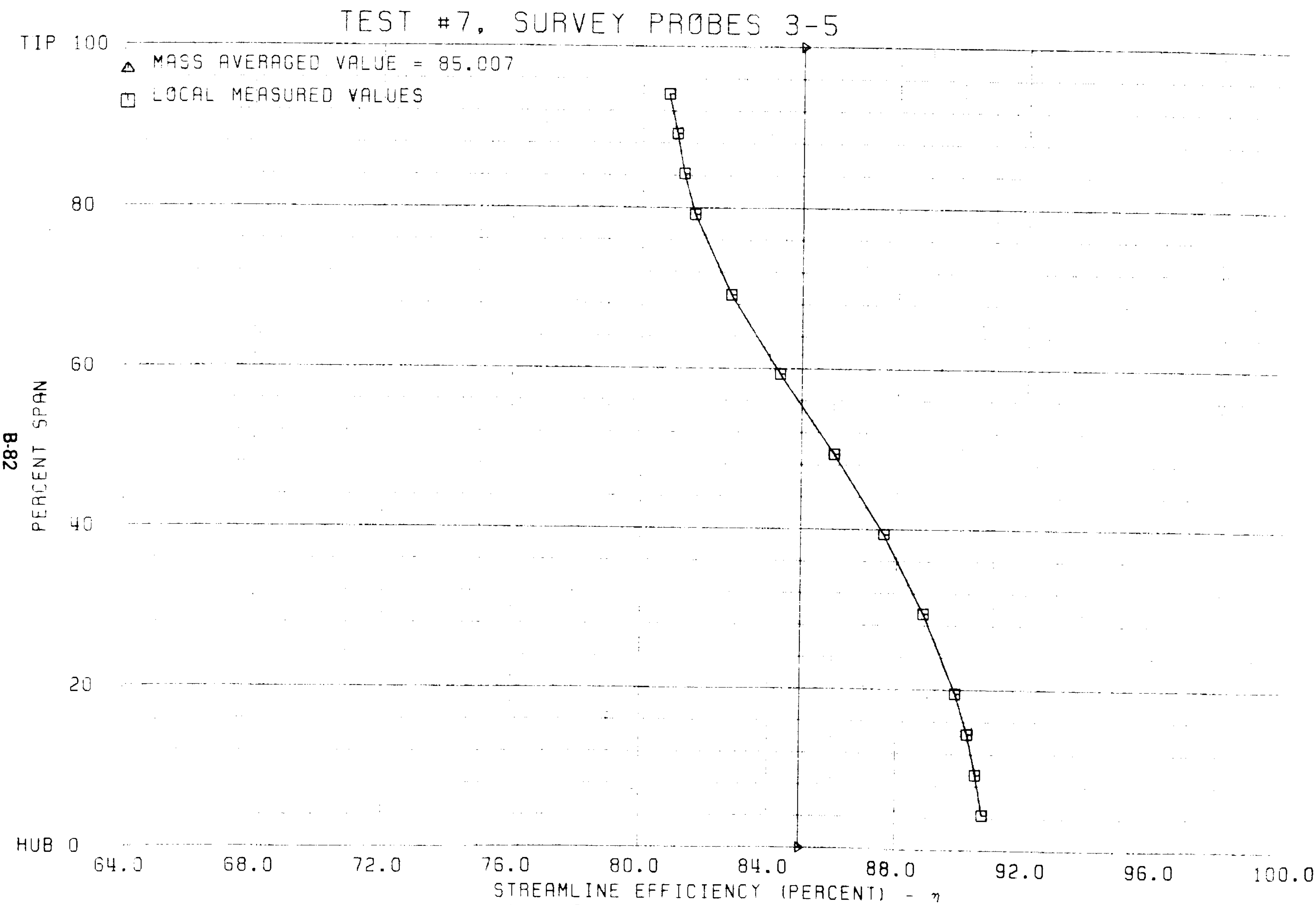

Figure B-82 Mixed Out Plane Survey - Streamline Efficiency vs. Percent Rotor Exit Span, Test No. 7, Moveable Hub, 81.1 Percent Area

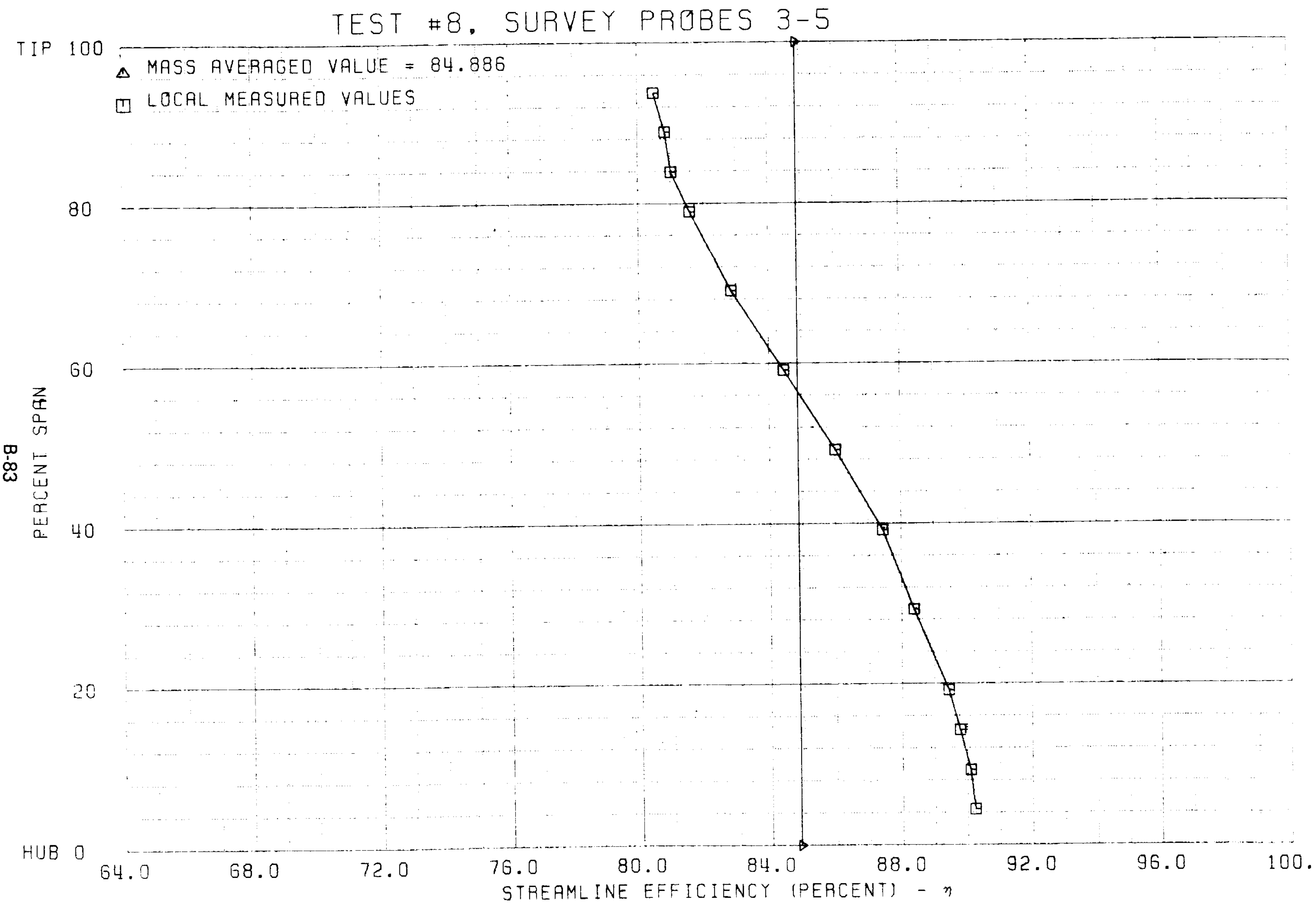

Figure B-83 Mixed Out Plane Survey - Streamline Efficiency vs. Percent Rotor Exit Span, Test No. 8, Moveable Hub, 81.1 Percent Area

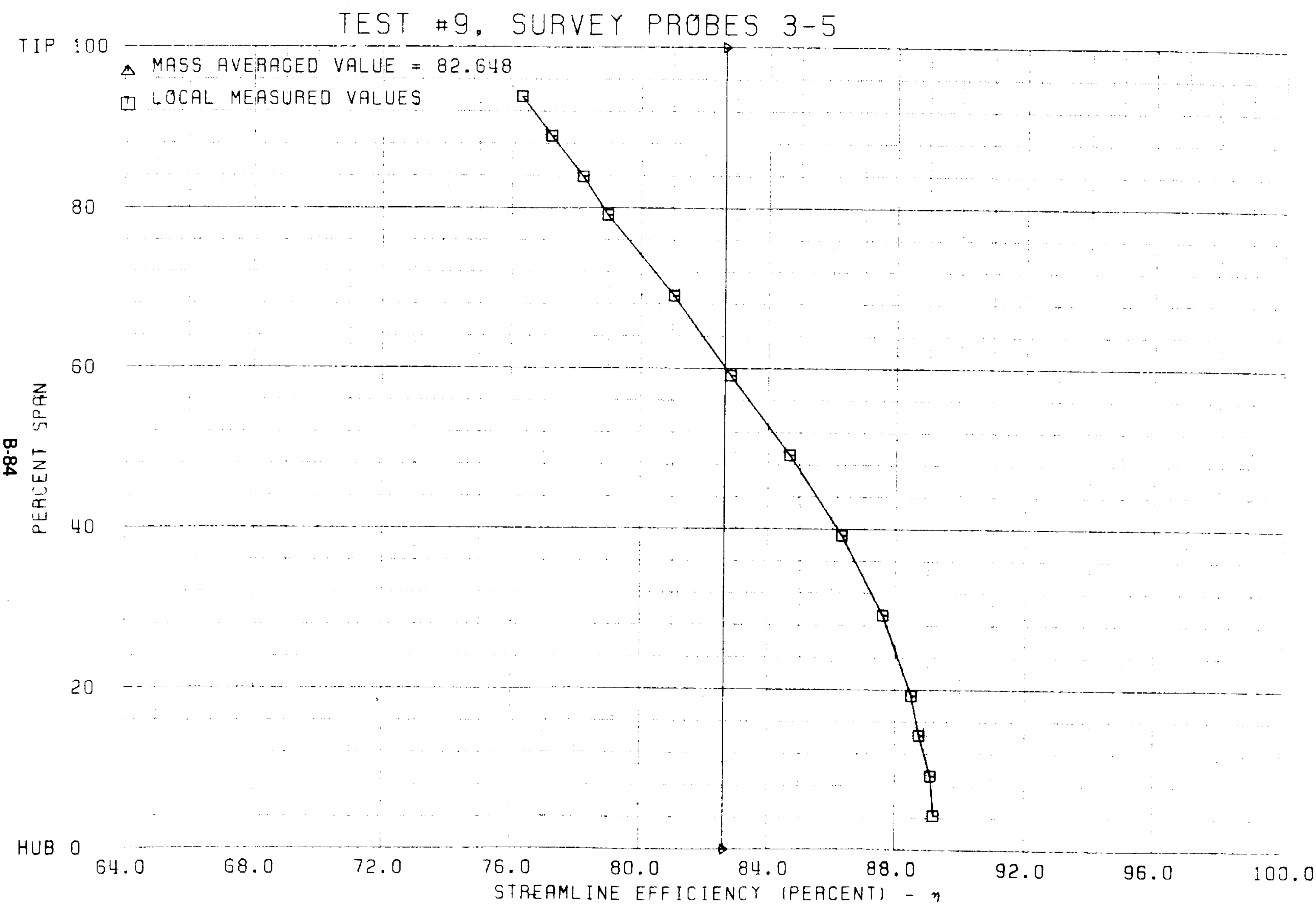

Figure B-84 Mixed Out Plane Survey - Streamline Efficiency vs. Percent Rotor Exit Span, Test No. 9, Moveable Hub, 62.2 Percent Area

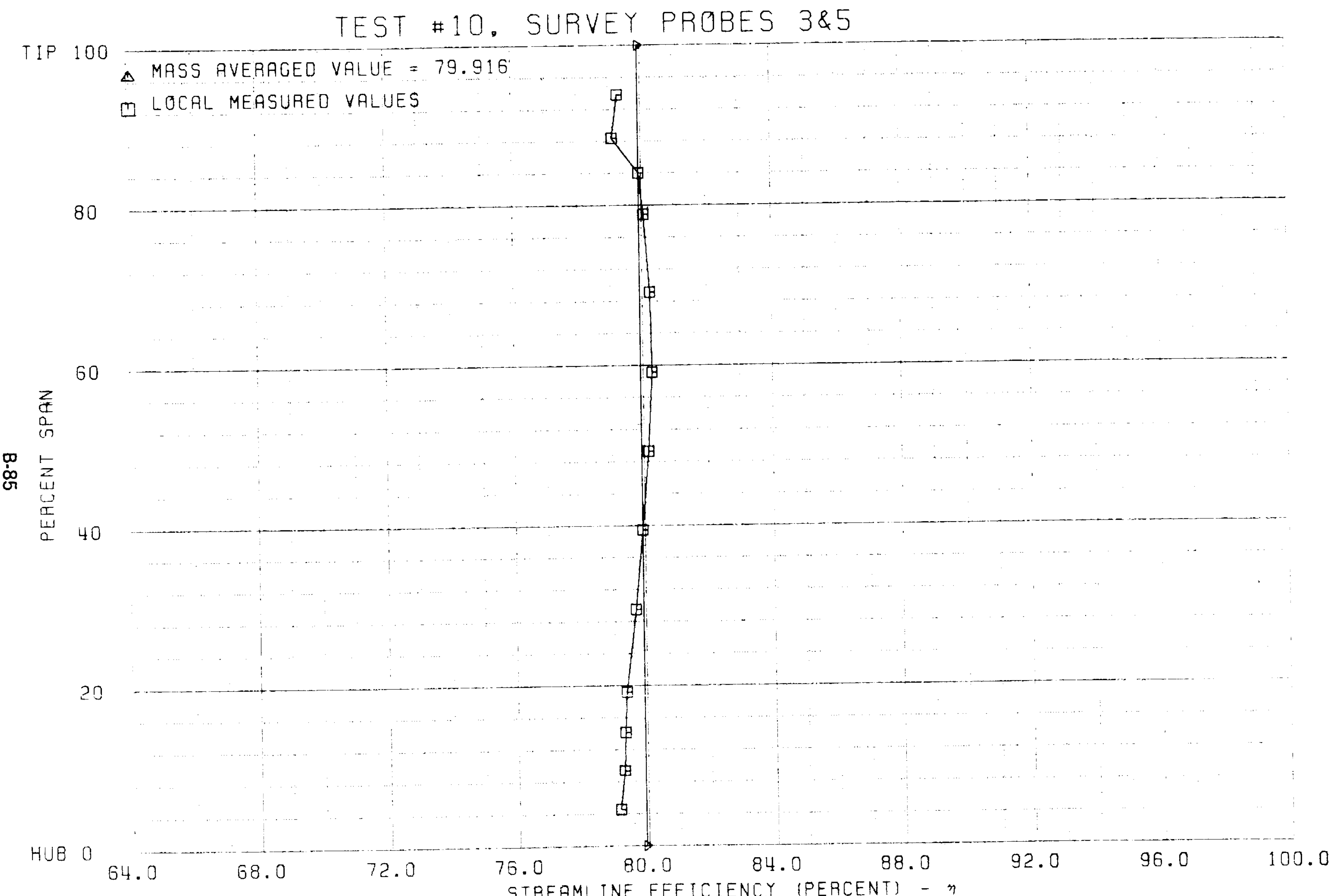

Figure B-85 Mixed Out Plane Survey - Streamline Efficiency vs. Percent Rotor Exit Span, Test No. 10, Moveable Hub, 62.2 Percent Area

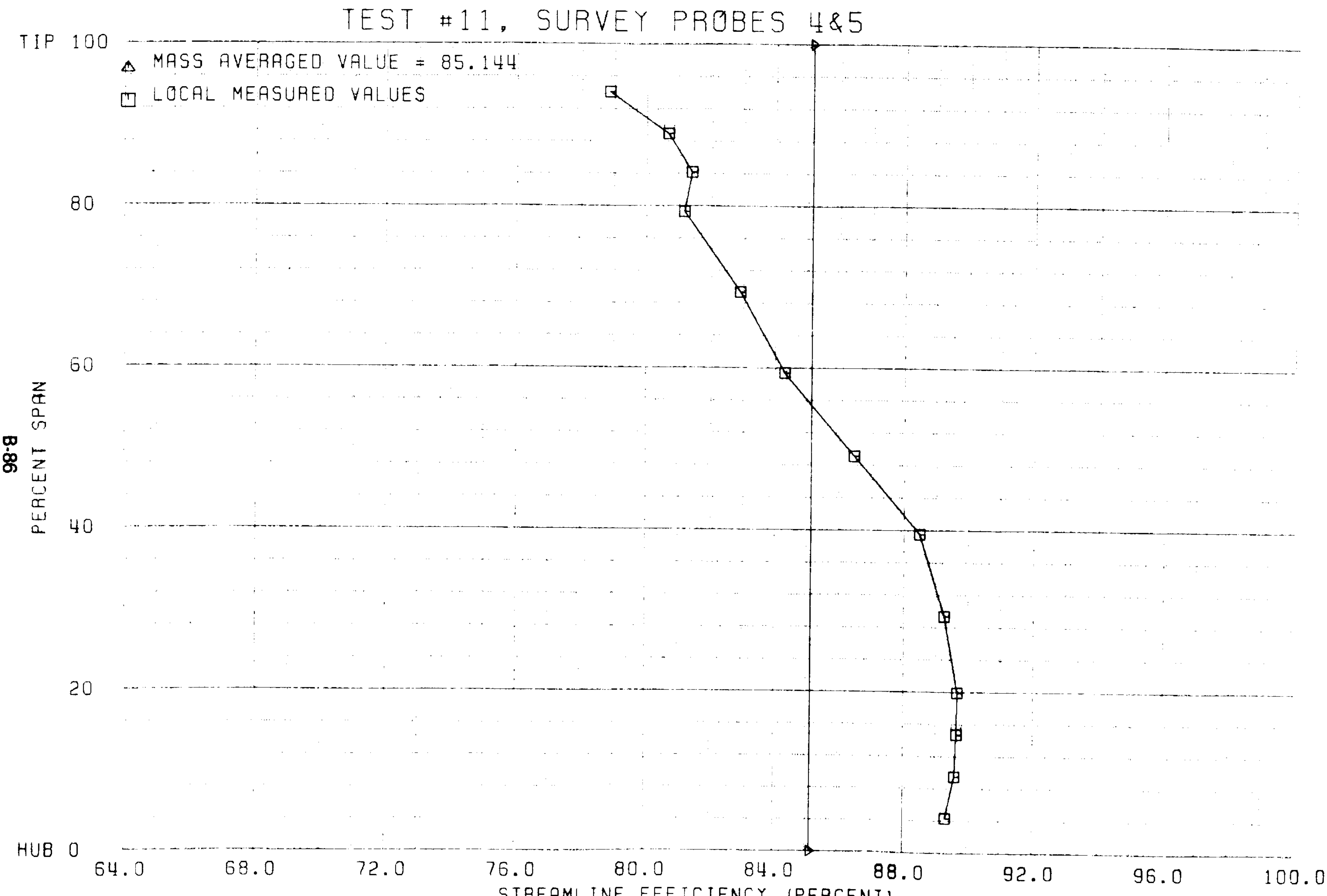

Figure B-86 Mixed Out Plane Survey - Streamline Efficiency vs. Percent Rotor Exit Span, Test No. 11, Moveable Hub, 103.5 Percent Area

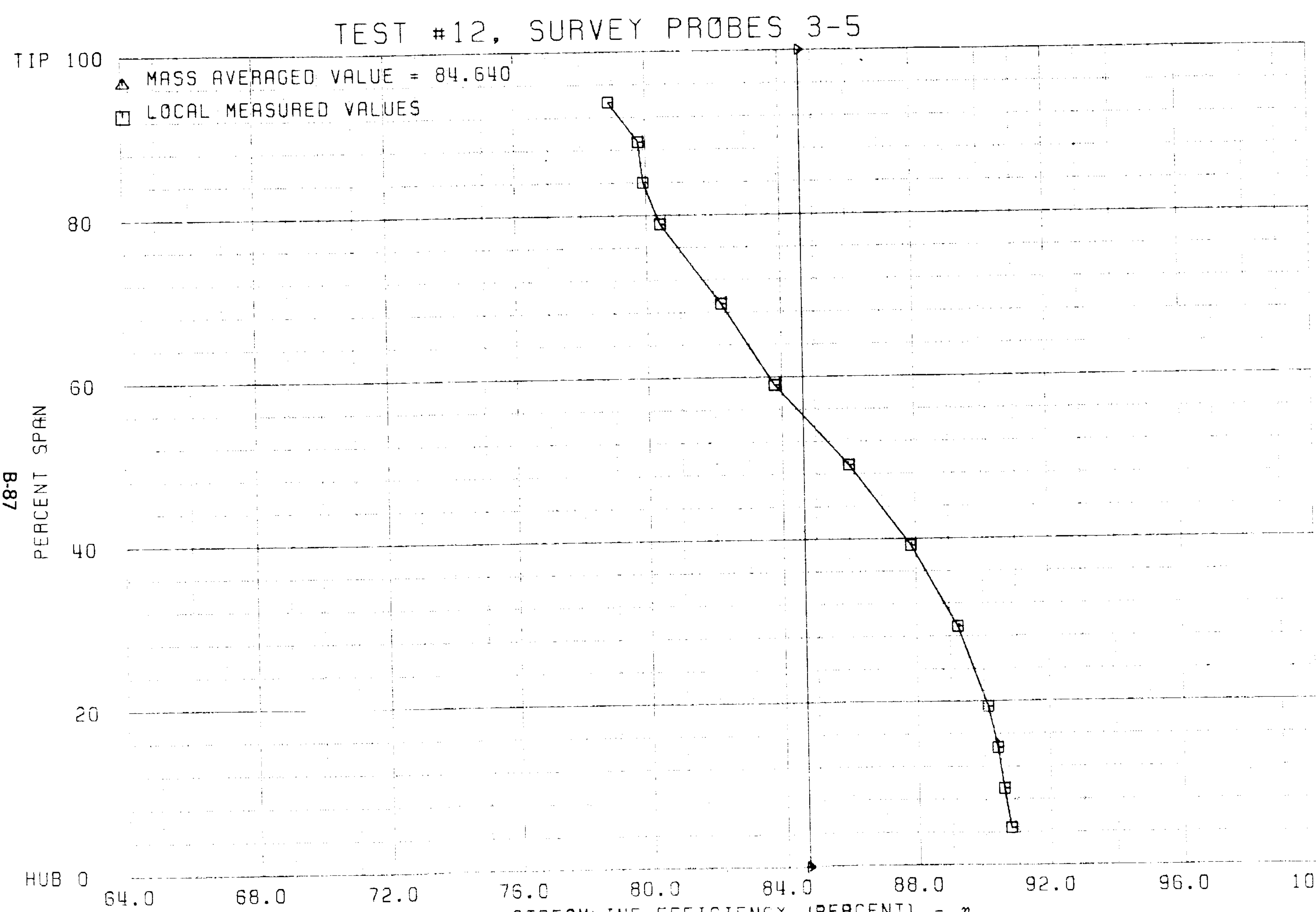

Figure B-87 Mixed Out Plane Survey - Streamline Efficiency vs. Percent Rotor Exit Span, Test No. 12, Moveable Hub, 84.6 Percent Area

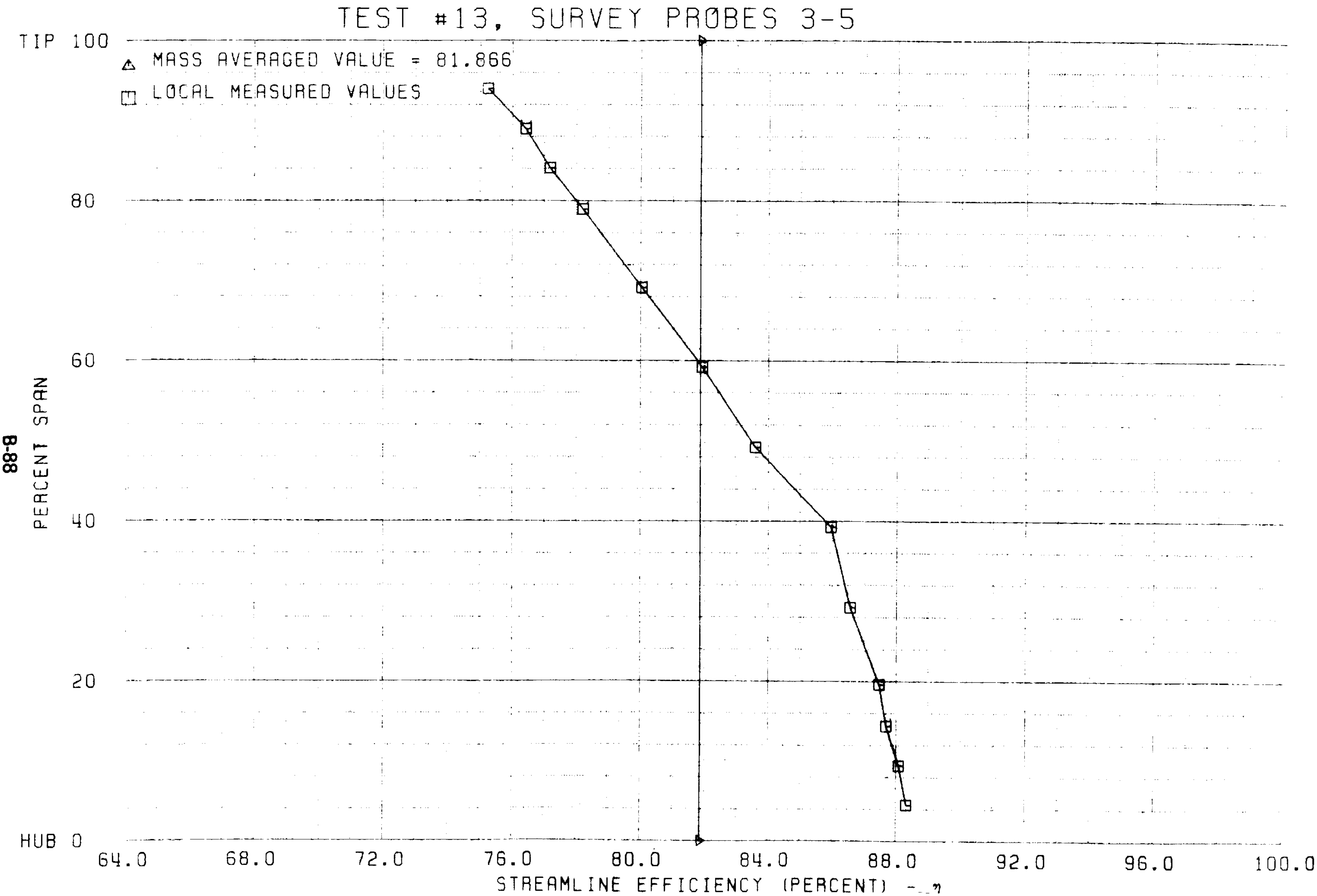

Figure B-88 Mixed Out Plane Survey - Streamline Efficiency vs. Percent Rotor Exit Span, Test No. 13, Moveable Hub, 66.0 Percent Area

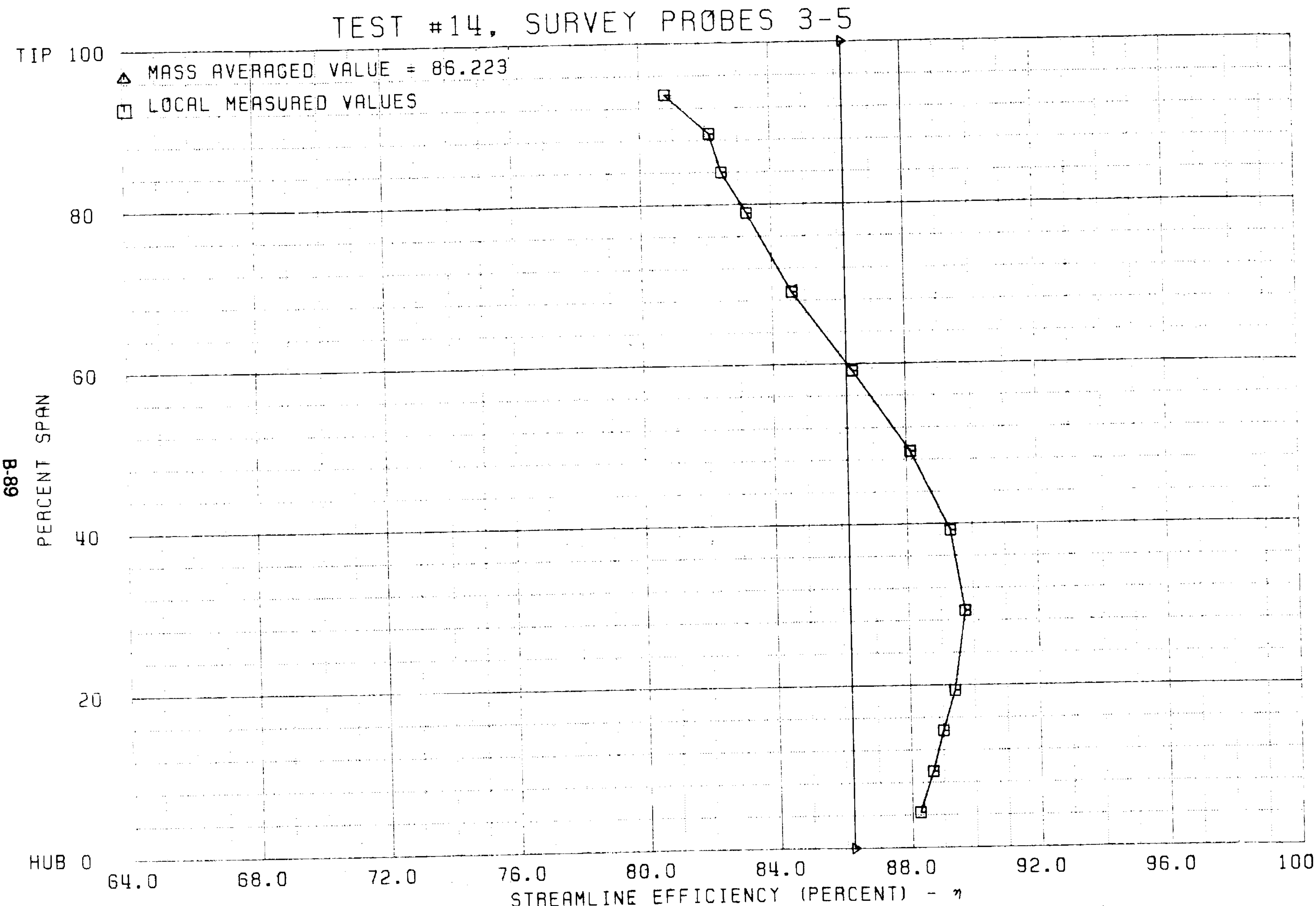

Figure B-89 Mixed Out Plane Survey - Streamline Efficiency vs. Percent Rotor Exit Span, Test No. 14, Moveable Shroud, 81.1 Percent Area

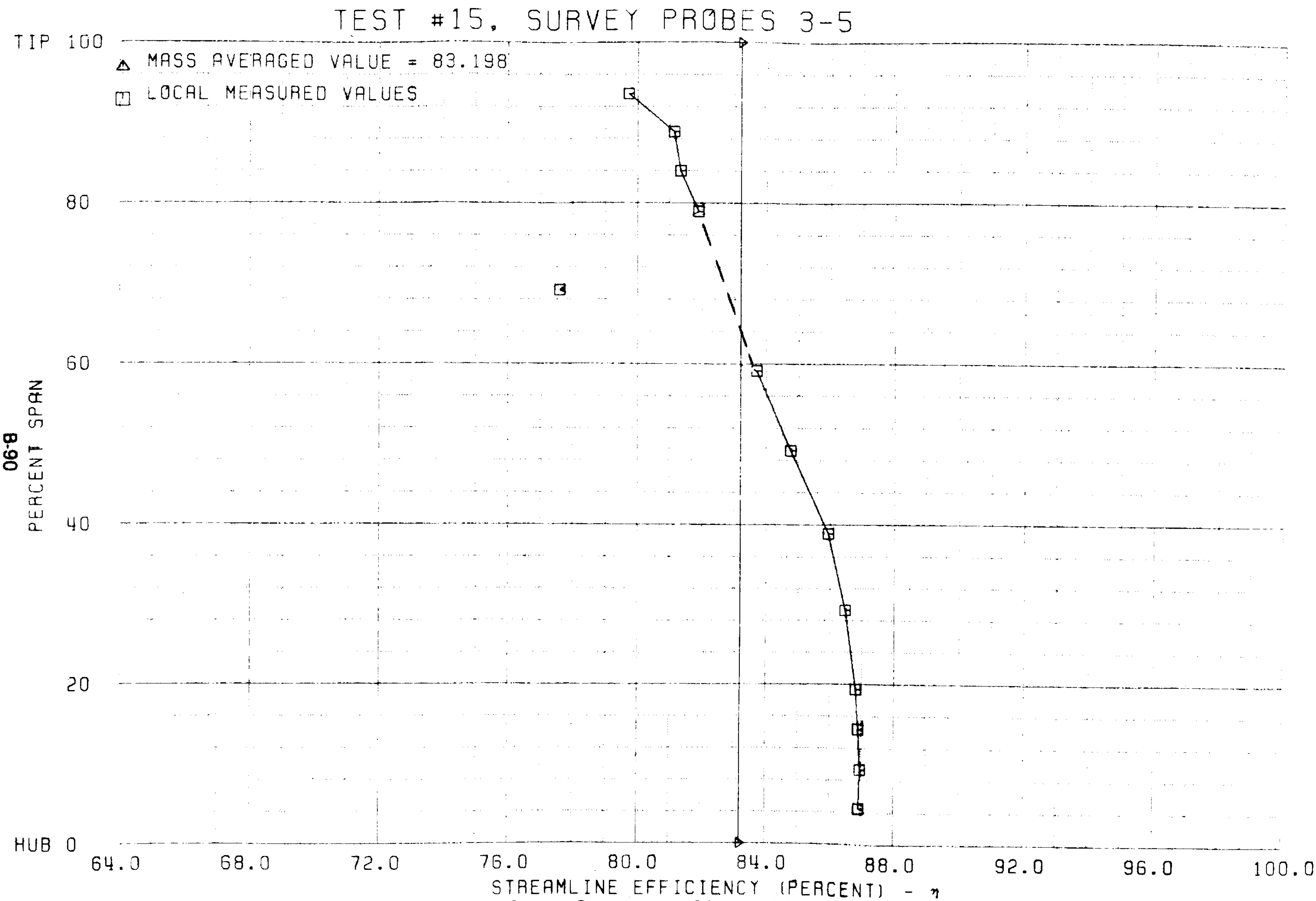

Figure B-90 Mixed Out Plane Survey - Streamline Efficiency vs. Percent Rotor Exit Span, Test No. 15, Moveable Shroud, 62.5 Percent Area

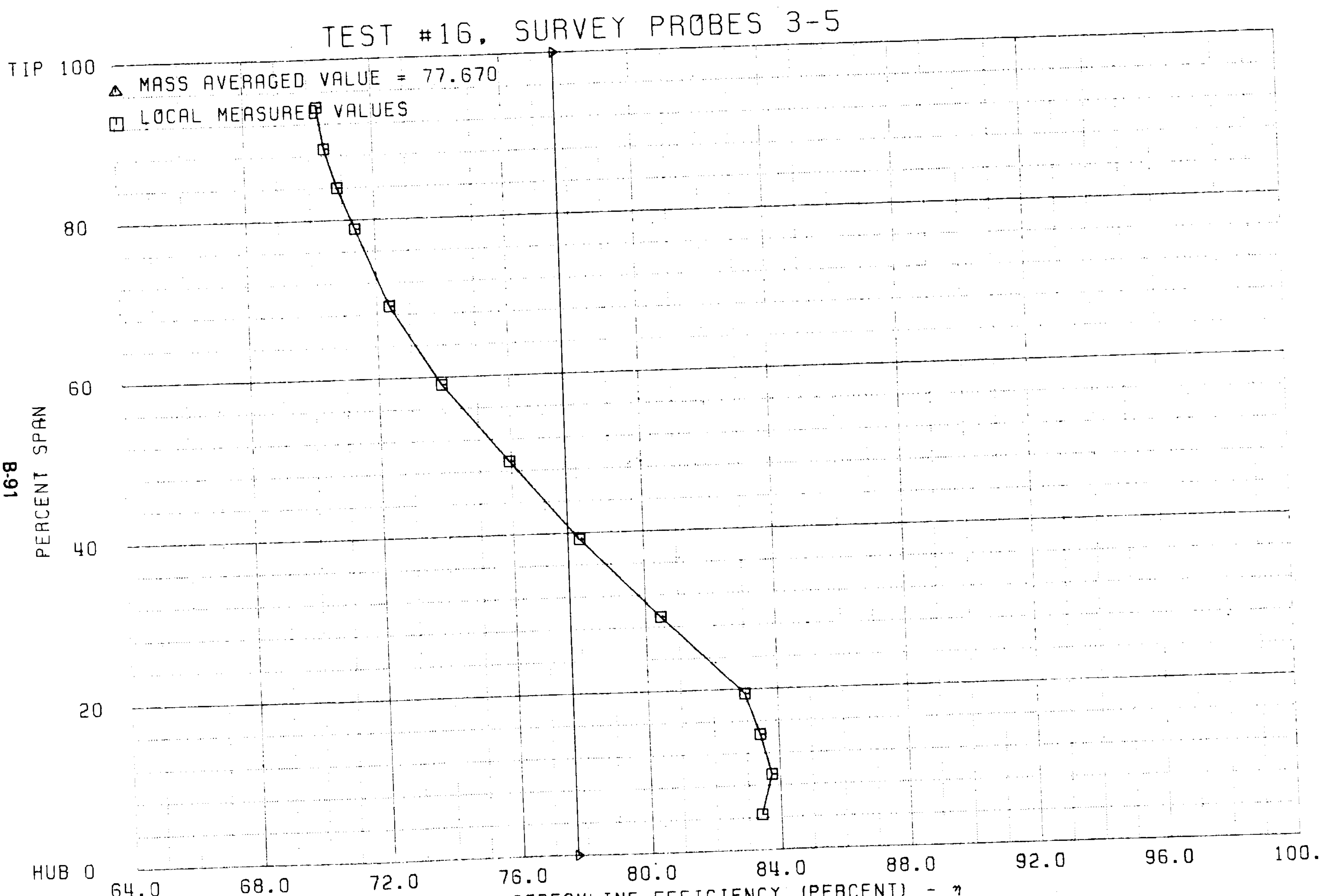

Figure B-91 Mixed Out Plane Survey - Streamline Efficiency vs. Percent Rotor Exit Span, Test No. 16, Moveable Shroud, 62.5 Percent Area

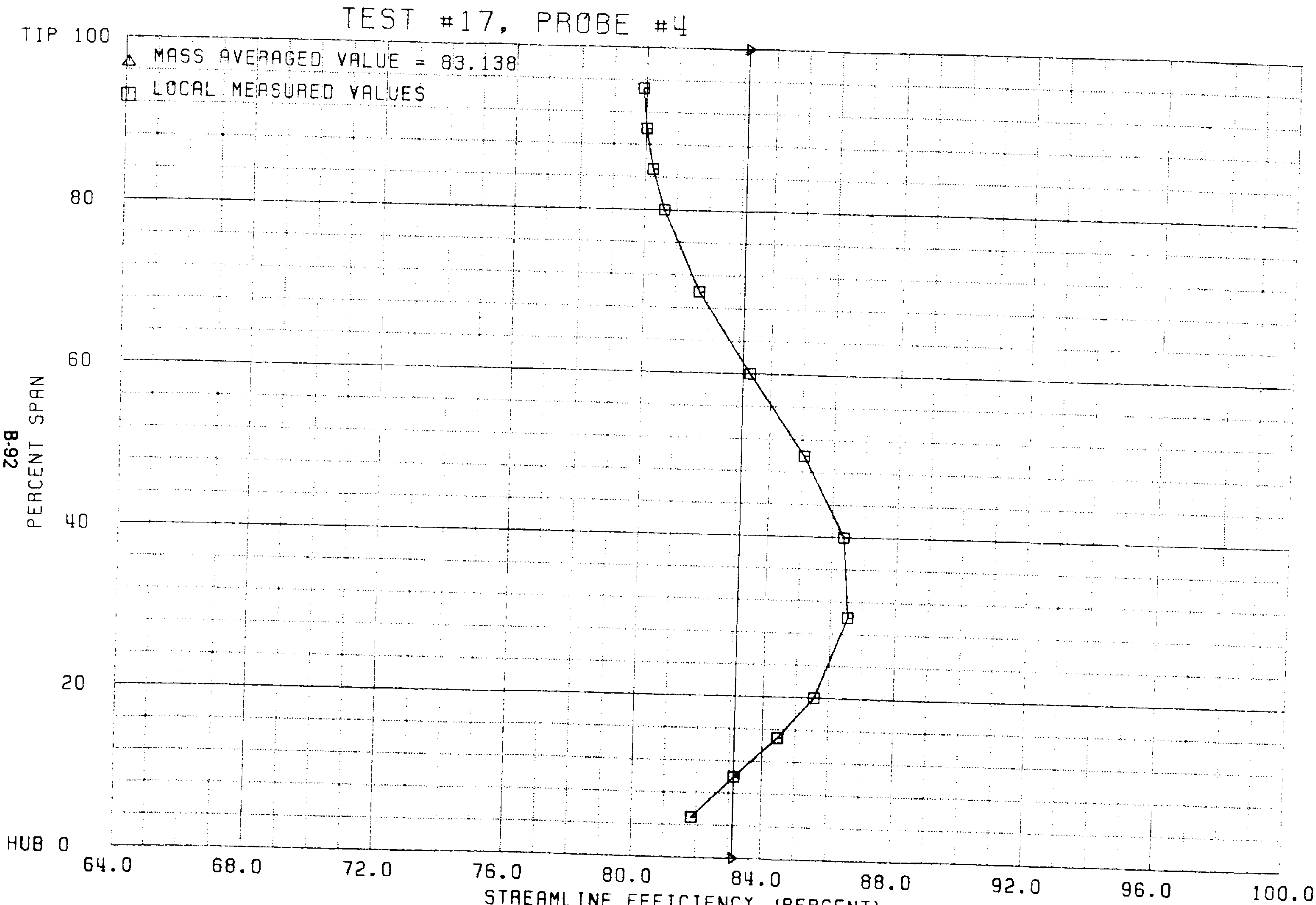

Figure B-92 Mixed Out Plane Survey - Streamline Efficiency vs. Percent Rotor Exit Span, Test No. 17, Moveable Shroud, 125.0 Percent Area

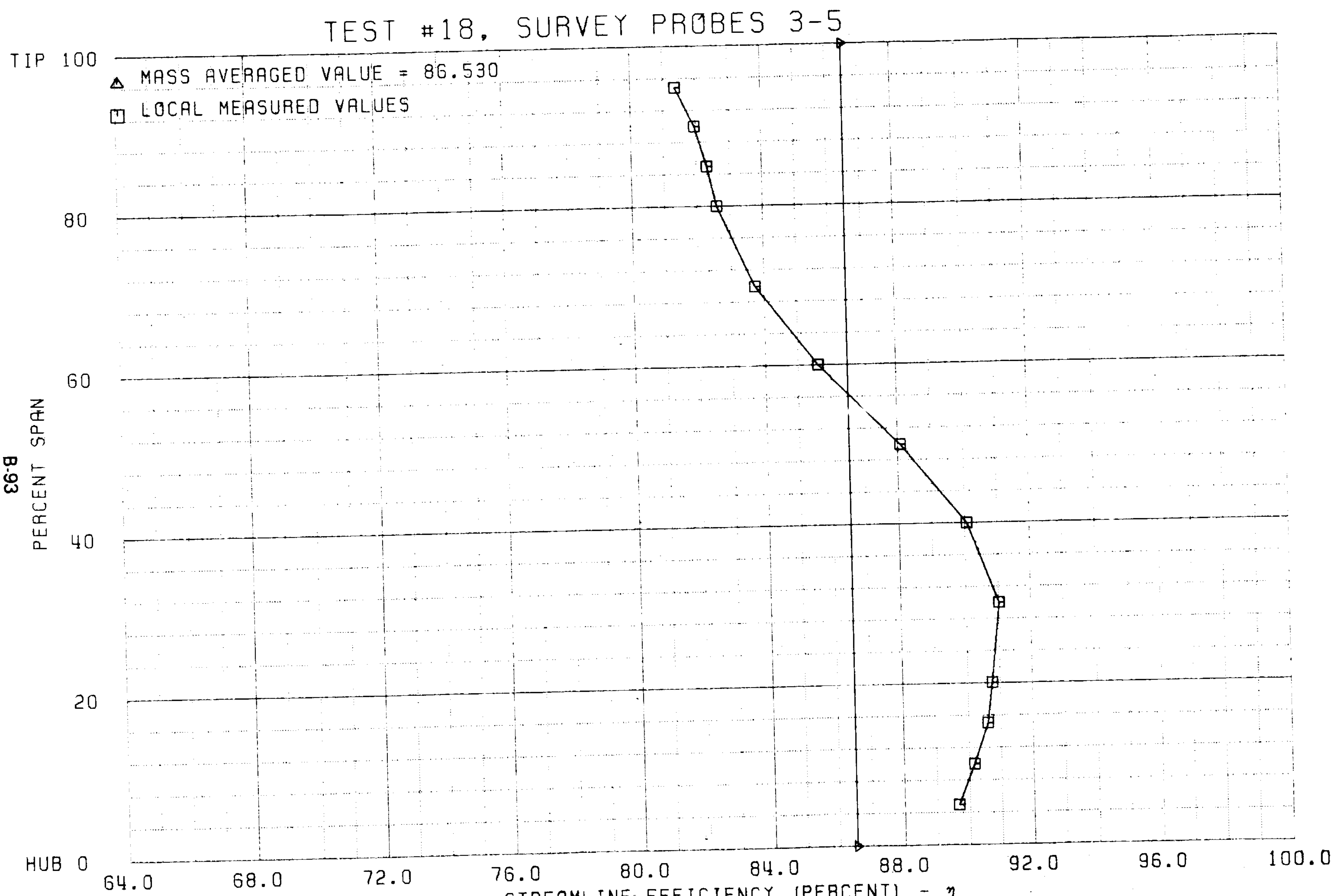

Figure B-93 Mixed Out Plane Survey - Streamline Efficiency vs. Percent Rotor Exit Span, Test No. 18, Moveable Shroud, 100.0 Percent Area

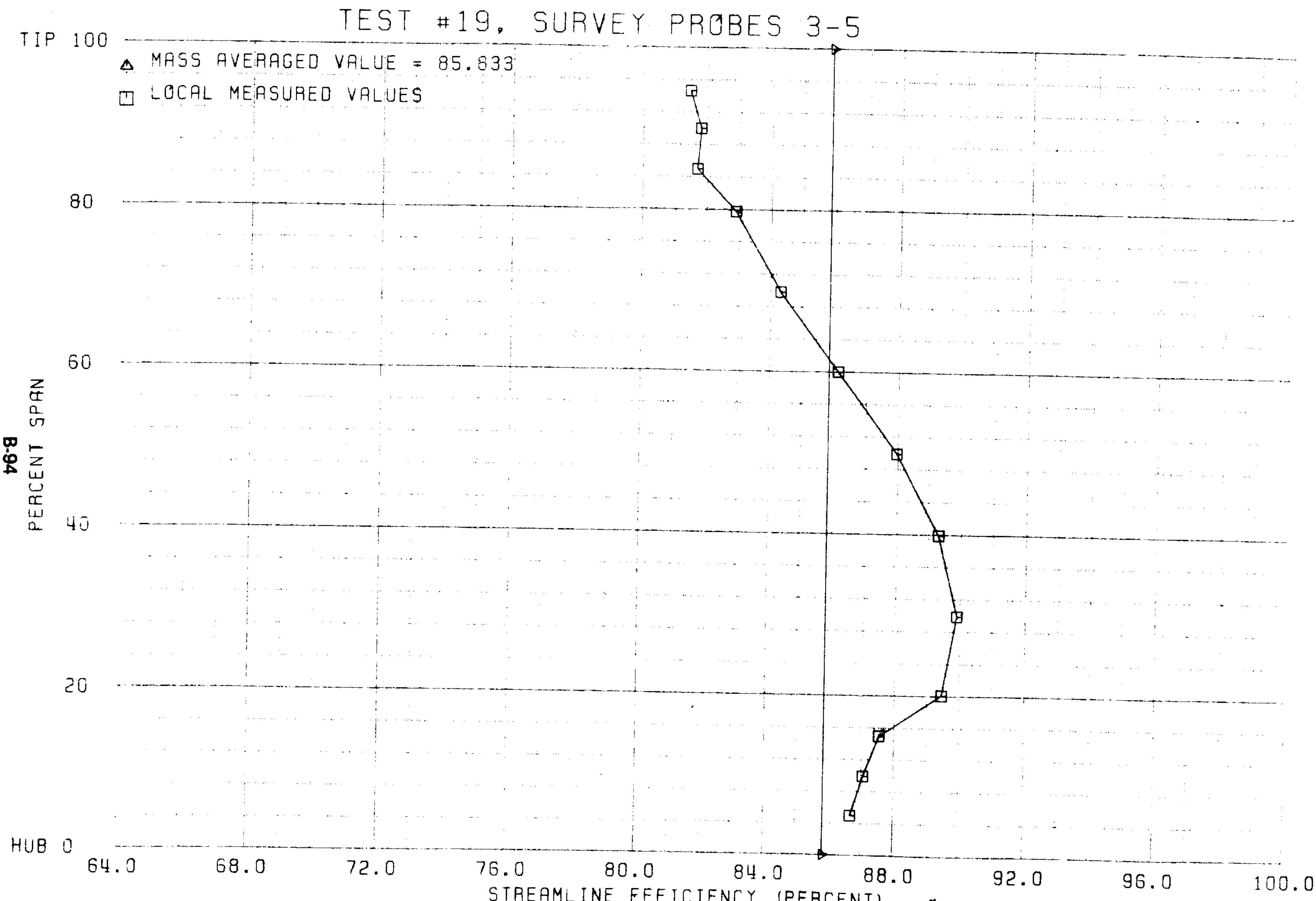

Figure B-94 Mixed Out Plane Survey - Streamline Efficiency vs. Percent Rotor Exit Span, Test No. 19, Moveable Shroud, 81.1 Percent Area

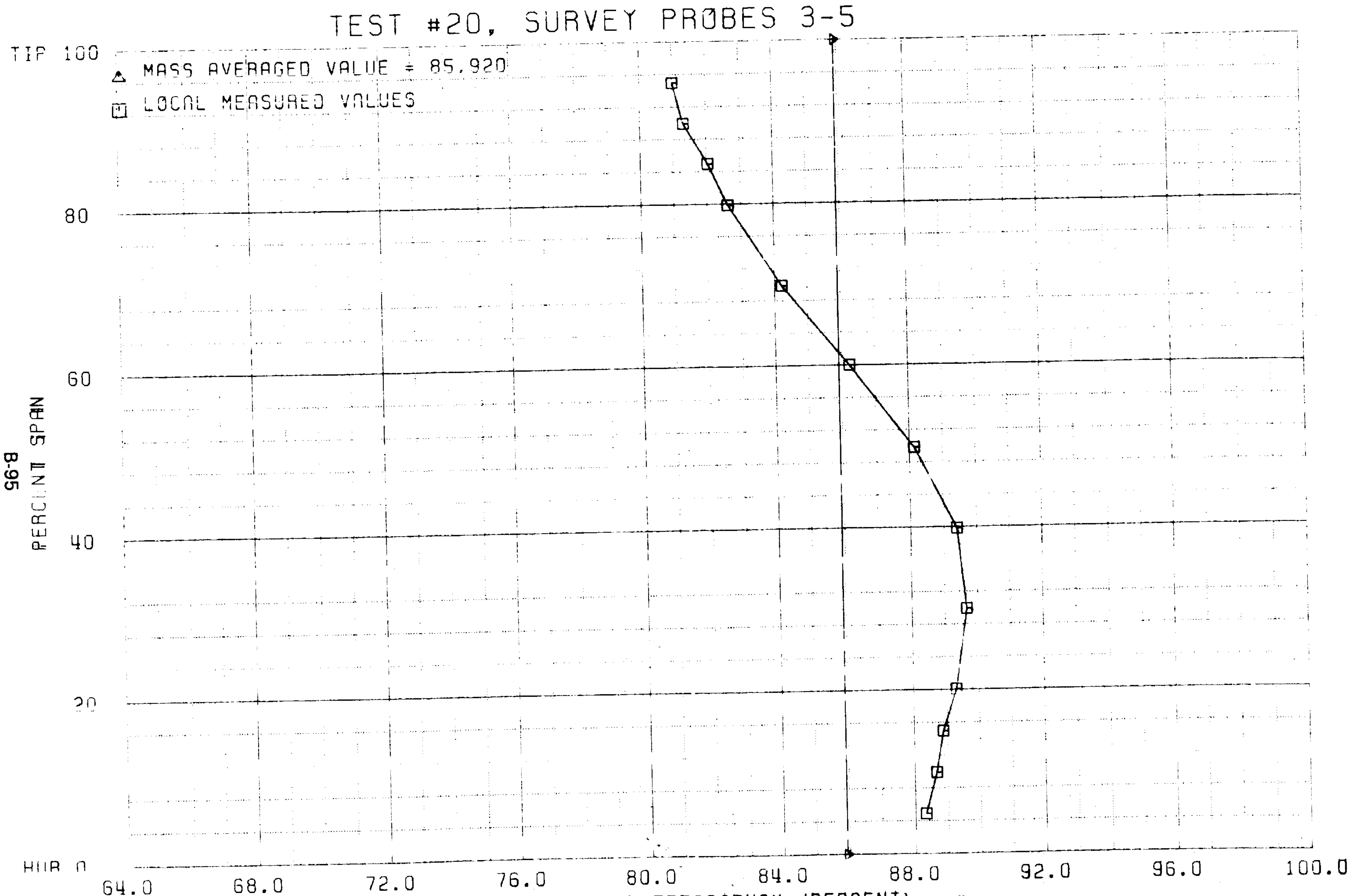

Figure B-95 Mixed Out Plane Survey - Streamline Efficiency vs. Percent Rotor Exit Span, Test No. 20, Moveable Shroud, 81.1 Percent Area

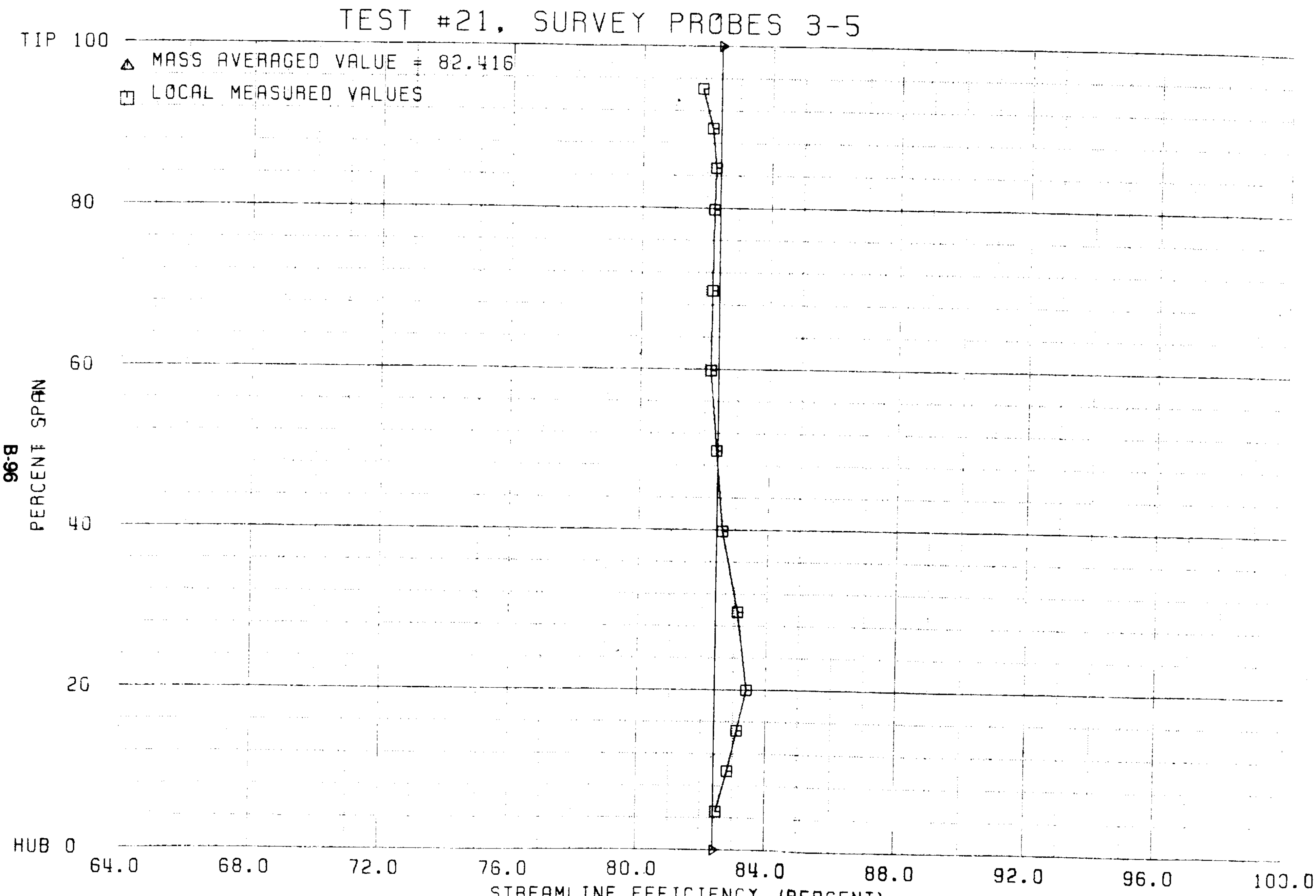

Figure B-96 Mixed Out Plane Survey - Streamline Efficiency vs. Percent Rotor Exit Span, Test No. 21, Moveable Shroud, 62.5 Percent Area

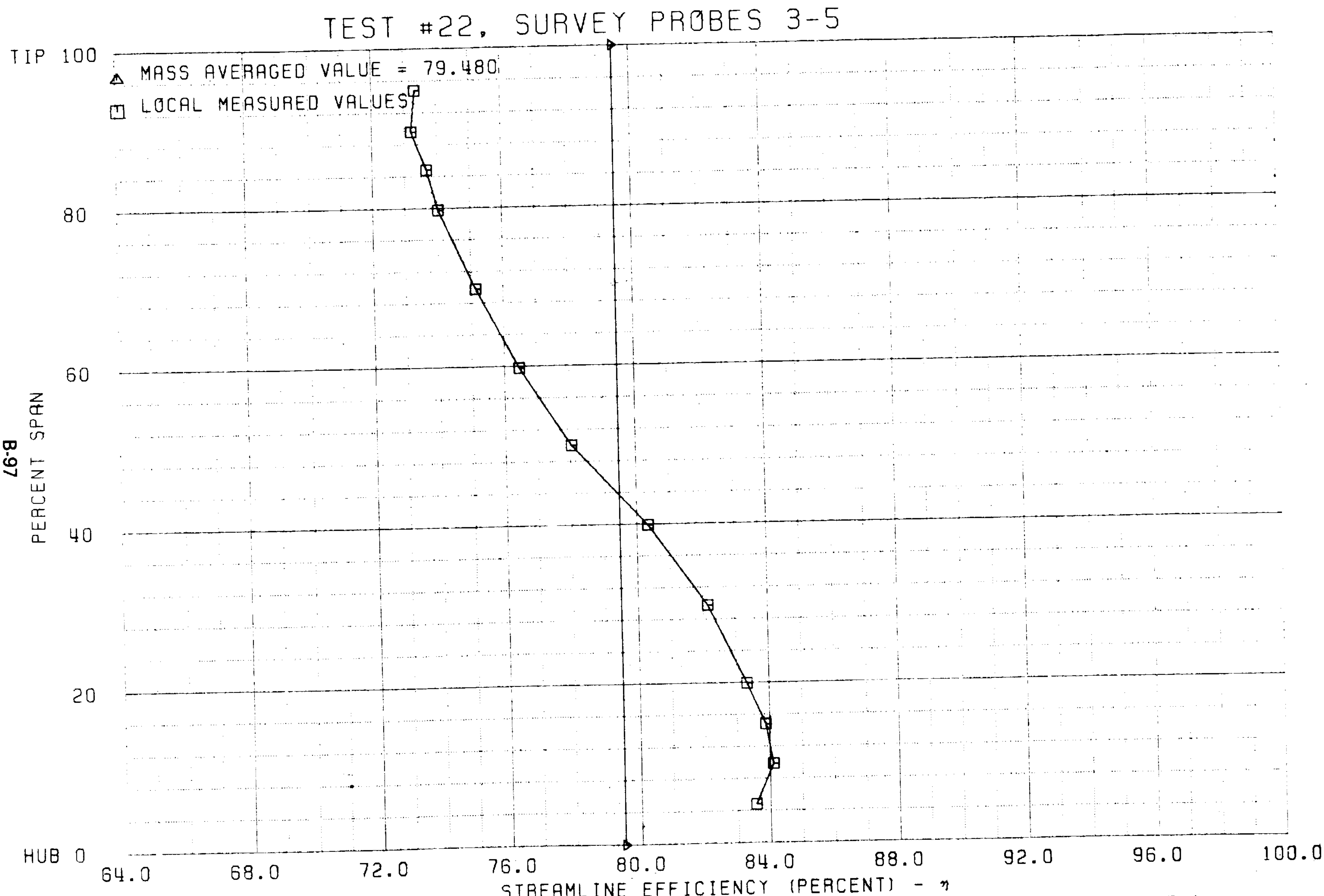

Figure B-97 Mixed Out Plane Survey - Streamline Efficiency vs. Percent Rotor Exit Span, Test No. 22, Moveable Shroud, 62.5 Percent Area

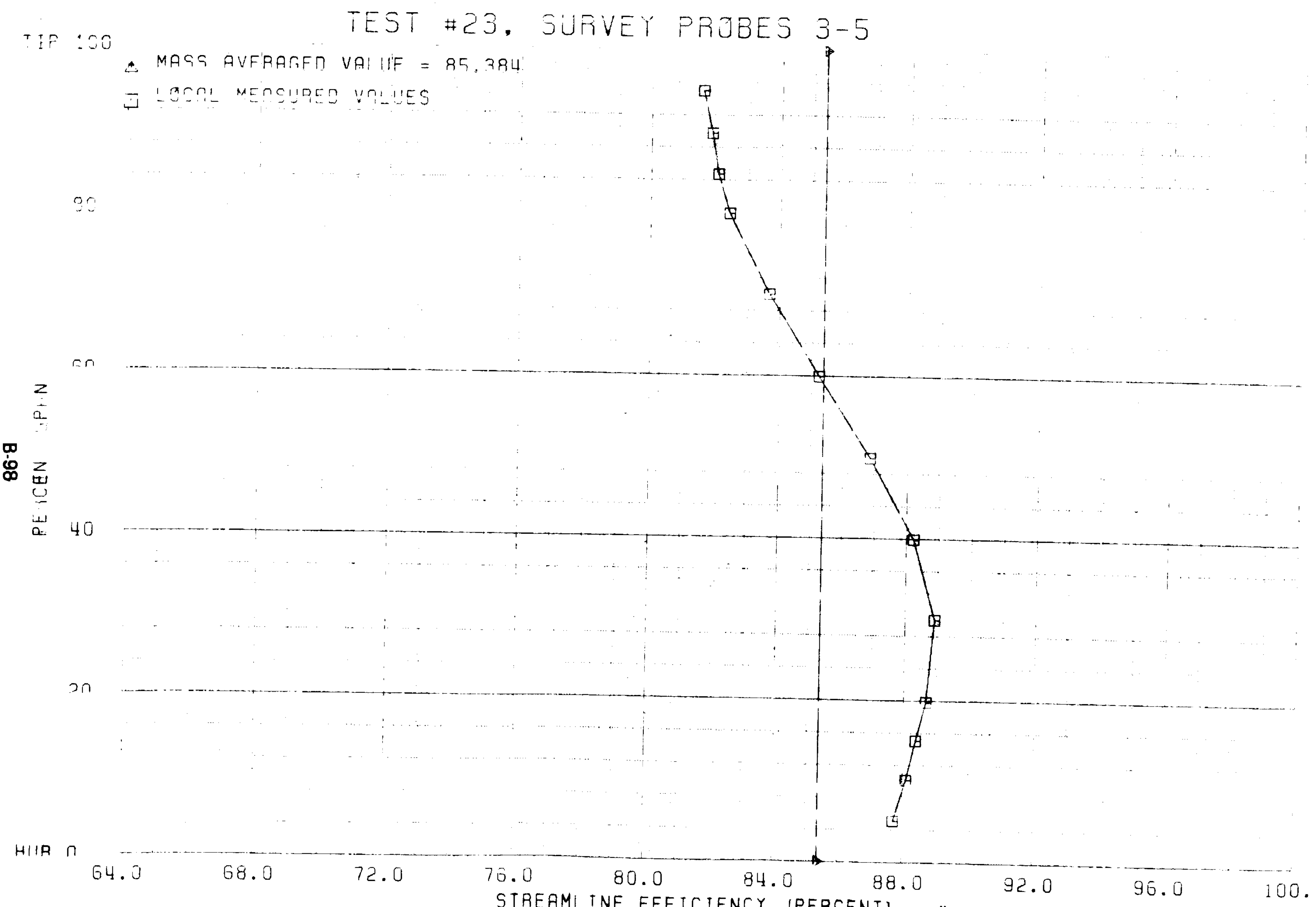

Figure B-98 Mixed Out Plane Survey - Streamline Efficiency vs. Percent Rotor Exit Span, Test No. 23, Moveable Shroud, 81.1 Percent Area

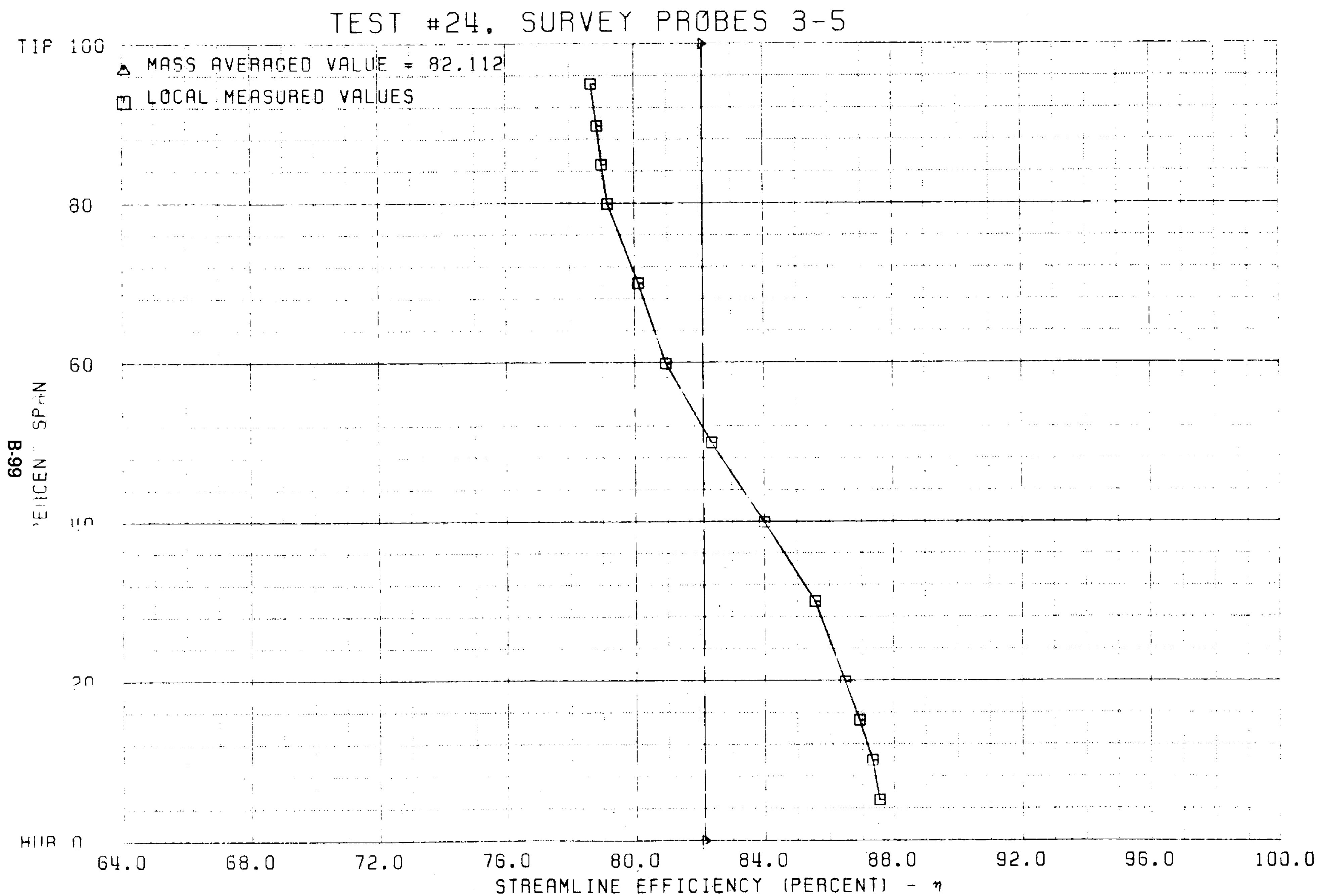

Figure B-99 Mixed Out Plane Survey - Streamline Efficiency vs. Percent Rotor Exit Span, Test No. 24, Moveable Shroud, 62.5 Percent Area

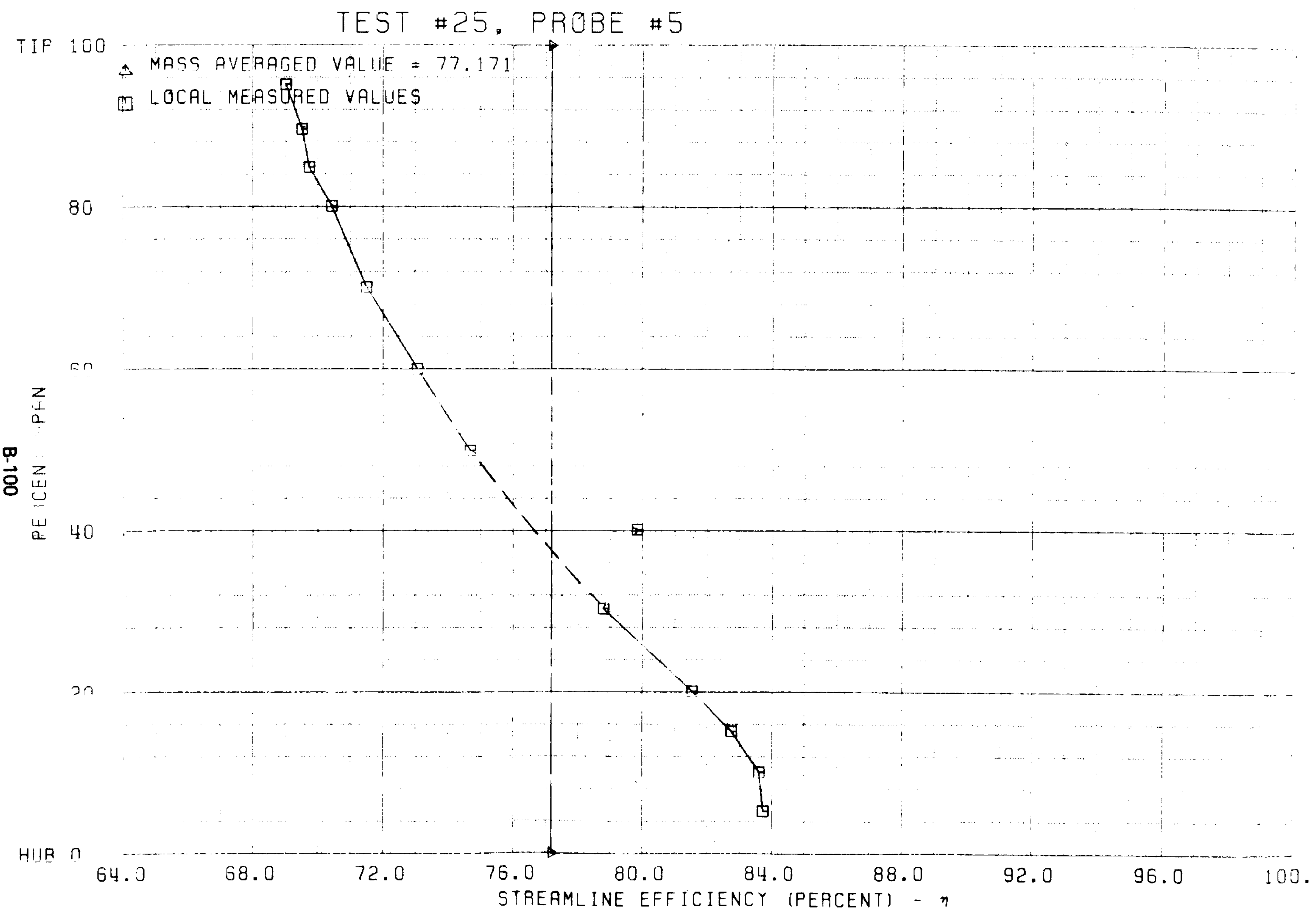

Figure B-100 Mixed Out Plane Survey - Streamline Efficiency vs. Percent Rotor Exit Span, Test No. 25, Moveable Shroud, 62.5 Percent Area

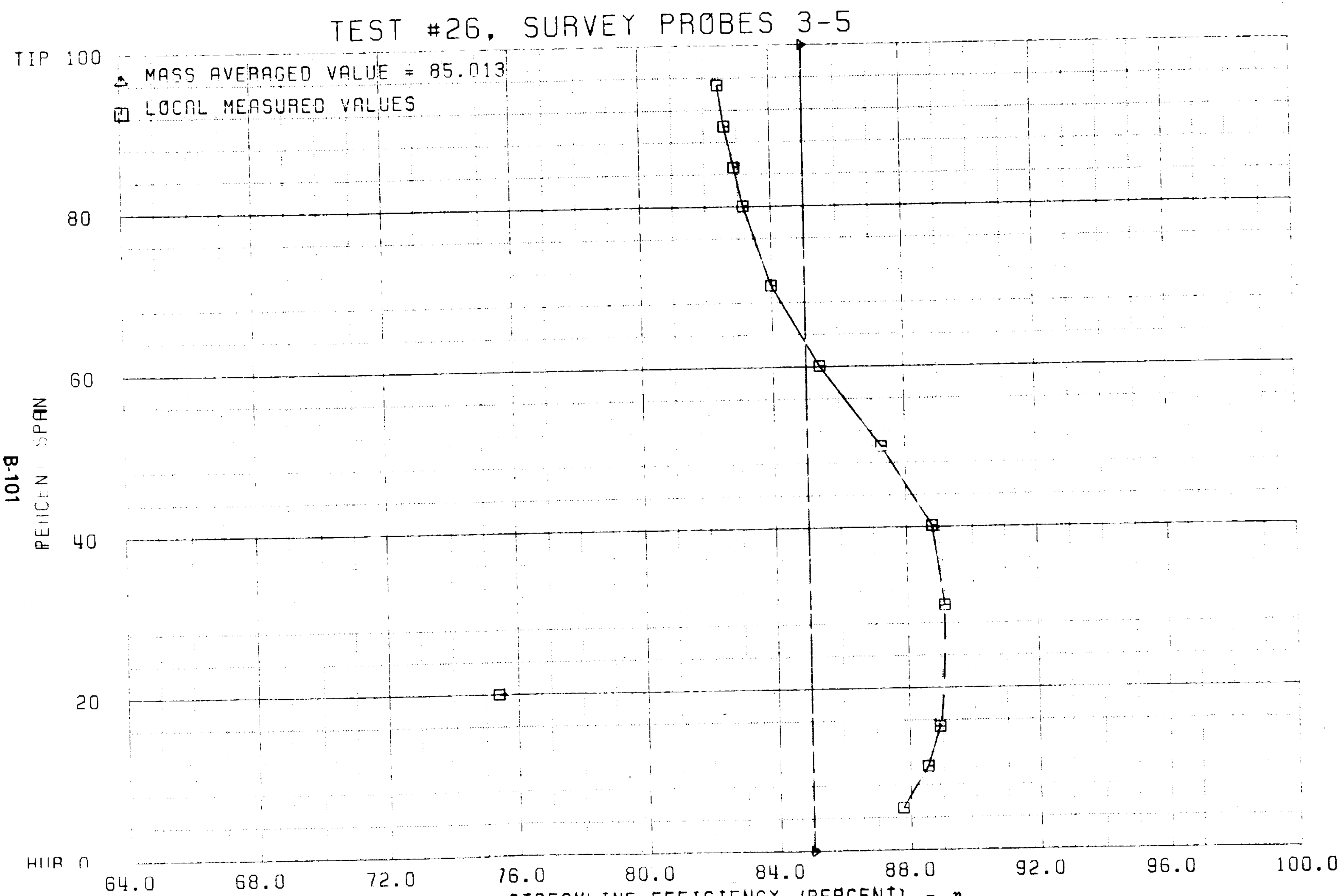

Figure B-101 Mixed Out Plane Survey - Streamline Efficiency vs. Percent Rotor Exit Span, Test No. 26, Moveable Shroud, 103.5 Percent Area

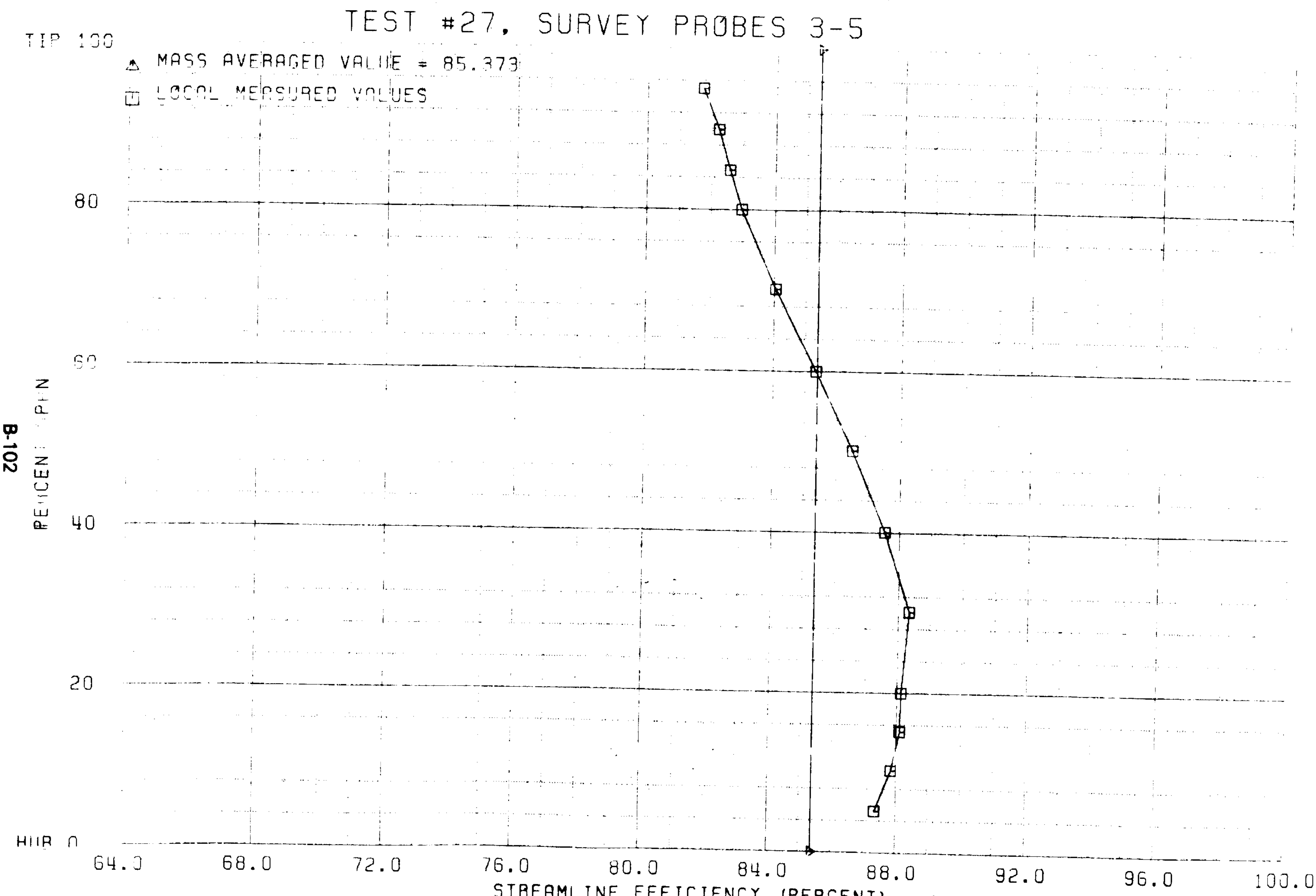

Figure B-102 Mixed Out Plane Survey - Streamline Efficiency vs. Percent Rotor Exit Span, Test No. 27, Moveable Shroud, 84.6 Percent Area

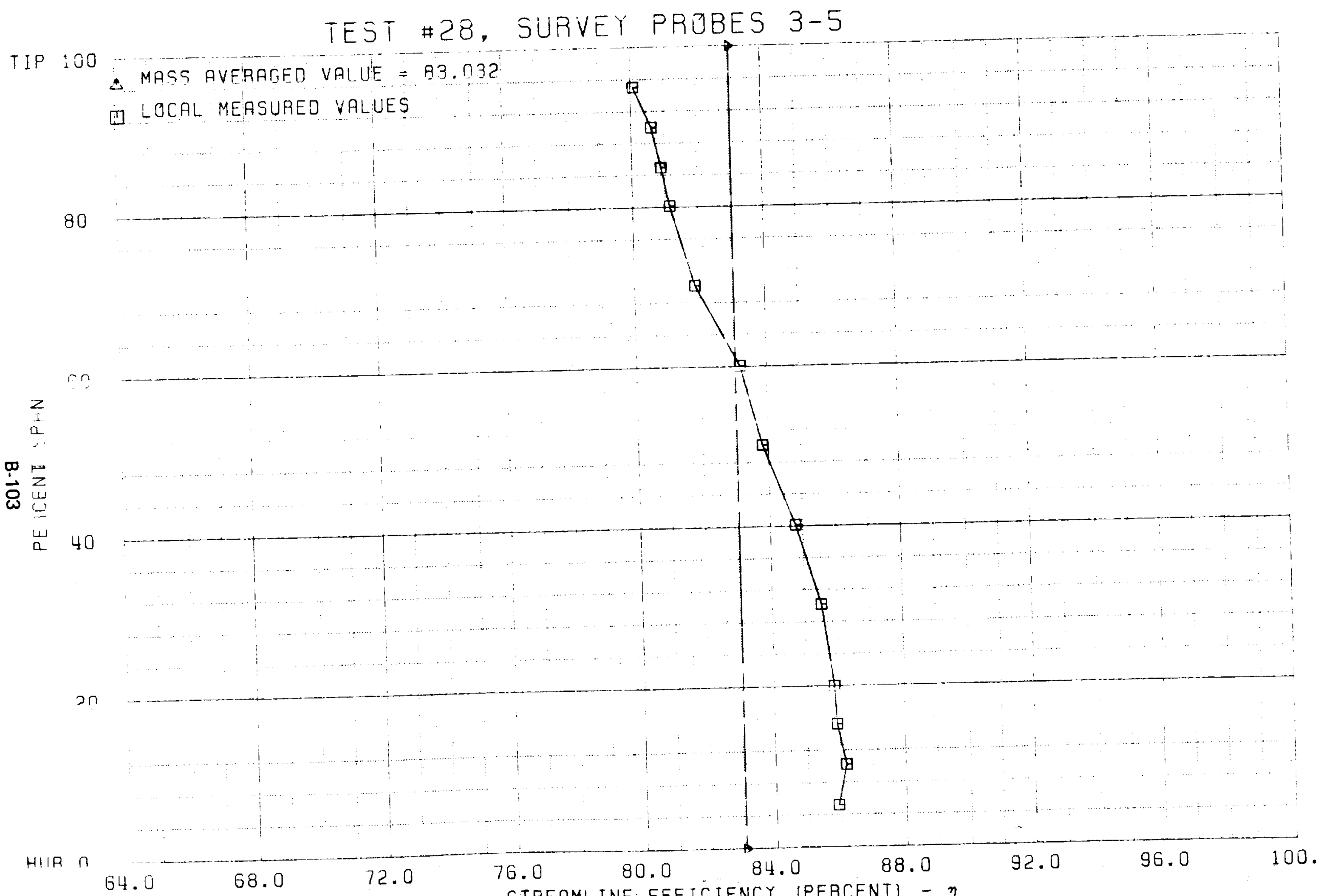

Figure B-103 Mixed Out Plane Survey - Streamline Efficiency vs. Percent Rotor Exit Span, Test No. 28, Moveable Shroud, 66.0 Percent Area

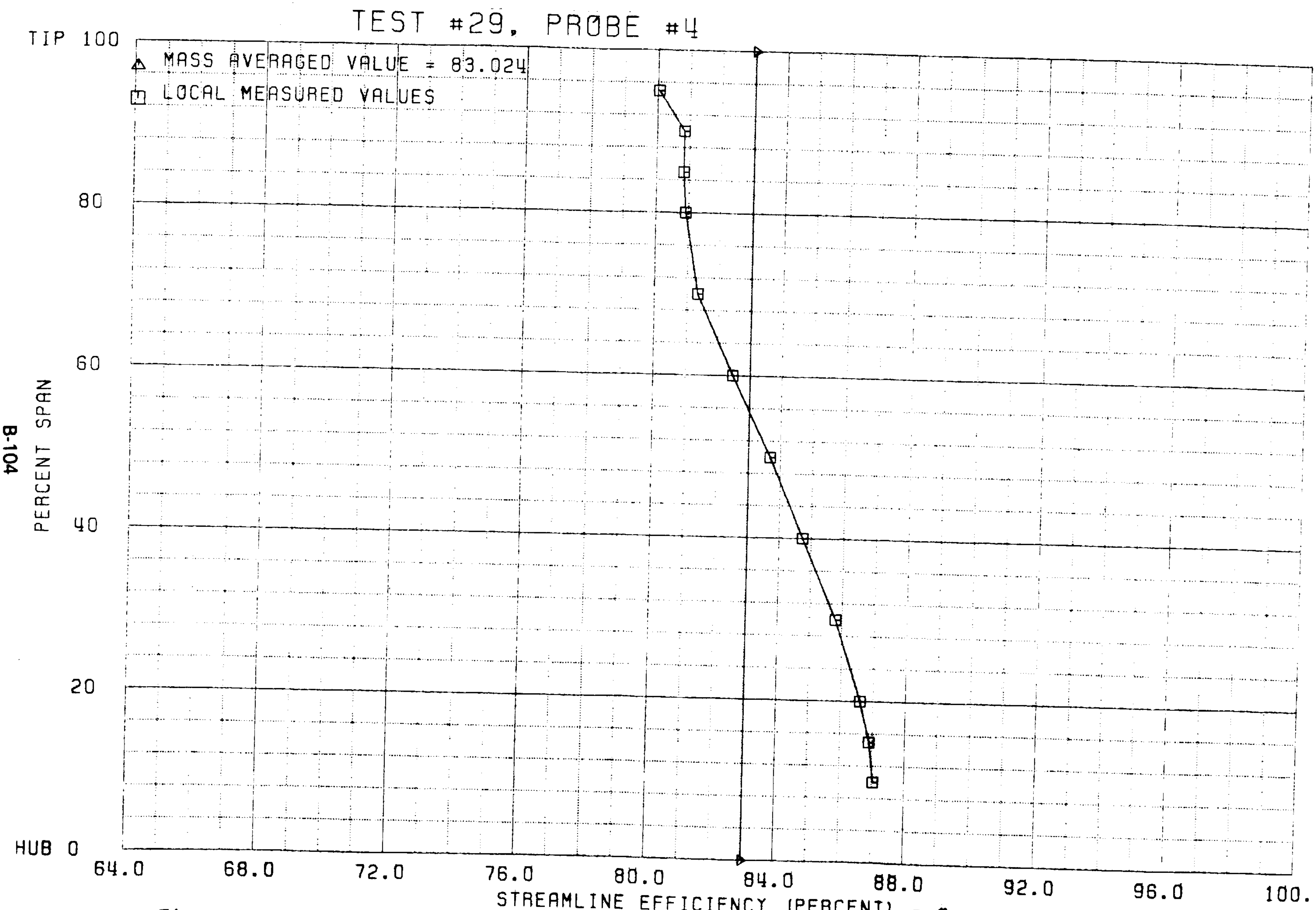

Figure B-104 Mixed Out Plane Survey - Streamline Efficiency vs. Percent Rotor Exit Span, Test No. 29, Moveable Shroud, 62.2 Percent Area

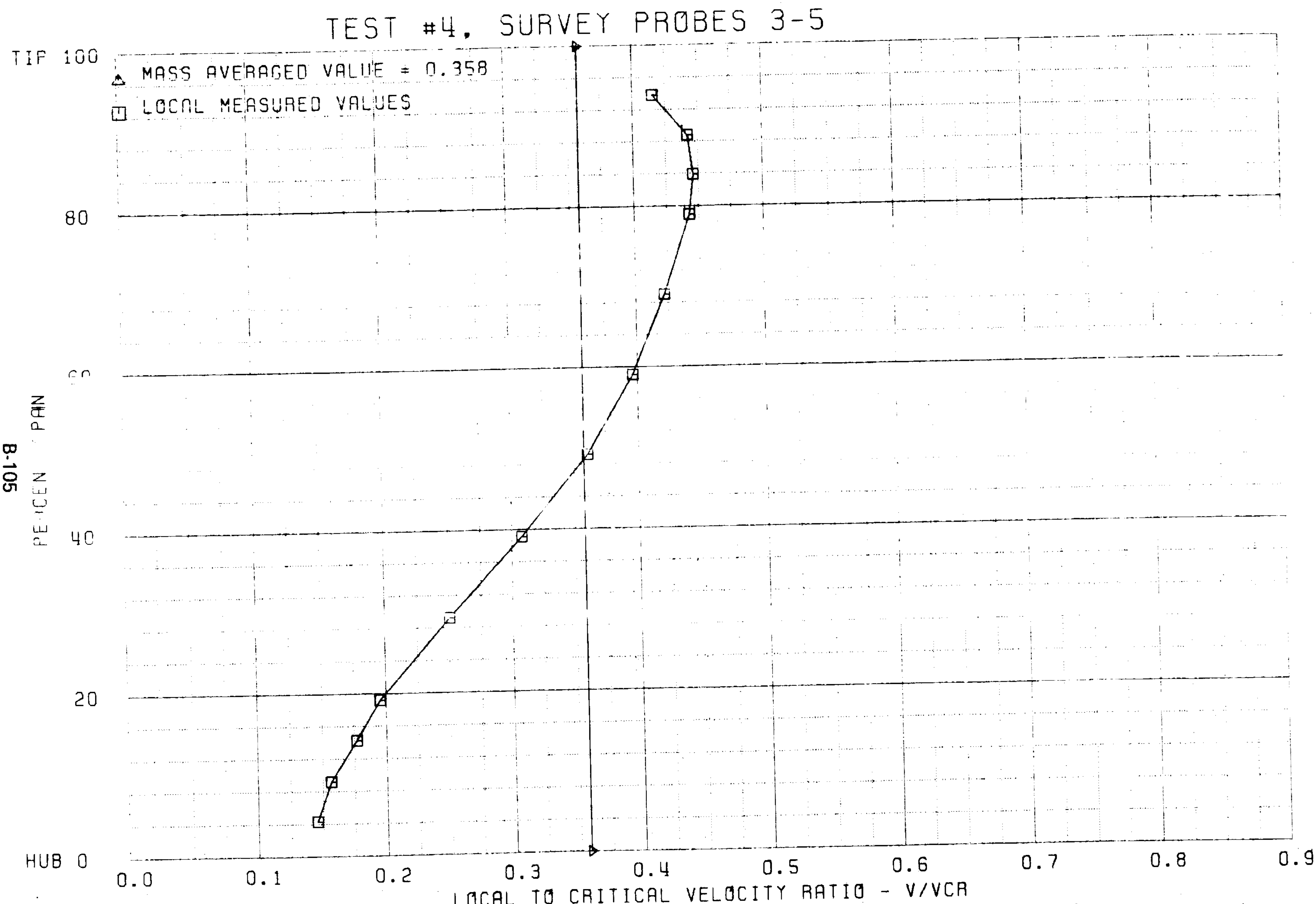

Figure B-105 Mixed Out Plane Survey - Local to Critical Velocity Ratio vs. Percent Rotor Exit Span, Test No. 4, Moveable Hub, 62.2 Percent Area

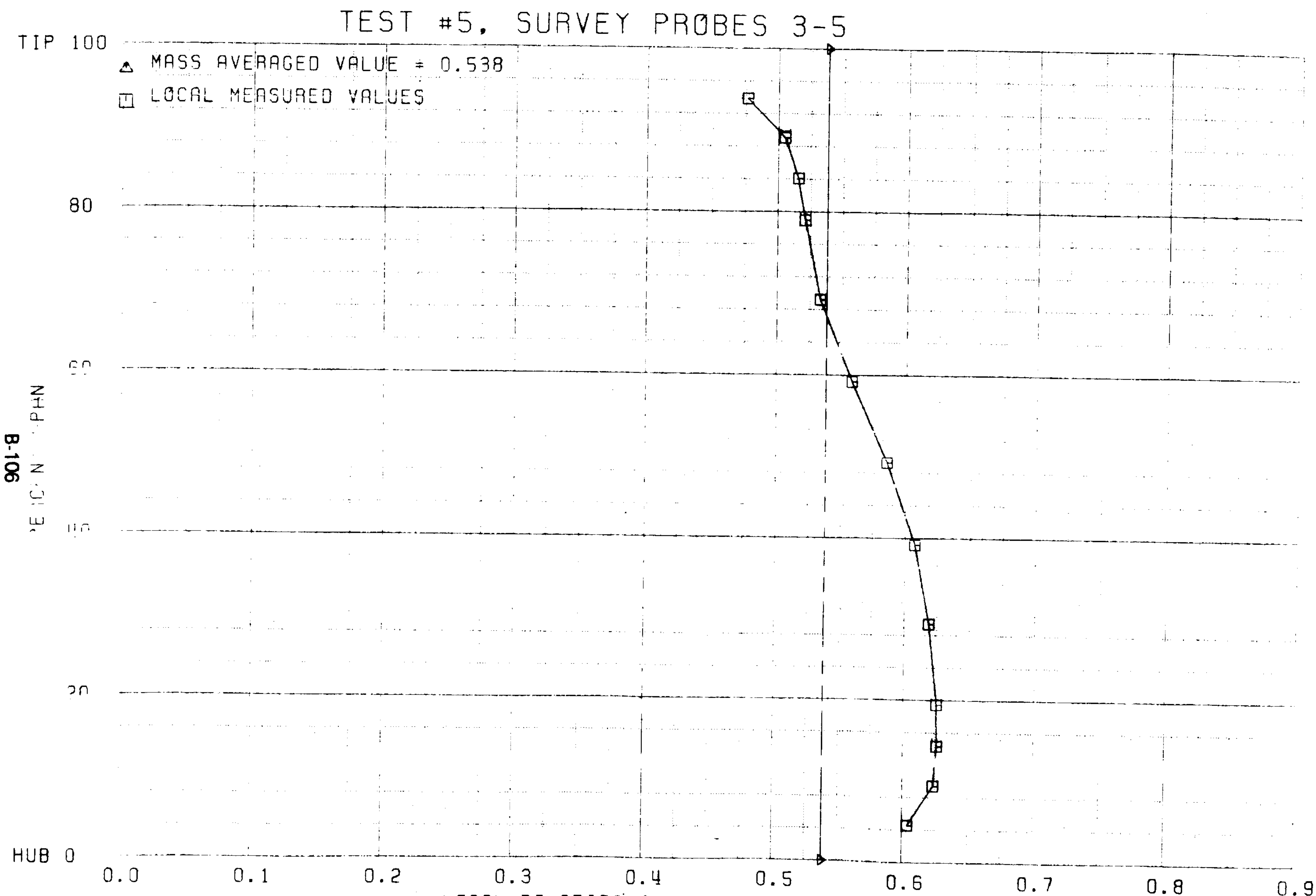

Figure B-106 Mixed Out Plane Survey - Local to Critical Velocity Ratio vs. Percent Rotor Exit Span, Test No. 5, Moveable Hub, 108.8 Percent Area

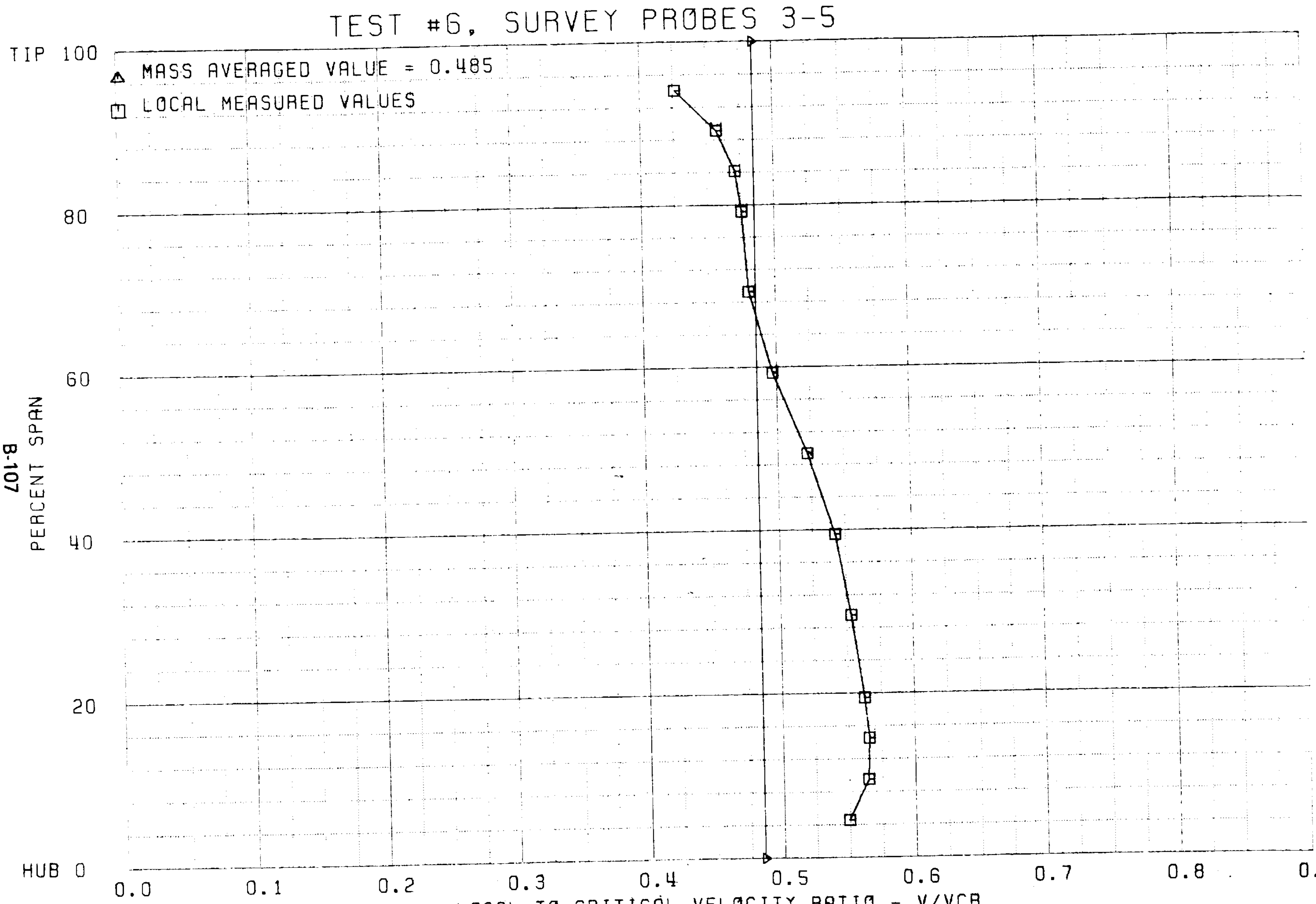

Figure B-107 Mixed Out Plane Survey - Local to Critical Velocity Ratio vs. Percent Rotor Exit Span, Test No. 6, Moveable Hub, 100.0 Percent Area

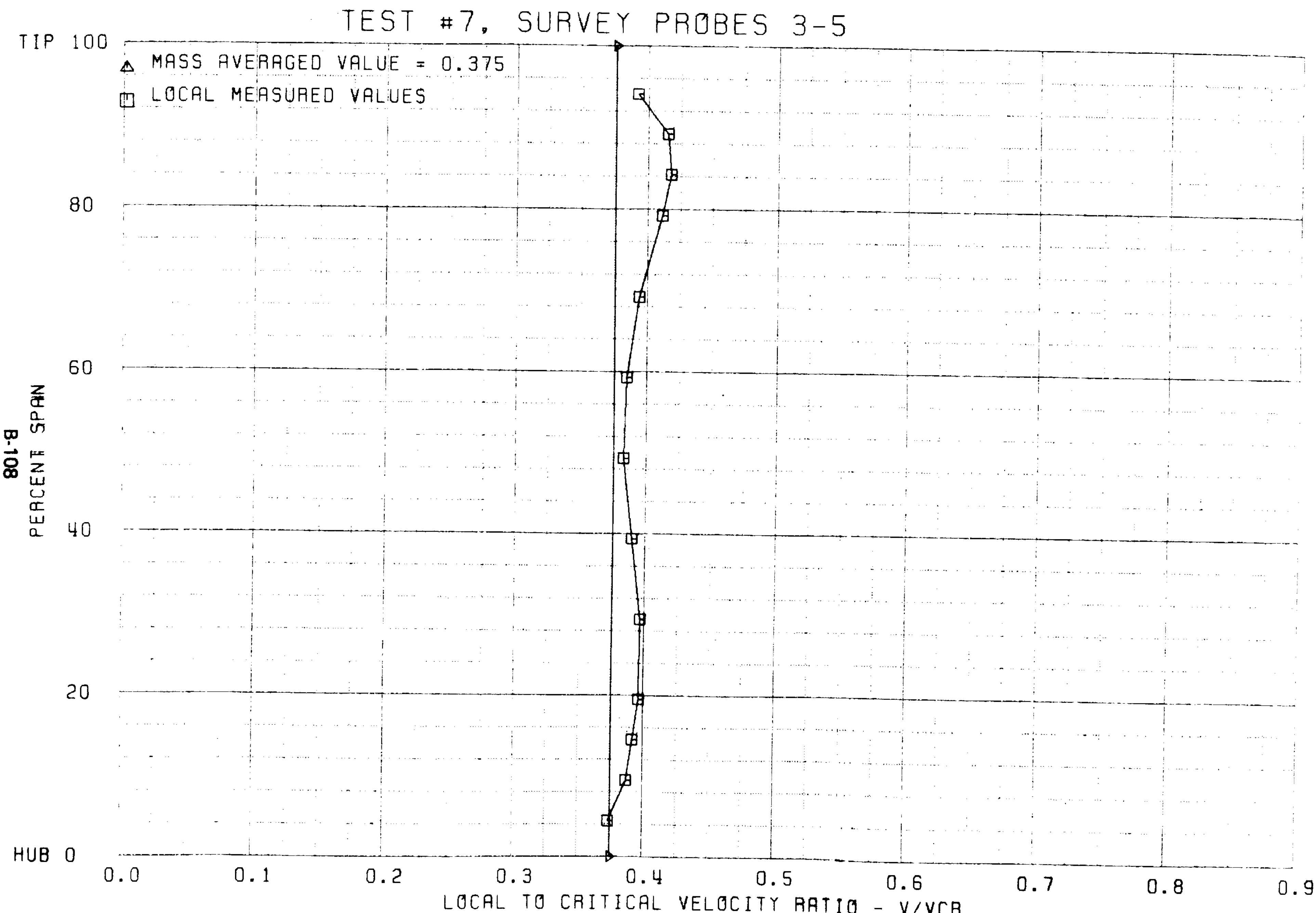

Figure B-108 Mixed Out Plane Survey - Local to Critical Velocity Ratio vs. Percent Rotor Exit Span, Test No. 7, Moveable Hub, 81.1 Percent Area

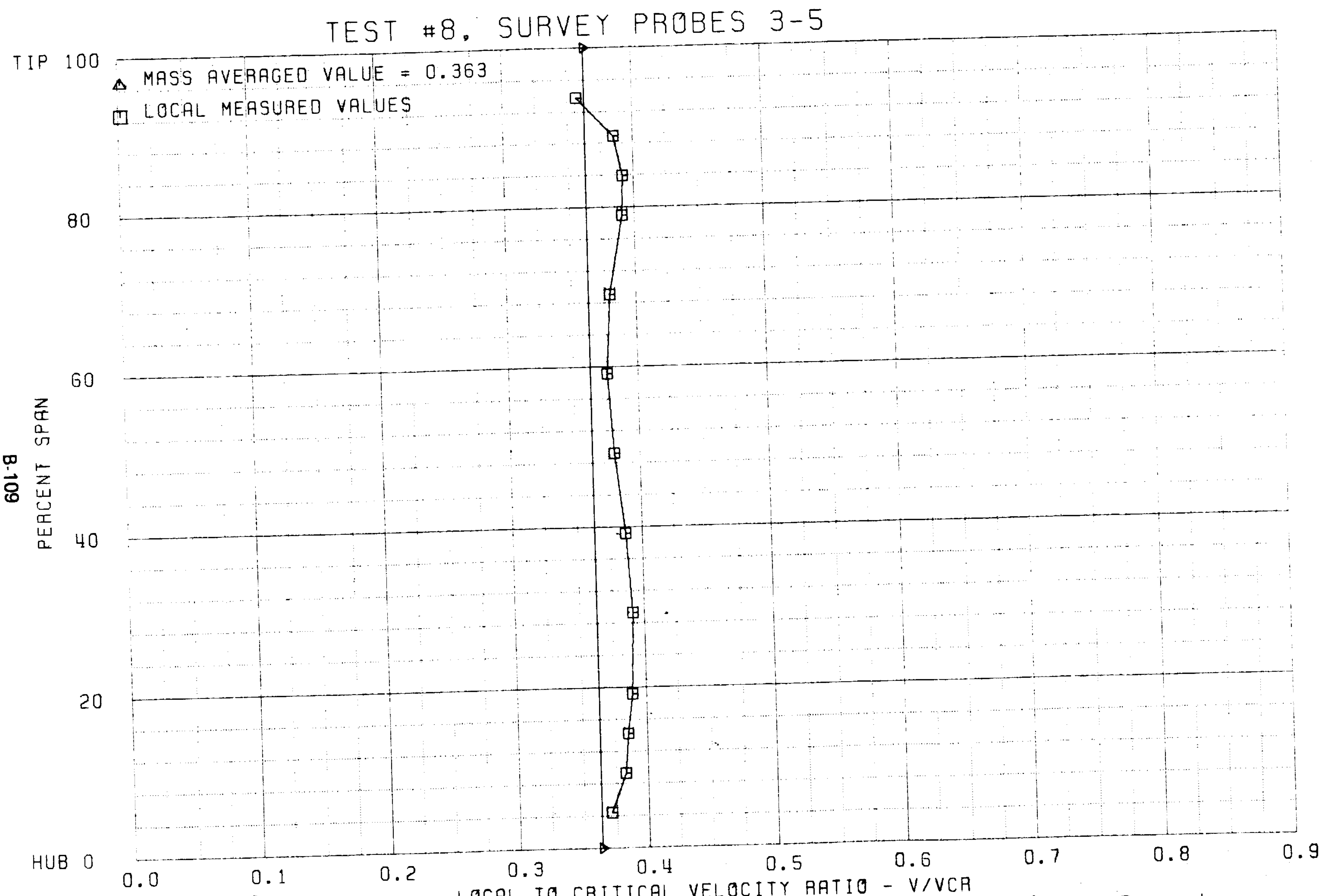

Figure B-109 Mixed Out Plane Survey - Local to Critical Velocity Ratio vs. Percent Rotor Exit Span, Test No. 8, Moveable Hub, 81.1 Percent Area

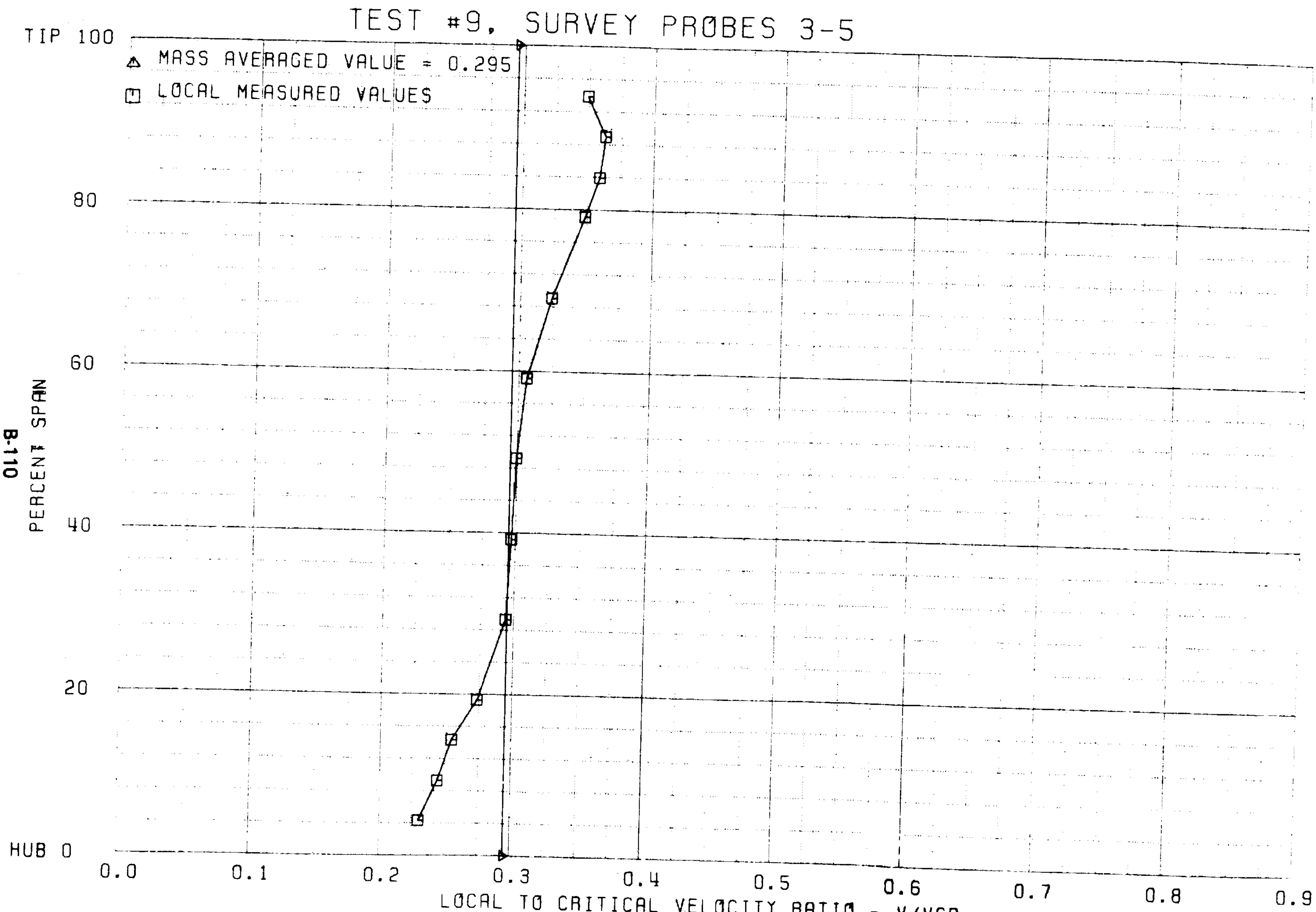

Figure B-110 Mixed Out Plane Survey - Local to Critical Velocity Ratio vs. Percent Rotor Exit Span, Test No. 9, Moveable Hub, 62.2 Percent Area

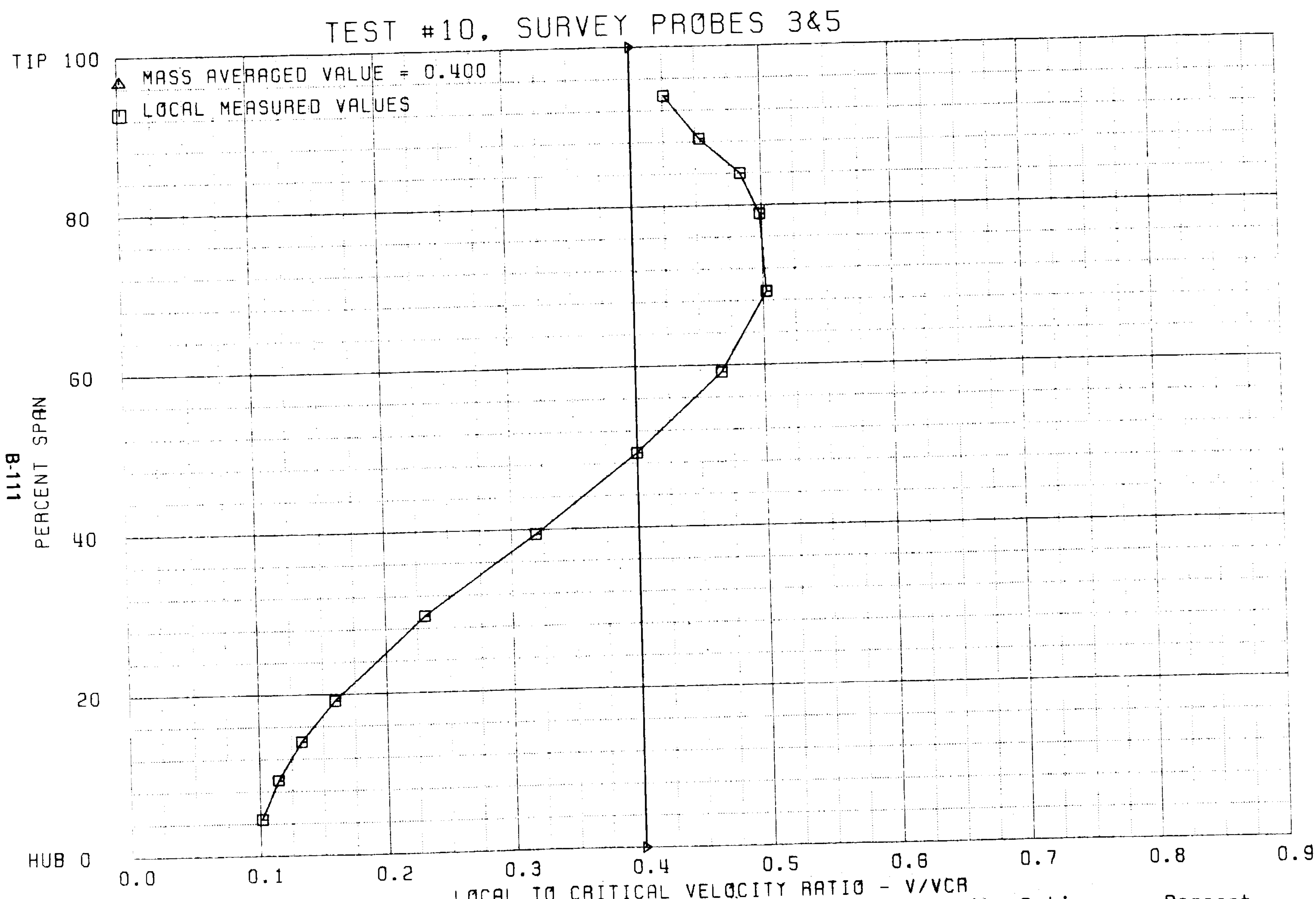

Figure B-111 Mixed Out Plane Survey - Local to Critical Velocity Ratio, vs. Percent Rotor Exit Span, Test No. 10, Moveable Hub, 62.2 Percent Area

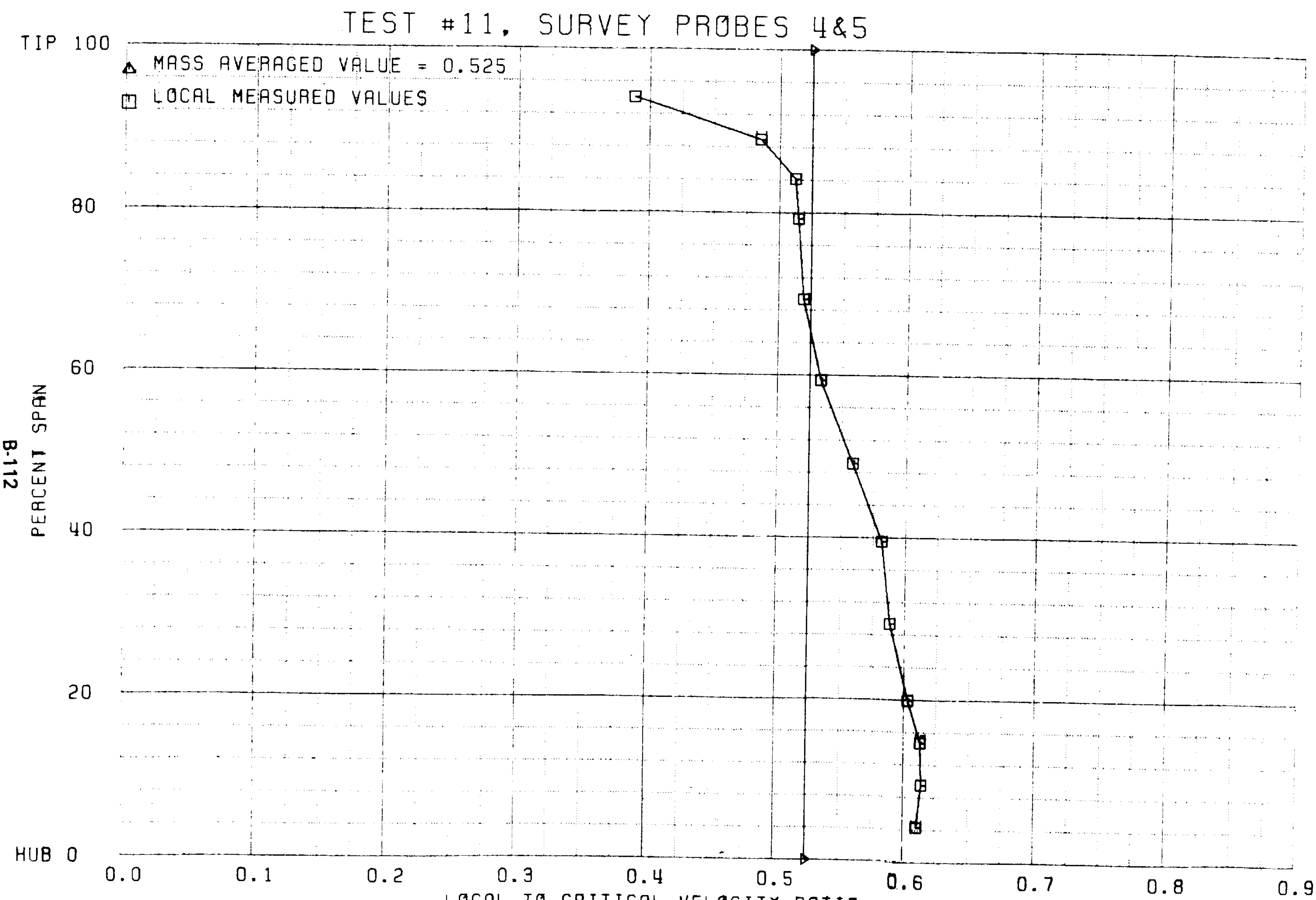

Figure B-112 Mixed Out Plane Survey - Local to Critical Velocity Ratio, vs. Percent Rotor Exit Span, Test No. 11, Moveable Hub, 103.5 Percent Area

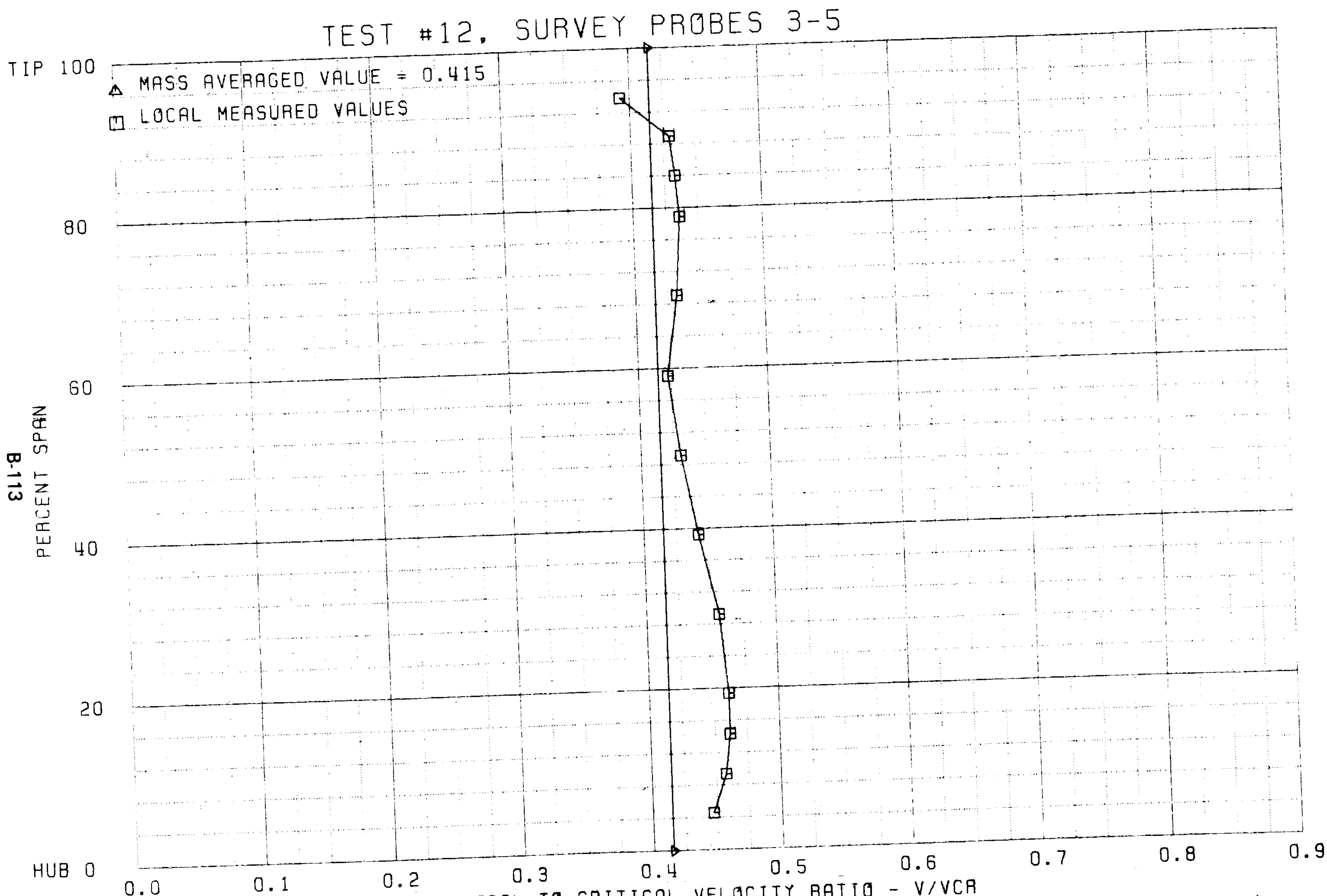

Figure B-113 Mixed Out Plane Survey - Local to Critical Velocity Ratio vs. Percent Rotor Exit Span, Test No. 12, Moveable Hub, 84.6 Percent Area

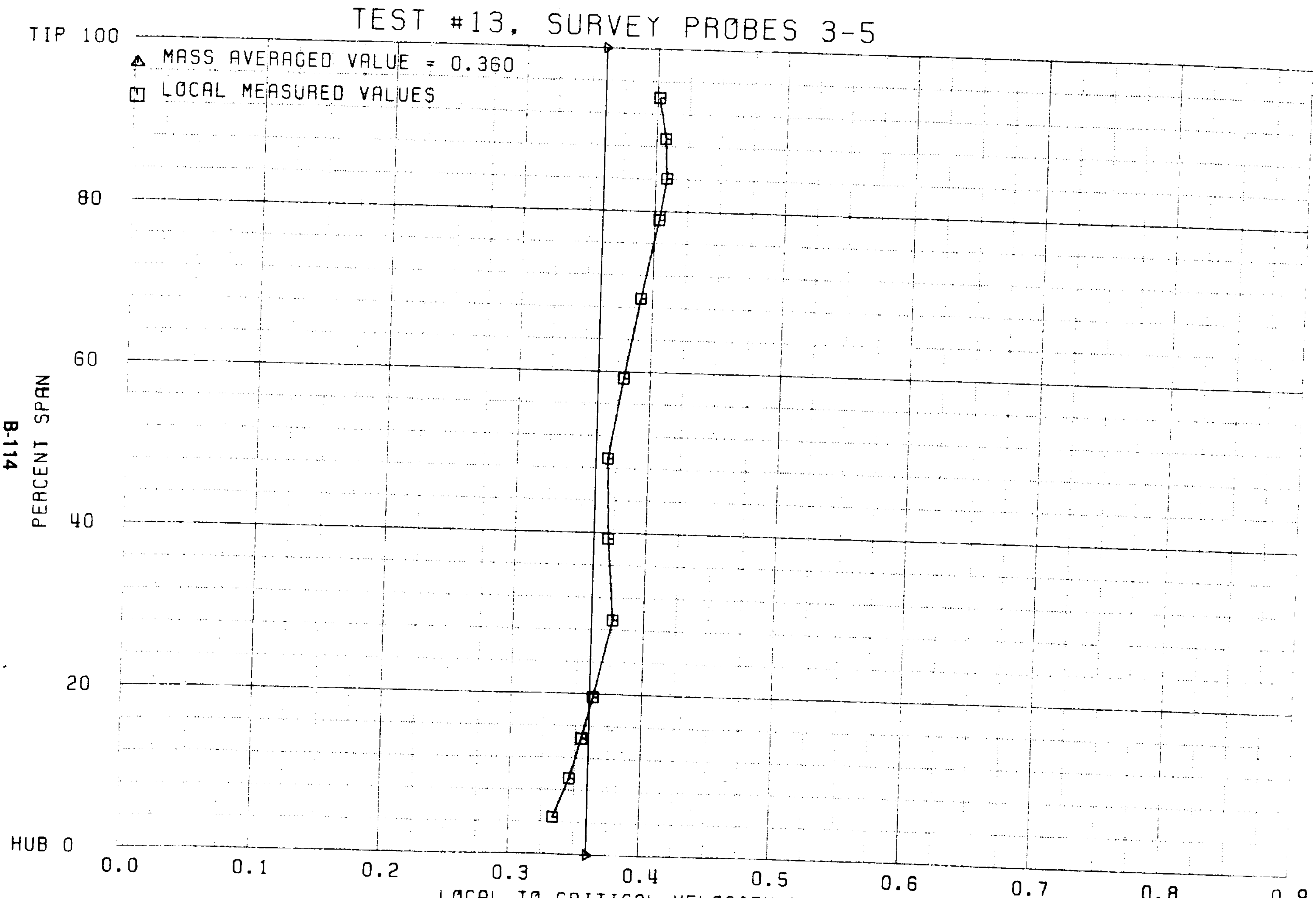

Figure B-114 Mixed Out Plane Survey - Local to Critical Velocity Ratio vs. Percent Rotor Exit Span, Test No. 13, Moveable Hub, 66.0 Percent Area

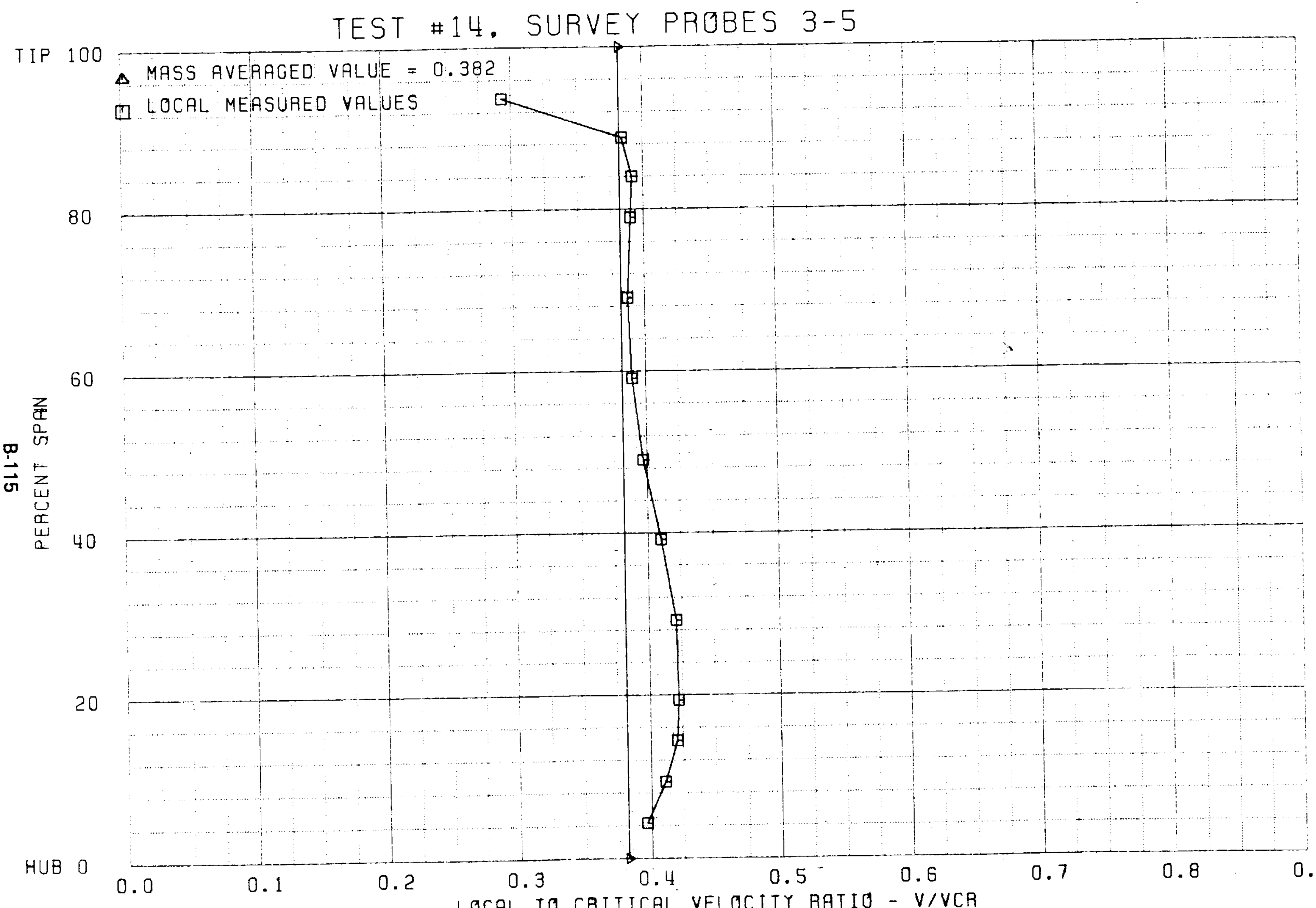

Figure B-115 Mixed Out Plane Survey - Local to Critical Velocity Ratio vs. Percent Rotor Exit Span, Test No. 14, Moveable Shroud, 81.1 Percent Area

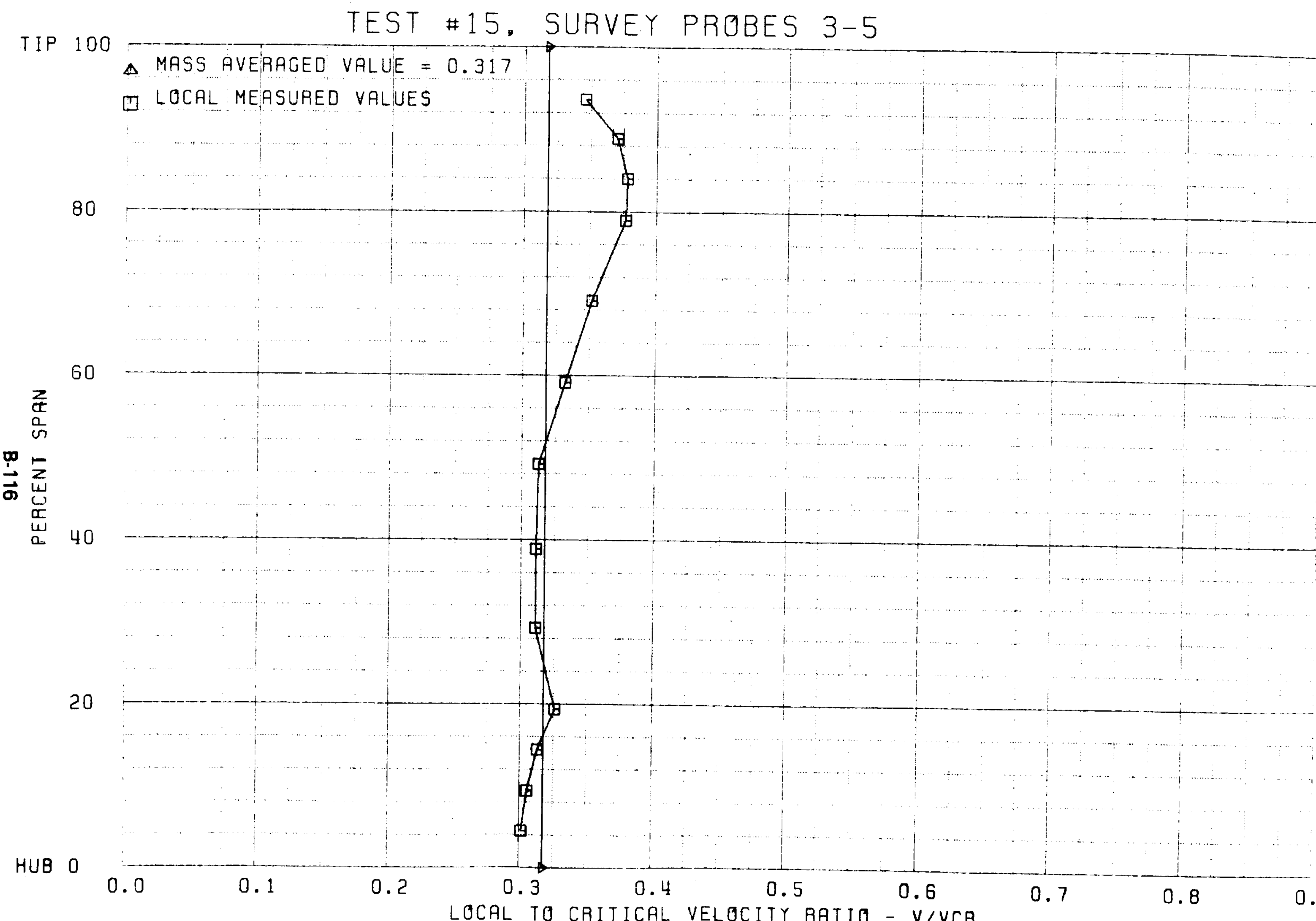

Figure B-116 Mixed Out Plane Survey - Local to Critical Velocity Ratio vs. Percent Rotor Exit Span, Test No. 15, Moveable Shroud, 62.5 Percent Area

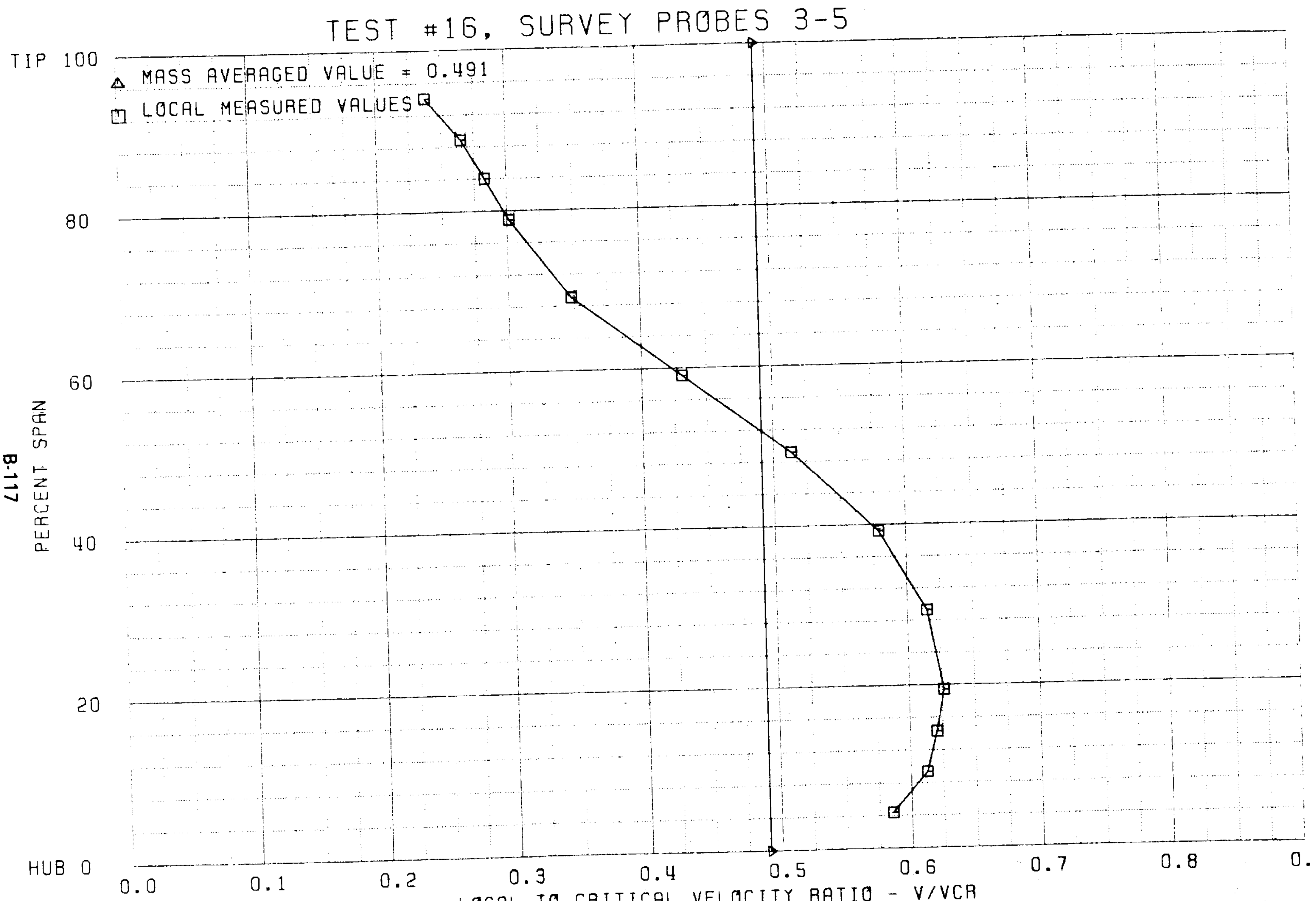

Figure B-117 Mixed Out Plane Survey - Local to Critical Velocity Ratio vs. Percent Rotor Exit Span, Test No. 16, Moveable Shroud, 62.5 Percent Area

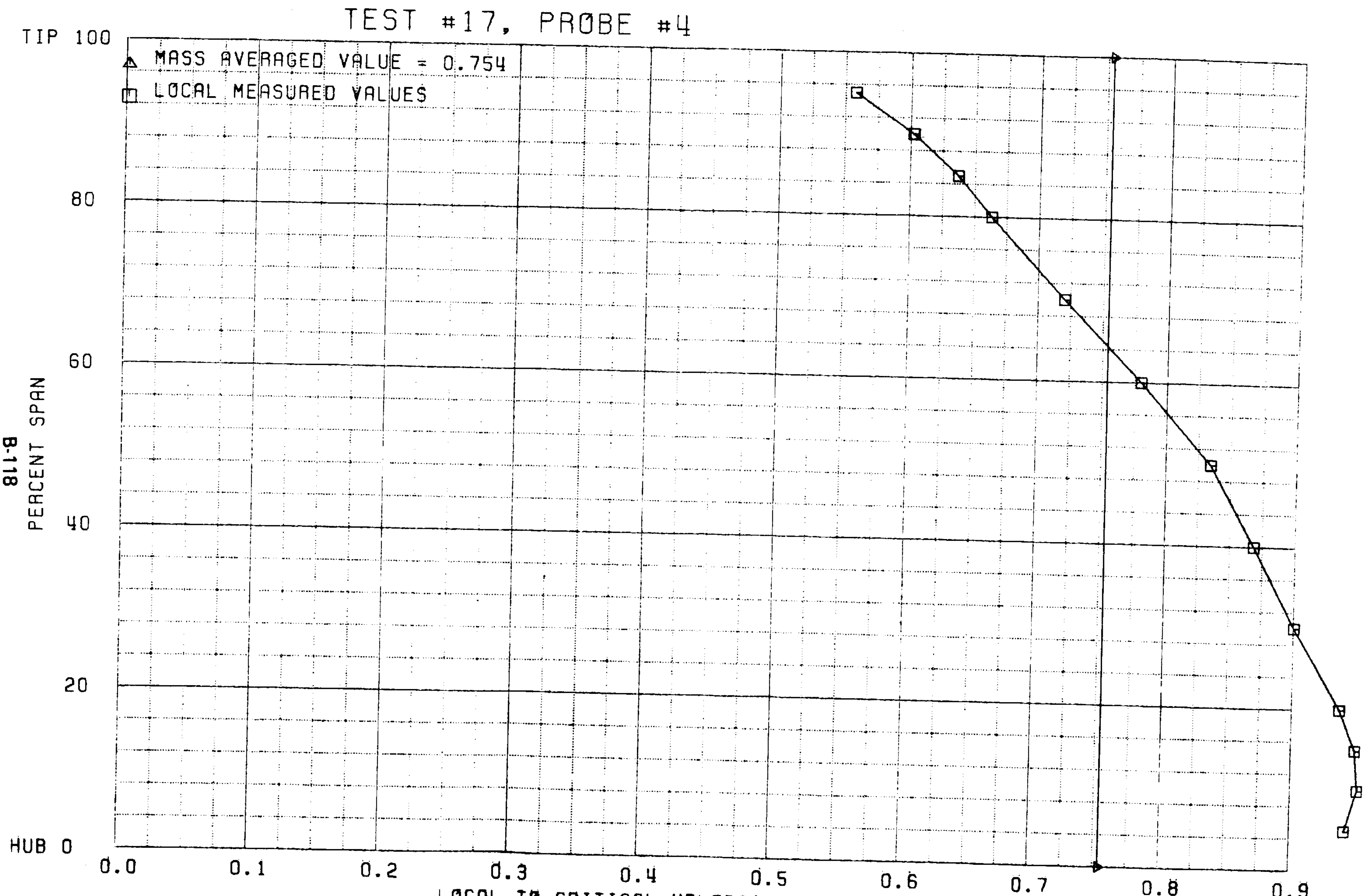

Figure B-118 Mixed Out Plane Survey - Local to Critical Velocity Ratio vs. Percent Rotor Exit Span, Test No. 17, Moveable Shroud, 125.0 Percent Area

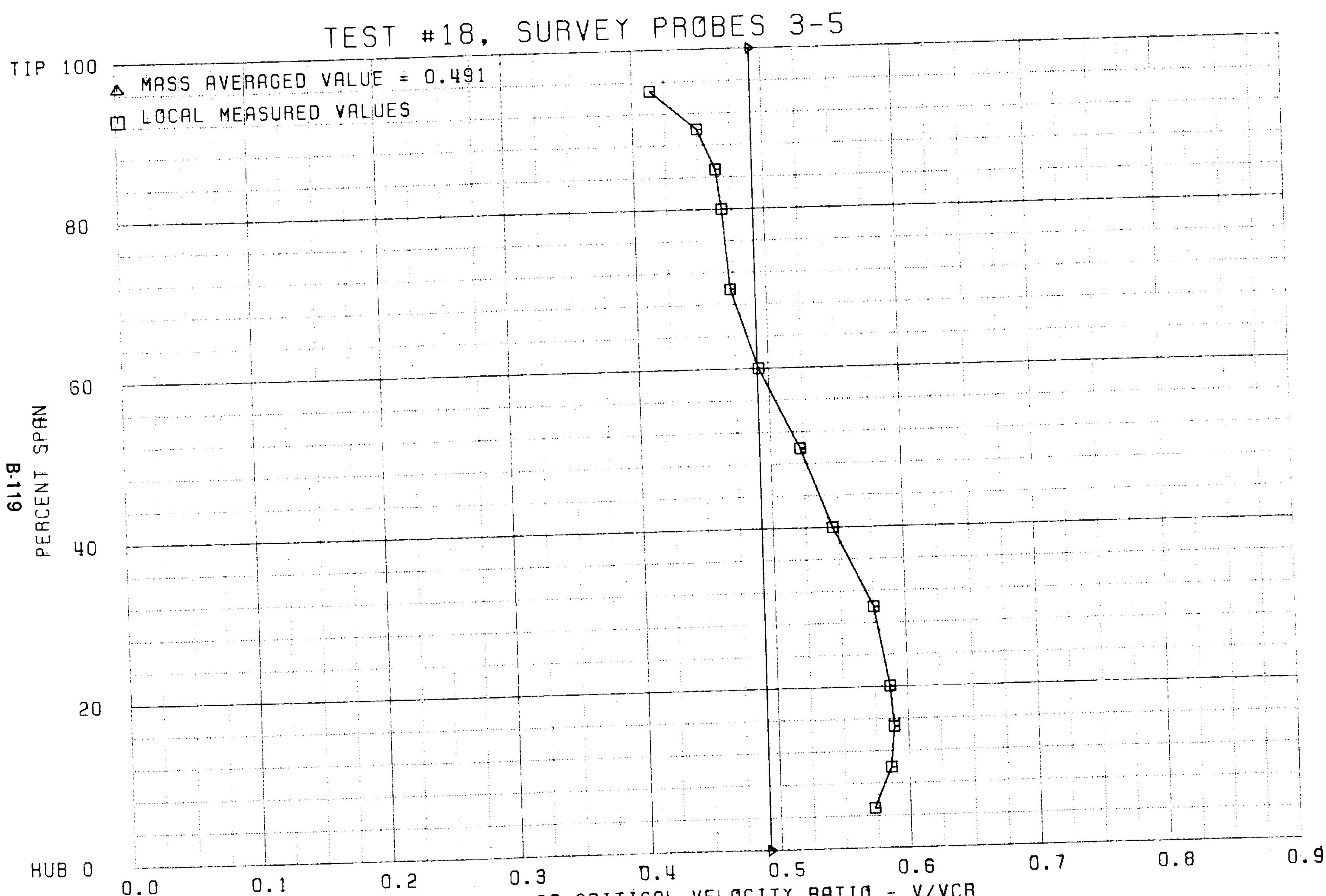

Figure B-119 Mixed Out Plane Survey - Local to Critical Velocity Ratio vs. Percent Rotor Exit Span, Test No. 18, Moveable Shroud, 100.0 Percent Area

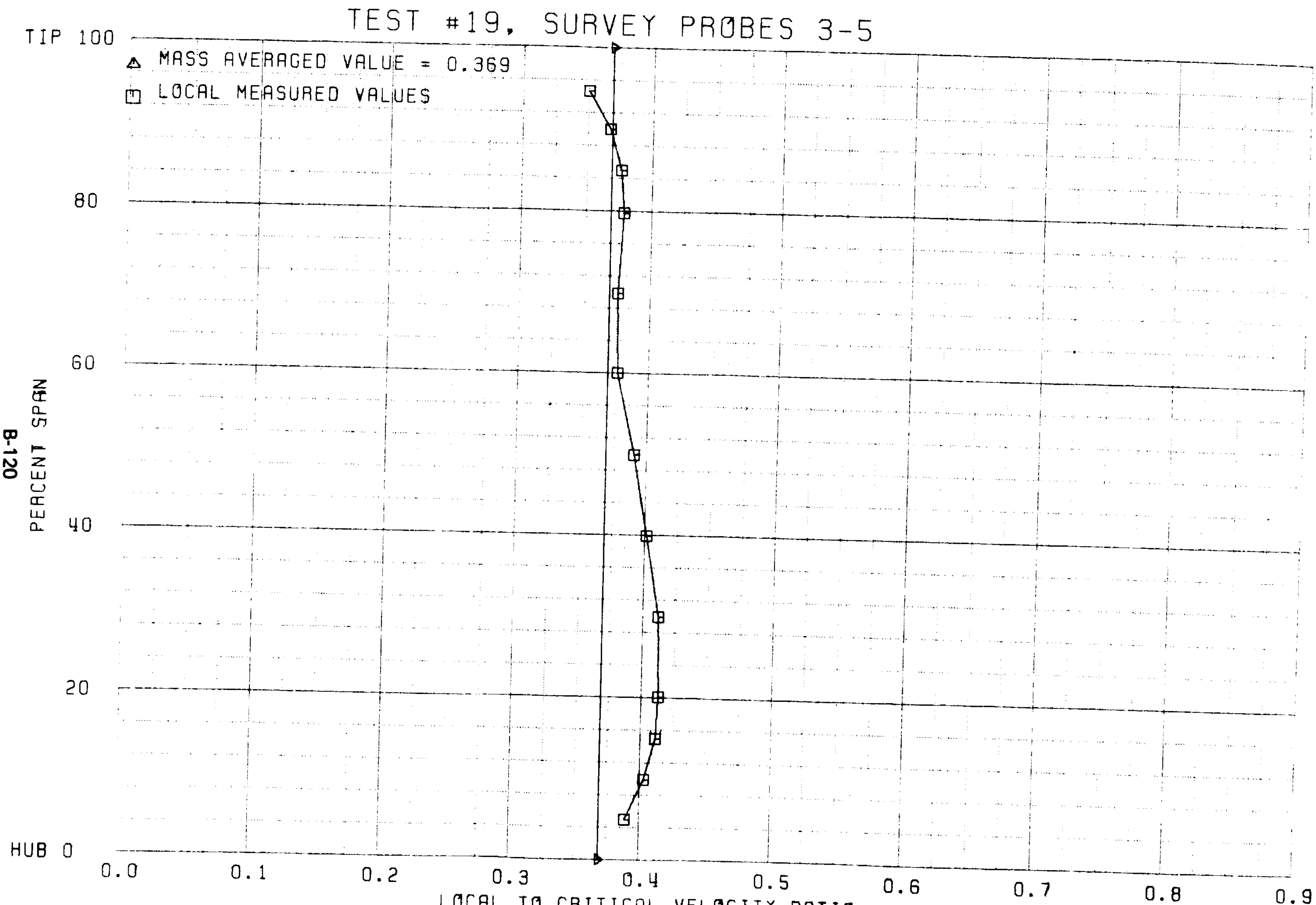

Figure B-120 Mixed Out Plane Survey - Local to Critical Velocity Ratio vs. Percent Rotor Exit Span, Test No. 19, Moveable Shroud, 81.1 Percent Area

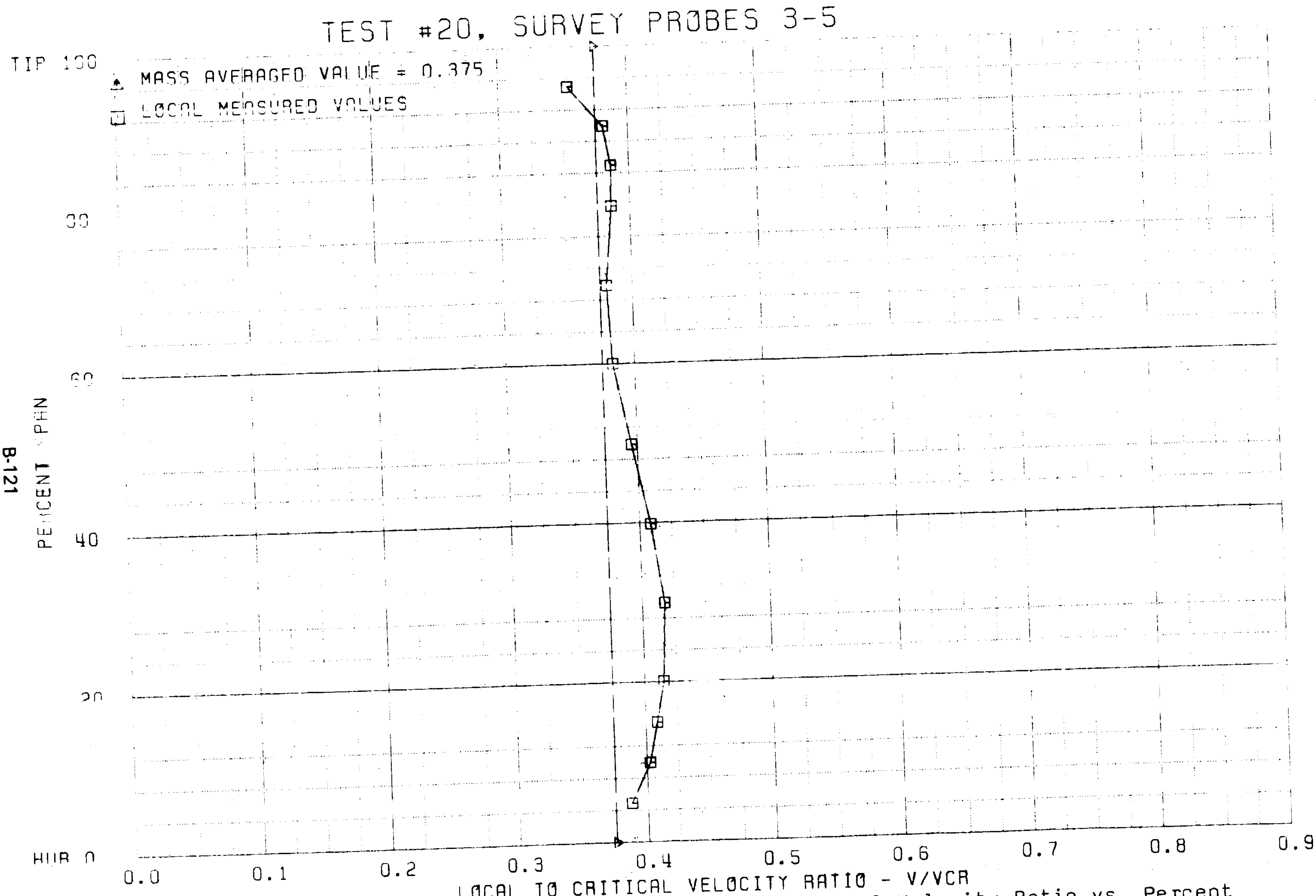

Figure B-121 Mixed Out Plane Survey - Local to Critical Velocity Ratio vs. Percent Rotor Exit Span, Test No. 20, Moveable Shroud, 81.1 Percent Area

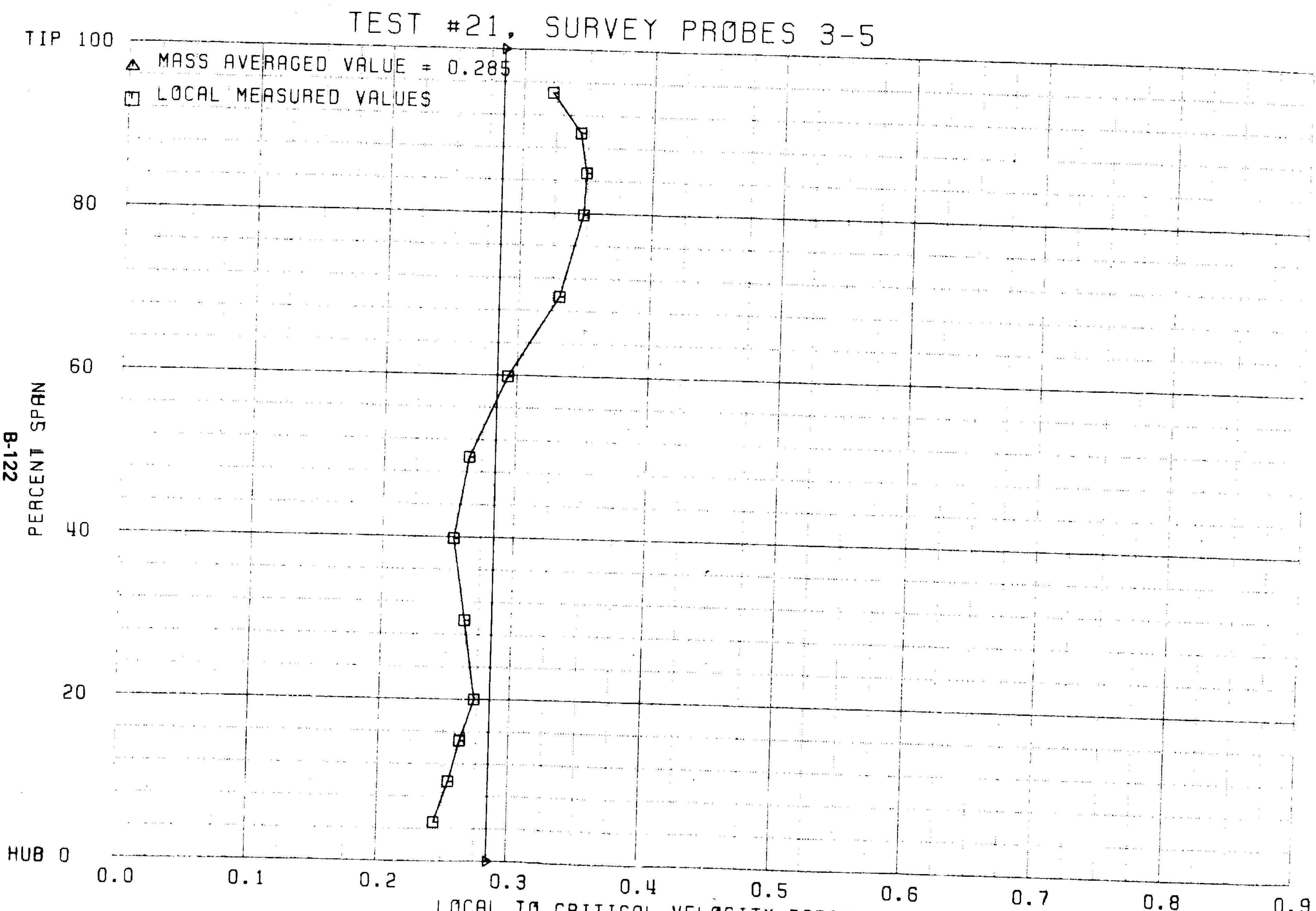

Figure B-122 Mixed Out Plane Survey - Local to Critical Velocity Ratio vs. Percent Rotor Exit Span, Test No. 21, Moveable Shroud, 62.5 Percent Area

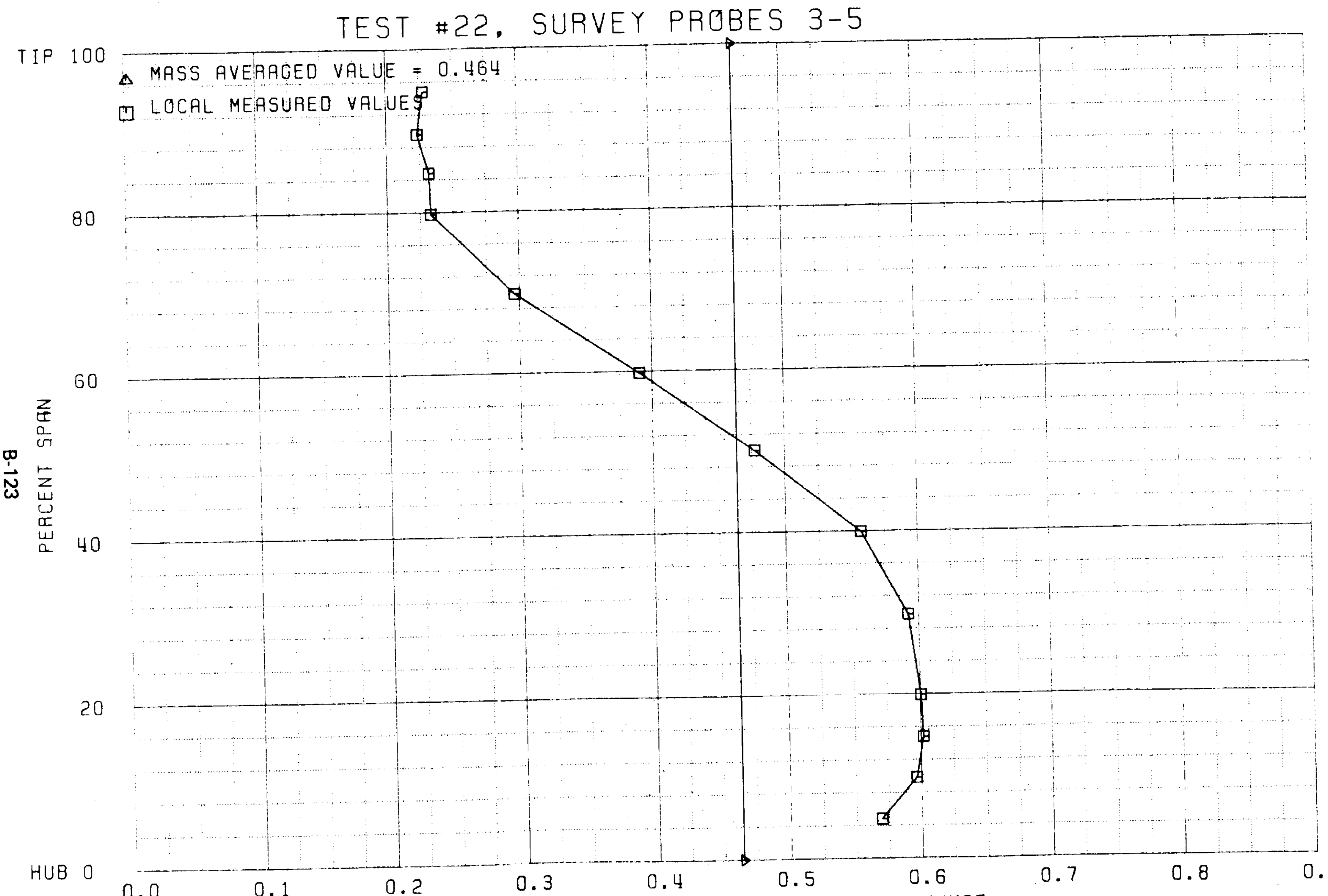

Figure B-123 Mixed Out Plane Survey - Local to Critical Velocity Ratio vs. Percent Rotor Exit Span, Test No. 22, Moveable Shroud, 62.5 Percent Area

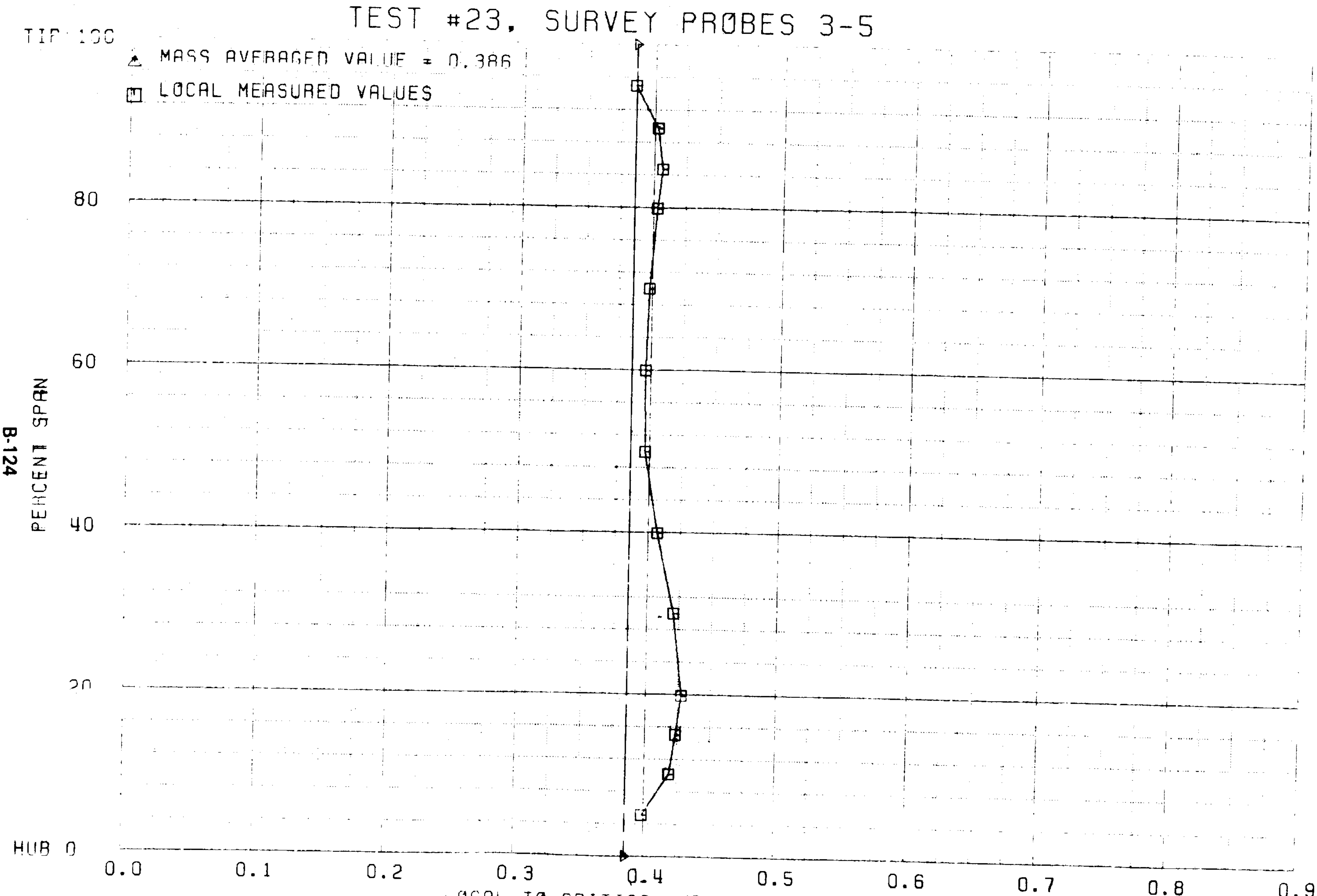

Figure B-124 Mixed Out Plane Survey - Local to Critical Velocity Ratio vs. Percent Rotor Exit Span, Test No. 23, Moveable Shroud, 81.1 Percent Area

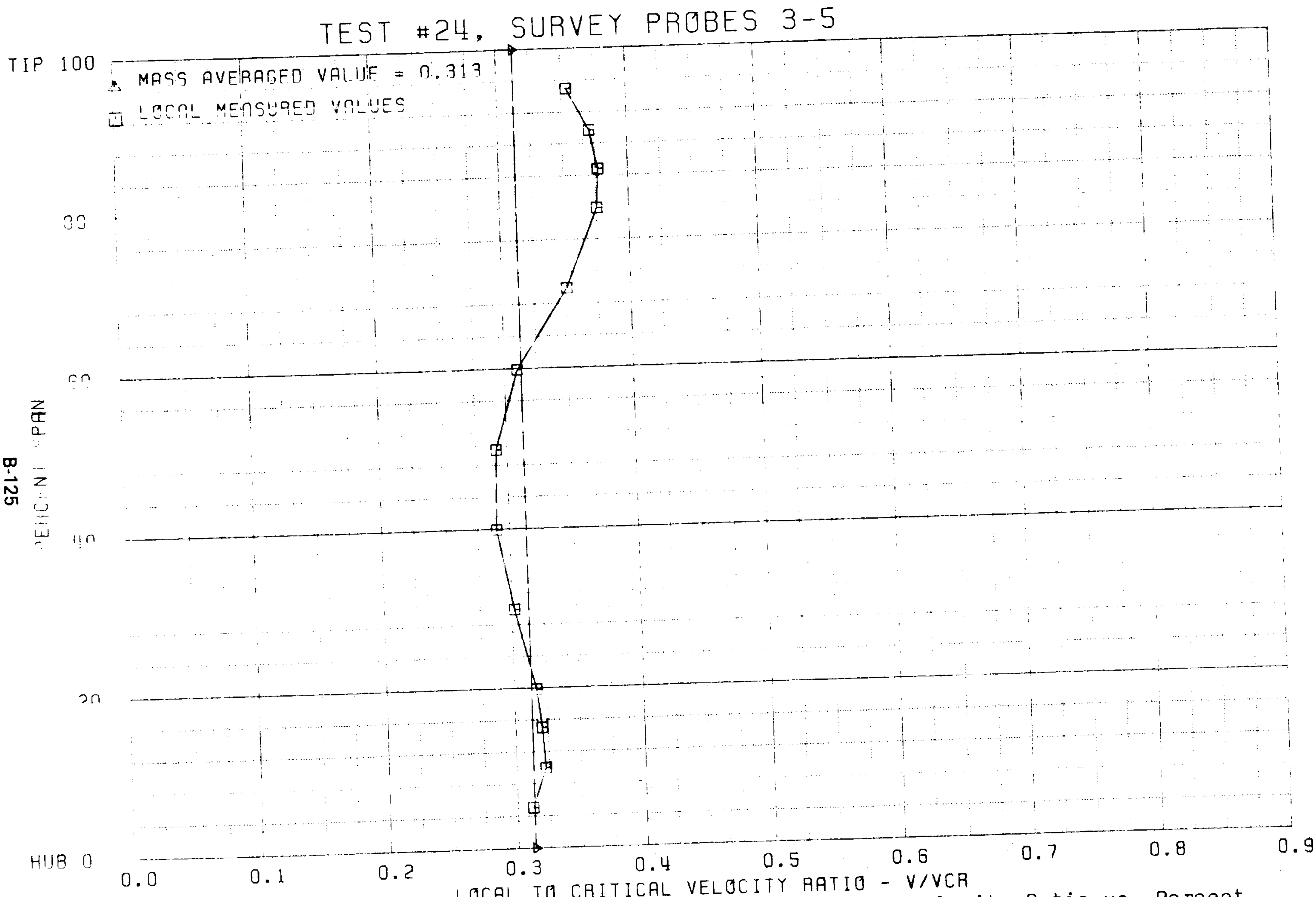

Figure B-125 Mixed Out Plane Survey - Local to Critical Velocity Ratio vs. Percent Rotor Exit Span, Test No. 24, Moveable Shroud, 62.5 Percent Area

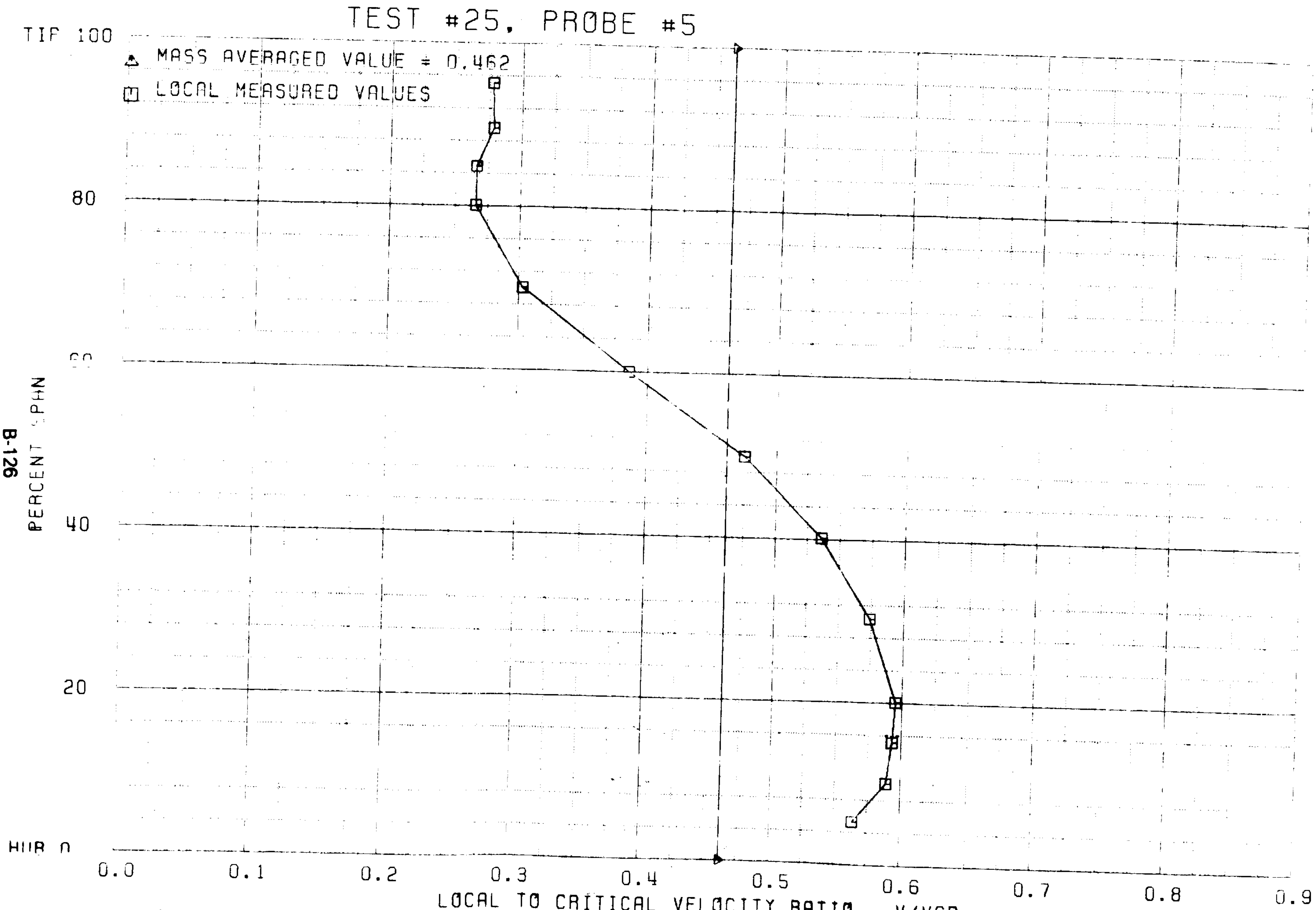

Figure B-126 Mixed Out Plane Survey - Local to Critical Velocity Ratio vs. Percent Rotor Exit Span, Test No. 25, Moveable Shroud, 62.5 Percent Area

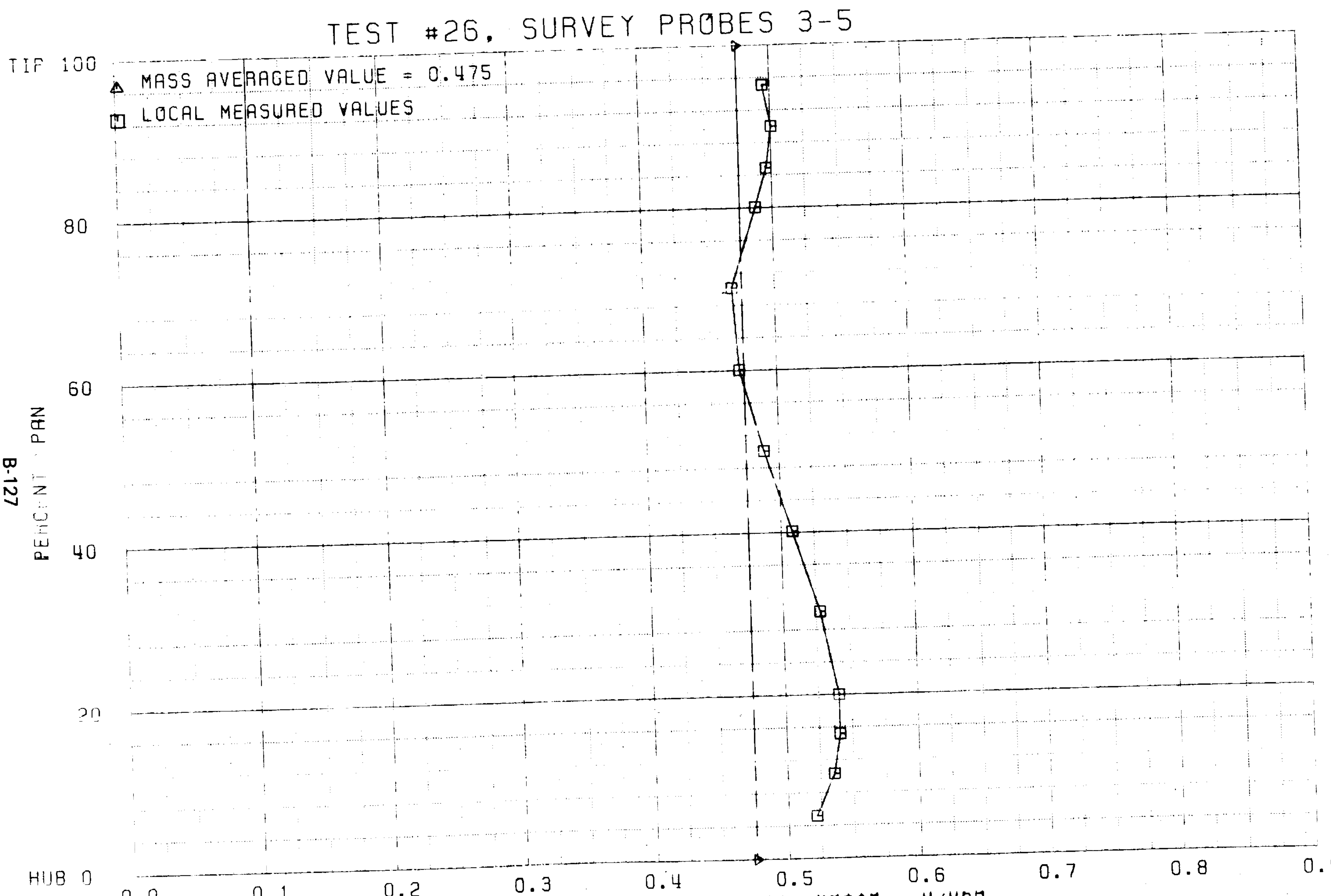

Figure B-127 Mixed Out Plane Survey - Local to Critical Velocity Ratio vs. Percent Rotor Exit Span, Test No. 26, Moveable Shroud, 103.5 Percent Area

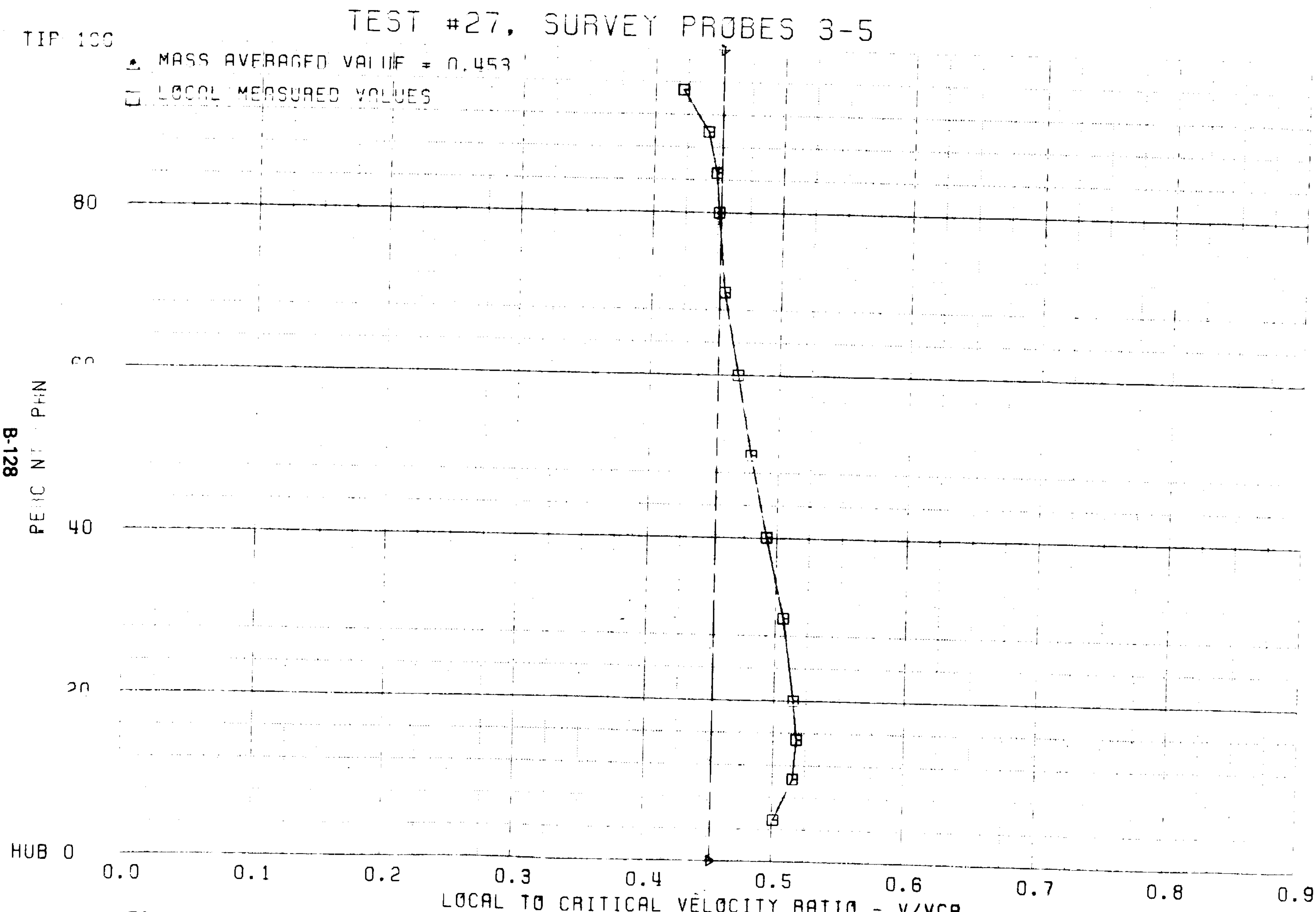

Figure B-128 Mixed Out Plane Survey - Local to Critical Velocity Ratio vs. Percent Rotor Exit Span, Test No. 27, Moveable Shroud, 84.6 Percent Area

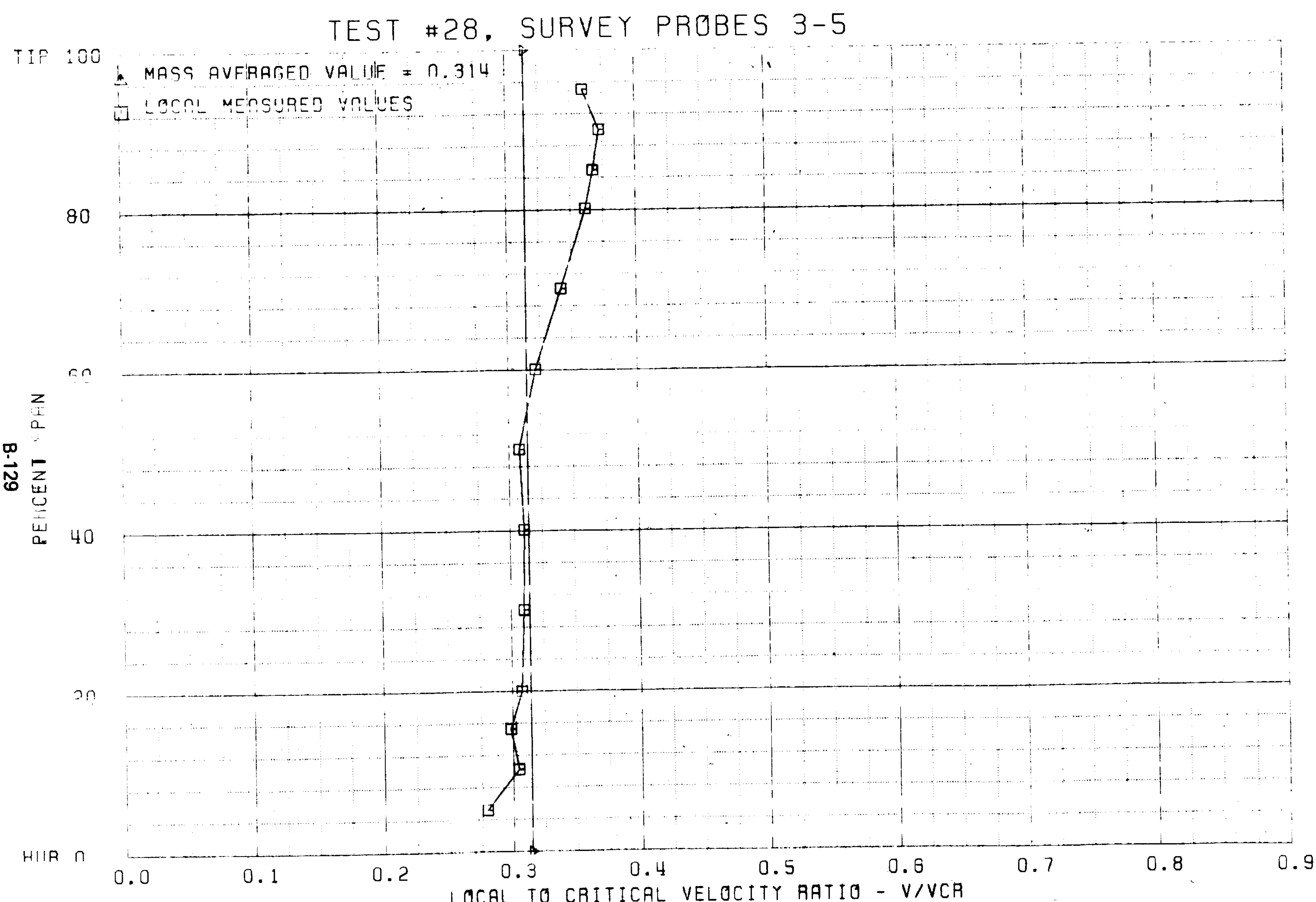

Figure B-129 Mixed Out Plane Survey - Local to Critical Velocity Ratio vs. Percent Rotor Exit Span, Test No. 28, Moveable Shroud, 66.0 Percent Area

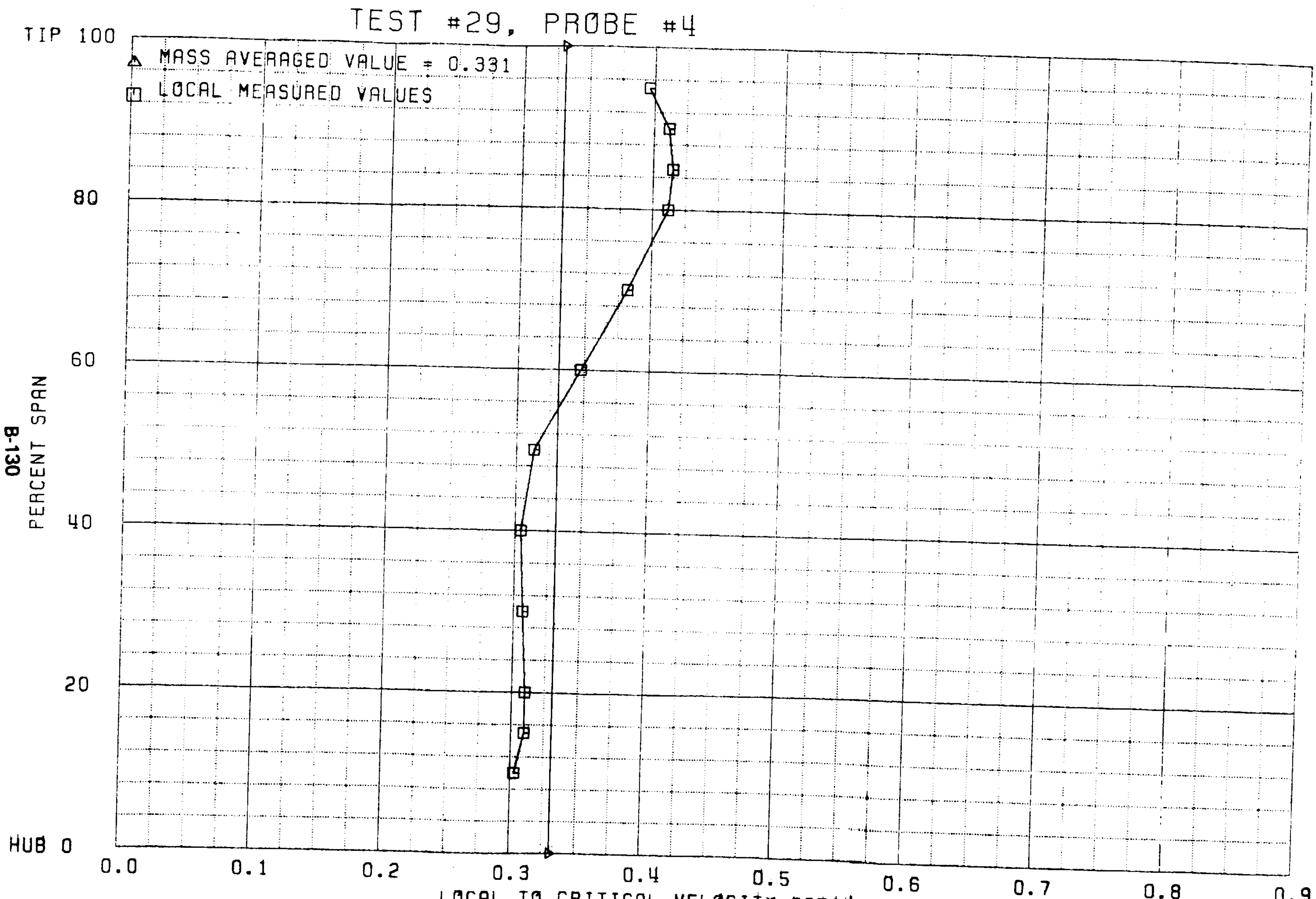

Figure B-130 Mixed Out Plane Survey - Local to Critical Velocity Ratio vs. Percent Rotor Exit Span, Test No. 29, Moveable Shroud, 62.2 Percent Area

APPENDIX C

ROTOR EXDUCER SURVEY DATA

Swirl Angle
Total Pressure
Total Temperature
Streamline Efficiency
Local to Critical Velocity Ratio

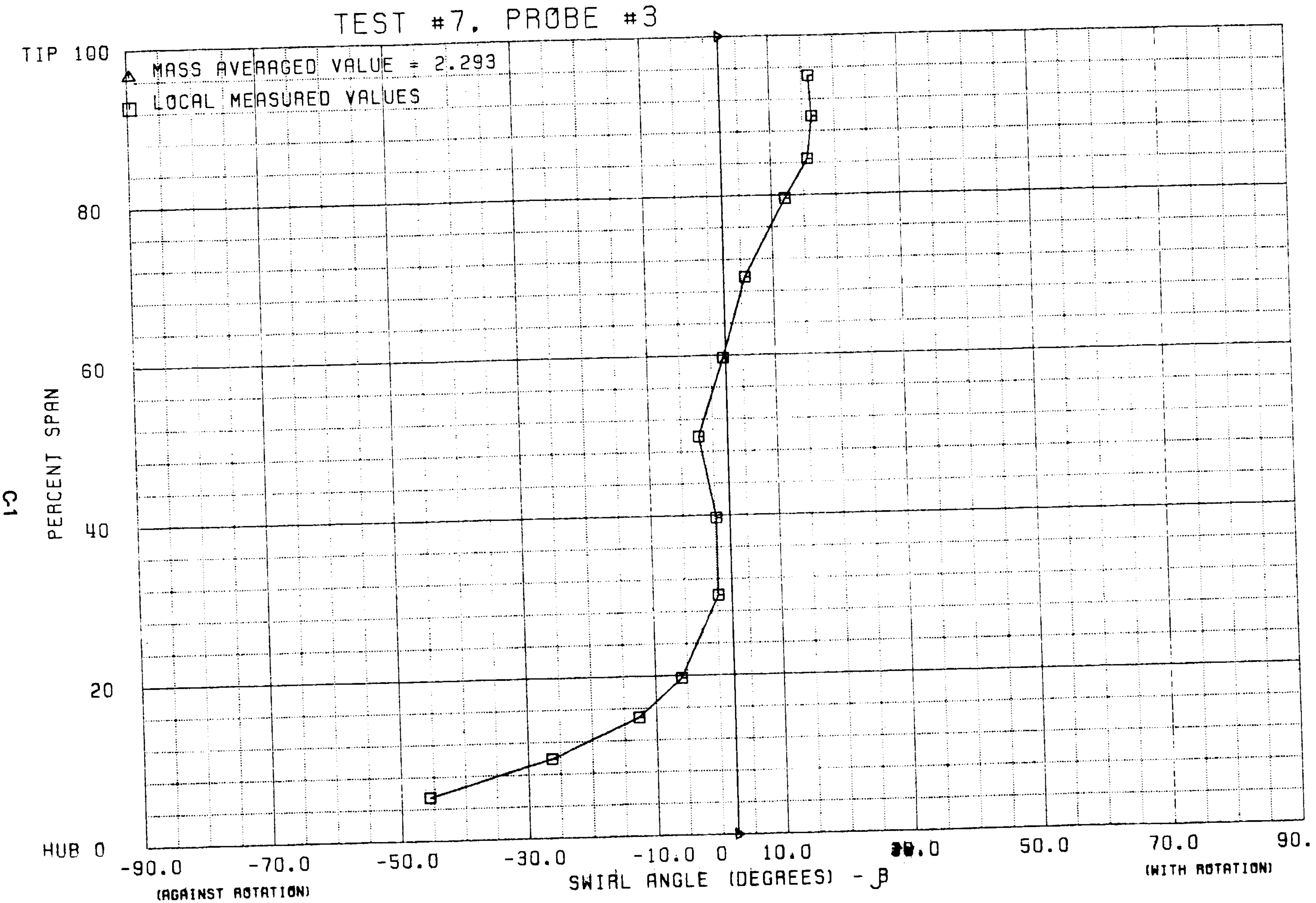

Figure C-1 Exit Survey - Swirl Angle vs. Percent Exducer Span, Test No. 7, Moveable Hub, 81.1 Percent Area

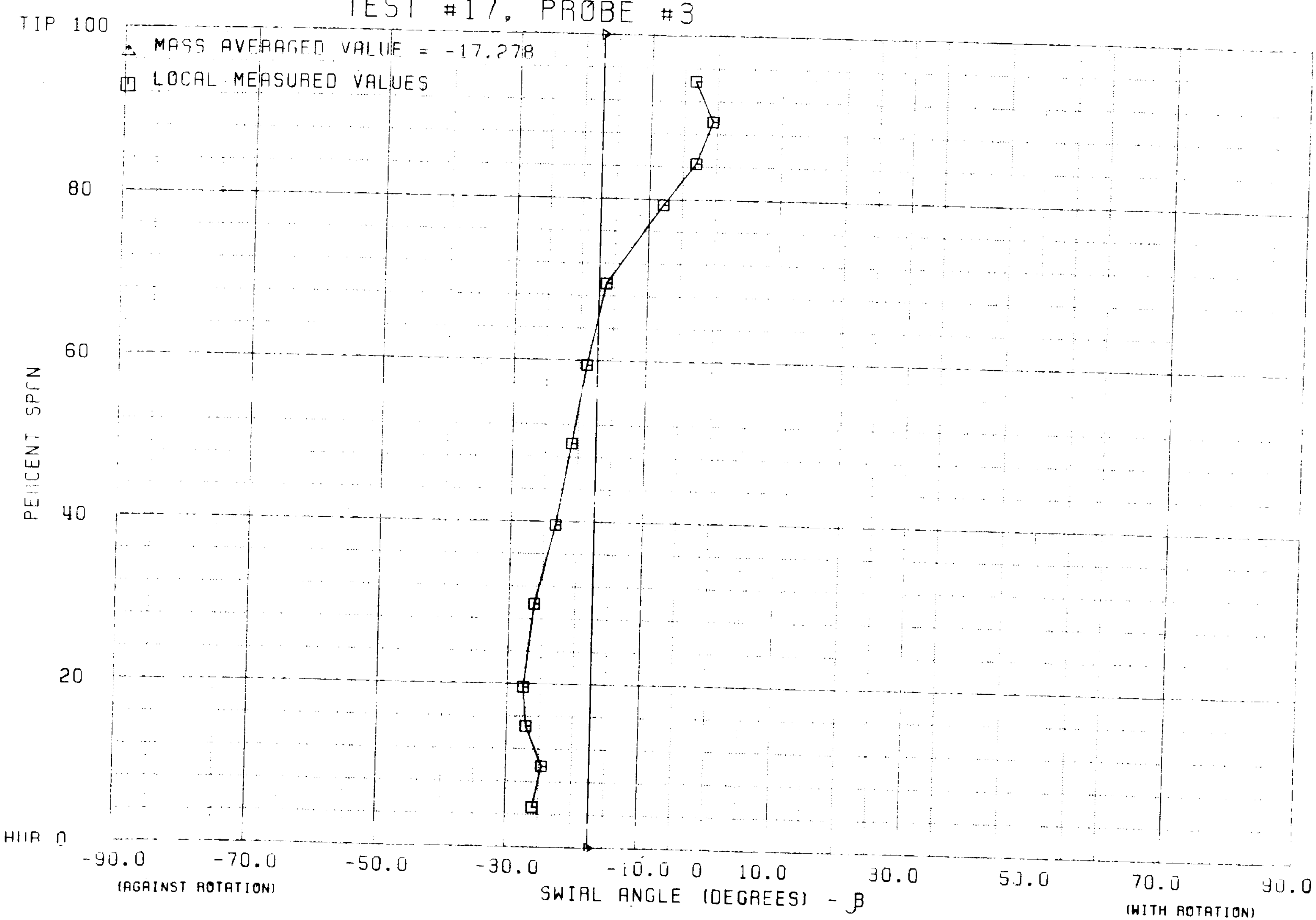

Figure C-2 Exit Survey - Swirl Angle vs. Percent Exducer Span, Test No. 17, Moveable Shroud, 125.0 Percent Area

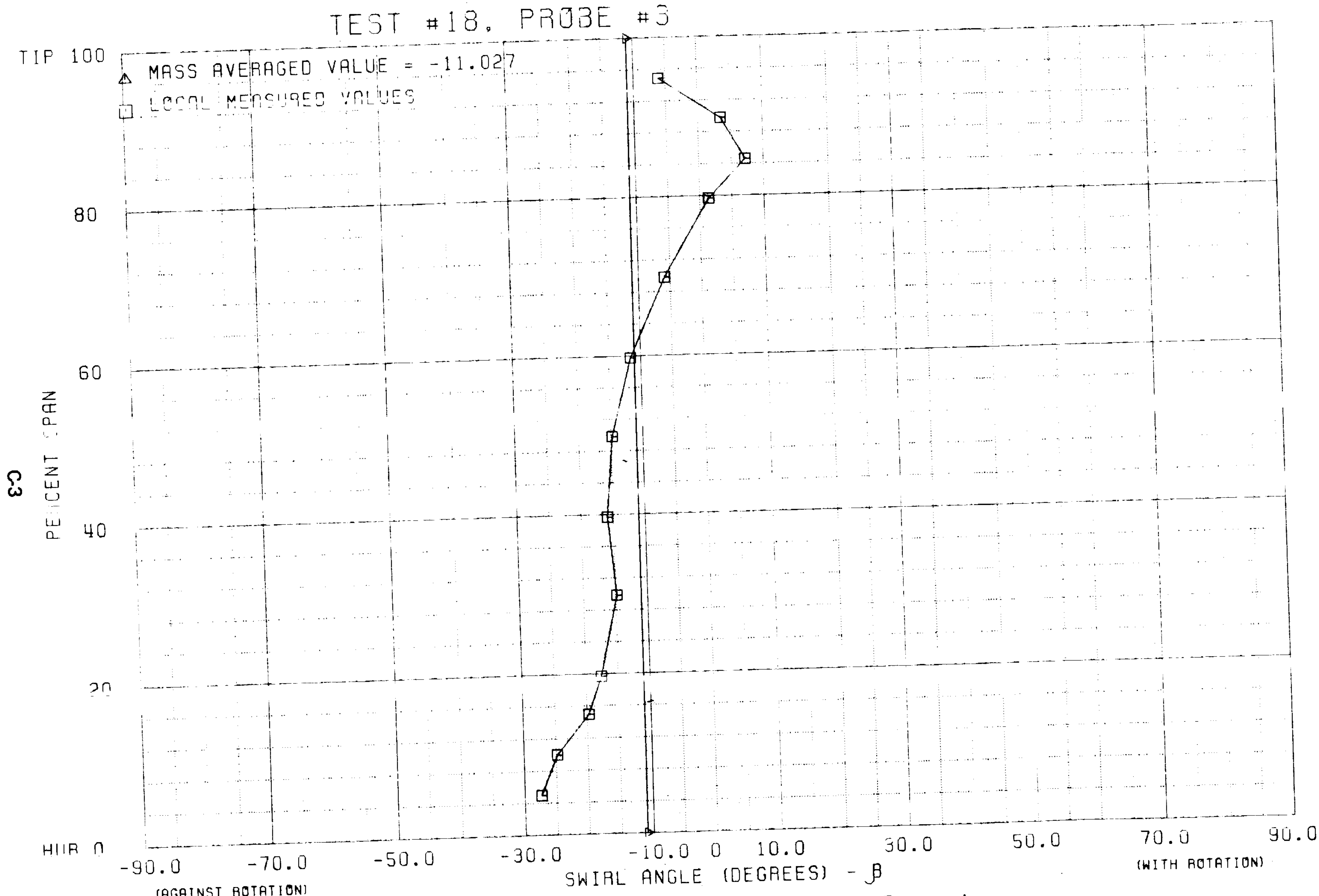

Figure C-3 Exit Survey - Swirl Angle vs. Percent Exducer Span, Test No. 18, Moveable Shroud, 100.0 Percent Area

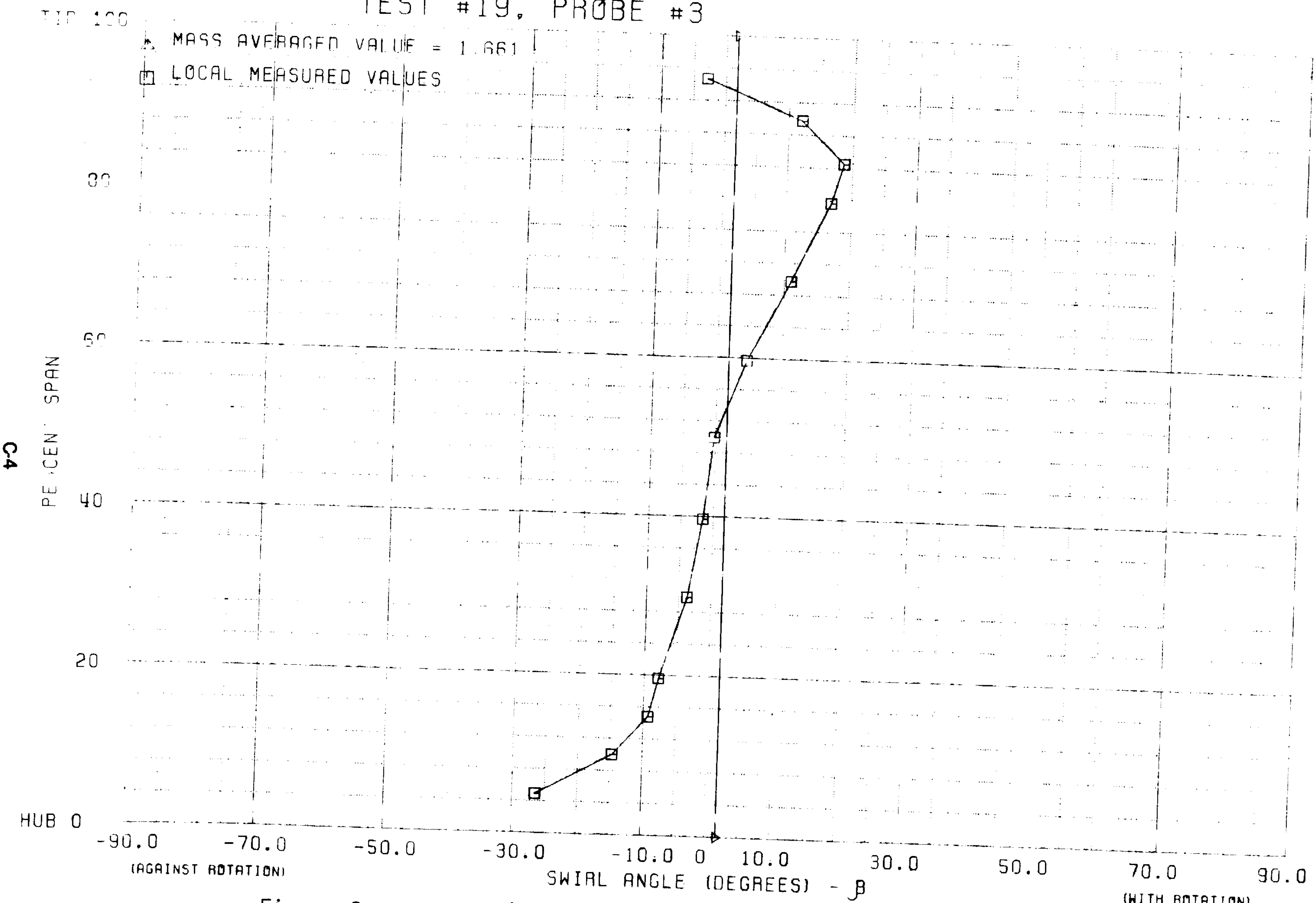

Figure C-4 Exit Survey - Swirl Angle vs. Percent Exducer Span, Test No. 19, Moveable Shroud, 81.1 Percent Area

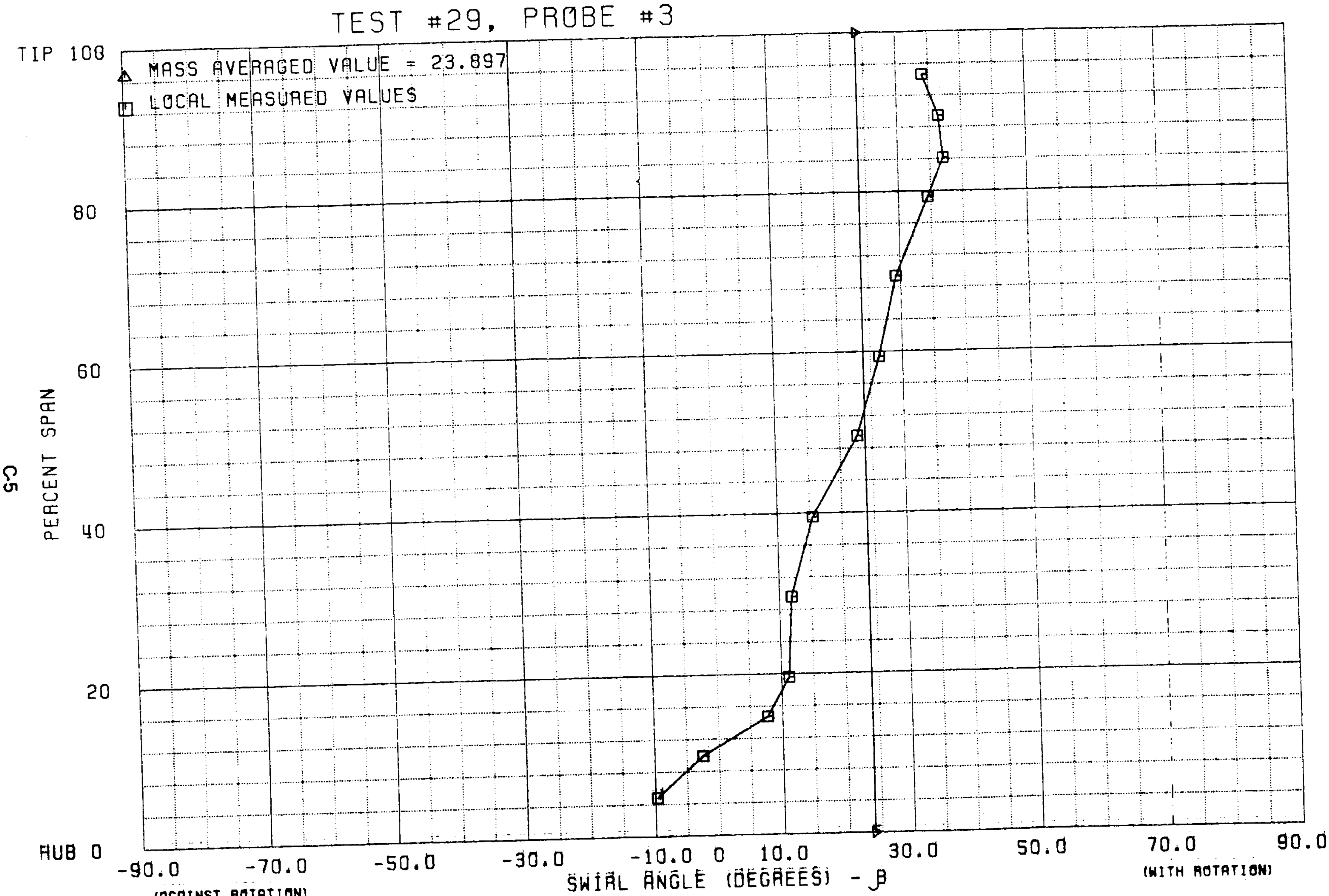

Figure C-5 Exit Survey - Swirl Angle vs. Percent Exducer Span, Test No. 29, Moveable Shroud, 62.2 Percent Area

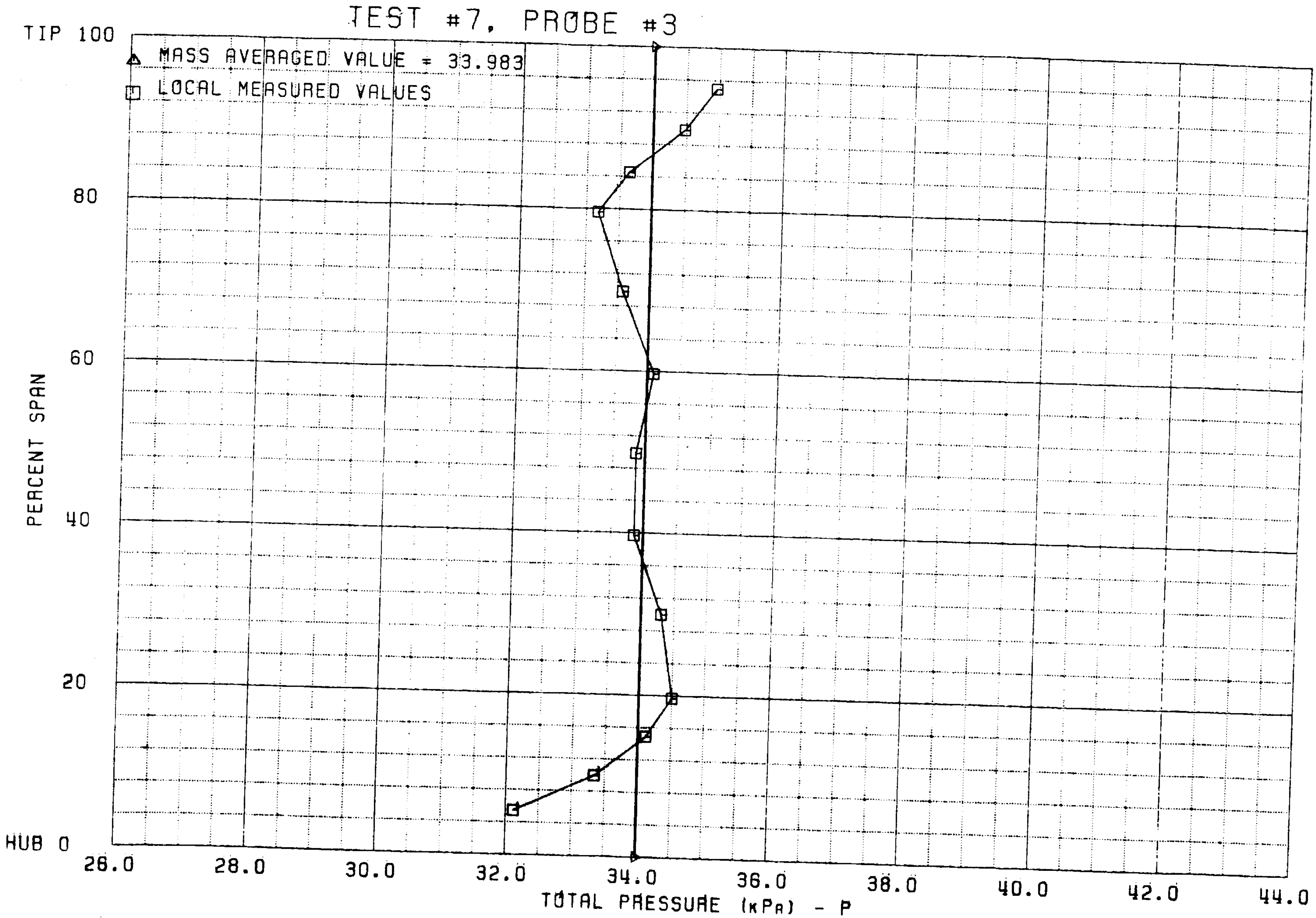

Figure C-6 Exit Survey - Total Pressure vs. Percent Exducer Span, Test No. 7, Moveable Hub, 81.1 Percent Area

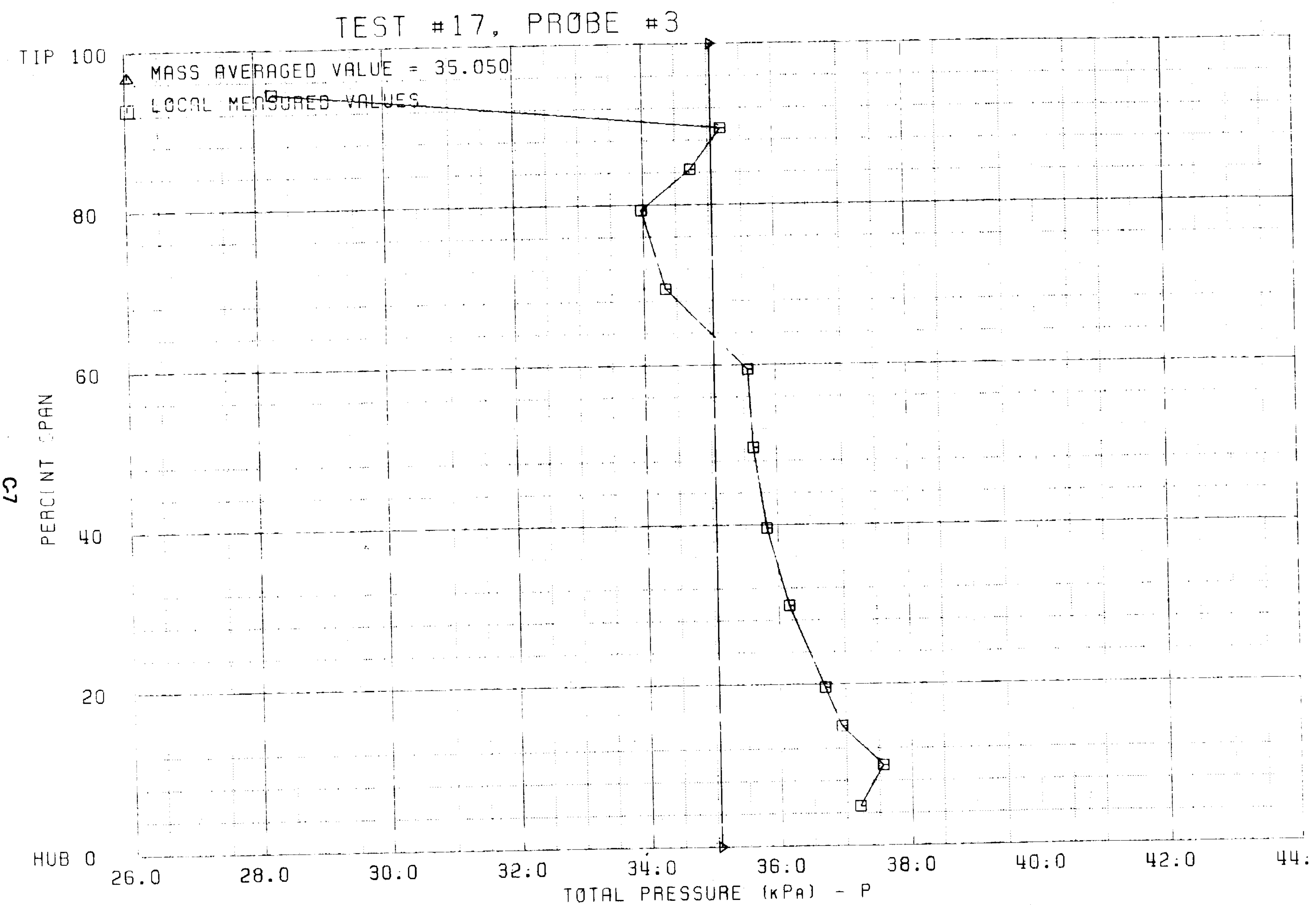

Figure C-7 Exit Survey - Total Pressure vs. Percent Exducer Span, Test No. 17, Moveable Shroud, 125.0 Percent Area

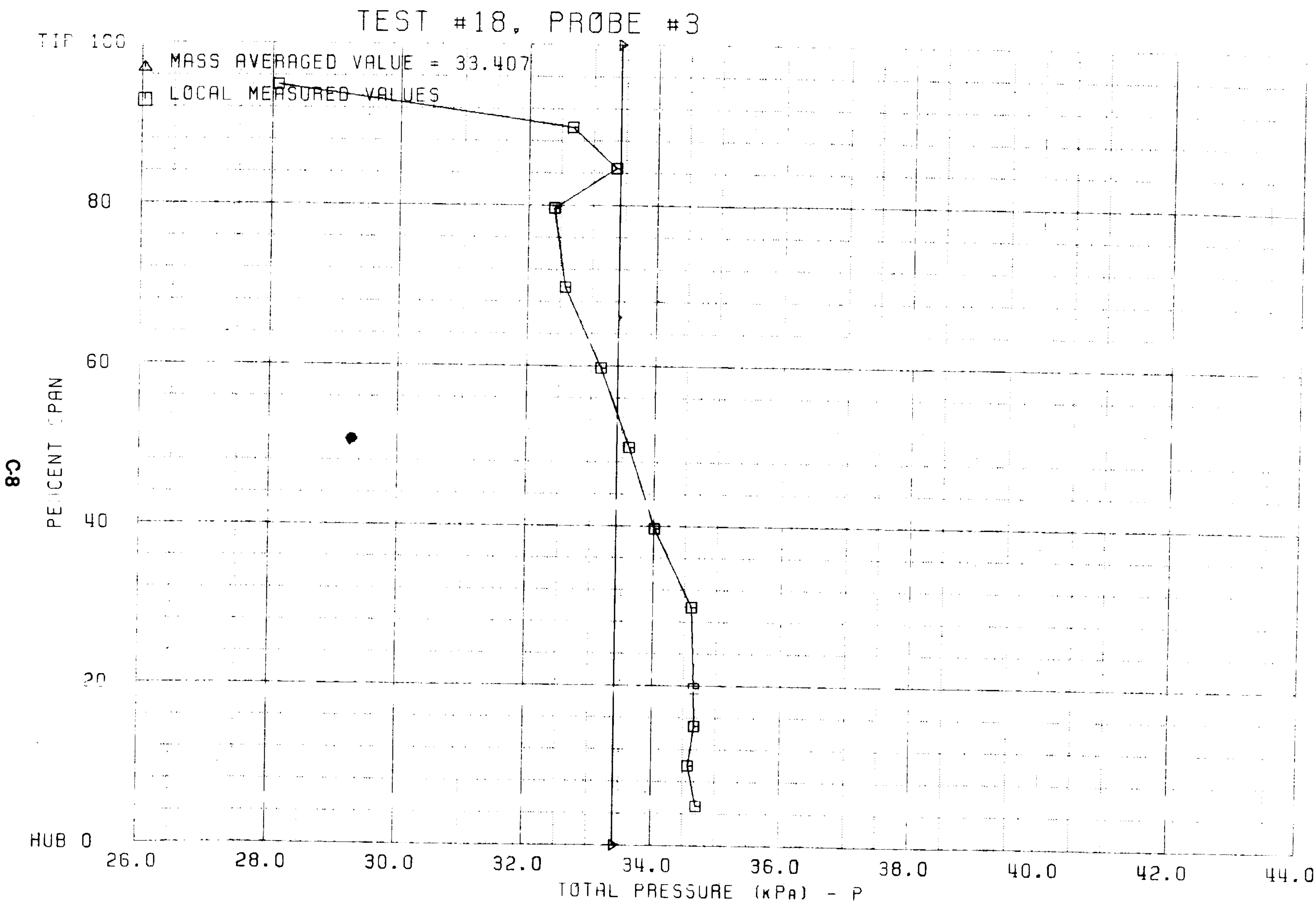

Figure C-8 Exit Survey - Total Pressure vs. Percent Exducer Span, Test No. 18, Moveable Shroud, 100.0 Percent Area

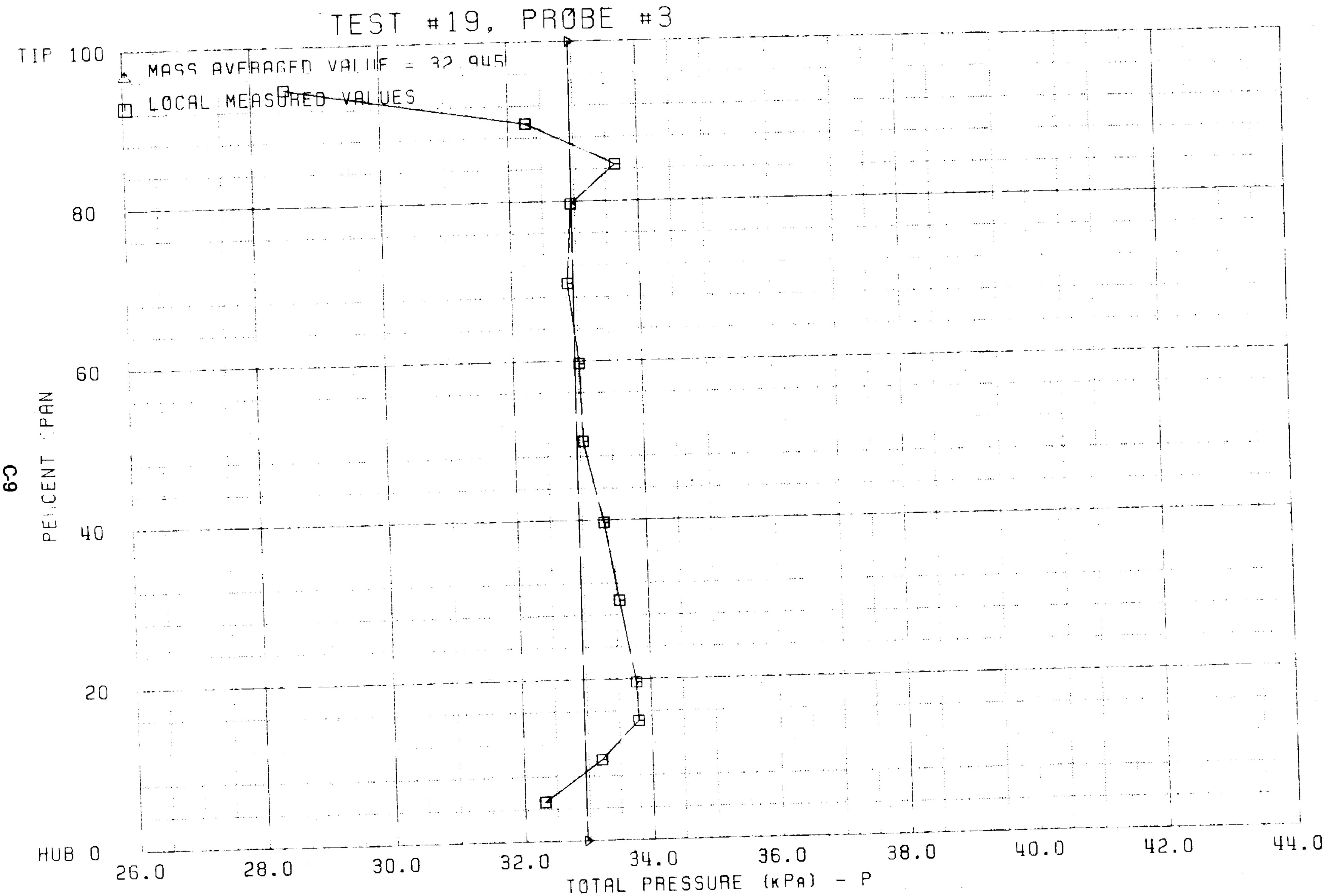

Figure C-9 Exit Survey - Total Pressure vs. Percent Exducer Span, Test No. 19, Moveable Shroud, 81.1 Percent Area

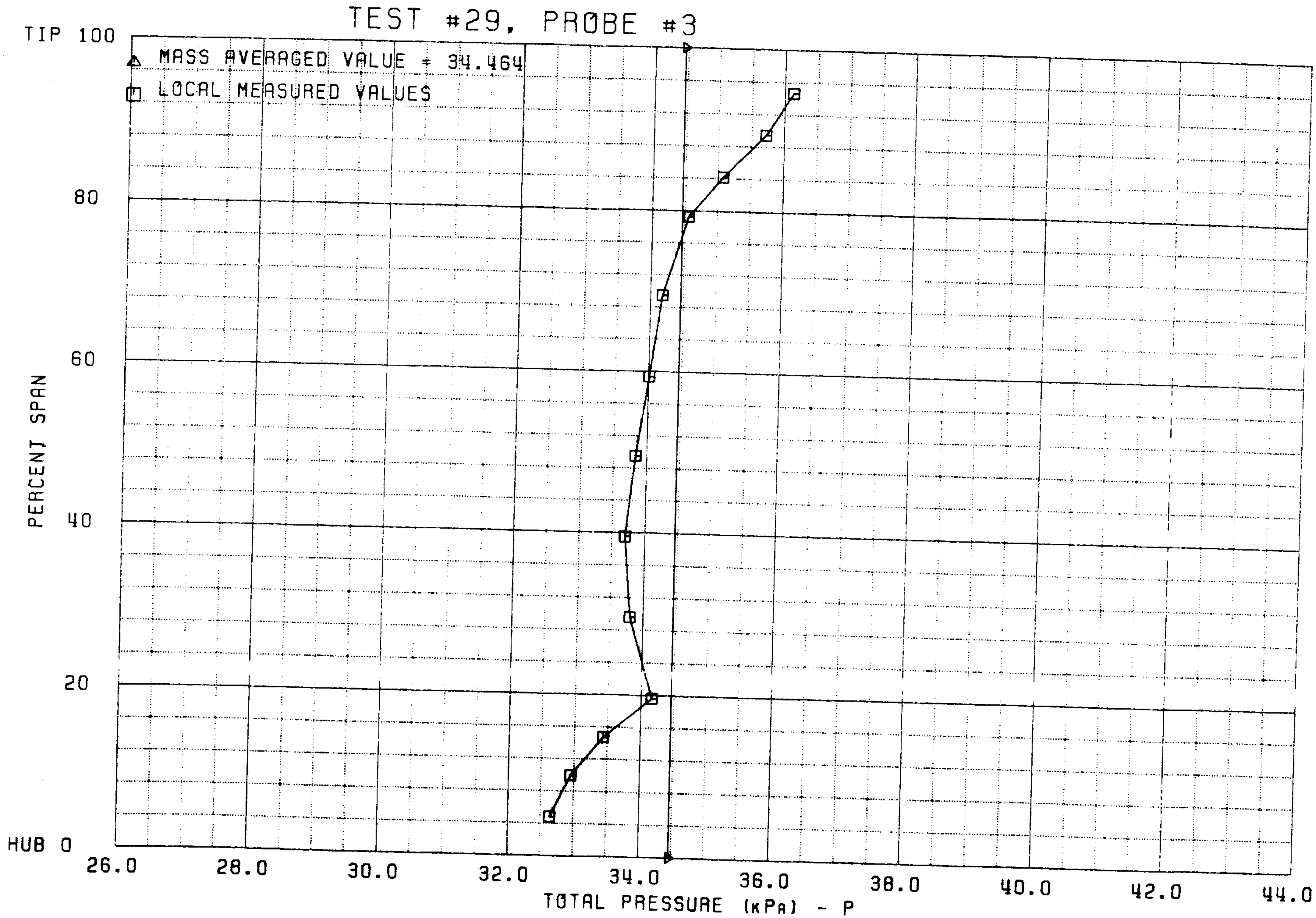

Figure C-10 Exit Survey - Total Pressure vs. Percent Exducer Span, Test No. 29, Moveable Shroud, 62.2 Percent Area

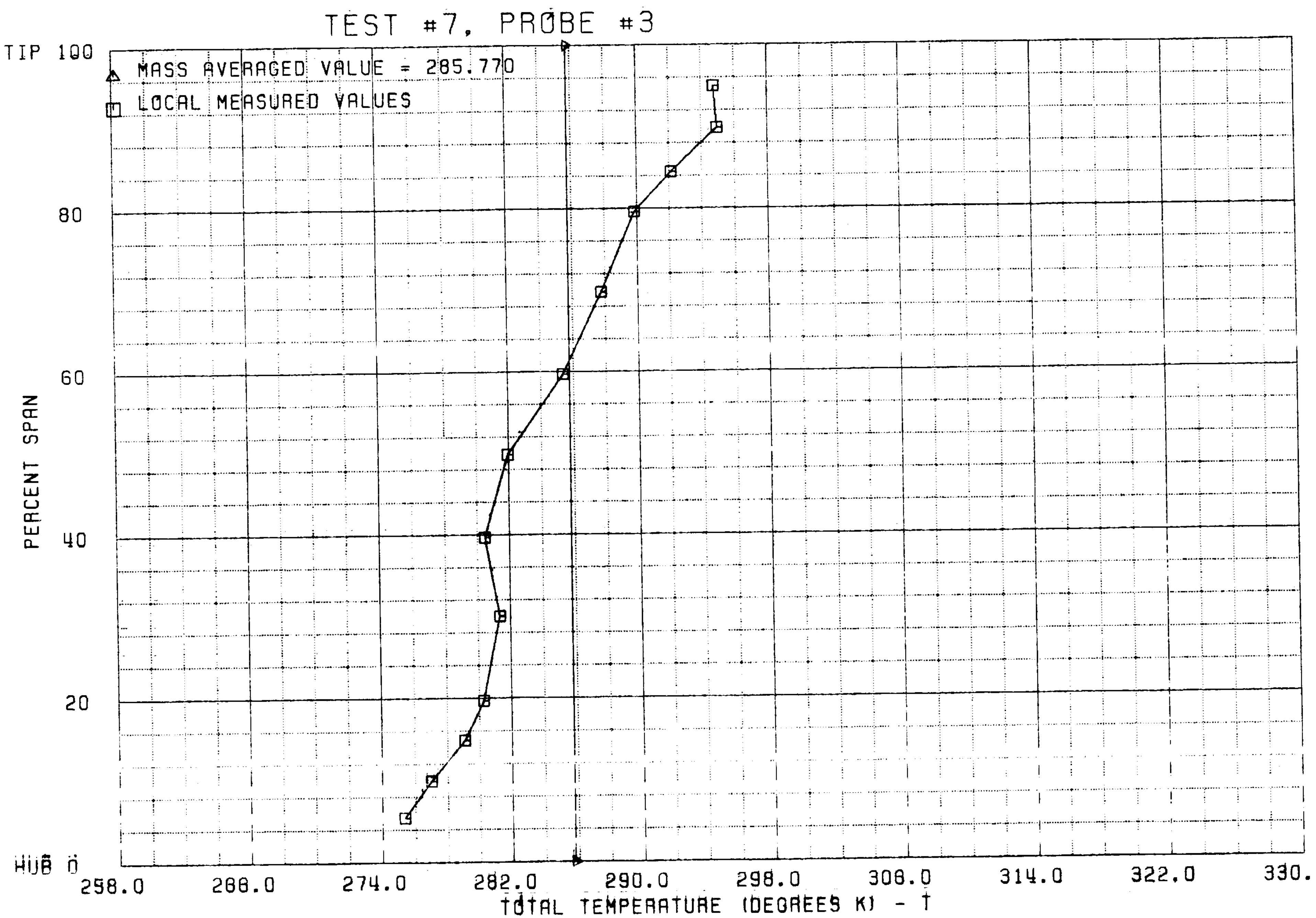

Figure C-11 Exit Survey - Total Temperature vs. Percent Exducer Span, Test No. 7, Moveable Hub, 81.1 Percent Area

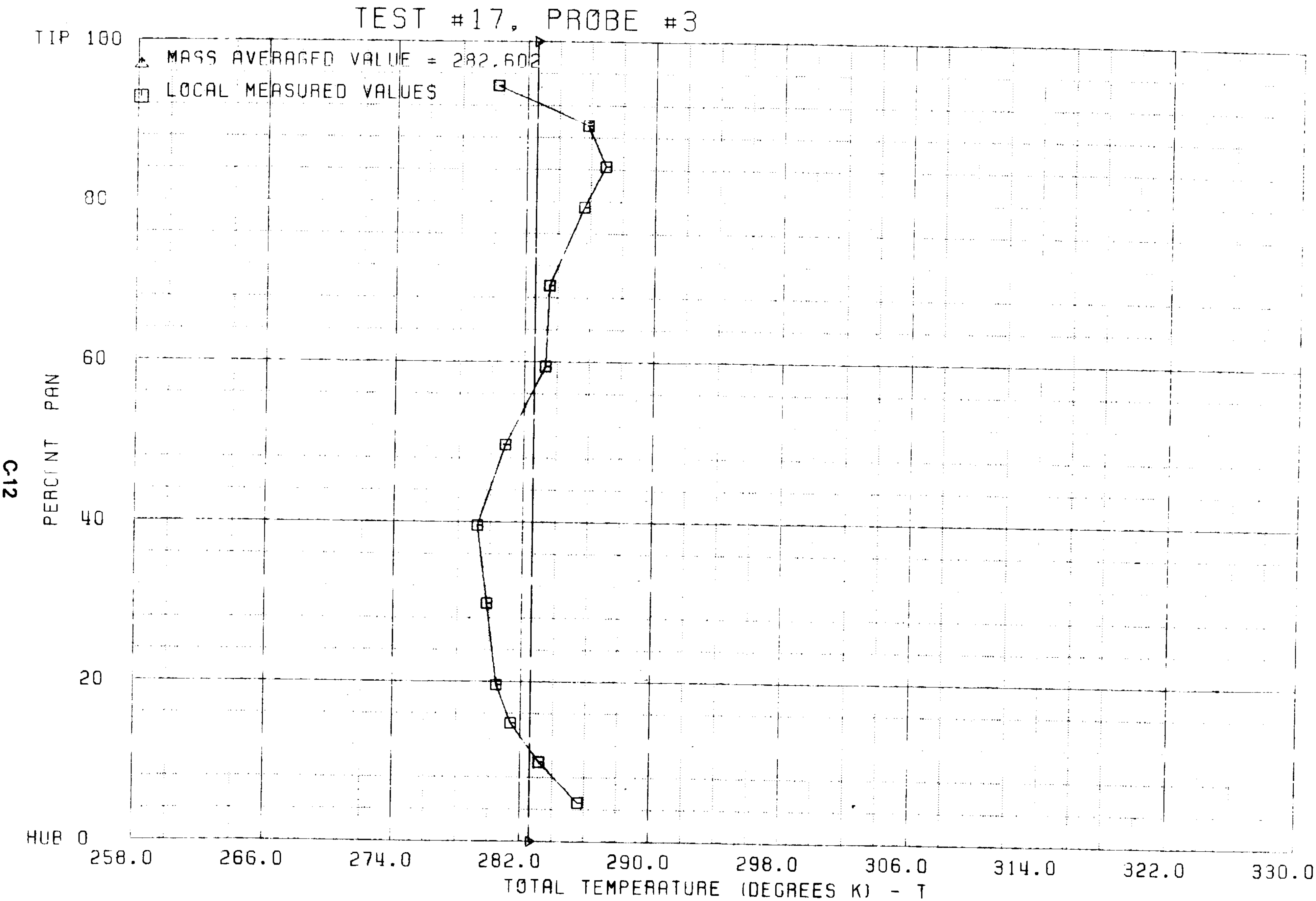

Figure C-12 Exit Survey - Total Temperature vs. Percent Exducer Span, Test No. 17, Moveable Shroud, 125.0 Percent Area

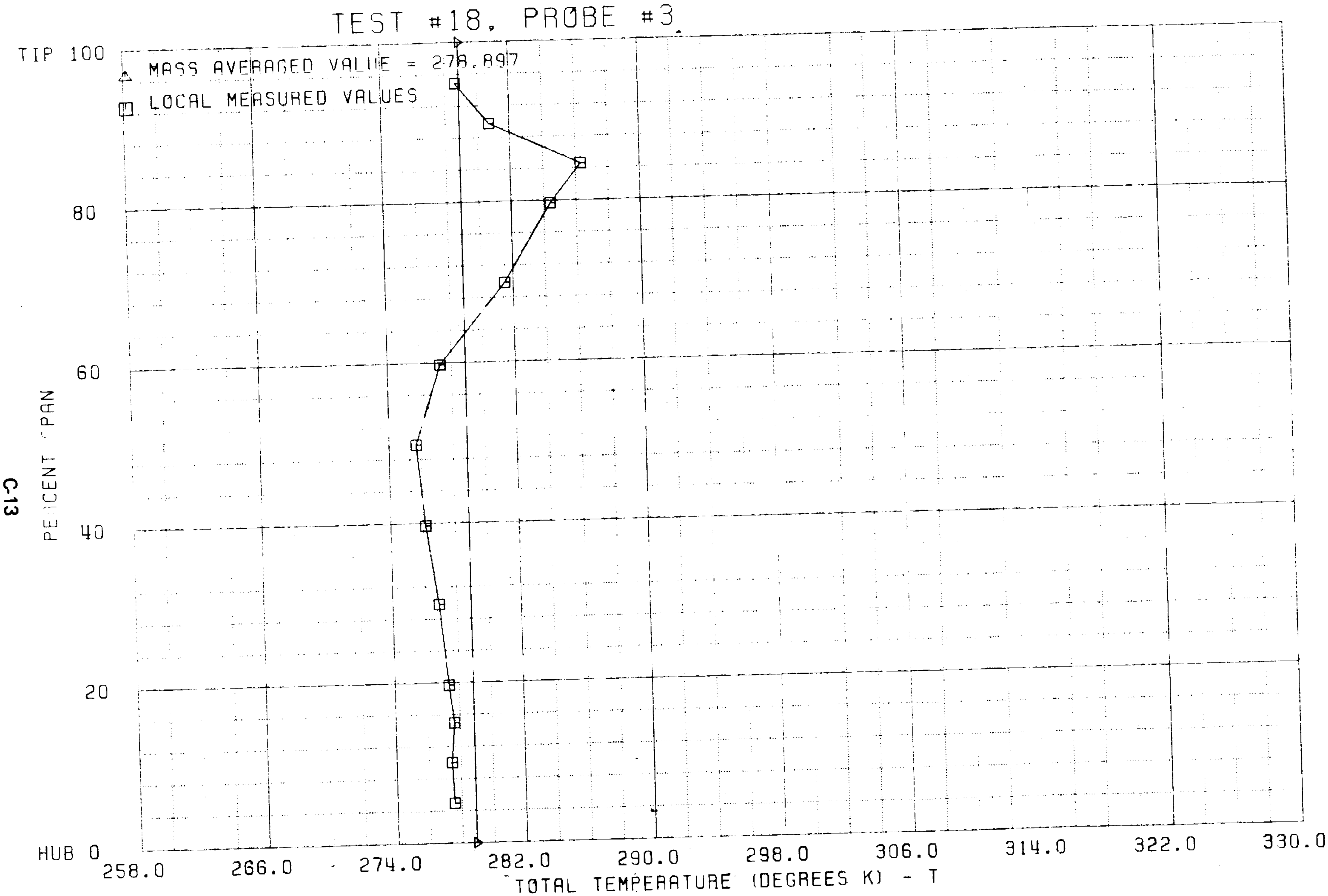

Figure C-13 Exit Survey - Total Temperature vs. Percent Exducer Span, Test No. 18, Moveable Shroud, 100.0 Percent Area

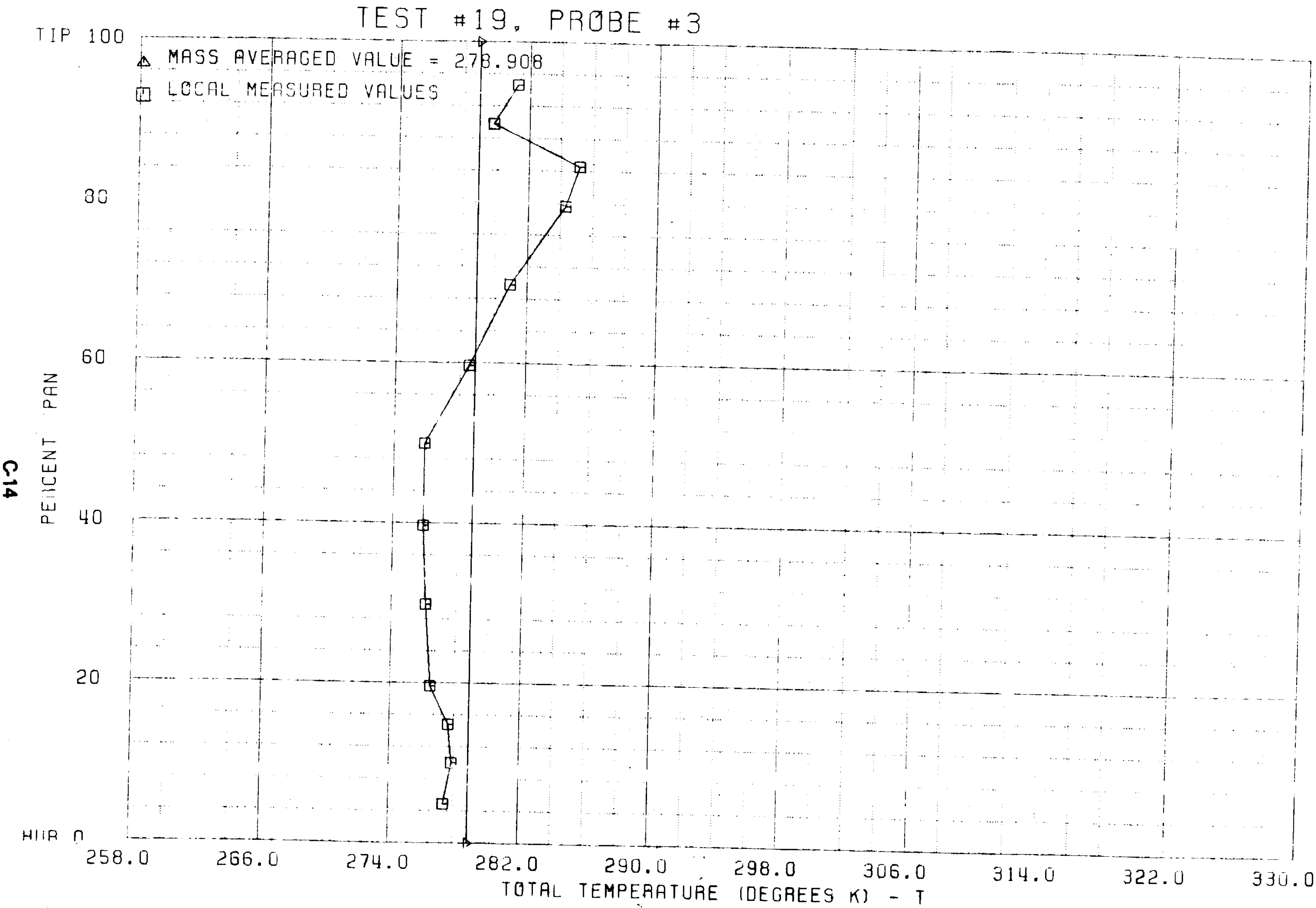

Figure C-14 Exit Survey - Total Temperature vs. Percent Exducer Span, Test No. 19, Moveable Shroud, 81.1 Percent Area

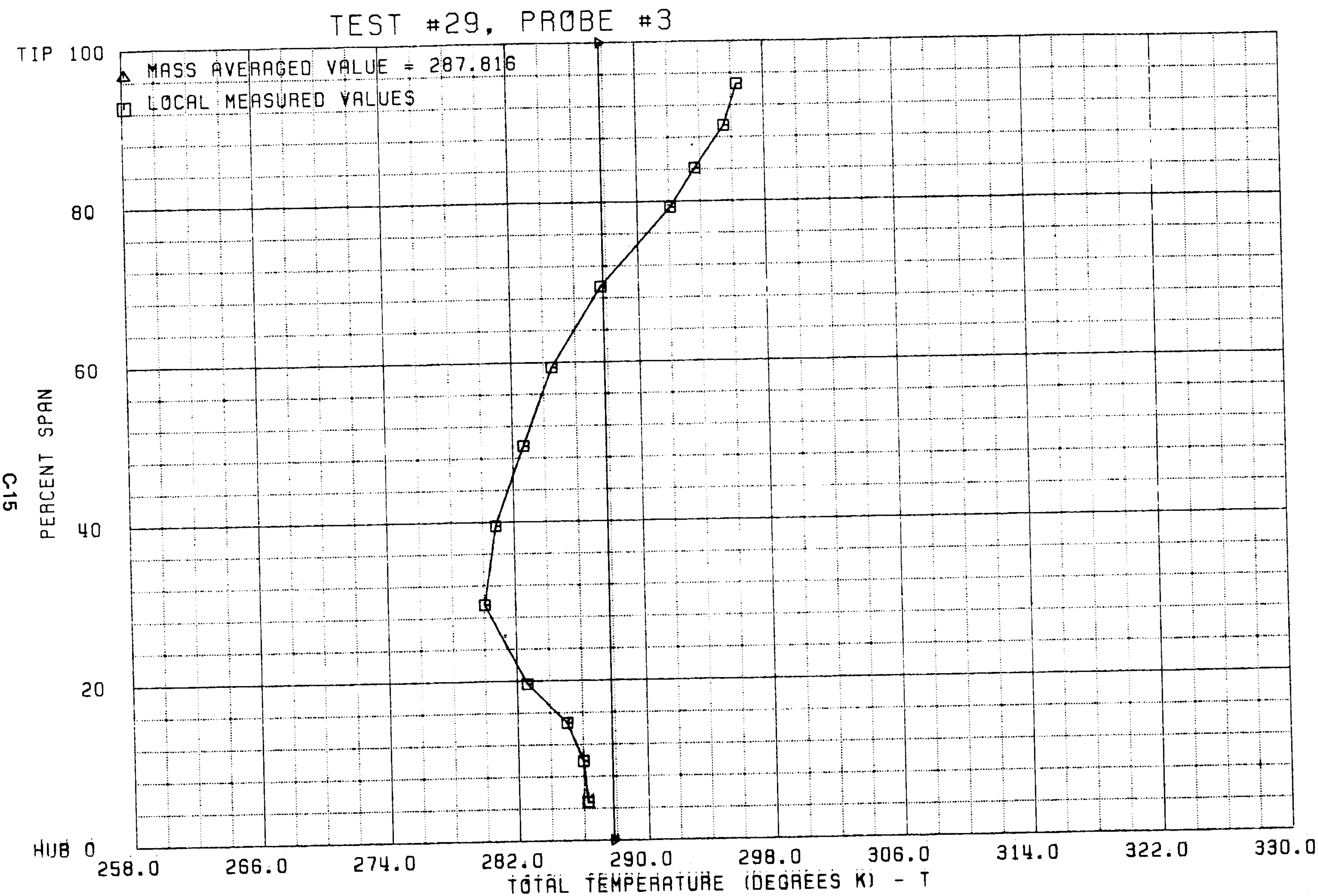

Figure C-15 Exit Survey - Total Temperature vs. Percent Exducer Span, Test No. 29, Moveable Shroud, 62.2 Percent Area

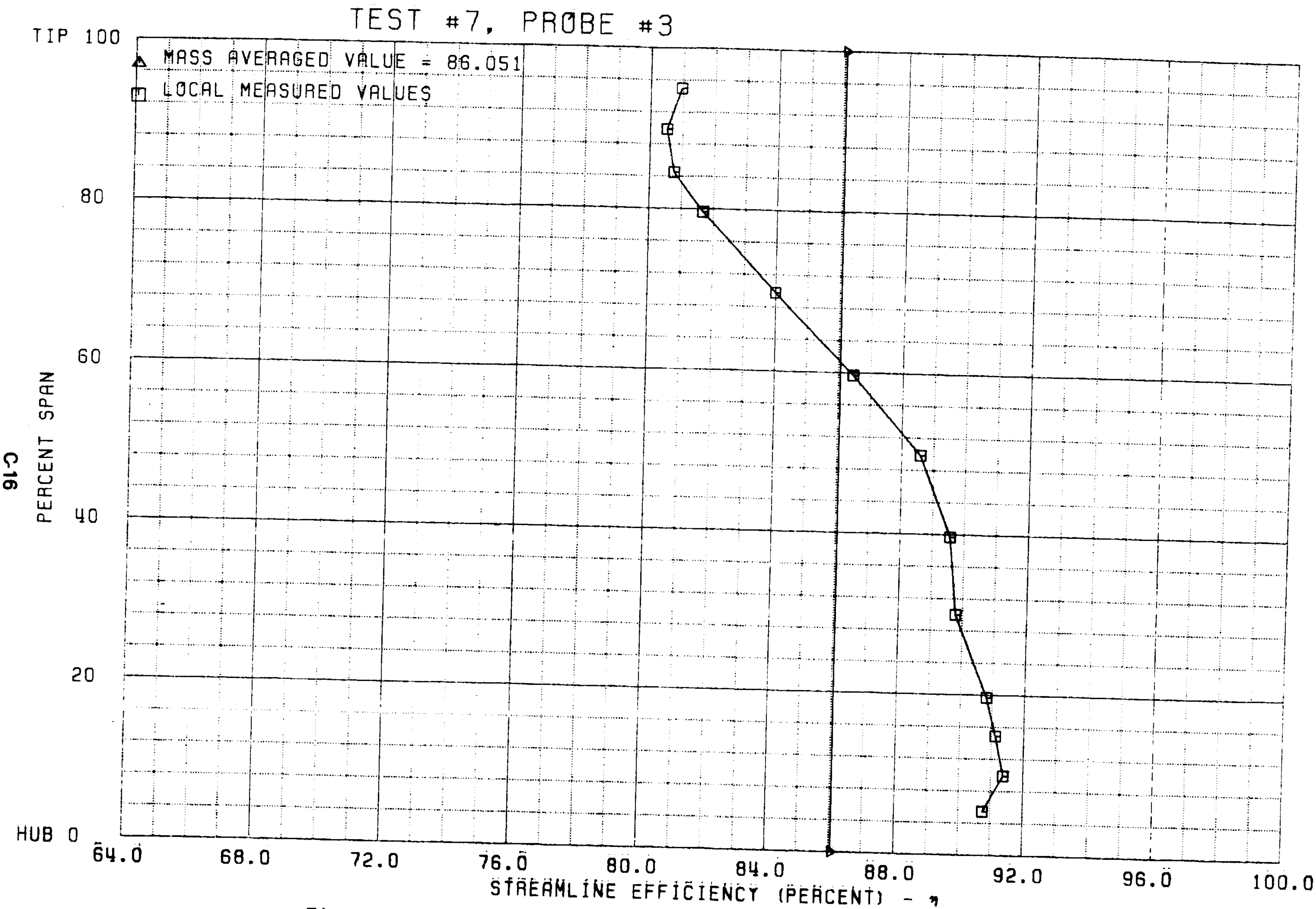

Figure C-16 Exit Survey - Streamline Efficiency vs. Percent Exducer Span, Test No. 7, Moveable Hub, 81.1 Percent Area

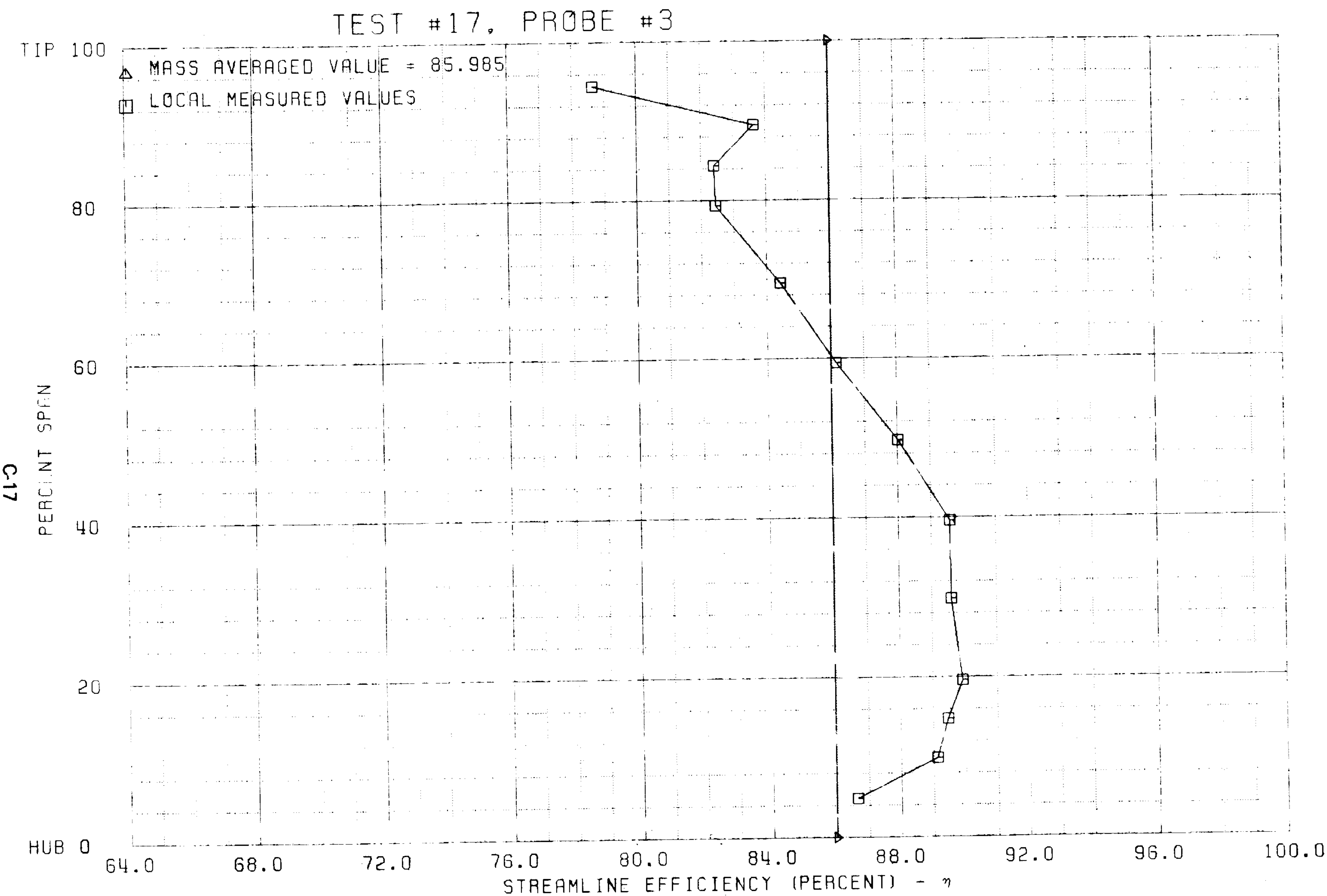

Figure C-17 Exit Survey - Streamline Efficiency vs. Percent Exducer Span, Test No. 17, Moveable Shroud, 125.0 Percent Area

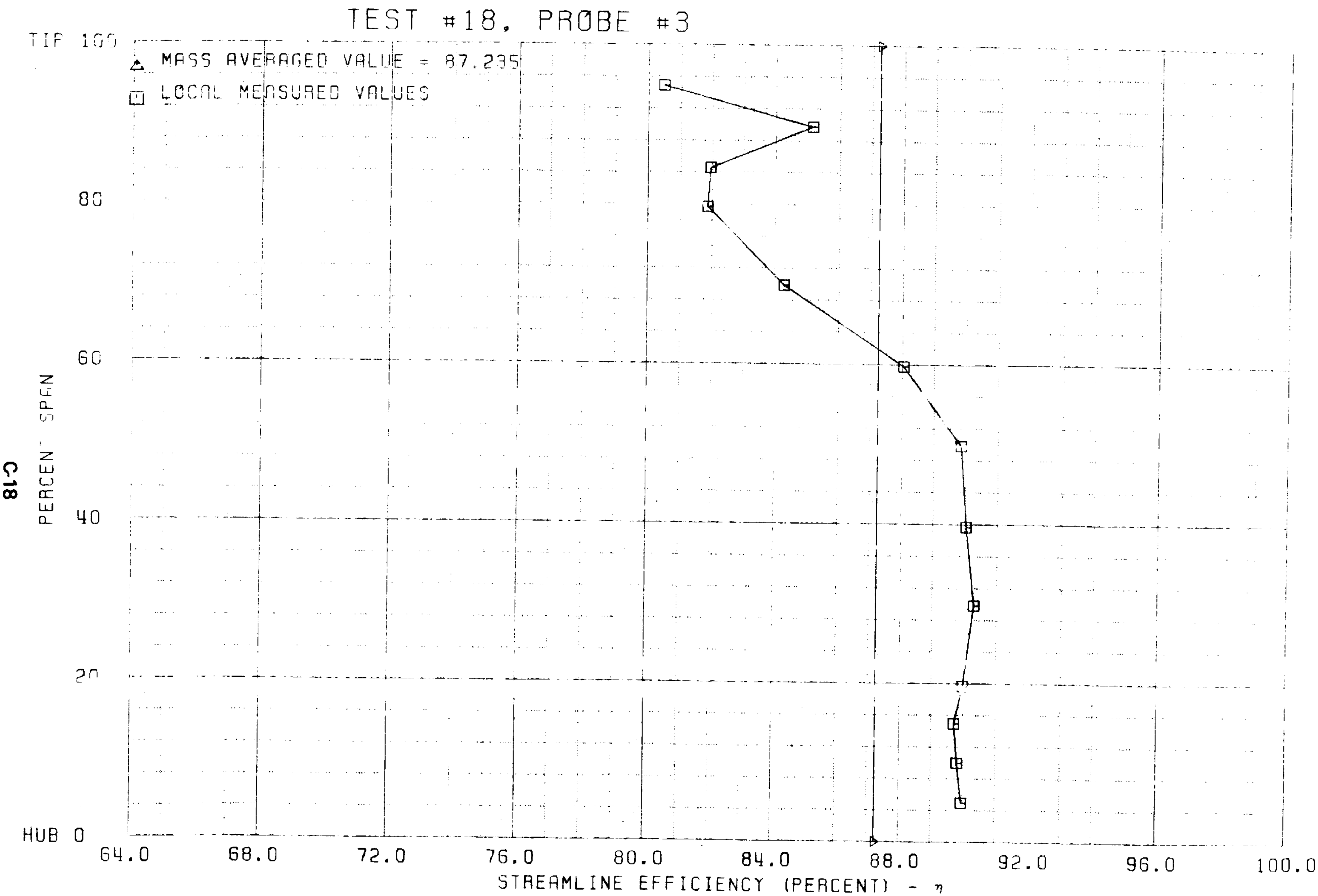

Figure C-18 Exit Survey - Streamline Efficiency vs. Percent Exducer Span, Test No. 18, Moveable Shroud, 100.0 Percent Area

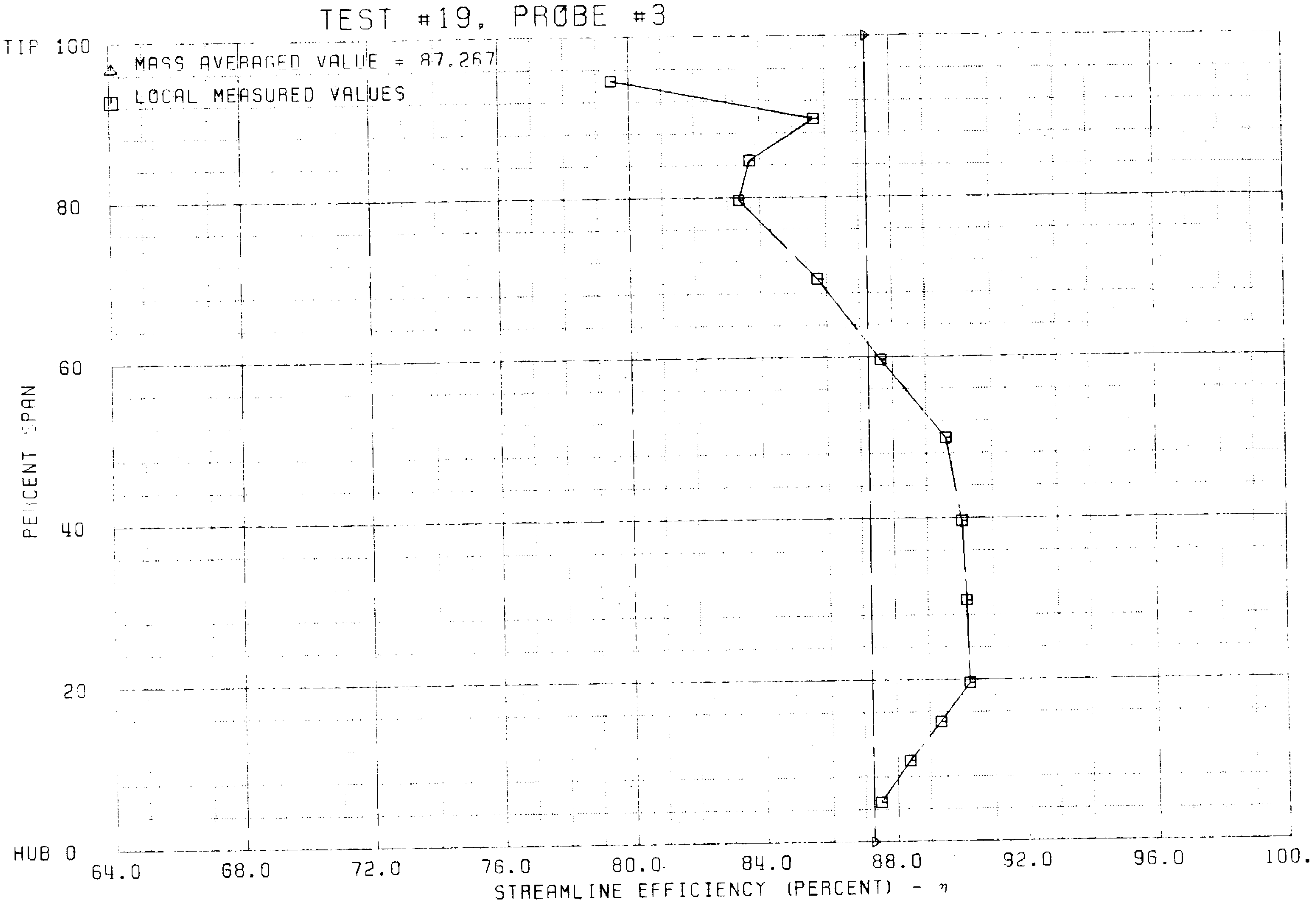

Figure C-19 Exit Survey - Streamline Efficiency vs. Percent Exducer Span, Test No. 19, Moveable Shroud, 81.1 Percent Area

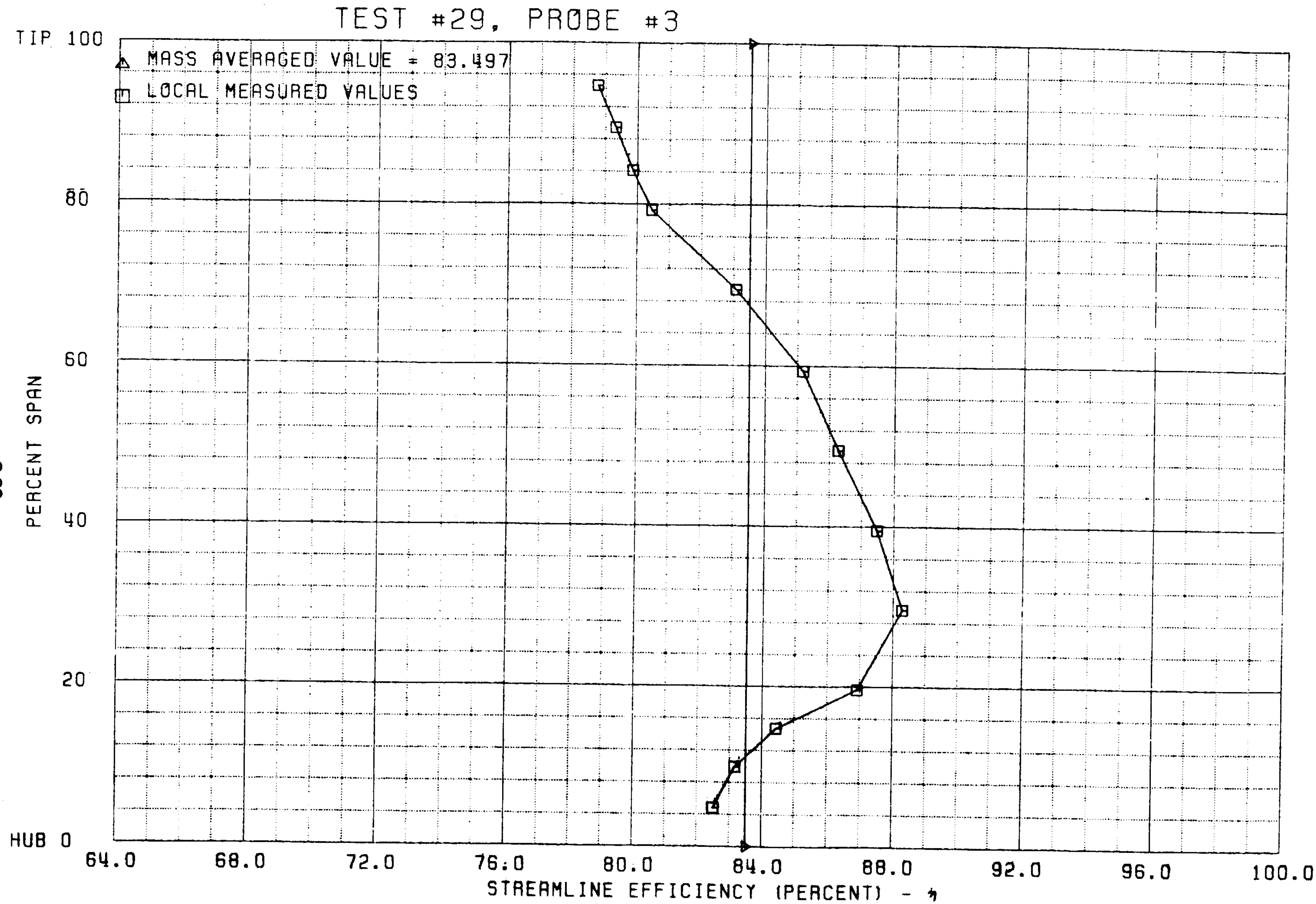

Figure C-20 Exit Survey - Streamline Efficiency vs. Percent Exducer Span, Test No. 29, Moveable Shroud, 62.2 Percent Area

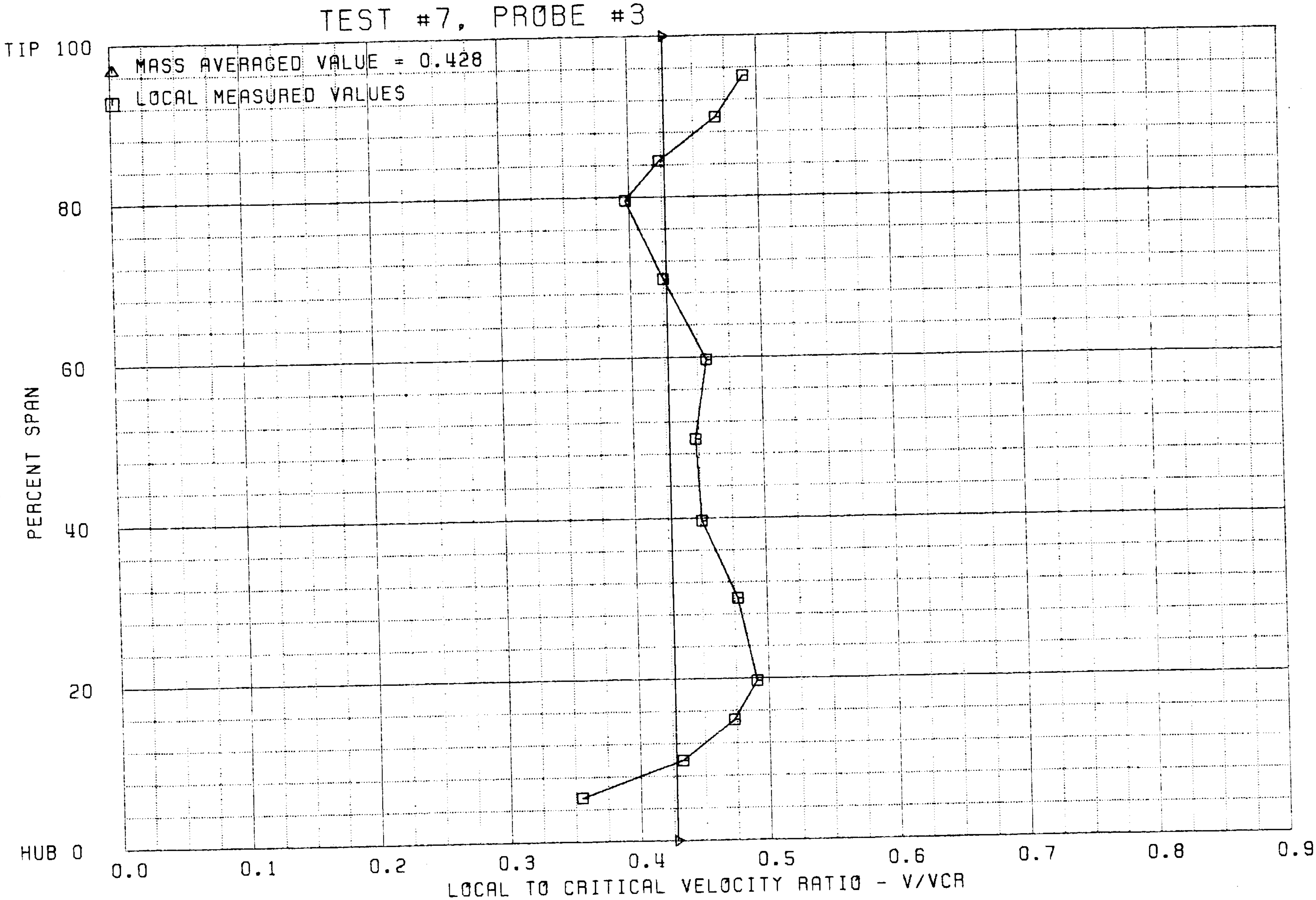

Figure C-21 Exit Survey - Local to Critical Velocity Ratio vs. Percent Exducer Span, Test No. 7, Moveable Hub, 81.1 Percent Area

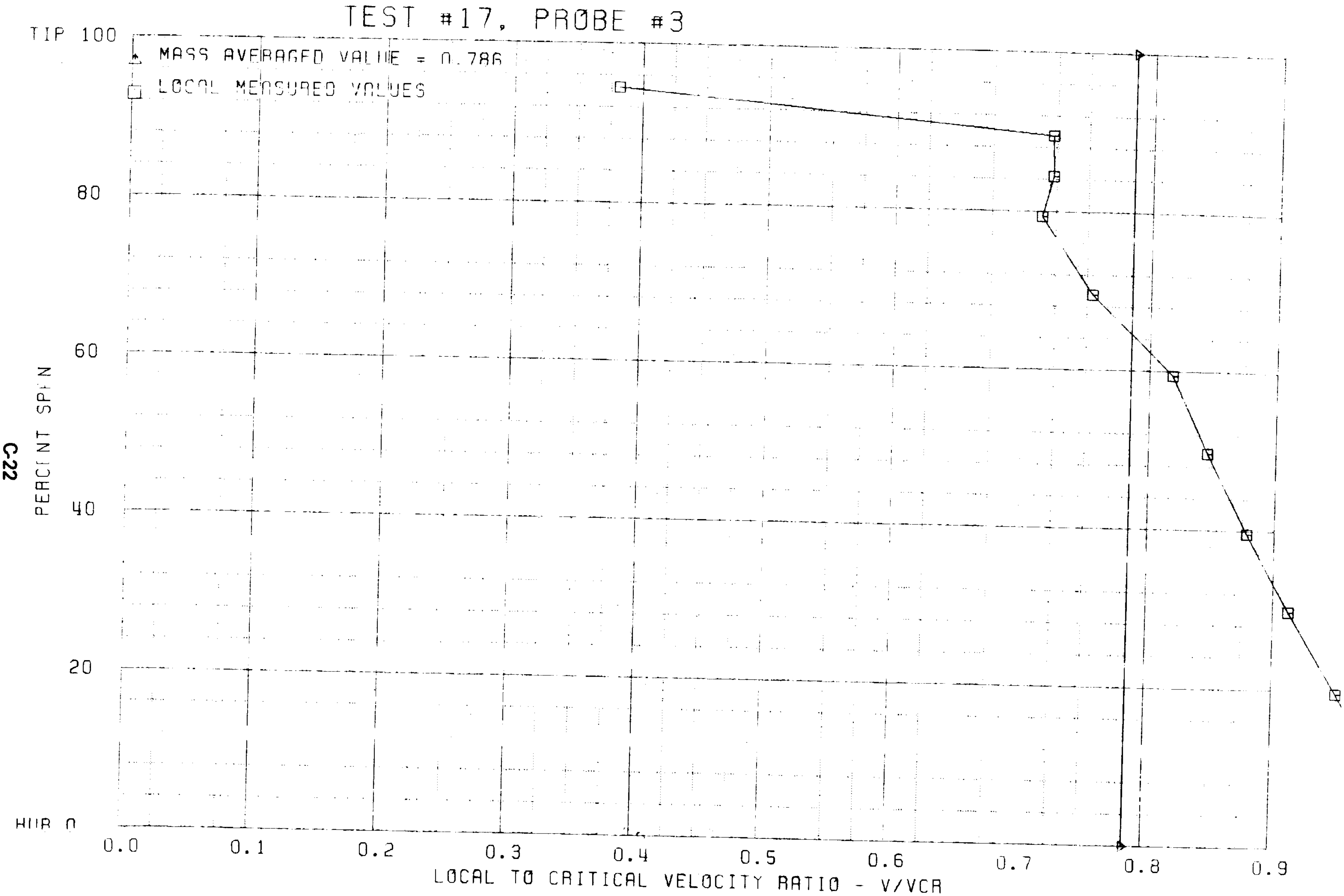

Figure C-22 Exit Survey - Local to Critical Velocity Ratio vs. Percent Exducer Span, Test No. 17, Moveable Shroud, 125.0 Percent Area

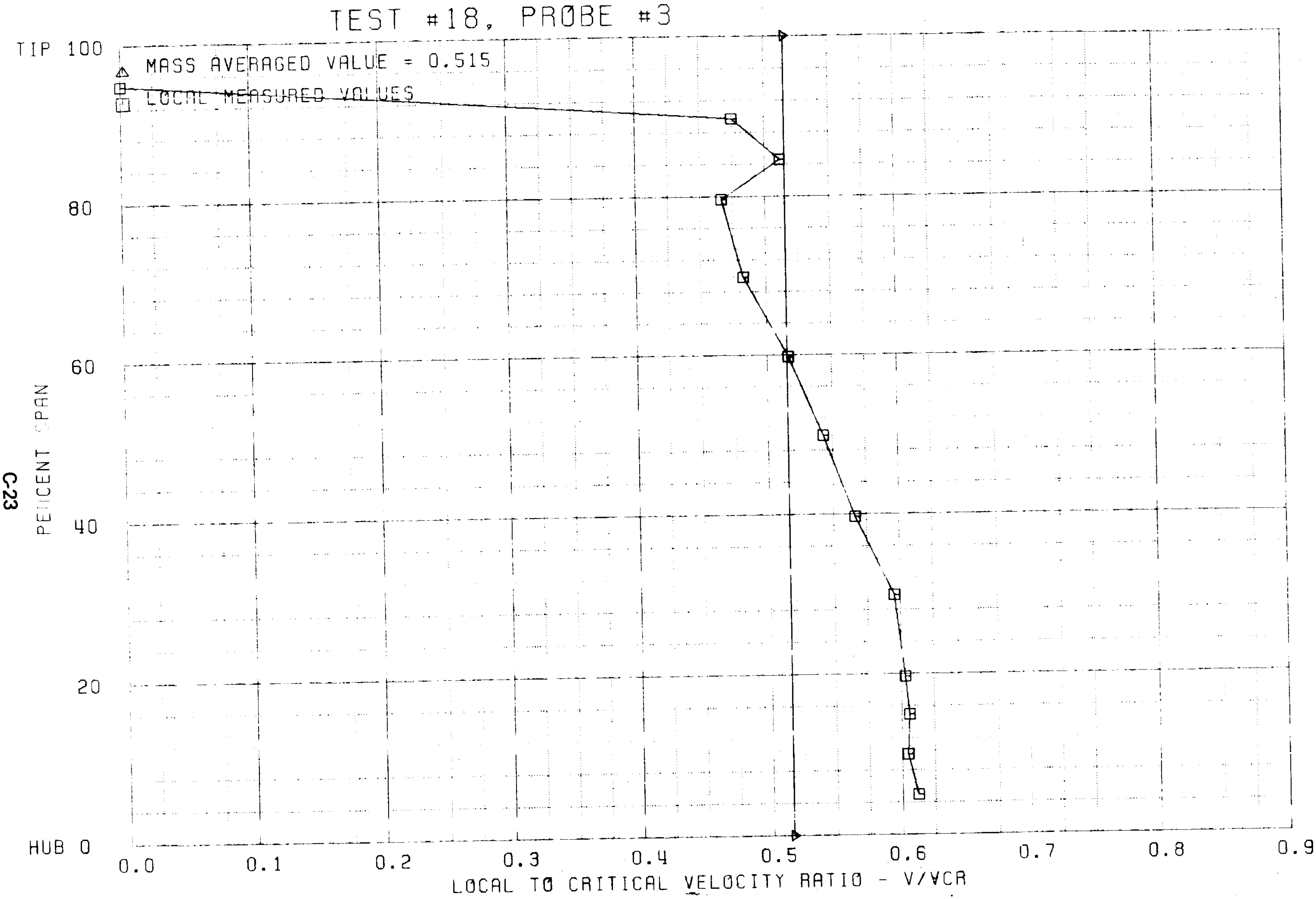

Figure C-23 Exit Survey - Local to Critical Velocity Ratio vs. Percent Exducer Span, Test No. 18, Moveable Shroud, 100.0 Percent Area

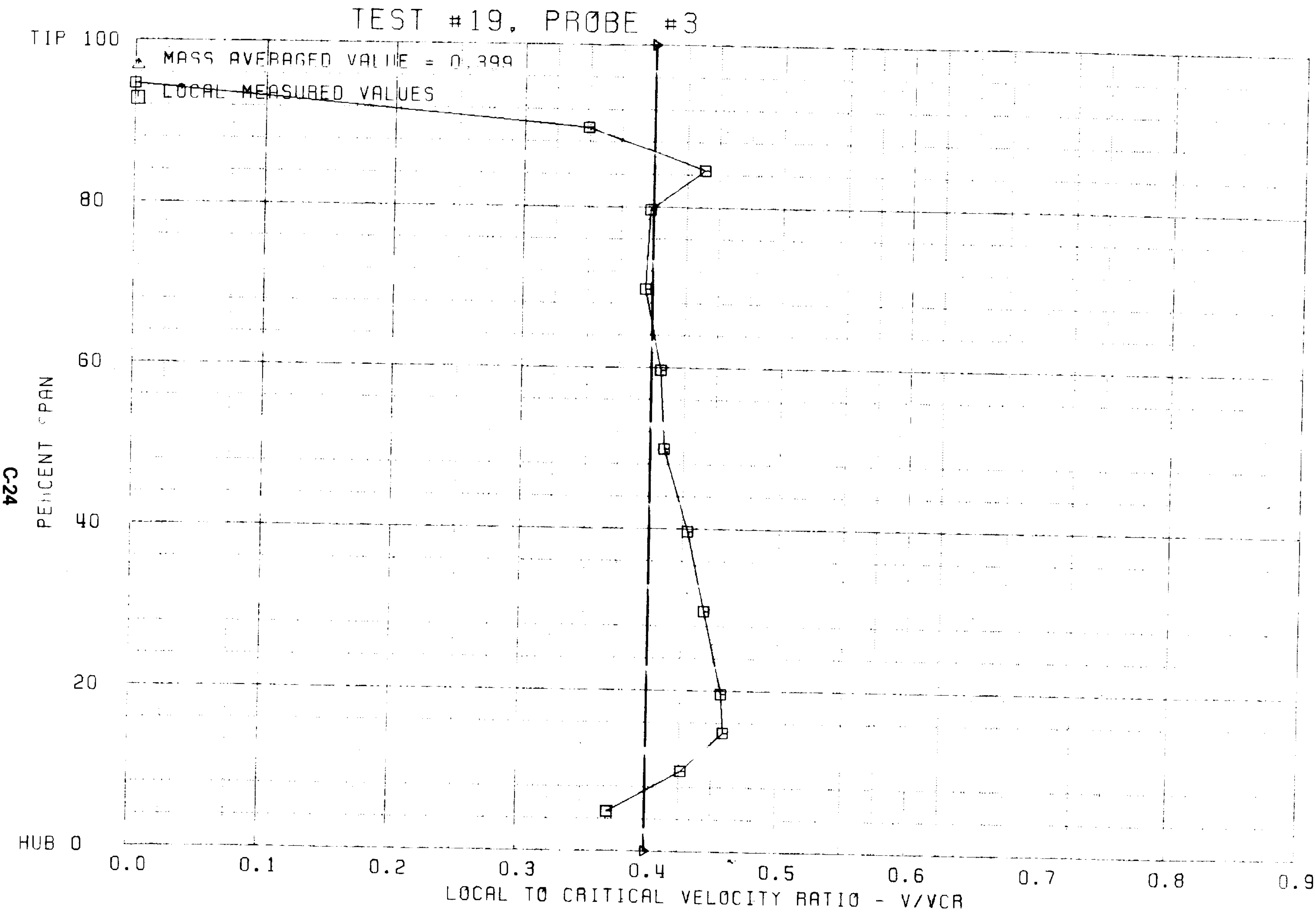

Figure C-24 Exit Survey - Local to Critical Velocity Ratio vs. Percent Exducer Span, Test No. 19, Moveable Shroud, 81.1 Percent Area

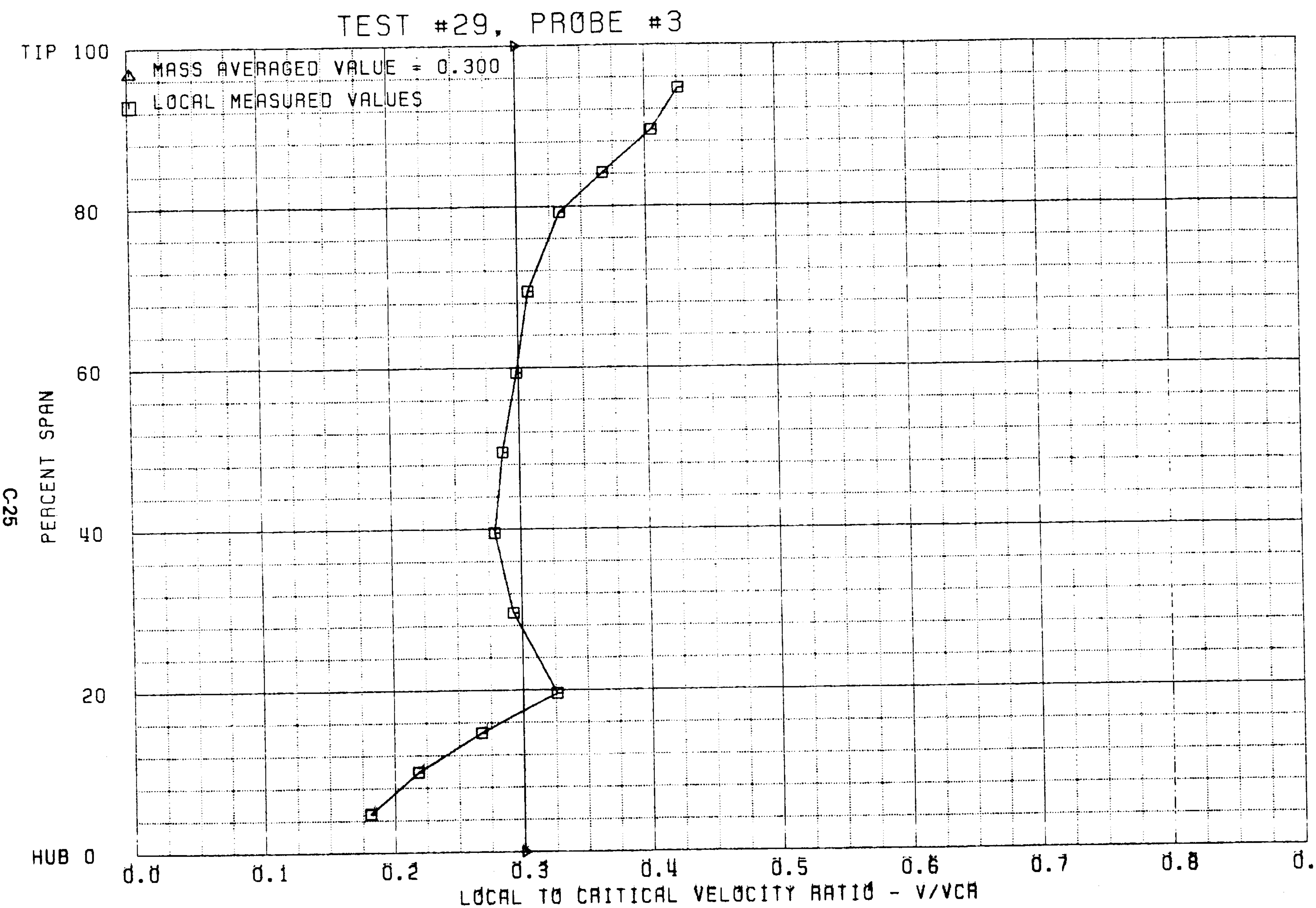

Figure C-25 Exit Survey - Local to Critical Velocity Ratio vs. Percent Exducer Span, Test No. 29, Moveable Shroud, 62.2 Percent Area

APPENDIX D

VANELESS SPACE SURVEY CONTOUR PLOT DATA

Flow Angle
Total Pressure Loss
Efficiency
Pressure Loss Coefficient

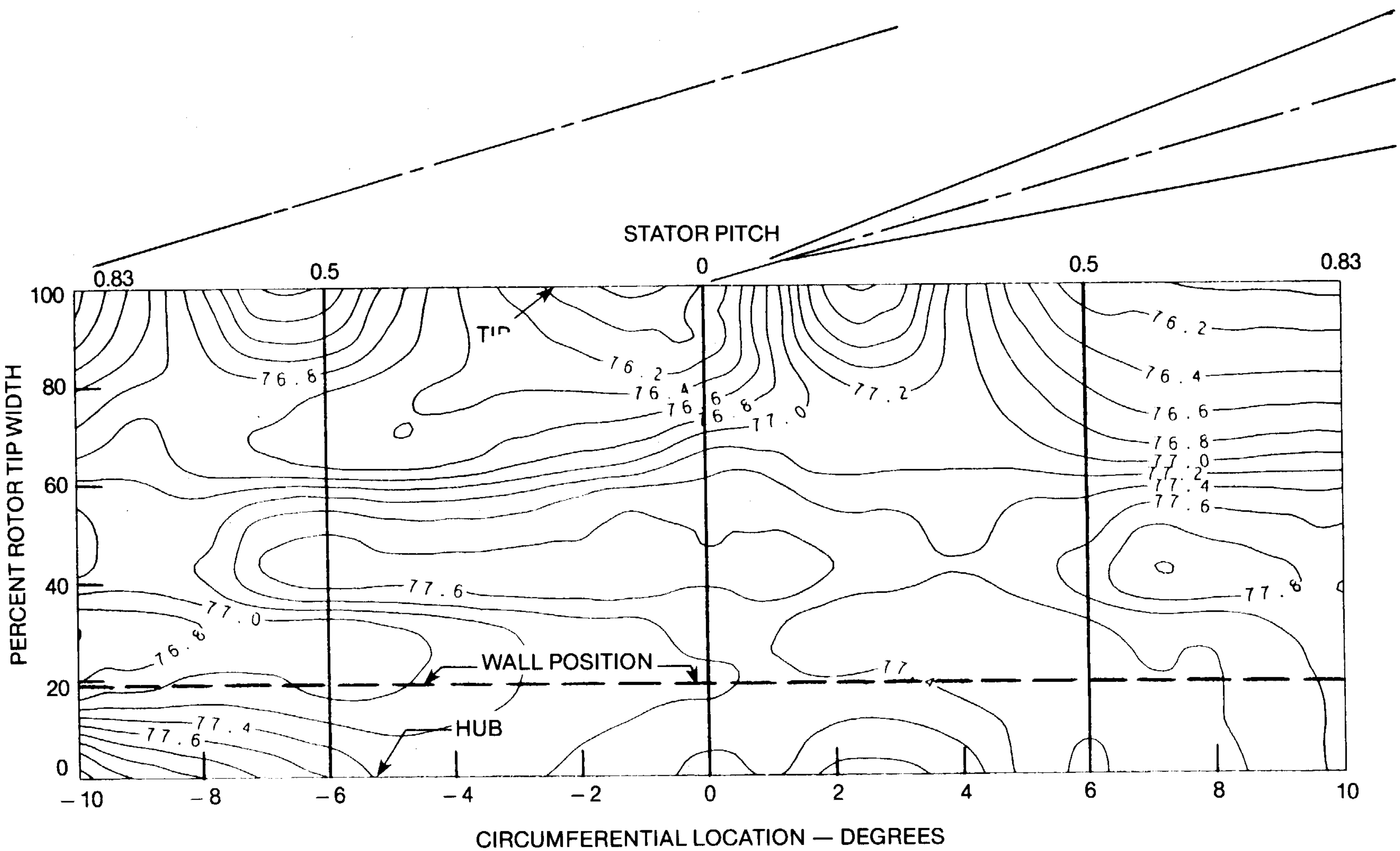

Figure D-1 Vaneless Space Survey of a 20° Circumferential Sector - Flow Angle, Test No. 7, Moveable Hub, 81.1 Percent Area

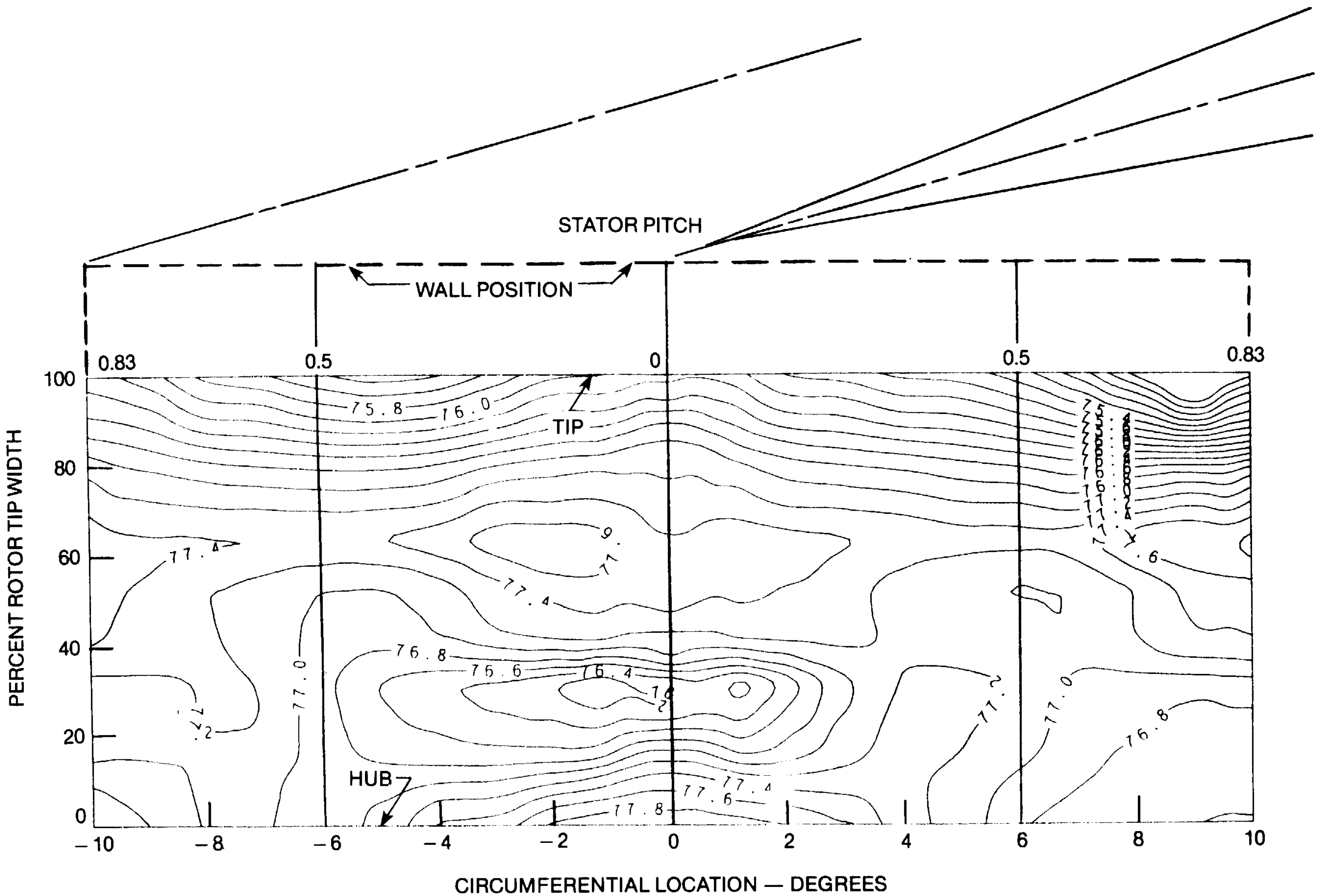

Figure D-2 Vaneless Space Survey of a 20° Circumferential Sector - Flow Angle, Test No. 17, Moveable Shroud, 125.0 Percent Area

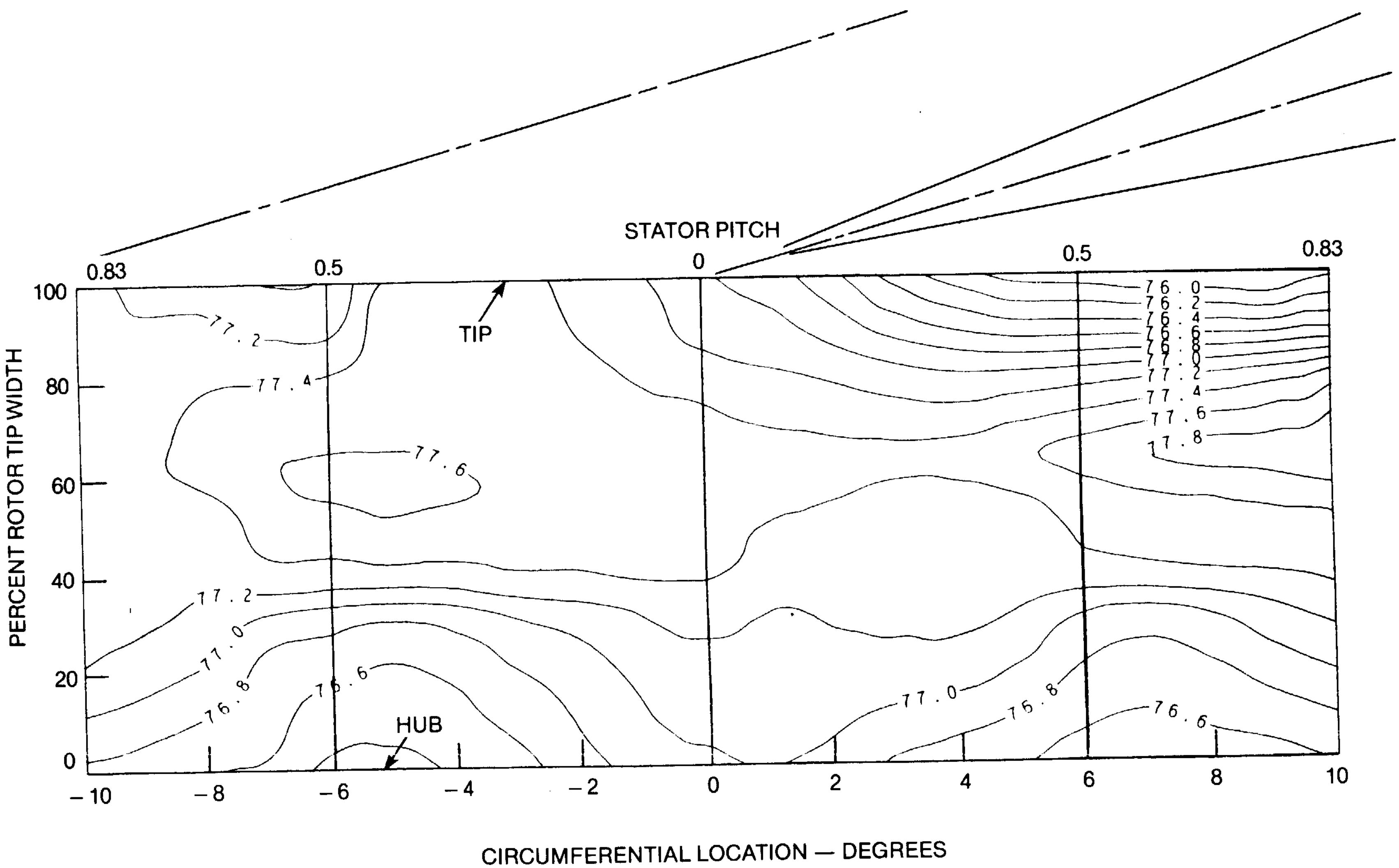

Figure D-3 Vaneless Space Survey of a 20^{0} Circumferential Sector - Flow Angle, Test No. 18, Moveable Shroud, 100.0 Percent Area

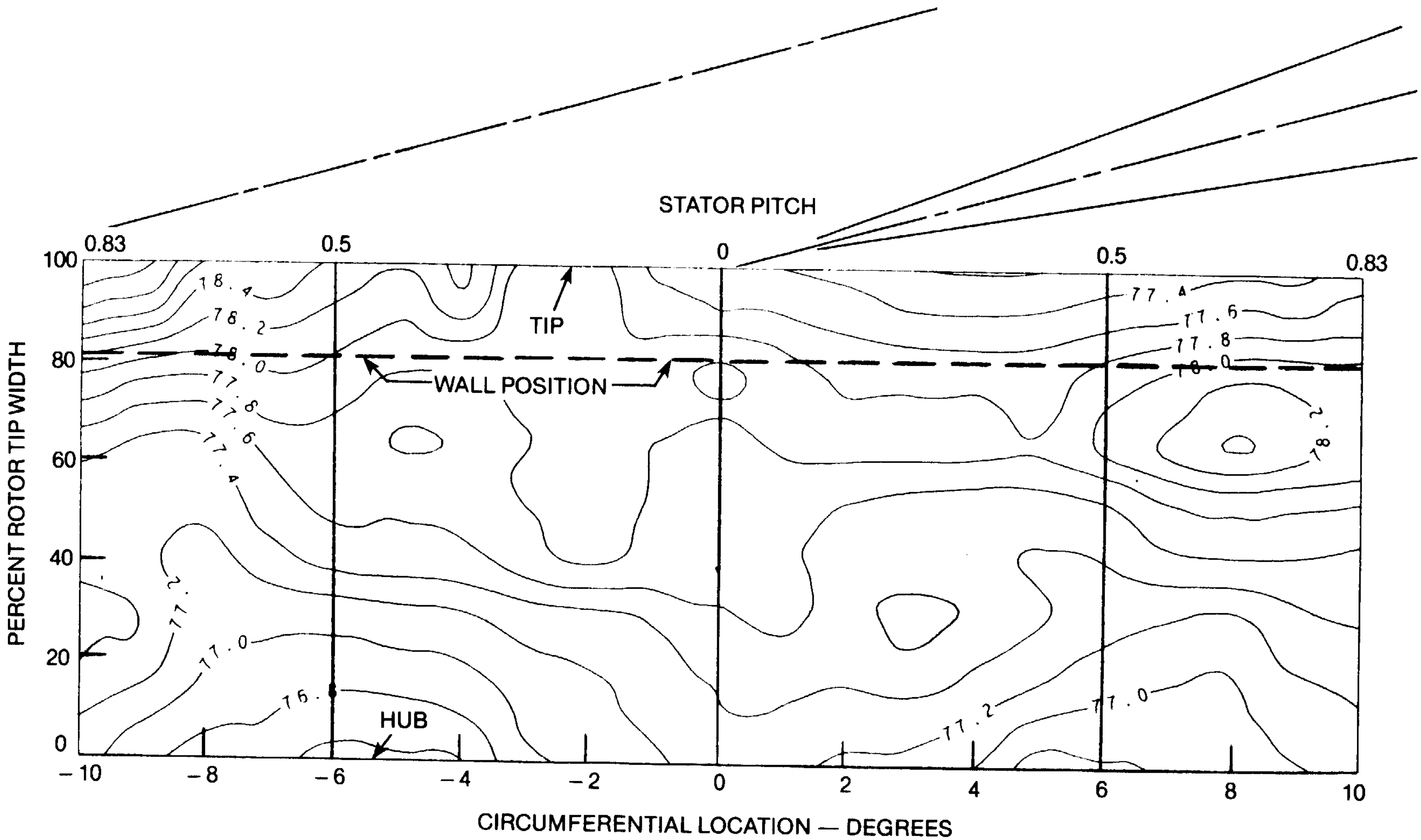

Figure D-4 Vaneless Space Survey of a 20^{o} Circumferential Sector - Flow Angle, Test No. 19, Moveable Shroud, 81.1 Percent Area

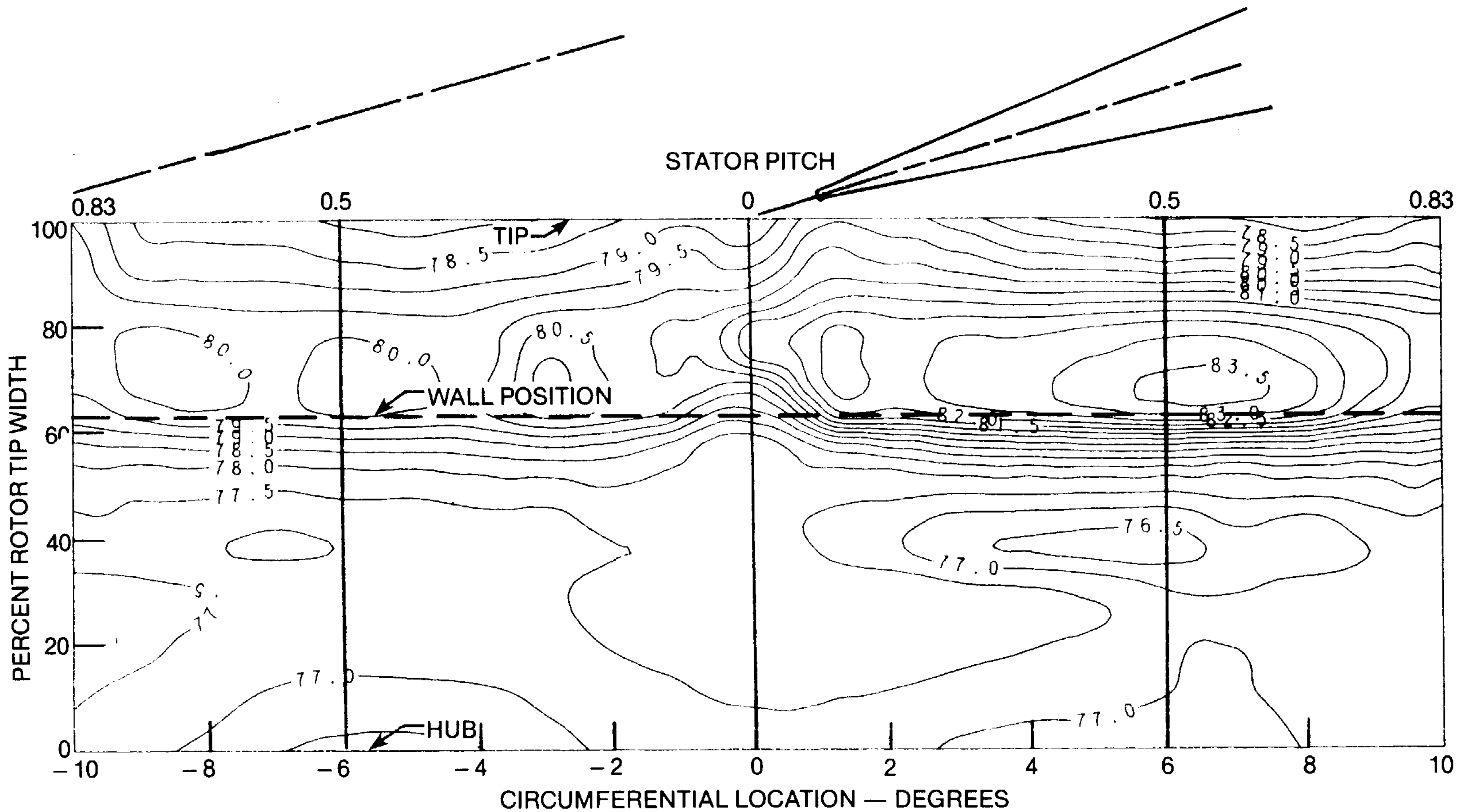

Figure D-5 Vaneless Space Survey of a 20° Circumferential Sector - Flow Angle, Test No. 29, Moveable Shroud, 62.2 Percent Area

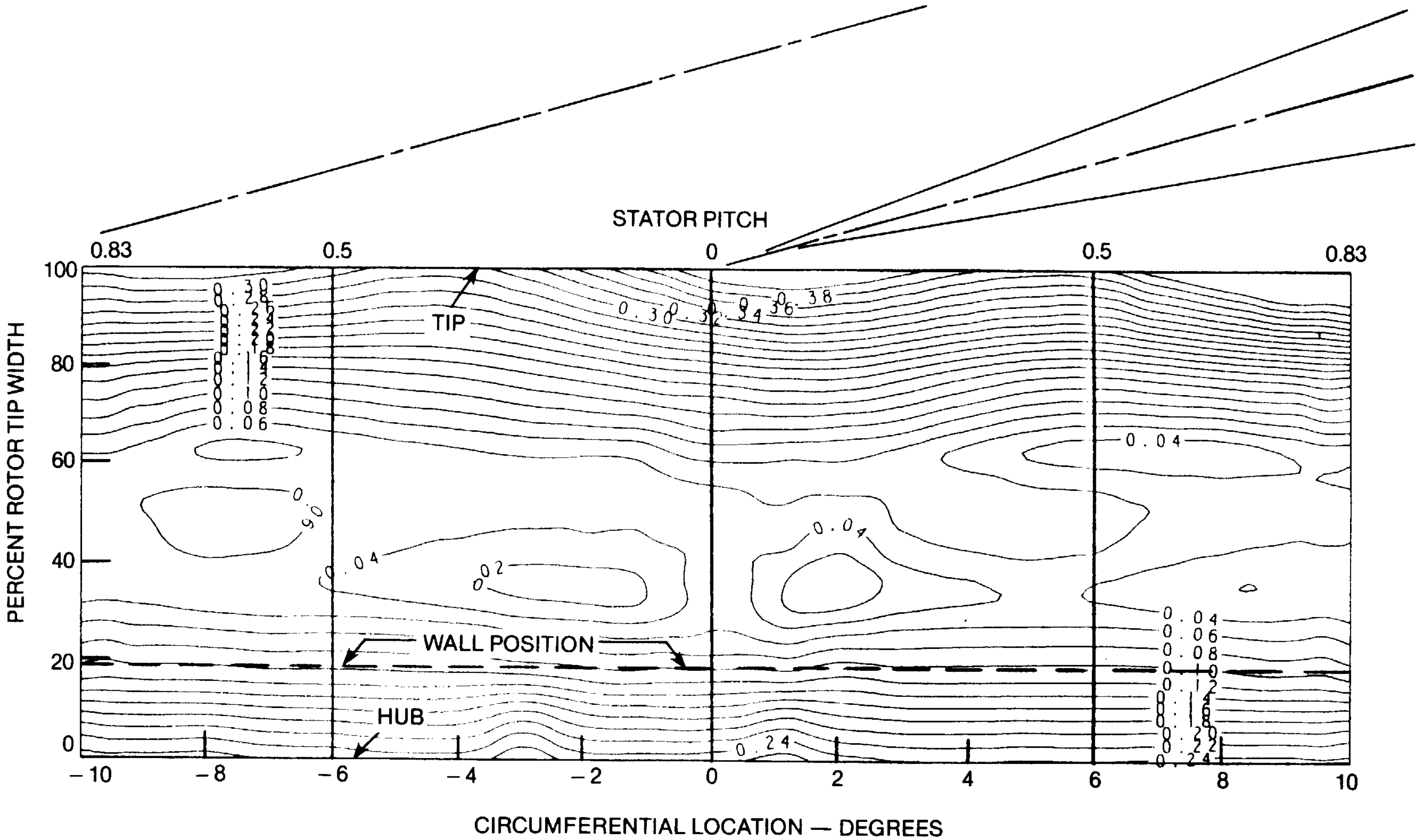

Figure D-6 Vaneless Space Survey of a 20° Circumferential Sector - Total Pressure Loss, Test No. 7, Moveable Hub, 81.1 Percent Area

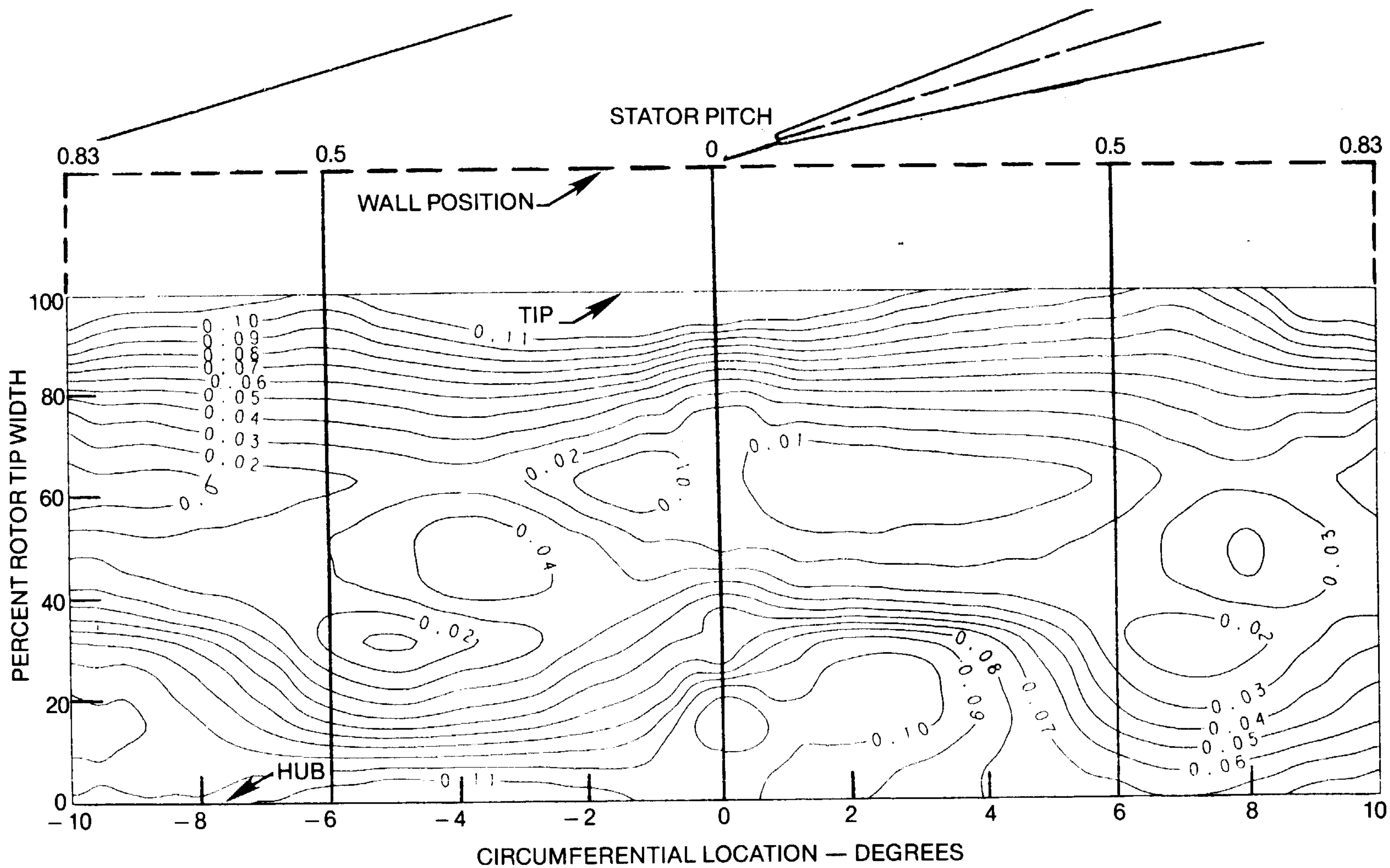

Figure D-7 Vaneless Space Survey of a 20° Circumferential Sector - Total Pressure Loss, Test No. 17, Moveable Shroud, 125.0 Percent Area

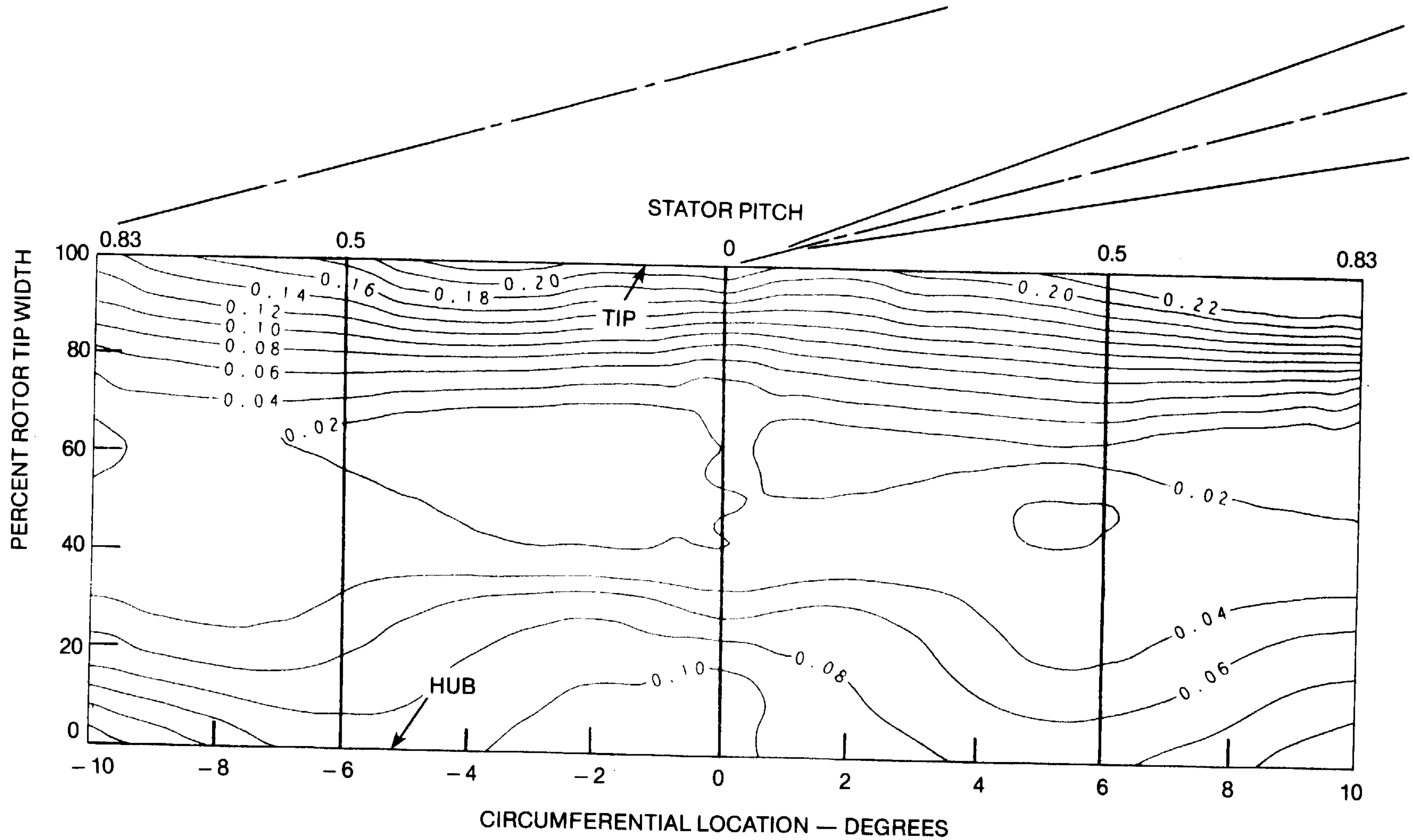

Figure D-8 Vaneless Space Survey of a 20° Circumferential Sector - Total Pressure Loss, Test No. 18, Moveable Shroud, 100.0 Percent Area

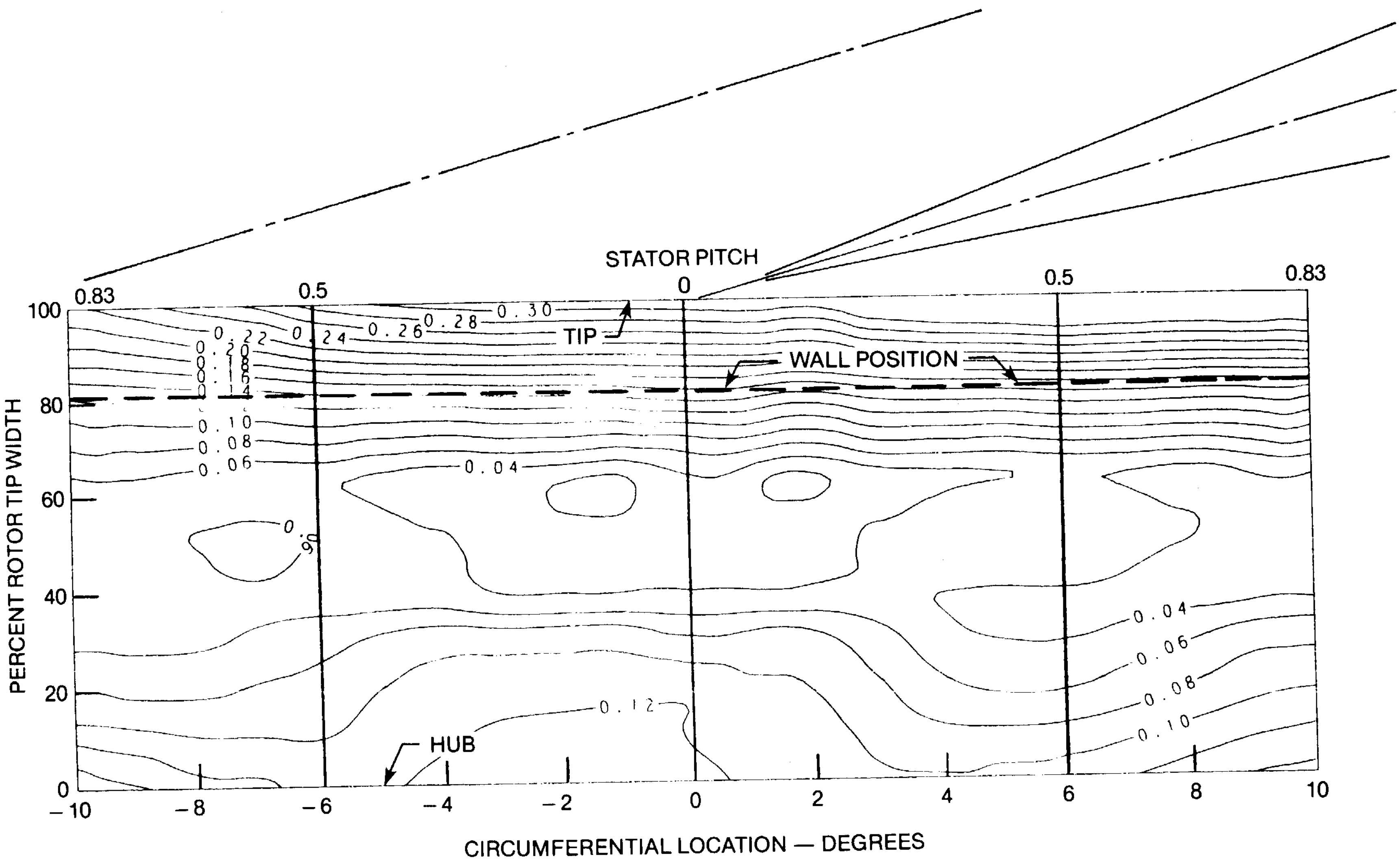

Figure D-9 Vaneless Space Survey of a 20^{o} Circumferential Sector - Total Pressure Loss, Test No. 19, Moveable Shroud, 81.1 Percent Area

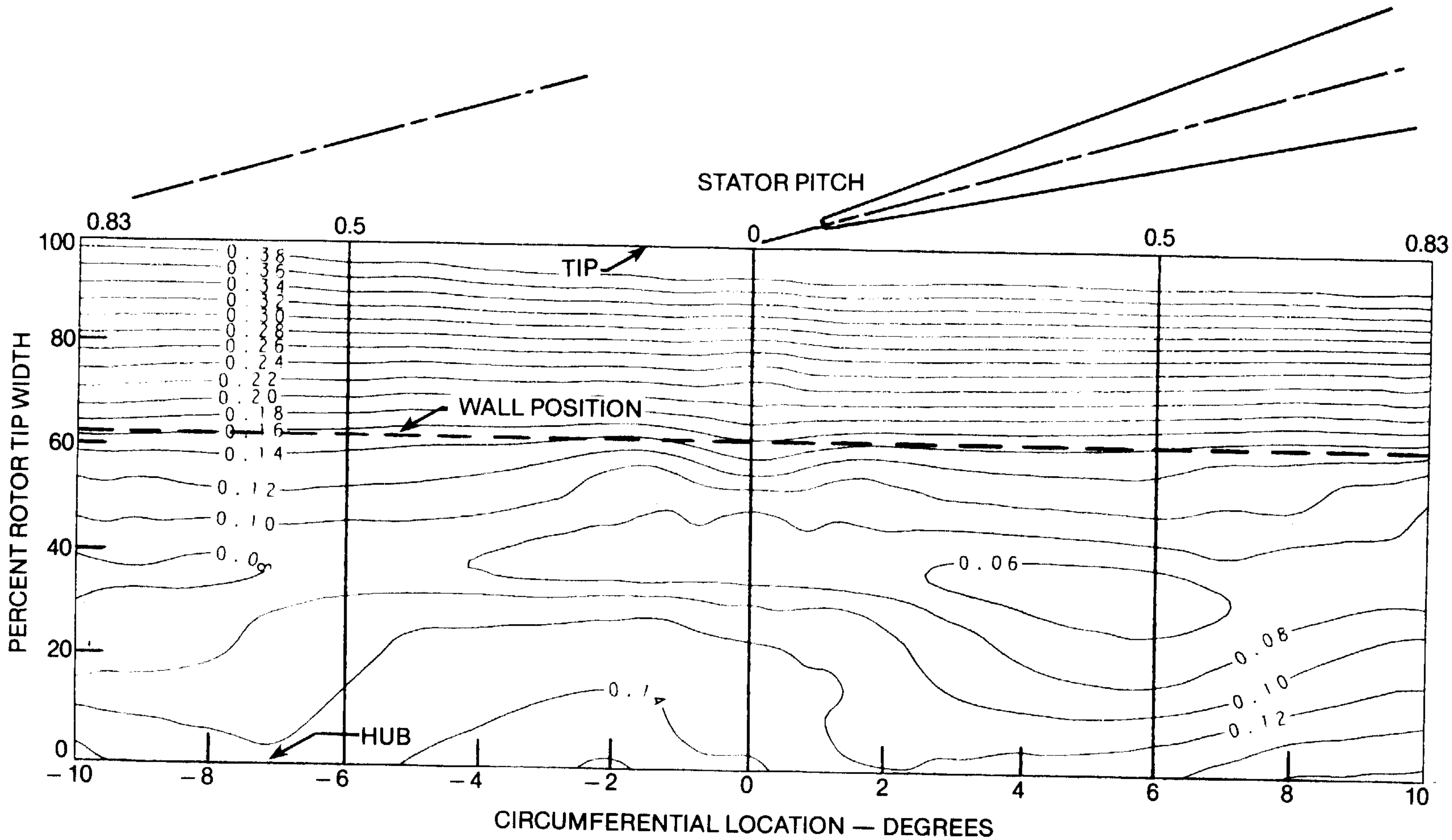

Figure D-10 Vaneless Space Survey of a 20° Circumferential Sector - Total Pressure Loss, Test No. 29, Moveable Shroud, 62.2 Percent Area

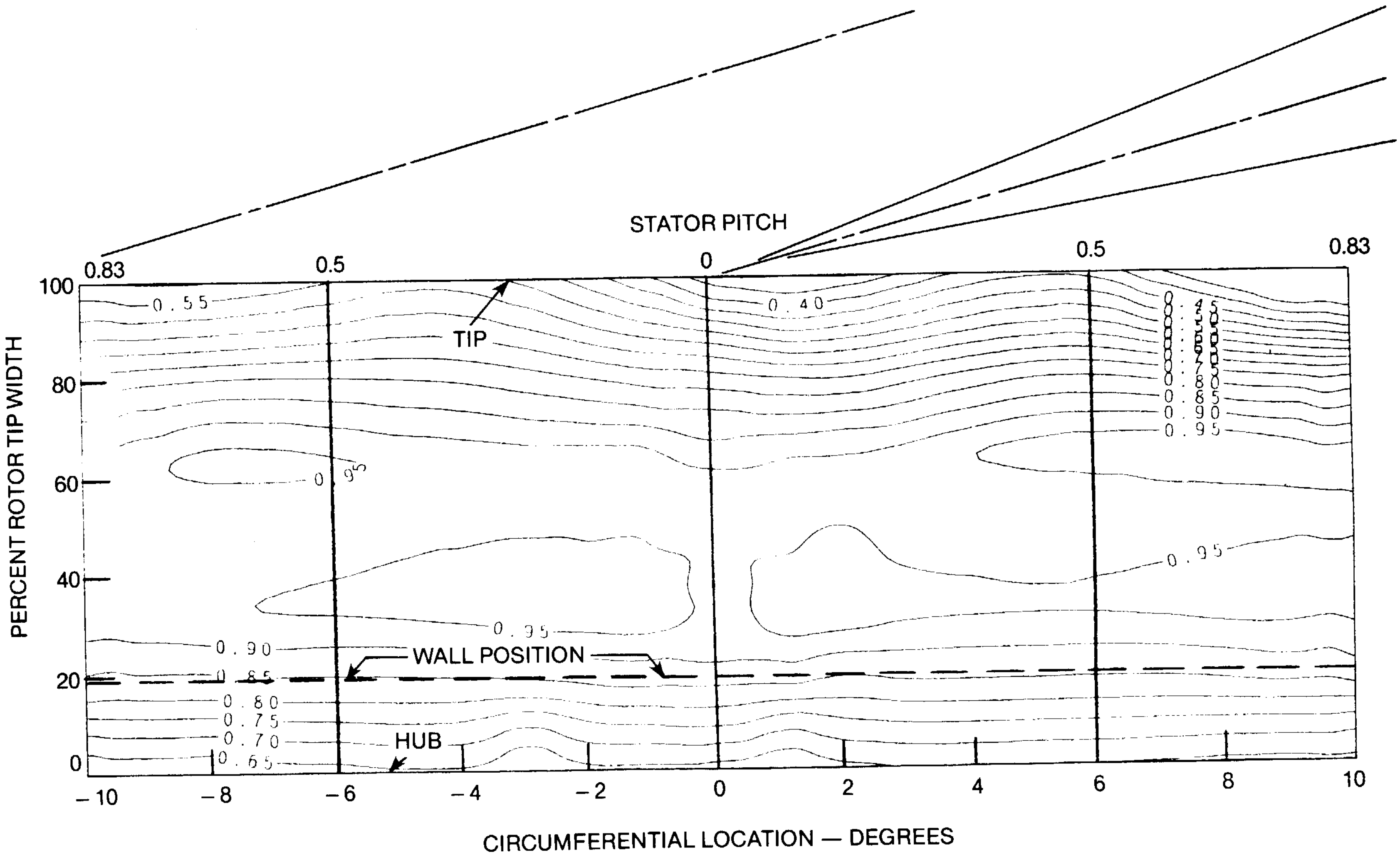

Figure D-11 Vaneless Space Survey of a 20° Circumferential Sector - Nozzle Efficiency, Test No. 7, Moveable Hub, 81.1 Percent Area

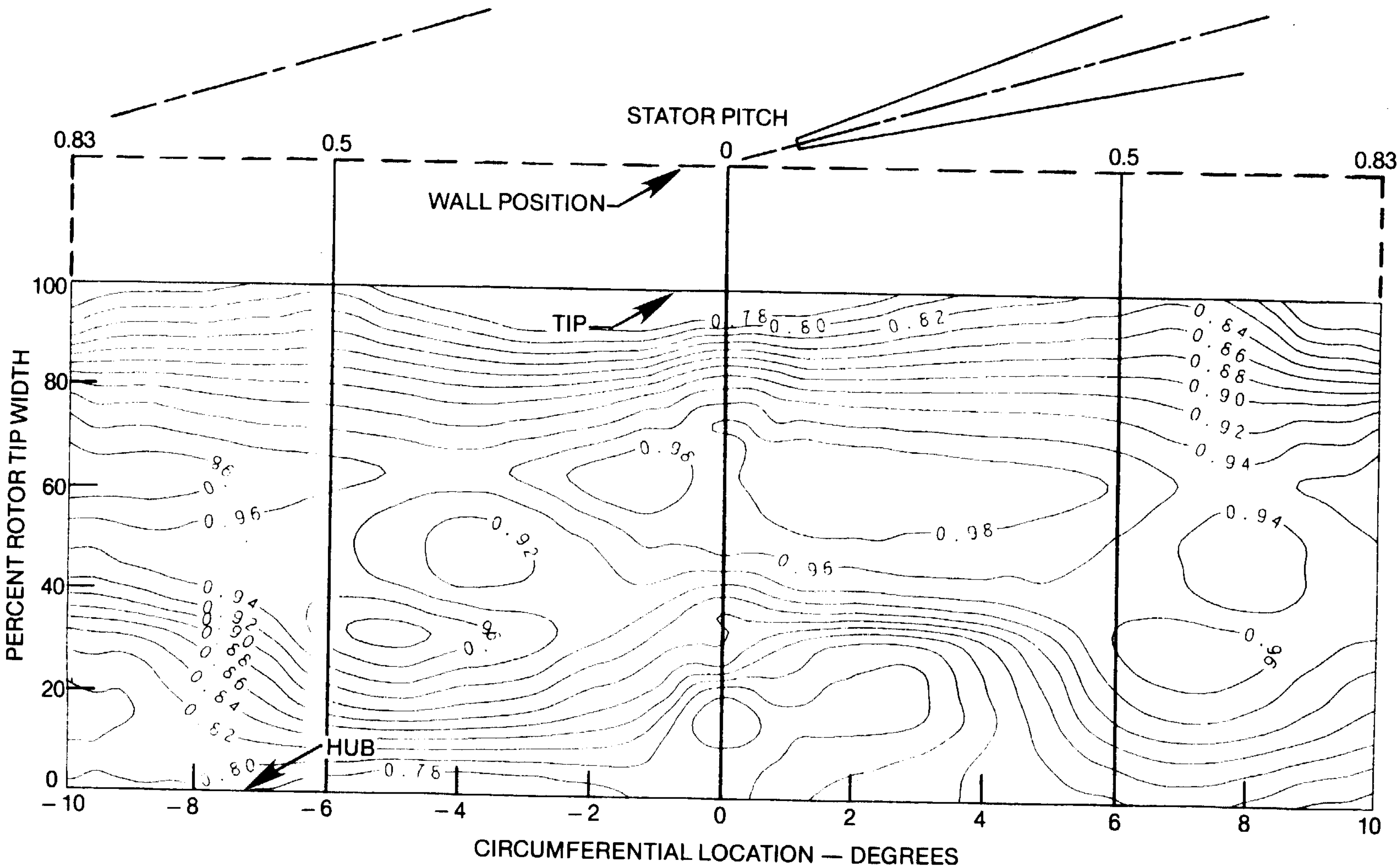

Figure D-12 Vaneless Space Survey of a 20° Circumferential Sector - Nozzle Efficiency, Test No. 17, Moveable Shroud, 125.0 Percent Area

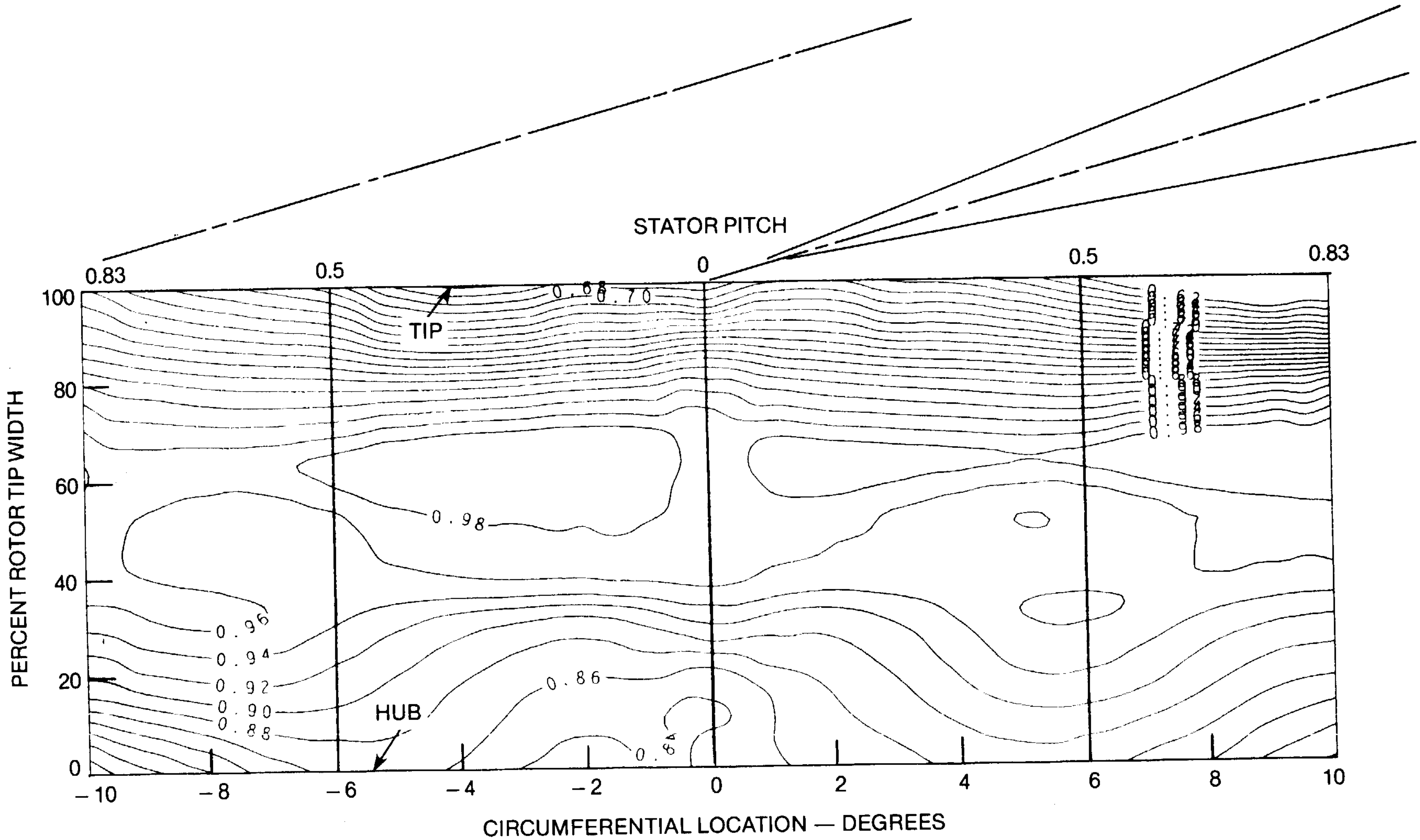

Figure D-13 Vaneless Space Survey of a 20° Circumferential Sector - Nozzle Efficiency, Test No. 18, Moveable Shroud, 100.0 Percent Area

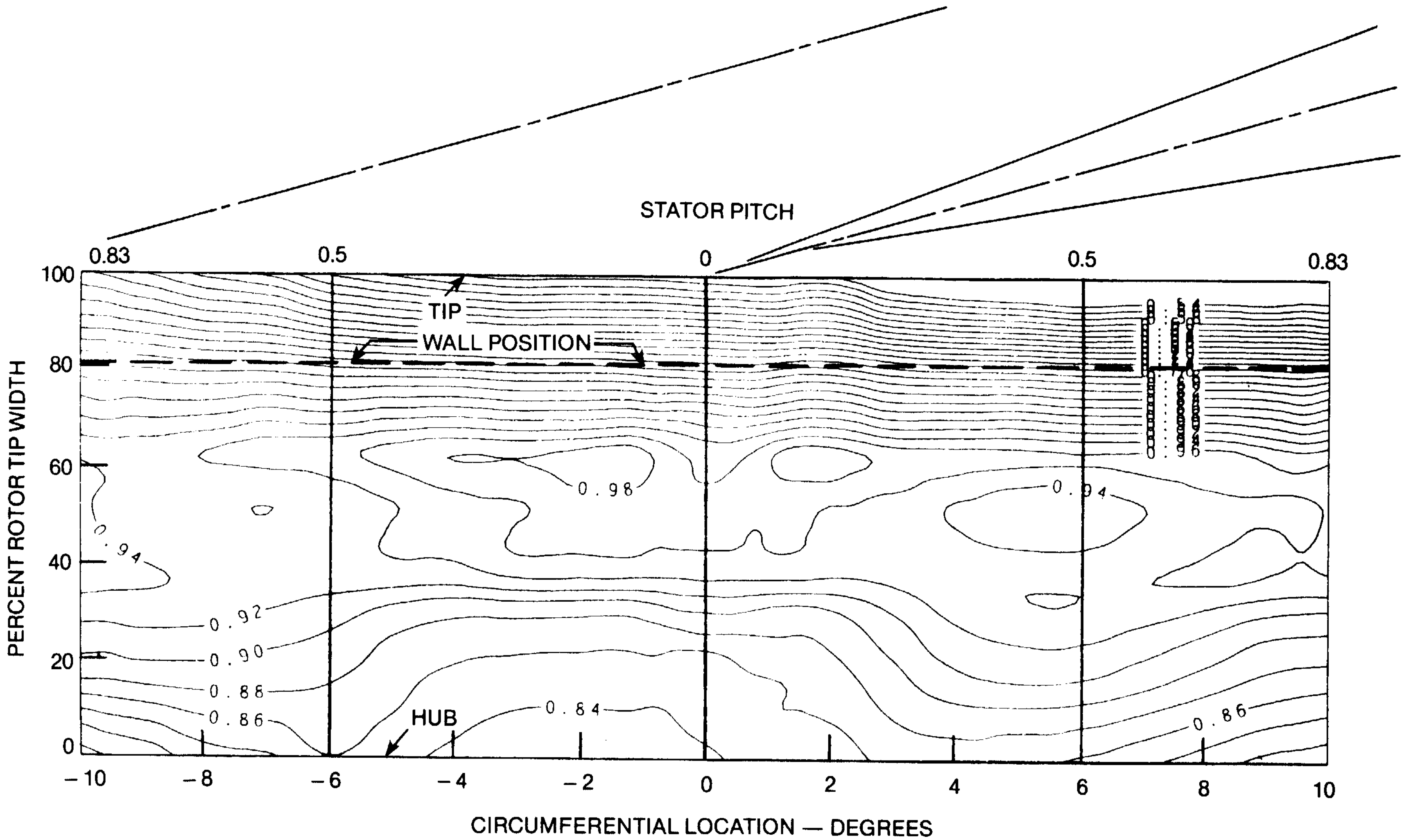

Figure D-14 Vaneless Space Survey of a 20° Circumferential Sector - Nozzle Efficiency, Test No. 19, Moveable Shroud, 81.1 Percent Area

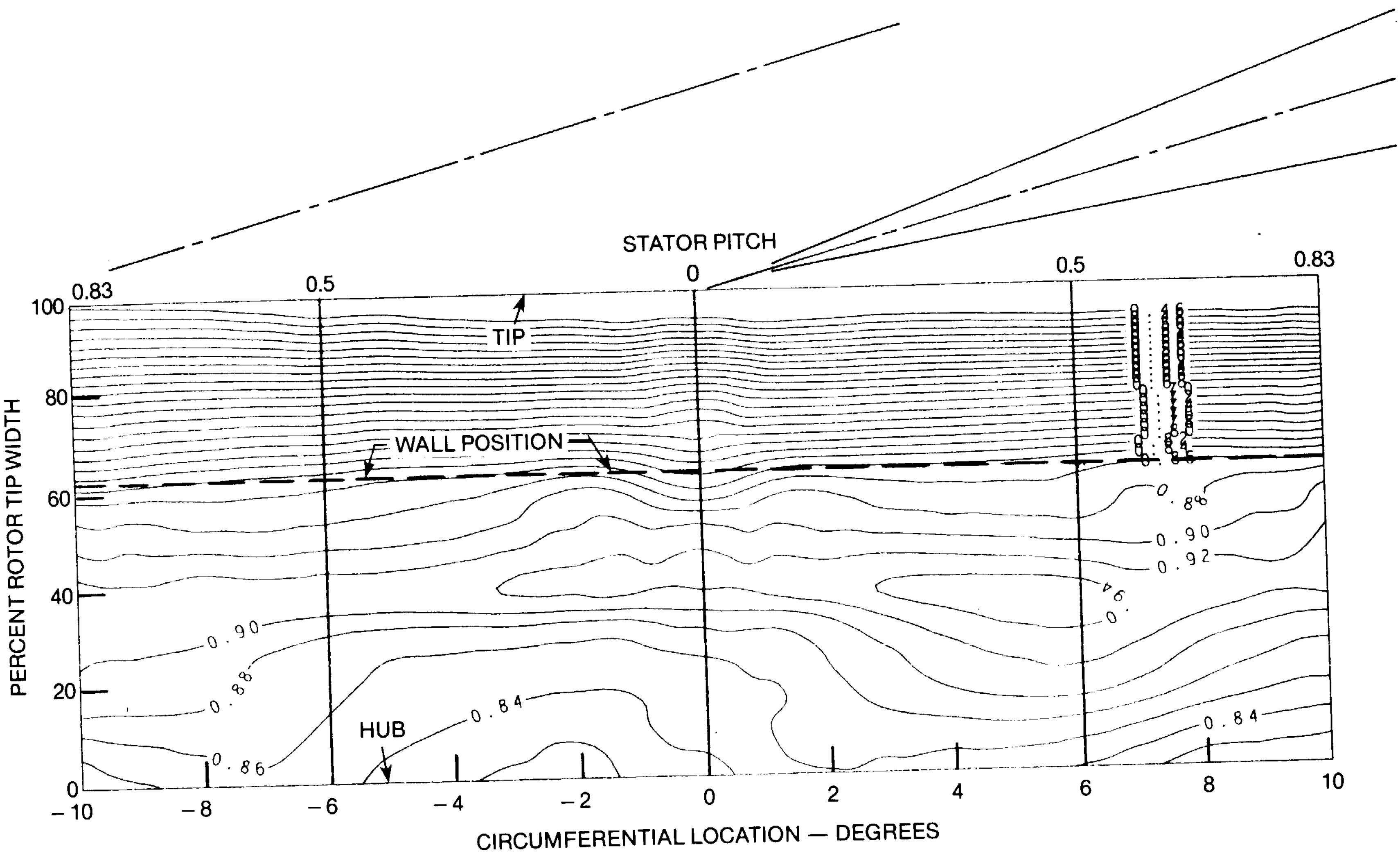

Figure D-15 Vaneless Space Survey of a 20° Circumferential Sector - Nozzle Efficiency, Test No. 29, Moveable Shroud, 62.2 Percent Area

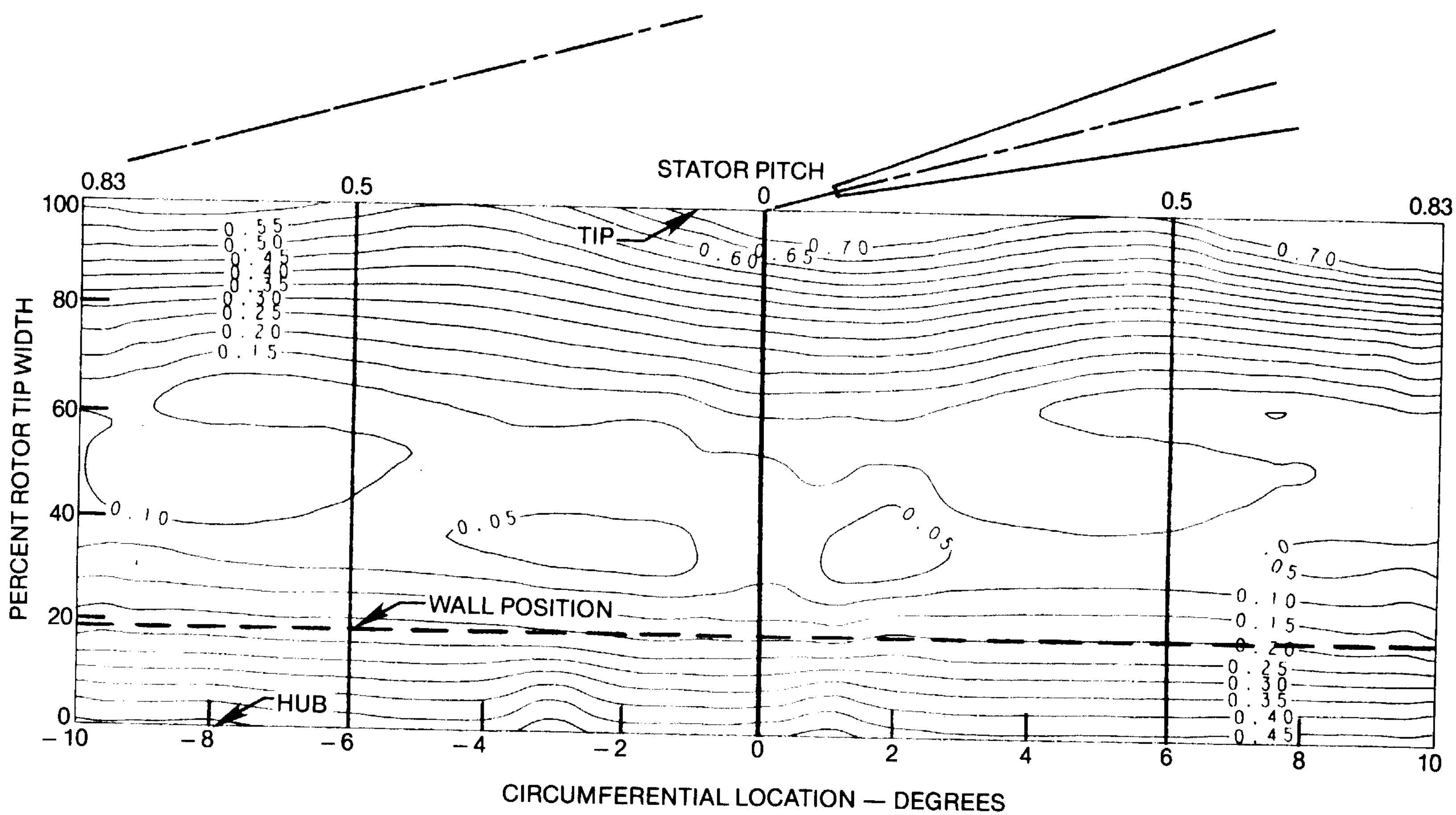

Figure D-16 Vaneless Space Survey of a 20° Circumferential Sector - Pressure Loss Coefficient, Test No. 7, Moveable Hub, 81.1 Percent Area

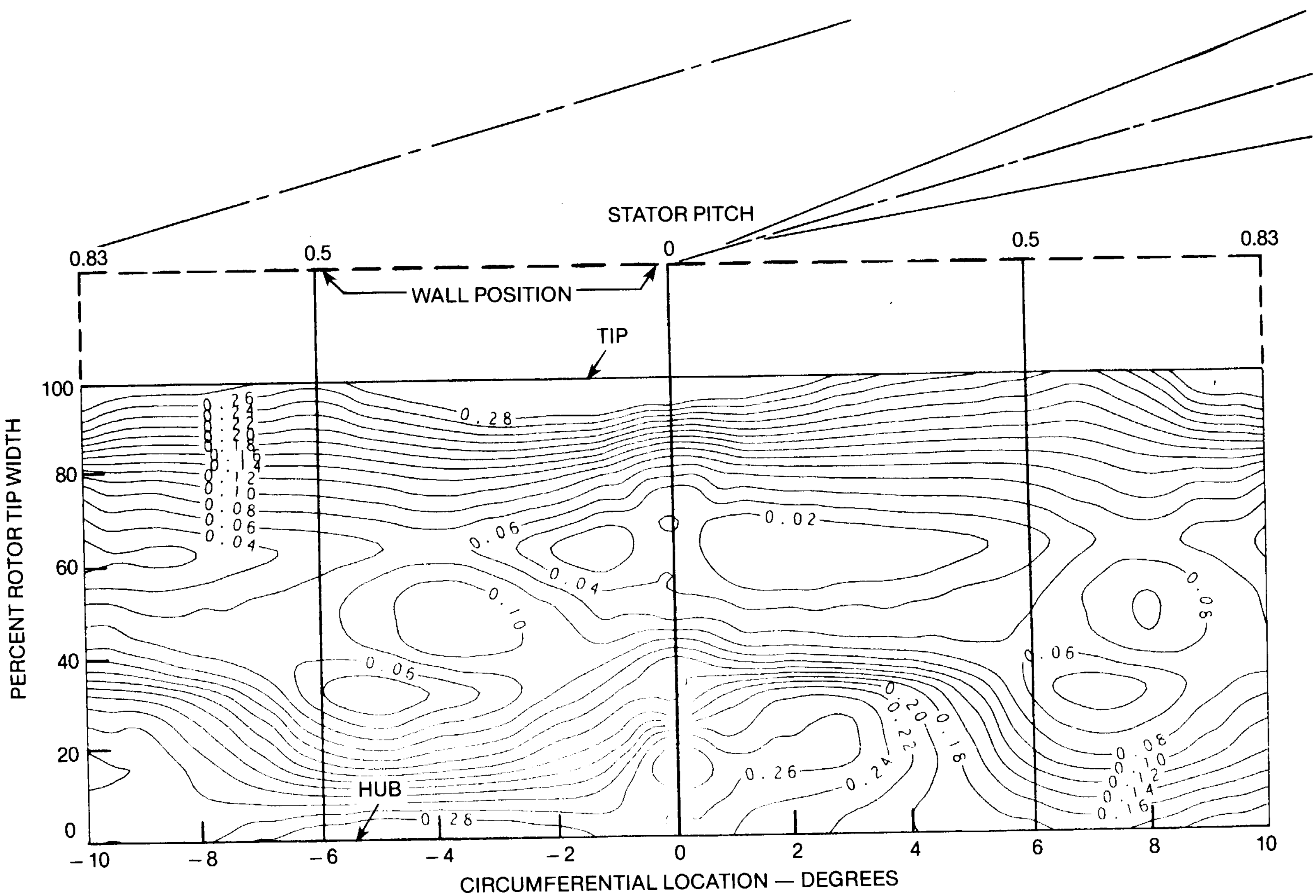

Figure D-17 Vaneless Space Survey of a 20° Circumferential Sector - Pressure Loss Coefficient, Test No. 17, Moveable Shroud, 125.0 Percent Area

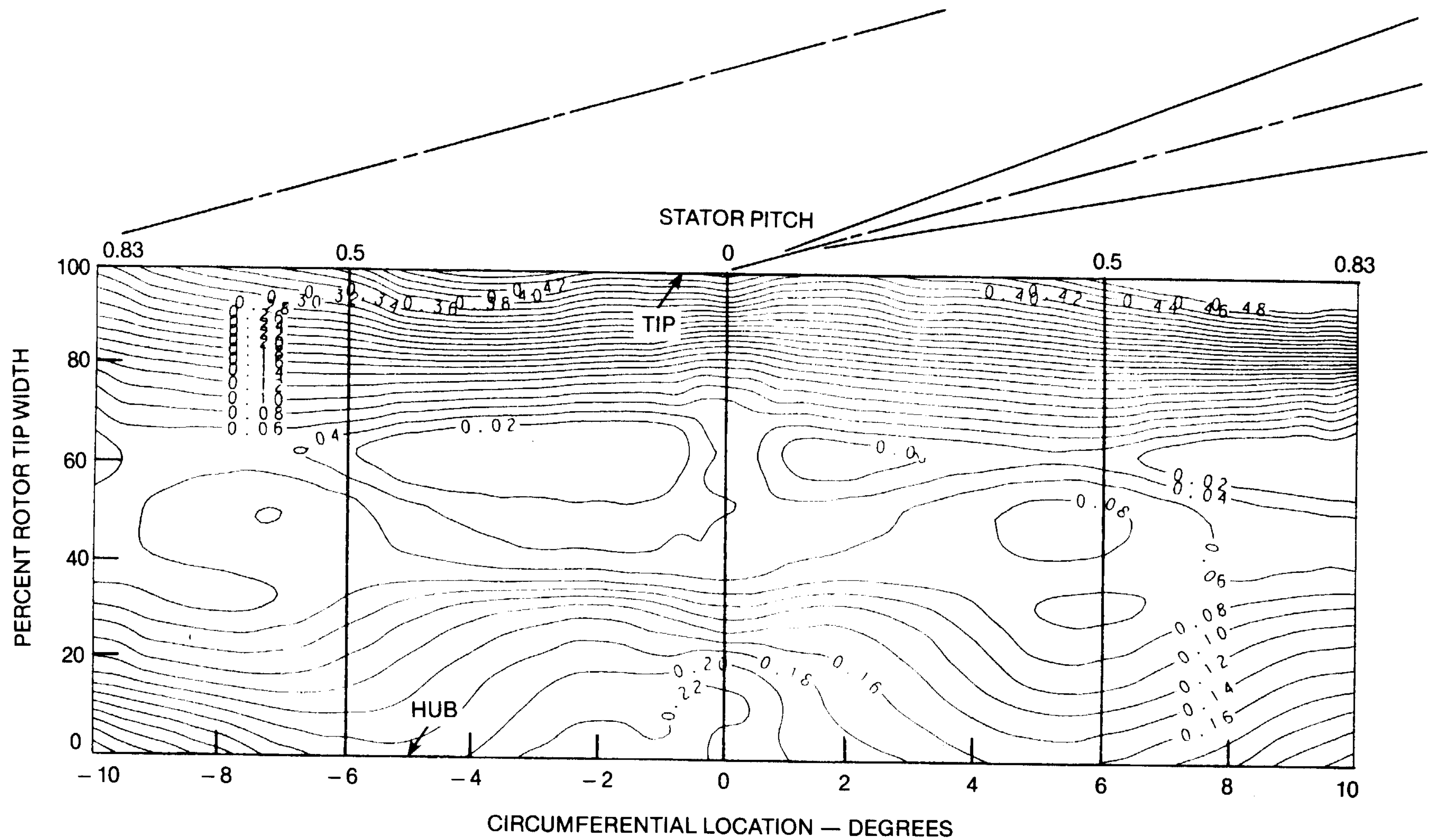

Figure D-18 Vaneless Space Survey of a 20° Circumferential Sector - Pressure Loss Coefficient, Test No. 18, Moveable Shroud, 100.0 Percent Area

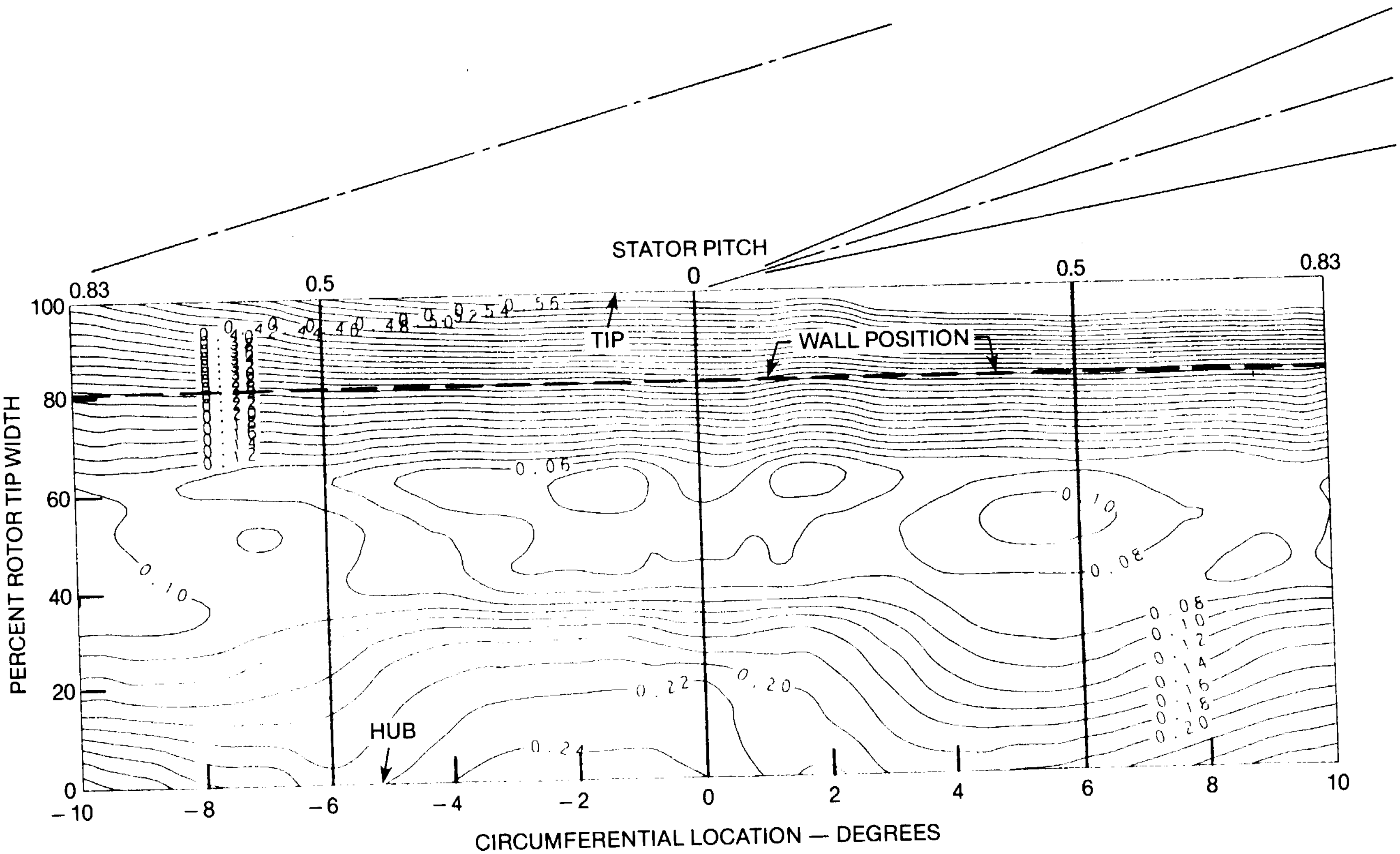

Figure D-19 Vaneless Space Survey of a 20^{o} Circumferential Sector - Pressure Loss Coefficient, Test No. 19, Moveable Shroud, 81.1 Percent Area

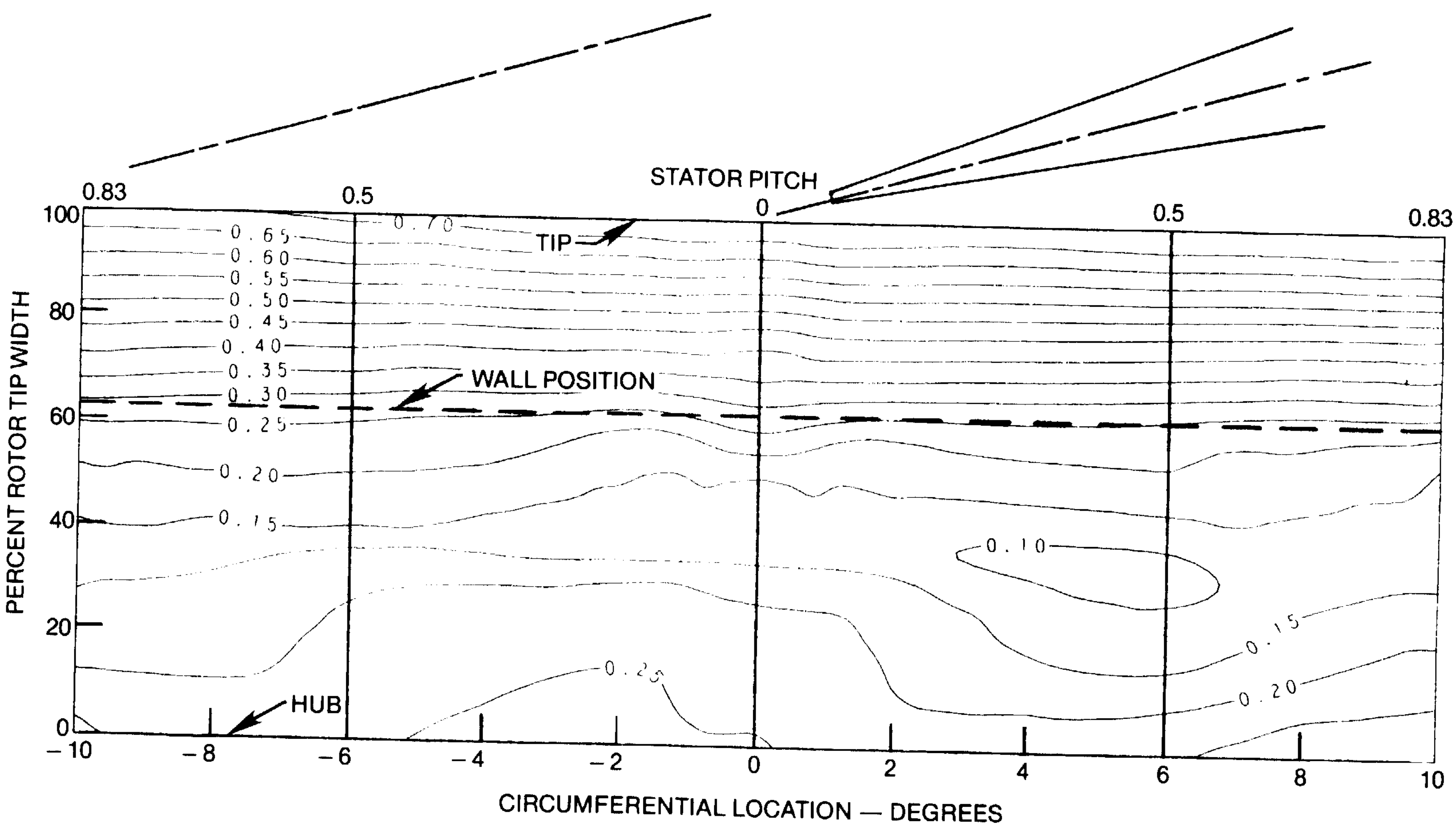

Figure D-20 Vaneless Space Survey of a 20° Circumferential Sector - Pressure Loss Coefficient, Test No. 29, Moveable Shroud, 62.2 Percent Area