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Nineteen-Foot Diameter Explosively Driven Blast Simulator

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Abstract

This report describes the 19-foot diameter blast tunnel at Sandia National Laboratories. The blast tunnel configuration consists of a 6 foot diameter by 200 foot long shock tube, a 6 foot diameter to 19 foot diameter conical expansion section that is 40 feet long, and a 19 foot diameter test section that is 65 feet long. Therefore, the total blast tunnel length is 305 feet.

The development of this 19-foot diameter blast tunnel is presented. The small scale research test results using 4 inch by 8 inch diameter and 2 foot by 6 foot diameter shock tube facilities are included.

Analytically predicted parameters are compared to experimentally measured blast tunnel parameters in this report. The blast tunnel parameters include distance, time, static, overpressure, stagnation pressure, dynamic pressure, reflected pressure, shock Mach number, flow Mach number, shock velocity, flow velocity, impulse, flow duration, etc. Shadowgraphs of the shock wave are included for the three different size blast tunnels.

Acknowledgments

Mike Kaneshige's and Vincent Loyola's efforts are greatly appreciated in reviewing the report and also for their helpful comments and recommendations. Thanks to Patricia L. Sanchez for her efforts in getting this report published in a timely manner.

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LIST OF SYMBOLS

A^*	Area where M = 1
A_1	Nozzle inlet area – ft^2
A_2	Nozzle exit area – ft^2
a_i	Sonic velocity in state i (Figure 1) – ft/sec
C_1	Contact surface generated before the divergent section
C_3	Contact surface generated in the divergent section
I	Static impulse – (psi-sec)
M_i	Flow Mach number in state I
M_3	Flow Mach number in state 3
M^*	Primary transmitted shock Mach number = (W_3/ a_0)
M_{si}	Shock Mach number in state I
M_{2s}	Secondary shock Mach number (Figure 1)
P_e	Nozzle exit static pressure (P_3) – psia
P_0	Initial test gas pressure – psia
P_i	Static pressure in state I
P_{ti}	Stagnation (total) pressure in state i – psia
S_2	Secondary upstream-facing, nozzle-generated shock wave
S_3	Primary transmitted shock wave after the nozzle
t	Positive flow duration – sec
T_i	Static temperature in state i - °R
T_{ti}	Stagnation temperature in state i - °R
u_i	Flow or particle velocity in state i – ft/sec
V_s	Shock velocity – fps
V_i	Nozzle inlet primary shock velocity (W_1) – ft/sec
V_e	Nozzle exit primary shock velocity (W_3) – ft/sec
W	Explosive driver charge weight (pounds)
W_2	Secondary upstream-facing, nozzle-generated shock-wave velocity – ft/sec
W_3	Primary transmitted shock-wave velocity after the nozzle – ft/sec
ρ_i	Density in state i – lbs/ft^3
γ	Ratio of specific heats
'(Prime)	Denotes state (3') between the secondary shock waves S_2 and the contact surface C_3
ΔP	Static overpressure – psig

Nineteen-Foot Diameter Explosively Driven Blast Simulator

1.0 Introduction

This report describes the development of a 19-foot-diameter test section for Sandia National Laboratories' (SNL) explosively driven 6-foot-diameter by 200-foot-long shock tube or blast simulator.

SNL has been involved in evaluating the ability of nuclear weapons components and systems to withstand blast-loading environments for a long time. The 6-foot diameter by 200-foot long blast tube has been used to blast test Re-entry Vehicle (RV) type weapons by simulating the blast environment encountered when the RV flies through the blast environment generated by the detonation of another RV in the vicinity.

Current interest in the blast testing of the W76-1/MK-4 system has required that available explosively driven shock tube facilities be evaluated to conduct this program. Sandia National Laboratories (SNL) explosively driven shock tube facilities were last used on the W88/MK-5 blast program in about 1986. Therefore, SNL must make a decision whether to re-start or refurbish the shock tube facilities here or to conduct the W76-1/MK-4 blast program at an outside facility if a qualified site is found. As part of the evaluation of shock tube facilities and to help in the decision making, this report is one of several documenting SNL shock tube facilities and their performance parameters.

A number of explosively driven blast simulators of up to 6 feet in diameter have been used [1-4]. A requirement to blast test the Sprint Anti-Ballistic Missile second stage, which was 16 feet long, led to the development of a 19-foot-diameter blast simulator. The 19-foot diameter was believed to be sufficient to blast test the Sprint missile at a 70 degree angle of attack relative to the blast tunnel axis. At the time, a totally new blast simulator with a constant diameter of 19 feet was not economically acceptable. Also, operational costs associated with such simulator would be much greater. Therefore, a research study was started to investigate the possibility of expanding the blast wave from the existing 6- foot simulator into a 19–foot–diameter test section.

A number of requirements had to be established to demonstrate feasibility prior to construction. Most important was generation of sufficient static overpressure input to the expansion or divergent section to provide the test levels required in the 19–foot–diameter test section. Further consideration had to be given to the effects of expansion upon the shock/blast front and the pressure profile of the blast wave in the test section.

The 6–foot simulator is a steel tube or tunnel 200 feet long as shown in the figures in Appendix G. The first 50 feet of this simulator is the driver section having a 3–inch thick wall. It is capable of containing the energy of up to 370 pounds of PETN primacord at a maximum explosive loading density of 7.4 pounds per foot. Primacord strands which are evenly distributed over the driver cross section (Figure G2 in Appendix G), parallel to the driver axis, providing a planar detonation front driving into the test gas in the remaining portion (150 feet)

of the simulator. The driver end of the simulator is closed with an 18-inch thick, plywood, cylindrical, blowout plug which is backed by a concrete tamping mass (30,000 pounds) that takes the resultant reaction. The plywood plug thickness and tamping mass are selected to prevent driver end pre-mature venting until test conditions have been produced at the test section.

A wide range of conditions have been achieved in this simulator using various explosive charge weights, initial test gas pressures, and test gases.[2] Maximum blast parameters achieved at the 200–foot test station using air as the test gas are:

Shock velocity*:	8850 ft/sec
Flow Mach number*:	1.79
Static pressure**:	200psia
Stagnation pressure**:	590 psia

* - Initial test gas pressure: 0.5 psia
** - Initial test gas pressure: 12.1 psia (ambient)

The effects of the divergent section upon the blast wave are discussed. An expression was derived to predict the outlet shock parameters for various area ratios across the divergent section. An experimental program was conducted in smaller shock tubes to verify the design prior to constructing the full-scale facility. Pressure-time data and shock time–of–arrival data were measured to obtain the experimental blast wave parameters. Shock– front shadowgraphs were obtained to verify shock front planarity.

2.0 Primary Shock – Wave Diffraction and Flow Processes Through a Divergent Cross-Section

It has been theorized and verified experimentally that when the inlet condition to a divergent cross section is such that the flow behind the primary shock wave (S_1) is supersonic, a secondary, rearward-facing shock wave (S_2) is generated [5-10]. Supersonic flow conditions exist when the shock Mach number is greater than 2.068 in air. Figure 1 shows the resultant wave system after passing through the divergent section.

As the primary shock enters the divergent section, it is decelerated due to the decrease in energy density behind it as a result of the increasing volume. However, the fluid particles, which were set into motion by the primary shock before it reached the divergent section, are accelerated by expansion waves as they flow into the divergent section. Therefore, a secondary shock of finite amplitude is generated between this accelerated flow region and the decelerated region behind the primary shock. The pressure discontinuity across this secondary shock is such that this shock tends to propagate into the flow; however, it is swept out of the divergent section when the flow velocity in region (2) is greater than the secondary shock velocity. It is possible for this shock to grow sufficient in strength to remain standing in the divergent section. The test conditions considered in this report were such that the secondary shock was always swept through the divergent section. This secondary shock tends to attenuate much faster than the primary shock and, at some point beyond the divergent section, the blast wave again has an exponential decay.

In addition to creating a secondary shock, the divergent section may also cause a temporary curvature in the primary shock front. The point at which the secondary shock and the curvature in the primary shock are no longer a factor was established experimentally and will be discussed later.

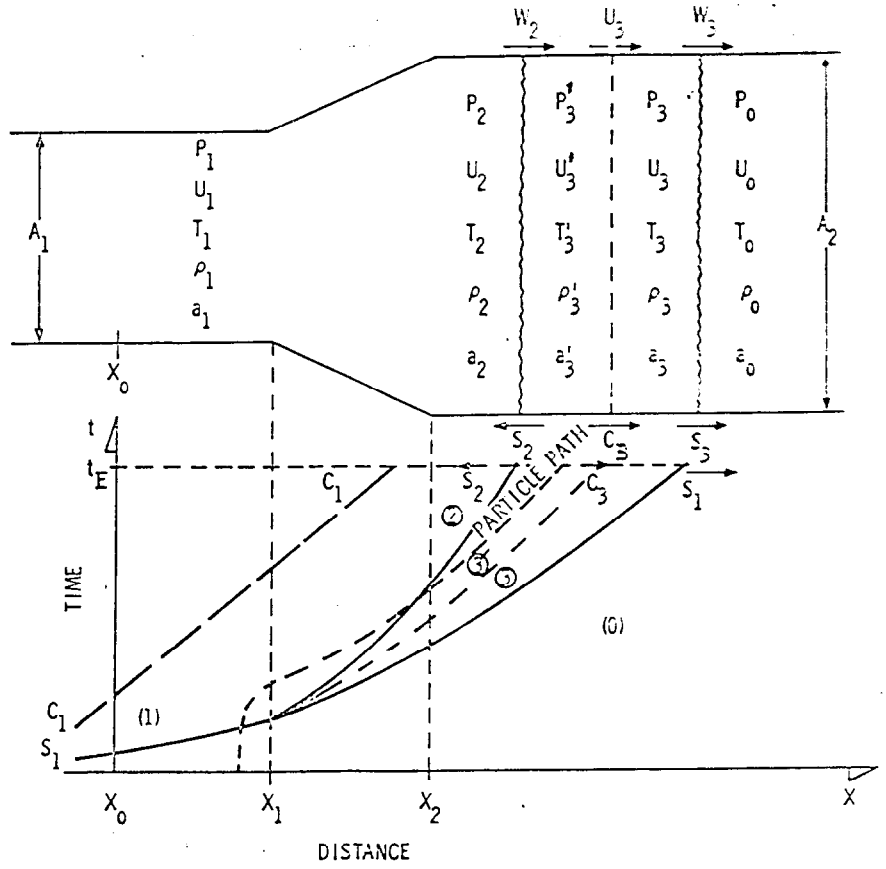


Figure 1. Shock Wave System in a Shock Tube with a Divergent Cross-Section

The x-t diagram in Figure 1 depicts the passage of a shock wave system through a divergent section showing the development of the secondary shock. The sketch at the top of Figure 1 shows the five states that exist at some time, t_E , when the system has propagated beyond the divergent section.

State 0 is the initial test gas conditions. State 1 is the condition behind the primary shock and prior to entry into the divergent section. State 3 is the condition behind the primary shock in the gas that was originally downstream of the divergent section inlet. State 3' is the condition of the gas that was originally in the smaller diameter section and has been accelerated by the divergent section and then passed through the secondary shock, S_2. The contact surface C_3 separates States 3 and 3' since there is a difference in temperature or entropy in these two regions as illustrated by Figure 2.

Figure 2 also indicates the variations in several other blast wave parameters along a shock tube with divergent cross section, and illustrates the fact that the static pressure and flow velocity in States 3 and 3' are the same. State 2 is the condition of the accelerated region between the divergent section inlet and the secondary shock.

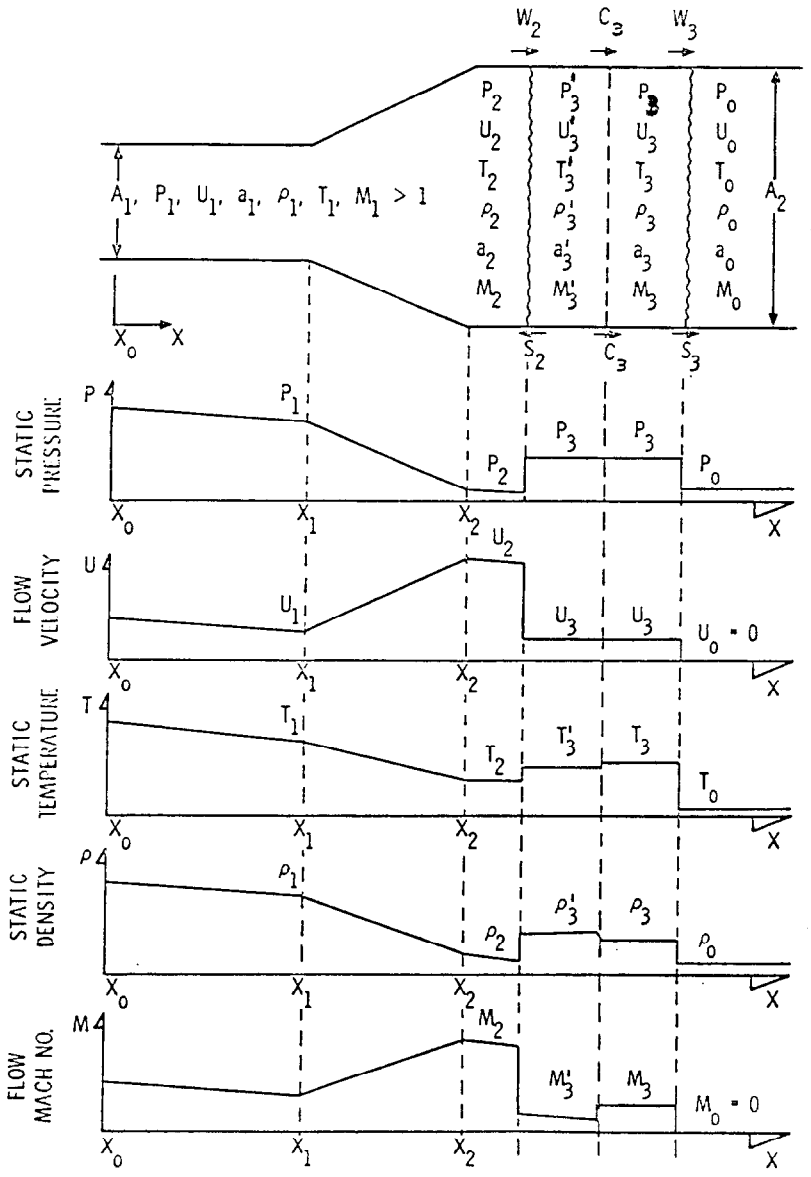


Figure 2. Blast Wave Parameters Along a Shock Tube with a Divergent Cross-Section

3.0 Calculation of Blast Parameters Across a Divergent Section

Shock time– of – arrival (used to calculate shock velocity or Mach number) and pressures are the easiest blast parameters to measure. Therefore, it was desirable to obtain an expression for the test-section shock velocity or Mach number as a function of the divergent section inlet blast parameters, specific heat ratio (γ), and area ratio. The test – section shock velocity (controls Sprint engulfment time) and pressures (control aerodynamic loading) are the most important blast parameters in simulating portions of an actual Sprint blast encounter in the blast tunnel. The equations were not derived for any specific test gas and are in terms of an arbitrary γ which was assumed constant for a given test gas. Using the steady isentropic expansion equations and the

Rankine-Hugoniot relations across the shock waves, the desired expression for the primary transmitted shock Mach number is derived in Appendix A and the solution by the Newton iteration method [12,16] is shown below. Shock Mach number was chosen rather than shock velocity in order to work with a non-dimensionalized blast parameter which is independent of test gas temperature.

$$M^*_{n+1} = M^*_n - \frac{(1-A)^2 - A\left[B - \left(\frac{\gamma+1}{2}\right)M_2\right]^2}{\frac{-4M^*P_0(1-A)}{P_2} - \frac{2M^*P_0}{P_2}\left[B - \frac{\gamma+1}{2}M_2\right]^2 - \frac{2a_0}{a_2}\left(1+\frac{1}{M^{*2}}\right)A\left[B - \frac{\gamma+1}{2}M_2\right]} \quad (1)$$

where

$$M^* = \frac{W_3}{a_0}$$

$$A = \frac{\gamma-1}{2\gamma}\frac{P_0}{P_2}\left(\frac{2\gamma}{\gamma-1}M^{*2} + \frac{P_2}{P_0} - 1\right) \quad (2)$$

$$B = \frac{a_0}{a_2}\left(M^* - \frac{1}{M^*}\right) \quad (3)$$

$$P_2 = P_0\left[\frac{2\gamma}{\gamma+1}M_{s1}^2 - \frac{\gamma-1}{\gamma+1}\right]\left[\frac{(\gamma-1)M_1^2+2}{(\gamma-1)M_2^2+2}\right]^{\frac{\gamma}{\gamma-1}} \quad (4)$$

$$a_2 = \frac{2a_0}{(\gamma+1)M_{s1}}\left\{\left[\gamma M_{s1}^2 - \frac{\gamma-1}{2}\right]\left[\frac{\gamma-1}{2}M_{s1}^2 + 1\right]\left[\frac{(\gamma-1)M_1^2+2}{(\gamma-1)M_2^2+2}\right]\right\}^{1/2} \quad (5)$$

M_2 is given by equation (A-6) in Appendix A. Once the solution of Equation (1) for M* is obtained, the equations of the complete wave system parameters of the nozzle can be solved. Appendix B shows the equations necessary for the complete system parameters.

A Fortran computer program called "DIVNOZ" was written for the equations of Appendices A and B and the DIVNOZ code is included in Appendix C. Appendix D includes tables generated by DIVNOZ which list blast parameters across a divergent nozzle for a specific heat ratio (γ) of 1.4 and area ratios between 1.0 and 15.

Figure 3 shows the variation of the shock parameters for an isentropic expansion of a shock wave through a divergent section. This figure is for a nozzle inlet shock Mach number (M_{s1}) of 3.6. In Figure 3, the curve labeled M* is the shock Mach number of the primary incident shock after it is transmitted through the divergent section or nozzle. The equations in Appendices A and B were used to obtain the curves in Figure 3. Figure 3 was useful in determining whether desired test-section conditions were possible, given the inlet conditions and the area ratio. This figure

illustrates the fact that, as the area ratio increases, the shock strength, P_3/P_2, of the secondary shock wave, S_2, increases. The curves of interest for this study were those for P_3/P_0 and M^*, since they concern the primary transmitted shock, S_1.

Figure 3 also suggests that the optimum condition would be to obtain the desired enlarged test section while minimizing the area ratio across the divergent section. The reasoning here is that the energy density driving the primary shock wave into the divergent section is reduced as the shock wave propagates into an increasing volume. The aerodynamic structure to be tested is long and slender, suggesting that an elliptical test section would meet both the minimum area ratio and size requirements. However, the expensive, complex techniques for constructing a test section with an elliptical cross– sectional area are undesirable. Therefore, it was decided to investigate cylindrical and rectangular test sections.

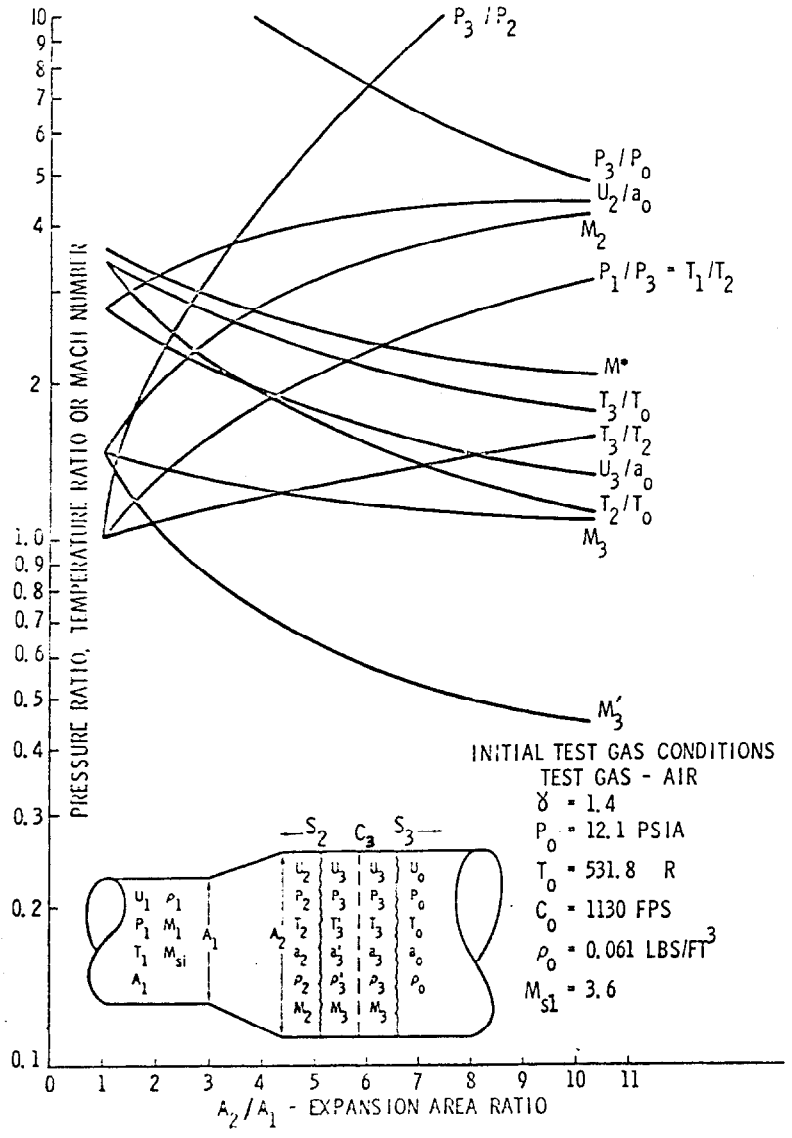


Figure 3. Isentropic Expansion of a Blast Wave in a Divergent Shock Tube

4.0 Blast Facilities

The 4–inch–diameter by 15–foot–long and the 2-foot diameter by 200–foot–long shock tube facilities were modified so that this preliminary study could be performed. Shock tube measurements in all tests included static and stagnation pressures throughout the shock tunnel, shock velocity measurements, and shock photograph (shadowgraphs) at two locations after the divergent section (nozzle).

4.1 4–Inch Shock Tube Studies

The 4–Inch–diameter shock tube shown in Figure 4 was modified by the addition of a nozzle and test section for these studies. Concentrated Composition C-4, explosive charges were used to generate the blast parameters entering the nozzle expansion. The nozzles (divergent sections) considered here were 16 inches long, which results in an expansion angle of 7.23 degrees.

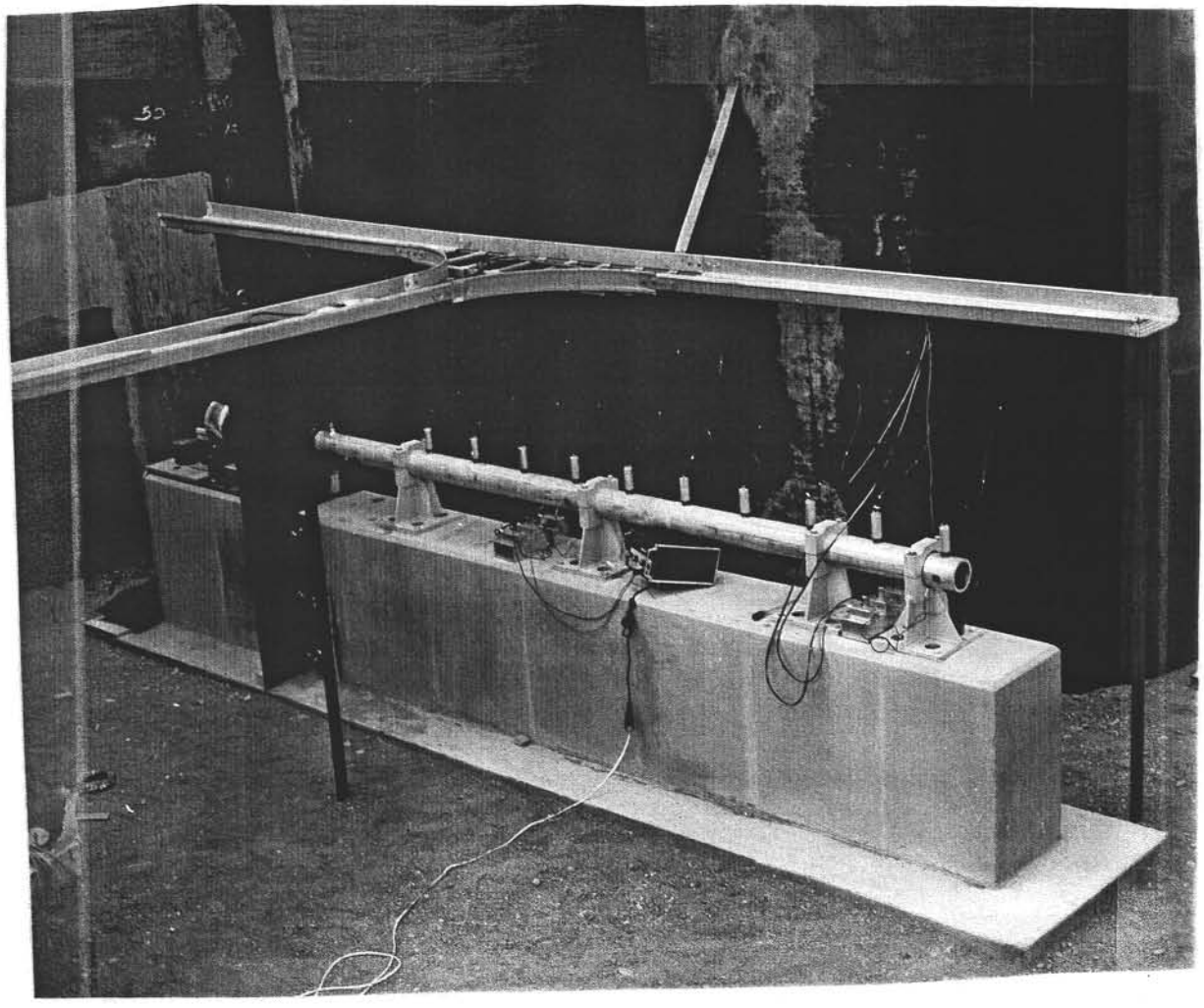


Figure 4. Four Inch Diameter by 15 Foot Long Explosively driven Shock Tube

4.1.1 Conical Nozzle Expansion

The test configuration used for this portion of the study is shown in Figure 5, and the range of the test parameters covered in the test series is presented in Table 1. The two test gasses considered in this portion of the study were air and helium. The nozzle exit to nozzle inlet area was 4 for this test configuration.

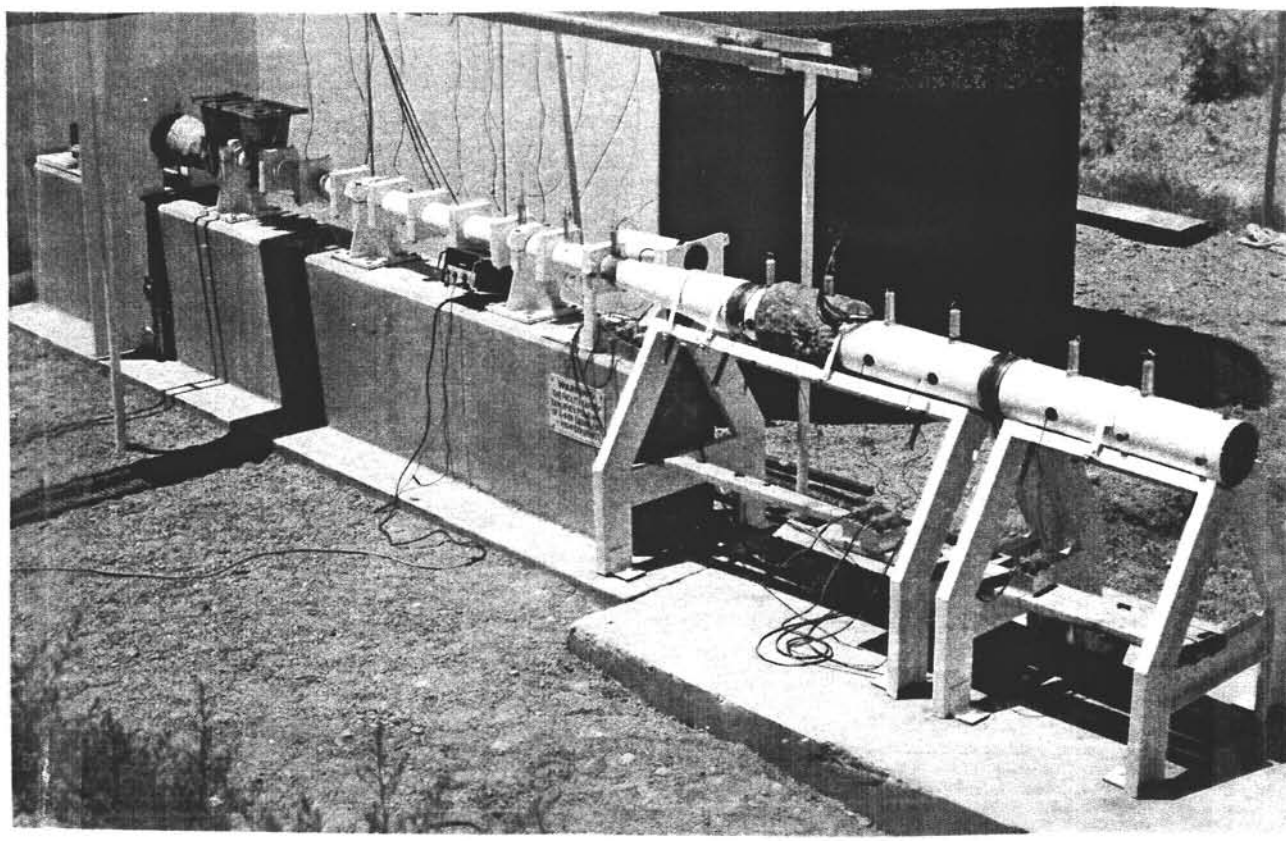


Figure 5. Shock Tube Test Configuration for the Conical Nozzle

Results for the Conical Nozzle Expansion – Figure 6 shows a shadowgraph of the shock wave taken at the nozzle exit. The test gas was air at 12.1 psia (ambient), and the shock velocity at the nozzle exit was 3100 feet per second. The shock wave is planar and is typically of all shadowgraphs taken at this location for the test series of Table 1.

Table 1. Range of Test Parameters for Conicial Expansion Test Series

Test Gas	Initial Test Gas Pressure (psia)	Explosive Weight (PETN) (lbs)	Nozzle Inlet Shock Velocity (fps)	Nozzle Exit Shock Velocity (fps)	Nozzle Inlet Static Pressure (psia)	Nozzle Exit Static Pressure (psia)
Air	$1<=P_0<=12.1$	$0.02<=W<=0.16$	$2000<=V_i<=11000$	$1500<=V_e<=9100$	$50<=P_I<=475$	$25<=P_e<=225$
Helium	$1<=P_0<=12.1$	$0.04<=W<=0.08$	$8500<=V_i<=15500$	$7000<=V_e<=12000$	$30<=P_I<=190$	$15<=P_e<=80$

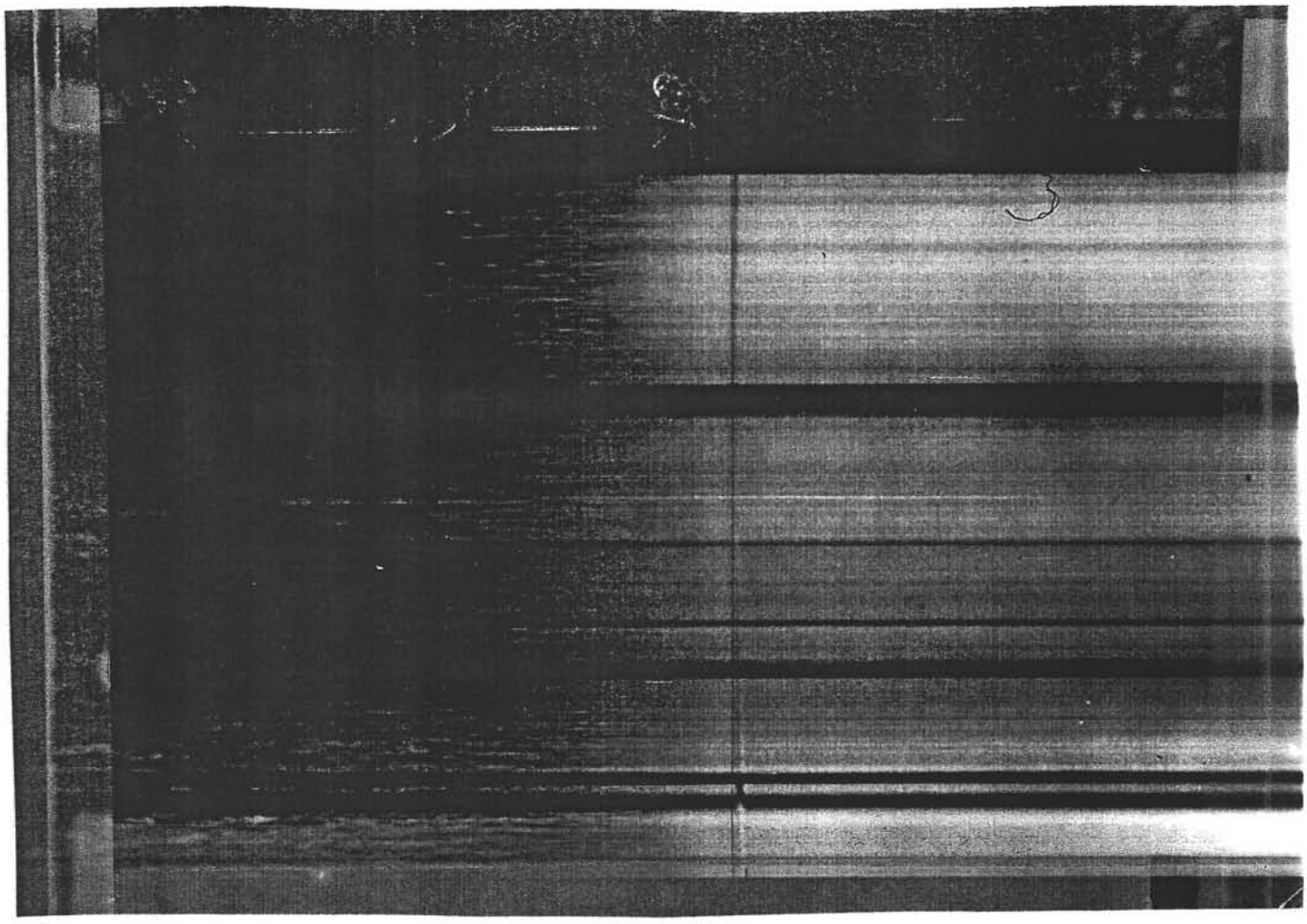


Figure 6. Shadowgraph of the Shock Wave at the Conical Nozzle Exit

It was convenient to display the nozzle inlet and exit data in terms of Mach numbers and shock strength since these dimensionless parameters are easily obtained from the measured velocity and pressure data.

Figure 7 shows the nozzle exit shock Mach number, M*, as a function of the nozzle inlet shock Mach number , M_{SI}, for both helium and air at various initial test gas pressures in the range $1.0 \leq P_0 \leq 12.1$ psia. The experimental measurements shown on this figure are in good agreement with the theoretical values calculated from ideal gas theory for an isentropic expansion through the nozzle, Equation (1). This figure also indicates that, for a conical nozzle with an area ratio of 4, the exit shock Mach number is 75 percent of the inlet shock Mach number.

Figure 8 shows the nozzle inlet shock strength, P_1/P_0, required for the nozzle exit shock strength, P_3/P_0. Here again, the experimentally measured data are in fair agreement with the ideal gas theory calculations. This figure indicates that the nozzle exit shock strength is about 50 percent of the nozzle inlet shock strength for an area ratio of 4.

4.1.2 Cylindrical to Rectangular Nozzle Expansion

Figures 3 and 9 show the effects of reducing the area across an expansion section. The Rankine–Hugoniot equations for the primary incident shock wave and for the upstream facing, nozzle–generated shock waves were used to determine the nozzle exit conditions for various area ratios in Figure 9.

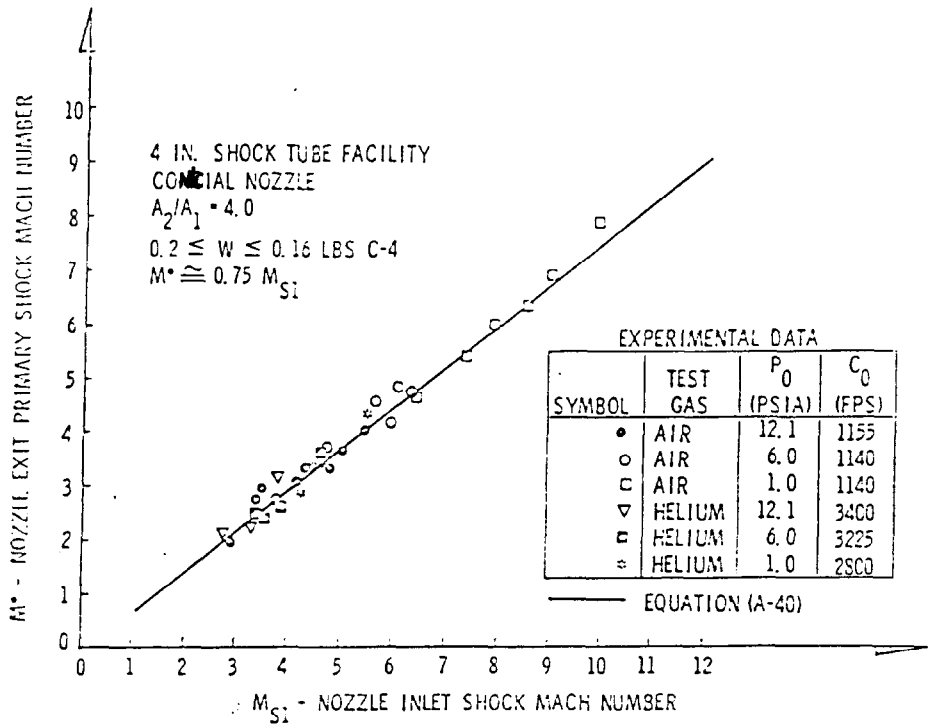


Figure 7. Nozzle Exit Primary Shock Mach Number as a Function of Nozzle Inlet Shock Mach Number

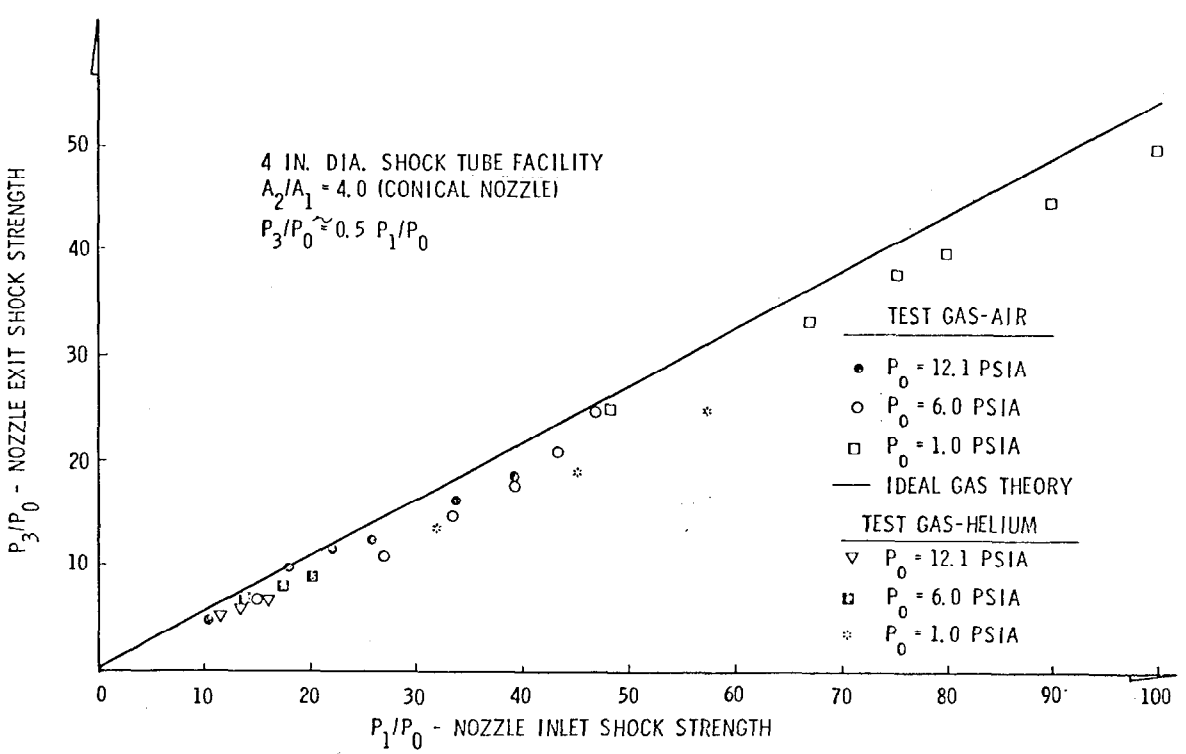


Figure 8. Nozzle Exit Shock Strength as a Function of Nozzle Inlet Shock Strength

The Figure 9 data are for an inlet shock Mach number, M_{SI}, of 4.09. This figure illustrates that the static pressure and flow velocity in states 3 and 3' increases. This is shown by the intersection of the Rankine–Hugoniot curves for the primary shock wave, S_1, and the secondary upstream–facing secondary shock wave, S_2. This figure also shows that the static pressure, P_2, indicated by a, +, decreases as the area ratio increases. The flow velocity in state 2, corresponding to P_2, increases as the static pressure decreases and the area ratio increases.

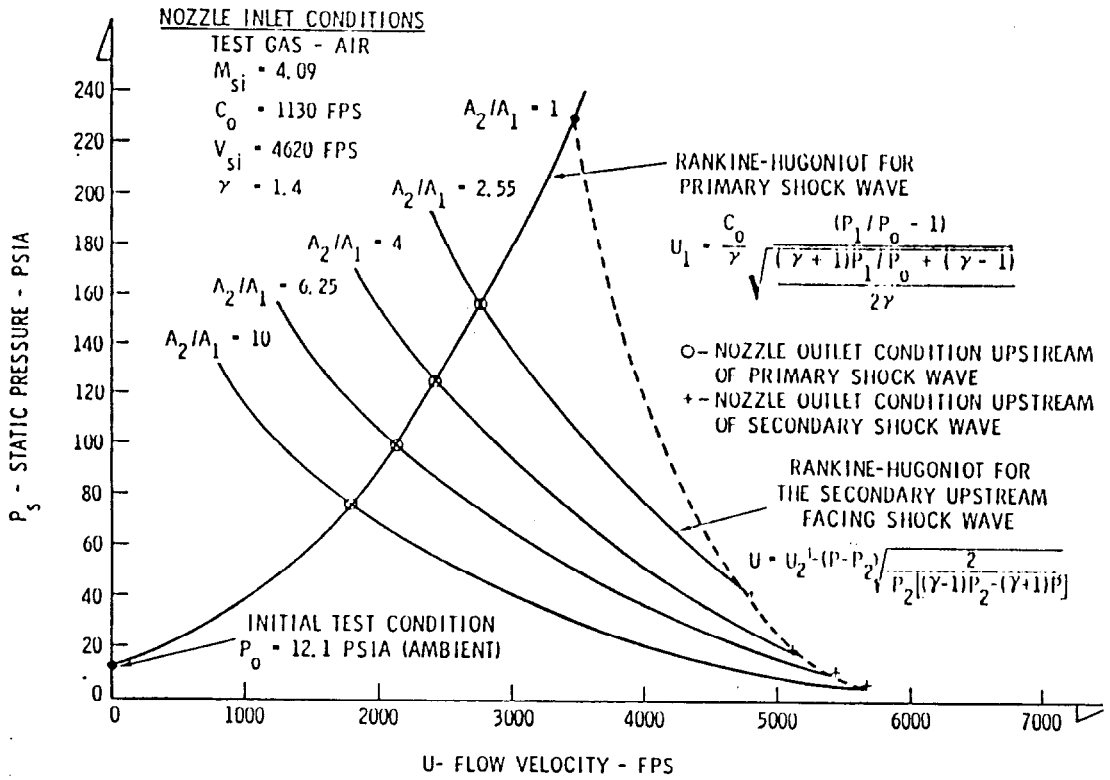


Figure 9. Rankine-Hugoniot Curves for the Primary Incident Shock Wave and Secondary Upstream-Facing Shock Wave

In an effort to study the effect of reducing the area ratio while still maintaining the magnitude of the major dimension, 8 inches, the 4–inch shock tube of Figure 4 was modified by the addition of a cylindrical to rectangular expansion transition section plus a 4–by 8–inch rectangular test section as shown in Figure 10. The area ratio across the expansion transition was 2.55 for this test configuration.

Results for the Cylindrical to Rectangular Divergent Section – Figure 11 shows the planarity of the shock wave at a distance of 8 inches after the nozzle exit. This figure displays the curvature of the shock front due to the area expansion. Figure 12 shows the shock wave of Figure 11 at a distance of 29.3 inches after the nozzle exit. This shadowgraph shows the shock wave becomes as a plane shock front at this distance.

Figure 13 shows the nozzle inlet shock Mach number, M_{SI}, required for a certain exit shock Mach number, M*, for both the conical nozzle transition and the cylindrical to rectangular

transition. The effect of reducing the area ratio is illustrated by Figure 13, and an increase in the measured exit shock Mach number is about 10 percent, due to an area ratio reduction of 4 to 2.55.

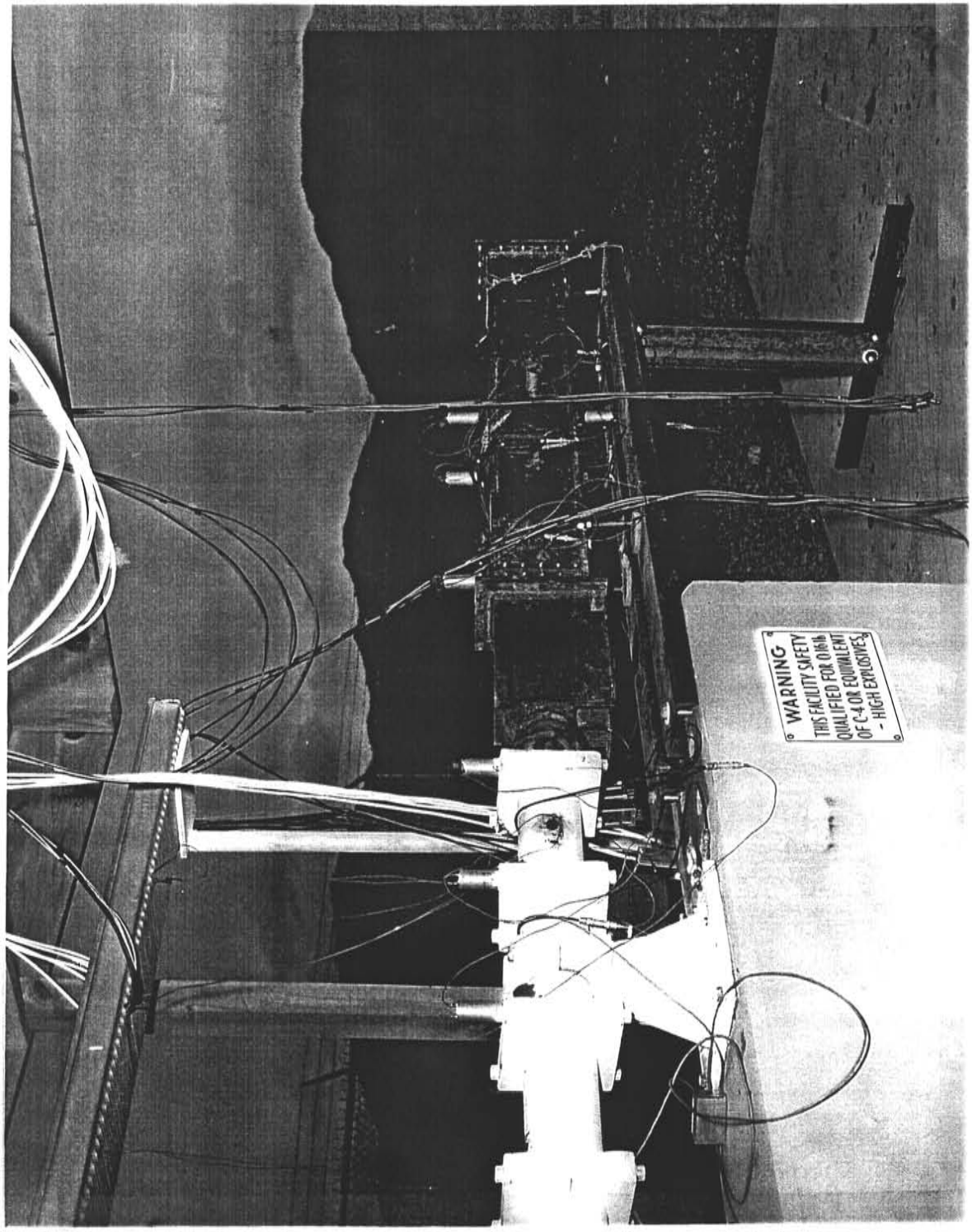


Figure 10. Shock Tube Test Configuration for the Cylindrical to Rectangular Nozzle

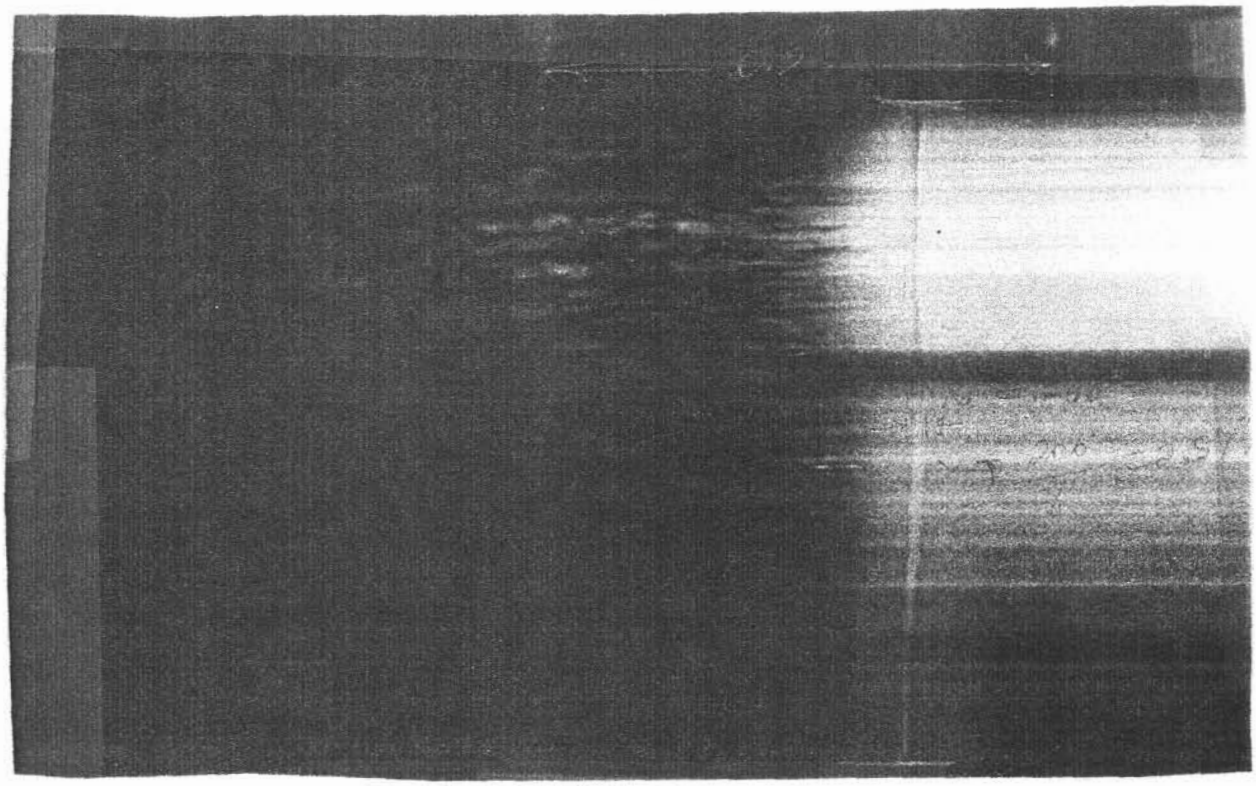


Figure 11. Shadowgraph of the Shock Wave 8" After the Nozzle Exit

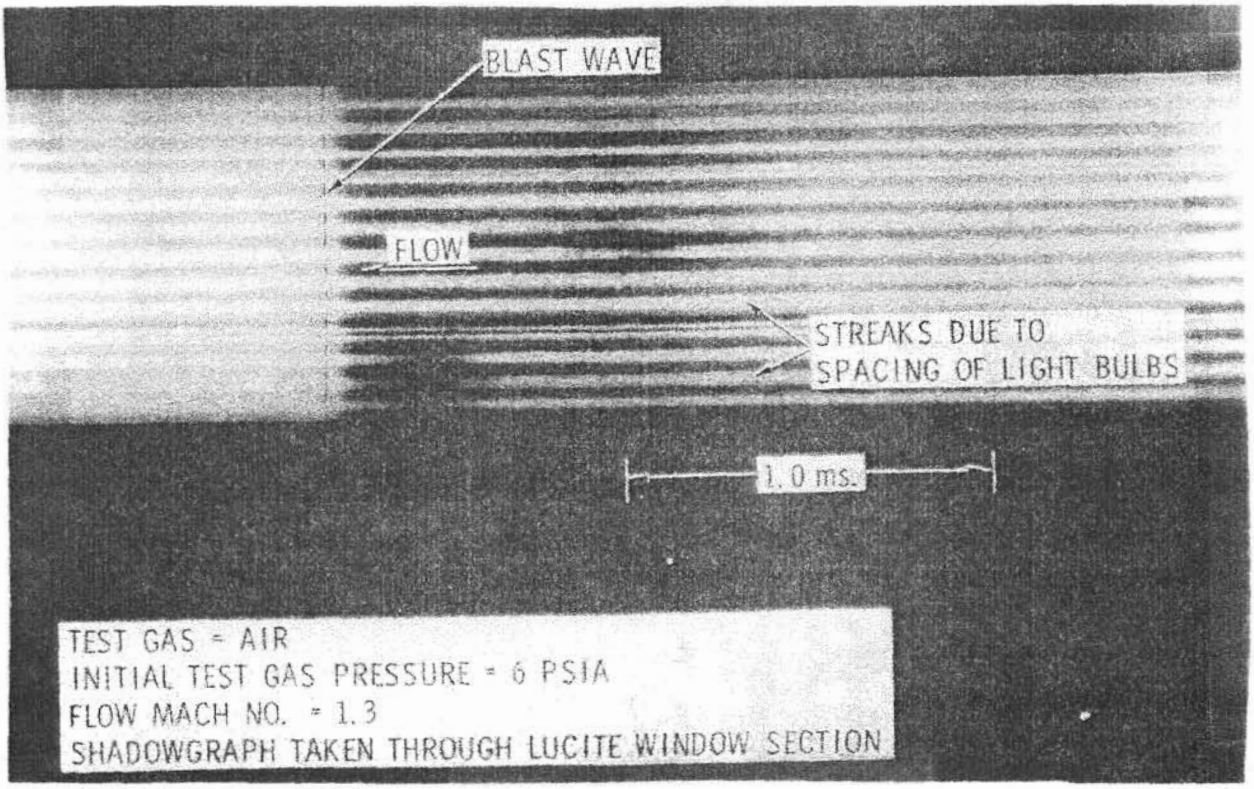


Figure 12. Shadowgraph of the Shock Wave 29.3" After Nozzle Exit

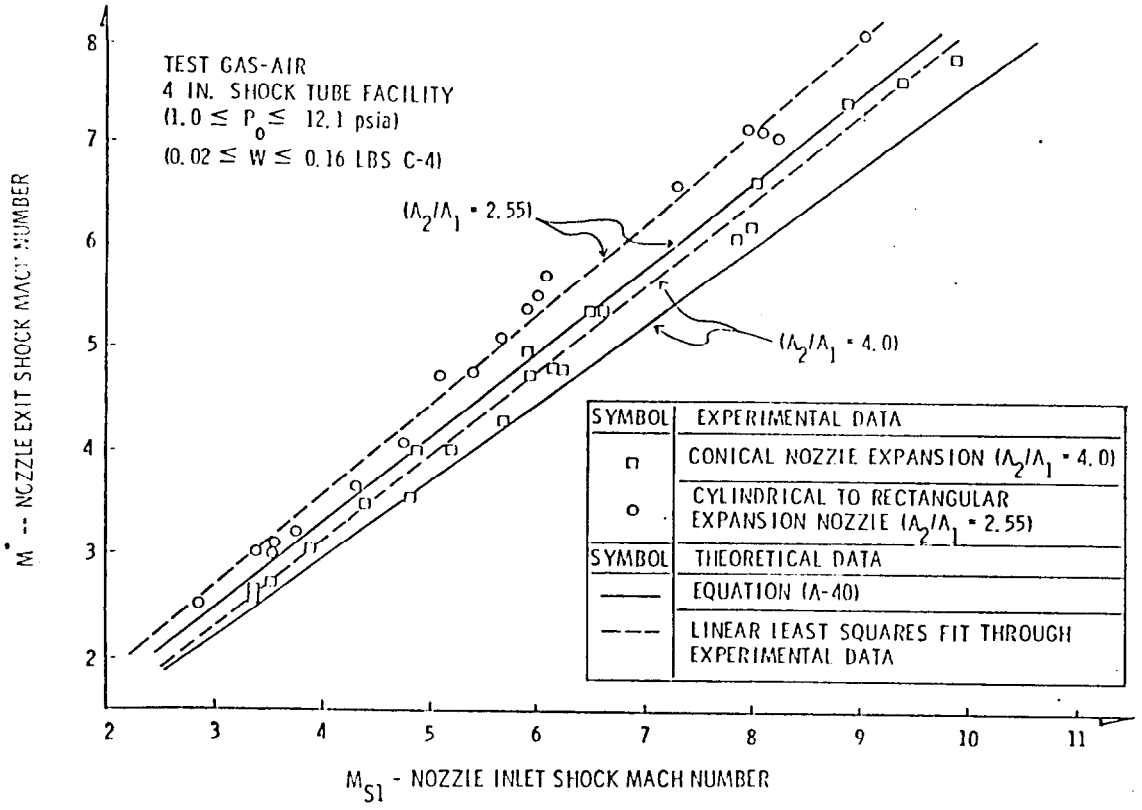


Figure 13. Nozzle Exit Primary Transmitted Shock Mach Number as a Function of Nozzle Inlet Shock Mach Number

4.1.3 Discontinuous Expansion from a Cylindrical Tube to a Rectangular Test Section

Figure 14 shows the modification made to the 4–inch shock tube facility of Figure 4 to obtain a discontinuous expansion transition. The purpose here was to investigate the planarity of the shock wave after the discontinuous expansion and to look at the possibility of eliminating the transition or expansion section. The blast – wave parameters beyond the divergent section were also of interest. The length of the 4–inch–diameter tube is 16 inches longer for the discontinuous area transition tests in order to keep the nozzle exit station the same for three configurations considered.

Results for the Discontinuous Expansion from a Cylindrical Tube to a Regular Test Section – Figure 15 shows the curvature of the shock wave due to a discontinuous expansion at 2.3 inches after the area discontinuity. Figure 16 shows this same shock wave at 17.1 inches after the area discontinuity.

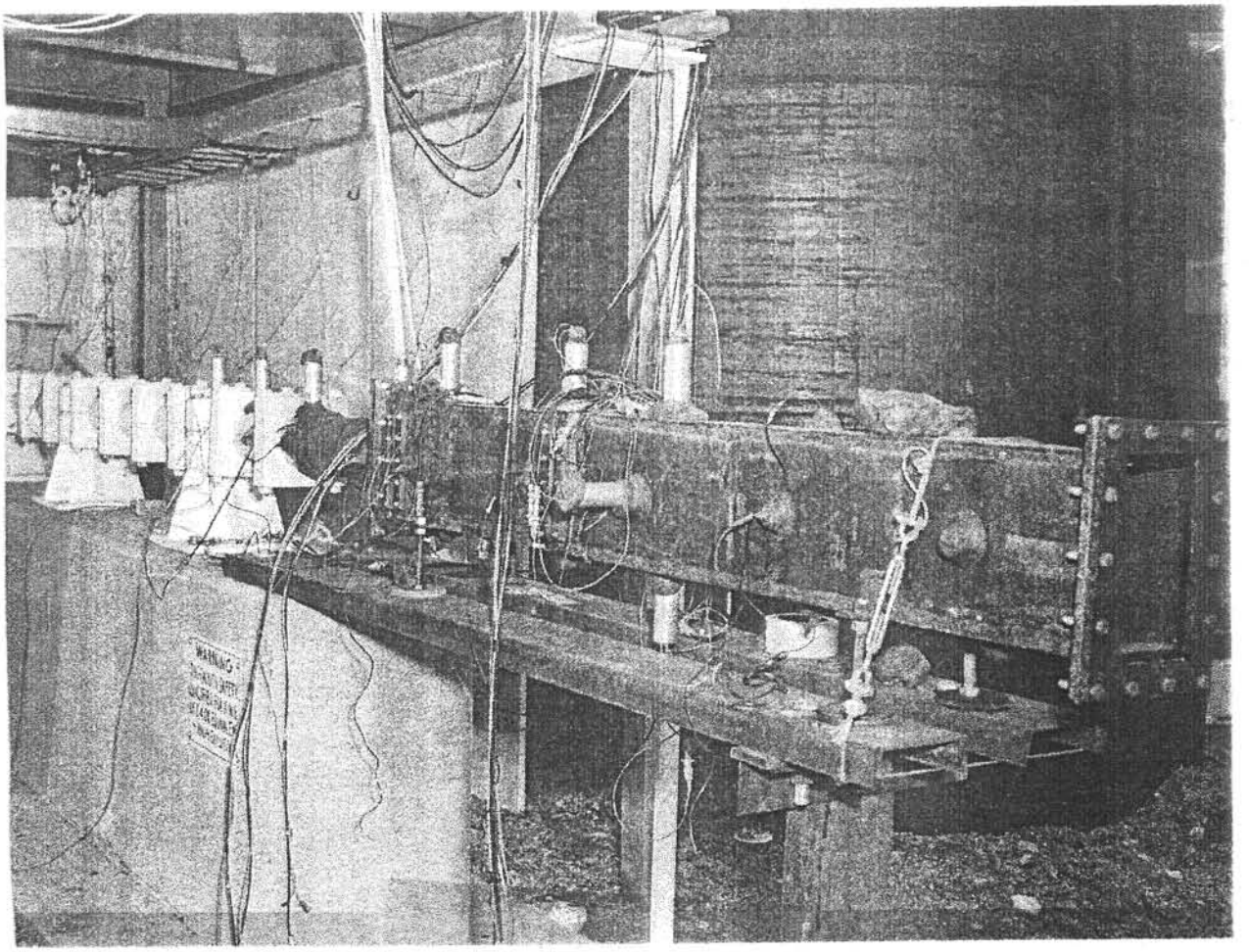


Figure 14. Shock Tube Test Configuration for the Discontinuous Area Expansion Tube

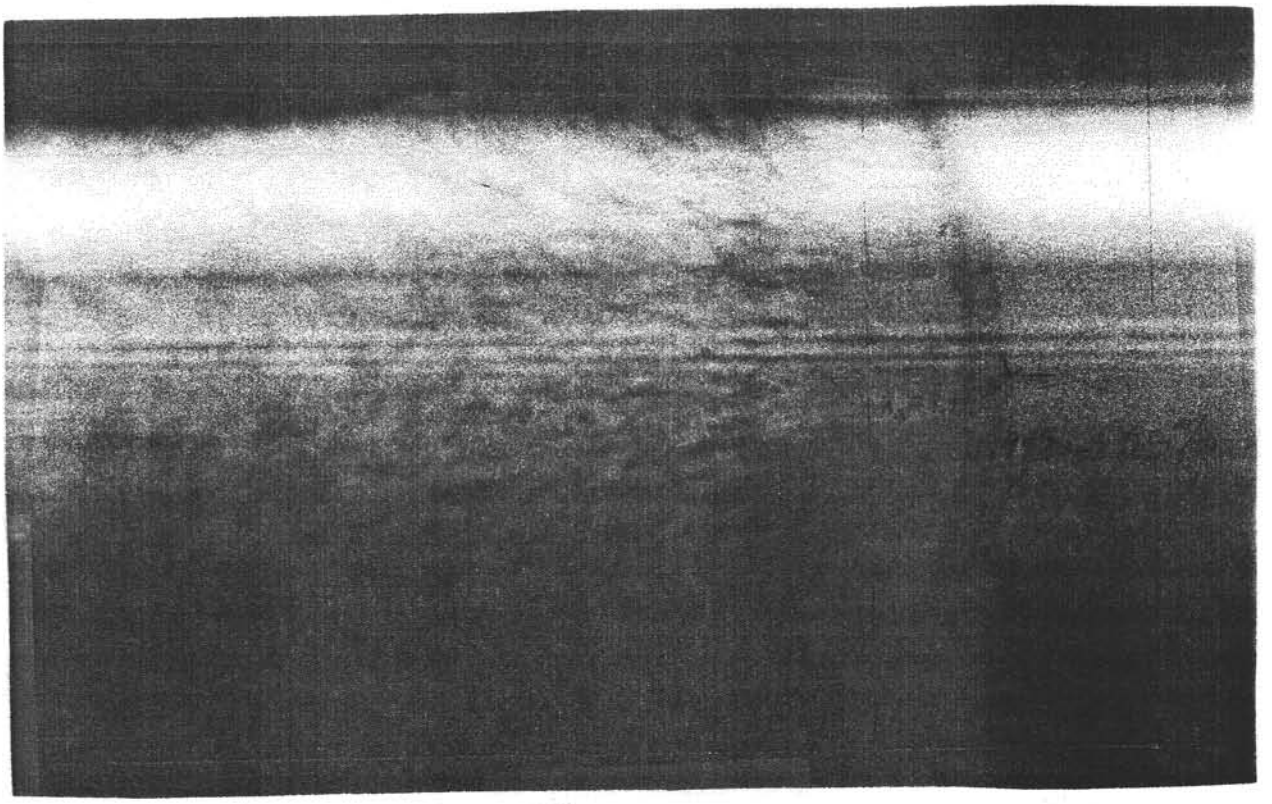


Figure 15. Shadowgraph of Shock Wave 2.3"

The curvature of the shock wave in Figure 16 is still evident. Also, a reflected shock wave from the shock tube walls has been observed in some of the finer shadowgraphs. Figure 17 illustrates the inlet shock Mach number, M_{SI}, necessary to obtain a certain exit shock Mach number, M*, for the discontinuous area expansion and for the cylindrical to rectangular area transition. The exit shock Mach number for the cylindrical to rectangular transition was about 6 percent higher at a given inlet shock Mach number than for the discontinuous area transition. This difference is attributed to the loss of energy due to flow separation and turbulence at the discontinuous area transition. Table 2 shows the comparison of measured performances for the three different area transitions. All tests were conducted at ambient (12.1 psia) initial test gas pressure with air as the test gas. Two explosive weights were used for each of the three test configurations.

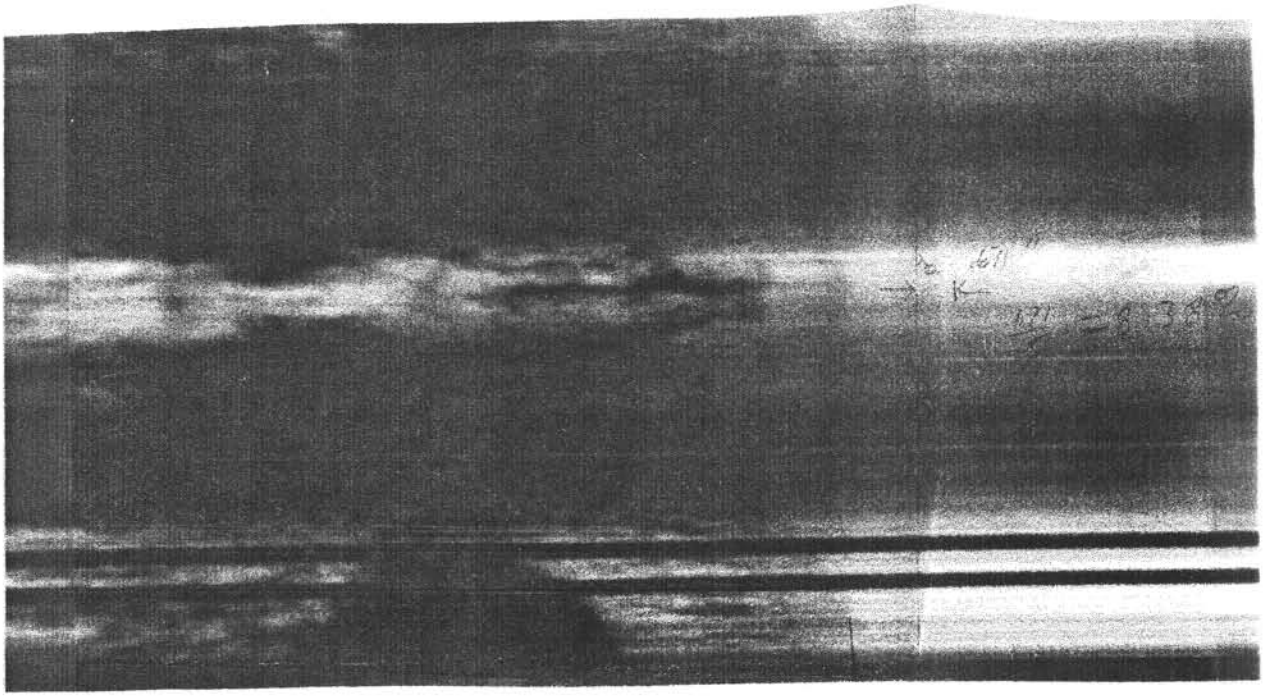


Figure 16. Shadowgraph of Shock Wave 17.7" after Discontinuous Area Expansion

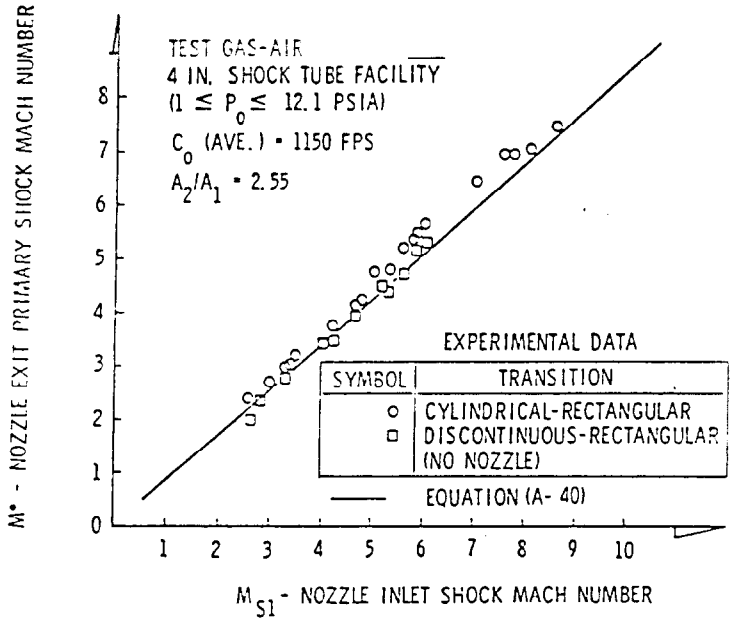


Figure 17. Nozzle Exit Primary Shock Mach Number as a Function of Nozzle Inlet Shock Mach Number

Table 2. Shock Parameters for a Conical Nozzle, a Cylindrical to Rectangular Transition Nozzle, & a discontinuous (no nozzle) Transition

Type Nozzle	Explosive Weight (lb)	Initial Test Gas Pressure (psia)	Exit to Inlet Area Ratio	Nozzle Inlet Shock Velocity (fps)	Nozzle Exit Chock Velocity (fps)	Nozzle Inlet Static Pressure (psia)	Nozzle Exit Static Pressure (psia)
Conical (8" exit dia.)	0.04	12.1	4	4450	3060	205	105
Conical (8" exit dia.)	0.12	12.1	4	6000	4200	410	180
Rectangular (4x8" exit area)	0.04	12.1	2.55	4425	3950	220	125
Rectangular (4x8" exit area)	0.12	12.1	2.55	6100	5400	470	245
No nozzle (4x8" exit area)	0.04	12.1	2.55	4100	3400	200	90
No nozzle (4x8" exit area)	0.12	12.1	2.55	6000	5000	400	190

4.2 2 – Foot – Diameter to 6 – Foot- Diameter Conical nozzle Shock Tunnel

A 2–foot-diameter (actually 1.89 feet inside diameter) to a 6–foot– diameter conical nozzle 12 feet long was constructed to couple 63 feet of an existing 2–foot–diameter shock tube to a 23–foot–long section of a 6–foot– diameter shock tube. The resultant shock tunnel is shown in Figure 18. The area ratio across the nozzle for this test facility is 10. This was a 0.315 scale model of the full–scale shock or blast tunnel to be discussed later. Table 3 lists the test series that was conducted in this facility along with some blast-wave parameters in the shock-tunnel test section 3.67 diameters beyond the nozzle exit. All tests conducted in this shock tunnel were with air as the test gas and initial-test-gas pressures in the range $1.0 \leq P_0 \leq 12.1$ psia (see Reference 4). The explosive primacord (PETN) charge weight used to drive the facility was held constant at 10 pounds. The reason for choosing 10 pounds is that it scales (Cube Root Scaling, Scale factor = 3.15) to 320 pounds, the reasonably safe charge weight for the existing 6-foot-diameter shock tube driver. The inlet blast pressures to the nozzle were varied by varying the initial test-gas pressure.

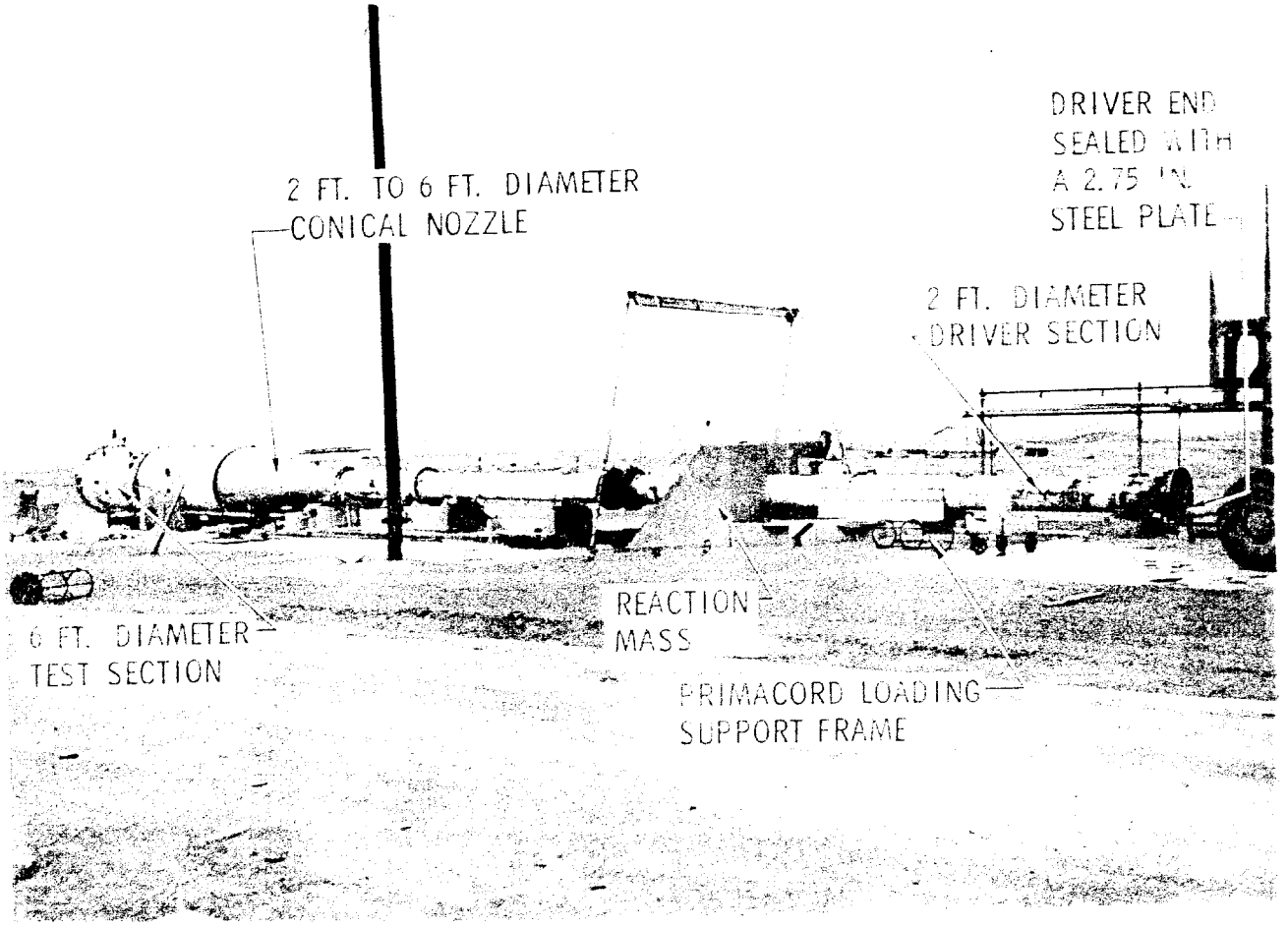


Figure 18. Shock Tube Test Configuration with a 2' Diameter to a 6' Diameter Nozzle

Table 3. Test Section Blast Wave Parameters Calculated from Measured Shock Velocities Using Ideal Gas Relations

EVENT No.	P_0 (psia)	α (degrees)	V_s (fps)	C_0 (fps)	M_s	M_f	P_α (psia)	q (psia)
69-168	12.1	70	2200	1172	1.9	0.9	59.2	32.7
69-12	12.1	30	2350	1117	2.1	1.0	60.2	44
69-25	12.1	50	2270	1097	2.1	1.0	60.0	43.2
69-35	12.1	70	2401	1119	2.2	1.0	61	45.3
69-159	6.0	30	3125	1136	2.8	1.3	52	60.1
69-49	6.0	70	3140	1129	2.8	1.3	53.1	62.2
69-102	1.0	30	4200	1134	3.7	1.5	15.8	25.2
69-184	1.0	70	4100	1139	3.6	1.5	15.0	23.2

4.2.1 Results in the 2-Foot Shock Tunnel

Figure 19 is a shadowgraph of the shock wave at the exit of the conical nozzle. Figure 20 is a shadowgraph of the same shock wave 20 feet (3.33 diameters) downstream of the nozzle exit. The planarity of the shock wave is good in both shadowgraphs. Therefore, a conical nozzle with an area ratio of 10 and a half-angle of 9.7 degrees is satisfactory from a shock planarity standpoint.

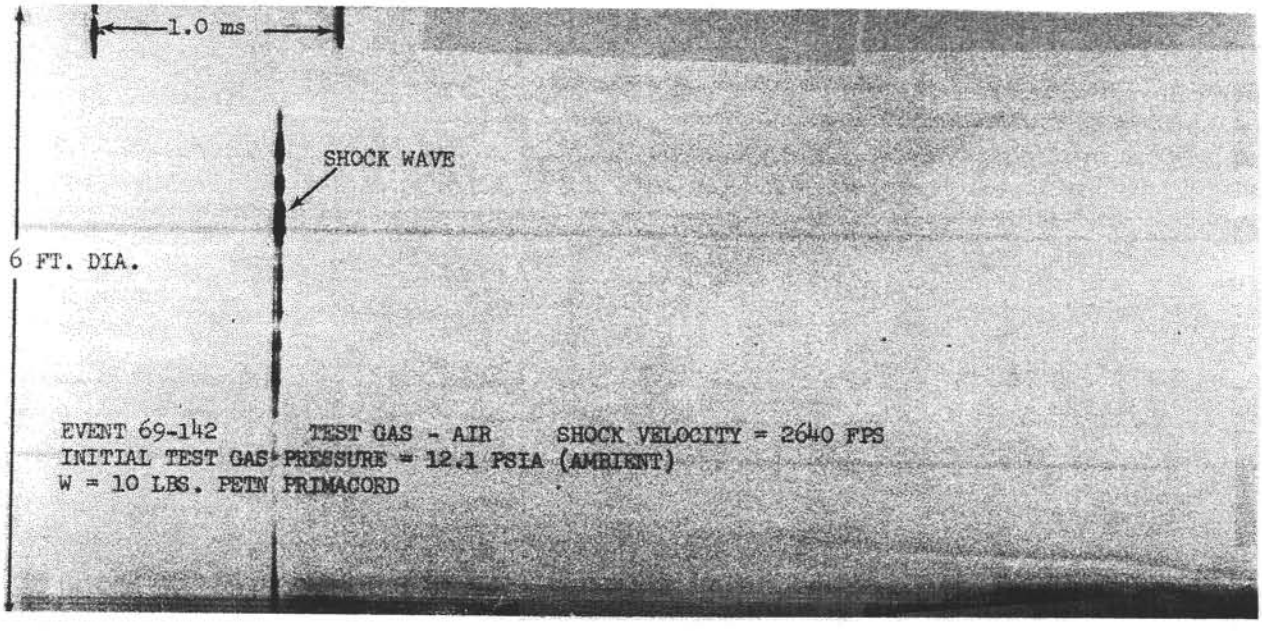


Figure 19. Shadowgraph of the Shock Wave at the Nozzle Exit

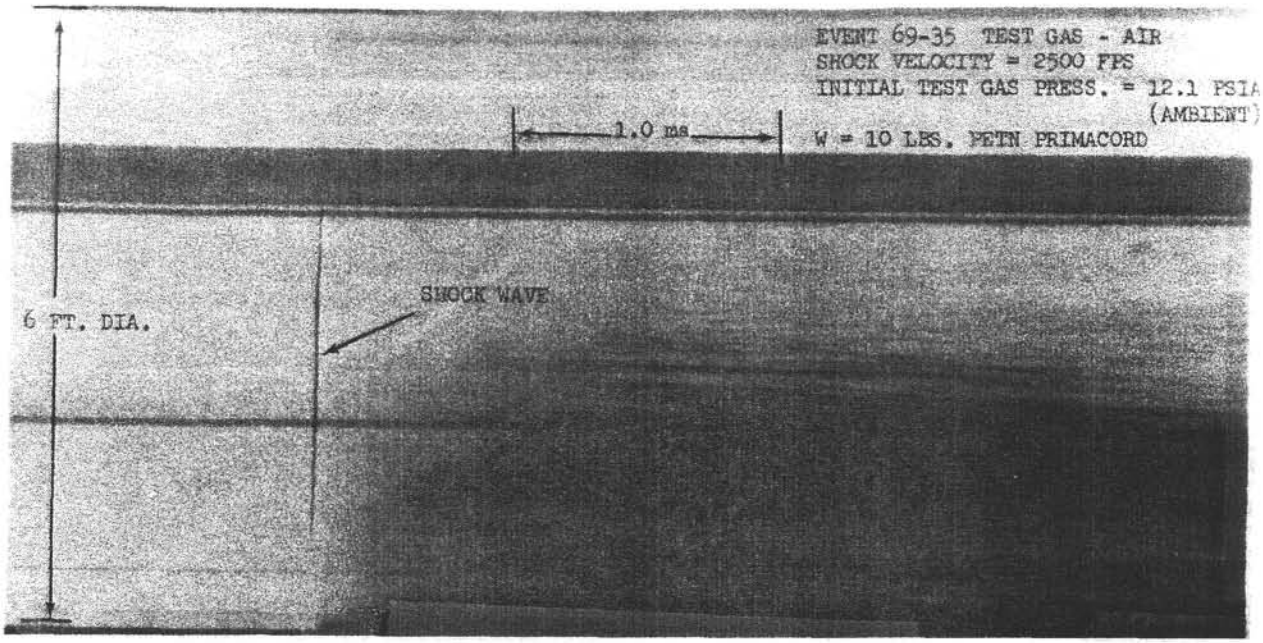


Figure 20. Shadowgraph of the Shock Wave 3.33 Diameters After the Nozzle Exit

In order to investigate the blast-wave profile downstream of the nozzle, four stagnation pressure transducers were mounted at the same shock-tube station and 90 degrees apart around the tube circumference. Figures 21 and 22 show the pressure-time histories from these four pressure transducers for initial test-gas pressures of 6.0 and 12.1 (ambient) psia, respectively.

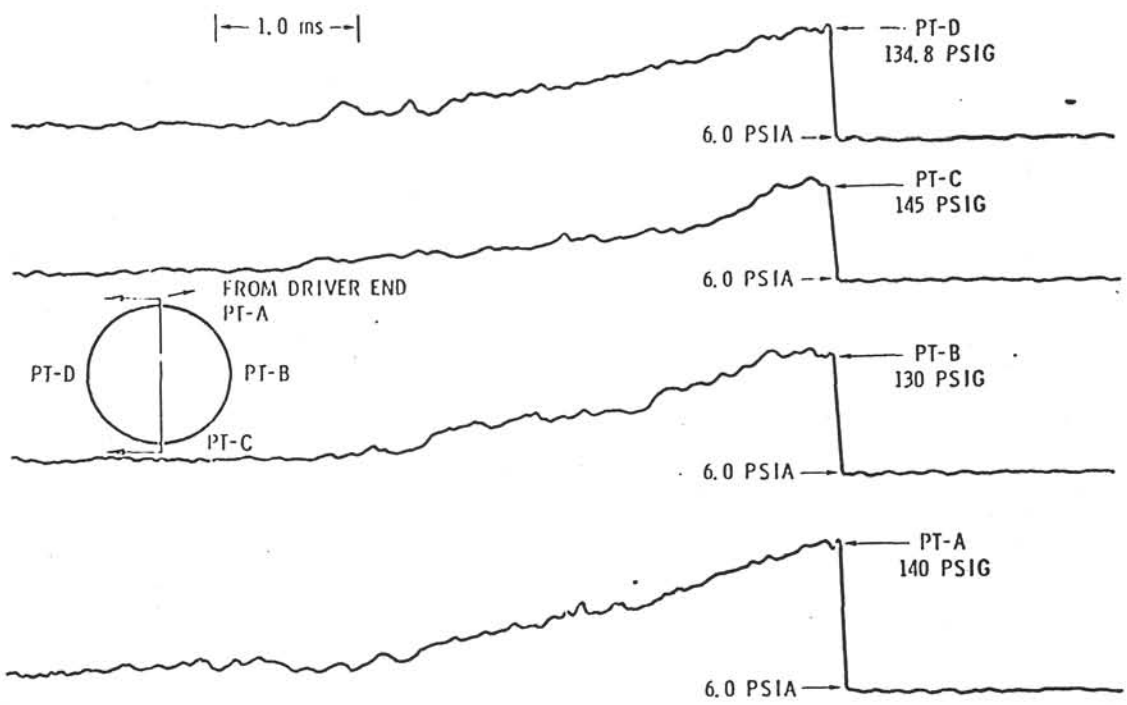


Figure 21. Stagnation Pressure Profiles from Four Transducers at 2.3 Diameter

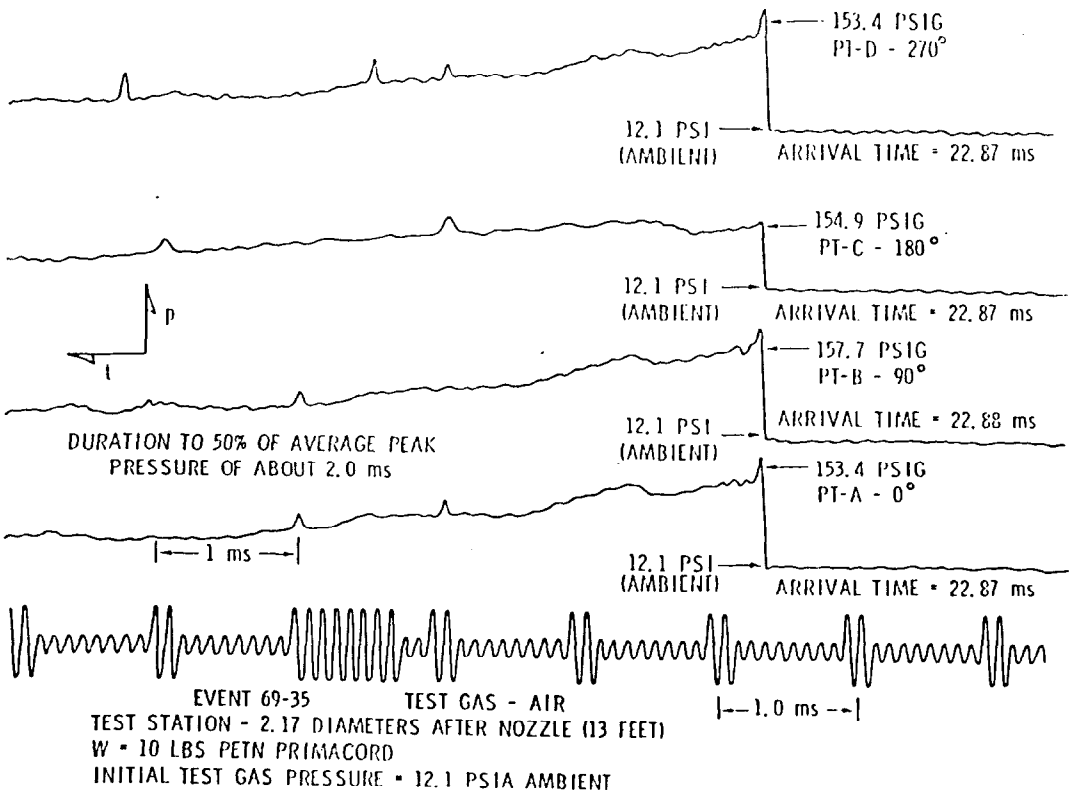


Figure 22. Stagnation Pressure Profiles 2.17 Diameters After the 2' Diameter to 6' Diameter Nozzle

The four transducers were located 1 foot upstream of the shock tube station where the shadowgraph of Figure 20 was taken. They were mounted 10 inches from the shock tube wall. Previous work and the fact that the calculated stagnation pressure agrees closely with the measured stagnation pressure indicate that these measurements were well beyond the wall boundary layer region. These measurements indicate that the pressure profiles and amplitudes are comparable, indicating that the flow behind the shock wave is uniform. Figure 23 shows the nozzle exit shock Mach number, M*, as function of nozzle inlet shock Mach number, M_{s1} . Figure 24 shows the nozzle inlet shock strength, P_1/P_0, required for a nozzle exit shock strength, P_3/P_0 .

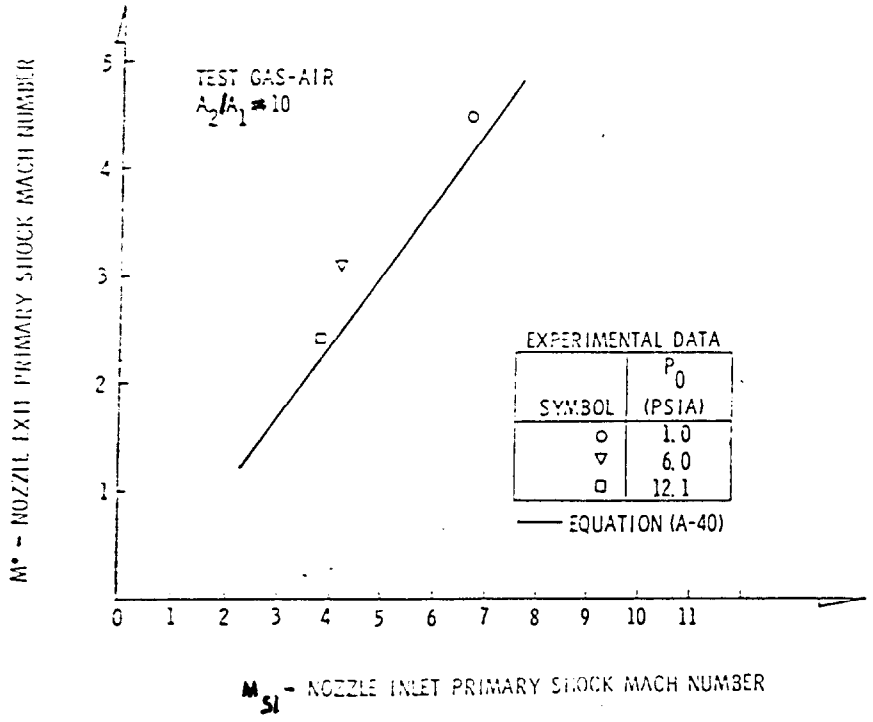


Figure 23. Nozzle Exit Primary Shock Match Number as a Function of Nozzle Inlet Shock Mach Number

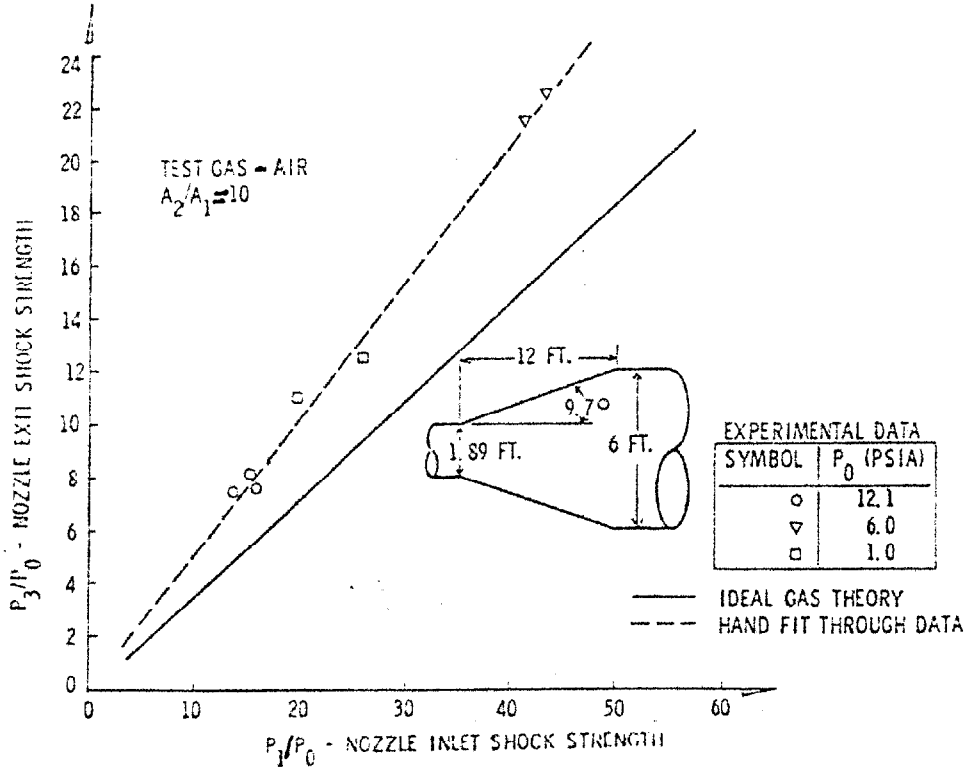


Figure 24. Nozzle Exit Shock Strength as a Function of Nozzle Inlet Shock Strength in the 2' to 6' Diameter Shock Tunnel

Figure 25 shows a static pressure measurement at the nozzle inlet. Figure 26 shows the static pressure measurement at the nozzle exit for a test with the same initial test-gas conditions as Event 69-35 (Table 2). The presence of the secondary shock wave is illustrated in this figure.

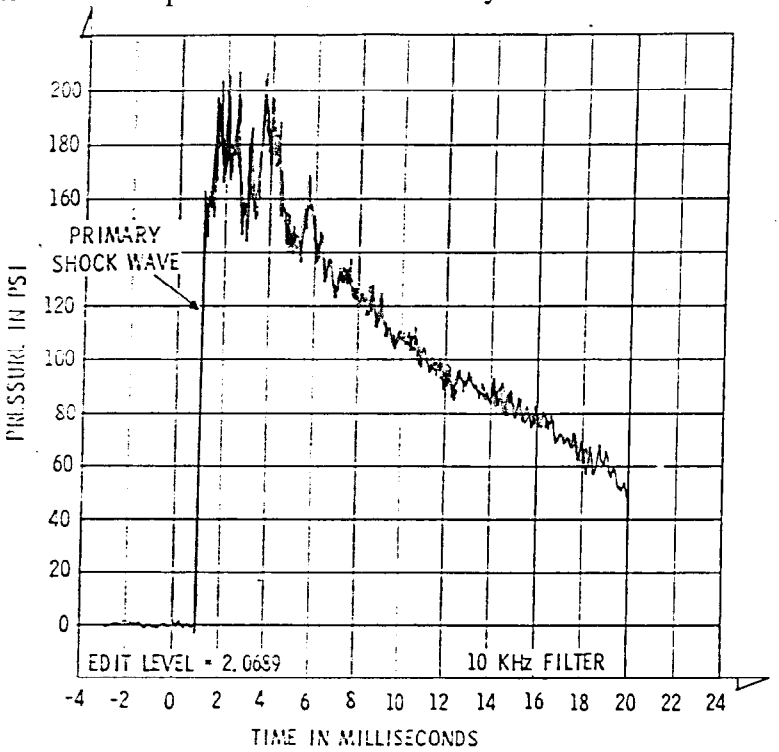


Figure 25. Static Pressure Profile at Nozzle Inlet (2 to 6' Diameter Nozzle)

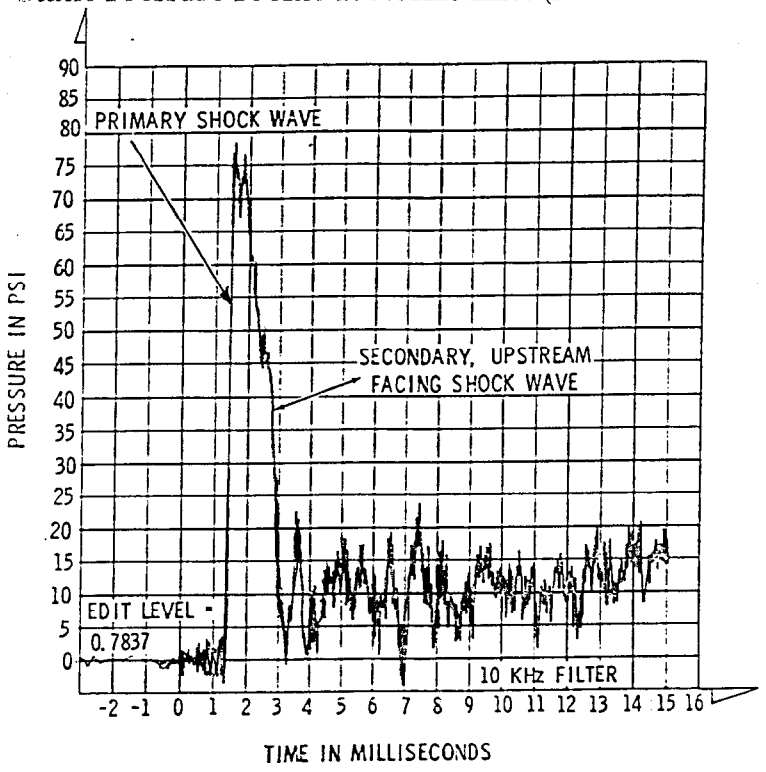
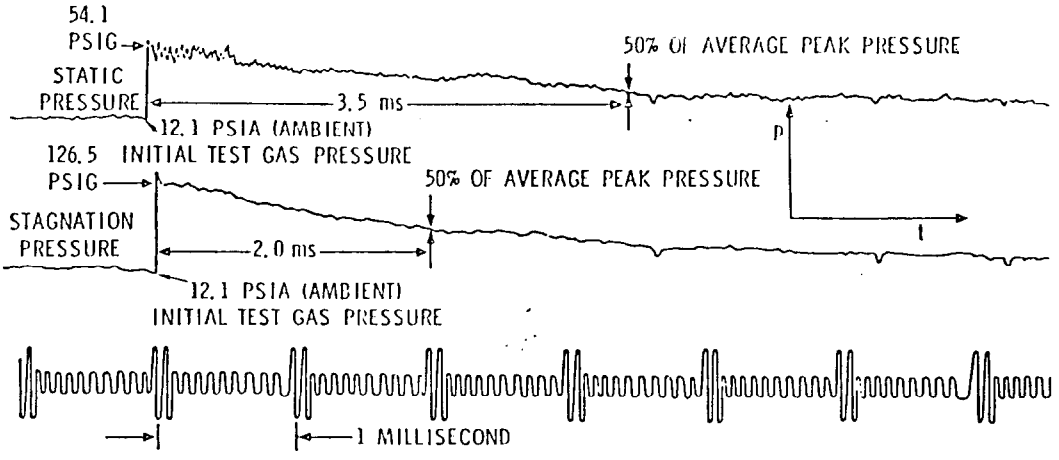


Figure 26. Static Pressure Profile at Nozzle Exit in the 2 to 6' Diameter Nozzle

Figure 27 shows the measured test-section static and stagnation pressure profiles. This figure shows that the secondary shock wave is not present and the static pressure profile is again that of a typical blast wave, an exponential decay behind the shock wave. Figure 28 shows a comparison between the measured shock Mach number results for area ratios of 2.55, 4.0, and 10 at the two shock tube facilities.



EVENT 69-35
TEST GAS - AIR
W = 10 LBS PETN PRIMACORD (EQUIVALENT TO 320 LBS PETN IN THE 6 FT DIA. x 200 FT SHOCK TUBE)
INITIAL TEST GAS PRESSURE = 12.1 PSIA (AMBIENT)
TEST STATION - 3.67 DIAMETERS AFTER NOZZLE (22 FEET)

Figure 27. Static and Stagnation Pressure Profiles in the Test Section 3.67 Diameters after the Nozzle

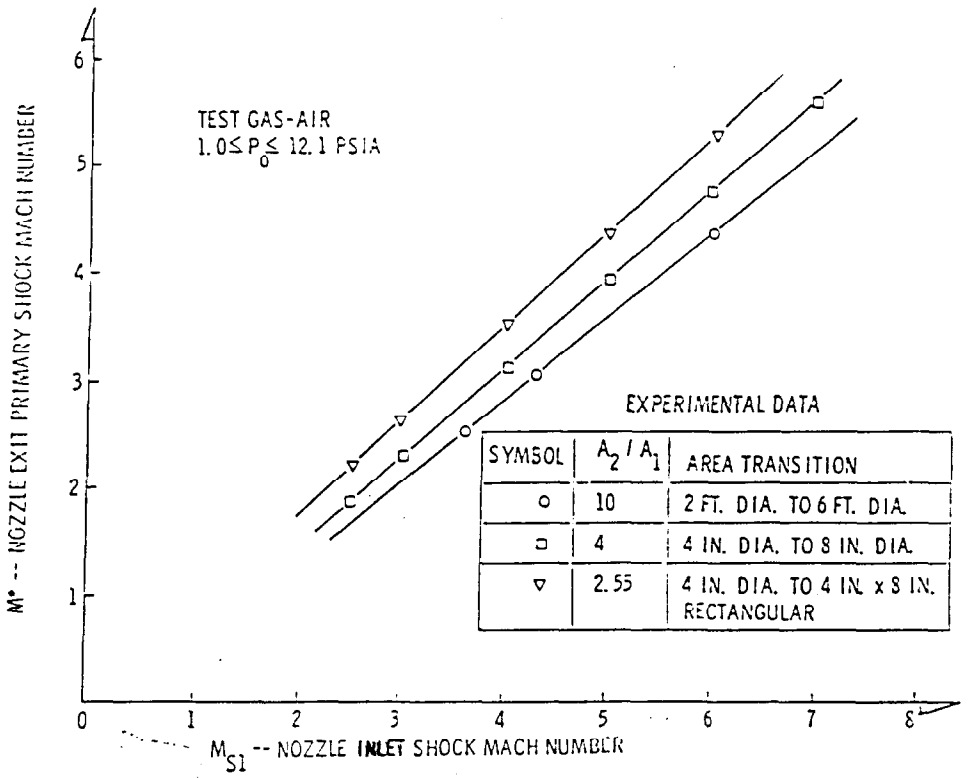


Figure 28. Measured Nozzle Exit Shock Mach Number as a Function of Measured Nozzle Inlet Shock Mach Number for Three Area Ratios

4.2.2 Conclusions from the 2-Foot to 6-Foot Shock Tunnel

It was concluded that, in order to obtain a planar shock wave with a uniformly decaying flow behind it, the test section for the proposed full-scale facility must be at least three nozzle exit diameters downstream of the nozzle.

4.3 6-Foot-Diameter to 19-Foot-Diameter Shock Tunnel

The test section for the 6-foot-diameter shock tube was designed from the requirements to blast-test the Sprint missile second stage and from the results obtained in the scaled shock/blast tunnels. Scaling parameters for the 2-foot and 6-foot-diameter shock tunnels have been derived from the Cube Root Scaling Laws as documented in Reference 1. This reference shows that the explosive driver weights, times, and distances are scaled as follows:

$$W_6 = 32\ W_2$$
$$T_6 = 3.17\ T_2$$
$$X_6 = 3.17\ X_2$$

The 19-foot-diameter blast/shock tunnel was selected based on the fact that the Sprint burned out second stage is about 16 feet long and is to be tested at angles of attack of up to 80 degrees. This test-section diameter results in an area ration of 10 across the divergent nozzle. This ratio dictated the test-section diameter for the 2-foot-diameter shock tube in obtaining a 0.315 geometrically scaled 2- to 6-foot-diameter shock tunnel. The length of the 2-foot-diameter portion (63 feet) was obtained as 0.315 times the maximum available 6-foot-diameter shock tube length of 200 feet. The 12-foot length of the divergent nozzle in the 0.315 scaled shock tunnel was obtained from results in the 4-inch shock tube studies. According to the geometrical scaling

parameters, the divergent nozzle (40 feet long) of the 19-foot-diameter shock tunnel should be about 3.17 times longer than the nozzle of the 0.315 scaled facility.

Results from the 4-inch and the 2-foot shock tube experiments were used in determining the length of test section needed after the nozzle (at least three nozzle exit diameters). Therefore, the length of 19-foot-diameter test section was established as 65 feet of 3.8 diameters.

4.3.1 Results in the 6-Foot to 19-Foot-Diameter Shock Tunnel

The 19-foot diameter or blast tunnel was completed in early July of 1971 and its final dimensions are shown in Figure 29.

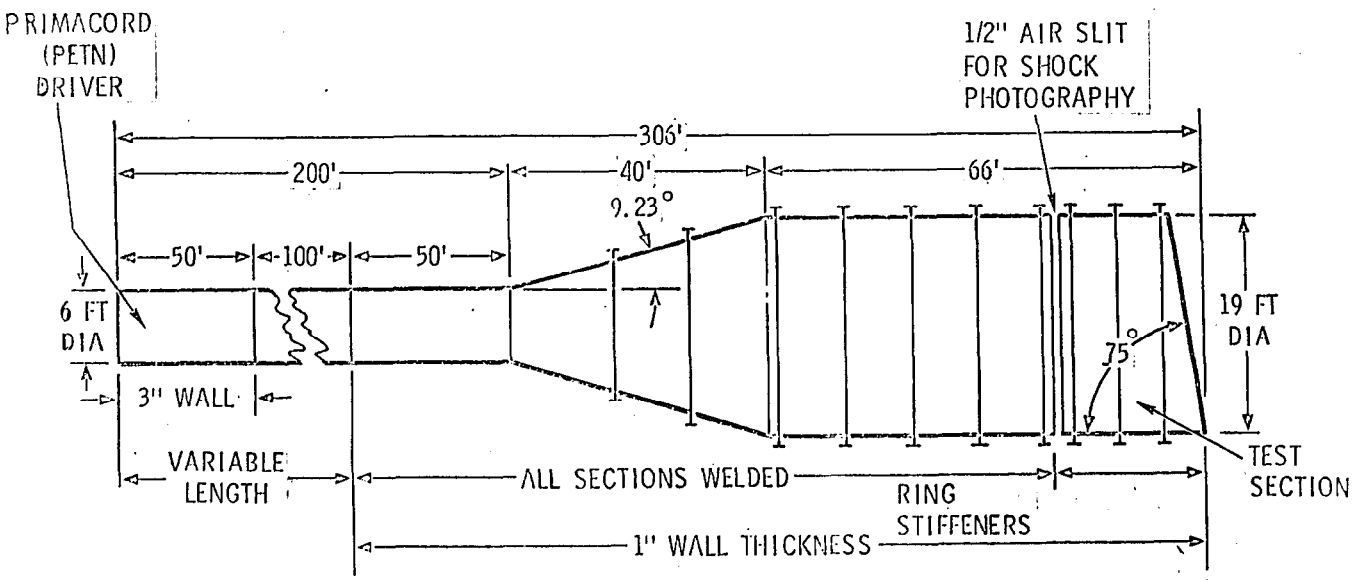


Figure 29. 19' Diameter Explosively Driven Blast Tunnel

The facility was calibrated for the Sprint Blast Program in a series of eight tests listed in Table 4. This test series is discussed in detail in Reference 15. Table 4 also includes the driver explosive weight (W), the static overpressure (ΔP), initial test gas pressure (P_0), initial sonic velocity (a_0), primary shock Mach number (M^*), shock velocity (V_S), flow Mach number (M_3), shock strength (P_3/P_0), static impulse (I), and positive flow duration (t). These blast parameters were obtained from the measured overpressures (static and stagnation) in the test section near the muzzle end and 295 feet from the driver end.

The impulse values listed in Table 4 were calculated by integrating the static overpressure profile. A good approximation to the profile is obtained from the following equation:

$$\Delta P_s = P_{so}\,[1-(t/t_0)]e^{-(t/t_0)}$$

Where P_{so} = peak static overpressure and t_o= positive phase duration. Figures 30 and 31 show static and stagnation overpressure measurements near the muzzle end, respectively. The positive flow duration is about 32 milliseconds.

Table 4. Nineteen Foot Diameter Blast Tunnel Flow Calibration Tests

TEST DATE	EVENT NO.	W (lb)	ΔP (psia)	a_0 (fps)	M*	V_s (fps)	M_3	P_3/P_0	I (psi-S)	t (S)
7/23/71	71-137	160	38	1147	1.9	2180	0.90	4.0	0.665	0.035
8/25/71	71-146	135	33	1145	1.8	2050	0.82	3.73	0.58	0.035
8/17/71	71-144	112	28	1142	1.7	1976	0.78	3.31	0.50	0.035
9/13/71	710178	112	29	1140	1.76	2006	0.80	3.40	0.5	0.034
9/16/71	71-179	112	28	1133	1.73	1950	0.77	3.31	0.5	0.035
8/18/71	71-145	90	23	1142	1.63	1861	0.70	2.9	0.33	0.029
8/27/71	71-176	72	19.5	1147	1.55	1778	0.63	2.61	0.273	0.028
8/27/71	71-177	72	19	1147	1.54	1766	0.62	2.57	0.27	0.028

(test section: 295 feet from driver end, near test unit nose)

P_0 = 12.1 psia

This facility will initially be used with nozzle inlet shock Mach numbers in the 3.0 to 4.5 range. Figure 32 shows the calculated corresponding nozzle exit conditions that could be generated. This figure shows the Rankie-Hugoniot curves for the primary incident shock wave and for the secondary rearward-facing shock wave. The intersection of these curves yields the static pressure, P_3, and flow velocity, U_3. The static pressure, P_2, and flow velocity, U_2, are indicated by an "X" in this figure.

Figure 33 shows nozzle exit shock Mach number as a function of nozzle inlet shock Mach number. Data from the eight tests listed in Table 4 are included in this figure. The calculated values shown in this figure as a solid line were obtained from Equation (1). The measured values are in close agreement with the theoretical values.

Figure 34 shows the nozzle exit shock strength as a function of the nozzle inlet shock strength. The measured pressures from the eight tests of Table 4 are plotted in this figure and agree very well with theoretical predictions.

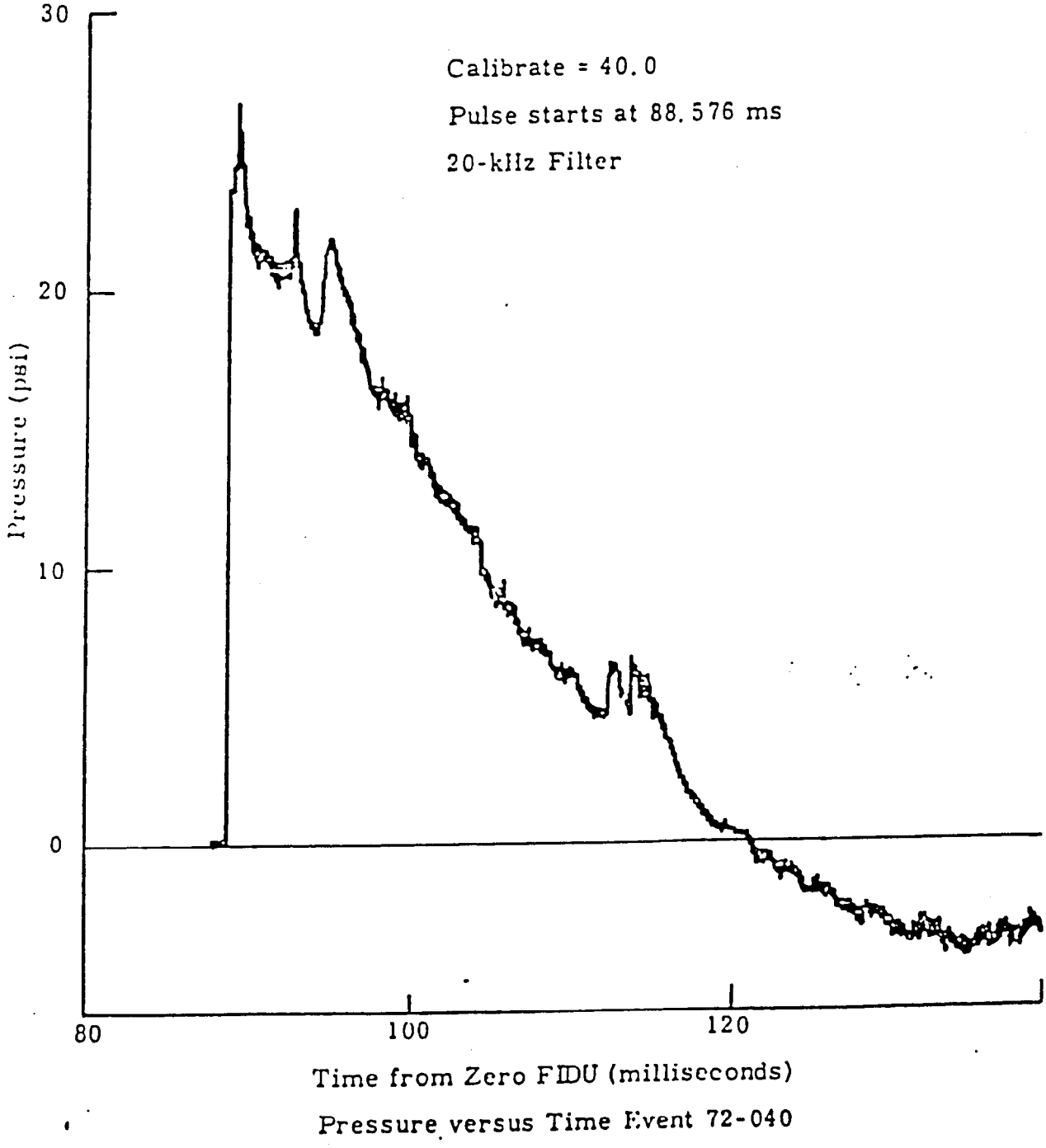


Figure 30. Static Overpressure Profile Near the Nozzle End of the 19' Diameter Blast Tunnel

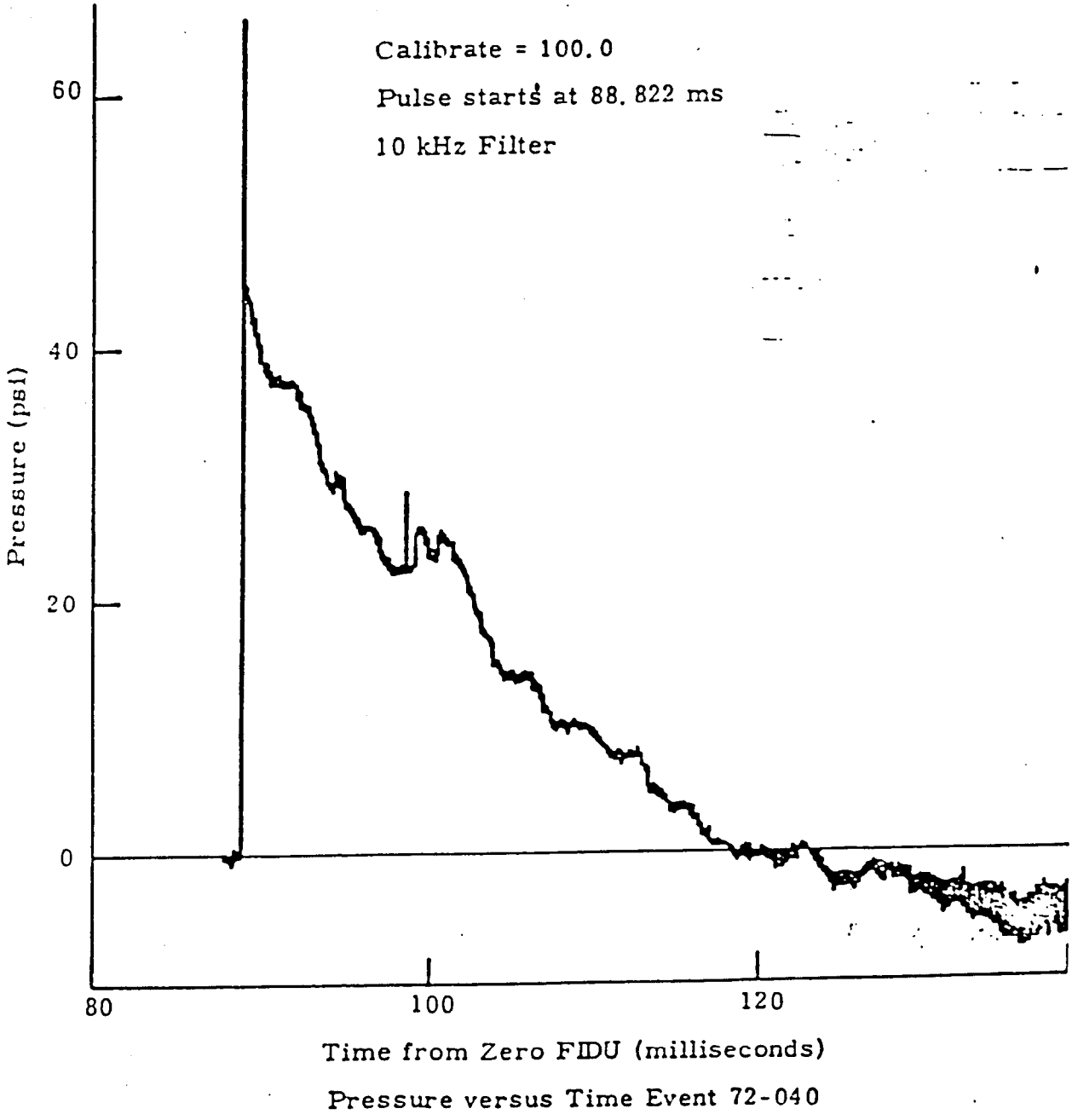


Figure 31. Stagnation Overpressure Profile Measured Near the Nozzle End of the 19' Diameter Blast Tunnel

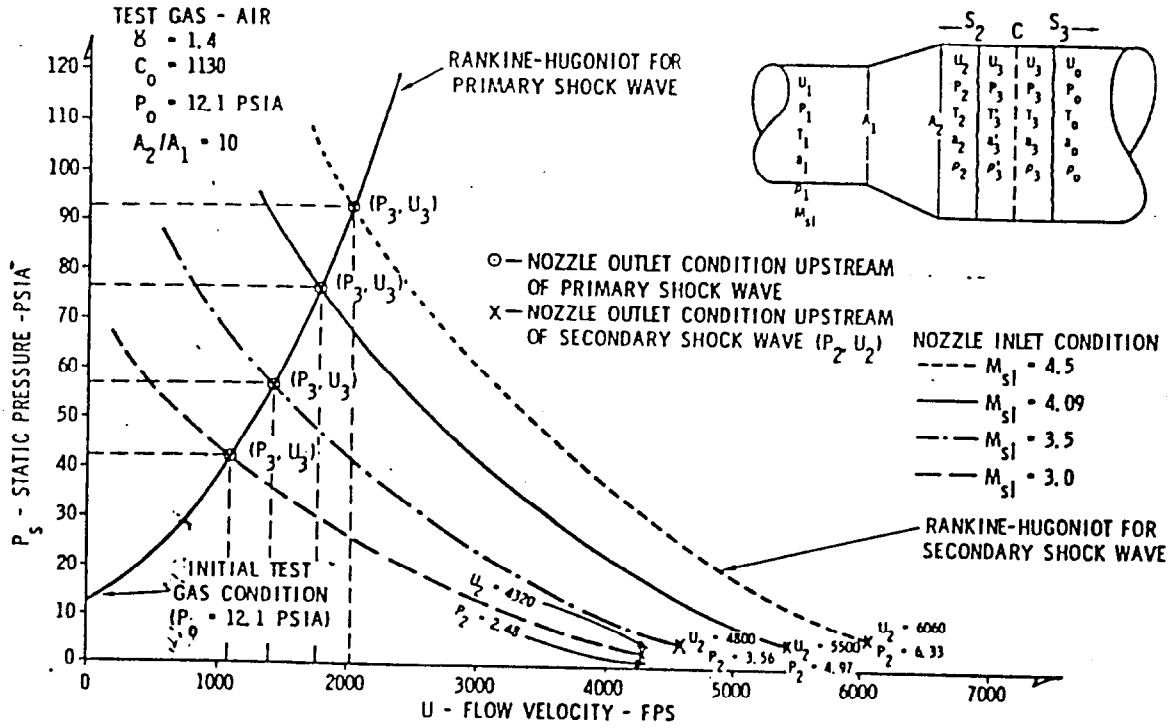


Figure 32. Rankine-Hugoniot Curves for the Primary Incident Shock Wave and for the Secondary Upstream-Facing Shock Wave at Various Nozzle Inlet Shock Mach Numbers

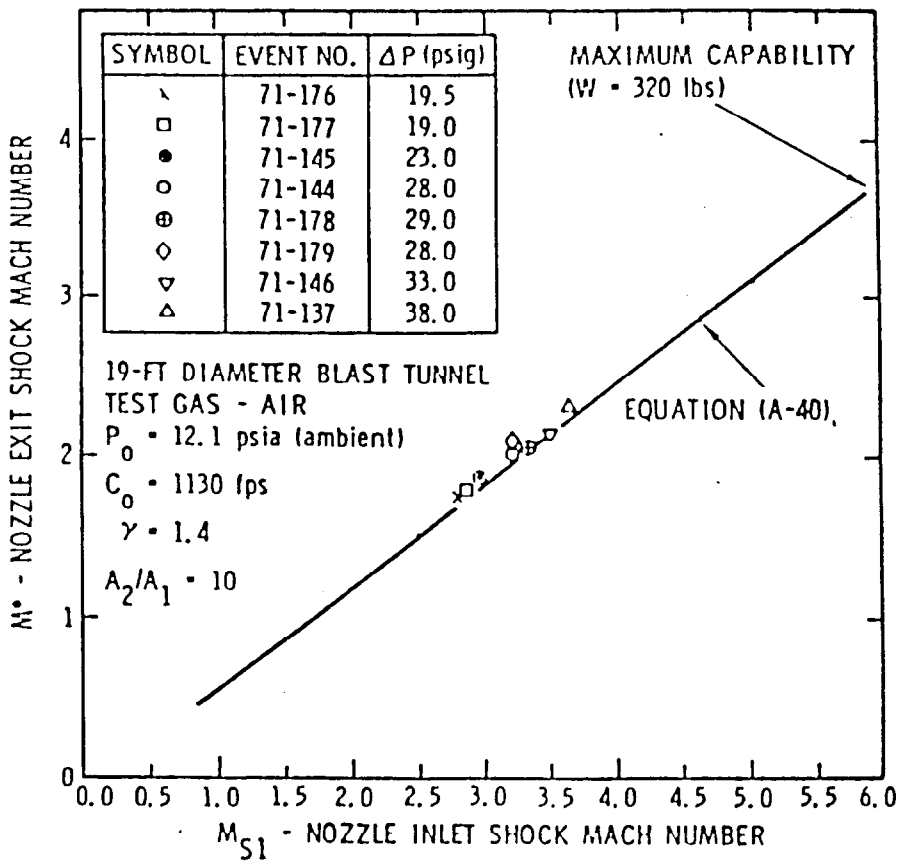


Figure 33. Nozzle Exit Shock Mach Numbers as a Function of Nozzle Inlet Shock Mach Number (Primary Shock)

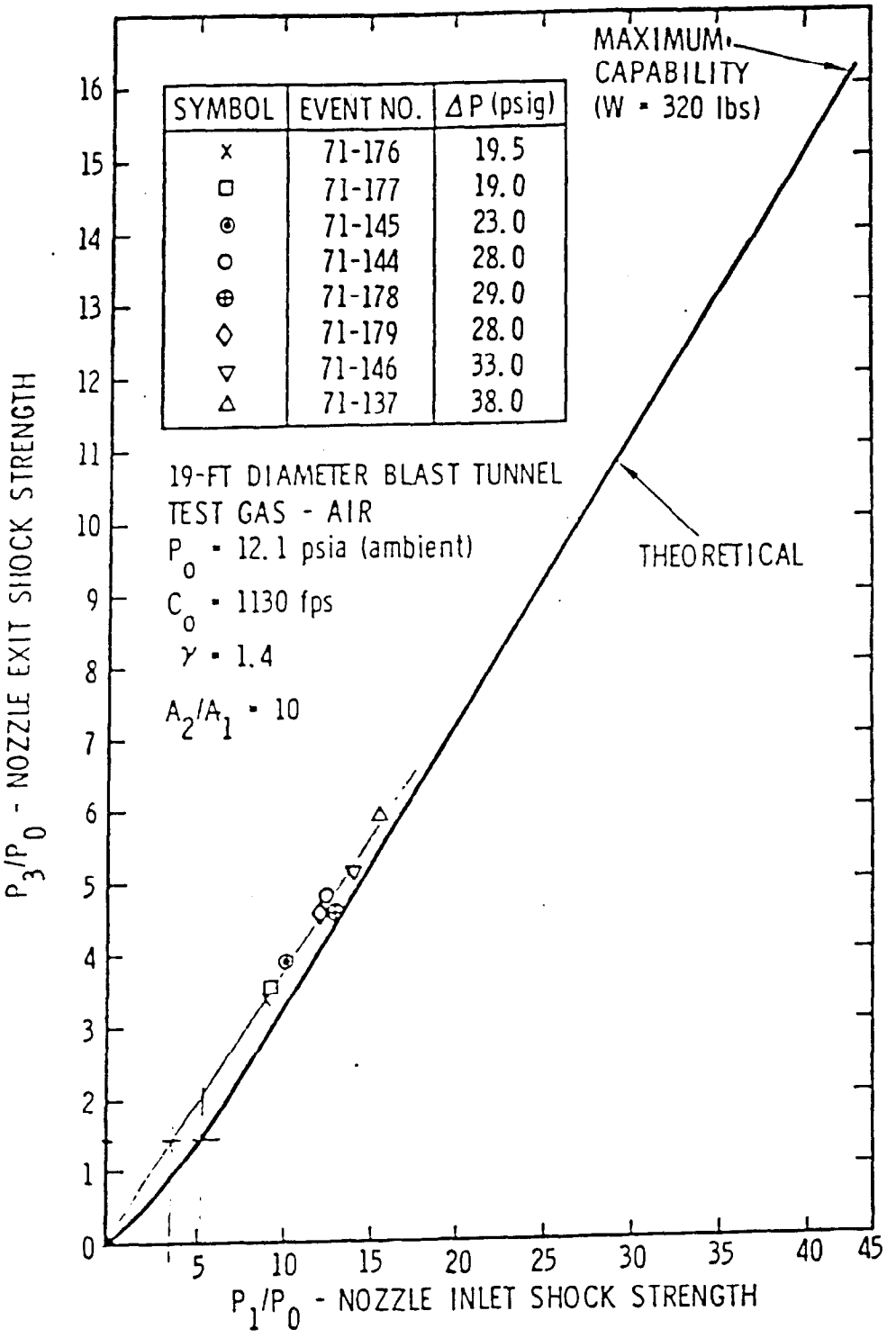


Figure 34. Nozzle Exit Shock Strength as a Function of Nozzle Inlet Shock Strength

Figure 35 illustrates the variation of the measured static overpressure from 147 to 303 feet from the driver end. Data are presented for three tests which include the overpressure range for the Sprint Blast Program.

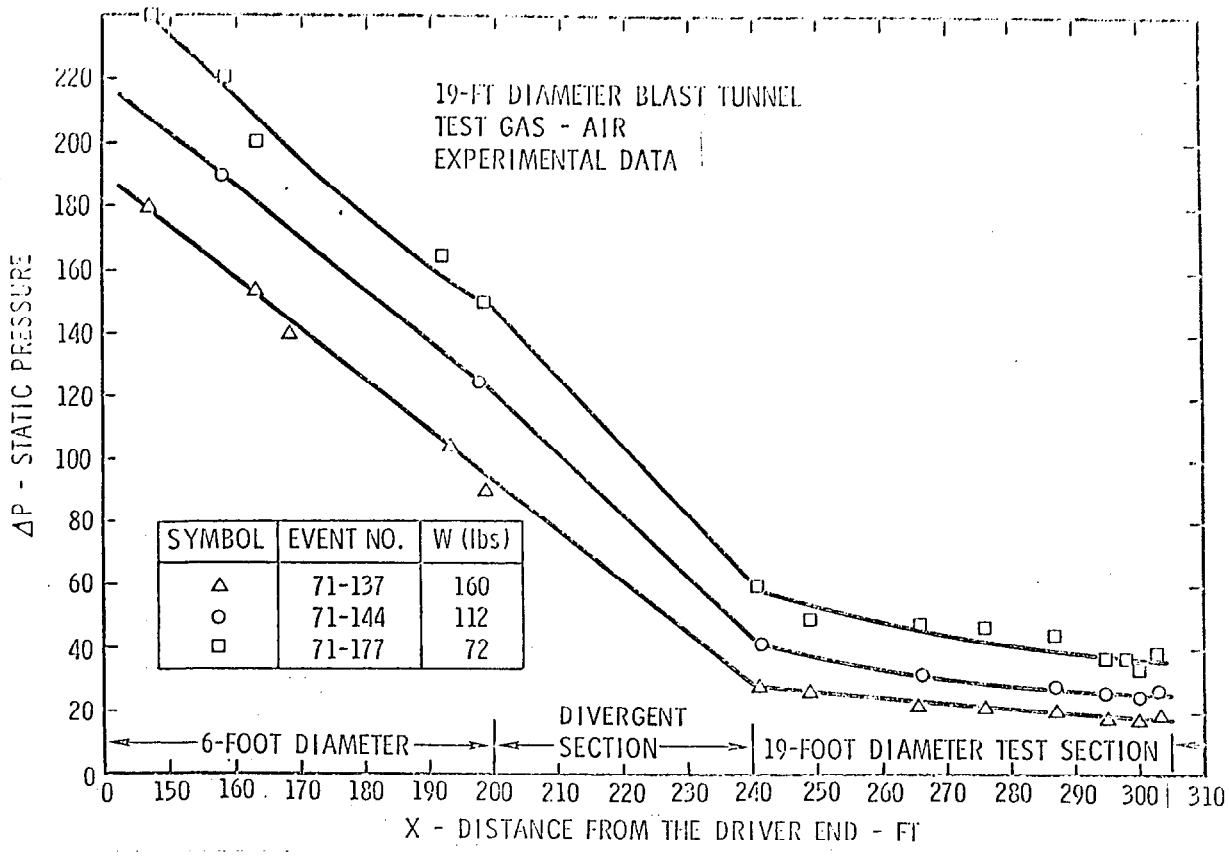


Figure 35. Static Overpressure Versus Distance From the Driver End

Figure 36 shows the measured static overpressures at the 295-foot station as a function of explosive driver charge weight. The linear relationship is shown in this figure for explosive charge weights between 72 and 160 pounds.

Figure 37 shows the overpressure, static impulse, and positive flow duration in the 19-foot-diameter test section. This figure includes the predicted maximum parameters.

Figure 38 shows a shadowgraph of the shock front at the muzzle end of the blast tunnel. The image motion camera used to obtain this shadowgraph was aligned perpendicular to the tube centerline. The tunnel test section is beveled at a 75-degree angle and the curvature of the shock front in the upper portion of Figure 38 is due to the earlier expansion of the flow near the top. This figure does show that the shock front is planar and perpendicular to the tunnel centerline for at least the lower half of the tunnel diameter which is a good indication that the shock front is

planar over the whole tunnel diameter before reaching the muzzle end. The dark area toward the right edge of this figure is believed to be due to water vapor and/or to carbon material deposited on the walls in previous test and swept of the surface on this test. The resultant giant smoke ring is shown in Figure 40 as the blast front reaches the muzzle end.

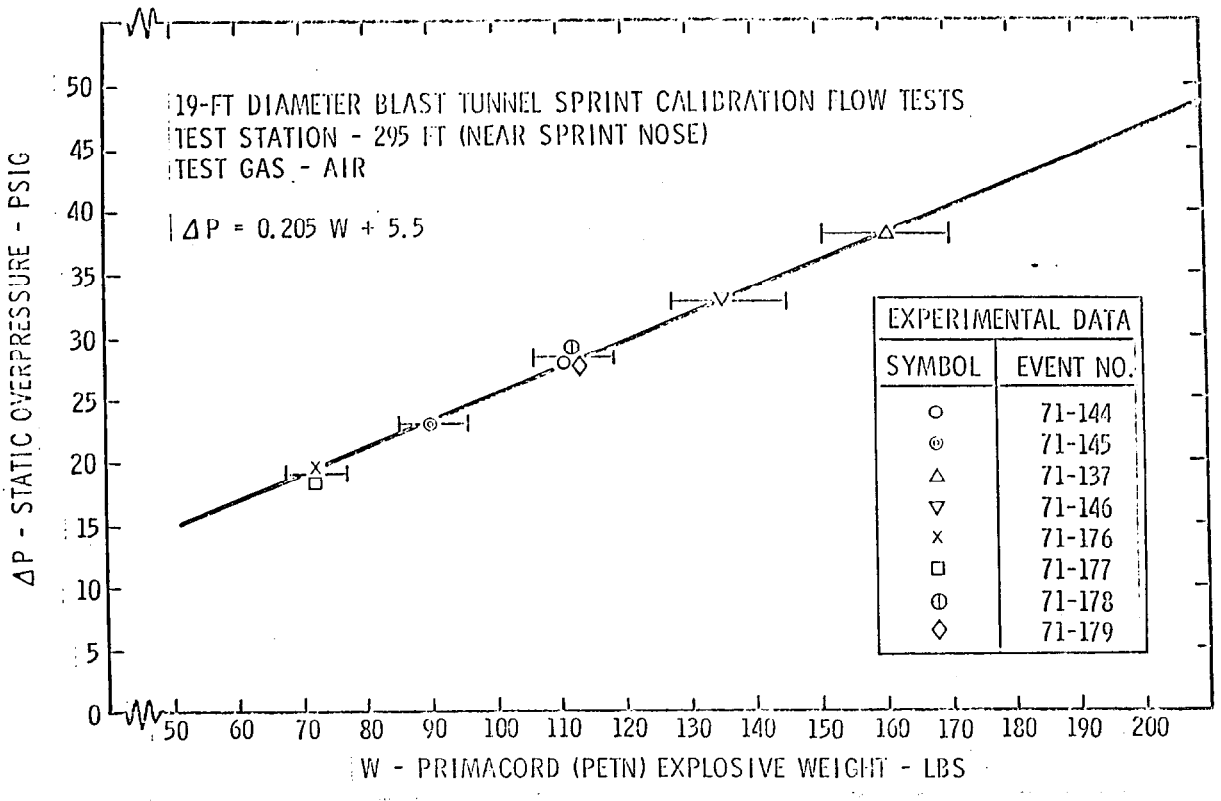


Figure 36. Static Overpressure Versus Explosive Driver Weight for the 19-foot Diameter Blast Tunnel Test Section

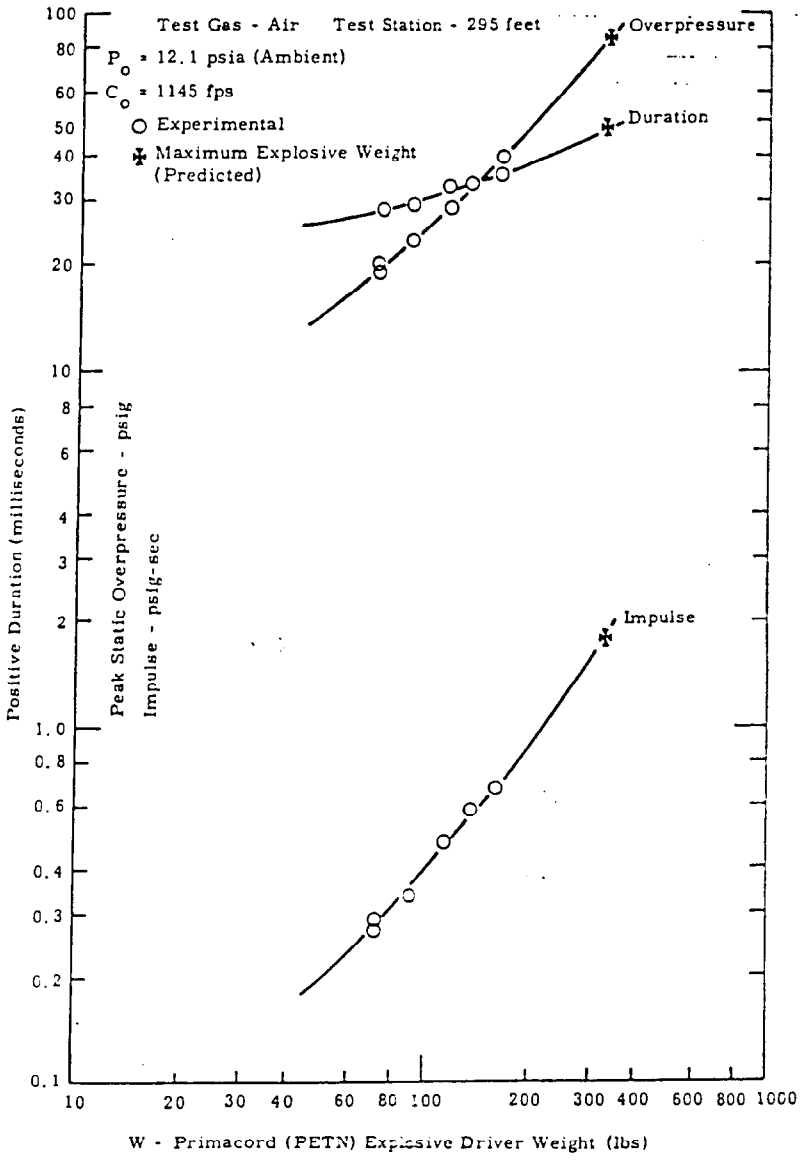


Figure 37. Blast Parameters for the 19-foot Diameter Blast Tunnel

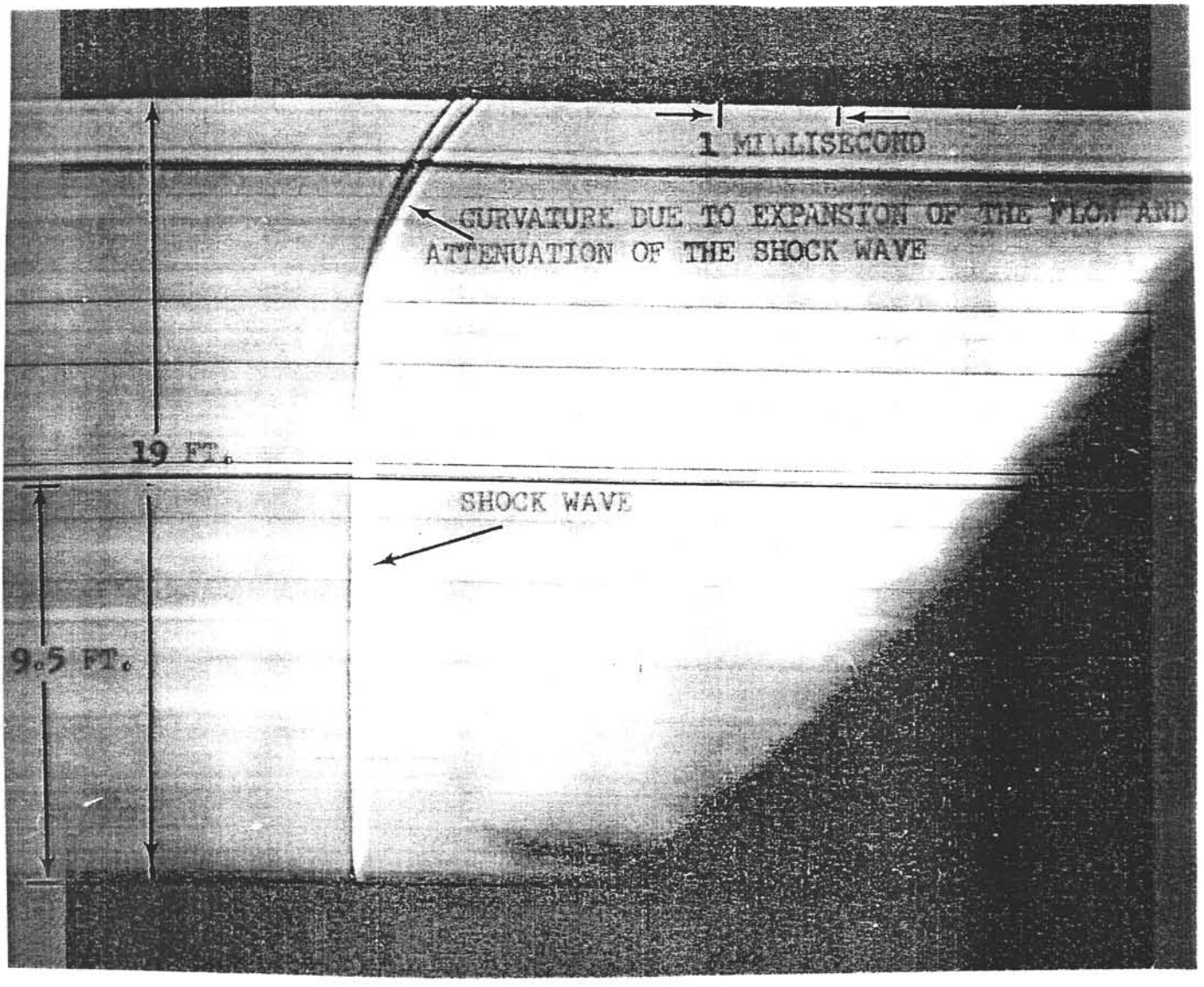


Figure 38. Shadowgraph of Shock Front at the Muzzle End of the 19-Foot Diameter Blast Tunnel

Figure 39 shows the Sprint Calibration Test Unit (CTU) in the 19-foot diameter test section. Also shown in this figure is the wire suspension rope that is explosively cut when the shock wave reaches the test unit. The nylon ropes shown in Figure 39 are used orient or align the CTU leading edge.

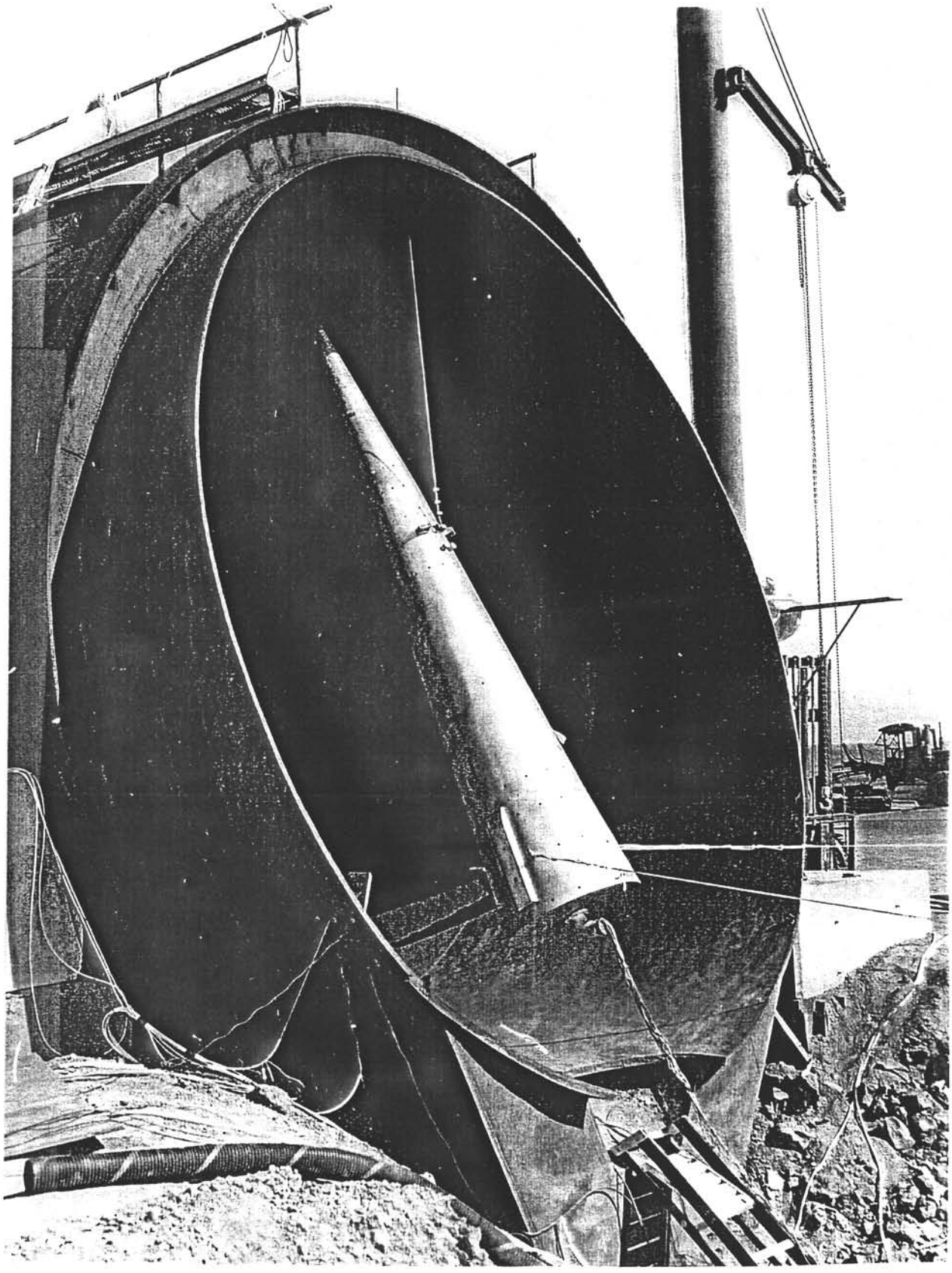
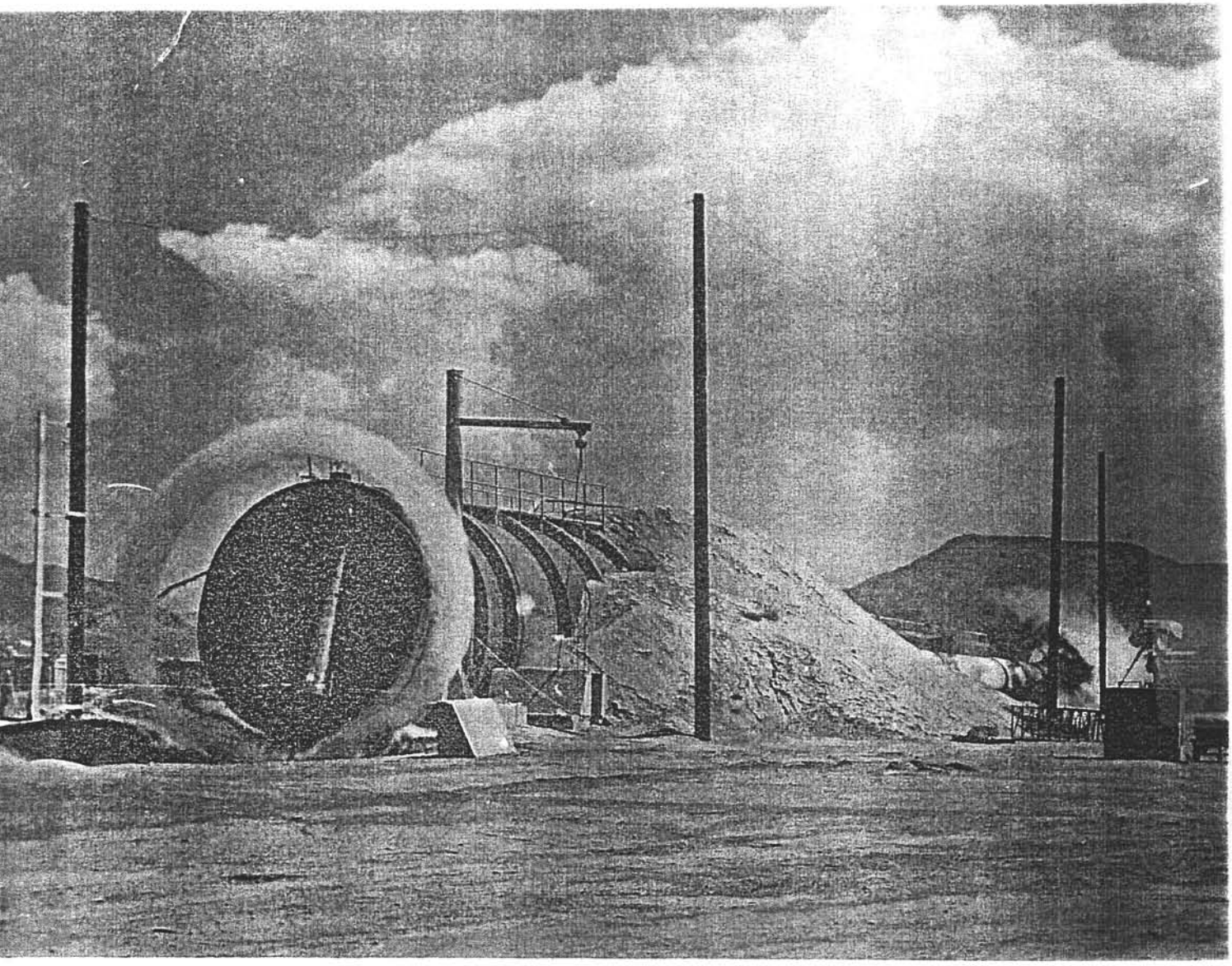


Figure 39. Calibration Test Unit (CTU) in the 19-foot Diameter Blast Tunnel Test Section



5.0 Blast Facilities/Additional Photos/Shadowgraphs

Shadowgraphs of the blast wave engulfing a conical test model in the 4 inch by 8 inch diameter blast tunnel facility are included in Appendix E. These shadowgraphs include the following features:

a. Conical model at 30 degree angle of attack, attached bow wave,
b. Conical model at 70 degree angle of attack, detached bow wave,
c. Conical model at 30 degree angle of attack, shock engulfing unit.

Additional photographs of the 2 to a 6-foot diameter facility are included in Appendix F. These photographs include the following features:

a. A conical, test unit in the 6-foot diameter test section, and
b. The aluminum, diaphragm used to seal the muzzle end of the facility reduced, (initial pressures below the 12.1 psia ambient pressure or when using test gases other than air, such as helium, sulferhexaflouride, etc.) initial test gas pressure tests.
c. Conical test unit in beveled, 45 degree, 6-foot diameter muzzle end/test section,
d. Shadowgraph of shock front, compressed initial test gas, and following detonation product gases

Additional photographs of the 6-foot diameter shock tube facility are Included in Appendix G. These photographs include the following features:

a. Six ft. diameter by 200 ft. long shock tube,
b. Four hundred grain per foot, PETN, primacord explosive distribution in the re-usable, 3 inch thick by 50 foot long driver, and
c. Six foot shock tube during blast test.

Additional photographs of the 6 to 19-foot diameter facility are included in Appendix H. These photographs include the following features:

a. The beveled, 75 degree, 6-foot diameter muzzle end/test section,
b. Giant water vapor-smoke ring at muzzle end during test,
c. Shadowgraph of shock front, and bow wave from Sprint CTU,
d. A conical, Calibration Test Unit (CTU) in the 19-foot diameter test section,
e. The 16-foot long, 1200 pounds, Sprint missile, CTU trajectory measured from 400 frame/sec camera, and
f. The Sprint missile, CTU in the large sawdust, soft recovery, pit after the test.
g. The stagnation pressure measurement fixture(tansducers installed 3, 6, 9, and 12 inches from blast tunnel surface/measure boundary layer effects)

6.0 Discussion

The research and development work for the design of a 19-foot diameter test section for the 6-foot diameter by 200-foot long shock tube has been was presented. The theory used in computer programs to predict the blast tunnel flow parameters was included. The measured flow parameters were presented and compared to the predicted flow parameters.

The 19-foot-diameter blast tunnel was used to successfully blast-test the Sprint missile second stage . This facility was designed to test at initial test gas pressures between 1.0 and 12.1 psia (ambient). (Structural, "T" configured re-enforcing rings were welded exterior to the 19-foot diameter test section at a 10 foot interval) although, to date, test requirements have been such that test conditions have been obtained at an ambient (12.1 psia) initial test gas pressure. The Sprint Missile Program was successfully completed in this facility.

The 6-foot diameter by 19-foot diameter by 306-foot long blast tunnel was later modified to simulate low over pressure, long flow duration free field blast environments to successfully test aircraft components (B-1 bomber nose, fusolage panels)(Boeing KC-131 fusolage panels), and

military (Army) field components as documented in references 17-23. This modified blast simulator is shown in the last figures in Appendix H and included the following components in series:

a. Two foot diameter by 236 foot long shock tube,
b. Two foot diameter to 6 foot diameter by 12 foot long conical expansion section,
c. Six foot diameter by 297 foot long shock tube,
d. Six foot diameter to 19 foot diameter by 40 foot long conical expansion section, and
e. Nineteen foot diameter by 65 foot long test section.

The total length of this blast tunnel was about 650 feet. Cylindrical, Composition C-4, explosive charges were suspended along the centerline of the 2 foot (actually 1.6 foot) diameter driver to generate the required blast flow conditions in the 19-foot diameter test section as documented in references 17-13. Figures with the following information are included in Appendix H:

a. Nineteen foot diameter blast simulator drawing/low overpressure long flow duration configuration 650 feet long
b. Photo of 650 foot long blast tunnel

This facility was the largest explosively driven blast simulator in the country capable of generating supersonic flows at the muzzle end.

References

1. Vigil, M. G. , Explosive Driven Shock Tubes and Blast Wave Parameters in Air, Sulfur Hexafluoride and Freon- (318), 39th Shock and Vibration Symposium, Monterey, California, October 22-24, 1968.

2. Vigil, M. G., Bickel, D. C. , Leisher, W. B., A Method for Predicting Forcing Functions for Structures Being Tested in a Shock Tube , The institute of Environmental Sciences, 16th Annual Technical Meeting, Boston, Massachusetts, April 16, 1970.

3. Vigil, M. G., Bickle, L. W., Preformance Characteristics of Concentrated Charge Explosive Driven Shock Tubes , Sandia Laboratories, Albuquerque, New Mexico, SC-R-69-1239, December 1968.

4. Vigil, M. G. , Blast Wave Parameters for a Sharp 5-Degree Half-Angle Cone at Flow Mach Numbers from 0.9 to 1.5 and Angles of Attack from 30 to 70 Degrees , Sandia Laboratories, Albuquerque, New Mexico, SC-DR-69-746, November 1969.

5. Glick, H. S. , Hertzberg, A. , Smith, W. E. , Flow Phenomena in Starting a Hypersonic Shock Tunnel , Cornell Areo. Lab. , Buffalo, New York, Rep. No. AD-789-A-3, March 1955.

6. Hertzburg, A. , Shock Tubes for Hypersonic Flow , Cornell Areo. Lab. , Buffalo, New York, Rep. No. AF-702-A-1, May 1951.

7. Yoler, Y. A. , Hypersonic Shock Tubes , Galcit Memo No. 18, July 1954.

8. Rudinger, G. , Wave Diagrams for Nonsteady Flow in Ducts , Van Nostrand, New York, 1955.

9. Henshell, B. D. , Gadd, G. E. , Factors Affecting the Preformance of the Nozzle of a Hypersonic Shock Tube , Aeronautical Research Council, ARC.- CP-293, 1956.

10. Squire, W. , Hertzburg, A. , Smith, W. E. , Real Gas Effects in a Hypersonic Shock Tunnel , Cornell Aero. Lab. , Buffalo, New York, Rep. No. AD-789-A-1, Contract No. AF40(600)-6, March 1955.

11. Rotty, R. M. , Introduction to Gas Dynamics , John Wiley and

12. Kreyszig, E. , Advanced Engineering Mathematics , John Wiley and Sons, Inc. , New York, 1965.

13. Gaydon, A. G. , Hurle, I. R. , The Shock Tube in High-Temperature chemical Physics , Reinhold Pub. Corp. , New York, 1961.

14. Ferri, A. , Fundamental Data Obtained from Shock-Tube Experiments , Pergamon Press, New York, New York, 1961.

15. Vigil, M. G. , Sprint Blast Program Calibration Flow Tests in the 19-Foot Diameter Blast Tunnel , Sandia Laboratories, Albuquerque, New Mexico, SC-TM-72 0494, 1972.

16. McCracken, D. D. , Dorn, W. S. , Numerical Methods and Fortran Programming , John Wiley and Sons, Inc. , New York, 1968.

17. Vigil, M.G., Bickel, D.C., "Blast Simulator Instrumentation Study", SC-DC-70-5120, Second International Symposium on Military Applications of Blast Simulators, Dahlgren, Virginia, 1970.

18. Vigil, M.G., Bickel, D.C., "Sandia Laboratories' 19-Foot Diameter Blast Simulator", Third International Symposium on Military Applications of Blast Simulators, Schwetzingen, Germany, September 19-21, 1972.

19. Vigil, M.G., "Calibration of Sandia Laboratories' 19-Foot diameter Explosively Driven Blast Simulator", 19th Annual Technical Meeting of the Institute of Environmental Sciences, Anaheim, California, April 1973.

20. Vigil, M.G., "Performance Characteristics of Sandia Laboratories' 5.8 - Meter Diameter Explosively Driven Blast Simulator", Fourth International Symposium on Military Applications of Blast Simulators, London, September 9-12, 1974.

21. Vigil, M.G., "Low-Overpressure, Long-Positive-Phase-Duration Flows in a 5.8-Metre Diameter Facility for Simulating Blast Environments from Nuclear Weapons", Fifth International Symposium on Military Applications of Blast Simulators, Stockholm, Sweden, May 1977.

22. Vigil, M.G., "A Method for Predicting the Test Section Blast Parameters of a 5.8 Metre Diameter Blast Simulator", SC-R-70_4376, Sixth International Symposium on Military Applications of Blast Simulators, Cahors, France, june 25-29, 1979.

23. Vigil, M.G., "New 306-Ft Transonic Shock tunnel Aids Sandia Labs" Testing Program", Sandia National Laboratories/Sandia Science News, Vol. 6, No.3, September 1971.

24. Vigil, M.G., "Simulated Nuclear Blast Testing for Aircraft Segments", Sandia National Laboratories/Sandia Technology, SAND76-0264, August 1976.

Appendix A.

EQUATIONS FOR THE BLAST WAVE PARAMETERS AFT OF DEVERGENT NOZZLE, GIVEN THE NOZZLE INLET PARAMETERS

The main objective is to obtain an expression for $M^* = W_3/a_0$, the primary transmitted shock Mach number. Solution of the blast-wave parameters after the nozzle is then simplified.

Given the nozzle-inlet blast-wave parameters and the area ratio across the divergent nozzle, it is possible to find the blast-wave parameters in state 2 using the steady isentropic channel flow equations. Equation (A-1) below (from reference 11) can be used to find an expression for the flow Mach number, M_2, in state 2 in terms of the area ratio across the nozzle and the flow Mach number M_1 in state 1.

$$\frac{dA}{A} = \frac{\gamma+1}{2(\gamma-1)} \frac{d\left(1+\frac{\gamma-1}{2}M^2\right)}{\left(1+\frac{\gamma-1}{2}M^2\right)} + \frac{ds}{R} - \frac{dM}{M} \qquad \text{(A-1)}$$

Since ds = 0 for isentropic flow, equation (A-1) can be integrated between limits A_1 and A_2 to obtain equation (A-2) below.

$$\ln\frac{A_2}{A_1} = \frac{\gamma+1}{2(\gamma-1)} \ln\left[\frac{1+\frac{\gamma-1}{2}M_2^2}{1+\frac{\gamma-1}{2}M_1^2}\right] - \ln\left(\frac{M_2}{M_1}\right) \qquad \text{(A-2)}$$

Equation (A-2) can be rearranged and simplified to yield equation (A-3),

$$\frac{A_2}{A_1} = \frac{M_1}{M_2}\left[\frac{1+\frac{\gamma-1}{2}M_2^2}{1+\frac{\gamma-1}{2}M_1^2}\right]^{\frac{\gamma+1}{2(\gamma-1)}} \qquad \text{(A-3)}$$

Rewriting Equation (A-3),

$$M_2 A_2 = M_1 A_1 \left[\frac{(\gamma-1)M_2^2+2}{(\gamma-1)M_1^2+2}\right]^{\frac{\gamma+1}{2(\gamma-1)}} = 0 \qquad \text{(A-4)}$$

The flow Mach number, M_2, can be solved for in Equation (A-4) by trial and error, the Newton-Raphson method, or some other iterative method.

Equation (A-4) is of the form f(M)=0. The solution by the Newton-Raphson method is in the following form:

$$M_{n+1} = M_n - \frac{f(M)}{f'(M)}. \tag{A-5}$$

This numerical technique converges, provided:
1. M_0 is sufficiently close to a root of f(M) = 0,
2. F"(M) does not become excessively large,
3. f'(M) is not close to zero (no two roots too close together.

Equation (A-5) was used to solve for the flow Mach number in region 2, M_2, and the solution is given by Equation (A-6) below.

$$M_{n+1} = M_n - \frac{M_2 A_2 - M_1 A_1 \left[\frac{(\gamma-1)M_2^2+2}{(\gamma-1)M_1^2+2}\right]^{\frac{\gamma+1}{2(\gamma-1)}}}{A_2 - \frac{(\gamma+1)M_1 M_2 A_1}{(\gamma-1)M_1^2+2}\left[\frac{(\gamma-1)M_2^2+2}{(\gamma-1)M_1^2+2}\right]^{\left[\frac{(\gamma+1)-2(\gamma-1)}{2(\gamma-1)}\right]}} \tag{A-6}$$

This equation will be needed in the solution of the primary transmitted shock Mach number, M*.

The Rankine - Hugoniot relations (references 11 and 13) for flow conditions across the shock wave and the ideal gas law can then be used to obtain the following expression involving M*:

$$\left[1 - \frac{\gamma-1}{2\gamma}\frac{P_0}{P_2}\left(\frac{2\gamma}{\gamma-1}M^{*2} + \frac{P_2}{P_0} - 1\right)\right]^2 - \left[\frac{\gamma-1}{2\gamma}\frac{P_0}{P_2}\left(\frac{2\gamma}{\gamma-1}M^{*2} + \frac{P_2}{P_0} - 1\right)\right] \cdot \left[\frac{a_0}{a_2}\left(M^* - \frac{1}{M^*}\right) - \frac{\gamma+1}{2}M_2\right]^2 = 0 \tag{A-7}$$

The solution of Equation (A-7) for M* using Equation (A-5) is given below:

$$M_{n+1}^* = M_n^* - \frac{(1-A)^2 - A\left[B - \left(\frac{\gamma+1}{2}\right)M_2\right]^2}{-\frac{4M^*P_0(1-A)}{P_2} - \frac{2M^*P_0}{P_2}\left[B - \frac{(\gamma+1)}{2}M_2\right]^2 - \frac{2a_0}{a_2}\left[1 + \frac{1}{M^{*2}}\right]A\left[B - \frac{\gamma+1}{2}M_2\right]} \tag{A-8}$$

where

$$A = \frac{\gamma-1}{2\gamma}\frac{P_0}{P_2}\left[\frac{2\gamma}{\gamma-1}M^{*2} + \frac{P_2}{P_0} - 1\right] \tag{A-9}$$

$$B = \frac{a_0}{a_2}\left(M^* - \frac{1}{M^*}\right) \tag{A-10}$$

$$P_2 = P_0\left[\frac{2\gamma}{\gamma+1}M_{s1}^2 - \frac{\gamma-1}{\gamma+1}\right]\left[\frac{(\gamma-1)M_1^2+2}{(\gamma-1)M_2^2+2}\right]^{\frac{\gamma}{\gamma-1}} \tag{A-11}$$

$$a_2 = \frac{2a_0}{(\gamma+1)M_{s1}}\left\{\left[\gamma M_{s1}^2 - \frac{\gamma-1}{2}\right]\left[\frac{\gamma-1}{2}M_{s1}^2+1\right]\left[\frac{(\gamma-1)M_1^2+2}{(\gamma-1)M_2^2+2}\right]\right\}^{1/2} \tag{A-12}$$

Equation (A-8) for M* along with the equations of Appendix B were used to obtain the theoretical curves plotted in the figures of this report. These equations were also used to generate the tables in Appendix C.

Appendix B.

EQUATIONS FOR THE SOLUTION OF THE COMPLETE WAVE SYSTEM AFT OF NOZZLE

Knowing the shock parameters in states 0, 1, and the primary transmitted shock Mach number, M*, the necessary equations to completely solve the wave system after the nozzle are the following:

State 2 Equations:

P_2 is given by Equation (A-11).
a_2 is given by Equation (A-12).
M_2 is given by Equation (A-6).

$$M_{2s} = \left[\frac{P_0}{P_2}\left(M^{*2} - \frac{\gamma-1}{2\gamma}\right) + \frac{\gamma-1}{2\gamma}\right]^{1/2} \tag{B-1}$$

$$W_2 = M_{2s} a_2 \tag{B-2}$$

$$u_2 = M_2 a_2 \tag{B-3}$$

$$T_2 = \frac{a_2^2}{\gamma R} \tag{B-4}$$

$$\rho_2 = \frac{P_2}{RT_2} \tag{B-5}$$

$$P_{t_2} = P_{t_1}, T_{t_2} = T_{t_1}, \rho_{t_2} = \rho_{t_1} \tag{B-6}$$

State 3 Equations:

$$P_3 = \frac{2\gamma P_0}{\gamma+1}\left[M^{*2} - \frac{\gamma-1}{2\gamma}\right] \tag{B-7}$$

$$u_3 = \frac{2a_0 M^*}{\gamma+1}\left[1 - \frac{1}{M^{*2}}\right] \tag{B-8}$$

$$M_3 = \frac{2(M^{*2}-1)}{\left\{\left[2\gamma M^{*2} - (\gamma-1)\right]\left[(\gamma-1)M^{*2} + 2\right]\right\}^{1/2}} \tag{B-9}$$

$$a_3 = \frac{u_3}{M_3} \tag{B-10}$$

$$T_3 = \frac{a_3^2}{\gamma R} \tag{B-11}$$

$$\rho_3 = \frac{P_3}{RT_3} \tag{B-12}$$

State 3' Equations:

$$P_3 = P_3'$$

$$u_3 = u_3'$$

$$M_3' = \left\{ \frac{1 + \frac{\gamma - 1}{2}\left(\frac{u_2 - W_2}{a_2}\right)^2}{\gamma\left(\frac{u_2 - W_2}{a_2}\right)^2 - \left(\frac{\gamma - 1}{2}\right)} \right\}^2 \tag{B-13}$$

$$M_3' = \left\{ \frac{1 + \frac{\gamma - 1}{2} M_{2s}^2}{\gamma M_{2s}^2 - \frac{\gamma - 1}{2}} \right\}^{1/2} \tag{B-14}$$

$$a_3' = u_3' / M_3' \tag{B-15}$$

$$T_3' = \frac{(a_3')^2}{\gamma R} \tag{B-16}$$

$$\rho_3' = \frac{P_3}{R T_3'} \tag{B-17}$$

Appendix C.

FORTRAN COMPUTER CODE, "DIVNOZ", INCORPORATING THE EQUATIONS OF APPENDICES A AND B FOR CALCULATION OF BLAST PARAMETERS TABULATED IN APPENDIX D

```
PROGRAM     DIVNOZ      CDC 6600 FTN V3.0-V258 OPT=1   08/21/72  10.46.53.

                      PROGRAM DIVNOZ(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
                      COMMON PR1(100),UR1(100),TR1(100),FM1(100),FM2(100),
                    1 PR2(100),AR2(100),FMS3(100),PR3(100),UR3(100),FM3(100),
                    2 AR3(100),TR3(100),FMS2(100),TR2(100),UR2(100),PR3P(100),
                    3 UR3P(100),FMS1(100),FM11(100),R(100),FM22(100),
                    4 FMS33(100),R2(100),AR22(100),PR22(100),FM3P(100)
            C
            C         THIS PROGRAM CALCULATES THE BLAST WAVE PARAMETERS AT THE
            C         EXIT OF A DIVERGENT NOZZLE GIVEN THE NOZZLE INLET
            C         CONDITIONS , THE SPECIFIC HEAT RATIO (GAMMA) OF THE
            C         TEST GAS, AND THE AREA RATIO.
            C
            C         NSETS=NUMBER OF SETS OF DATA
            C         M=NUMBER OF PAGES OF OUTPUT
            C         N=NUMBER OF LINES OF OUTPUT
            C
            C         FMS1=MS1=NOZZLE INLET SHOCK MACH NUMBER
            C         FM1=M1=NOZZLE INLET FLOW MACH NUMBER
            C         UR1=U1/A0=NOZZLE INLET FLOW VELOCITY TO INITIAL SONIC
            C                   VELOCITY RATIO
            C         PR1=P1/P0=NOZZLE INLET SHOCK STRENGTH (STATIC PRESSURE
            C                   BEHIND THE SHOCK TO INITIAL PRESSURE RATIO)
            C         TR1=T1/T0=NOZZLE INLET STATIC TEMPERATURE RATIO ACROSS SHOCK
            C
            C
            C
            C         FMS2=MS2=NOZZLE EXIT SECONDARY SHOCK MACH NUMBER
            C         FM2=M2=NOZZLE EXIT FLOW MACH NUMBER UPSTREAM OF THE
            C                   SECONDARY SHOCK FRONT
            C         UR2=U2/A0=NOZZLE EXIT FLOW VELOCITY TO INITIAL SONIC
            C                   VELOCITY RATIO UPSTREAM OF SECONDARY SHOCK FRONTC
            C         PR2=P2/P0=STATIC PRESSURE UPSTREAM OF SECONDARY SHOCK TO
            C                   INITIAL TEST GAS PRESSURE RATIO
            C         TR2=T2/T0=STATIC TEMPERATURE UPSTREAM OF SECONDARY SHOCK
            C                   TO INITIAL TEST GAS TEMPERATURE RATIO
            C
            C         FMS3=MS3=M*=NOZZLE EXIT PRIMARY TRANSMITTED SHOCK MACH NO.
            C         FM3=M3=NOZZLE EXIT PRIMARY TRANSMITTED SHOCK FLOW
            C                   MACH NUMBER
            C         UR3=U3/A0=VELOCITY RATIO ACROSS THE PRIMARY TRANSMITTED SHOCK
            C                   (FLOW TO SONIC VELOCITY)
            C         PR3=P3/P0=SHOCK STRENGTH OR STATIC PRESSURE RATIO
            C                   ACROSS THE PRIMARY TRANSMITTED SHOCK FRONT
            C         TR3=T3/T0=STATIC TEMPERATURE RATIO ACROSS THE PRIMARY
            C                   TRANSMITTED SHOCK FRONT
            C         AR3=A3/A0=SONIC VELOCITY RATIO ACROSS THE PRIMARY TRANSMITTED
            C                   SHOCK FRONT
            C         FM3P=M3(PRIME)=FLOW MACH NUMBER IN THE REGION BETWEEN THE
            C                   SECONDARY SHOCK AND THE CONTACT SURFACE FOLLOWING
            C                   THE PRIMARY TRANSMITTED SHOCK(BEYOND THE NOZZLE)
            C
            C
            C
                      REAL MU
                      READ (5,13)NSETS
```

```
PROGRAM     DIVNOZ    CDC 6600 FTN V3.0-V258 OPT=1   08/21/72  10.46.53.

      13            FORMAT (I2)
                    DO 970 IA=1,NSETS
                    READ (5,15)GA,AR,TMIN,DMS1,TMAX
      15            FORMAT (5F15.7)
                    FM1(1)=0
                    FM1(2)=0
                    FM22(1)=0
                    FMS1(1)=TMIN
                    N=(TMAX-TMIN)/DMS1
                    M=(N/40)+1
                    DO 950 L=1,M
                    WRITE  (6,520)
      520           FORMAT (1H1)
                    WRITE  (6,510)
      510           FORMAT (1H ,* BLAST WAVE PARAMETERS BEFORE AND AFTER A DIVERGENT
                1   NOZZLE *,///)
                    WRITE  (6,530)GA
      530           FORMAT (1H ,* SPECIFIC HEAT RATIO (GAMMA) = *,F6.3)
                    WRITE  (6,540)AR
      540           FORMAT (1H ,* AREA RATIO ACROSS THE DIVERGENT NOZZLE*
                5   * = *,F6.2,//)
                    WRITE  (6,550)
      550           FORMAT (1H ,*(((((((NOZZLE INLET CONDITIONS)))))))))*
                6   *(((((SECONDARY SHOCK CONDITIONS)))))))((PRIMARY *
                7   * TRANSMITTED SHOCK CONDITIONS))*,/)
                    WRITE  (6,560)
      560           FORMAT (1H ,*SHOCK*,3X,*FLOW*,3X,*FLOW*,4X,*SHOCK*,4X,
                8   *TEMP*,3X,*2NDRY*2X,*2NDRY*,3X,*2NDRY*,3X,*2NDRY*,3X,
                9   *2NDRY*,2X,*PRIM*,3X,*PRIM*,3X,*PRIM*,2X,*PRIM*,3X,
                1   *PRIM*,3X,*SONIC*,4X,*MACH NO.*)
                    WRITE  (6,570)
      570           FORMAT (1H ,*MACH*,4X,*MACH*,3X,*VEL.*,4X,*STREN*,4X,
                1   *RATIO*,2X,*SHOCK*,2X,*FLOW*,4X,*FLOW*,4X,*SHOCK*,3X,
                3   *TEMP*,3X,*SHOCK*,2X,*FLOW*,3X,*FLOW*,2X,*SHOCK*,2X,
                4   *TEMP*,3X,*VEL.*,5X,*BET. CONT.*)
                    WRITE  (6,580)
      580           FORMAT (1H ,*NO.*,5X,*NO.*,4X,*RATIO*,19X,*MACH*,3X,
                5   *MACH*,4X,*VEL.*,4X,*STREN*,3X,*RATIO*,2X,*MACH*,3X,
                5   *MACH*,3X,*VEL.*,2X,*STREN.*,1X,*RATIO*,2X,*RATIO*,4X,
                7   *AND 2NDRY*)
                    WRITE  (6,590)
      590           FORMAT (1H ,39X,*NO.*,4X,*NO.*,5X,*RATIO*,18X,
                1   *NO.*,4X,*NO.*,4X,*RATIO*,24X,*SHOCK*,/)
                    WRITE  (6,600)
      600           FORMAT (1H ,*MS1*,5X,*M1*,5X,*U1/A0*,3X,*P1/P0*,4X,
                7   *T1/T0*,2X,*MS2*,4X,*M2*,6X,*U2/A0*,3X,*P2/P0*,
                8   3X,*T2/T0*,2X,*MS3*,4X,*M3*,5X,*U3/A0*,1X,*P3/P0*,
                9   2X,*T3/T0*,2X,*A3/A0*,4X,*M3(PRIME)*,//)
                    DO 900 I=2,42
                    FMS1(I)=FMS1(I-1)+DMS1
                    PR1(I)=((2.*GA)/(GA+1.)*FMS1(I)**2-(GA-1.)/(GA+1.))
                    UR1(I)=(2.*FMS1(I))/(GA+1.)*(1.-(1./FMS1(I)**2))
                    TR1(I)=(PR1(I)*(1.+(GA-1.)/(GA+1.)*PR1(I)))/
                6   ((GA-1.)/(GA+1.)+PR1(I))
                    MU=(GA-1.)/(GA+1.)
```

```
PROGRAM      DIVNOZ    CDC 6600 FTN V3.0-V25B OPT=1   08/21/72  10.46.53.

                       FM1(I)=((1.-MU)*(PR1(I)-1.)*SQRT(1./TR1(I)))/
                   7   (SQRT((1.+MU)*(PR1(I)+MU)))
                       CALL FLOH2 (AR,GA,C1,C2,C3,C4,C5,I)
                       C6=GA/(GA-1.)
 115                   C7=(2.*GA/(GA+1.)*FMS1(I)**2-(GA-1.)/(GA+1.))
                       PR2(I)=C7*(1./C1)**C6
                       C8=(GA*(FMS1(I)**2)-(GA-1.)/2.)
                       C9=((GA-1.)/2.)*(FMS1(I)**2)+1.
                       AR2(I)=(2./((GA+1.)*FMS1(I)))*((C8*C9*(1./C1))**.5)
 120                   CALL SHOM3(GA,I,C10,C11,C12)
                       CALL SYST (GA,I,C13,C14)
                       WRITE  (6,620)(FMS1(I),FM1(I),UR1(I),PR1(I),TR1(I),
                   1   FMS2(I),FM2(I),UR2(I),PR2(I),TR2(I),FMS3(I),
                   2   FM3(I),UR3(I),PR3(I),TR3(I),AR3(I),FM3P(I))
 125          620     FORMAT (1H ,F5.2,3X,F4.2,2X,F5.2,3X,F6.2,3X,F6.2,1X,
                   3   F5.2,1X,F6.2,3X,F5.2,3X,F6.2,3X,F5.2,2X,F5.2,2X,F4.2,2X,
                   4   F5.2,2X,F6.2,1X,F5.2,2X,F4.2,4X,F4.2)
                       IF(I-42)900,805,805
              900      CONTINUE
 130          805      FMS1(1)=FMS1(I)
              950      CONTINUE
              970      CONTINUE
                       STOP
                       END
```

```
CDC 6600 FTN V3.0-V258 OPT=1  08/21/72  10.46.53.

      C     SUBROUTINE FLOW CALCULATES THE FLOW MACH NUMBER
      C     UPSTREAM OF THE SECONDARY SHOCK AND BEYOND THE NOZZLE EXIT
            SUBROUTINE FLOW2 (AR,GA,C1,C2,C3,C4,C5,I)
            COMMON PR1(100),UR1(100),TR1(100),FM1(100),FM2(100),
            PR2(100),AR2(100),FMS3(100),PR3(100),UR3(100),FM3(100),
            AR3(100),TR3(100),FMS2(100),TR2(100),UR2(100),PR3P(100),
            UR3P(100),FMS1(100),FM11(100),R(100),FM22(100),
            FMS33(100),R2(100),AR22(100),PR22(100),FM3P(100)
            FM22(2)=4.1
            DO 800 J=2,200
            C1=((GA-1.)*(FM22(J)**2)+2.)/((GA-1.)*(FM1(I)**2)+2.)
            C2=((GA+1.)-2.*(GA-1.))/(2.*(GA-1.))
            C3=((GA+1.)*FM1(I)*FM22(J))/((GA-1.)*(FM1(I)**2)+2.)
            C4=(GA+1.)/(2.*(GA-1.))
            C5=FM22(J)*AR
            R(J)=(C5-FM1(I)*(C1**C4))/(AR-C3*C1**C2)
            FM22(J+1)=FM22(J)-R(J)
            IF (ABS(FM22(J+1)-FM22(J))-.0005)810,810,800
      800   CONTINUE
      810   FM2(I)=FM22(J+1)
            RETURN
            END
```

```
COC 6600 FTN V3.0-V25B OPT=1  08/21/72  10.46.53.

      C     SUBROUTINE SHOM3 CALCULATES THE NOZZLE EXIT PRIMARY
      C     TRANSMITTED SHOCK MACH NUMBER
            SUBROUTINE SHOM3(GA,I,C10,C11,C12)
            COMMON PR1(100),UR1(100),TR1(100),FM1(100),FM2(100),
        3   PR2(100),AR2(100),FMS3(100),PR3(100),UR3(100),FM3(100),
        4   AR3(100),TR3(100),FMS2(100),TR2(100),UR2(100),PR3P(100),
        5   UR3P(100),FMS1(100),FM11(100),R(100),FM22(100),
        6   FMS33(100),R2(100),AR22(100),PR22(100),FM3P(100)
            FMS33(2)=.75*FMS1(I)
            DO 860 K=2,200
            A=((GA-1.)/(2.*GA))*(1./PR2(I))*((2.*GA/(GA-1.))*(FMS33(K)**2)
        6   +PR2(I)-1.)
            B=(1./AR2(I))*(FMS33(K)-(1./FMS33(K)))
            C12=1.-A
            C10=(B-((GA+1.)/2.)*FM2(I))
            C11=1.+(1./(FMS33(K)**2))
            R2(K)=(C12**2-(A*(C10**2)))/((-4.*FMS33(K)*(1./PR2(I))
        7   *C12)-(2.*FMS33(K)*(1./PR2(I))*C10**2)-(2.*(1./AR2(I))
        8   *A*C11*C10))
            FMS33(K+1)=FMS33(K)-P2(K)
            IF (ABS(FMS33(K+1)-FMS33(K))-.0005)870,870,860
      860   CONTINUE
      870   FMS3(I)=FMS33(K+1)
            RETURN
            END
```

```
CDC 6600 FTN V3.0-V258 OPT=1  08/21/72  10.46.53.

      C     SUBROUTINE SYST CALCULATES THE SYSTEM BLAST PARAMETERS
      C     BETWEEN THE PRIMARY TRANSMITTED SHOCK AND THE SECONDARY
      C     SHOCK FRONT
            SUBROUTINE SYST (GA,I,C13,C14)
            COMMON PR1(100),UR1(100),TR1(100),FM1(100),FM2(100),
          9 PR2(100),AR2(100),FMS3(100),PR3(100),UR3(100),FM3(100),
          1 AR3(100),TR3(100),FMS2(100),TR2(100),UR2(100),PR3P(100),
          2 UR3P(100),FMS1(100),FM11(100),R(100),FM22(100),
          7 FMS33(100),R2(100),AR22(100),PR22(100),FM3P(100)
            PR3(I)=2.*GA/(GA+1.)*(FMS3(I)**2-(GA-1.)/2.)
            UR3(I)=2.*FMS3(I)/(GA+1.)*(1.-1./FMS3(I)**2)
            C13=2.*GA*FMS3(I)**2-(GA-1.)
            C14=((GA-1.)*FMS3(I)**2+2.)
            FM3(I)=2.*(FMS3(I)**2-1.)/(C13*C14)**.5
            AR3(I)=UR3(I)/FM3(I)
            TR3(I)=AR3(I)**2
            FMS2(I)=(1./PR2(I)*(FMS3(I)**2-(GA-1.)/(2.*GA))
          3 +(GA-1.)/(2.*GA))**.5
            TR2(I)=AR2(I)**2
            UR2(I)=FM2(I)*AR2(I)
            PR3P(I)=PR3(I)
            UR3P(I)=UR3(I)
            FM3P(I)=((1.+((GA-1.)/2.)*(FMS2(I)**2))/(GA*(FMS2(I)**2)
          2 -((GA-1.)/2.)))**.5
            RETURN
            END
```

Appendix D.

TABLES FOR BLAST PARAMETERS ACROSS A DIVERGENT CONICAL SECTION FOR A SPECIFIC HEAT RATIO(GAMMA) OF 1.4(AIR) AND VARIOUS AREA RATIOS BETWEEN 1.0 AND 15.0

BLAST WAVE PARAMETERS BEFORE AND AFTER A DIVERGENT NOZZLE

TABLE D-I

SPECIFIC HEAT RATIO (GAMMA) = 1.400
AREA RATIO ACROSS THE DIVERGENT NOZZLE = 1.00

(((((NOZZLE INLET CONDITIONS))))))					(((((SECONDARY SHOCK CONDITIONS)))))					(((PRIMARY TRANSMITTED SHOCK CONDITIONS)))						
SHOCK MACH NO.	FLOW MACH NO.	FLOW VEL. RATIO	SHOCK STREN	TEMP RATIO	2NDRY SHOCK MACH NO.	2NDRY FLOW MACH NO.	2NDRY FLOW VEL. RATIO	2NDRY SHOCK STREN	2NDRY TEMP RATIO	PRIM SHOCK MACH NO.	PRIM FLOW MACH NO.	PRIM FLOW VEL. RATIO	PRIM SHOCK STREN.	PRIM TEMP RATIO	SONIC VEL. RATIO	MACH NO. BET. CONT. AND 2NDRY SHOCK
MS1	M1	U1/A0	P1/P0	T1/T0	MS2	M2	U2/A0	P2/P0	T2/T0	MS3	M3	U3/A0	P3/P0	T3/T0	A3/A0	M3(PRIME)
2.20	1.07	1.45	5.48	1.86	1.00	1.07	1.45	5.48	1.86	2.20	1.07	1.45	5.41	1.86	1.36	1.00
2.30	1.11	1.55	6.00	1.95	1.00	1.11	1.55	6.00	1.95	2.30	1.11	1.56	5.94	1.95	1.40	1.00
2.40	1.16	1.65	6.55	2.04	1.00	1.16	1.65	6.55	2.04	2.40	1.16	1.65	6.49	2.04	1.43	1.00
2.50	1.20	1.75	7.12	2.14	1.00	1.20	1.75	7.12	2.14	2.50	1.20	1.75	7.07	2.14	1.46	1.00
2.60	1.23	1.85	7.72	2.24	1.00	1.23	1.85	7.72	2.24	2.60	1.23	1.85	7.66	2.24	1.50	1.00
2.70	1.27	1.94	8.34	2.34	1.00	1.27	1.94	8.34	2.34	2.70	1.27	1.94	8.27	2.34	1.53	1.00
2.80	1.30	2.04	8.98	2.45	1.00	1.30	2.04	8.98	2.45	2.80	1.30	2.04	8.92	2.45	1.57	1.00
2.90	1.33	2.13	9.64	2.56	1.00	1.33	2.13	9.64	2.56	2.90	1.33	2.13	9.58	2.56	1.60	1.00
3.00	1.36	2.22	10.33	2.68	1.00	1.36	2.22	10.33	2.68	3.00	1.36	2.22	10.27	2.68	1.64	1.00
3.10	1.38	2.31	11.04	2.80	1.00	1.38	2.31	11.04	2.80	3.10	1.38	2.31	10.98	2.80	1.67	1.00
3.20	1.41	2.41	11.78	2.92	1.00	1.41	2.41	11.77	2.92	3.20	1.41	2.41	11.74	2.93	1.71	1.00
3.30	1.43	2.50	12.54	3.05	1.00	1.43	2.50	12.53	3.05	3.30	1.43	2.50	12.49	3.05	1.75	1.00
3.40	1.45	2.59	13.32	3.18	1.00	1.45	2.59	13.32	3.18	3.40	1.45	2.59	13.26	3.18	1.78	1.00
3.50	1.47	2.68	14.12	3.32	1.00	1.47	2.68	14.12	3.31	3.50	1.47	2.68	14.07	3.32	1.82	1.00
3.60	1.49	2.77	14.95	3.45	1.00	1.49	2.77	14.95	3.45	3.60	1.49	2.77	14.89	3.45	1.86	1.00
3.70	1.51	2.86	15.80	3.60	1.00	1.51	2.86	15.80	3.60	3.70	1.51	2.86	15.74	3.60	1.90	1.00
3.80	1.52	2.95	16.68	3.74	1.00	1.52	2.95	16.68	3.74	3.80	1.52	2.95	16.62	3.74	1.93	1.00
3.90	1.54	3.04	17.58	3.89	1.00	1.54	3.04	17.58	3.89	3.90	1.54	3.04	17.52	3.89	1.97	1.00
4.00	1.56	3.12	18.50	4.05	1.00	1.55	3.12	18.50	4.05	4.00	1.55	3.13	18.44	4.05	2.01	1.00
4.10	1.57	3.21	19.44	4.20	1.00	1.57	3.21	19.44	4.20	4.10	1.57	3.21	19.38	4.21	2.05	1.00
4.20	1.58	3.30	20.41	4.37	1.00	1.58	3.30	20.41	4.37	4.20	1.58	3.30	20.35	4.37	2.09	1.00
4.30	1.59	3.39	21.40	4.53	1.00	1.59	3.39	21.40	4.53	4.30	1.59	3.39	21.34	4.53	2.13	1.00
4.40	1.60	3.48	22.42	4.70	1.00	1.60	3.48	22.42	4.70	4.40	1.60	3.48	22.36	4.70	2.17	1.00
4.50	1.61	3.56	23.46	4.88	1.00	1.61	3.56	23.46	4.88	4.50	1.61	3.57	23.40	4.88	2.21	1.00
4.60	1.62	3.65	24.52	5.05	1.00	1.62	3.65	24.52	5.05	4.60	1.62	3.65	24.46	5.05	2.25	1.00
4.70	1.63	3.74	25.60	5.23	1.00	1.63	3.74	25.60	5.23	4.70	1.63	3.74	25.54	5.23	2.29	1.00
4.80	1.64	3.83	26.71	5.42	1.00	1.64	3.83	26.71	5.42	4.80	1.64	3.83	26.65	5.42	2.33	1.00
4.90	1.65	3.91	27.84	5.61	1.00	1.65	3.91	27.84	5.61	4.90	1.65	3.91	27.78	5.61	2.37	1.00
5.00	1.66	4.00	29.00	5.80	1.00	1.66	4.00	29.00	5.80	5.00	1.66	4.00	28.94	5.80	2.41	1.00
5.10	1.67	4.09	30.18	6.00	1.00	1.67	4.09	30.18	6.00	5.10	1.67	4.09	30.12	6.00	2.45	1.00
5.20	1.68	4.17	31.38	6.20	1.00	1.68	4.17	31.38	6.20	5.20	1.68	4.17	31.32	6.20	2.49	1.00
5.30	1.68	4.26	32.60	6.40	1.00	1.68	4.26	32.60	6.40	5.30	1.68	4.26	32.54	6.40	2.53	1.00
5.40	1.69	4.35	33.85	6.61	1.00	1.69	4.35	33.85	6.61	5.40	1.69	4.35	33.79	6.61	2.57	1.00
5.50	1.70	4.43	35.12	6.82	1.00	1.70	4.43	35.12	6.82	5.50	1.70	4.43	35.06	6.82	2.61	1.00
5.60	1.70	4.52	36.42	7.04	1.00	1.70	4.52	36.42	7.04	5.60	1.70	4.52	36.36	7.04	2.65	1.00
5.70	1.71	4.60	37.74	7.26	1.00	1.71	4.60	37.74	7.26	5.70	1.71	4.60	37.68	7.26	2.69	1.00
5.80	1.71	4.69	39.08	7.48	1.00	1.71	4.69	39.08	7.48	5.80	1.71	4.69	39.02	7.48	2.74	1.00
5.90	1.72	4.78	40.44	7.71	1.00	1.72	4.78	40.44	7.71	5.90	1.72	4.78	40.38	7.71	2.78	1.00
6.00	1.73	4.86	41.83	7.94	1.00	1.73	4.86	41.83	7.94	6.00	1.73	4.86	41.77	7.94	2.82	1.00
6.10	1.73	4.95	43.24	8.18	1.00	1.73	4.95	43.24	8.18	6.10	1.73	4.95	43.18	8.18	2.86	1.00
6.20	1.73	5.03	44.68	8.42	1.00	1.73	5.03	44.68	8.42	6.20	1.73	5.03	44.62	8.42	2.90	1.00

BLAST WAVE PARAMETERS BEFORE AND AFTER A DIVERGENT NOZZLE

TABLE D-I

SPECIFIC HEAT RATIO (GAMMA) = 1.400
AREA RATIO ACROSS THE DIVERGENT NOZZLE = 1.00

((((((NOZZLE INLET CONDITIONS))					(((((SECONDARY SHOCK CONDITIONS))					((PRIMARY TRANSMITTED SHOCK CONDITIONS))						
SHOCK MACH NO. MS1	FLOW MACH NO. M1	FLOW VEL. RATIO V1/A0	SHOCK STREN P1/P0	TEMP RATIO T1/T0	2NDRY SHOCK MACH NO. MS2	2NDRY FLOW MACH NO. M2	2NDRY FLOW VEL. RATIO V2/A0	2NDRY SHOCK STREN P2/P0	2NDRY TEMP RATIO T2/T0	PRIM SHOCK MACH NO. MS3	PRIM FLOW MACH NO. M3	PRIM FLOW VEL. RATIO V3/A0	PRIM SHOCK STREN. P3/P0	PRIM TEMP RATIO T3/T0	SONIC VEL. RATIO A3/A0	MACH NO. BET. CONT. AND 2NDRY SHOCK M3(PRIME)
6.30	1.74	5.12	45.14	8.66	1.00	1.74	5.12	46.14	8.66	6.30	1.74	5.12	46.08	8.66	2.94	1.00
6.40	1.74	5.20	47.62	8.91	1.00	1.74	5.20	47.62	8.91	6.40	1.74	5.20	47.56	8.91	2.98	1.00
6.50	1.75	5.29	49.12	9.16	1.00	1.75	5.29	49.12	9.16	6.50	1.75	5.29	49.06	9.16	3.03	1.00
6.60	1.75	5.37	50.65	9.41	1.00	1.75	5.37	50.65	9.41	6.60	1.75	5.37	50.59	9.41	3.07	1.00
6.70	1.76	5.46	52.20	9.67	1.00	1.76	5.46	52.17	9.67	6.71	1.76	5.46	52.23	9.68	3.11	1.00
6.80	1.76	5.54	53.78	9.93	1.00	1.76	5.54	53.74	9.93	6.81	1.76	5.55	53.80	9.95	3.15	1.00
6.90	1.76	5.63	55.38	10.20	1.00	1.76	5.63	55.34	10.20	6.91	1.76	5.63	55.40	10.21	3.20	1.00
7.00	1.77	5.71	57.00	10.47	1.00	1.77	5.71	56.96	10.47	7.01	1.77	5.72	57.02	10.48	3.24	1.00
7.10	1.77	5.80	58.64	10.74	1.00	1.77	5.80	58.61	10.74	7.11	1.77	5.80	58.66	10.76	3.28	1.00
7.20	1.77	5.88	60.31	11.02	1.00	1.77	5.88	60.28	11.02	7.20	1.77	5.89	60.33	11.04	3.32	1.00
7.30	1.78	5.97	62.00	11.30	1.00	1.78	5.97	61.97	11.30	7.30	1.78	5.97	62.02	11.32	3.36	1.00
7.40	1.78	6.05	63.72	11.59	1.00	1.78	6.05	63.68	11.59	7.40	1.78	6.06	63.73	11.60	3.41	1.00
7.50	1.78	6.14	65.46	11.88	1.00	1.78	6.14	65.42	11.88	7.50	1.78	6.14	65.47	11.89	3.45	1.00
7.60	1.78	6.22	67.22	12.17	1.00	1.78	6.22	67.18	12.17	7.60	1.78	6.23	67.23	12.19	3.49	1.00
7.70	1.79	6.31	69.00	12.47	1.00	1.79	6.31	68.97	12.47	7.70	1.79	6.31	69.02	12.48	3.53	1.00
7.80	1.79	6.39	70.81	12.77	1.00	1.79	6.33	70.78	12.77	7.80	1.79	6.40	70.82	12.79	3.58	1.00
7.90	1.79	6.48	72.64	13.08	1.00	1.79	6.48	72.61	13.08	7.90	1.79	6.48	72.66	13.09	3.62	1.00
8.00	1.79	6.56	74.50	13.39	1.00	1.79	6.56	74.46	13.38	8.00	1.79	6.57	74.51	13.40	3.66	1.00
8.10	1.80	6.65	76.38	13.70	1.00	1.80	6.65	76.34	13.70	8.10	1.80	6.65	76.39	13.71	3.70	1.00
8.20	1.80	6.73	78.28	14.02	1.00	1.80	6.73	78.25	14.02	8.20	1.80	6.74	78.29	14.03	3.75	1.00
8.30	1.80	6.82	80.20	14.34	1.00	1.80	6.82	80.17	14.34	8.30	1.80	6.82	80.21	14.35	3.79	1.00
8.40	1.80	6.90	82.15	14.66	1.00	1.80	6.90	82.12	14.66	8.40	1.80	6.90	82.16	14.68	3.83	1.00
8.50	1.80	6.99	84.12	14.99	1.00	1.80	6.98	84.09	14.99	8.50	1.80	6.99	84.13	15.00	3.87	1.00
8.60	1.81	7.07	86.12	15.32	1.00	1.81	7.07	86.09	15.32	8.60	1.81	7.07	86.13	15.34	3.92	1.00
8.70	1.81	7.15	88.14	15.66	1.00	1.81	7.15	88.10	15.66	8.70	1.81	7.16	88.15	15.67	3.96	1.00
8.80	1.81	7.24	90.18	16.00	1.00	1.81	7.24	90.14	16.00	8.80	1.81	7.24	90.19	16.01	4.00	1.00
8.90	1.81	7.32	92.24	16.34	1.00	1.81	7.32	92.21	16.34	8.90	1.81	7.33	92.25	16.36	4.04	1.00
9.00	1.81	7.41	94.33	16.69	1.00	1.81	7.41	94.30	16.69	9.00	1.81	7.41	94.34	16.71	4.09	1.00
9.10	1.81	7.49	96.44	17.04	1.00	1.81	7.49	96.41	17.04	9.10	1.81	7.49	96.45	17.06	4.13	1.00
9.20	1.82	7.58	98.58	17.40	1.00	1.82	7.58	98.54	17.40	9.20	1.82	7.58	98.59	17.41	4.17	1.00
9.30	1.82	7.66	100.74	17.76	1.00	1.82	7.66	100.70	17.76	9.30	1.82	7.66	100.75	17.77	4.22	1.00
9.40	1.82	7.74	102.92	18.12	1.00	1.82	7.74	102.88	18.12	9.40	1.82	7.75	102.93	18.14	4.26	1.00
9.50	1.82	7.83	105.12	18.49	1.00	1.82	7.83	105.09	18.49	9.50	1.82	7.83	105.13	18.50	4.30	1.00
9.60	1.82	7.91	107.35	18.86	1.00	1.82	7.91	107.32	18.86	9.60	1.82	7.92	107.36	18.88	4.34	1.00
9.70	1.82	8.00	109.60	19.24	1.00	1.82	8.00	109.57	19.24	9.70	1.82	8.00	109.61	19.25	4.39	1.00
9.80	1.82	8.08	111.88	19.62	1.00	1.82	8.08	111.84	19.62	9.80	1.82	8.08	111.89	19.63	4.43	1.00
9.90	1.83	8.17	114.18	20.00	1.00	1.83	8.17	114.14	20.00	9.90	1.83	8.17	114.19	20.01	4.47	1.00
10.00	1.83	8.25	116.50	20.39	1.00	1.83	8.25	116.46	20.39	10.00	1.83	8.25	116.51	20.40	4.52	1.00
10.10	1.83	8.33	118.84	20.78	1.00	1.83	8.33	118.81	20.78	10.10	1.83	8.34	118.86	20.79	4.56	1.00
10.20	1.83	8.42	121.21	21.17	1.00	1.83	8.42	121.18	21.17	10.20	1.83	8.42	121.22	21.19	4.60	1.00
10.30	1.83	8.50	123.60	21.57	1.00	1.83	8.50	123.57	21.57	10.30	1.83	8.51	123.62	21.58	4.65	1.00

BLAST WAVE PARAMETERS BEFORE AND AFTER A DIVERGENT NOZZLE

TABLE D-II

SPECIFIC HEAT RATIO (GAMMA) = 1.400
AREA RATIO ACROSS THE DIVERGENT NOZZLE = 1.78

((((((NOZZLE INLET CONDITIONS))))))))))					((((((SECONDARY SHOCK CONDITIONS))))))))					((PRIMARY TRANSMITTED SHOCK CONDITIONS))						
SHOCK MACH NO. MS1	FLOW MACH NO. M1	FLOW VEL. RATIO U1/A0	SHOCK STREN P1/P0	TEMP RATIO T1/T0	2NDRY SHOCK MACH NO. MS2	2NDRY FLOW MACH NO. M2	2NDRY FLOW VEL. RATIO U2/A0	2NDRY SHOCK STREN P2/P0	2NDRY TEMP RATIO T2/T0	PRIM SHOCK MACH NO. MS3	PRIM FLOW MACH NO. M3	PRIM FLOW VEL. RATIO U3/A0	PRIM SHOCK STREN. P3/P0	PRIM TEMP RATIO T3/T0	SONIC VEL. RATIO A3/A0	MACH NO. BET. CONT. AND 2NDRY SHOCK M3(PRIME)
2.20	1.07	1.45	5.48	1.86	1.74	2.07	2.29	1.29	1.23	1.97	.94	1.22	4.28	1.66	1.29	.63
2.30	1.11	1.55	6.00	1.95	1.70	2.08	2.37	1.44	1.31	2.06	.99	1.31	4.70	1.73	1.32	.64
2.40	1.16	1.65	6.55	2.04	1.67	2.09	2.45	1.68	1.38	2.15	1.04	1.40	5.14	1.81	1.35	.65
2.50	1.20	1.75	7.12	2.14	1.65	2.10	2.54	1.89	1.46	2.23	1.08	1.49	5.59	1.89	1.37	.65
2.60	1.23	1.85	7.72	2.24	1.62	2.11	2.62	2.11	1.54	2.32	1.12	1.58	6.07	1.97	1.40	.66
2.70	1.27	1.94	8.34	2.34	1.61	2.12	2.71	2.33	1.63	2.41	1.16	1.67	6.56	2.05	1.43	.67
2.80	1.30	2.04	8.98	2.45	1.59	2.14	2.80	2.57	1.71	2.50	1.20	1.75	7.07	2.14	1.46	.67
2.90	1.33	2.13	9.64	2.56	1.58	2.15	2.89	2.81	1.80	2.59	1.23	1.84	7.59	2.23	1.49	.68
3.00	1.36	2.22	10.33	2.68	1.56	2.17	2.98	3.06	1.89	2.68	1.26	1.92	8.14	2.32	1.52	.68
3.10	1.38	2.31	11.04	2.80	1.55	2.18	3.07	3.32	1.98	2.77	1.29	2.00	8.70	2.42	1.55	.68
3.20	1.41	2.41	11.78	2.92	1.54	2.19	3.16	3.58	2.08	2.86	1.32	2.09	9.28	2.51	1.59	.69
3.30	1.43	2.50	12.54	3.05	1.53	2.21	3.25	3.86	2.18	2.94	1.34	2.17	9.88	2.61	1.62	.69
3.40	1.45	2.59	13.32	3.18	1.53	2.22	3.35	4.14	2.28	3.03	1.37	2.25	10.50	2.72	1.65	.69
3.50	1.47	2.68	14.12	3.32	1.52	2.23	3.44	4.44	2.38	3.12	1.39	2.33	11.14	2.83	1.68	.69
3.60	1.49	2.77	14.95	3.45	1.51	2.24	3.54	4.74	2.49	3.21	1.41	2.42	11.79	2.94	1.71	.70
3.70	1.51	2.86	15.80	3.60	1.51	2.25	3.63	5.05	2.60	3.30	1.43	2.50	12.47	3.05	1.75	.70
3.80	1.52	2.95	16.68	3.74	1.50	2.26	3.72	5.36	2.71	3.39	1.45	2.58	13.16	3.16	1.78	.70
3.90	1.54	3.04	17.58	3.89	1.50	2.27	3.82	5.68	2.82	3.48	1.47	2.66	13.86	3.28	1.81	.70
4.00	1.55	3.12	18.50	4.05	1.49	2.28	3.91	6.02	2.94	3.56	1.48	2.74	14.59	3.40	1.85	.70
4.10	1.57	3.21	19.44	4.20	1.49	2.29	4.01	6.36	3.06	3.65	1.50	2.82	15.34	3.53	1.88	.70
4.20	1.58	3.30	20.41	4.37	1.49	2.30	4.10	6.71	3.18	3.74	1.51	2.90	16.10	3.66	1.91	.71
4.30	1.59	3.39	21.40	4.53	1.48	2.31	4.20	7.07	3.30	3.83	1.53	2.97	16.89	3.79	1.95	.71
4.40	1.60	3.48	22.42	4.70	1.48	2.32	4.29	7.44	3.43	3.92	1.54	3.05	17.69	3.92	1.98	.71
4.50	1.61	3.56	23.46	4.88	1.48	2.33	4.39	7.81	3.56	4.01	1.55	3.13	18.51	4.06	2.02	.71
4.60	1.62	3.65	24.52	5.05	1.47	2.33	4.49	8.20	3.69	4.10	1.57	3.21	19.35	4.20	2.05	.71
4.70	1.63	3.74	25.60	5.23	1.47	2.34	4.58	8.59	3.83	4.19	1.58	3.29	20.21	4.34	2.08	.71
4.80	1.64	3.83	26.71	5.42	1.47	2.35	4.68	8.99	3.97	4.28	1.59	3.37	21.09	4.49	2.12	.71
4.90	1.65	3.91	27.84	5.61	1.47	2.35	4.77	9.40	4.11	4.36	1.60	3.45	21.98	4.64	2.15	.71
5.00	1.66	4.00	29.00	5.80	1.47	2.36	4.87	9.82	4.26	4.45	1.61	3.52	22.90	4.79	2.19	.71
5.10	1.67	4.09	30.18	6.00	1.46	2.37	4.97	10.24	4.40	4.54	1.62	3.60	23.83	4.95	2.22	.71
5.20	1.68	4.17	31.38	6.20	1.46	2.37	5.06	10.68	4.55	4.63	1.63	3.68	24.79	5.11	2.26	.72
5.30	1.68	4.26	32.60	6.40	1.46	2.38	5.16	11.12	4.71	4.72	1.64	3.76	25.75	5.27	2.30	.72
5.40	1.69	4.35	33.85	6.61	1.46	2.38	5.25	11.57	4.86	4.81	1.64	3.83	26.74	5.43	2.33	.72
5.50	1.70	4.43	35.12	6.82	1.46	2.39	5.35	12.03	5.02	4.90	1.65	3.91	27.74	5.60	2.37	.72
5.60	1.70	4.52	36.42	7.04	1.46	2.39	5.45	12.50	5.18	4.99	1.66	3.99	28.77	5.77	2.40	.72
5.70	1.71	4.60	37.74	7.26	1.45	2.40	5.54	12.98	5.35	5.07	1.67	4.06	29.81	5.95	2.44	.72
5.80	1.71	4.69	39.08	7.48	1.45	2.40	5.64	13.46	5.52	5.16	1.67	4.14	30.87	6.12	2.47	.72
5.90	1.72	4.78	40.44	7.71	1.45	2.41	5.74	13.95	5.69	5.25	1.68	4.22	31.95	6.30	2.51	.72
6.00	1.73	4.86	41.83	7.94	1.45	2.41	5.83	14.46	5.86	5.34	1.69	4.29	33.05	6.49	2.55	.72
6.10	1.73	4.95	43.24	8.18	1.45	2.41	5.93	14.97	6.04	5.43	1.69	4.37	34.17	6.67	2.58	.72
6.20	1.73	5.03	44.68	8.42	1.45	2.42	6.03	15.48	6.22	5.52	1.70	4.45	35.30	6.86	2.62	.72

BLAST WAVE PARAMETERS BEFORE AND AFTER A DIVERGENT NOZZLE

TABLE D-II (Cont.)

SPECIFIC HEAT RATIO (GAMMA) = 1.400
AREA RATIO ACROSS THE DIVERGENT NOZZLE = 1.78

((((((NOZZLE INLET CONDITIONS))))))))))					((((((SECONDARY SHOCK CONDITIONS))))))))					((PRIMARY TRANSMITTED SHOCK CONDITIONS))						
SHOCK MACH NO.	FLOW MACH NO.	FLOW VEL. RATIO	SHOCK STREN	TEMP RATIO	2NDRY SHOCK MACH NO.	2NDRY FLOW MACH NO.	2NDRY FLOW VEL. RATIO	2NDRY SHOCK STREN	2NDRY TEMP RATIO	PRIM SHOCK MACH NO.	PRIM FLOW MACH NO.	PRIM FLOW VEL. RATIO	PRIM SHOCK STREN.	PRIM TEMP RATIO	SONIC VEL. RATIO	MACH NO. BET. CONT. AND 2NDRY SHOCK
MS1	M1	U1/A0	P1/P0	T1/T0	MS2	M2	U2/A0	P2/P0	T2/T0	MS3	M3	U3/A0	P3/P0	T3/T0	A3/A0	M3(PRIME)
6.30	1.74	5.12	46.14	8.66	1.45	2.42	6.12	16.01	6.40	5.61	1.70	4.52	36.45	7.05	2.66	.72
6.40	1.74	5.20	47.62	8.91	1.45	2.42	6.22	16.55	6.58	5.70	1.71	4.60	37.63	7.25	2.69	.72
6.50	1.75	5.29	49.12	9.16	1.45	2.43	6.32	17.09	6.77	5.79	1.71	4.68	38.82	7.45	2.73	.72
6.60	1.75	5.37	50.65	9.41	1.45	2.43	6.41	17.64	6.96	5.87	1.72	4.75	40.03	7.65	2.77	.72
6.70	1.76	5.46	52.20	9.67	1.45	2.43	6.51	18.20	7.16	5.96	1.72	4.83	41.25	7.85	2.80	.72
6.80	1.76	5.54	53.78	9.93	1.44	2.44	6.61	18.77	7.35	6.05	1.73	4.91	42.50	8.06	2.84	.72
6.90	1.76	5.63	55.38	10.20	1.44	2.44	6.70	19.35	7.55	6.14	1.73	4.98	43.76	8.27	2.88	.72
7.00	1.77	5.71	57.00	10.47	1.44	2.44	6.80	19.93	7.75	6.23	1.74	5.06	45.05	8.49	2.91	.72
7.10	1.77	5.80	58.64	10.74	1.44	2.44	6.90	20.53	7.96	6.32	1.74	5.13	46.35	8.70	2.95	.72
7.20	1.77	5.88	60.31	11.02	1.44	2.45	6.99	21.13	8.17	6.41	1.74	5.21	47.67	8.92	2.99	.72
7.30	1.78	5.97	62.00	11.30	1.44	2.45	7.09	21.74	8.38	6.50	1.75	5.29	49.01	9.15	3.02	.72
7.40	1.78	6.05	63.72	11.59	1.44	2.45	7.19	22.36	8.59	6.59	1.75	5.36	50.36	9.37	3.06	.72
7.50	1.78	6.14	65.46	11.88	1.44	2.45	7.28	22.99	8.81	6.67	1.75	5.44	51.74	9.60	3.10	.72
7.60	1.78	6.22	67.22	12.17	1.44	2.46	7.38	23.62	9.03	6.76	1.76	5.51	53.13	9.84	3.14	.72
7.70	1.79	6.31	69.00	12.47	1.44	2.46	7.48	24.27	9.25	6.85	1.76	5.59	54.54	10.07	3.17	.72
7.80	1.79	6.39	70.81	12.77	1.44	2.46	7.57	24.92	9.48	6.94	1.76	5.66	55.97	10.31	3.21	.72
7.90	1.79	6.48	72.64	13.08	1.44	2.46	7.67	25.58	9.71	7.03	1.77	5.74	57.42	10.55	3.25	.72
8.00	1.79	6.56	74.50	13.39	1.44	2.46	7.77	26.25	9.94	7.12	1.77	5.82	58.89	10.80	3.29	.72
8.10	1.80	6.65	76.38	13.70	1.44	2.47	7.86	26.93	10.17	7.21	1.77	5.89	60.38	11.04	3.32	.72
8.20	1.80	6.73	78.28	14.02	1.44	2.47	7.96	27.61	10.41	7.30	1.78	5.97	61.88	11.29	3.36	.72
8.30	1.80	6.82	80.20	14.34	1.44	2.47	8.06	28.31	10.65	7.39	1.78	6.04	63.40	11.55	3.40	.72
8.40	1.80	6.90	82.15	14.66	1.44	2.47	8.15	29.01	10.89	7.47	1.78	6.12	64.95	11.81	3.44	.72
8.50	1.80	6.99	84.12	14.99	1.44	2.47	8.25	29.72	11.14	7.56	1.78	6.19	66.51	12.07	3.47	.72
8.60	1.81	7.07	86.12	15.32	1.44	2.47	8.35	30.44	11.38	7.65	1.79	6.27	68.08	12.33	3.51	.73
8.70	1.81	7.15	88.14	15.66	1.44	2.48	8.44	31.17	11.64	7.74	1.79	6.34	69.68	12.59	3.55	.73
8.80	1.81	7.24	90.18	16.00	1.44	2.48	8.54	31.91	11.89	7.83	1.79	6.42	71.30	12.86	3.59	.73
8.90	1.81	7.32	92.24	16.34	1.43	2.48	8.64	32.65	12.15	7.92	1.79	6.49	72.93	13.14	3.62	.73
9.00	1.81	7.41	94.33	16.69	1.43	2.48	8.73	33.41	12.41	8.01	1.79	6.57	74.58	13.41	3.66	.73
9.10	1.81	7.49	96.44	17.04	1.43	2.48	8.83	34.17	12.67	8.10	1.80	6.64	76.25	13.69	3.70	.73
9.20	1.82	7.58	98.58	17.40	1.43	2.48	8.93	34.94	12.94	8.19	1.80	6.72	77.94	13.97	3.74	.73
9.30	1.82	7.66	100.74	17.76	1.43	2.48	9.02	35.72	13.21	8.27	1.80	6.79	79.65	14.26	3.78	.73
9.40	1.82	7.74	102.92	18.12	1.43	2.48	9.12	36.51	13.48	8.36	1.80	6.87	81.37	14.54	3.81	.73
9.50	1.82	7.83	105.12	18.49	1.43	2.49	9.22	37.30	13.75	8.45	1.80	6.95	83.12	14.83	3.85	.73
9.60	1.82	7.91	107.35	18.86	1.43	2.49	9.32	38.11	14.03	8.54	1.80	7.02	84.88	15.13	3.89	.73
9.70	1.82	8.00	109.60	19.24	1.43	2.49	9.41	38.92	14.31	8.63	1.81	7.10	86.66	15.43	3.93	.73
9.80	1.82	8.08	111.88	19.62	1.43	2.49	9.51	39.74	14.60	8.72	1.81	7.17	88.46	15.73	3.97	.73
9.90	1.83	8.17	114.18	20.00	1.43	2.49	9.61	40.57	14.88	8.81	1.81	7.25	90.28	16.03	4.00	.73
10.00	1.83	8.25	116.50	20.39	1.43	2.49	9.70	41.41	15.17	8.90	1.81	7.32	92.12	16.33	4.04	.73
10.10	1.83	8.33	118.84	20.78	1.43	2.49	9.80	42.25	15.46	8.99	1.81	7.40	93.97	16.64	4.08	.73
10.20	1.83	8.42	121.21	21.17	1.43	2.49	9.90	43.11	15.76	9.07	1.81	7.47	95.85	16.96	4.12	.73
10.30	1.83	8.50	123.60	21.57	1.43	2.49	9.99	43.97	16.06	9.16	1.82	7.55	97.74	17.27	4.16	.73

BLAST WAVE PARAMETERS BEFORE AND AFTER A DIVERGENT NOZZLE

TABLE D-III

SPECIFIC HEAT RATIO (GAMMA) = 1.400
AREA RATIO ACROSS THE DIVERGENT NOZZLE = 2.55

(((((NOZZLE INLET CONDITIONS))					(((((SECONDARY SHOCK CONDITIONS))					(((PRIMARY TRANSMITTED SHOCK CONDITIONS))						
SHOCK MACH NO.	FLOW MACH NO.	FLOW VEL. RATIO	SHOCK STREN	TEMP RATIO	2NDRY SHOCK MACH NO.	2NDRY FLOW MACH NO.	2NDRY FLOW VEL. RATIO	2NDRY SHOCK STREN	2NDRY TEMP RATIO	PRIM SHOCK MACH NO.	PRIM FLOW MACH NO.	PRIM FLOW VEL. RATIO	PRIM SHOCK STREN.	PRIM TEMP RATIO	SONIC VEL. RATIO	MACH NO. BET. CONT. AND 2NDRY SHOCK
MS1	M1	U1/A0	P1/P0	T1/T0	MS2	M2	U2/A0	P2/P0	T2/T0	MS3	M3	U3/A0	P3/P0	T3/T0	A3/A0	M3(PRIME)
2.20	1.07	1.45	5.48	1.86	2.17	2.47	2.50	.69	1.03	1.82	.85	1.06	3.62	1.55	1.24	.55
2.30	1.11	1.55	6.00	1.95	2.12	2.48	2.59	.79	1.09	1.90	.90	1.15	3.98	1.61	1.27	.56
2.40	1.16	1.65	6.55	2.04	2.09	2.48	2.67	.90	1.16	1.98	.95	1.23	4.36	1.67	1.29	.56
2.50	1.20	1.75	7.12	2.14	2.05	2.50	2.76	1.01	1.22	2.07	1.00	1.32	4.75	1.74	1.32	.57
2.60	1.23	1.85	7.72	2.24	2.02	2.51	2.85	1.13	1.29	2.15	1.04	1.40	5.15	1.81	1.35	.57
2.70	1.27	1.94	8.34	2.34	2.00	2.52	2.94	1.26	1.36	2.23	1.08	1.49	5.57	1.88	1.37	.58
2.80	1.30	2.04	8.98	2.45	1.98	2.53	3.04	1.38	1.44	2.31	1.12	1.57	6.01	1.96	1.40	.58
2.90	1.33	2.13	9.64	2.56	1.96	2.55	3.13	1.52	1.51	2.40	1.16	1.65	6.46	2.04	1.43	.58
3.00	1.36	2.22	10.33	2.68	1.94	2.56	3.22	1.65	1.59	2.48	1.19	1.73	6.93	2.12	1.45	.59
3.10	1.38	2.31	11.04	2.80	1.93	2.57	3.32	1.80	1.67	2.56	1.22	1.81	7.41	2.20	1.48	.59
3.20	1.41	2.41	11.78	2.92	1.91	2.58	3.42	1.95	1.75	2.64	1.25	1.89	7.91	2.28	1.51	.59
3.30	1.43	2.50	12.54	3.05	1.90	2.60	3.51	2.10	1.83	2.72	1.28	1.96	8.42	2.37	1.54	.60
3.40	1.45	2.59	13.32	3.18	1.89	2.61	3.61	2.26	1.91	2.81	1.30	2.04	8.95	2.46	1.57	.60
3.50	1.47	2.68	14.12	3.32	1.88	2.62	3.71	2.42	2.00	2.89	1.33	2.12	9.49	2.55	1.60	.60
3.60	1.49	2.77	14.95	3.45	1.87	2.63	3.80	2.58	2.09	2.97	1.35	2.19	10.06	2.64	1.63	.60
3.70	1.51	2.86	15.80	3.60	1.86	2.64	3.90	2.76	2.18	3.05	1.37	2.27	10.63	2.74	1.66	.60
3.80	1.52	2.95	16.68	3.74	1.86	2.65	4.00	2.93	2.28	3.13	1.39	2.35	11.22	2.84	1.69	.60
3.90	1.54	3.04	17.58	3.89	1.85	2.66	4.10	3.11	2.37	3.22	1.41	2.42	11.83	2.94	1.72	.61
4.00	1.55	3.12	18.50	4.05	1.84	2.67	4.20	3.30	2.47	3.30	1.43	2.50	12.46	3.05	1.75	.61
4.10	1.57	3.21	19.44	4.20	1.84	2.68	4.30	3.49	2.57	3.38	1.45	2.57	13.09	3.15	1.78	.61
4.20	1.58	3.30	20.41	4.37	1.83	2.69	4.40	3.68	2.68	3.46	1.46	2.64	13.75	3.26	1.81	.61
4.30	1.59	3.39	21.40	4.53	1.83	2.70	4.50	3.88	2.78	3.54	1.48	2.72	14.42	3.38	1.84	.61
4.40	1.60	3.48	22.42	4.70	1.82	2.70	4.60	4.09	2.89	3.63	1.49	2.79	15.11	3.49	1.87	.61
4.50	1.61	3.56	23.46	4.88	1.82	2.71	4.70	4.30	3.00	3.71	1.51	2.87	15.81	3.61	1.90	.61
4.60	1.62	3.65	24.52	5.05	1.82	2.72	4.80	4.51	3.11	3.79	1.52	2.94	16.53	3.73	1.93	.61
4.70	1.63	3.74	25.60	5.23	1.81	2.73	4.90	4.73	3.23	3.87	1.53	3.01	17.26	3.85	1.96	.61
4.80	1.64	3.83	26.71	5.42	1.81	2.73	5.00	4.95	3.35	3.95	1.55	3.08	18.01	3.98	1.99	.61
4.90	1.65	3.91	27.84	5.61	1.81	2.74	5.10	5.18	3.47	4.04	1.56	3.16	18.78	4.10	2.03	.62
5.00	1.66	4.00	29.00	5.80	1.80	2.74	5.20	5.42	3.59	4.12	1.57	3.23	19.56	4.24	2.06	.62
5.10	1.67	4.09	30.18	6.00	1.80	2.75	5.30	5.65	3.72	4.20	1.58	3.30	20.36	4.37	2.09	.62
5.20	1.68	4.17	31.38	6.20	1.80	2.76	5.40	5.90	3.84	4.28	1.59	3.37	21.17	4.50	2.12	.62
5.30	1.68	4.26	32.60	6.40	1.79	2.76	5.50	6.14	3.97	4.37	1.60	3.45	22.00	4.64	2.15	.62
5.40	1.69	4.35	33.85	6.61	1.79	2.77	5.60	6.39	4.11	4.45	1.61	3.52	22.84	4.78	2.19	.62
5.50	1.70	4.43	35.12	6.82	1.79	2.77	5.71	6.65	4.24	4.53	1.62	3.59	23.70	4.93	2.22	.62
5.60	1.70	4.52	36.42	7.04	1.79	2.78	5.81	6.91	4.38	4.61	1.63	3.66	24.58	5.07	2.25	.62
5.70	1.71	4.60	37.74	7.26	1.79	2.78	5.91	7.18	4.52	4.69	1.63	3.73	25.47	5.22	2.29	.62
5.80	1.71	4.69	39.08	7.48	1.78	2.78	6.01	7.45	4.66	4.78	1.64	3.81	26.38	5.37	2.32	.62
5.90	1.72	4.78	40.44	7.71	1.78	2.79	6.11	7.72	4.80	4.86	1.65	3.88	27.30	5.53	2.35	.62
6.00	1.73	4.86	41.83	7.94	1.78	2.79	6.21	8.00	4.95	4.94	1.66	3.95	28.24	5.68	2.38	.62
6.10	1.73	4.95	43.24	8.18	1.78	2.80	6.31	8.29	5.10	5.02	1.66	4.02	29.20	5.84	2.42	.62
6.20	1.73	5.03	44.68	8.42	1.78	2.80	6.41	8.58	5.25	5.10	1.67	4.09	30.17	6.01	2.45	.62

BLAST WAVE PARAMETERS BEFORE AND AFTER A DIVERGENT NOZZLE

TABLE D-III (Cont.)

SPECIFIC HEAT RATIO (GAMMA) = 1.400
AREA RATIO ACROSS THE DIVERGENT NOZZLE = 2.55

((((((NOZZLE INLET CONDITIONS))))))))))					(((((SECONDARY SHOCK CONDITIONS)))))))					((PRIMARY TRANSMITTED SHOCK CONDITIONS))						
SHOCK MACH NO.	FLOW MACH NO.	FLOW VEL. RATIO	SHOCK STREN	TEMP RATIO	2NDRY SHOCK MACH NO.	2NDRY FLOW MACH NO.	2NDRY FLOW VEL. RATIO	2NDRY SHOCK STREN	2NDRY TEMP RATIO	PRIM SHOCK MACH NO.	PRIM FLOW MACH NO.	PRIM FLOW VEL. RATIO	PRIM SHOCK STREN.	PRIM TEMP RATIO	SONIC VEL. RATIO	MACH NO. BET. CONT. AND 2NDRY SHOCK
MS1	M1	U1/A0	P1/P0	T1/T0	MS2	M2	U2/A0	P2/P0	T2/T0	MS3	M3	U3/A0	P3/P0	T3/T0	A3/A0	M3(PRIME)
6.30	1.74	5.12	46.14	8.66	1.78	2.80	6.52	8.87	5.41	5.19	1.68	4.16	31.16	6.17	2.48	.62
6.40	1.74	5.20	47.62	8.91	1.78	2.81	6.62	9.17	5.56	5.27	1.68	4.23	32.16	6.34	2.52	.62
6.50	1.75	5.29	49.12	9.16	1.77	2.81	6.72	9.48	5.72	5.35	1.69	4.30	33.18	6.51	2.55	.62
6.60	1.75	5.37	50.65	9.41	1.77	2.81	6.82	9.78	5.88	5.43	1.69	4.37	34.21	6.68	2.58	.62
6.70	1.76	5.46	52.20	9.67	1.77	2.81	6.92	10.10	6.05	5.52	1.70	4.45	35.26	6.86	2.62	.62
6.80	1.76	5.54	53.78	9.93	1.77	2.82	7.02	10.41	6.21	5.60	1.70	4.52	36.33	7.03	2.65	.62
6.90	1.76	5.63	55.38	10.20	1.77	2.82	7.13	10.74	6.38	5.68	1.71	4.59	37.41	7.21	2.69	.62
7.00	1.77	5.71	57.00	10.47	1.77	2.82	7.23	11.06	6.55	5.76	1.71	4.66	38.51	7.40	2.72	.62
7.10	1.77	5.80	58.64	10.74	1.77	2.83	7.33	11.40	6.73	5.84	1.72	4.73	39.62	7.58	2.75	.62
7.20	1.77	5.88	60.31	11.02	1.77	2.83	7.43	11.73	6.90	5.93	1.72	4.80	40.75	7.77	2.79	.62
7.30	1.78	5.97	62.00	11.30	1.77	2.83	7.53	12.07	7.08	6.01	1.73	4.87	41.90	7.96	2.82	.62
7.40	1.78	6.05	63.72	11.59	1.77	2.83	7.63	12.42	7.26	6.09	1.73	4.94	43.06	8.16	2.86	.62
7.50	1.78	6.14	65.46	11.88	1.77	2.83	7.74	12.77	7.45	6.17	1.73	5.01	44.23	8.35	2.89	.62
7.60	1.78	6.22	67.22	12.17	1.76	2.84	7.84	13.13	7.63	6.26	1.74	5.08	45.43	8.55	2.92	.62
7.70	1.79	6.31	69.00	12.47	1.76	2.84	7.94	13.49	7.82	6.34	1.74	5.15	46.63	8.75	2.96	.62
7.80	1.79	6.39	70.81	12.77	1.76	2.84	8.04	13.85	8.01	6.42	1.74	5.22	47.86	8.96	2.99	.62
7.90	1.79	6.48	72.64	13.08	1.76	2.84	8.14	14.22	8.21	6.50	1.75	5.29	49.10	9.16	3.03	.63
8.00	1.79	6.56	74.50	13.39	1.76	2.84	8.25	14.59	8.40	6.58	1.75	5.36	50.35	9.37	3.06	.63
8.10	1.80	6.65	76.38	13.70	1.76	2.85	8.35	14.97	8.60	6.67	1.75	5.43	51.62	9.58	3.10	.63
8.20	1.80	6.73	78.28	14.02	1.76	2.85	8.45	15.36	8.80	6.75	1.76	5.50	52.91	9.80	3.13	.63
8.30	1.80	6.82	80.20	14.34	1.76	2.85	8.55	15.75	9.00	6.83	1.76	5.57	54.21	10.02	3.16	.63
8.40	1.80	6.90	82.15	14.66	1.76	2.85	8.65	16.14	9.21	6.91	1.76	5.64	55.53	10.24	3.20	.63
8.50	1.80	6.99	84.12	14.99	1.76	2.85	8.76	16.54	9.42	7.00	1.77	5.71	56.87	10.46	3.23	.63
8.60	1.81	7.07	86.12	15.32	1.76	2.85	8.86	16.94	9.63	7.08	1.77	5.78	58.22	10.68	3.27	.63
8.70	1.81	7.15	88.14	15.66	1.76	2.86	8.96	17.33	9.84	7.16	1.77	5.85	59.56	10.91	3.30	.63
8.80	1.81	7.24	90.18	16.00	1.76	2.86	9.06	17.74	10.06	7.24	1.77	5.92	60.94	11.14	3.34	.63
8.90	1.81	7.32	92.24	16.34	1.76	2.86	9.16	18.16	10.27	7.32	1.78	5.99	62.33	11.37	3.37	.63
9.00	1.81	7.41	94.33	16.69	1.76	2.86	9.26	18.58	10.49	7.41	1.78	6.06	63.75	11.61	3.41	.63
9.10	1.81	7.49	96.44	17.04	1.76	2.86	9.37	19.01	10.72	7.49	1.78	6.13	65.18	11.84	3.44	.63
9.20	1.82	7.58	98.58	17.40	1.76	2.86	9.47	19.44	10.94	7.57	1.78	6.20	66.62	12.08	3.48	.63
9.30	1.82	7.66	100.74	17.76	1.76	2.86	9.57	19.87	11.17	7.65	1.79	6.27	68.08	12.33	3.51	.63
9.40	1.82	7.74	102.92	18.12	1.76	2.86	9.67	20.31	11.40	7.73	1.79	6.34	69.56	12.57	3.55	.63
9.50	1.82	7.83	105.12	18.49	1.75	2.87	9.78	20.76	11.63	7.82	1.79	6.41	71.05	12.82	3.58	.63
9.60	1.82	7.91	107.35	18.86	1.75	2.87	9.88	21.21	11.87	7.90	1.79	6.48	72.56	13.07	3.62	.63
9.70	1.82	8.00	109.60	19.24	1.75	2.87	9.98	21.66	12.11	7.98	1.79	6.55	74.08	13.33	3.65	.63
9.80	1.82	8.08	111.88	19.62	1.75	2.87	10.08	22.12	12.35	8.06	1.80	6.62	75.62	13.58	3.69	.63
9.90	1.83	8.17	114.18	20.00	1.75	2.87	10.18	22.58	12.59	8.15	1.80	6.69	77.18	13.84	3.72	.63
10.00	1.83	8.25	116.50	20.39	1.75	2.87	10.29	23.05	12.83	8.23	1.80	6.76	78.75	14.11	3.76	.63
10.10	1.83	8.33	118.84	20.78	1.75	2.87	10.39	23.53	13.08	8.31	1.80	6.82	80.34	14.37	3.79	.63
10.20	1.83	8.42	121.21	21.17	1.75	2.87	10.49	24.00	13.33	8.39	1.80	6.89	81.94	14.64	3.83	.63
10.30	1.83	8.50	123.60	21.57	1.75	2.87	10.59	24.49	13.58	8.47	1.80	6.96	83.56	14.91	3.86	.63

BLAST WAVE PARAMETERS BEFORE AND AFTER A DIVERGENT NOZZLE

TABLE D-IV

SPECIFIC HEAT RATIO (GAMMA) = 1.400
AREA RATIO ACROSS THE DIVERGENT NOZZLE = 4.00

((((((NOZZLE INLET CONDITIONS)))))))))))((((((SECONDARY SHOCK CONDITIONS))))))))((PRIMARY TRANSMITTED SHOCK CONDITIONS))

SHOCK MACH NO. MS1	FLOW MACH NO. M1	FLOW VEL. RATIO U1/A0	SHOCK STREN P1/P0	TEMP RATIO T1/T0	2NDRY SHOCK MACH NO. MS2	2NDRY FLOW MACH NO. M2	2NDRY FLOW VEL. RATIO U2/A0	2NDRY SHOCK STREN P2/P0	2NDRY TEMP RATIO T2/T0	PRIM SHOCK MACH NO. MS3	PRIM FLOW MACH NO. M3	PRIM FLOW VEL. RATIO U3/A0	PRIM SHOCK STREN. P3/P0	PRIM TEMP RATIO T3/T0	SONIC VEL. RATIO A3/A0	MACH NO. BET. CONT. AND 2NDRY SHOCK M3(PRIME)
2.20	1.07	1.45	5.48	1.86	2.78	2.94	2.69	.33	.83	1.63	.72	.85	2.87	1.41	1.19	.49
2.30	1.11	1.55	6.00	1.95	2.72	2.95	2.78	.38	.89	1.71	.77	.93	3.17	1.46	1.21	.49
2.40	1.16	1.65	6.55	2.04	2.67	2.96	2.87	.43	.94	1.78	.83	1.02	3.47	1.52	1.23	.50
2.50	1.20	1.75	7.12	2.14	2.62	2.97	2.96	.49	.99	1.86	.88	1.10	3.79	1.57	1.25	.50
2.60	1.23	1.85	7.72	2.24	2.59	2.98	3.06	.55	1.05	1.93	.92	1.18	4.11	1.63	1.28	.50
2.70	1.27	1.94	8.34	2.34	2.55	2.99	3.15	.61	1.11	2.00	.96	1.25	4.46	1.69	1.30	.51
2.80	1.30	2.04	8.98	2.45	2.53	3.01	3.25	.67	1.17	2.08	1.01	1.33	4.81	1.75	1.32	.51
2.90	1.33	2.13	9.64	2.56	2.50	3.02	3.35	.73	1.23	2.15	1.04	1.41	5.17	1.82	1.35	.51
3.00	1.36	2.22	10.33	2.68	2.48	3.03	3.45	.80	1.29	2.23	1.08	1.48	5.55	1.88	1.37	.52
3.10	1.38	2.31	11.04	2.80	2.46	3.05	3.55	.87	1.36	2.30	1.11	1.56	5.94	1.95	1.40	.52
3.20	1.41	2.41	11.78	2.92	2.44	3.06	3.65	.95	1.42	2.37	1.15	1.63	6.35	2.02	1.42	.52
3.30	1.43	2.50	12.54	3.05	2.42	3.07	3.75	1.02	1.49	2.45	1.18	1.70	6.76	2.09	1.44	.52
3.40	1.45	2.59	13.32	3.18	2.41	3.08	3.85	1.10	1.56	2.52	1.21	1.77	7.19	2.16	1.47	.52
3.50	1.47	2.68	14.12	3.32	2.40	3.09	3.95	1.18	1.63	2.60	1.23	1.84	7.63	2.23	1.49	.52
3.60	1.49	2.77	14.95	3.45	2.39	3.10	4.05	1.26	1.70	2.67	1.26	1.91	8.09	2.31	1.52	.52
3.70	1.51	2.86	15.80	3.60	2.37	3.11	4.15	1.34	1.78	2.74	1.28	1.98	8.55	2.39	1.55	.53
3.80	1.52	2.94	16.68	3.74	2.36	3.13	4.26	1.43	1.86	2.82	1.31	2.05	9.03	2.47	1.57	.53
3.90	1.54	3.04	17.58	3.89	2.36	3.13	4.36	1.52	1.93	2.89	1.33	2.12	9.52	2.55	1.60	.53
4.00	1.55	3.12	18.50	4.05	2.35	3.14	4.46	1.61	2.02	2.97	1.35	2.19	10.03	2.64	1.62	.53
4.10	1.57	3.21	19.44	4.20	2.34	3.15	4.57	1.71	2.10	3.04	1.37	2.26	10.55	2.73	1.65	.53
4.20	1.58	3.30	20.41	4.37	2.33	3.16	4.67	1.80	2.18	3.11	1.39	2.33	11.08	2.82	1.68	.53
4.30	1.59	3.39	21.40	4.53	2.33	3.17	4.78	1.90	2.27	3.19	1.40	2.39	11.62	2.91	1.70	.53
4.40	1.60	3.48	22.42	4.70	2.32	3.18	4.88	2.00	2.36	3.26	1.42	2.46	12.18	3.00	1.73	.53
4.50	1.61	3.56	23.46	4.88	2.31	3.18	4.98	2.11	2.45	3.34	1.44	2.53	12.75	3.10	1.76	.53
4.60	1.62	3.65	24.52	5.05	2.31	3.19	5.09	2.21	2.54	3.41	1.45	2.60	13.33	3.19	1.79	.53
4.70	1.63	3.74	25.60	5.23	2.30	3.20	5.19	2.32	2.64	3.48	1.47	2.66	13.92	3.29	1.81	.53
4.80	1.64	3.83	26.71	5.42	2.30	3.21	5.30	2.43	2.73	3.56	1.48	2.73	14.53	3.39	1.84	.53
4.90	1.65	3.91	27.84	5.61	2.30	3.21	5.40	2.54	2.83	3.63	1.50	2.80	15.15	3.50	1.87	.53
5.00	1.66	4.00	29.00	5.80	2.29	3.22	5.51	2.66	2.93	3.71	1.51	2.86	15.78	3.60	1.90	.54
5.10	1.67	4.09	30.18	6.00	2.29	3.22	5.61	2.78	3.03	3.78	1.52	2.93	16.43	3.71	1.93	.54
5.20	1.68	4.17	31.38	6.20	2.28	3.23	5.72	2.90	3.14	3.85	1.53	2.99	17.09	3.82	1.95	.54
5.30	1.68	4.26	32.60	6.40	2.28	3.23	5.82	3.02	3.24	3.93	1.54	3.06	17.76	3.93	1.98	.54
5.40	1.69	4.35	33.85	6.61	2.28	3.24	5.93	3.15	3.35	4.00	1.55	3.13	18.44	4.05	2.01	.54
5.50	1.70	4.43	35.12	6.82	2.27	3.24	6.04	3.27	3.46	4.07	1.56	3.19	19.14	4.16	2.04	.54
5.60	1.70	4.52	36.42	7.04	2.27	3.25	6.14	3.40	3.57	4.15	1.57	3.26	19.85	4.28	2.07	.54
5.70	1.71	4.60	37.74	7.26	2.27	3.25	6.25	3.53	3.69	4.22	1.58	3.32	20.57	4.40	2.10	.54
5.80	1.71	4.69	39.08	7.48	2.27	3.26	6.35	3.67	3.81	4.30	1.59	3.39	21.31	4.53	2.13	.54
5.90	1.72	4.78	40.44	7.71	2.26	3.26	6.46	3.80	3.92	4.37	1.60	3.45	22.05	4.65	2.16	.54
6.00	1.73	4.86	41.83	7.94	2.26	3.27	6.57	3.94	4.04	4.44	1.61	3.52	22.81	4.78	2.19	.54
6.10	1.73	4.95	43.24	8.18	2.26	3.27	6.67	4.08	4.17	4.52	1.62	3.58	23.59	4.91	2.22	.54
6.20	1.73	5.03	44.68	8.42	2.26	3.27	6.78	4.23	4.29	4.59	1.62	3.65	24.37	5.04	2.24	.54

BLAST WAVE PARAMETERS BEFORE AND AFTER A DIVERGENT NOZZLE

TABLE D-IV (Cont.)

SPECIFIC HEAT RATIO (GAMMA) = 1.400
AREA RATIO ACROSS THE DIVERGENT NOZZLE = 4.00

((((((NOZZLE INLET CONDITIONS)))))))))((((((SECONDARY SHOCK CONDITIONS)))))))((PRIMARY TRANSMITTED SHOCK CONDITIONS))																
SHOCK MACH NO.	FLOW MACH NO.	FLOW VEL. RATIO	SHOCK STREN	TEMP RATIO	2NDRY SHOCK MACH NO.	2NDRY FLOW MACH NO.	2NDRY FLOW VEL. RATIO	2NDRY SHOCK STREN	2NDRY TEMP RATIO	PRIM SHOCK MACH NO.	PRIM FLOW MACH NO.	PRIM FLOW VEL. RATIO	PRIM SHOCK STREN.	PRIM TEMP RATIO	SONIC VEL. RATIO	MACH NO. BET. CONT. AND 2NDRY SHOCK
MS1	M1	U1/A0	P1/P0	T1/T0	MS2	M2	U2/A0	P2/P0	T2/T0	MS3	M3	U3/A0	P3/P0	T3/T0	A3/A0	M3(PRIME)
6.30	1.74	5.12	46.14	8.66	2.26	3.28	6.88	4.37	4.42	4.67	1.63	3.71	25.17	5.17	2.27	.54
6.40	1.74	5.20	47.62	8.91	2.25	3.28	6.99	4.52	4.54	4.74	1.64	3.77	25.98	5.31	2.30	.54
6.50	1.75	5.29	49.12	9.16	2.25	3.28	7.10	4.67	4.68	4.81	1.65	3.84	26.81	5.45	2.33	.54
6.60	1.75	5.37	50.65	9.41	2.25	3.29	7.20	4.83	4.81	4.89	1.65	3.90	27.65	5.59	2.36	.54
6.70	1.76	5.46	52.20	9.67	2.25	3.29	7.31	4.98	4.94	4.96	1.66	3.97	28.50	5.73	2.39	.54
6.80	1.76	5.54	53.78	9.93	2.25	3.29	7.42	5.14	5.08	5.04	1.66	4.03	29.36	5.87	2.42	.54
6.90	1.76	5.63	55.38	10.20	2.25	3.29	7.52	5.30	5.22	5.11	1.67	4.10	30.24	6.02	2.45	.54
7.00	1.77	5.71	57.00	10.47	2.24	3.30	7.63	5.46	5.36	5.18	1.68	4.16	31.12	6.17	2.48	.54
7.10	1.77	5.80	58.64	10.74	2.24	3.30	7.74	5.62	5.50	5.26	1.68	4.22	32.03	6.32	2.51	.54
7.20	1.77	5.88	60.31	11.02	2.24	3.30	7.84	5.79	5.64	5.33	1.69	4.29	32.94	6.47	2.54	.54
7.30	1.78	5.97	62.00	11.30	2.24	3.30	7.95	5.96	5.79	5.41	1.69	4.35	33.87	6.62	2.57	.54
7.40	1.78	6.05	63.72	11.59	2.24	3.31	8.06	6.13	5.94	5.48	1.70	4.41	34.81	6.78	2.60	.54
7.50	1.78	6.14	65.46	11.88	2.24	3.31	8.16	6.31	6.09	5.55	1.70	4.48	35.76	6.94	2.63	.54
7.60	1.78	6.22	67.22	12.17	2.24	3.31	8.27	6.48	6.24	5.63	1.70	4.54	36.73	7.10	2.66	.54
7.70	1.79	6.31	69.00	12.47	2.24	3.31	8.38	6.66	6.39	5.70	1.71	4.61	37.70	7.26	2.70	.54
7.80	1.79	6.39	70.81	12.77	2.24	3.31	8.48	6.84	6.55	5.78	1.71	4.67	38.70	7.43	2.73	.54
7.90	1.79	6.48	72.64	13.08	2.23	3.32	8.59	7.03	6.71	5.85	1.72	4.73	39.70	7.60	2.76	.54
8.00	1.79	6.56	74.50	13.39	2.23	3.32	8.70	7.21	6.87	5.92	1.72	4.80	40.72	7.77	2.79	.54
8.10	1.80	6.65	76.38	13.70	2.23	3.32	8.80	7.40	7.03	6.00	1.73	4.86	41.75	7.94	2.82	.54
8.20	1.80	6.73	78.28	14.02	2.23	3.32	8.91	7.59	7.20	6.07	1.73	4.92	42.79	8.11	2.85	.54
8.30	1.80	6.82	80.20	14.34	2.23	3.32	9.02	7.78	7.36	6.15	1.73	4.99	43.84	8.29	2.88	.54
8.40	1.80	6.90	82.15	14.66	2.23	3.33	9.13	7.98	7.53	6.22	1.74	5.05	44.91	8.46	2.91	.54
8.50	1.80	6.99	84.12	14.99	2.23	3.33	9.23	8.17	7.70	6.29	1.74	5.11	45.99	8.64	2.94	.54
8.60	1.81	7.07	86.12	15.32	2.23	3.33	9.34	8.37	7.87	6.37	1.74	5.18	47.08	8.83	2.97	.54
8.70	1.81	7.15	88.14	15.66	2.23	3.33	9.45	8.58	8.05	6.44	1.75	5.24	48.19	9.01	3.00	.54
8.80	1.81	7.24	90.18	16.00	2.23	3.33	9.55	8.78	8.22	6.52	1.75	5.30	49.31	9.20	3.03	.54
8.90	1.81	7.32	92.24	16.34	2.23	3.33	9.66	8.99	8.40	6.59	1.75	5.37	50.44	9.39	3.06	.54
9.00	1.81	7.41	94.33	16.69	2.23	3.33	9.77	9.20	8.58	6.66	1.75	5.43	51.59	9.58	3.09	.54
9.10	1.81	7.49	96.44	17.04	2.23	3.34	9.88	9.41	8.77	6.74	1.76	5.49	52.74	9.77	3.13	.54
9.20	1.82	7.58	98.58	17.40	2.23	3.34	9.98	9.62	8.95	6.81	1.76	5.55	53.91	9.97	3.16	.54
9.30	1.82	7.66	100.74	17.76	2.22	3.34	10.09	9.84	9.14	6.89	1.76	5.62	55.10	10.16	3.19	.54
9.40	1.82	7.74	102.92	18.12	2.22	3.34	10.20	10.05	9.32	6.96	1.76	5.68	56.29	10.36	3.22	.54
9.50	1.82	7.83	105.12	18.49	2.22	3.34	10.30	10.28	9.52	7.03	1.77	5.74	57.50	10.56	3.25	.54
9.60	1.82	7.91	107.35	18.86	2.22	3.34	10.41	10.50	9.71	7.11	1.77	5.81	58.72	10.77	3.28	.54
9.70	1.82	8.00	109.60	19.24	2.22	3.34	10.52	10.72	9.90	7.18	1.77	5.87	59.96	10.97	3.31	.54
9.80	1.82	8.08	111.88	19.62	2.22	3.34	10.63	10.95	10.10	7.26	1.77	5.93	61.20	11.18	3.34	.54
9.90	1.83	8.17	114.18	20.00	2.22	3.34	10.73	11.18	10.30	7.33	1.78	6.00	62.46	11.39	3.38	.54
10.00	1.83	8.25	116.50	20.39	2.22	3.35	10.84	11.41	10.50	7.40	1.78	6.06	63.73	11.60	3.41	.54
10.10	1.83	8.33	118.84	20.78	2.22	3.35	10.95	11.65	10.70	7.48	1.78	6.12	65.02	11.82	3.44	.54
10.20	1.83	8.42	121.21	21.17	2.22	3.35	11.05	11.89	10.91	7.55	1.78	6.18	66.32	12.03	3.47	.54
10.30	1.83	8.50	123.60	21.57	2.22	3.35	11.16	12.12	11.11	7.63	1.78	6.25	67.63	12.25	3.50	.54

BLAST WAVE PARAMETERS BEFORE AND AFTER A DIVERGENT NOZZLE

TABLE D-V

SPECIFIC HEAT RATIO (GAMMA) = 1.400
AREA RATIO ACROSS THE DIVERGENT NOZZLE = 5.67

((((((NOZZLE INLET CONDITIONS))))))))))					((((((SECONDARY SHOCK CONDITIONS))))))))					((PRIMARY TRANSMITTED SHOCK CONDITIONS))						
SHOCK MACH NO. MS1	FLOW MACH NO. M1	FLOW VEL. RATIO U1/A0	SHOCK STREN P1/P0	TEMP RATIO T1/T0	2NDRY SHOCK MACH NO. MS2	2NDRY FLOW MACH NO. M2	2NDRY FLOW VEL. RATIO U2/A0	2NDRY SHOCK STREN P2/P0	2NDRY TEMP RATIO T2/T0	PRIM SHOCK MACH NO. MS3	PRIM FLOW MACH NO. M3	PRIM FLOW VEL. RATIO U3/A0	PRIM SHOCK STREN. P3/P0	PRIM TEMP RATIO T3/T0	SONIC VEL. RATIO A3/A0	MACH NO. BET. CONT. AND 2NDRY SHOCK M3(PRIME)
2.20	1.07	1.45	5.48	1.86	3.30	3.31	2.80	.19	.71	1.49	.60	.68	2.36	1.31	1.15	.46
2.30	1.11	1.55	6.00	1.95	3.24	3.32	2.89	.22	.76	1.56	.66	.77	2.61	1.36	1.17	.46
2.40	1.16	1.65	6.55	2.04	3.18	3.33	2.99	.25	.80	1.63	.71	.85	2.86	1.41	1.19	.47
2.50	1.20	1.75	7.12	2.14	3.13	3.34	3.08	.28	.85	1.70	.77	.92	3.13	1.46	1.21	.47
2.60	1.23	1.85	7.72	2.24	3.08	3.35	3.18	.32	.90	1.77	.81	1.00	3.40	1.51	1.23	.47
2.70	1.27	1.94	8.34	2.34	3.04	3.36	3.28	.35	.95	1.83	.86	1.07	3.69	1.56	1.25	.47
2.80	1.30	2.04	8.98	2.45	3.01	3.38	3.38	.39	1.00	1.90	.90	1.15	3.98	1.61	1.27	.47
2.90	1.33	2.13	9.64	2.56	2.98	3.39	3.48	.43	1.05	1.97	.94	1.22	4.29	1.66	1.29	.48
3.00	1.36	2.22	10.33	2.68	2.95	3.40	3.58	.47	1.11	2.04	.98	1.29	4.61	1.72	1.31	.48
3.10	1.38	2.31	11.04	2.80	2.93	3.42	3.68	.51	1.16	2.10	1.02	1.36	4.93	1.77	1.33	.48
3.20	1.41	2.41	11.78	2.92	2.91	3.43	3.78	.55	1.22	2.17	1.05	1.43	5.27	1.83	1.35	.48
3.30	1.43	2.50	12.54	3.05	2.89	3.44	3.89	.59	1.28	2.24	1.09	1.49	5.62	1.89	1.38	.48
3.40	1.45	2.59	13.32	3.18	2.87	3.45	3.99	.64	1.34	2.31	1.12	1.56	5.97	1.95	1.40	.48
3.50	1.47	2.68	14.12	3.32	2.85	3.46	4.09	.69	1.40	2.37	1.15	1.63	6.34	2.02	1.42	.48
3.60	1.49	2.77	14.95	3.45	2.84	3.47	4.20	.73	1.46	2.44	1.17	1.69	6.72	2.08	1.44	.49
3.70	1.51	2.86	15.80	3.60	2.83	3.49	4.30	.78	1.52	2.51	1.20	1.76	7.12	2.15	1.47	.49
3.80	1.52	2.95	16.68	3.74	2.81	3.50	4.41	.84	1.59	2.58	1.23	1.82	7.52	2.22	1.49	.49
3.90	1.54	3.04	17.58	3.89	2.80	3.51	4.52	.89	1.66	2.64	1.25	1.89	7.93	2.28	1.51	.49
4.00	1.55	3.12	18.50	4.05	2.79	3.51	4.62	.94	1.73	2.71	1.27	1.95	8.35	2.36	1.54	.49
4.10	1.57	3.21	19.44	4.20	2.78	3.52	4.73	1.00	1.80	2.78	1.29	2.02	8.78	2.43	1.56	.49
4.20	1.58	3.30	20.41	4.37	2.77	3.53	4.83	1.05	1.87	2.85	1.31	2.08	9.23	2.50	1.58	.49
4.30	1.59	3.39	21.40	4.53	2.77	3.54	4.94	1.11	1.95	2.92	1.33	2.14	9.68	2.58	1.61	.49
4.40	1.60	3.48	22.42	4.70	2.76	3.55	5.05	1.17	2.02	2.98	1.35	2.21	10.15	2.66	1.63	.49
4.50	1.61	3.56	23.46	4.88	2.75	3.56	5.16	1.23	2.10	3.05	1.37	2.27	10.63	2.74	1.66	.49
4.60	1.62	3.65	24.52	5.05	2.75	3.56	5.26	1.30	2.18	3.12	1.39	2.33	11.11	2.82	1.68	.49
4.70	1.63	3.74	25.60	5.23	2.74	3.57	5.37	1.36	2.26	3.19	1.40	2.39	11.61	2.90	1.70	.49
4.80	1.64	3.83	26.71	5.42	2.73	3.58	5.48	1.42	2.34	3.25	1.42	2.46	12.12	2.99	1.73	.49
4.90	1.65	3.91	27.84	5.61	2.73	3.58	5.59	1.49	2.43	3.32	1.43	2.52	12.64	3.08	1.75	.49
5.00	1.66	4.00	29.00	5.80	2.72	3.59	5.69	1.56	2.52	3.39	1.45	2.58	13.17	3.17	1.78	.49
5.10	1.67	4.09	30.18	6.00	2.72	3.60	5.80	1.63	2.60	3.46	1.46	2.64	13.71	3.26	1.80	.49
5.20	1.68	4.17	31.38	6.20	2.72	3.60	5.91	1.70	2.69	3.52	1.48	2.70	14.26	3.35	1.83	.49
5.30	1.68	4.26	32.60	6.40	2.71	3.61	6.02	1.77	2.78	3.59	1.49	2.76	14.82	3.44	1.86	.49
5.40	1.69	4.35	33.85	6.61	2.71	3.61	6.13	1.84	2.88	3.66	1.50	2.82	15.39	3.54	1.88	.50
5.50	1.70	4.43	35.12	6.82	2.70	3.62	6.24	1.92	2.97	3.73	1.51	2.88	15.98	3.64	1.91	.50
5.60	1.70	4.52	36.42	7.04	2.70	3.62	6.34	1.99	3.07	3.79	1.52	2.94	16.57	3.74	1.93	.50
5.70	1.71	4.60	37.74	7.26	2.70	3.63	6.45	2.07	3.17	3.86	1.53	3.00	17.17	3.84	1.96	.50
5.80	1.71	4.69	39.08	7.48	2.69	3.63	6.56	2.15	3.27	3.93	1.54	3.06	17.79	3.94	1.98	.50
5.90	1.72	4.78	40.44	7.71	2.69	3.63	6.67	2.23	3.37	4.00	1.55	3.12	18.41	4.04	2.01	.50
6.00	1.73	4.86	41.83	7.94	2.69	3.64	6.78	2.31	3.47	4.07	1.56	3.18	19.05	4.15	2.04	.50
6.10	1.73	4.95	43.24	8.18	2.69	3.64	6.89	2.40	3.58	4.13	1.57	3.24	19.70	4.26	2.06	.50
6.20	1.73	5.03	44.68	8.42	2.68	3.65	7.00	2.48	3.68	4.20	1.58	3.30	20.36	4.37	2.09	.50

BLAST WAVE PARAMETERS BEFORE AND AFTER A DIVERGENT NOZZLE

TABLE D-V (Cont.)

SPECIFIC HEAT RATIO (GAMMA) = 1.400
AREA RATIO ACROSS THE DIVERGENT NOZZLE = 5.67

((((((NOZZLE INLET CONDITIONS)))))))))((((((SECONDARY SHOCK CONDITIONS)))))))((PRIMARY TRANSMITTED SHOCK CONDITIONS))																	
SHOCK MACH NO.	FLOW MACH NO.	FLOW VEL. RATIO	SHOCK STREN	TEMP RATIO	2NDRY SHOCK MACH NO.	2NDRY FLOW MACH NO.	2NDRY FLOW VEL. RATIO	2NDRY SHOCK STREN	2NDRY TEMP RATIO	PRIM SHOCK MACH NO.	PRIM FLOW MACH NO.	PRIM FLOW VEL. RATIO	PRIM SHOCK STREN.	PRIM TEMP RATIO	SONIC VEL. RATIO	MACH NO. BET. CONT. AND 2NDRY SHOCK	
MS1	M1	U1/A0	P1/P0	T1/T0	MS2	M2	U2/A0	P2/P0	T2/T0	MS3	M3	U3/A0	P3/P0	T3/T0	A3/A0	M3(PRIME)	
6.30	1.74	5.12	46.14	8.66	2.68	3.65	7.11	2.57	3.79	4.27	1.59	3.36	21.03	4.48	2.12	.50	
6.40	1.74	5.20	47.62	8.91	2.68	3.65	7.22	2.65	3.90	4.34	1.60	3.42	21.71	4.59	2.14	.50	
6.50	1.75	5.29	49.12	9.16	2.68	3.66	7.33	2.74	4.01	4.40	1.60	3.48	22.40	4.71	2.17	.50	
6.60	1.75	5.37	50.65	9.41	2.67	3.66	7.44	2.83	4.13	4.47	1.61	3.54	23.10	4.83	2.20	.50	
6.70	1.76	5.46	52.20	9.67	2.67	3.66	7.55	2.92	4.24	4.54	1.62	3.60	23.81	4.94	2.22	.50	
6.80	1.76	5.54	53.78	9.93	2.67	3.67	7.65	3.02	4.36	4.61	1.63	3.66	24.53	5.07	2.25	.50	
6.90	1.76	5.63	55.38	10.20	2.67	3.67	7.76	3.11	4.48	4.67	1.63	3.72	25.26	5.19	2.28	.50	
7.00	1.77	5.71	57.00	10.47	2.67	3.67	7.87	3.21	4.60	4.74	1.64	3.78	26.01	5.31	2.30	.50	
7.10	1.77	5.80	58.64	10.74	2.67	3.67	7.98	3.30	4.72	4.81	1.64	3.84	26.76	5.44	2.33	.50	
7.20	1.77	5.88	60.31	11.02	2.66	3.68	8.09	3.40	4.85	4.88	1.65	3.89	27.53	5.57	2.36	.50	
7.30	1.78	5.97	62.00	11.30	2.66	3.68	8.20	3.50	4.97	4.95	1.66	3.95	28.30	5.69	2.39	.50	
7.40	1.78	6.05	63.72	11.59	2.66	3.68	8.31	3.60	5.10	5.01	1.66	4.01	29.09	5.83	2.41	.50	
7.50	1.78	6.14	65.46	11.88	2.66	3.68	8.42	3.70	5.23	5.08	1.67	4.07	29.89	5.96	2.44	.50	
7.60	1.78	6.22	67.22	12.17	2.66	3.69	8.53	3.81	5.36	5.15	1.67	4.13	30.70	6.09	2.47	.50	
7.70	1.79	6.31	69.00	12.47	2.66	3.69	8.64	3.91	5.49	5.22	1.68	4.19	31.51	6.23	2.50	.50	
7.80	1.79	6.39	70.81	12.77	2.66	3.69	8.75	4.02	5.63	5.28	1.68	4.25	32.34	6.37	2.52	.50	
7.90	1.79	6.48	72.64	13.08	2.65	3.69	8.86	4.13	5.76	5.35	1.69	4.30	33.18	6.51	2.55	.50	
8.00	1.79	6.56	74.50	13.39	2.65	3.69	8.97	4.24	5.90	5.42	1.69	4.36	34.03	6.65	2.58	.50	
8.10	1.80	6.64	76.38	13.70	2.65	3.70	9.08	4.35	6.04	5.49	1.70	4.42	34.90	6.79	2.61	.50	
8.20	1.80	6.73	78.28	14.02	2.65	3.70	9.19	4.46	6.18	5.56	1.70	4.48	35.77	6.94	2.63	.50	
8.30	1.80	6.82	80.20	14.34	2.65	3.70	9.30	4.57	6.32	5.62	1.70	4.54	36.65	7.09	2.66	.50	
8.40	1.80	6.90	82.15	14.66	2.65	3.70	9.41	4.69	6.47	5.69	1.71	4.60	37.55	7.24	2.69	.50	
8.50	1.80	6.99	84.12	14.99	2.65	3.70	9.52	4.80	6.62	5.76	1.71	4.65	38.45	7.39	2.72	.50	
8.60	1.81	7.07	86.12	15.32	2.65	3.70	9.63	4.92	6.76	5.83	1.72	4.71	39.36	7.54	2.75	.50	
8.70	1.81	7.15	88.14	15.66	2.65	3.71	9.74	5.04	6.91	5.89	1.72	4.77	40.29	7.69	2.77	.50	
8.80	1.81	7.24	90.18	16.00	2.65	3.71	9.85	5.16	7.07	5.96	1.72	4.83	41.23	7.85	2.80	.50	
8.90	1.81	7.32	92.24	16.34	2.65	3.71	9.96	5.28	7.22	6.03	1.73	4.89	42.17	8.01	2.83	.50	
9.00	1.81	7.41	94.33	16.69	2.64	3.71	10.07	5.40	7.37	6.10	1.73	4.94	43.13	8.17	2.86	.50	
9.10	1.81	7.49	96.44	17.04	2.64	3.71	10.18	5.53	7.53	6.16	1.73	5.00	44.10	8.33	2.89	.50	
9.20	1.82	7.58	98.58	17.40	2.64	3.71	10.29	5.65	7.69	6.23	1.74	5.06	45.08	8.49	2.91	.50	
9.30	1.82	7.66	100.74	17.76	2.64	3.71	10.40	5.78	7.85	6.30	1.74	5.12	46.07	8.66	2.94	.50	
9.40	1.82	7.74	102.92	18.12	2.64	3.71	10.51	5.91	8.01	6.37	1.74	5.18	47.07	8.83	2.97	.50	
9.50	1.82	7.83	105.12	18.49	2.64	3.72	10.62	6.04	8.18	6.44	1.75	5.23	48.08	8.99	3.00	.50	
9.60	1.82	7.91	107.35	18.86	2.64	3.72	10.73	6.17	8.34	6.50	1.75	5.29	49.11	9.16	3.03	.50	
9.70	1.82	8.00	109.60	19.24	2.64	3.72	10.84	6.30	8.51	6.57	1.75	5.35	50.14	9.34	3.06	.50	
9.80	1.82	8.08	111.88	19.62	2.64	3.72	10.96	6.44	8.68	6.64	1.75	5.41	51.18	9.51	3.08	.50	
9.90	1.83	8.17	114.18	20.00	2.64	3.72	11.07	6.57	8.85	6.71	1.76	5.46	52.24	9.69	3.11	.50	
10.00	1.83	8.25	116.50	20.39	2.64	3.72	11.18	6.71	9.02	6.77	1.76	5.52	53.30	9.86	3.14	.50	
10.10	1.83	8.33	118.84	20.78	2.64	3.72	11.29	6.85	9.19	6.84	1.76	5.58	54.38	10.04	3.17	.50	
10.20	1.83	8.42	121.21	21.17	2.64	3.72	11.40	6.99	9.37	6.91	1.76	5.64	55.46	10.22	3.20	.50	
10.30	1.83	8.50	123.60	21.57	2.64	3.72	11.51	7.13	9.55	6.98	1.77	5.69	56.56	10.41	3.23	.50	

BLAST WAVE PARAMETERS BEFORE AND AFTER A DIVERGENT NOZZLE

TABLE D-VI

SPECIFIC HEAT RATIO (GAMMA) = 1.400
AREA RATIO ACROSS THE DIVERGENT NOZZLE = 7.50

((((((NOZZLE INLET CONDITIONS))))))					((((((SECONDARY SHOCK CONDITIONS))))))					((((((PRIMARY TRANSMITTED SHOCK CONDITIONS))))						
SHOCK MACH NO.	FLOW MACH NO.	FLOW VEL. RATIO	SHOCK STREN.	TEMP RATIO	2NDRY SHOCK MACH NO.	2NDRY FLOW MACH NO.	2NDRY FLOW VEL. RATIO	2NDRY SHOCK STREN	2NDRY TEMP RATIO	PRIM SHOCK MACH NO.	PRIM FLOW MACH NO.	PRIM FLOW VEL. RATIO	PRIM SHOCK STREN.	PRIM TEMP RATIO	SONIC VEL. RATIO	MACH NO. BET. CONT. AND 2NDRY SHOCK
MS1	M1	U1/A0	P1/P0	T1/T0	MS2	M2	U2/A0	P2/P0	T2/T0	MS3	M3	U3/A0	P3/P0	T3/T0	A3/A0	M3(PRIME)
2.20	1.07	1.45	5.48	1.86	3.77	3.61	2.87	.13	.63	1.38	.49	.55	2.00	1.24	1.12	.44
2.30	1.11	1.55	6.00	1.95	3.69	3.62	2.97	.14	.67	1.45	.56	.63	2.21	1.29	1.13	.44
2.40	1.16	1.65	6.55	2.04	3.62	3.63	3.06	.16	.71	1.51	.61	.71	2.43	1.33	1.15	.45
2.50	1.20	1.75	7.12	2.14	3.57	3.64	3.16	.19	.75	1.57	.67	.78	2.66	1.37	1.17	.45
2.60	1.23	1.85	7.72	2.24	3.52	3.65	3.26	.21	.80	1.64	.72	.85	2.89	1.41	1.19	.45
2.70	1.27	1.94	8.34	2.34	3.47	3.66	3.36	.23	.84	1.70	.77	.93	3.14	1.46	1.21	.45
2.80	1.30	2.04	8.98	2.45	3.43	3.68	3.46	.25	.89	1.76	.81	1.00	3.39	1.50	1.23	.45
2.90	1.33	2.13	9.64	2.56	3.40	3.69	3.56	.28	.93	1.83	.85	1.06	3.65	1.55	1.25	.46
3.00	1.36	2.22	10.33	2.68	3.37	3.70	3.67	.31	.98	1.89	.90	1.13	3.93	1.60	1.26	.46
3.10	1.38	2.31	11.04	2.80	3.34	3.72	3.77	.33	1.03	1.95	.93	1.20	4.21	1.65	1.28	.46
3.20	1.41	2.41	11.78	2.92	3.32	3.73	3.87	.36	1.08	2.01	.97	1.26	4.50	1.70	1.30	.46
3.30	1.43	2.50	12.54	3.05	3.29	3.74	3.95	.39	1.13	2.08	1.00	1.33	4.80	1.75	1.32	.46
3.40	1.45	2.59	13.32	3.18	3.27	3.75	4.05	.42	1.18	2.14	1.04	1.39	5.10	1.80	1.34	.46
3.50	1.47	2.68	14.12	3.32	3.26	3.77	4.19	.45	1.24	2.20	1.07	1.46	5.42	1.86	1.36	.46
3.60	1.49	2.77	14.95	3.45	3.24	3.78	4.30	.48	1.29	2.26	1.10	1.52	5.75	1.91	1.38	.46
3.70	1.51	2.86	15.80	3.60	3.22	3.79	4.40	.51	1.35	2.33	1.13	1.58	6.08	1.97	1.40	.46
3.80	1.52	2.95	16.68	3.74	3.21	3.80	4.51	.55	1.41	2.39	1.15	1.64	6.43	2.03	1.42	.46
3.90	1.54	3.04	17.58	3.89	3.20	3.81	4.62	.58	1.47	2.45	1.18	1.70	6.78	2.09	1.45	.46
4.00	1.55	3.12	18.50	4.05	3.19	3.82	4.73	.62	1.53	2.51	1.20	1.76	7.14	2.15	1.47	.47
4.10	1.57	3.21	19.44	4.20	3.18	3.83	4.83	.65	1.59	2.58	1.23	1.82	7.51	2.21	1.49	.47
4.20	1.58	3.30	20.41	4.37	3.17	3.84	4.94	.69	1.66	2.64	1.25	1.88	7.90	2.28	1.51	.47
4.30	1.59	3.39	21.40	4.53	3.16	3.85	5.05	.73	1.73	2.70	1.27	1.94	8.29	2.35	1.53	.47
4.40	1.60	3.48	22.42	4.70	3.19	3.85	5.16	.77	1.79	2.76	1.29	2.00	8.69	2.41	1.55	.47
4.50	1.61	3.56	23.46	4.88	3.14	3.86	5.27	.81	1.86	2.83	1.31	2.06	9.09	2.48	1.58	.47
4.60	1.62	3.65	24.52	5.05	3.13	3.87	5.38	.85	1.93	2.89	1.33	2.12	9.51	2.55	1.60	.47
4.70	1.63	3.74	25.60	5.23	3.13	3.88	5.49	.89	2.00	2.95	1.34	2.18	9.94	2.62	1.62	.47
4.80	1.64	3.83	26.71	5.42	3.12	3.88	5.60	.93	2.08	3.01	1.36	2.24	10.37	2.70	1.64	.47
4.90	1.65	3.91	27.84	5.61	3.11	3.89	5.71	.98	2.15	3.08	1.38	2.29	10.82	2.77	1.66	.47
5.00	1.66	4.00	29.00	5.80	3.11	3.90	5.82	1.02	2.23	3.14	1.39	2.35	11.27	2.85	1.69	.47
5.10	1.67	4.09	30.18	6.00	3.10	3.90	5.93	1.07	2.31	3.20	1.41	2.41	11.74	2.93	1.71	.47
5.20	1.68	4.17	31.38	6.20	3.10	3.91	6.04	1.11	2.39	3.27	1.42	2.47	12.21	3.01	1.73	.47
5.30	1.68	4.26	32.60	6.40	3.09	3.91	6.15	1.16	2.47	3.33	1.44	2.52	12.69	3.09	1.76	.47
5.40	1.69	4.35	33.85	6.61	3.09	3.92	6.26	1.21	2.55	3.39	1.45	2.58	13.18	3.17	1.78	.47
5.50	1.70	4.43	35.12	6.82	3.08	3.92	6.37	1.26	2.64	3.45	1.46	2.64	13.68	3.25	1.80	.47
5.60	1.70	4.52	36.42	7.04	3.08	3.93	6.48	1.31	2.72	3.52	1.47	2.69	14.19	3.34	1.83	.47
5.70	1.71	4.60	37.74	7.26	3.08	3.93	6.59	1.36	2.81	3.58	1.49	2.75	14.71	3.42	1.85	.47
5.80	1.71	4.69	39.08	7.48	3.07	3.94	6.70	1.41	2.90	3.64	1.50	2.81	15.24	3.51	1.87	.47
5.90	1.72	4.78	40.44	7.71	3.07	3.94	6.81	1.46	2.99	3.70	1.51	2.86	15.78	3.60	1.90	.47
6.00	1.73	4.86	41.83	7.94	3.07	3.95	6.92	1.52	3.08	3.77	1.52	2.92	16.32	3.69	1.92	.47
6.10	1.73	4.95	43.24	8.18	3.06	3.95	7.03	1.57	3.17	3.83	1.53	2.97	16.88	3.79	1.95	.47
6.20	1.73	5.03	44.68	8.42	3.06	3.95	7.15	1.63	3.27	3.89	1.54	3.03	17.45	3.88	1.97	.47

BLAST WAVE PARAMETERS BEFORE AND AFTER A DIVERGENT NOZZLE

TABLE D-VI (Cont.)

SPECIFIC HEAT RATIO (GAMMA) = 1.400
AREA RATIO ACROSS THE DIVERGENT NOZZLE = 7.50

((((((NOZZLE INLET CONDITIONS))))))					((((((SECONDARY SHOCK CONDITIONS))))))					((((((PRIMARY TRANSMITTED SHOCK CONDITIONS))))						
SHOCK MACH NO.	FLOW MACH NO.	FLOW VEL. RATIO	SHOCK STREN	TEMP RATIO	2NDRY SHOCK MACH NO.	2NDRY FLOW MACH NO.	2NDRY FLOW VEL. RATIO	2NDRY SHOCK STREN	2NDRY TEMP RATIO	PRIM SHOCK MACH NO.	PRIM FLOW MACH NO.	PRIM FLOW VEL. RATIO	PRIM SHOCK STREN.	PRIM TEMP RATIO	SONIC VEL. RATIO	MACH NO. BET. CONT. AND 2NDRY SHOCK
MS1	M1	U1/A0	P1/P0	T1/T0	MS2	M2	U2/A0	P2/P0	T2/T0	MS3	M3	U3/A0	P3/P0	T3/T0	A3/A0	M3(PRIME)
6.30	1.74	5.12	46.14	8.66	3.06	3.96	7.26	1.68	3.36	3.96	1.55	3.09	18.02	3.98	1.99	.47
6.40	1.74	5.20	47.62	8.91	3.05	3.96	7.37	1.74	3.46	4.02	1.56	3.14	18.60	4.08	2.02	.47
6.50	1.75	5.29	49.12	9.16	3.05	3.96	7.48	1.80	3.56	4.08	1.56	3.20	19.20	4.17	2.04	.47
6.60	1.75	5.37	50.65	9.41	3.05	3.97	7.59	1.86	3.66	4.14	1.57	3.25	19.80	4.27	2.07	.47
6.70	1.76	5.46	52.20	9.67	3.05	3.97	7.70	1.92	3.76	4.21	1.58	3.31	20.41	4.38	2.09	.47
6.80	1.76	5.54	53.78	9.93	3.04	3.97	7.81	1.98	3.87	4.27	1.59	3.36	21.03	4.48	2.12	.47
6.90	1.76	5.63	55.38	10.20	3.04	3.98	7.93	2.04	3.97	4.33	1.60	3.42	21.66	4.59	2.14	.47
7.00	1.77	5.71	57.00	10.47	3.04	3.98	8.04	2.11	4.08	4.39	1.60	3.47	22.30	4.69	2.17	.47
7.10	1.77	5.80	58.64	10.74	3.04	3.98	8.15	2.17	4.19	4.46	1.61	3.53	22.94	4.80	2.19	.47
7.20	1.77	5.88	60.31	11.02	3.04	3.98	8.26	2.23	4.30	4.52	1.62	3.58	23.60	4.91	2.22	.47
7.30	1.78	5.97	62.00	11.30	3.04	3.99	8.37	2.30	4.41	4.58	1.62	3.64	24.27	5.02	2.24	.47
7.40	1.78	6.05	63.72	11.59	3.03	3.99	8.48	2.37	4.52	4.65	1.63	3.69	24.94	5.13	2.27	.47
7.50	1.78	6.14	65.46	11.88	3.03	3.99	8.60	2.43	4.64	4.71	1.64	3.75	25.63	5.25	2.29	.47
7.60	1.78	6.22	67.22	12.17	3.03	3.99	8.71	2.50	4.75	4.77	1.64	3.80	26.32	5.36	2.32	.47
7.70	1.79	6.31	69.00	12.47	3.03	4.00	8.82	2.57	4.87	4.83	1.65	3.86	27.02	5.48	2.34	.47
7.80	1.79	6.39	70.81	12.77	3.03	4.00	8.93	2.64	4.99	4.90	1.65	3.91	27.74	5.60	2.37	.47
7.90	1.79	6.48	72.64	13.08	3.03	4.00	9.04	2.71	5.11	4.96	1.66	3.96	28.46	5.72	2.39	.47
8.00	1.79	6.56	74.50	13.39	3.03	4.00	9.16	2.78	5.23	5.02	1.66	4.02	29.19	5.84	2.42	.47
8.10	1.80	6.65	76.38	13.70	3.02	4.00	9.27	2.86	5.36	5.08	1.67	4.07	29.93	5.97	2.44	.47
8.20	1.80	6.73	78.28	14.02	3.02	4.01	9.38	2.93	5.48	5.15	1.67	4.13	30.68	6.09	2.47	.47
8.30	1.80	6.82	80.20	14.34	3.02	4.01	9.49	3.00	5.61	5.21	1.68	4.18	31.43	6.22	2.49	.47
8.40	1.80	6.90	82.15	14.66	3.02	4.01	9.60	3.08	5.74	5.27	1.68	4.24	32.20	6.35	2.52	.47
8.50	1.80	6.99	84.12	14.99	3.02	4.01	9.72	3.16	5.87	5.34	1.69	4.29	32.98	6.47	2.54	.47
8.60	1.81	7.07	86.12	15.32	3.02	4.01	9.83	3.23	6.00	5.40	1.69	4.34	33.76	6.61	2.57	.47
8.70	1.81	7.15	88.14	15.66	3.02	4.01	9.94	3.31	6.13	5.46	1.69	4.40	34.56	6.74	2.60	.47
8.80	1.81	7.24	90.18	16.00	3.02	4.02	10.05	3.39	6.27	5.52	1.70	4.45	35.36	6.87	2.62	.47
8.90	1.81	7.32	92.24	16.34	3.02	4.02	10.17	3.47	6.40	5.59	1.70	4.51	36.18	7.01	2.65	.47
9.00	1.81	7.41	94.33	16.69	3.01	4.02	10.28	3.55	6.54	5.65	1.71	4.56	37.00	7.15	2.67	.47
9.10	1.81	7.49	96.44	17.04	3.01	4.02	10.39	3.63	6.68	5.71	1.71	4.61	37.83	7.28	2.70	.47
9.20	1.82	7.58	98.58	17.40	3.01	4.02	10.50	3.72	6.82	5.77	1.71	4.67	38.67	7.42	2.72	.47
9.30	1.82	7.66	100.74	17.76	3.01	4.02	10.61	3.80	6.96	5.84	1.72	4.72	39.52	7.57	2.75	.47
9.40	1.82	7.74	102.92	18.12	3.01	4.02	10.73	3.88	7.11	5.90	1.72	4.78	40.38	7.71	2.78	.47
9.50	1.82	7.83	105.12	18.49	3.01	4.03	10.84	3.97	7.25	5.96	1.72	4.83	41.25	7.85	2.80	.47
9.60	1.82	7.91	107.35	18.86	3.01	4.03	10.95	4.06	7.40	6.03	1.73	4.88	42.12	8.00	2.83	.47
9.70	1.82	8.00	109.60	19.24	3.01	4.03	11.06	4.14	7.55	6.09	1.73	4.94	43.01	8.15	2.85	.47
9.80	1.82	8.08	111.88	19.62	3.01	4.03	11.18	4.23	7.70	6.15	1.73	4.99	43.91	8.30	2.88	.47
9.90	1.83	8.17	114.18	20.00	3.01	4.03	11.29	4.32	7.85	6.21	1.74	5.04	44.81	8.45	2.91	.47
10.00	1.83	8.25	116.50	20.39	3.01	4.03	11.40	4.41	8.00	6.28	1.74	5.10	45.73	8.60	2.93	.47
10.10	1.83	8.33	118.84	20.78	3.01	4.03	11.51	4.50	8.16	6.34	1.74	5.15	46.65	8.75	2.96	.47
10.20	1.83	8.42	121.21	21.17	3.01	4.03	11.63	4.59	8.31	6.40	1.74	5.20	47.58	8.91	2.99	.47
10.30	1.83	8.50	123.60	21.57	3.01	4.03	11.74	4.69	8.47	6.46	1.75	5.26	48.52	9.07	3.01	.47

BLAST WAVE PARAMETERS BEFORE AND AFTER A DIVERGENT NOZZLE

TABLE D-VII

SPECIFIC HEAT RATIO (GAMMA) = 1.400
AREA RATIO ACROSS THE DIVERGENT NOZZLE = 9.00

((((((NOZZLE INLET CONDITIONS)))))))))))((((((SECONDARY SHOCK CONDITIONS)))))))((PRIMARY TRANSMITTED SHOCK CONDITIONS))																
SHOCK MACH NO.	FLOW MACH NO.	FLOW VEL. RATIO	SHOCK STREN	TEMP RATIO	2NDRY SHOCK MACH NO.	2NDRY FLOW MACH NO.	2NDRY FLOW VEL. RATIO	2NDRY SHOCK STREN	2NDRY TEMP RATIO	PRIM SHOCK MACH NO.	PRIM FLOW MACH NO.	PRIM FLOW VEL. RATIO	PRIM SHOCK STREN.	PRIM TEMP RATIO	SONIC VEL. RATIO	MACH NO. BET. CONT. AND 2NDRY SHOCK
MS1	M1	U1/A0	P1/P0	T1/T0	MS2	M2	U2/A0	P2/P0	T2/T0	MS3	M3	U3/A0	P3/P0	T3/T0	A3/A0	M3(PRIME)
2.20	1.07	1.45	5.48	1.86	4.09	3.81	2.91	.10	.58	1.32	.42	.46	1.78	1.20	1.10	.43
2.30	1.11	1.55	6.00	1.95	4.01	3.82	3.01	.11	.62	1.38	.49	.54	1.97	1.24	1.11	.43
2.40	1.16	1.65	6.55	2.04	3.94	3.83	3.11	.13	.66	1.44	.55	.62	2.17	1.28	1.13	.44
2.50	1.20	1.75	7.12	2.14	3.87	3.84	3.20	.14	.70	1.50	.60	.69	2.38	1.32	1.15	.44
2.60	1.23	1.85	7.72	2.24	3.82	3.85	3.30	.16	.74	1.56	.65	.76	2.59	1.36	1.17	.44
2.70	1.27	1.94	8.34	2.34	3.77	3.86	3.41	.18	.78	1.62	.70	.83	2.81	1.40	1.18	.44
2.80	1.30	2.04	8.98	2.45	3.73	3.88	3.51	.19	.82	1.67	.75	.90	3.04	1.44	1.20	.44
2.90	1.33	2.13	9.64	2.56	3.69	3.89	3.61	.21	.86	1.73	.79	.96	3.27	1.48	1.22	.44
3.00	1.36	2.22	10.33	2.68	3.66	3.90	3.72	.23	.91	1.79	.83	1.03	3.52	1.53	1.24	.45
3.10	1.38	2.31	11.04	2.80	3.63	3.92	3.82	.25	.95	1.85	.87	1.09	3.77	1.57	1.25	.45
3.20	1.41	2.41	11.78	2.92	3.60	3.93	3.93	.27	1.00	1.91	.91	1.16	4.03	1.62	1.27	.45
3.30	1.43	2.50	12.54	3.05	3.58	3.94	4.03	.30	1.05	1.97	.95	1.22	4.30	1.66	1.29	.45
3.40	1.45	2.59	13.32	3.18	3.56	3.96	4.14	.32	1.09	2.03	.98	1.28	4.58	1.71	1.31	.45
3.50	1.47	2.68	14.12	3.32	3.54	3.97	4.25	.34	1.14	2.09	1.01	1.34	4.87	1.76	1.33	.45
3.60	1.49	2.77	14.95	3.45	3.52	3.99	4.35	.37	1.20	2.15	1.04	1.40	5.16	1.81	1.35	.45
3.70	1.51	2.86	15.80	3.60	3.50	3.99	4.46	.39	1.25	2.21	1.07	1.46	5.46	1.87	1.37	.45
3.80	1.52	2.95	16.68	3.74	3.49	4.00	4.57	.42	1.30	2.27	1.10	1.52	5.77	1.92	1.39	.45
3.90	1.54	3.04	17.58	3.89	3.47	4.01	4.68	.44	1.36	2.33	1.13	1.58	6.09	1.97	1.40	.45
4.00	1.55	3.12	18.50	4.05	3.46	4.02	4.79	.47	1.42	2.39	1.15	1.64	6.42	2.03	1.42	.45
4.10	1.57	3.21	19.44	4.20	3.45	4.03	4.90	.50	1.48	2.45	1.18	1.70	6.75	2.09	1.44	.45
4.20	1.58	3.30	20.41	4.37	3.44	4.04	5.01	.53	1.54	2.51	1.20	1.76	7.10	2.14	1.46	.45
4.30	1.59	3.39	21.40	4.53	3.43	4.05	5.12	.56	1.60	2.57	1.22	1.81	7.45	2.20	1.48	.45
4.40	1.60	3.48	22.42	4.70	3.42	4.06	5.23	.58	1.66	2.63	1.24	1.87	7.81	2.26	1.50	.45
4.50	1.61	3.56	23.46	4.88	3.41	4.07	5.34	.62	1.72	2.68	1.26	1.93	8.18	2.33	1.53	.45
4.60	1.62	3.65	24.52	5.05	3.40	4.07	5.45	.65	1.79	2.74	1.28	1.98	8.55	2.39	1.55	.46
4.70	1.63	3.74	25.60	5.23	3.39	4.08	5.56	.68	1.85	2.80	1.30	2.04	8.94	2.46	1.57	.46
4.80	1.64	3.83	26.71	5.42	3.39	4.09	5.67	.71	1.92	2.86	1.32	2.09	9.33	2.52	1.59	.46
4.90	1.65	3.91	27.84	5.61	3.38	4.09	5.78	.74	1.99	2.92	1.34	2.15	9.73	2.59	1.61	.46
5.00	1.66	4.00	29.00	5.80	3.37	4.10	5.89	.78	2.06	2.98	1.35	2.21	10.14	2.66	1.63	.46
5.10	1.67	4.09	30.18	6.00	3.37	4.11	6.00	.81	2.14	3.04	1.37	2.26	10.56	2.73	1.65	.46
5.20	1.68	4.17	31.38	6.20	3.36	4.11	6.11	.85	2.21	3.10	1.38	2.32	10.98	2.80	1.67	.46
5.30	1.68	4.26	32.60	6.40	3.36	4.12	6.22	.88	2.28	3.16	1.40	2.37	11.42	2.87	1.69	.46
5.40	1.69	4.35	33.85	6.61	3.35	4.12	6.33	.92	2.36	3.22	1.41	2.42	11.86	2.95	1.72	.46
5.50	1.70	4.43	35.12	6.82	3.35	4.13	6.45	.96	2.44	3.28	1.43	2.48	12.31	3.02	1.74	.46
5.60	1.70	4.52	36.42	7.04	3.34	4.13	6.56	1.00	2.52	3.34	1.44	2.53	12.77	3.10	1.76	.46
5.70	1.71	4.60	37.74	7.26	3.34	4.14	6.67	1.04	2.60	3.40	1.45	2.59	13.24	3.18	1.78	.46
5.80	1.71	4.69	39.08	7.48	3.34	4.14	6.78	1.08	2.68	3.46	1.46	2.64	13.72	3.26	1.80	.46
5.90	1.72	4.78	40.44	7.71	3.33	4.15	6.89	1.12	2.76	3.52	1.47	2.69	14.20	3.34	1.83	.46
6.00	1.73	4.86	41.83	7.94	3.33	4.15	7.01	1.16	2.85	3.58	1.49	2.75	14.69	3.42	1.85	.46
6.10	1.73	4.95	43.24	8.18	3.32	4.16	7.12	1.20	2.94	3.64	1.50	2.80	15.19	3.51	1.87	.46
6.20	1.73	5.03	44.68	8.42	3.32	4.16	7.23	1.24	3.02	3.70	1.51	2.85	15.70	3.59	1.89	.46

BLAST WAVE PARAMETERS BEFORE AND AFTER A DIVERGENT NOZZLE

TABLE D-VII (Cont.)

SPECIFIC HEAT RATIO (GAMMA) = 1.400
AREA RATIO ACROSS THE DIVERGENT NOZZLE = 9.00

((((((NOZZLE INLET CONDITIONS))					((((((SECONDARY SHOCK CONDITIONS))					((((((PRIMARY TRANSMITTED SHOCK CONDITIONS))						
SHOCK MACH NO.	FLOW MACH NO.	FLOW VEL. RATIO	SHOCK STREN	TEMP RATIO	2NDRY SHOCK MACH NO.	2NDRY FLOW MACH NO.	2NDRY FLOW VEL. RATIO	2NDRY SHOCK STREN	2NDRY TEMP RATIO	PRIM SHOCK MACH NO.	PRIM FLOW MACH NO.	PRIM FLOW VEL. RATIO	PRIM SHOCK STREN.	PRIM TEMP RATIO	SONIC VEL. RATIO	MACH NO. BET. CONT. AND 2NDRY SHOCK
MS1	M1	U1/A0	P1/P0	T1/T0	MS2	M2	U2/A0	P2/P0	T2/T0	MS3	M3	U3/A0	P3/P0	T3/T0	A3/A0	M3(PRIME)
6.30	1.74	5.12	46.14	8.66	3.32	4.16	7.34	1.28	3.11	3.76	1.52	2.91	16.22	3.68	1.92	.46
6.40	1.74	5.20	47.62	8.91	3.32	4.17	7.46	1.33	3.20	3.81	1.53	2.96	16.74	3.76	1.94	.46
6.50	1.75	5.29	49.12	9.16	3.31	4.17	7.57	1.37	3.29	3.87	1.54	3.01	17.28	3.85	1.96	.46
6.60	1.75	5.37	50.65	9.41	3.31	4.17	7.68	1.42	3.39	3.93	1.54	3.07	17.82	3.94	1.99	.46
6.70	1.76	5.46	52.20	9.67	3.31	4.18	7.79	1.46	3.48	3.99	1.55	3.12	18.37	4.04	2.01	.46
6.80	1.76	5.54	53.78	9.93	3.31	4.18	7.91	1.51	3.58	4.05	1.56	3.17	18.93	4.13	2.03	.46
6.90	1.76	5.63	55.38	10.20	3.30	4.18	8.02	1.56	3.68	4.11	1.57	3.22	19.50	4.22	2.06	.46
7.00	1.77	5.71	57.00	10.47	3.30	4.19	8.13	1.60	3.78	4.17	1.58	3.28	20.07	4.32	2.08	.46
7.10	1.77	5.80	58.64	10.74	3.30	4.19	8.24	1.65	3.88	4.23	1.58	3.33	20.65	4.42	2.10	.46
7.20	1.77	5.88	60.31	11.02	3.30	4.19	8.36	1.70	3.98	4.29	1.59	3.38	21.25	4.52	2.13	.46
7.30	1.78	5.97	62.00	11.30	3.30	4.19	8.47	1.75	4.08	4.35	1.60	3.43	21.85	4.62	2.15	.46
7.40	1.78	6.05	63.72	11.59	3.29	4.20	8.58	1.80	4.19	4.41	1.60	3.49	22.45	4.72	2.17	.46
7.50	1.78	6.14	65.46	11.88	3.29	4.20	8.70	1.85	4.29	4.47	1.61	3.54	23.07	4.82	2.20	.46
7.60	1.78	6.22	67.22	12.17	3.29	4.20	8.81	1.91	4.40	4.53	1.62	3.59	23.70	4.93	2.22	.46
7.70	1.79	6.31	69.00	12.47	3.29	4.20	8.92	1.96	4.51	4.59	1.62	3.64	24.33	5.03	2.24	.46
7.80	1.79	6.39	70.81	12.77	3.29	4.20	9.04	2.01	4.62	4.65	1.63	3.69	24.97	5.14	2.27	.46
7.90	1.79	6.48	72.64	13.08	3.29	4.21	9.15	2.07	4.73	4.71	1.64	3.75	25.62	5.25	2.29	.46
8.00	1.79	6.56	74.50	13.39	3.28	4.21	9.26	2.12	4.84	4.77	1.64	3.80	26.28	5.36	2.31	.46
8.10	1.80	6.65	76.38	13.70	3.28	4.21	9.38	2.18	4.96	4.83	1.65	3.85	26.94	5.47	2.34	.46
8.20	1.80	6.73	78.28	14.02	3.28	4.21	9.49	2.23	5.07	4.89	1.65	3.90	27.62	5.58	2.36	.46
8.30	1.80	6.82	80.20	14.34	3.28	4.21	9.60	2.29	5.19	4.95	1.66	3.95	28.30	5.69	2.39	.46
8.40	1.80	6.90	82.15	14.66	3.28	4.22	9.72	2.35	5.31	5.01	1.66	4.00	28.99	5.81	2.41	.46
8.50	1.80	6.99	84.12	14.99	3.28	4.22	9.83	2.41	5.43	5.06	1.67	4.06	29.69	5.93	2.43	.46
8.60	1.81	7.07	86.12	15.32	3.28	4.22	9.94	2.47	5.55	5.12	1.67	4.11	30.40	6.04	2.46	.46
8.70	1.81	7.15	88.14	15.66	3.28	4.22	10.06	2.52	5.67	5.18	1.68	4.16	31.11	6.16	2.48	.46
8.80	1.81	7.24	90.18	16.00	3.27	4.22	10.17	2.59	5.80	5.24	1.68	4.21	31.84	6.28	2.51	.46
8.90	1.81	7.32	92.24	16.34	3.27	4.22	10.28	2.65	5.93	5.30	1.68	4.26	32.57	6.41	2.53	.46
9.00	1.81	7.41	94.33	16.69	3.27	4.23	10.40	2.71	6.05	5.36	1.69	4.31	33.31	6.53	2.56	.46
9.10	1.81	7.49	96.44	17.04	3.27	4.23	10.51	2.77	6.18	5.42	1.69	4.36	34.06	6.66	2.58	.46
9.20	1.82	7.58	98.58	17.40	3.27	4.23	10.62	2.83	6.31	5.48	1.70	4.42	34.82	6.78	2.60	.46
9.30	1.82	7.66	100.74	17.76	3.27	4.23	10.74	2.90	6.44	5.54	1.70	4.47	35.58	6.91	2.63	.46
9.40	1.82	7.74	102.92	18.12	3.27	4.23	10.85	2.96	6.58	5.60	1.70	4.52	36.36	7.04	2.65	.46
9.50	1.82	7.83	105.12	18.49	3.27	4.23	10.96	3.03	6.71	5.66	1.71	4.57	37.14	7.17	2.68	.46
9.60	1.82	7.91	107.35	18.86	3.27	4.23	11.08	3.09	6.85	5.72	1.71	4.62	37.93	7.30	2.70	.46
9.70	1.82	8.00	109.60	19.24	3.27	4.23	11.19	3.16	6.98	5.78	1.71	4.67	38.73	7.43	2.73	.46
9.80	1.82	8.08	111.88	19.62	3.27	4.24	11.30	3.23	7.12	5.84	1.72	4.72	39.53	7.57	2.75	.46
9.90	1.83	8.17	114.18	20.00	3.26	4.24	11.42	3.29	7.26	5.90	1.72	4.77	40.35	7.70	2.78	.46
10.00	1.83	8.25	116.50	20.39	3.26	4.24	11.53	3.36	7.40	5.96	1.72	4.82	41.17	7.84	2.80	.46
10.10	1.83	8.33	118.84	20.78	3.26	4.24	11.65	3.43	7.55	6.02	1.73	4.88	42.00	7.98	2.82	.46
10.20	1.83	8.42	121.21	21.17	3.26	4.24	11.76	3.50	7.69	6.08	1.73	4.93	42.84	8.12	2.85	.46
10.30	1.83	8.50	123.60	21.57	3.26	4.24	11.87	3.57	7.84	6.14	1.73	4.98	43.69	8.26	2.87	.46

BLAST WAVE PARAMETERS BEFORE AND AFTER A DIVERGENT NOZZLE

TABLE D-VIII

SPECIFIC HEAT RATIO (GAMMA) = 1.400
AREA RATIO ACROSS THE DIVERGENT NOZZLE = 10.00

((((((NOZZLE INLET CONDITIONS)))))))))))((((((SECONDARY SHOCK CONDITIONS)))))))((PRIMARY TRANSMITTED SHOCK CONDITIONS))																
SHOCK MACH NO.	FLOW MACH NO.	FLOW VEL. RATIO	SHOCK STREN	TEMP RATIO	2NDRY SHOCK MACH NO.	2NDRY FLOW MACH NO.	2NDRY FLOW VEL. RATIO	2NDRY SHOCK STREN	2NDRY TEMP RATIO	PRIM SHOCK MACH NO.	PRIM FLOW MACH NO.	PRIM FLOW VEL. RATIO	PRIM SHOCK STREN.	PRIM TEMP RATIO	SONIC VEL. RATIO	MACH NO. BET. CONT. AND 2NDRY SHOCK
MS1	M1	U1/A0	P1/P0	T1/T0	MS2	M2	U2/A0	P2/P0	T2/T0	MS3	M3	U3/A0	P3/P0	T3/T0	A3/A0	M3(PRIME)
2.20	1.07	1.45	5.48	1.86	4.28	3.93	2.93	.08	.56	1.28	.38	.41	1.67	1.18	1.08	.43
2.30	1.11	1.55	6.00	1.95	4.20	3.93	3.03	.09	.59	1.34	.44	.49	1.85	1.21	1.10	.43
2.40	1.16	1.65	6.55	2.04	4.12	3.94	3.13	.11	.63	1.39	.50	.56	2.03	1.25	1.12	.43
2.50	1.20	1.75	7.12	2.14	4.06	3.95	3.23	.12	.67	1.45	.56	.64	2.23	1.29	1.14	.43
2.60	1.23	1.85	7.72	2.24	4.00	3.97	3.33	.13	.70	1.51	.61	.71	2.43	1.33	1.15	.43
2.70	1.27	1.94	8.34	2.34	3.95	3.98	3.43	.15	.74	1.57	.66	.77	2.63	1.37	1.17	.44
2.80	1.30	2.04	8.98	2.45	3.91	3.99	3.53	.17	.78	1.63	.71	.84	2.85	1.41	1.19	.44
2.90	1.33	2.13	9.64	2.56	3.87	4.01	3.64	.18	.82	1.68	.75	.91	3.07	1.45	1.20	.44
3.00	1.36	2.22	10.33	2.68	3.83	4.02	3.74	.20	.87	1.74	.80	.97	3.30	1.49	1.22	.44
3.10	1.38	2.31	11.04	2.80	3.80	4.04	3.85	.22	.91	1.80	.84	1.03	3.54	1.53	1.24	.44
3.20	1.41	2.41	11.78	2.92	3.77	4.05	3.95	.23	.95	1.86	.87	1.10	3.78	1.57	1.25	.44
3.30	1.43	2.50	12.54	3.05	3.75	4.06	4.06	.25	1.00	1.91	.91	1.16	4.04	1.62	1.27	.44
3.40	1.45	2.59	13.32	3.18	3.73	4.07	4.17	.27	1.05	1.97	.95	1.22	4.30	1.66	1.29	.44
3.50	1.47	2.68	14.12	3.32	3.71	4.09	4.28	.29	1.09	2.03	.98	1.28	4.57	1.71	1.31	.44
3.60	1.49	2.77	14.95	3.45	3.69	4.10	4.38	.31	1.14	2.09	1.01	1.34	4.84	1.76	1.33	.44
3.70	1.51	2.86	15.80	3.60	3.67	4.11	4.49	.33	1.19	2.14	1.04	1.40	5.13	1.81	1.34	.44
3.80	1.52	2.95	16.68	3.74	3.65	4.12	4.60	.36	1.25	2.20	1.07	1.46	5.42	1.86	1.36	.45
3.90	1.54	3.04	17.58	3.89	3.64	4.13	4.71	.38	1.30	2.26	1.10	1.51	5.72	1.91	1.38	.45
4.00	1.55	3.12	18.50	4.05	3.63	4.14	4.82	.40	1.35	2.32	1.12	1.57	6.02	1.96	1.40	.45
4.10	1.57	3.21	19.44	4.20	3.61	4.15	4.93	.43	1.41	2.37	1.15	1.63	6.34	2.02	1.42	.45
4.20	1.58	3.30	20.41	4.37	3.60	4.16	5.04	.45	1.47	2.43	1.17	1.68	6.66	2.07	1.44	.45
4.30	1.59	3.39	21.40	4.53	3.59	4.17	5.15	.47	1.53	2.49	1.19	1.74	6.99	2.13	1.46	.45
4.40	1.60	3.48	22.42	4.70	3.58	4.18	5.26	.50	1.59	2.55	1.21	1.79	7.33	2.18	1.48	.45
4.50	1.61	3.56	23.46	4.88	3.57	4.18	5.37	.53	1.65	2.60	1.24	1.85	7.68	2.24	1.50	.45
4.60	1.62	3.65	24.52	5.05	3.56	4.19	5.48	.55	1.71	2.66	1.26	1.90	8.03	2.30	1.52	.45
4.70	1.63	3.74	25.60	5.23	3.56	4.20	5.59	.58	1.77	2.72	1.27	1.96	8.39	2.36	1.54	.45
4.80	1.64	3.83	26.71	5.42	3.55	4.21	5.70	.61	1.84	2.78	1.29	2.01	8.76	2.43	1.56	.45
4.90	1.65	3.91	27.84	5.61	3.54	4.21	5.82	.64	1.91	2.83	1.31	2.07	9.14	2.49	1.58	.45
5.00	1.66	4.00	29.00	5.80	3.53	4.22	5.93	.67	1.97	2.89	1.33	2.12	9.52	2.55	1.60	.45
5.10	1.67	4.09	30.18	6.00	3.53	4.23	6.04	.70	2.04	2.95	1.34	2.18	9.92	2.62	1.62	.45
5.20	1.68	4.17	31.38	6.20	3.52	4.23	6.15	.73	2.11	3.01	1.36	2.23	10.32	2.69	1.64	.45
5.30	1.68	4.26	32.60	6.40	3.52	4.24	6.26	.76	2.18	3.06	1.37	2.28	10.72	2.76	1.66	.45
5.40	1.69	4.35	33.85	6.61	3.51	4.24	6.38	.79	2.26	3.12	1.39	2.33	11.14	2.83	1.68	.45
5.50	1.70	4.43	35.12	6.82	3.51	4.25	6.49	.82	2.33	3.18	1.40	2.39	11.56	2.90	1.70	.45
5.60	1.70	4.52	36.42	7.04	3.50	4.25	6.60	.85	2.41	3.24	1.42	2.44	11.99	2.97	1.72	.45
5.70	1.71	4.60	37.74	7.26	3.50	4.26	6.71	.89	2.48	3.30	1.43	2.49	12.43	3.04	1.74	.45
5.80	1.71	4.69	39.08	7.48	3.49	4.26	6.82	.92	2.56	3.35	1.44	2.55	12.88	3.12	1.77	.45
5.90	1.72	4.78	40.44	7.71	3.49	4.27	6.94	.95	2.64	3.41	1.45	2.60	13.33	3.19	1.79	.45
6.00	1.73	4.86	41.83	7.94	3.49	4.27	7.05	.99	2.72	3.47	1.46	2.65	13.80	3.27	1.81	.45
6.10	1.73	4.95	43.24	8.18	3.48	4.28	7.16	1.02	2.81	3.53	1.48	2.70	14.27	3.35	1.83	.45
6.20	1.73	5.03	44.68	8.42	3.48	4.28	7.28	1.06	2.89	3.58	1.49	2.75	14.74	3.43	1.85	.45

BLAST WAVE PARAMETERS BEFORE AND AFTER A DIVERGENT NOZZLE

TABLE D-VIII (Cont.)

SPECIFIC HEAT RATIO (GAMMA) = 1.400
AREA RATIO ACROSS THE DIVERGENT NOZZLE = 10.00

((((((NOZZLE INLET CONDITIONS)))))))))((((((SECONDARY SHOCK CONDITIONS)))))))((PRIMARY TRANSMITTED SHOCK CONDITIONS))																
SHOCK MACH NO.	FLOW MACH NO.	FLOW VEL. RATIO	SHOCK STREN	TEMP RATIO	2NDRY SHOCK MACH NO.	2NDRY FLOW MACH NO.	2NDRY FLOW VEL. RATIO	2NDRY SHOCK STREN	2NDRY TEMP RATIO	PRIM SHOCK MACH NO.	PRIM FLOW MACH NO.	PRIM FLOW VEL. RATIO	PRIM SHOCK STREN.	PRIM TEMP RATIO	SONIC VEL. RATIO	MACH NO. BET. CONT. AND 2NDRY SHOCK
MS1	M1	U1/A0	P1/P0	T1/T0	MS2	M2	U2/A0	P2/P0	T2/T0	MS3	M3	U3/A0	P3/P0	T3/T0	A3/A0	M3(PRIME)
6.30	1.74	5.12	46.14	8.66	3.48	4.28	7.39	1.10	2.98	3.64	1.50	2.80	15.23	3.51	1.87	.45
6.40	1.74	5.20	47.62	8.91	3.47	4.29	7.50	1.14	3.06	3.70	1.51	2.86	15.72	3.59	1.90	.45
6.50	1.75	5.29	49.12	9.16	3.47	4.29	7.62	1.17	3.15	3.76	1.52	2.91	16.22	3.68	1.92	.45
6.60	1.75	5.37	50.65	9.41	3.47	4.29	7.73	1.21	3.24	3.81	1.53	2.96	16.73	3.76	1.94	.45
6.70	1.76	5.46	52.20	9.67	3.47	4.30	7.84	1.25	3.33	3.87	1.53	3.01	17.25	3.85	1.96	.45
6.80	1.76	5.54	53.78	9.93	3.46	4.30	7.95	1.29	3.42	3.93	1.54	3.06	17.77	3.94	1.98	.45
6.90	1.76	5.63	55.38	10.20	3.46	4.30	8.07	1.33	3.52	3.99	1.55	3.11	18.31	4.03	2.01	.45
7.00	1.77	5.71	57.00	10.47	3.46	4.31	8.18	1.37	3.61	4.04	1.56	3.16	18.85	4.12	2.03	.45
7.10	1.77	5.80	58.64	10.74	3.46	4.31	8.30	1.41	3.71	4.10	1.57	3.22	19.40	4.21	2.05	.45
7.20	1.77	5.88	60.31	11.02	3.45	4.31	8.41	1.46	3.80	4.16	1.57	3.27	19.96	4.30	2.07	.45
7.30	1.78	5.97	62.00	11.30	3.45	4.31	8.52	1.50	3.90	4.22	1.58	3.32	20.52	4.40	2.10	.45
7.40	1.78	6.05	63.72	11.59	3.45	4.32	8.64	1.54	4.00	4.28	1.59	3.37	21.09	4.49	2.12	.45
7.50	1.78	6.14	65.46	11.88	3.45	4.32	8.75	1.59	4.10	4.33	1.60	3.42	21.67	4.59	2.14	.45
7.60	1.78	6.22	67.22	12.17	3.45	4.32	8.86	1.63	4.21	4.39	1.60	3.47	22.26	4.69	2.16	.45
7.70	1.79	6.31	69.00	12.47	3.44	4.32	8.98	1.68	4.31	4.45	1.61	3.52	22.86	4.79	2.19	.45
7.80	1.79	6.39	70.81	12.77	3.44	4.33	9.09	1.72	4.42	4.51	1.62	3.57	23.46	4.89	2.21	.45
7.90	1.79	6.48	72.64	13.08	3.44	4.33	9.20	1.77	4.52	4.56	1.62	3.62	24.07	4.99	2.23	.45
8.00	1.79	6.56	74.50	13.39	3.44	4.33	9.32	1.82	4.63	4.62	1.63	3.67	24.69	5.09	2.26	.45
8.10	1.80	6.65	76.38	13.70	3.44	4.33	9.43	1.86	4.74	4.68	1.63	3.72	25.31	5.20	2.28	.45
8.20	1.80	6.73	78.28	14.02	3.44	4.33	9.55	1.91	4.85	4.74	1.64	3.77	25.95	5.30	2.30	.45
8.30	1.80	6.82	80.20	14.34	3.44	4.34	9.66	1.96	4.96	4.79	1.64	3.82	26.59	5.41	2.33	.45
8.40	1.80	6.90	82.15	14.66	3.43	4.34	9.77	2.01	5.08	4.85	1.65	3.87	27.24	5.52	2.35	.45
8.50	1.80	6.99	84.12	14.99	3.43	4.34	9.89	2.06	5.19	4.91	1.65	3.92	27.90	5.63	2.37	.45
8.60	1.81	7.07	86.12	15.32	3.43	4.34	10.00	2.11	5.31	4.97	1.66	3.97	28.56	5.74	2.40	.45
8.70	1.81	7.15	88.14	15.66	3.43	4.34	10.12	2.16	5.43	5.03	1.66	4.02	29.23	5.85	2.42	.45
8.80	1.81	7.24	90.18	16.00	3.43	4.34	10.23	2.21	5.55	5.08	1.67	4.07	29.91	5.96	2.44	.45
8.90	1.81	7.32	92.24	16.34	3.43	4.35	10.34	2.26	5.67	5.14	1.67	4.12	30.60	6.08	2.47	.45
9.00	1.81	7.41	94.33	16.69	3.43	4.35	10.46	2.32	5.79	5.20	1.68	4.17	31.30	6.19	2.49	.45
9.10	1.81	7.49	96.44	17.04	3.43	4.35	10.57	2.37	5.91	5.26	1.68	4.22	32.00	6.31	2.51	.45
9.20	1.82	7.58	98.58	17.40	3.43	4.35	10.69	2.42	6.04	5.31	1.68	4.27	32.71	6.43	2.54	.45
9.30	1.82	7.66	100.74	17.76	3.42	4.35	10.80	2.48	6.16	5.37	1.69	4.32	33.43	6.55	2.56	.45
9.40	1.82	7.74	102.92	18.12	3.42	4.35	10.92	2.53	6.29	5.43	1.69	4.37	34.16	6.67	2.58	.45
9.50	1.82	7.83	105.12	18.49	3.42	4.35	11.03	2.59	6.42	5.49	1.70	4.42	34.90	6.79	2.61	.45
9.60	1.82	7.91	107.35	18.86	3.42	4.35	11.14	2.65	6.55	5.55	1.70	4.47	35.64	6.92	2.63	.45
9.70	1.82	8.00	109.60	19.24	3.42	4.36	11.26	2.70	6.68	5.60	1.70	4.52	36.39	7.04	2.65	.45
9.80	1.82	8.08	111.88	19.62	3.42	4.36	11.37	2.76	6.81	5.66	1.71	4.57	37.15	7.17	2.68	.45
9.90	1.83	8.17	114.18	20.00	3.42	4.36	11.49	2.82	6.95	5.72	1.71	4.62	37.91	7.30	2.70	.45
10.00	1.83	8.25	116.50	20.39	3.42	4.36	11.60	2.88	7.08	5.78	1.71	4.67	38.69	7.43	2.73	.45
10.10	1.83	8.33	118.84	20.78	3.42	4.36	11.72	2.94	7.22	5.83	1.72	4.72	39.47	7.56	2.75	.45
10.20	1.83	8.42	121.21	21.17	3.42	4.36	11.83	3.00	7.36	5.89	1.72	4.77	40.26	7.69	2.77	.45
10.30	1.83	8.50	123.60	21.57	3.42	4.36	11.94	3.06	7.50	5.95	1.72	4.82	41.06	7.82	2.80	.45

BLAST WAVE PARAMETERS BEFORE AND AFTER A DIVERGENT NOZZLE

TABLE D-IX

SPECIFIC HEAT RATIO (GAMMA) = 1.400
AREA RATIO ACROSS THE DIVERGENT NOZZLE = 15.00

(((((NOZZLE INLET CONDITIONS))))))))))					(((((SECONDARY SHOCK CONDITIONS)))))))					(PRIMARY TRANSMITTED SHOCK CONDITIONS))						
SHOCK MACH NO. MS1	FLOW MACH NO. M1	FLOW VEL. RATIO U1/A0	SHOCK STREN P1/P0	TEMP RATIO T1/T0	2NDRY SHOCK MACH NO. MS2	2NDRY FLOW MACH NO. M2	2NDRY FLOW VEL. RATIO U2/A0	2NDRY SHOCK STREN P2/P0	2NDRY TEMP RATIO T2/T0	PRIM SHOCK MACH NO. MS3	PRIM FLOW MACH NO. M3	PRIM FLOW VEL. RATIO U3/A0	PRIM SHOCK STREN. P3/P0	PRIM TEMP RATIO T3/T0	SONIC VEL. RATIO A3/A0	MACH NO. BET. CONT. AND 2NDRY SHOCK M3(PRIME)
2.20	1.07	1.45	5.48	1.86	5.09	4.39	3.01	.04	.47	1.14	.21	.21	1.28	1.09	1.04	.41
2.30	1.11	1.55	6.00	1.95	4.98	4.40	3.11	.05	.50	1.19	.27	.29	1.41	1.12	1.06	.42
2.40	1.16	1.65	6.55	2.04	4.90	4.41	3.21	.06	.53	1.24	.34	.36	1.56	1.15	1.07	.42
2.50	1.20	1.75	7.12	2.14	4.82	4.42	3.31	.07	.56	1.29	.39	.43	1.71	1.18	1.09	.42
2.60	1.23	1.85	7.72	2.24	4.75	4.43	3.41	.07	.59	1.34	.45	.50	1.87	1.22	1.10	.42
2.70	1.27	1.94	8.34	2.34	4.69	4.44	3.52	.08	.63	1.39	.50	.56	2.03	1.25	1.12	.42
2.80	1.30	2.04	8.98	2.45	4.64	4.46	3.62	.09	.66	1.44	.55	.62	2.19	1.28	1.13	.42
2.90	1.33	2.13	9.64	2.56	4.60	4.47	3.73	.10	.69	1.49	.60	.69	2.37	1.32	1.15	.42
3.00	1.36	2.22	10.33	2.65	4.56	4.49	3.83	.11	.73	1.54	.64	.75	2.55	1.35	1.16	.42
3.10	1.38	2.31	11.04	2.80	4.52	4.50	3.94	.12	.77	1.59	.69	.81	2.73	1.38	1.18	.42
3.20	1.41	2.41	11.78	2.92	4.48	4.52	4.05	.13	.80	1.65	.73	.86	2.92	1.42	1.19	.42
3.30	1.43	2.50	12.54	3.05	4.45	4.53	4.16	.14	.84	1.70	.76	.92	3.12	1.46	1.21	.42
3.40	1.45	2.59	13.32	3.18	4.43	4.54	4.27	.15	.88	1.75	.80	.98	3.32	1.49	1.22	.42
3.50	1.47	2.68	14.12	3.32	4.40	4.56	4.37	.16	.92	1.80	.84	1.03	3.53	1.53	1.24	.43
3.60	1.49	2.77	14.95	3.45	4.38	4.57	4.48	.17	.96	1.85	.87	1.09	3.75	1.57	1.25	.43
3.70	1.51	2.86	15.80	3.60	4.36	4.58	4.60	.18	1.01	1.90	.90	1.14	3.97	1.61	1.27	.43
3.80	1.52	2.95	16.68	3.74	4.34	4.59	4.71	.20	1.05	1.95	.93	1.20	4.20	1.65	1.28	.43
3.90	1.54	3.04	17.58	3.89	4.32	4.60	4.82	.21	1.10	2.00	.96	1.25	4.43	1.69	1.30	.43
4.00	1.55	3.12	18.50	4.05	4.31	4.61	4.93	.22	1.14	2.05	.99	1.30	4.67	1.73	1.31	.43
4.10	1.57	3.21	19.44	4.20	4.29	4.62	5.04	.23	1.19	2.10	1.02	1.35	4.91	1.77	1.33	.43
4.20	1.58	3.30	20.41	4.37	4.28	4.63	5.15	.25	1.24	2.15	1.04	1.41	5.16	1.81	1.35	.43
4.30	1.59	3.39	21.40	4.53	4.26	4.64	5.26	.26	1.29	2.20	1.07	1.46	5.42	1.86	1.36	.43
4.40	1.60	3.48	22.42	4.70	4.25	4.65	5.38	.27	1.34	2.25	1.09	1.51	5.68	1.90	1.38	.43
4.50	1.61	3.56	23.46	4.88	4.24	4.66	5.49	.29	1.39	2.30	1.12	1.56	5.95	1.95	1.40	.43
4.60	1.62	3.65	24.52	5.05	4.23	4.67	5.60	.30	1.44	2.35	1.14	1.61	6.23	2.00	1.41	.43
4.70	1.63	3.74	25.60	5.23	4.22	4.68	5.72	.32	1.49	2.40	1.16	1.66	6.51	2.04	1.43	.43
4.80	1.64	3.83	26.71	5.42	4.21	4.68	5.83	.33	1.55	2.45	1.18	1.71	6.80	2.09	1.45	.43
4.90	1.65	3.91	27.84	5.61	4.20	4.69	5.94	.35	1.61	2.51	1.20	1.76	7.09	2.14	1.46	.43
5.00	1.66	4.00	29.00	5.80	4.20	4.70	6.06	.37	1.66	2.56	1.22	1.80	7.39	2.19	1.48	.43
5.10	1.67	4.09	30.18	6.00	4.19	4.70	6.17	.38	1.72	2.61	1.24	1.85	7.70	2.25	1.50	.43
5.20	1.68	4.17	31.38	6.20	4.18	4.71	6.28	.40	1.78	2.66	1.25	1.90	8.01	2.30	1.52	.43
5.30	1.68	4.26	32.60	6.40	4.17	4.72	6.40	.42	1.84	2.71	1.27	1.95	8.32	2.35	1.53	.43
5.40	1.69	4.35	33.85	6.61	4.17	4.72	6.51	.43	1.90	2.76	1.29	2.00	8.65	2.41	1.55	.43
5.50	1.70	4.43	35.12	6.82	4.16	4.73	6.63	.45	1.97	2.81	1.30	2.04	8.98	2.46	1.57	.43
5.60	1.70	4.52	36.42	7.04	4.16	4.73	6.74	.47	2.03	2.86	1.32	2.09	9.31	2.52	1.59	.43
5.70	1.71	4.60	37.74	7.26	4.15	4.74	6.86	.49	2.09	2.91	1.33	2.14	9.66	2.58	1.61	.43
5.80	1.71	4.69	39.08	7.48	4.15	4.74	6.97	.51	2.16	2.96	1.35	2.19	10.00	2.63	1.62	.43
5.90	1.72	4.78	40.44	7.71	4.14	4.75	7.09	.53	2.23	3.01	1.36	2.23	10.36	2.69	1.64	.43
6.00	1.73	4.86	41.83	7.94	4.14	4.75	7.20	.54	2.30	3.06	1.37	2.28	10.72	2.75	1.66	.43
6.10	1.73	4.95	43.24	8.18	4.13	4.76	7.32	.56	2.37	3.11	1.39	2.33	11.08	2.82	1.68	.43
6.20	1.73	5.03	44.68	8.42	4.13	4.76	7.43	.58	2.44	3.17	1.40	2.37	11.45	2.88	1.70	.43

BLAST WAVE PARAMETERS BEFORE AND AFTER A DIVERGENT NOZZLE

TABLE D-IX (Cont.)

SPECIFIC HEAT RATIO (GAMMA) = 1.400
AREA RATIO ACROSS THE DIVERGENT NOZZLE = 15.00

((((((NOZZLE INLET CONDITIONS))))))))))					((((((SECONDARY SHOCK CONDITIONS))))))))					((PRIMARY TRANSMITTED SHOCK CONDITIONS))						
SHOCK MACH NO.	FLOW MACH NO.	FLOW VEL. RATIO	SHOCK STREN	TEMP RATIO	2NDRY SHOCK MACH NO.	2NDRY FLOW MACH NO.	2NDRY FLOW VEL. RATIO	2NDRY SHOCK STREN	2NDRY TEMP RATIO	PRIM SHOCK MACH NO.	PRIM FLOW MACH NO.	PRIM FLOW VEL. RATIO	PRIM SHOCK STREN.	PRIM TEMP RATIO	SONIC VEL. RATIO	MACH NO. BET. CONT. AND 2NDRY SHOCK
MS1	M1	U1/A0	P1/P0	T1/T0	MS2	M2	U2/A0	P2/P0	T2/T0	MS3	M3	U3/A0	P3/P0	T3/T0	A3/A0	M3(PRIME)
6.30	1.74	5.12	46.14	8.66	4.12	4.76	7.55	.60	2.51	3.22	1.41	2.42	11.83	2.94	1.72	.43
6.40	1.74	5.20	47.62	8.91	4.12	4.77	7.66	.63	2.58	3.27	1.42	2.47	12.22	3.01	1.73	.43
6.50	1.75	5.29	49.12	9.16	4.12	4.77	7.78	.65	2.66	3.32	1.43	2.51	12.61	3.07	1.75	.43
6.60	1.75	5.37	50.65	9.41	4.11	4.77	7.89	.67	2.73	3.37	1.44	2.56	13.00	3.14	1.77	.43
6.70	1.76	5.46	52.20	9.67	4.11	4.78	8.01	.69	2.81	3.42	1.46	2.61	13.41	3.21	1.79	.43
6.80	1.76	5.54	53.78	9.93	4.11	4.78	8.12	.71	2.89	3.47	1.47	2.65	13.81	3.27	1.81	.43
6.90	1.76	5.63	55.38	10.20	4.10	4.78	8.24	.73	2.96	3.52	1.48	2.70	14.23	3.34	1.83	.43
7.00	1.77	5.71	57.00	10.47	4.10	4.79	8.35	.76	3.04	3.57	1.48	2.74	14.65	3.41	1.85	.43
7.10	1.77	5.80	58.64	10.74	4.10	4.79	8.47	.78	3.13	3.62	1.49	2.79	15.07	3.49	1.87	.43
7.20	1.77	5.88	60.31	11.02	4.10	4.79	8.58	.80	3.21	3.67	1.50	2.83	15.51	3.56	1.89	.43
7.30	1.78	5.97	62.00	11.30	4.09	4.80	8.70	.83	3.29	3.72	1.51	2.88	15.95	3.63	1.91	.43
7.40	1.78	6.05	63.72	11.59	4.09	4.80	8.82	.85	3.38	3.77	1.52	2.92	16.39	3.71	1.92	.43
7.50	1.78	6.14	65.46	11.88	4.09	4.80	8.93	.87	3.46	3.83	1.53	2.97	16.84	3.78	1.94	.43
7.60	1.78	6.22	67.22	12.17	4.09	4.80	9.05	.90	3.55	3.88	1.54	3.02	17.30	3.86	1.96	.43
7.70	1.79	6.31	69.00	12.47	4.09	4.81	9.16	.92	3.64	3.93	1.54	3.06	17.76	3.93	1.98	.43
7.80	1.79	6.39	70.81	12.77	4.08	4.81	9.28	.95	3.72	3.98	1.55	3.11	18.23	4.01	2.00	.43
7.90	1.79	6.48	72.64	13.08	4.08	4.81	9.40	.97	3.81	4.03	1.56	3.15	18.70	4.09	2.02	.43
8.00	1.79	6.56	74.50	13.39	4.08	4.81	9.51	1.00	3.91	4.08	1.56	3.20	19.18	4.17	2.04	.43
8.10	1.80	6.65	76.38	13.70	4.08	4.81	9.63	1.03	4.00	4.13	1.57	3.24	19.67	4.25	2.06	.43
8.20	1.80	6.73	78.28	14.02	4.08	4.82	9.74	1.05	4.09	4.18	1.58	3.29	20.16	4.34	2.08	.43
8.30	1.80	6.82	80.20	14.34	4.07	4.82	9.86	1.08	4.19	4.23	1.58	3.33	20.66	4.42	2.10	.43
8.40	1.80	6.90	82.15	14.66	4.07	4.82	9.98	1.11	4.28	4.28	1.59	3.37	21.17	4.50	2.12	.43
8.50	1.80	6.99	84.12	14.99	4.07	4.82	10.09	1.13	4.38	4.33	1.60	3.42	21.68	4.59	2.14	.43
8.60	1.81	7.07	86.12	15.32	4.07	4.82	10.21	1.16	4.48	4.38	1.60	3.46	22.20	4.68	2.16	.43
8.70	1.81	7.15	88.14	15.66	4.07	4.83	10.32	1.19	4.58	4.44	1.61	3.51	22.72	4.76	2.18	.43
8.80	1.81	7.24	90.18	16.00	4.07	4.83	10.44	1.22	4.68	4.49	1.61	3.55	23.25	4.85	2.20	.43
8.90	1.81	7.32	92.24	16.34	4.07	4.83	10.56	1.25	4.78	4.54	1.62	3.60	23.78	4.94	2.22	.43
9.00	1.81	7.41	94.33	16.69	4.06	4.83	10.67	1.28	4.88	4.59	1.62	3.64	24.33	5.03	2.24	.43
9.10	1.81	7.49	96.44	17.04	4.06	4.83	10.79	1.31	4.99	4.64	1.63	3.69	24.87	5.12	2.26	.43
9.20	1.82	7.58	98.58	17.40	4.06	4.83	10.91	1.34	5.09	4.69	1.63	3.73	25.43	5.21	2.28	.43
9.30	1.82	7.66	100.74	17.76	4.06	4.83	11.02	1.37	5.20	4.74	1.64	3.77	25.99	5.31	2.30	.43
9.40	1.82	7.74	102.92	18.12	4.06	4.84	11.14	1.40	5.30	4.79	1.64	3.82	26.55	5.40	2.32	.43
9.50	1.82	7.83	105.12	18.49	4.06	4.84	11.26	1.43	5.41	4.84	1.65	3.86	27.12	5.50	2.34	.43
9.60	1.82	7.91	107.35	18.86	4.06	4.84	11.37	1.46	5.52	4.89	1.65	3.91	27.70	5.59	2.37	.43
9.70	1.82	8.00	109.60	19.24	4.06	4.84	11.49	1.49	5.63	4.94	1.66	3.95	28.29	5.69	2.39	.43
9.80	1.82	8.08	111.88	19.62	4.06	4.84	11.60	1.52	5.75	4.99	1.66	4.00	28.87	5.79	2.41	.43
9.90	1.83	8.17	114.18	20.00	4.05	4.84	11.72	1.55	5.86	5.05	1.66	4.04	29.47	5.89	2.43	.43
10.00	1.83	8.25	116.50	20.39	4.05	4.84	11.84	1.59	5.97	5.10	1.67	4.08	30.07	5.99	2.45	.43
10.10	1.83	8.33	118.84	20.78	4.05	4.84	11.95	1.62	6.09	5.15	1.67	4.13	30.68	6.09	2.47	.43
10.20	1.83	8.42	121.21	21.17	4.05	4.85	12.07	1.65	6.20	5.20	1.68	4.17	31.29	6.19	2.49	.43
10.30	1.83	8.50	123.60	21.57	4.05	4.85	12.19	1.68	6.32	5.25	1.68	4.22	31.91	6.30	2.51	.43

Appendix E.

SHADOWGRAPHS OF SHOCK WAVE FORMATIONS AND FLOW OVER A CONICAL TEST UNIT

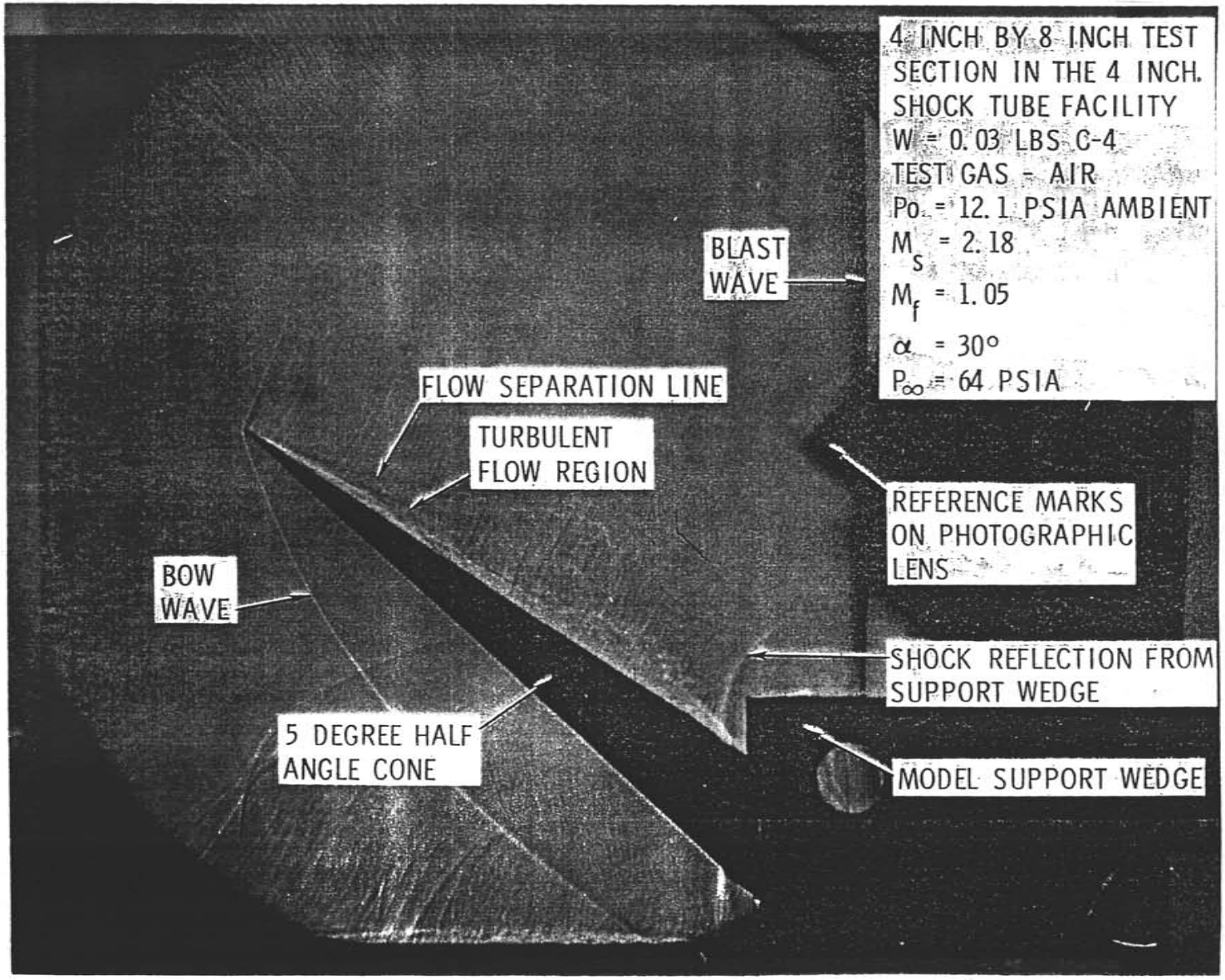


Figure E1. Shadowgraph of Flow Behind a Blast Wave Engulfing a Conical Model at a 30% Angle of Attack

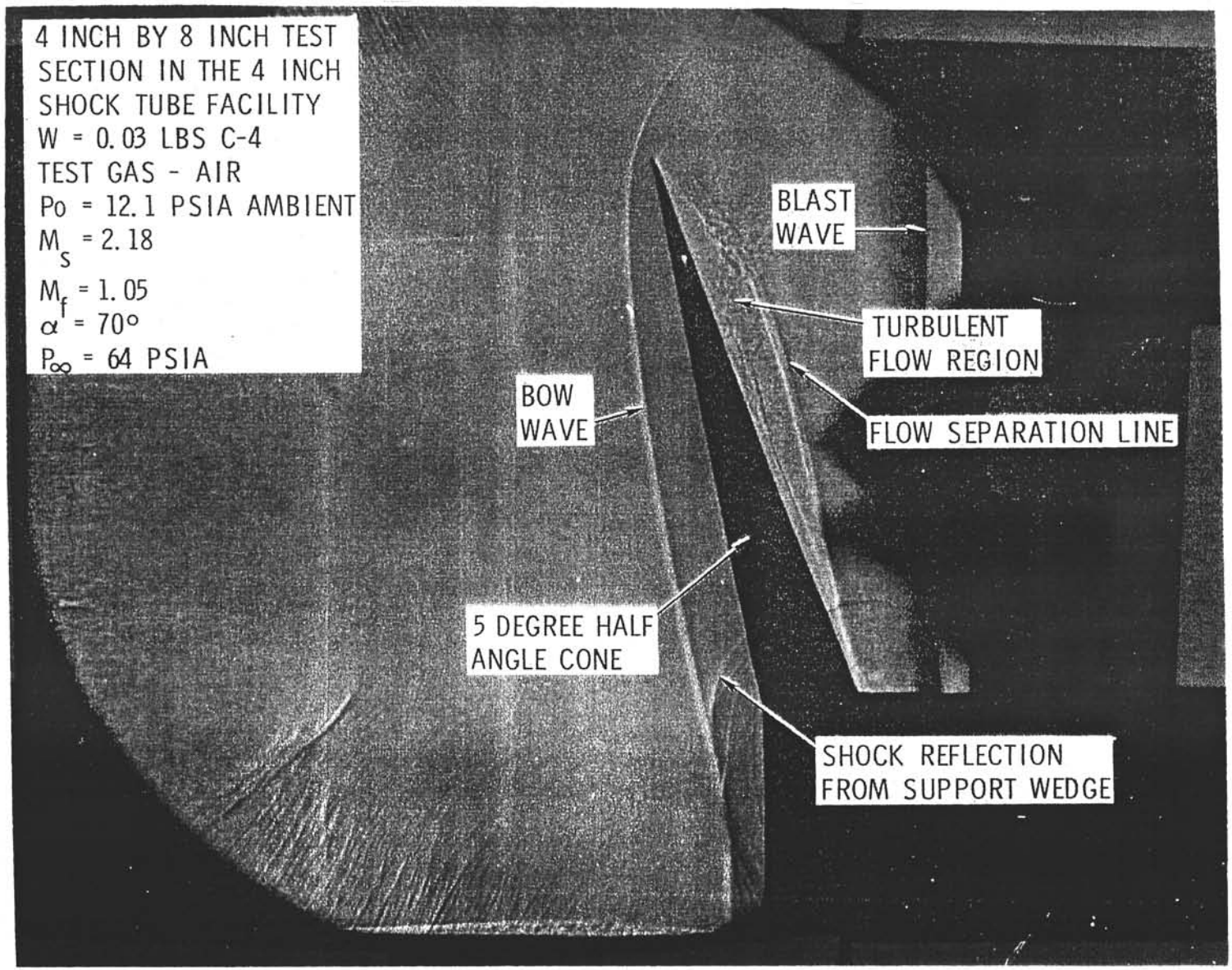


Figure E2. Shadowgraph of Flow Behind a Blast Wave Engulfing a Conical Model at a 70% Angle of Attack

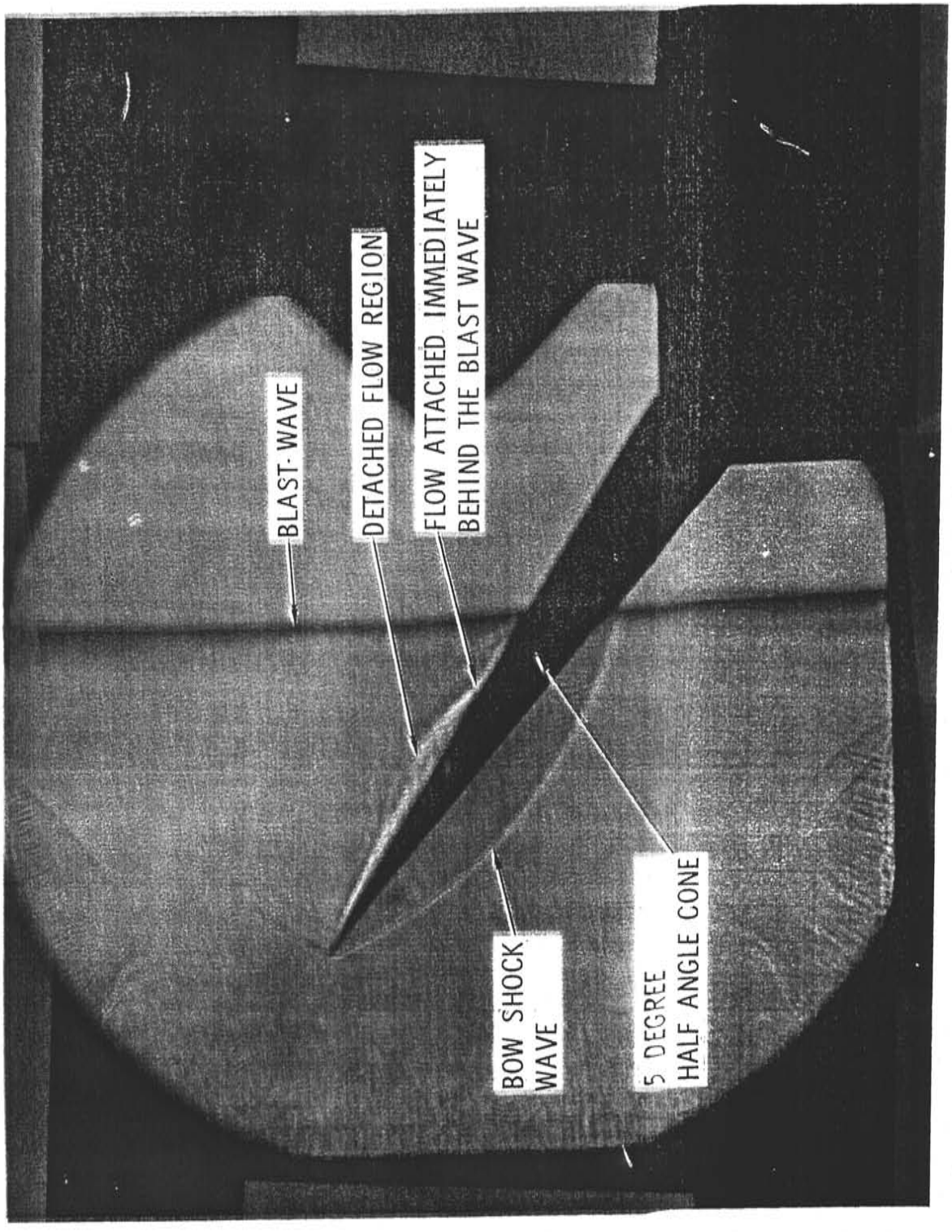


Figure E3. Blast Wave Engulfing a 5% Half Angle Conical Model at a 30% Angle of Attack

Appendix F.

TWO TO SIX-FOOT DIAMETER BLAST TUNNEL/ADDITIONAL PHOTOS

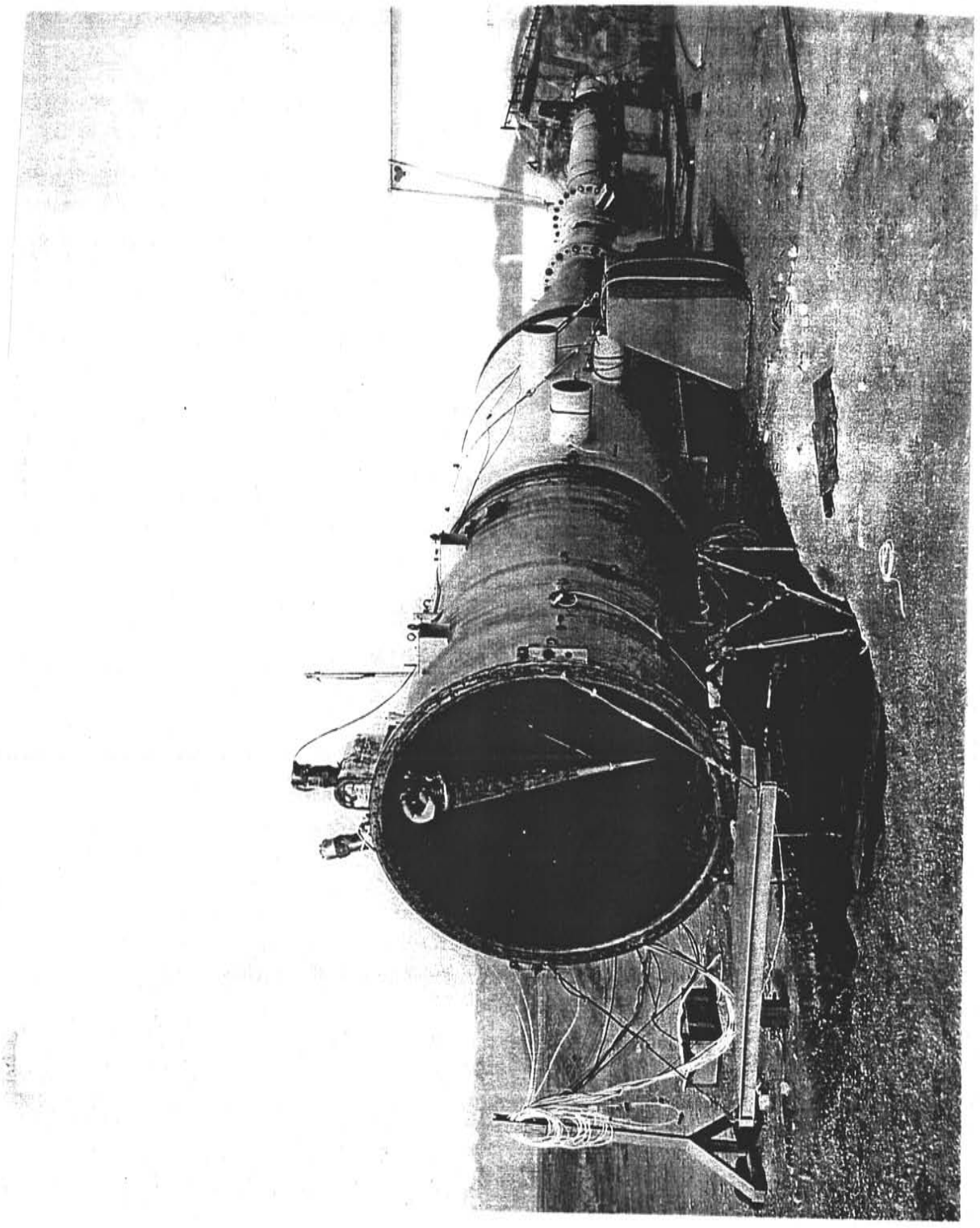


Figure F1. Two by six foot Diameter Blast Tunnel/Conical Unit in Test Section (Ambient Air Test)

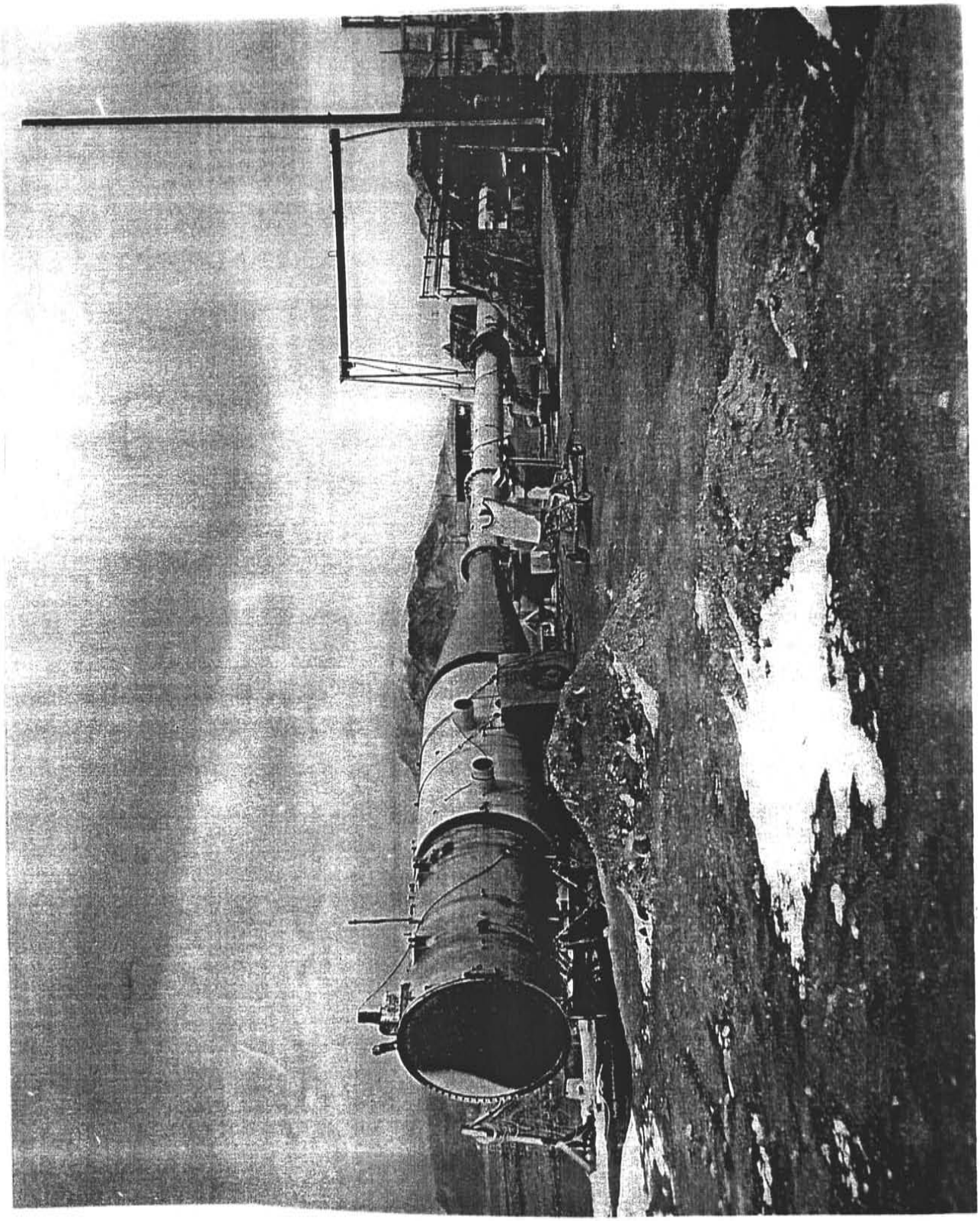


Figure F2. Two by Six foot Diameter Blast Tunnel/Aluminum Diaphragm at Muzzle End for Initial Test Gas Pressure

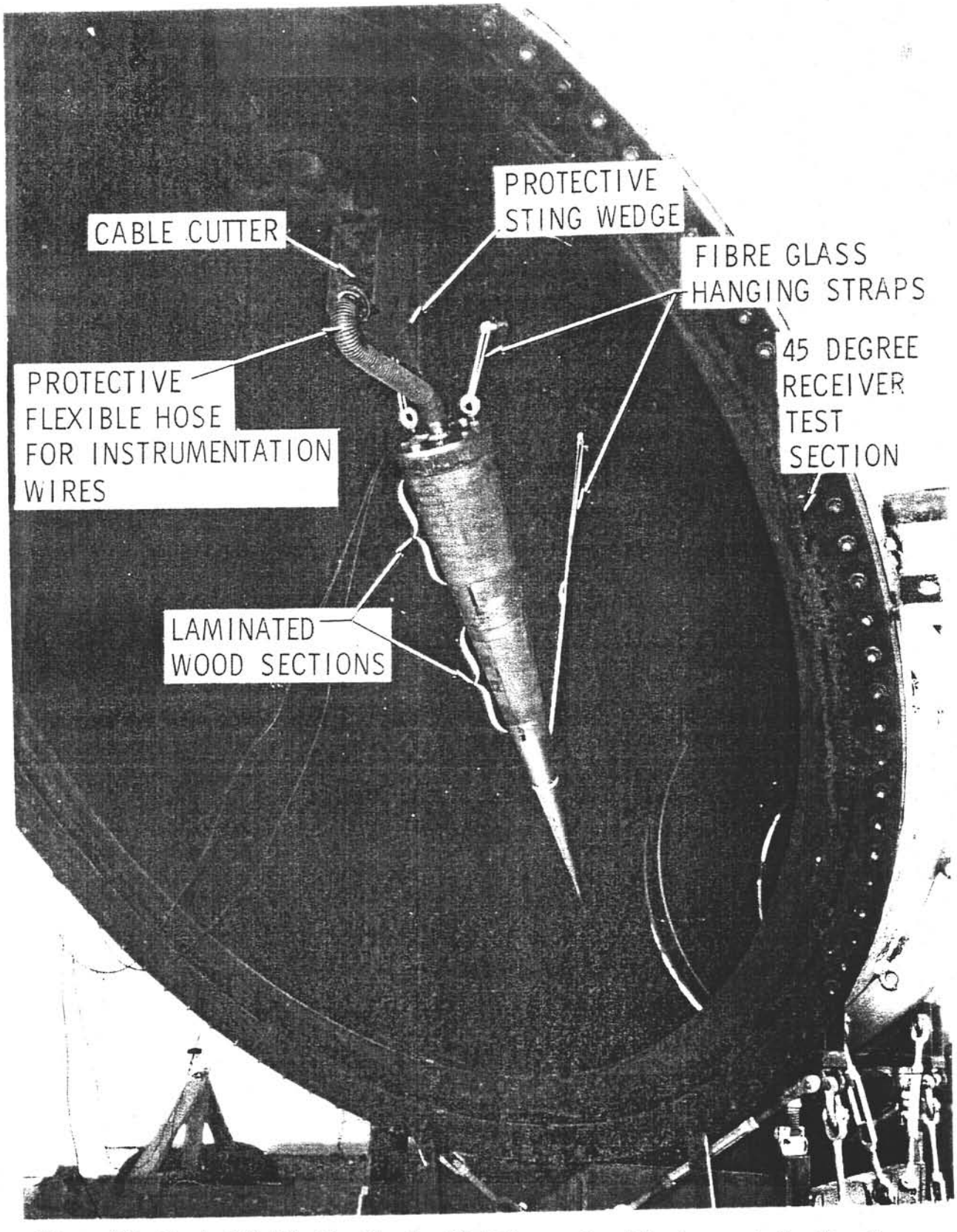


Figure F3. Conical Unit in Test Section/Unit Suspension & Instrumentation Bundle Explosively Cut after it is Engulfed by Blast Wave

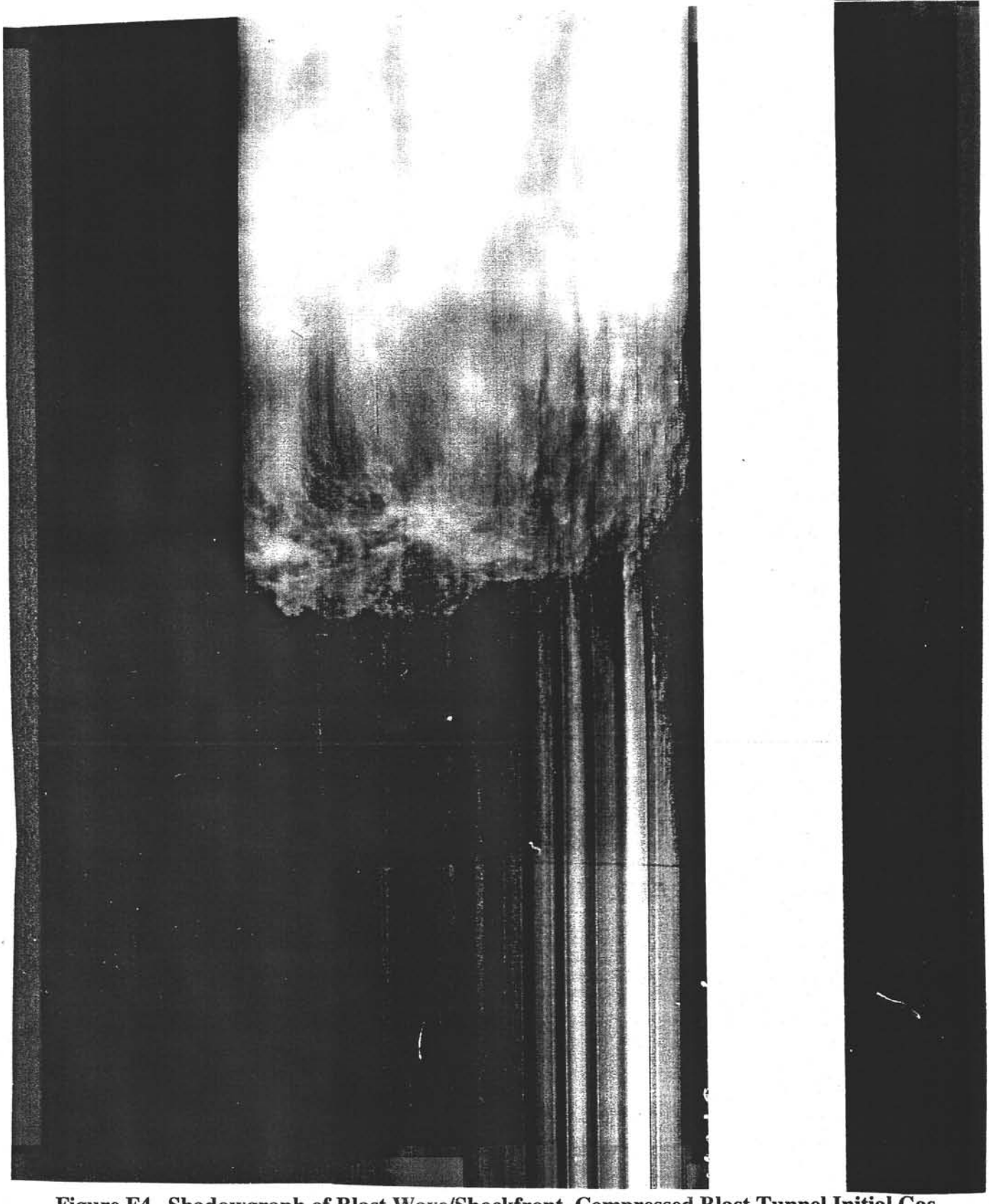


Figure F4. Shadowgraph of Blast Wave/Shockfront, Compressed Blast Tunnel Initial Gas

Appendix G.

Six foot-diameter by 200-foot long shock tube/additional photos

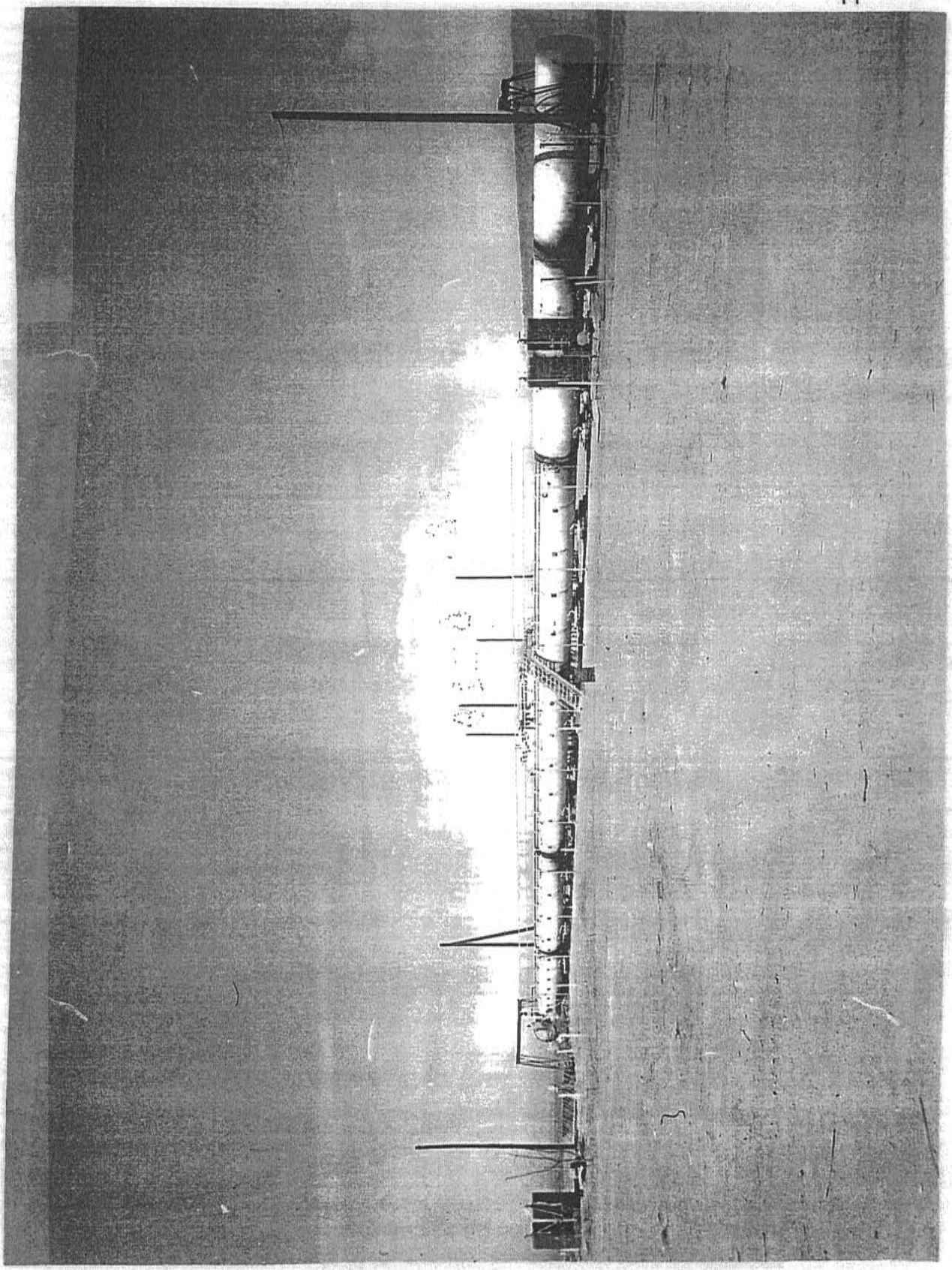


Figure G1. Six foot Diameter by 200 foot Long Shock Tube/3" Thick by 50 ft. Long, Re-usable Driver Section

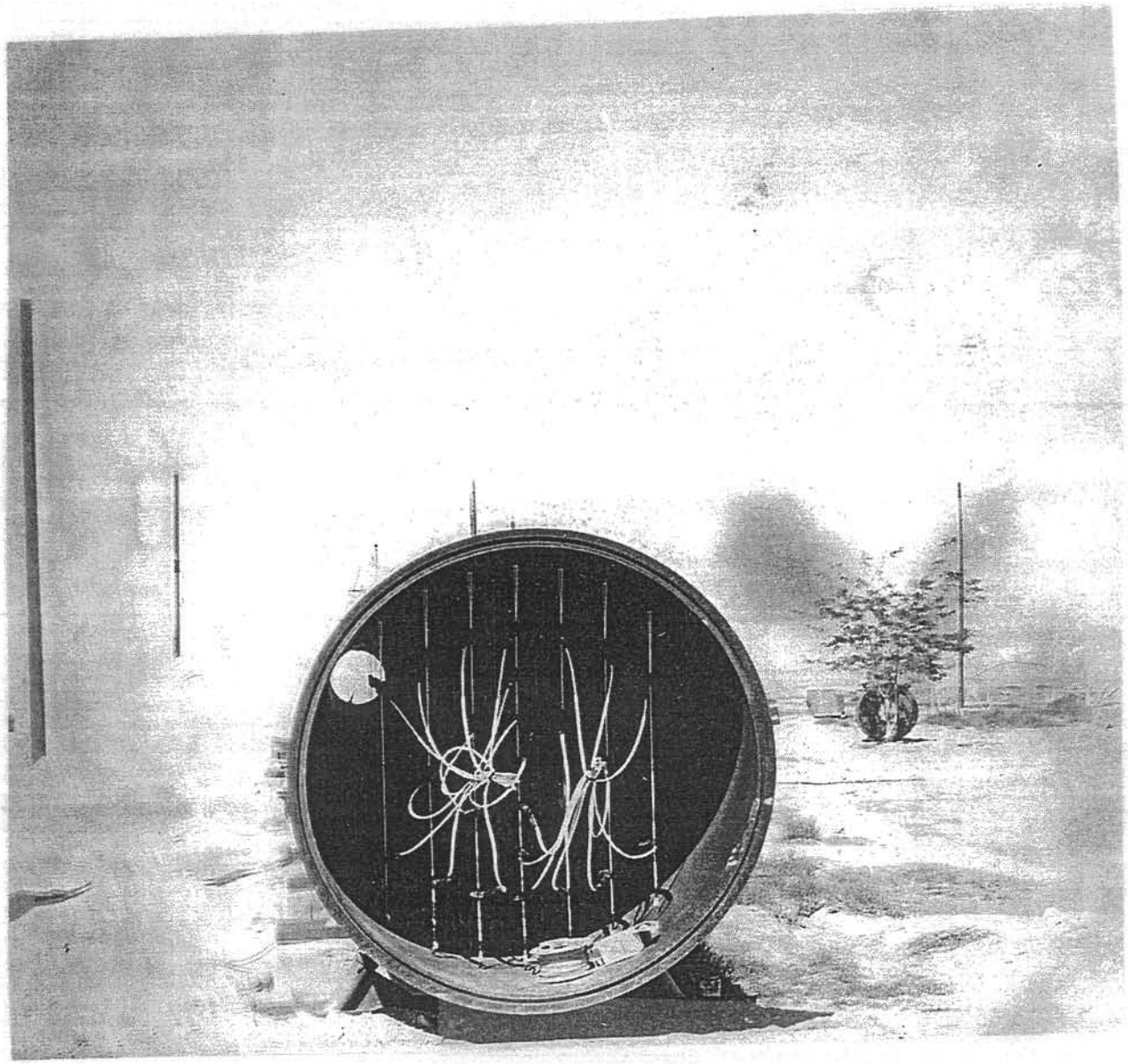


Figure G2. PETN Explosive, 400 Grain/Foot, Primacord Configuration at Driver End/7 Vertical Plains of Primacord/Ends Taped Together with RP-1 Detonators

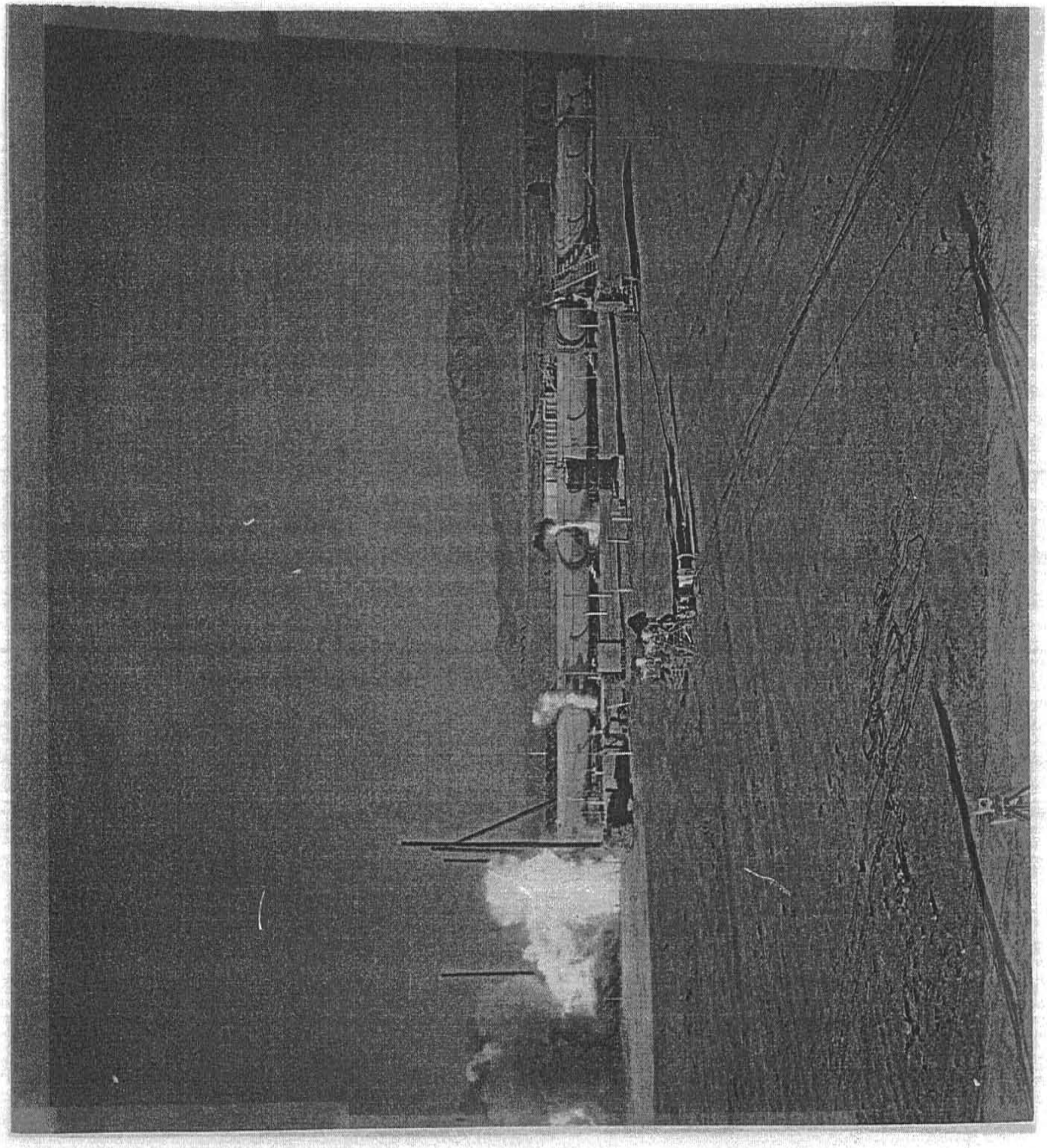


Figure G3. Six foot Diameter by 200 ft. Long Shocktube During Test

Appendix H.

Six foot Diameter by 19 ft. Diameter Blast Tunnel Configuration Photos

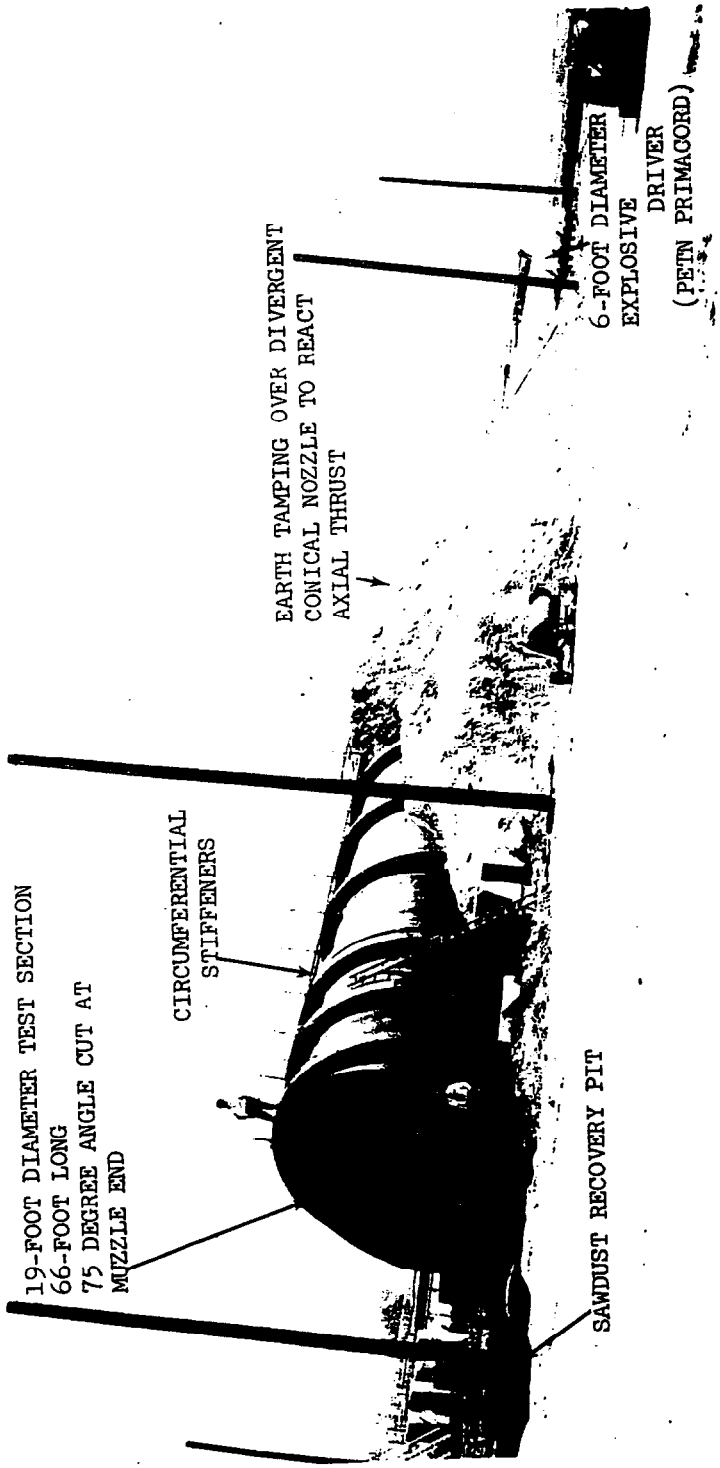


Figure H1. Six ft. by 19 ft. by 306 ft. Long Blast Tunnel

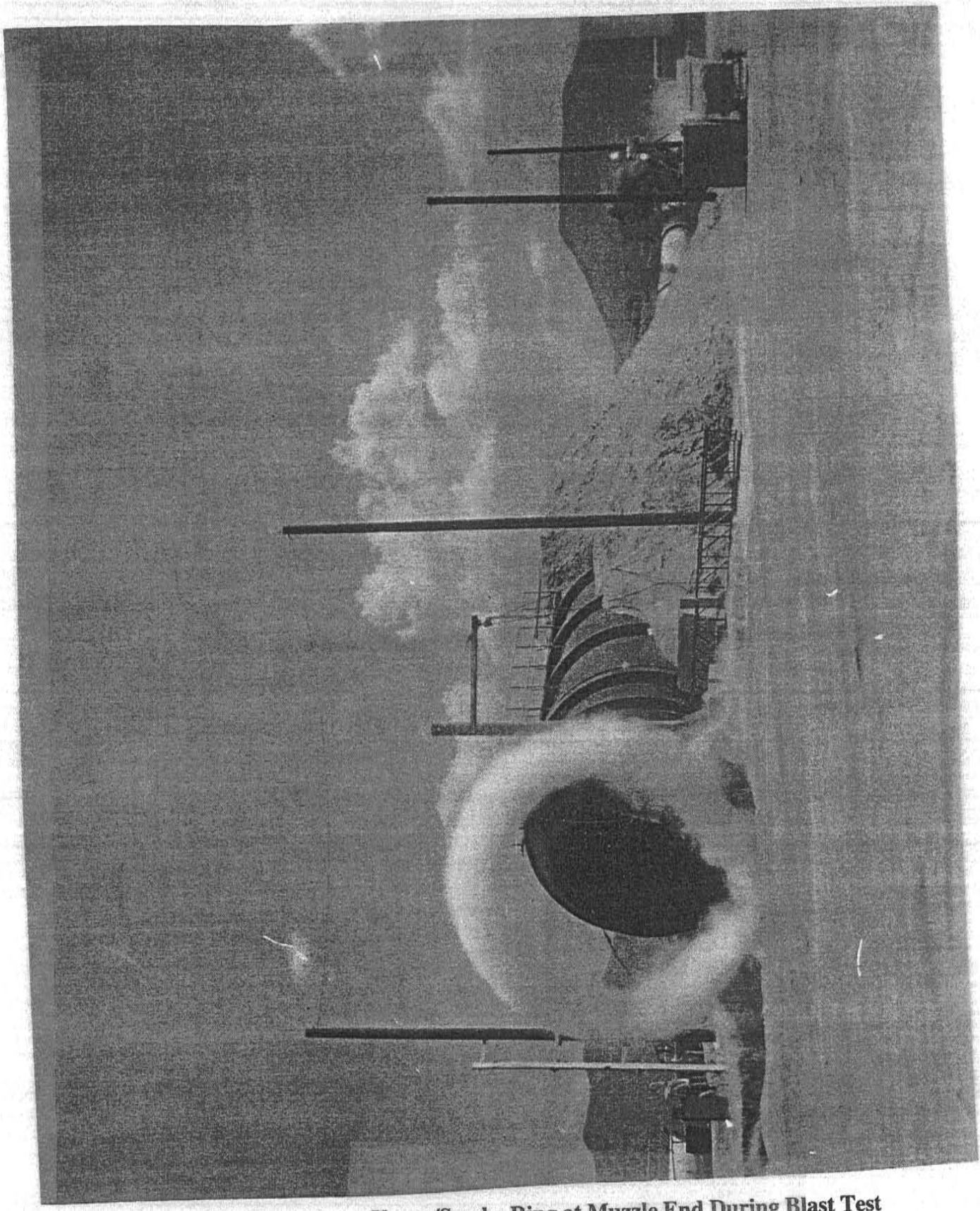


Figure H2. Giant Water Vapor/Smoke Ring at Muzzle End During Blast Test

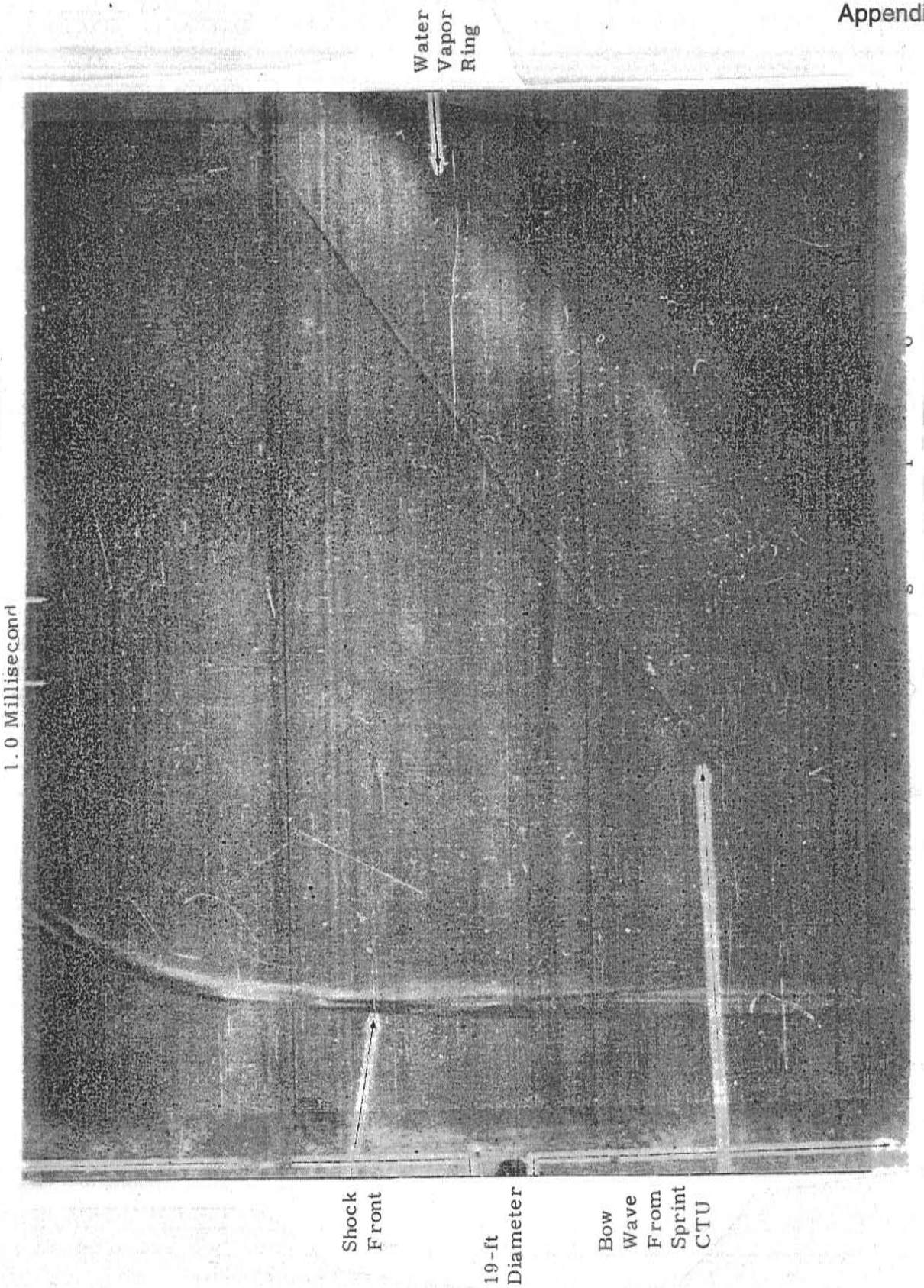


Figure H3. Shadowgraph/Shock Front/bow Wave from Sprint CTU/Water Vapor/Smoke Ring

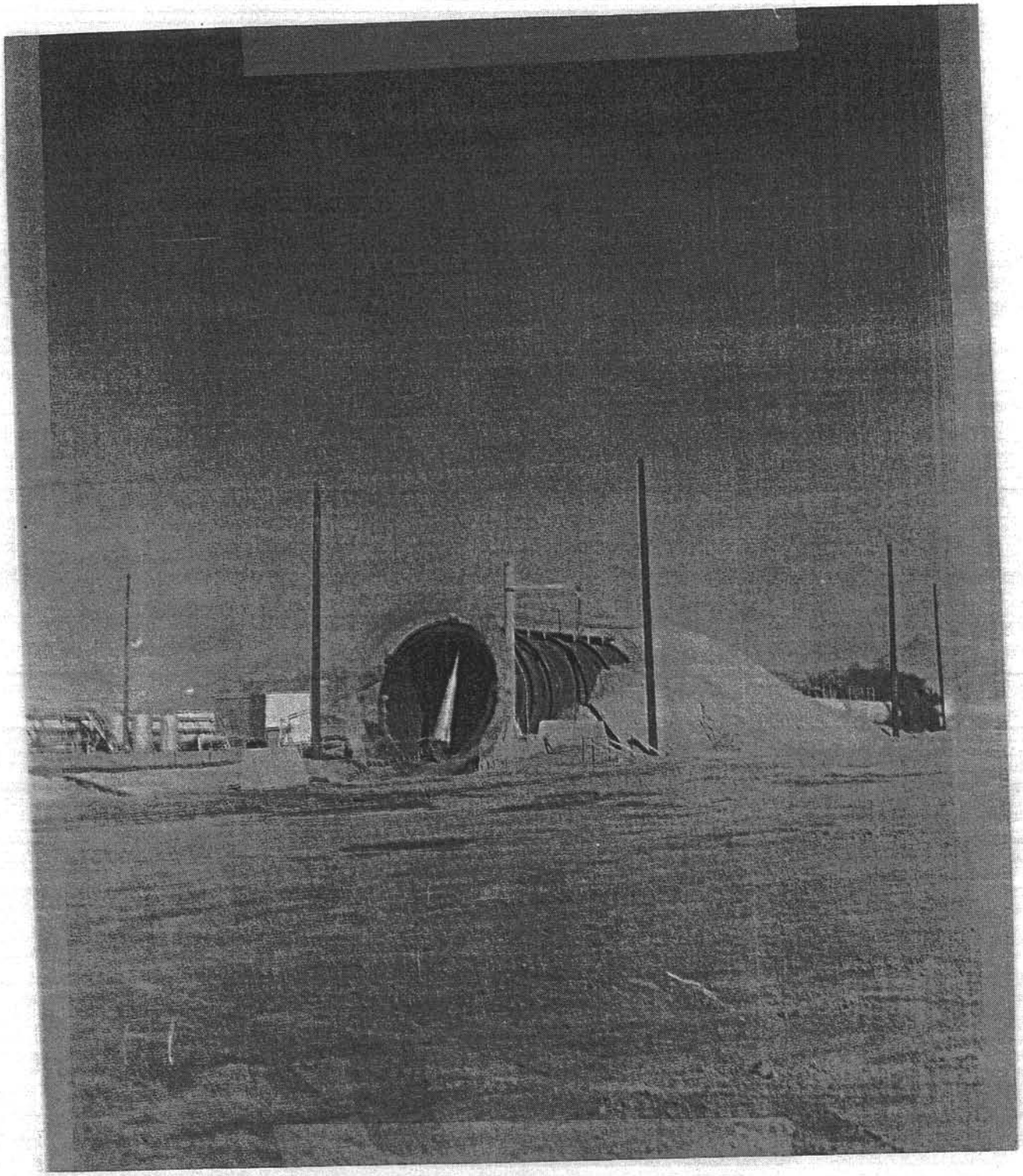


Figure H4. Photo/Sprint CTU/Water Vapor - Smoke Ring/During Blast Test

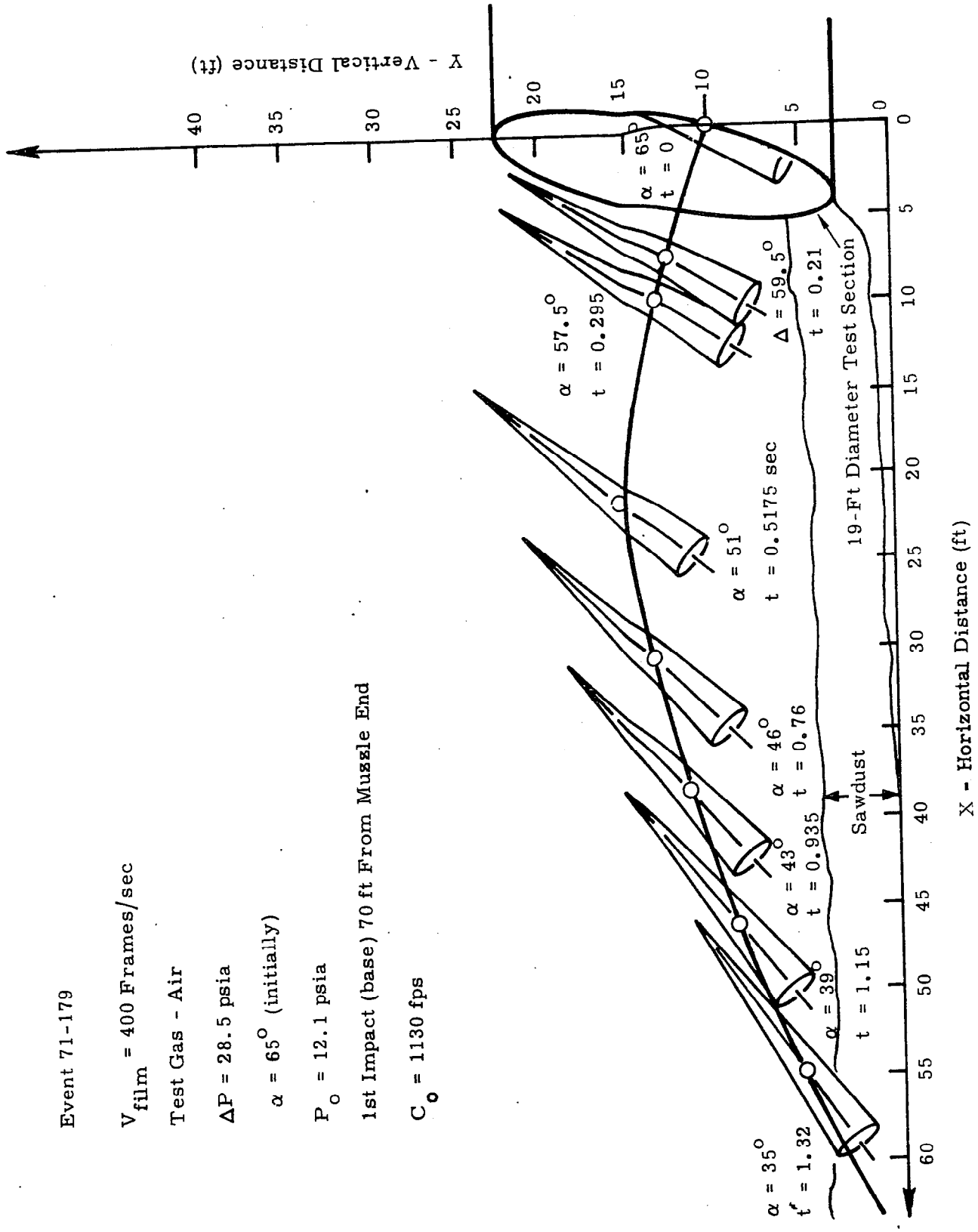


Figure H5. Sprint CTU Trajectory Measure from 400 Frame/Second Film/1200 lb CTU/Landed in Soft-Recovery Sawdust Pit and About 65 feet from Original Position

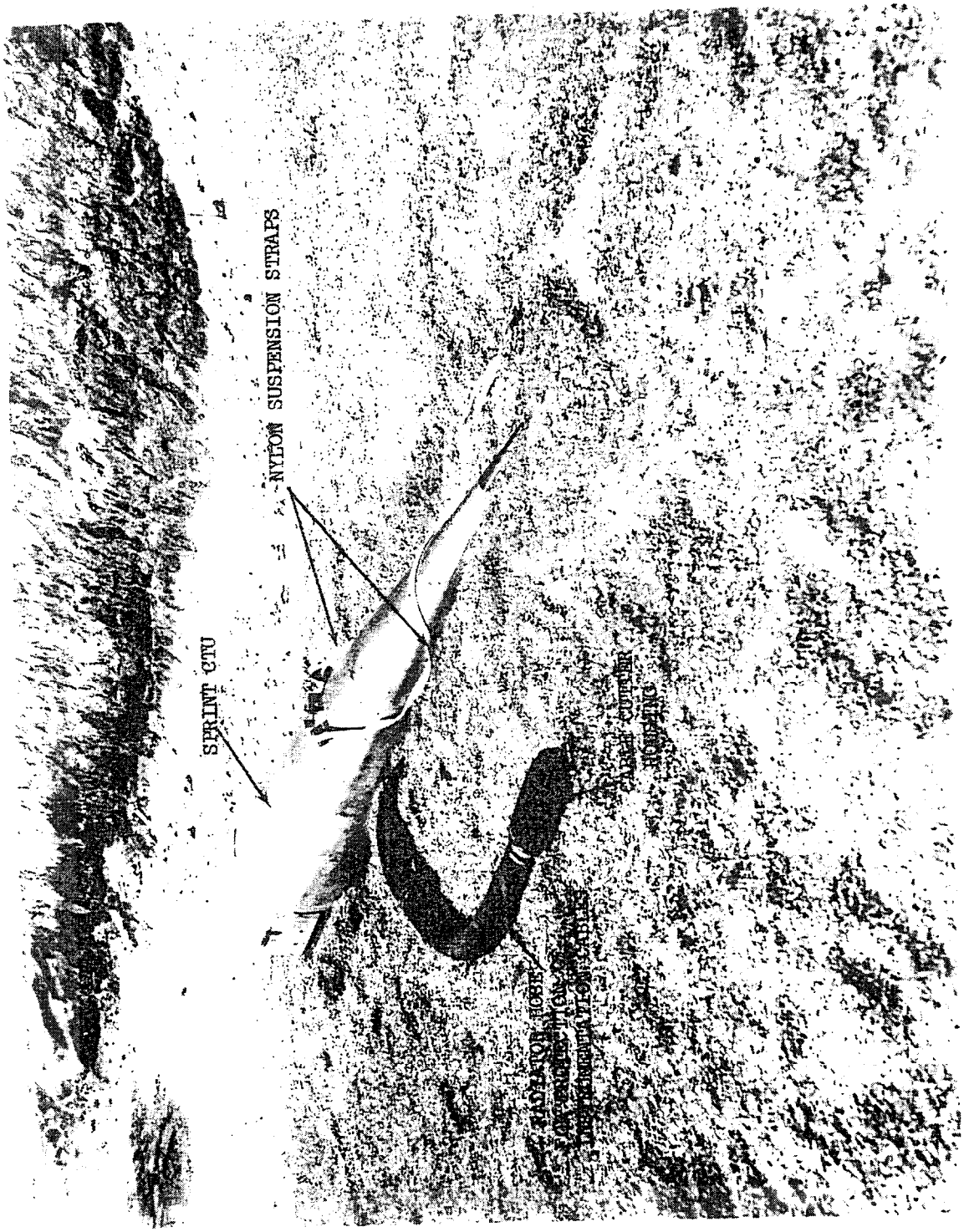


Figure H6. Two foot diameter to 6 foot diameter to 19 foot diameter by 650 foot long Blast Tunnel

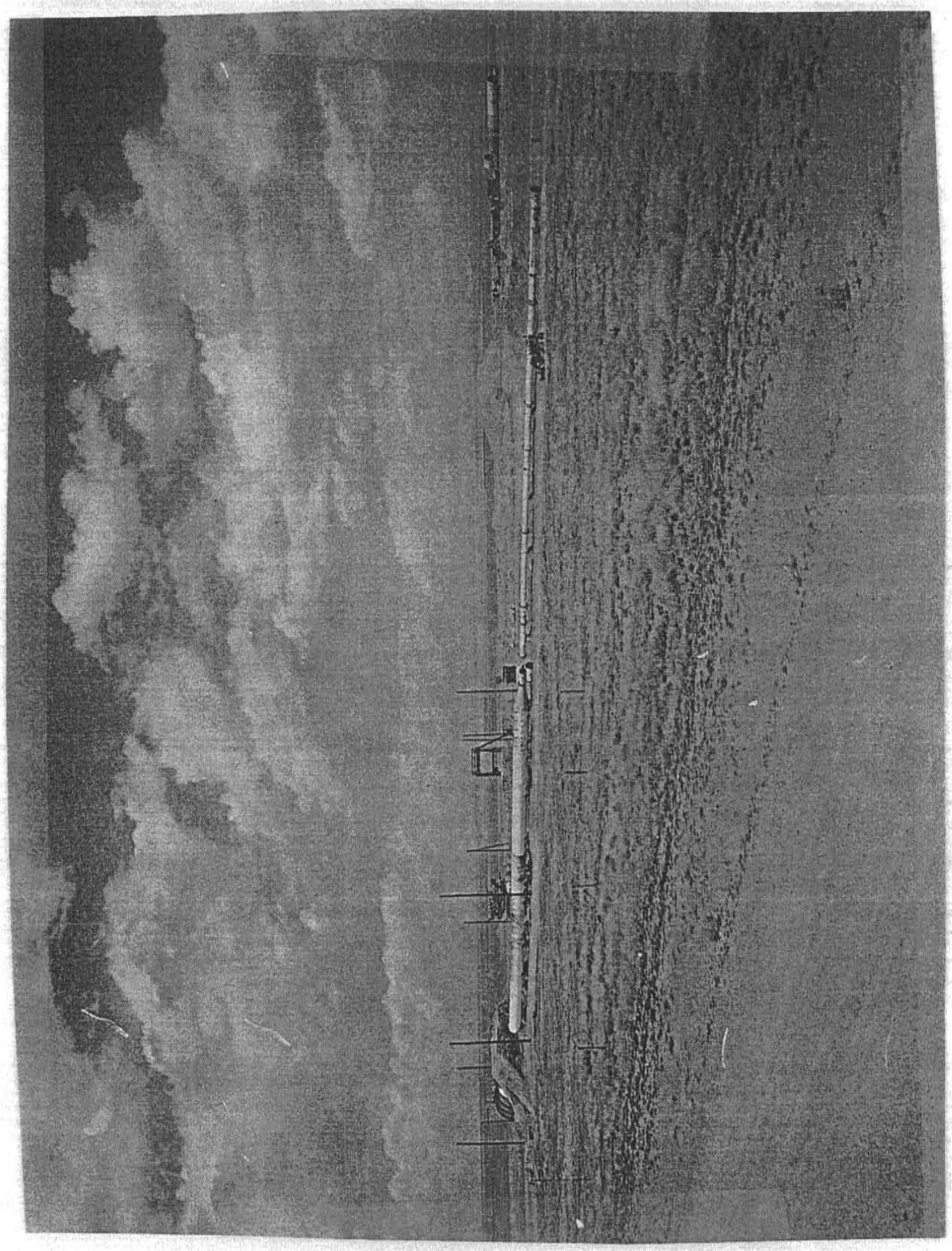


Figure H7. Two Foot Diameter to Six Foot Diameter to 19 foot Diameter by 650 Foot Long Blast Tunnel

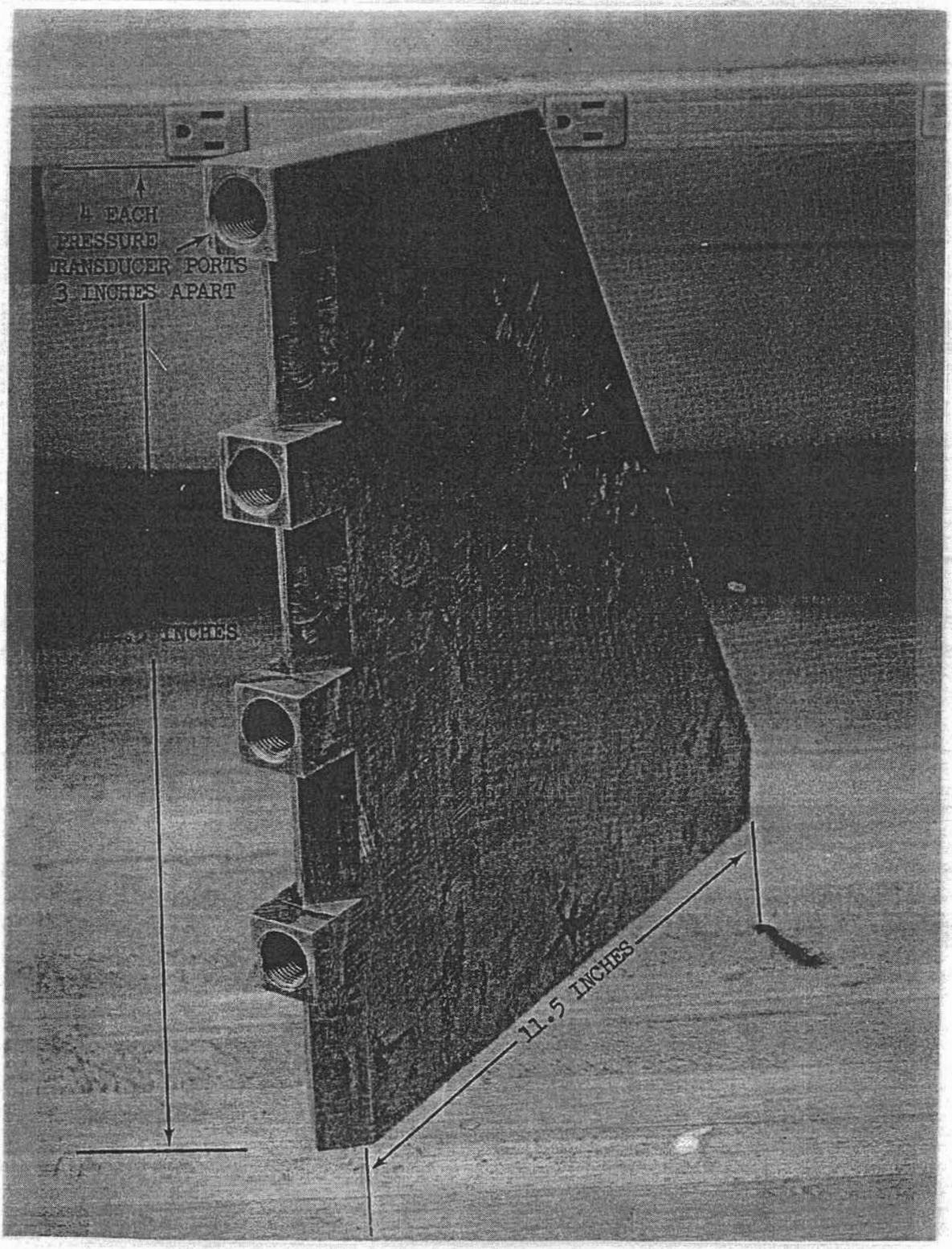


Figure H8. Stagnation Pressure Measurement Fixture/Transducers Installed 3, 6, 9, & 12 Inches From the Blast Tunnel Surface/Boundary Layer Evaluation

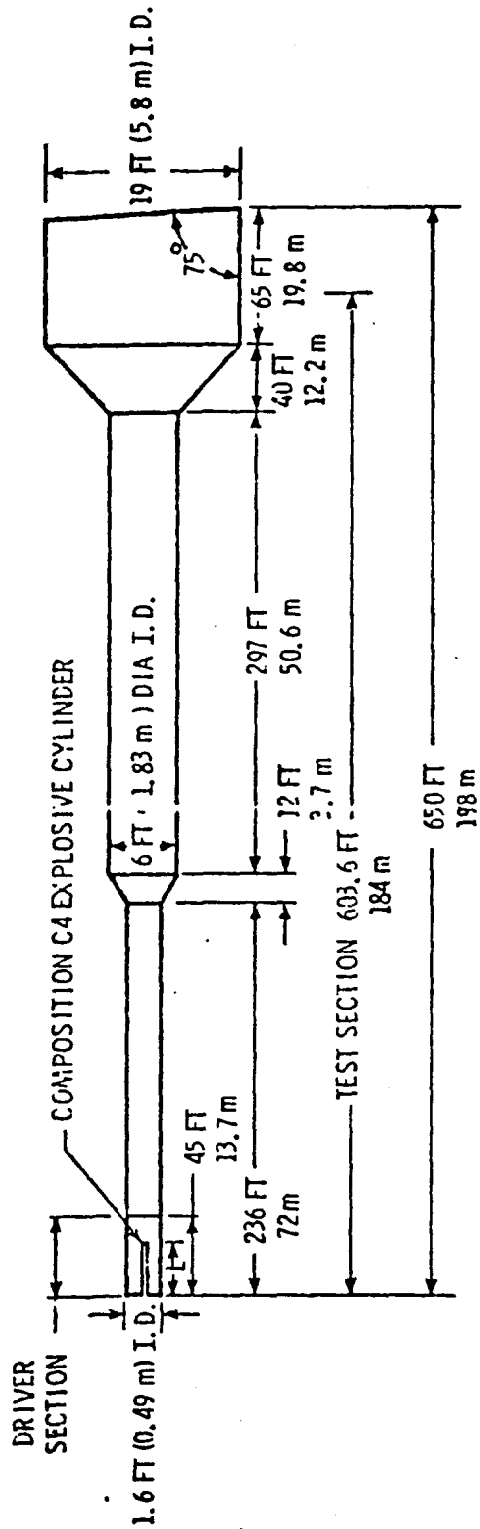


Figure H9. Two foot Diameter to 6 foot Diameter to 19 Foot Diameter by 650 foot Long Blast Tunnel Drawing

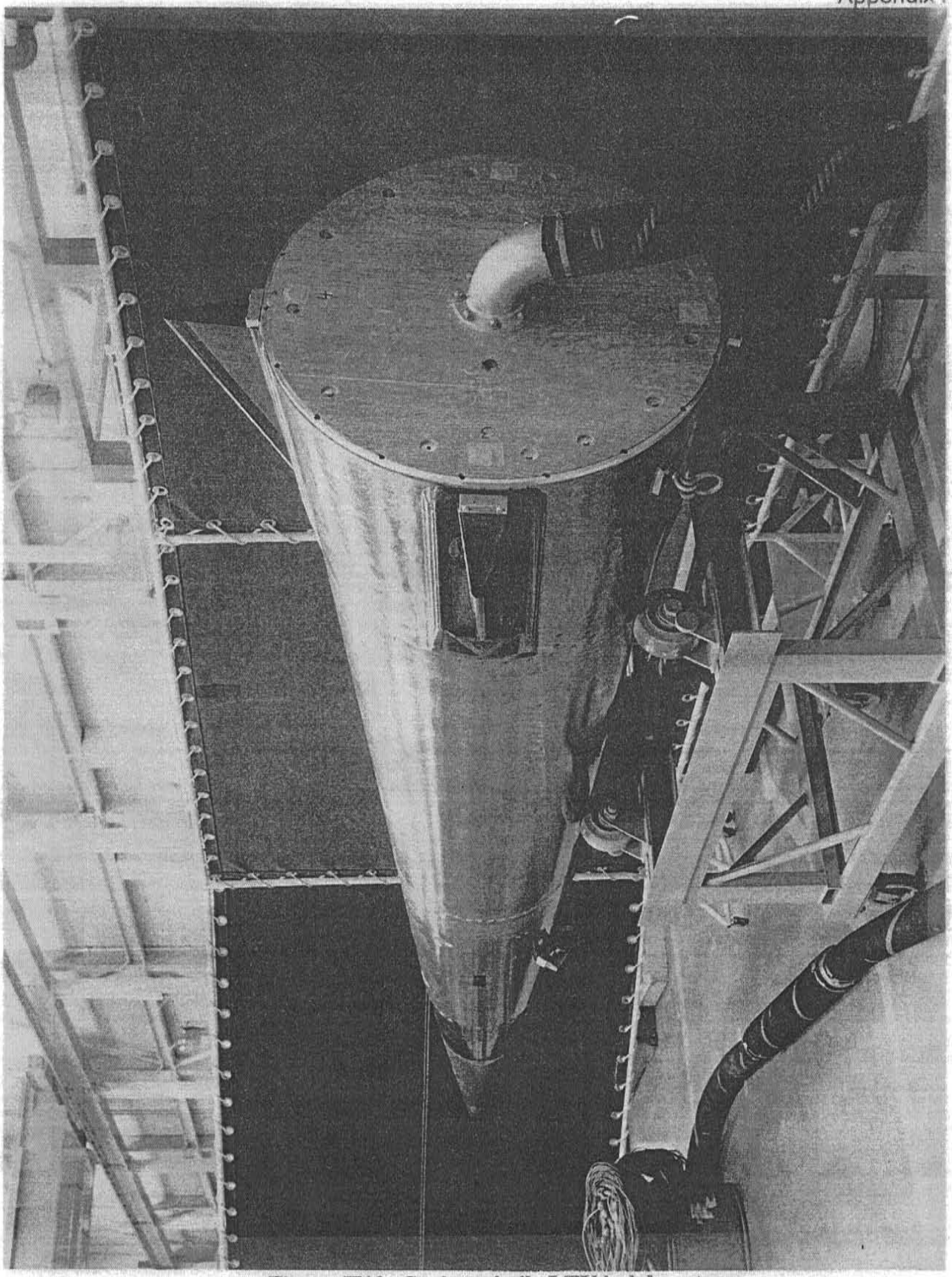


Figure H10. Sprint missile LTU in laboratory

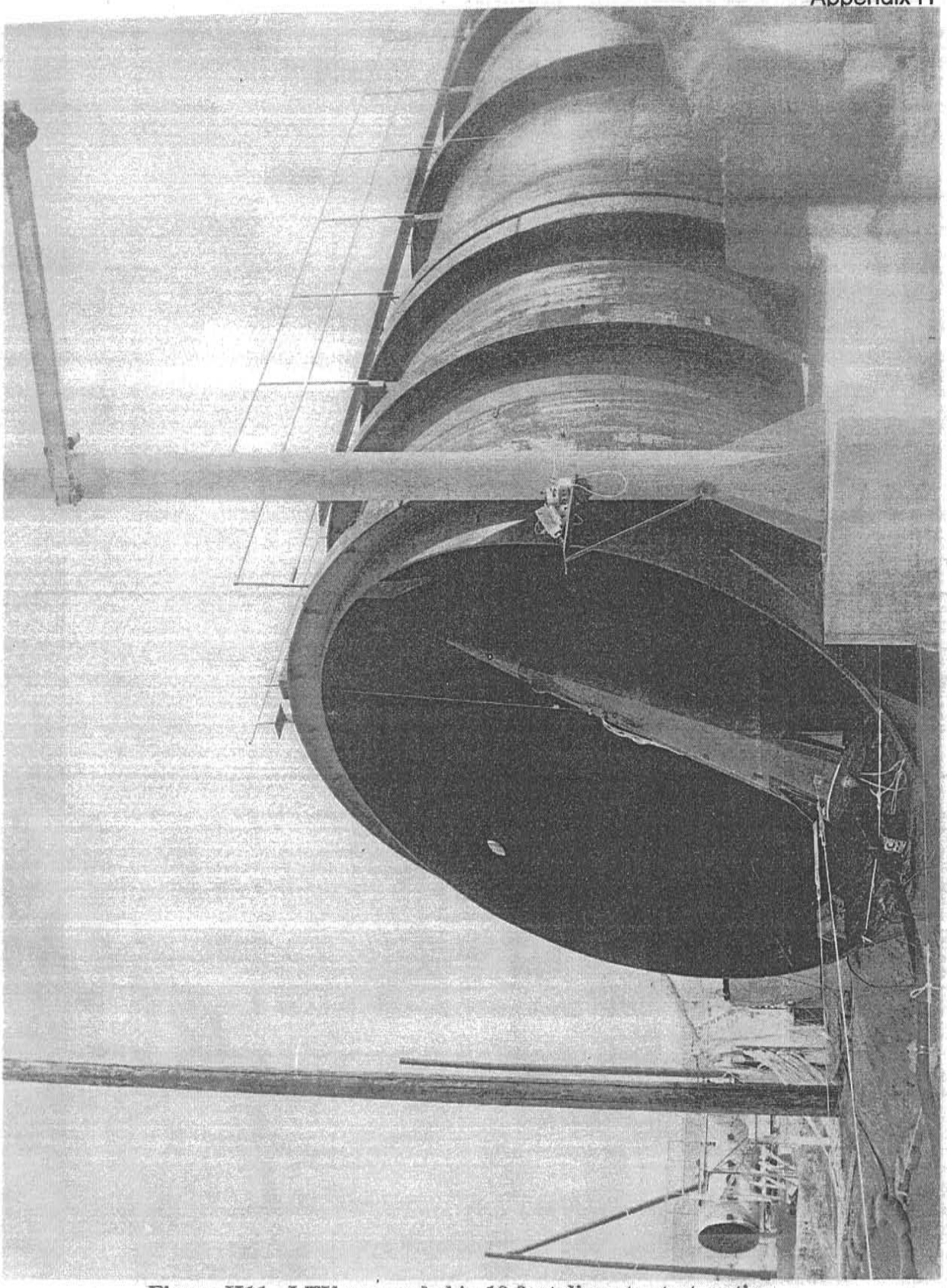


Figure H11. LTU suspended in 19 foot diameter test section

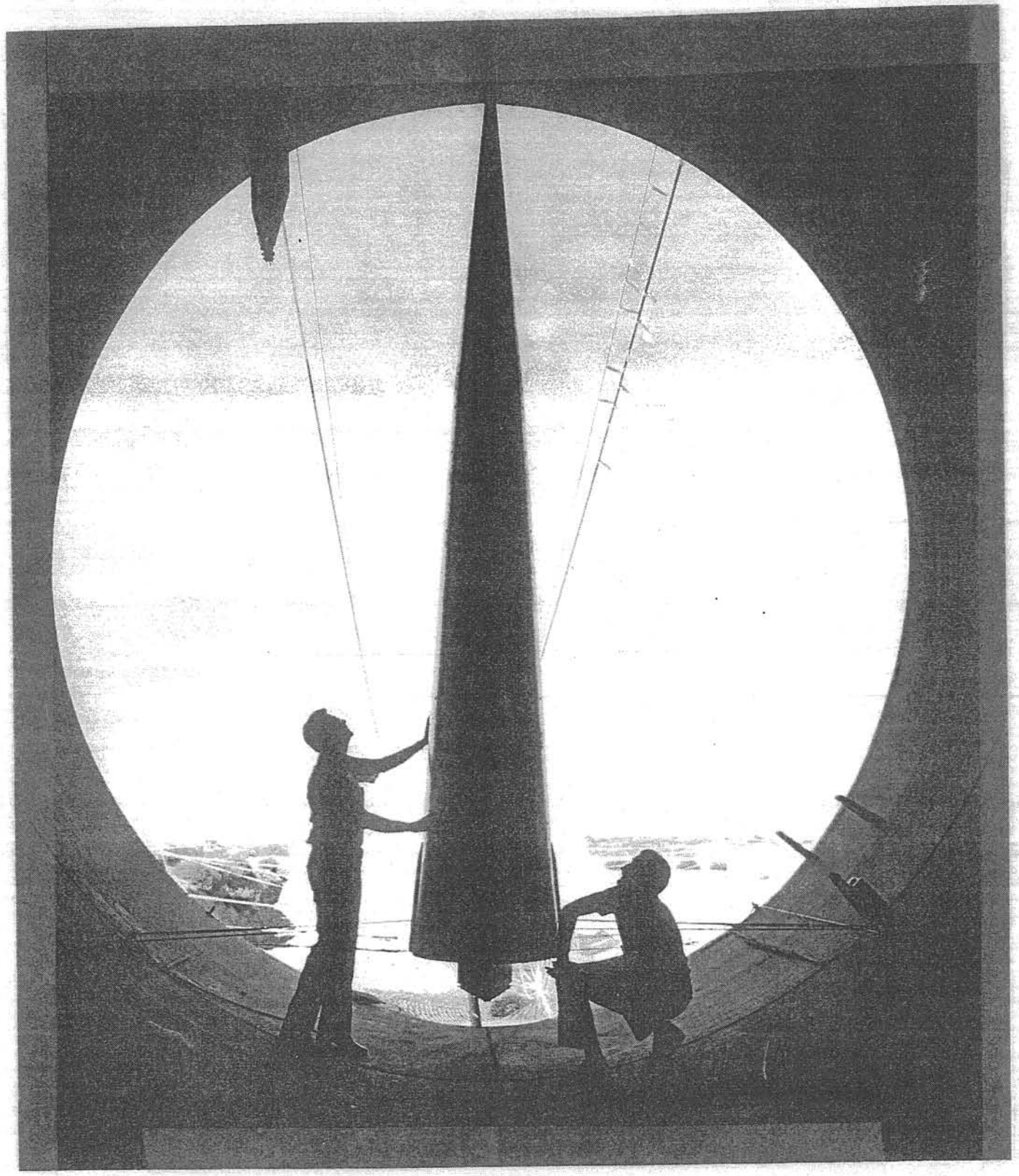


Figure H12. LTU in 19 foot test section

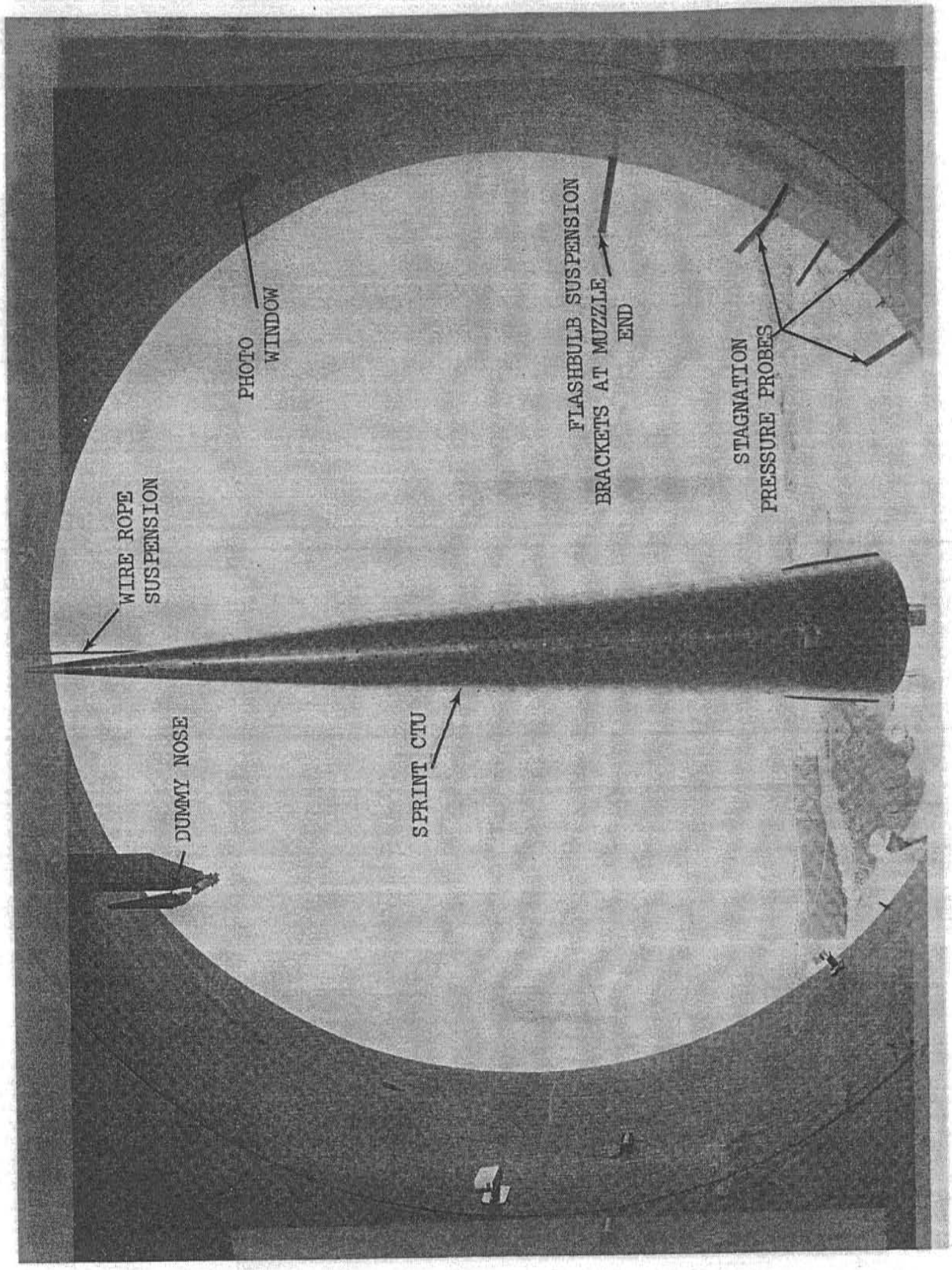


Figure H13. LTU/instrumentation/photo window

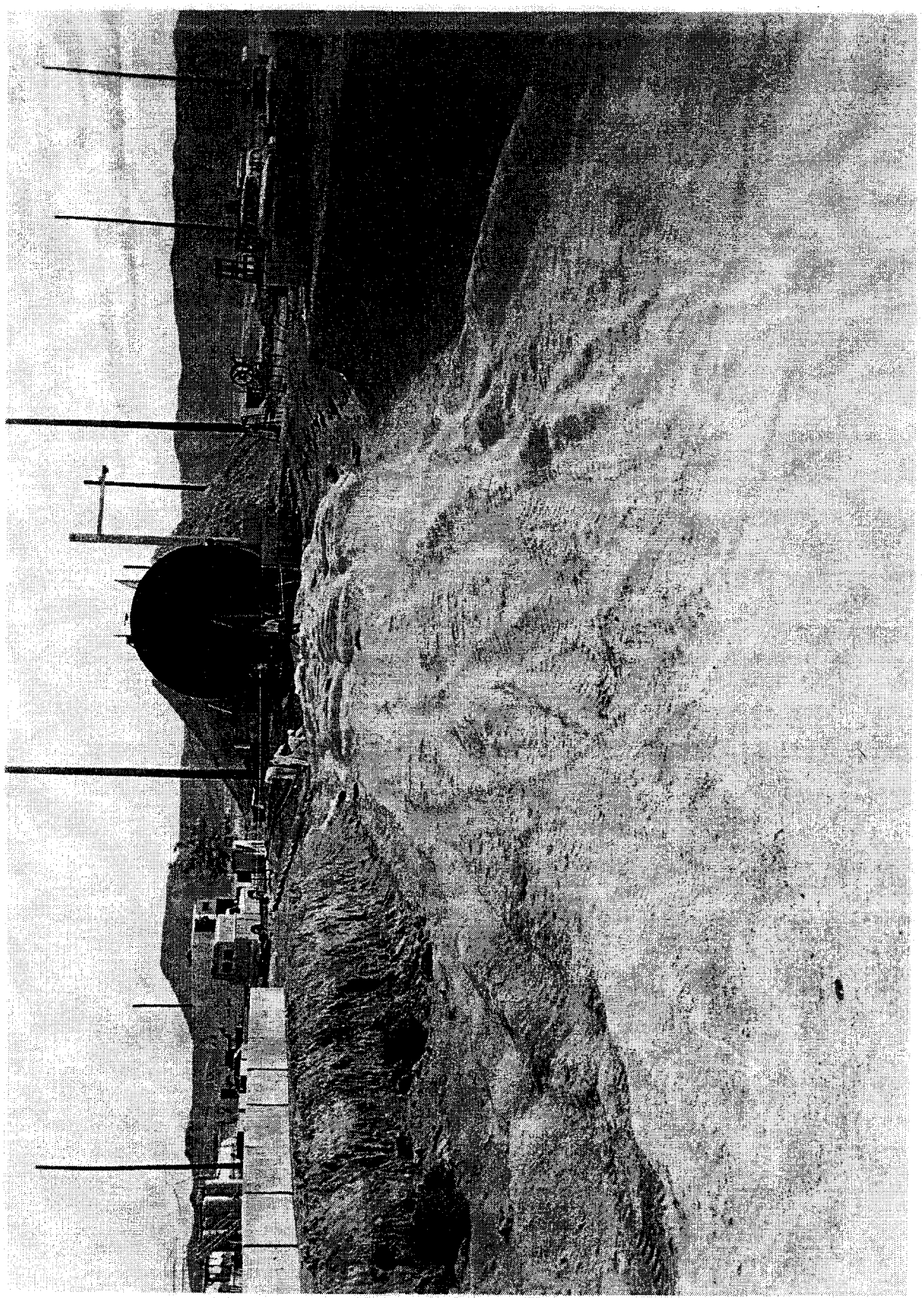


Figure H14. Large sawdust soft recovery pit

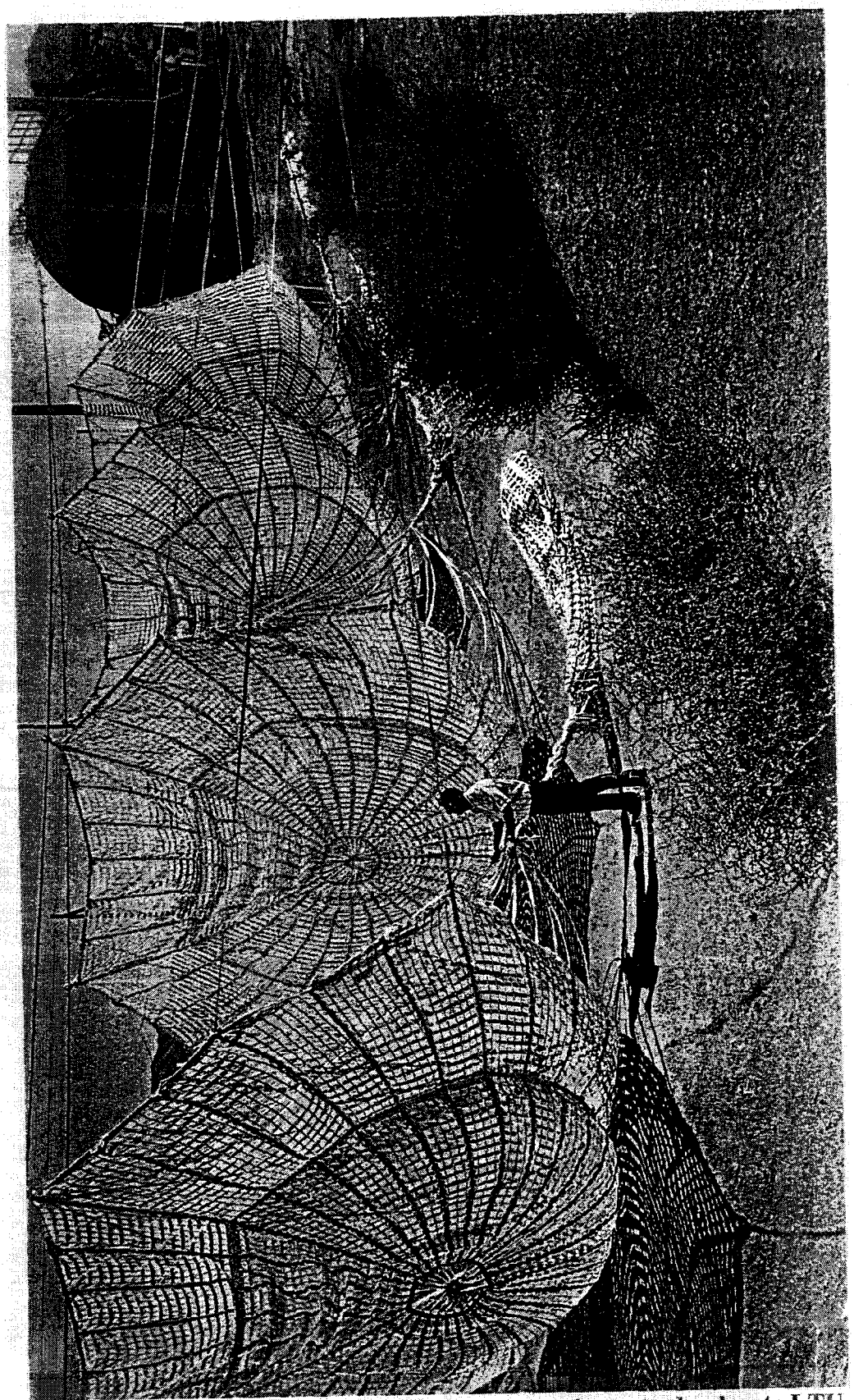


Figure H15. Twenty foot diameter, nylon, parachutes to decelerate LTU

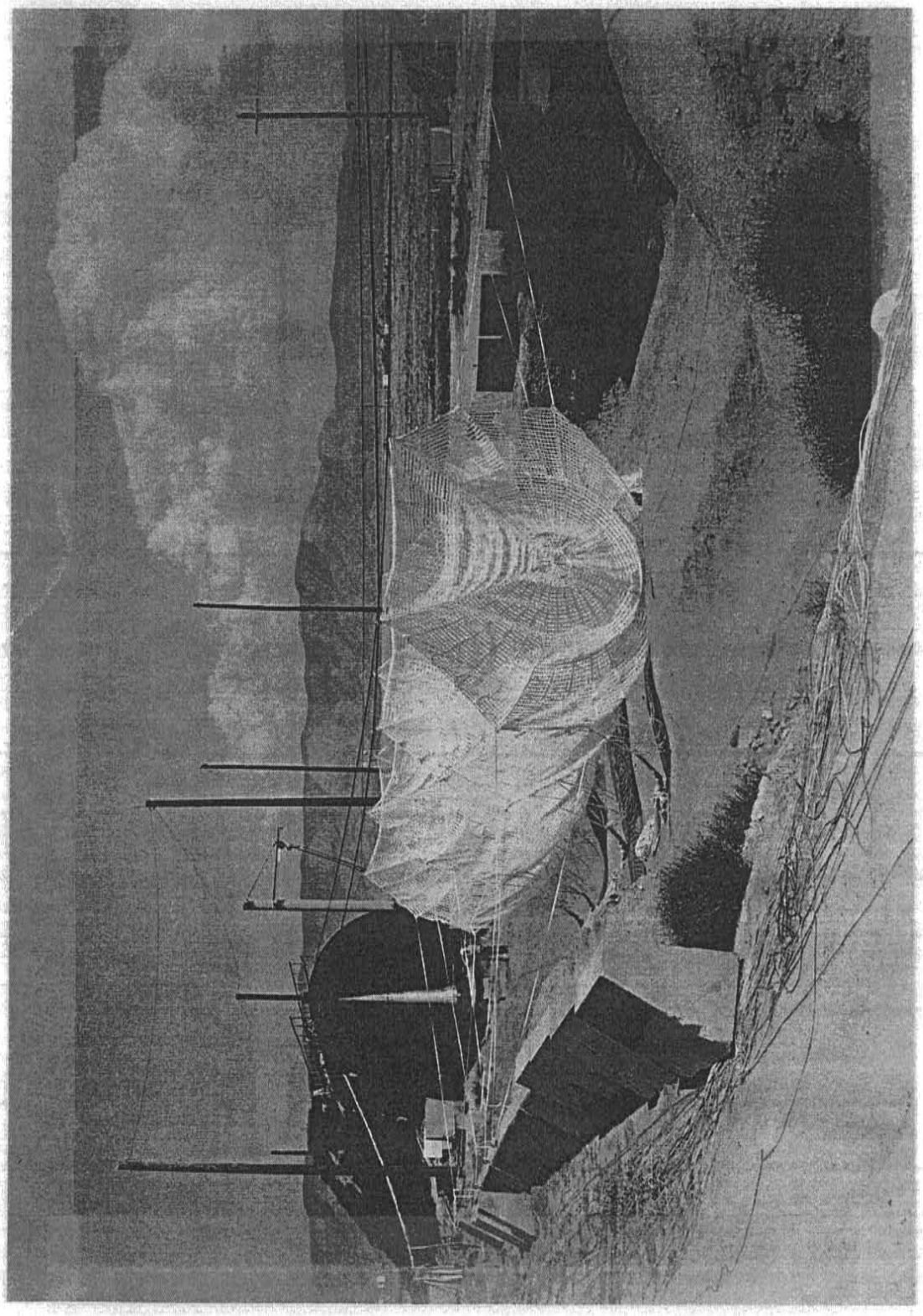


Figure H16. Final pre-test, LTU-parachutes-sawdust pit configuration

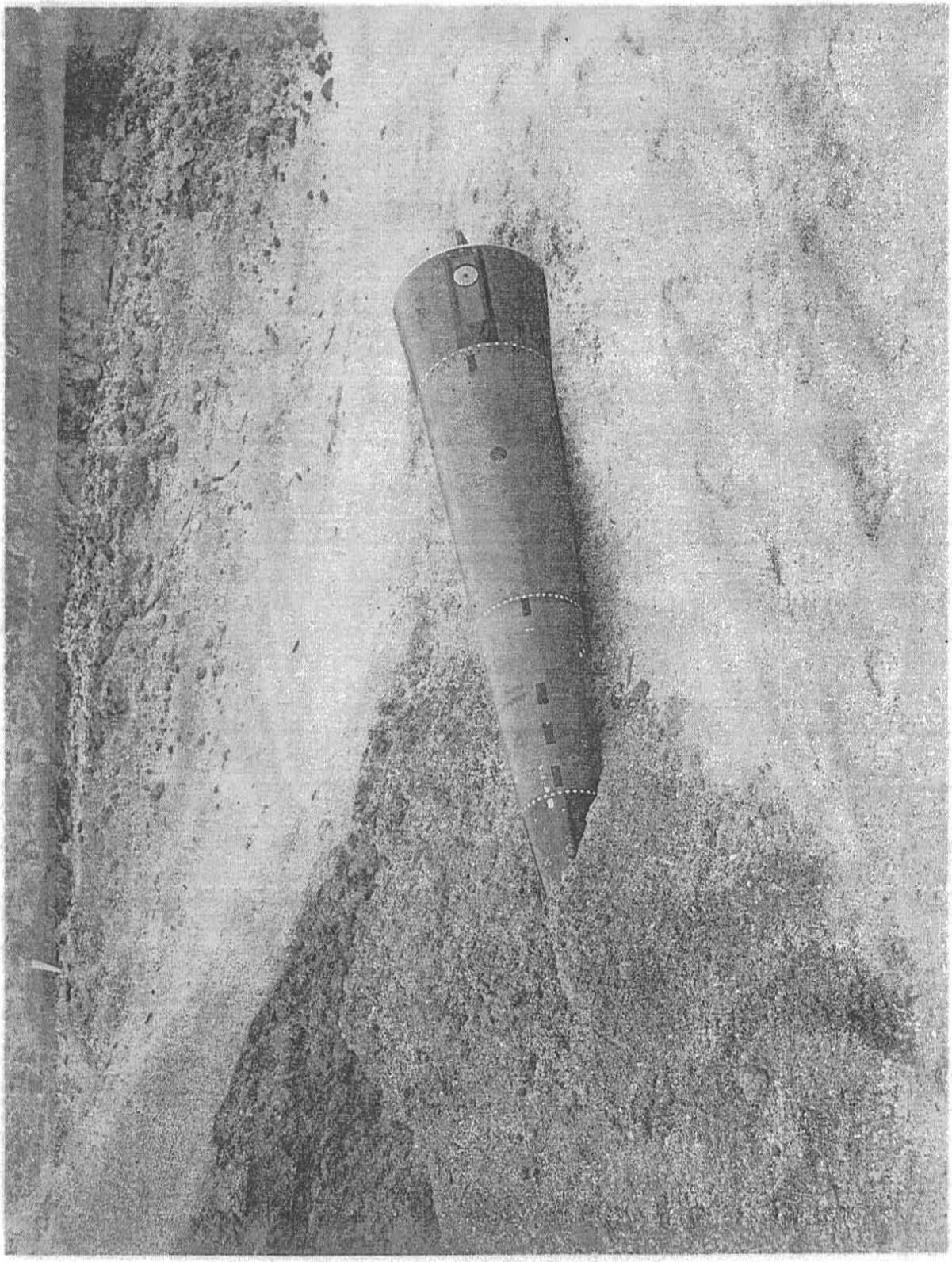


Figure H17. Post-test, LTU in sawdust pit

Distribution

Unclassified unlimited release

1	MS0130	Joseph Polito Jr., 1200
1	MS1167	Frederick Hartman, 15343
1	MS0481	Mark Rosenthal, 2114
5	MS0481	Tom Hendrickson, 2114
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1	MS0481	Bill Moffatt, 2114
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1	MS0557	David Clauss, 9125
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1	MS1453	Greg Scharrer, 2553
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5	MS1454	Mike Kaneshige, 2554
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2	MS0899	Technical Library, 9616
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