NASA Technical Memorandum

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5000 GPM FIREFIGHTING MODULE EVALUATION TEST

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Space Administration

George C. Marshall Space Flight Center

ACKNOWLEDGMENTS

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INTRODUCTION

Module Brief Description

The 5,000 gpm lightweight firefighting module (LFFM) is a gas turbine driven, compact, self-contained, portable water pumping device which can deliver a large volume of water with a suction life capability of 20 ft. It was designed to respond to emergencies requiring the pumping or delivery of a significant volume of water or other fluid as the occasion might arise. Among the possible uses are firefighting, especially in remote areas where the unit could be airlifted by helicopter sling; water pumping such as water supply to large vessels, especially where brought into port on short notice; dewatering to salvage an endangered vessel; flood control and other uses.

Purpose of Test

The test was performed to verify module performance and determine module suitability to be returned to service.

Test Location

The test was performed on piers J and K at the North Island Naval Air Station, San Diego, California, September 16-25, 1985.

Brief Test Results

The results of this test indicate that module can safely be returned to service. The module satisfied two of the three specification flow criteria conditions. Prime time was excessive, but appears to be correctable. Tiedown loads during normal operation are well within limits and present no operational problem. Great care, however, must be exercised to verify that discharge hose connections at the module are in good condition and have received recent pressure tests — failure of a hose at the module can induce high lift and turnover loads and create a hazardous condition. Operation in the automatic, rather than manual mode, further enhances safety, since a broken hose would cause overspeed and should result in automatic engine shutdown.

MODULE DESCRIPTION

The module is very similar in external appearance to the 2500 gpm module. Figure 1 is a photograph depicting the original 5000 gpm module external configuration (prior to final rework). Internally, significant changes have been made. Figure 2 shows four views of the module during the original buildup. In summary the more significant changes are: a larger pump designed and manufactured by the Ochsner Pump Company; a larger version of the Allison 250 series gas turbine engine, a 250-C30 (industrial designation – 250-KD); a modified electronic control system; and an electrically driven lube oil pump for the main water pump. Figure 3 illustrates four views of the final module configuration with the side door panels removed, and the more significant components identified. It should be noted that the prime pump plumbing configuration reflects changes which were made since this evaluation test was completed. The control panel is illustrated in Figure 4 with the more significant controls identified. Figure 5 illustrates the primary electronic components; one view is looking into the end compartment behind the instrument panel and the other view shows the removable printed circuit cards inside the electronic control box. Figure 6 illustrates the internal fuel tank baffles.

The original module pump and the 5000 gpm pump are similar in design concept. Figure 7 is an illustration of the difference in size. Figure 8 is a schematic representation of the pump illustrating its main elements and the approximate location of the inlet and outlet lube oil, waterlines, and seal drain lines. Figure 9 illustrates the three pump impellers, side and front views of the inducer and first stage impellers are shown with a side view of the second stage. The second stage rotates at the engine output shaft speed, 6016 rpm at 100 percent speed, while the inducer and first stage impellers, which are mounted on a common shaft, rotate at approximately 1/3 that speed. Figure 10 is a photograph of the internally mounted gearbox, illustrating the ring gear which is mounted to the pump housing, and the four planetary gears mounted in the gear carrier which is attached to the first stage shaft. The driving sungear, not shown in the photograph, is attached to the second stage shaft which is driven by the engine, thus the engine drives the second stage impeller shaft which in turn drives the first stage shaft through the gearbox. This arrangement provides sufficient net positive suction pressure (NPSH) to the second stage impeller. High flow and head pressure, yet small size, are achieved by the relatively high rotating speed of the second stage impeller.

The engine is a standard production helicopter engine manufactured by the Allison Gas Turbine Operations of the General Motors Corporation. Figure 11 is a schematic illustrating the significant engine features.

PURPOSE OF TEST

The overall purpose of the test was to conduct a performance evaluation and determine if it is safe to return the module to service. A module checkout test was performed by the Navy prior to the start of this evaluation test. A significant number of anomalies were found where errors had been made by prime contractor during reassembly. These were corrected by Navy personnel prior to start of evaluation test. The following tests were performed during this evaluation:

1) Determine the loads induced in the module tiedown lines by system operation. Record vibration g levels generated by the pump and engine.

2) Establish pump flow/head curves when operating with the 8-in. Stang water cannon and the truck mounted Fecon 8-in. water cannon. Test at various back pressures as induced by water cannon nozzle sizes from 2 in. to 4 in. Test at various rpm ranges from 45 percent to the maximum possible as limited by available engine horsepower. Compare the performance differences between the Stang 8-in. cannon and the Fecon 8-in. truck mounted cannon.

TEST EQUIPMENT

The equipment being tested included the following: 5000 gpm firefighting module; Stang 8-in. skid mounted water cannon; Fecon 8-in. truck mounted water cannon; 5-in. firehose in 50-ft lengths; 8-in. flexible suction sleeves in 8-ft lengths; suction strainers; and various adapters for attaching firehose.

Test equipment included a Fluke electronic data logger; Honeywell portable tape recorder; Potter flowmeters; Toroid load cells; various pressure transducers; thermocouples; accelerometers and pressure gauges.

TEST SETUP AND BASIC TEST DESCRIPTION

The test setup on piers J and K at the North Island Naval Air Station, San Diego, California, is illustrated in Figure 12, showing the module, water cannon, hose layout, test trailer, and a support truck. Figure 13 is an exterior and interior view of the instrumentation trailer where the recording equipment was located. Two basic module setups were tested:

1) 5000 gpm module and Stang water cannon — The suction hose configuration consisted of three sets of three each 8-ft long–8-in. diameter suction sleeves with inlet strainers. The discharge configuration consisted of three sets of two each 5-in.diameter hose, 50 ft long. A flowmeter was located in each set of hose where the two hoses were connected. An instrumentation trailer was located within approximately 50 ft of the module. Load cells were located in each of the four module tiedown lines. Pressure transducers, pressure gauges, accelerometers, and thermocouples were mounted at various locations to collect data. A board was mounted at one end of the module trailer for mounting test gauges; it can be seen in Figure 12.

2) 5000 gpm module and truck mounted Fecon water cannon — The configuration was the same as that above except that only two sets of discharge hose and two flowmeters were used due to the inlet configuration of the Fecon cannon — the rear module discharge line was not used.

In each of the above tests, the module was mounted on its trailer with two crossed chain tiedowns on each end of module, a sketch of the tiedown lengths is shown in Figure 14. As a safety precaution, an additional chain was looped through the module forklift tunnel and under the trailer to hold the module in the event the normal tiedowns failed. Also the trailer was secured to the dock by chains, one off each side of the rear of the trailer and off of the tongue of the trailer. In each case chain tension was applied by a load binder.

The following tests were performed:

1) Tiedown load evaluation — The purpose of this test was to determine if any significant loads are applied to the tiedown chains during normal module operation. The test setup was the same as the module test setup number 1 above. Tests were performed with and without the elbow discharge fittings with 2-in. and 4-in. cannon tips. Instrumentation was set up to maximize the data acquisition from the load cells into the data logger.

2) Tiedown load evaluation with only one of the three discharge valves open — Two sets of data were taken, one with the hose opposite the control panel flowing and the other with the rear discharge flowing. The test setup, otherwise, was the same as the basic module test setup number 1.

3) Tiedown load evaluation with one discharge hose removed and water flowing open butt — Two sets of data were taken, one with the hose opposite the instrument panel removed and water flowing with the other two discharge valves closed. The other set of data was taken with the rear discharge hose removed and the other two discharge valves closed. The discharge hose in each was removed from the elbow allowing water to discharge open butt directly from the elbow. The test setup otherwise was the same as the basic module test setup number 1.

4) Performance evaluation with the Stang 8-in. water cannon — Data were taken to establish a flow/head curve at speeds of 45, 60, 75, and 90 percent, and also the maximum speed possible based on available engine horsepower. The water cannon tip size used ranged, in 1/4-in. increments, from 2 in. to 4 in.

The 4-in. tip was actually the adapter onto which the nozzle is normally threaded. These tests were performed with the discharge elbow mounted in place, a total of 45 test runs were completed. After this, several runs were made with the 4-in. Stang tip and a 2½-in. and 2¾-in. NASA nozzle.

5) Performance evaluation with the truck mounted Fecon water cannon — Forty-five runs were completed as per the above, except the straight discharge fittings were used and neither the NASA tips nor the 4-in. Stang tip were retested. When a 4-in. tip was needed, the 4-in. adapter tip was used.

6) Prime test — One set of data were taken during a nominal prime sequence.

7) Evaluation of the effects of operating the module without the demister filters — The demister panels through which the engine compressor inlet air must pass were removed to evaluate the effects of demister pressure drop on engine horsepower. The demisters were replaced with coarse screens to prevent contaminants, such as paper, from being sucked into the engine. The module and hose were otherwise set up the same as basic module setup number 1.

DISCUSSION OF TEST RESULTS

The following is a discussion of the test results and data curves which have been plotted.

1) Tiedown load evaluation — The intent of this initial load test was to obtain an overall quick indication of the magnitude of the tiedown load increase for the maximum and minimum nozzle sizes as the engine power level was increased with a normal module setup and determine if the module was considered safe to operate. The electronic data logger was set up to obtain the maximum number of tiedown load data points at the expense of data such as flow, temperature, and pressure. This data indicated that there are no significant tiedown load changes as a result of engine speed or tip size changes or whether an elbow or straight discharge connection is used between module and discharge hose. The data plots which were made indicate an inconsistency with less than a 100 lb inline load change with an increase in pump speed from 45 percent to maximum. Since this data did not indicate any trends, plots were not included in the report.

As can be seen in Figure 15, priming the module produces a variation in tiedown loads; as the suction sleeve fills with water, the tiedown loads on the section end of module decrease by approximately 120 lb each and the loads on the other end increase by approximately 210 lb each. By readjusting load binders after prime, a more consistent preload can be maintained during operation. These loads are the inline chain loads not the actual vertical loads. Load binder preloads of more than 400 lb should be avoided. It should be noted that during 1984 testing with the original pump impeller, severe vibration and recirculating flow conditions occurred in the pump suction at high back pressure conditions. During the September 1985 test, being reported here, significantly smoother module operation occurred under these conditions.

A cursory evaluation of the vibration data recorded indicated no significant trends as related to operating condition other than the fact that an increase in operating speed caused an overall increase in the overall power spectral density.

2) Tiedown load evaluation with only one of the three discharge valves open — Two sets of runs were made, one with discharge flow from the side opposite the control panel; the other with flow from the rear. No significant load changes were noted. Figure 14 is a plot of the data taken with water flowing from the discharge opposite the control panel side of the module. These data are also typical of that for item 1 above.

3) Tiedown load evaluation with one discharge hose removed and water flowing open butt — This test simulates the effect of a hose/coupling failure. Figure 16 data were taken with the discharge hose removed from the rear discharge elbow and water flowing only through this elbow. It illustrates an approximate 520 lb inline chain load increase on each chain on the suction end of the module as the pump speed is increased from 1800 to 4500 rpm. At the same time, the inline chain load on the end of the module opposite the suction is decreased by approximately 150 lb.

Figure 17 data were taken with the discharge hose removed from the side discharge elbow opposite the control panel and water flowing through that elbow. The L1 chain inline load increases by approximately 570 lb while the other side, L2, decreases by 80 lb as the speed is increased from approximately 2100 rpm to 4350 rpm. On the other end of the module, L4 is increasing by approximately 465 lb, while L3 is increasing by 275 lb. The suction end of the module appears to be trying to rotate. The weight of water in the suction hose appears to transfer the water thrust from the elbow into a rotating and lifting motion on the other end of the module. The maximum speed was limited by the module operator due to the dramatic increase in tiedown loads and a noticeable change in vibration and noise. Figure 18 combines the plots from Figures 16 and 17 for comparative purposes. These data indicate that large module lifting/rotating loads can be developed as a result of a failed hose connection at the module hose interface. It has been previously demonstrated that these type loads are sufficiently high to rotate and turn the module over (in the event of a tiedown failure). The module tiedown connect points were redesigned prior to this test and are considered adequate. From an operational safety standpoint, a primary concern is the reliability of the discharge hose and fitting — a heavier duty hose/ connection would be an improvement along with a hose pressure test at regular intervals. The chains and tiedowns to the trailer, of course, must be adequate. The previous problems of reverse flow in the suction hose and heavy vibration at high back pressures were not encountered during any of these tests.

4) Performance evaluation with the Stang 8-in. water cannon — Figure 19 is a plot showing module performance at 45, 60, 75, and 90 percent speed and maximum speed. (Maximum speed was that speed judged to be the maximum attainable without exceeding the automatic over temperature shutdown limits — a digital total outlet temperature, TOT, reading of 713°C and a panel gauge reading of 730°C.) Additional investigation should be performed to determine which of these TOT values represent the true temperature. The inlet air temperature for these tests ranged from 72 to 76°F.

Lines are drawn on the plot which connect test points representing the different tip sizes tested. Figure 20 is a comparison of performance and horsepower at 90 percent and maximum flow conditions. In running the maximum flow condition test, an attempt was made to keep the speed as high as possible without getting an automatic TOT shutdown, hence, the speed varied somewhat resulting in an uneven flow and horsepower curve. The variation in speed can be seen in Figure 21.

The original module performance requirement was to achieve the following conditions:

5000 gpm at a total pump pressure rise of 150 psi

3000 gpm at a total pump pressure rise of 200 psi

2500 gpm at a total pump pressure rise of 250 psi

As can be seen from Figure 21, extending the maximum pressure curve indicates that the 5000 gpm flow was probably achievable, however, it would have required a nozzle larger than the 4 in. available, in order to reduce the tip pressure drop. The 3000 gpm performance was achieved. The 2500 gpm performance could not be achieved, due primarily to a lack of engine horsepower. The engine horsepower criteria was specified at conditions of standard day temperature and sea level conditions, the test was actually run at average temperature conditions of approximately 73°F. The actual test conditions subtract approximately 50 horsepower from that normally available at specification conditions, however, the engine capability is still short of what is required to achieve the 2500 gpm requirement. The 100 percent speed curve indicates that the module could have achieved 2500 gpm at aproximately 245 psi if approximately 685 engine horsepower were available. For the inlet temperature condition of approximately 73°F and a TOT of 713°C, only 570 to 585 horsepower was indicated as being available. The inability of the engine to develop sufficient horsepower was recognized by the Government prior to awarding the module contract. The Allison engine was an uprated version of the previously used module engine and was the only one known with an output drive pad location near the center of the engine which was compatible with the original module pump configuration and would result in a minimum overall module length.

In addition to the horsepower limitation, the Allison 250-C30 has a speed range limitation for constant speed running in the range of 78 to 88 percent which creates an otherwise unnecessary constraint in module operation.

There were discrepancies in data taken in several areas. The most significant one was the total outlet temperature, TOT – the instrument panel digital reading varied from the panel gauge reading by from 12.4 to 20.1°C depending on engine speed. The tabulation in Figure 22, table 1, notes the error. The digital TOT reading is critical in that it controls engine shutdown due to engine overtemperature — an indicated reading lower than actual means that engine temperature damage could occur prior to a shutdown. On the other hand, an indicated reading higher than actual means that shutdown could occur prior to achieving available power. An accurate means of checking TOT calibration, at regular intervals, should be made available.

The torque gauge along with the speed readout gives a direct indication of developed engine horsepower, the instrument panel was in error from 5.2 psi at low power to 11.7 psi at high power as indicated in the tabulation in Figure 22, Table 2. The error at high power is equivalent to approximately 70 horsepower.

The module discharge pressure was also in error. The location of the pump discharge pressure pickup is at the check valve where there is considerable turbulence. In order to obtain better accuracy, an additional measurement was installed for the test near the original pickup but with 4 pressure pickups at 90 degree intervals manifolded together. As it turns out, by averaging the digital and the control panel gauge reading for each reading taken, a measurement can be obtained which is within approximately 1 psi of the calibrated measurement.

Figure 22, Table 3, illustrates the changes in some selected parameters as the tip sizes are changed while attempting to maintain maximum speed. The test setup is with the Stang water cannon set up as per basic module setup number 1. Compartment temperatures were relatively low. Figure 23 illustrates typical temperatures. The data shown was taken from the performance testing with the Stang water cannon and a 2-in. tip.

The engine and pump tested seem to be a viable combination for firefighting with short runs of hose to a large 8-in. water cannon such as was done during this test program. For pumping water through long runs of hose, however, the considerable dropoff in pump efficiency at high pump back pressures requires more power than is available from this engine. There is a considerable dropoff in pump efficiency below 3000 gpm/170 psi — at 2500 gpm the efficiency is 55 percent. It should be possible to design a similar pump with a maximum efficiency of 75 percent, targeted for 2500 gpm at 250 psi, which could be driven by this engine operating at an ambient temperature of 80°F or less.

During flow performance testing, photographs were made of the water stream at each test speed, 45, 60, 75, 90 percent and maximum, and with tip sizes from 2 in. to 4 in., in 1/4-in. increments to illustrate the reach and general condition of the stream for each case. Figures 24, 25, and 26 are photographs taken of the water stream with tip sizes of 4.00, 3.75, and 3.50 in., respectively, with the module operating at what was considered to be the maximum engine power level for the prevailing ambient temperature conditions. Of the nine tips tested, the maximum stream reach appeared to be with the 3.50 in. tip, while operating at maximum speed.

5) Performance evaluation with the truck mounted Fecon water cannon — Figure 27 is a plot illustrating how pressure increases at various points in the system as the water flow rate increases. Figure 28 is a similar plot but with module set per basic module setup number 1 with the Stang water cannon. Figure 29 compares the pressure drop of the Fecon 8-in. cannon and Stang 8-in. cannon. As can be seen, there is a very large pressure drop difference between them at high flow rates. It appears that a redesign of the Fecon cannon is in order to reduce this difference.

6) Prime Test — Figure 15 is a typical prime cycle. The time to prime for a 12-ft lift was approximately 295 sec with a battery drain averaging 51 to 54 A with both batteries providing power. The plots illustrate the rate at which water is drawn up the suction sleeves as well as the change in tiedown load as the suction sleeve fills with water.

7) Evaluation of the effects of operating the module without the demister filters — Two sets of runs were completed, each set consisting of runs at 45, 60, 75, 90, and maximum speed. It is known that a reduction in inlet air pressure drop to the compressor allows more air in and, hence, greater horsepower, but the variation and inconsistency in test data along with the expected fairly small change in horsepower did not produce any meaningful results. A 1 percent change at the higher horsepower band would be six horsepower and probably could not be measured except under laboratory conditions.

SUMMARY AND RECOMMENDATIONS

Test Objective

The test was performed to verify performance characteristics and determine if the module could be safely returned to service. The module was delivered late with a number of deficiencies which Navy personnel expeditiously corrected — corrections were made prior to arrival of NASA test personnel. The test was completed on September 24, 1985, pretty much as planned, with gear packed up on September 25, 1985. Portions of the testing, however, were shortened due to lack of time.

Performance

The module satisfied the specification performance criteria at 5000 gpm and at 3000 gpm, but not at 2500 gpm. Module operation, at an ambient temperature of say 90°F, instead of the average test temperature condition of 73°F, would reduce available engine horsepower by approximately 10 percent. This is, of course, an important consideration in sizing of future modules. It might be wise to consider a dual module configuration — that is, one basic module configuration and engine with different, but similar pumps. The difference would be the flow rate at which the maximum efficiency is based, one say at 4500 to 5000 gpm and the other at near

2500 gpm — this would require different impeller designs. The similarity would be the basic pump envelop and design to maximize spare parts interchangeability. The 5000 gpm pump would deliver water, at say 150 psi, for operation with 100 to 200 ft hose lays and a large 8-in. water cannon while the 2500 gpm pump could be designed to deliver a relatively high discharge pressure, say 250 psi, for pumping over longer hose layouts.

The prime time for a 12-ft lift was approximately 295 sec, which exceeds by a wide margin the specification requirement of 120 sec for a 20-ft lift. This prime time is excessive and could be reduced by the addition of a dual prime pump (which would also provide redundancy). Another consideration is to open up the flow passages in the plumbing lines. The current drain from a single prime pump is high — approaching 55 A at 24 V. A dual pump would require a different prime sequence than that now being used in order to conserve battery power. Instead of running the prime pump and then starting the engine after prime is completed, the engine could be started first, allowing the batteries to be charged during prime. There are two problems with this, one, the main pump is turning while the engine is running, meaning the rotating seals could be running dry, and two, during the final stages of prime, water is drawn into a rotating impeller causing surging. The first condition is probably not a real life limiting problem, however, testing could be performed to verify it. The second condition could be worked around by shutting down the engine during the final stages of prime and then restarting it after prime is completed. Since this evaluation test was completed, the Navy reported that the effective flow passage area in the prime pump suction line has been increased with a resulting improvement in prime time such that the two minute prime time can now be achieved. This change is reflected in one of the photographs in Figure 3.

Accuracy of the engine digital TOT reading is suspect, operation of the module at actual temperatures higher than specification limits, both during start and steady state operation, can lead to premature engine failure. Additional investigation is recommended.

Tiedown Loads

Module operation was smooth with the tiedown loads low in value and changing in a random manner, no consistent trend was noticed as the power level was increased. No recirculating flow was noted in the suction side of the pump as was noted in earlier test at high back pressure. The largest variation in tiedown loads for normal operation occurred during system prime — the loads on the suction end of the module decreased as weight was added to that end of the module as the suction hose filled with water. At the same time the load on the other end of the module was increasing. In order to maintain a more even distribution of tiedown loads during module operation, the tiedowns could be adjusted after prime completion.

The module was operated with one of the discharge hoses removed to simulate the effects of a failed discharge hose coupling. Immediate and significant load increases occurred as the speed and power level were increased. Due to the indicated real time increase in loads and vibration, these tests were stopped short of achieving full speed and power levels. It is recommended that frequent pressure tests of the discharge hose near the module be made at regular intervals. A heavier duty hose/coupling at this point is also recommended. Water hammer effects as a result of sudden or intermittent flow interruption could also be a significant hazard. (No attempt was made during test, however, to simulate this condition.) The fix for this condition is to set the module up such as to eliminate the possibility of a sudden flow interruption.

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3. Commercial Turboshaft Engine, Model 250-C30P, Specification C904, Detroit Diesel Allison, Division of General Motors Corporation.

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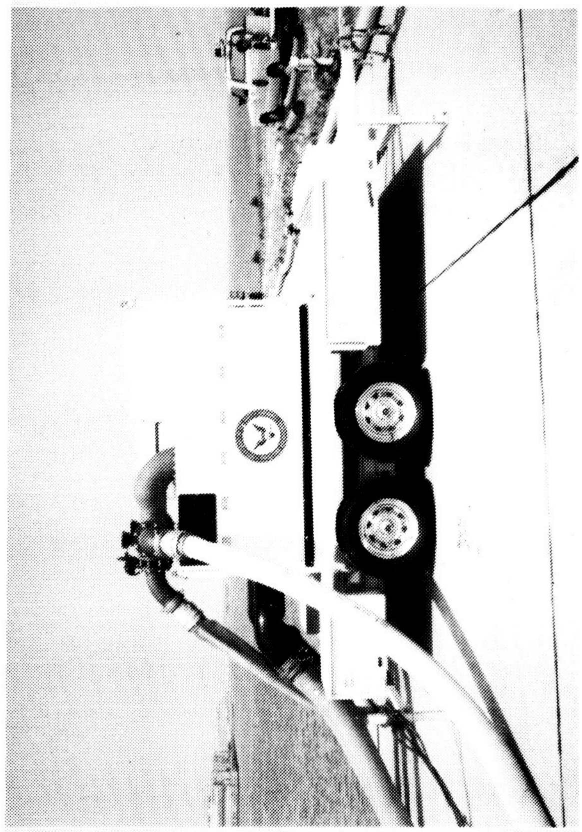


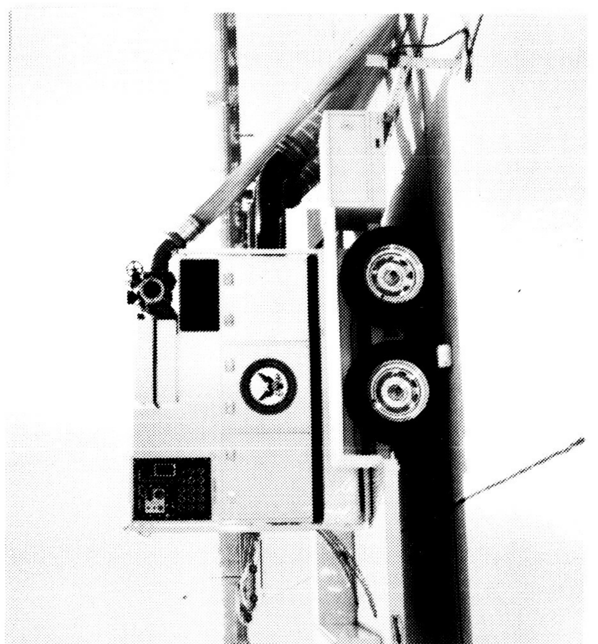


Figure 1. Module/trailer external side views (old configuration).

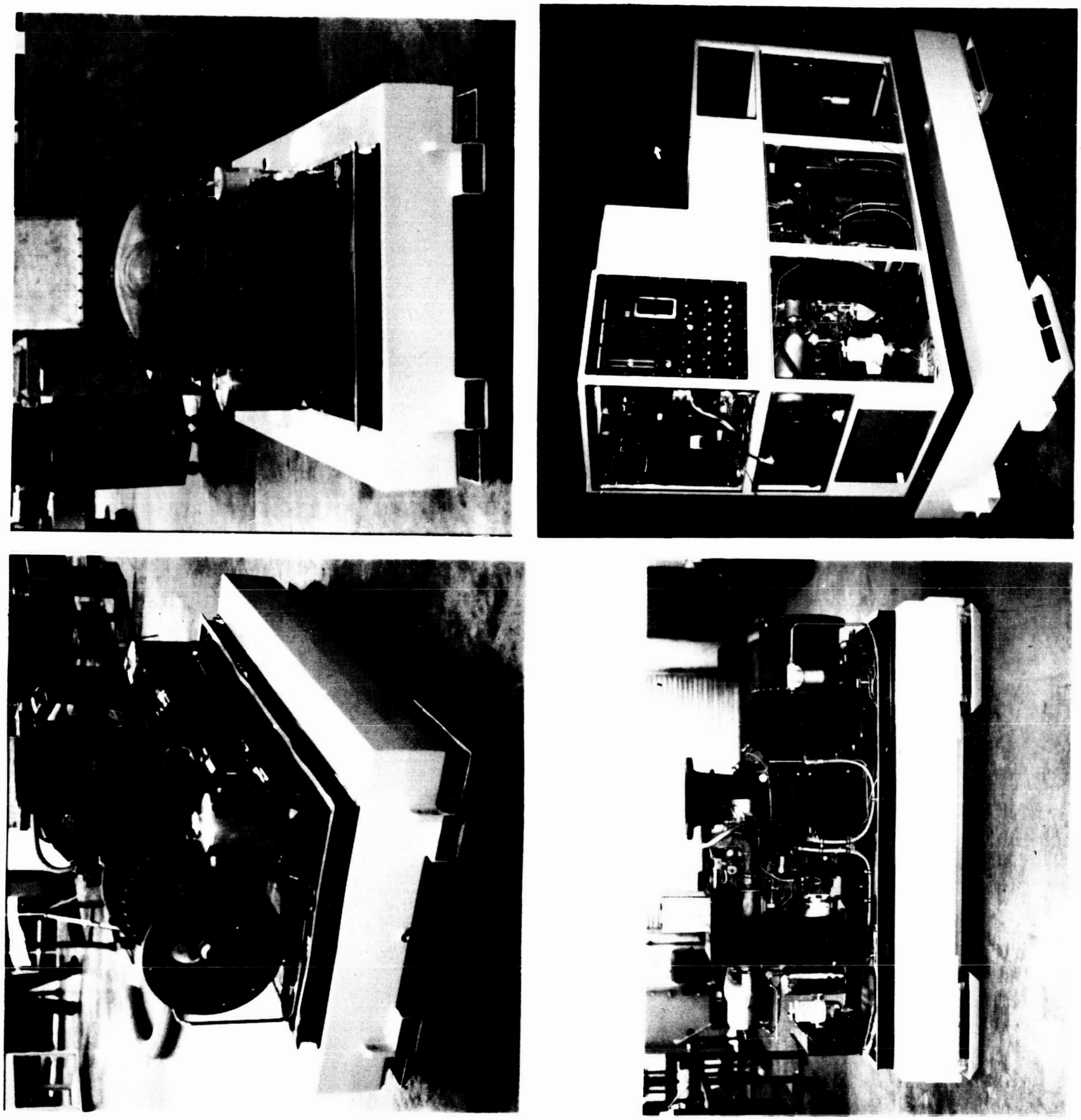


Figure 2. Module internal views during original buildup.

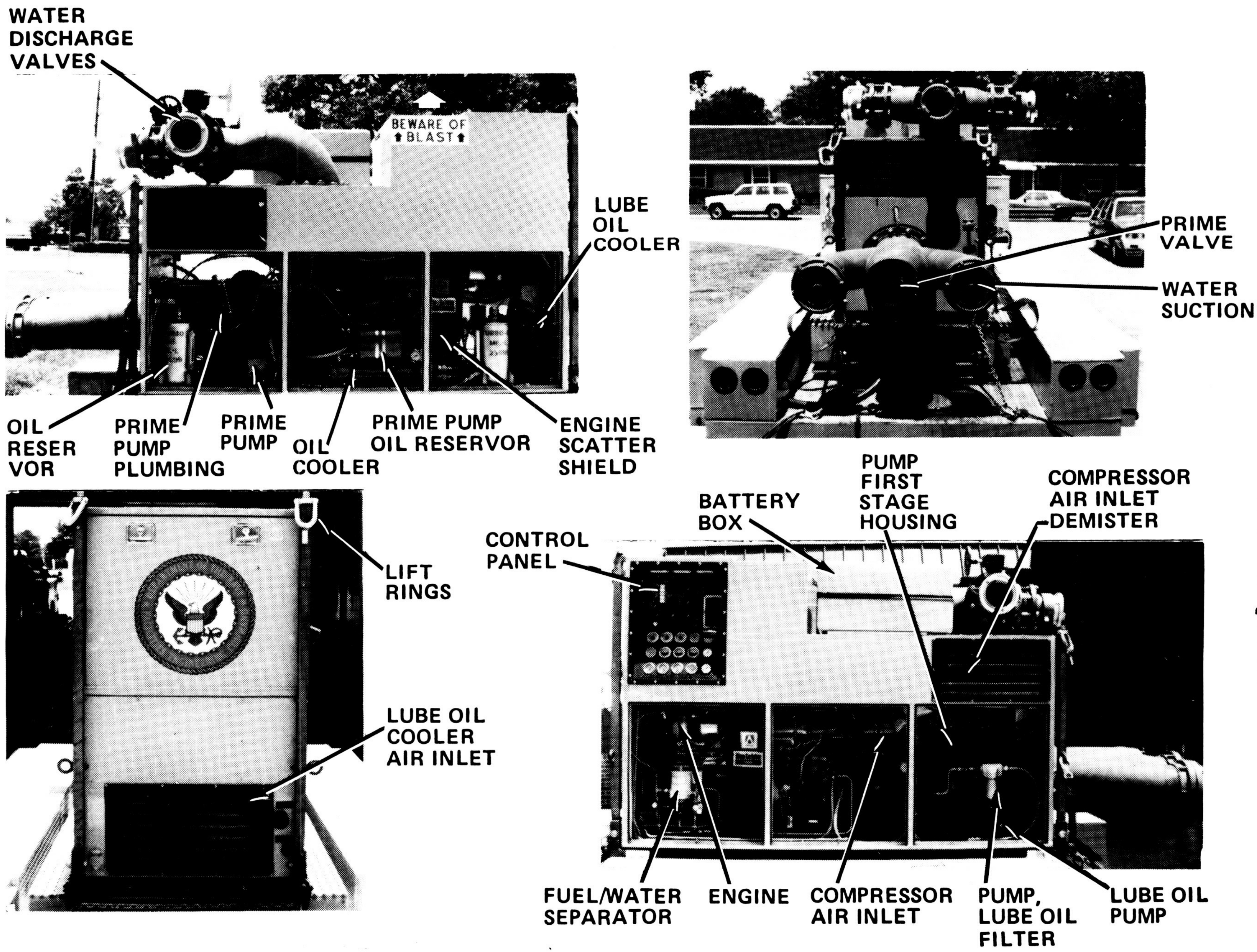


Figure 3. Module final configuration (panels removed).

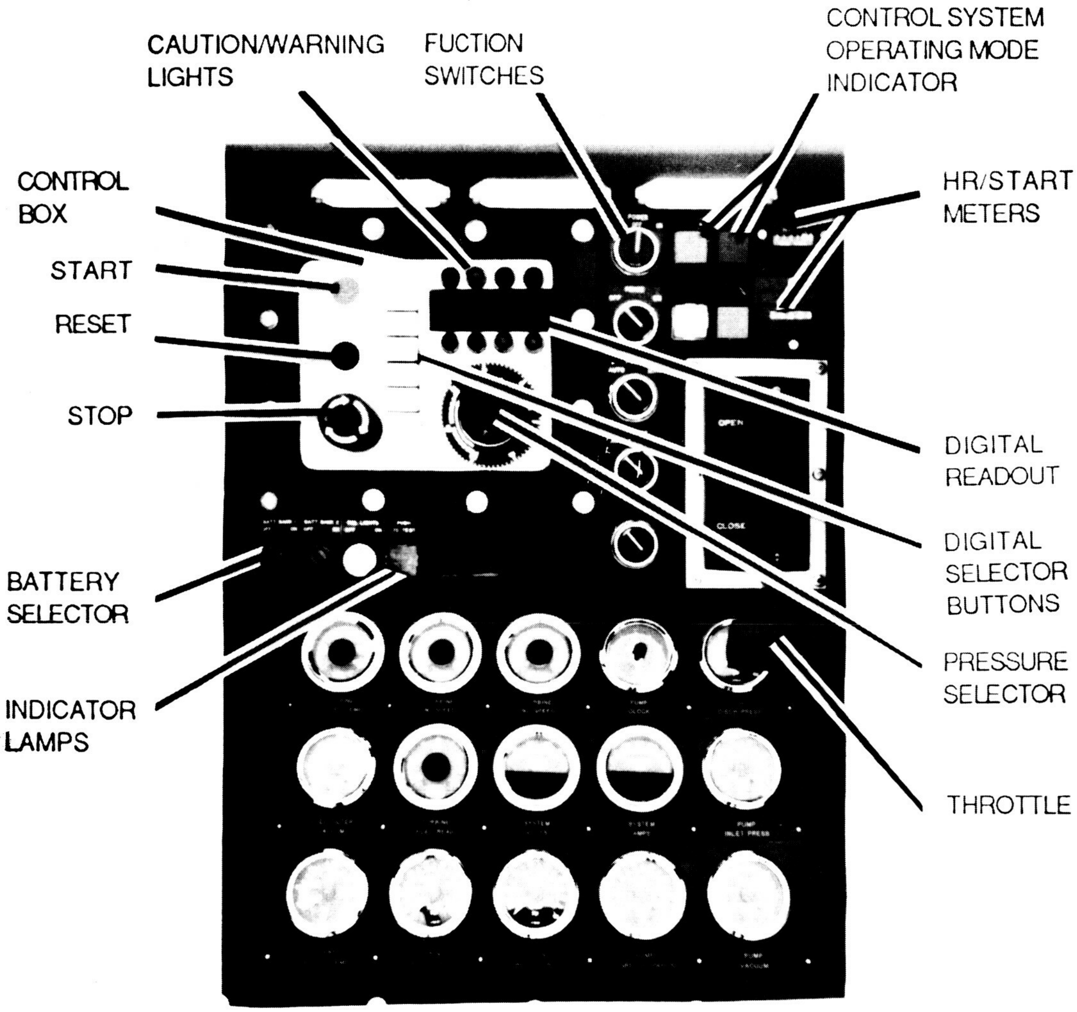
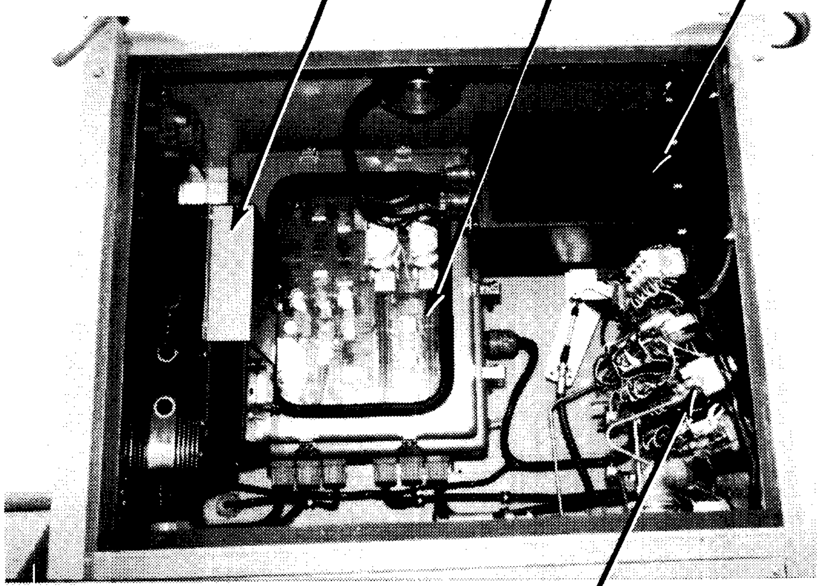


Figure 4. Control panel.



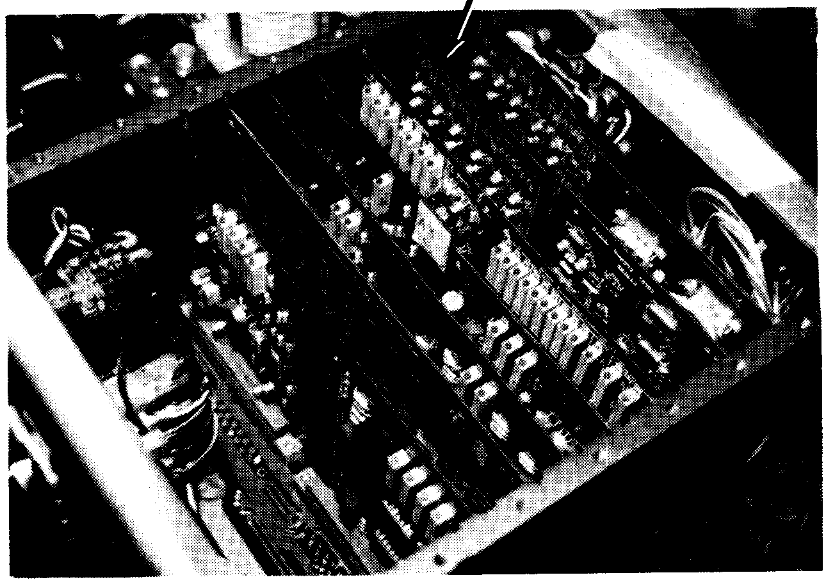


Figure 5. Module electronics.

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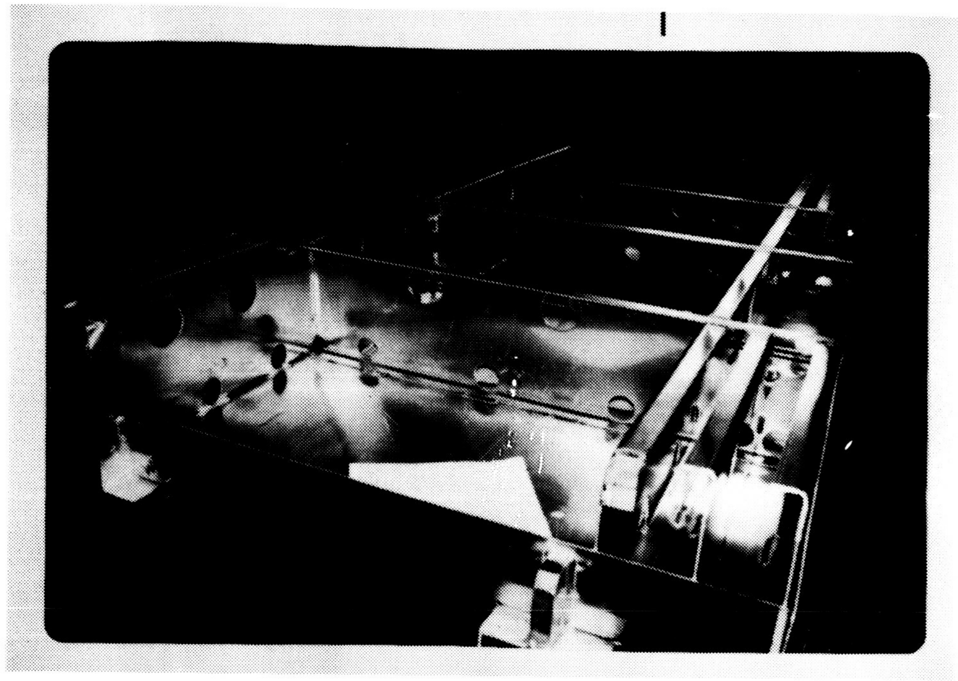

Figure 6. Fuel tank and internal baffles.

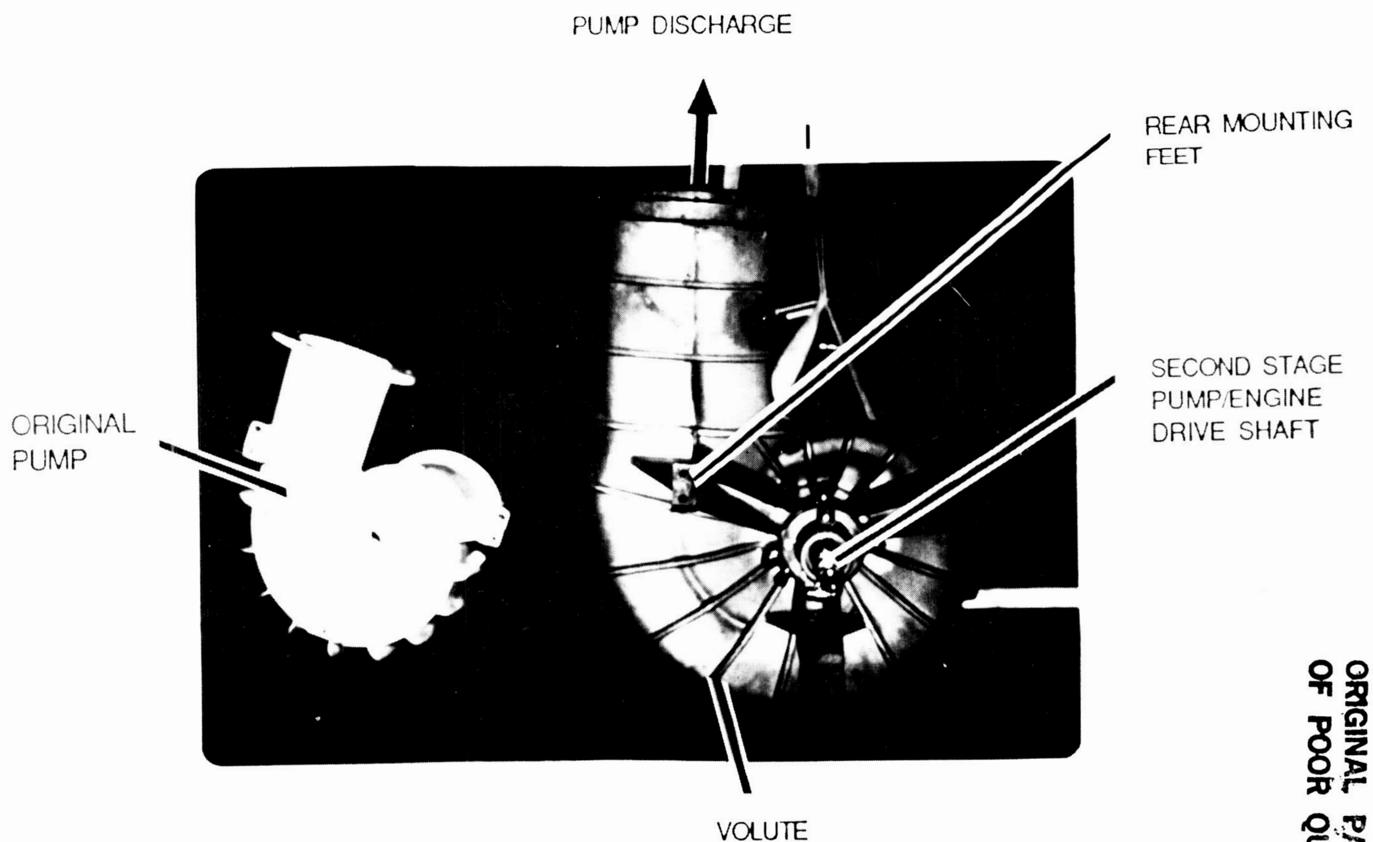

Figure 7. 5000 gpm pump size compared to original pump.

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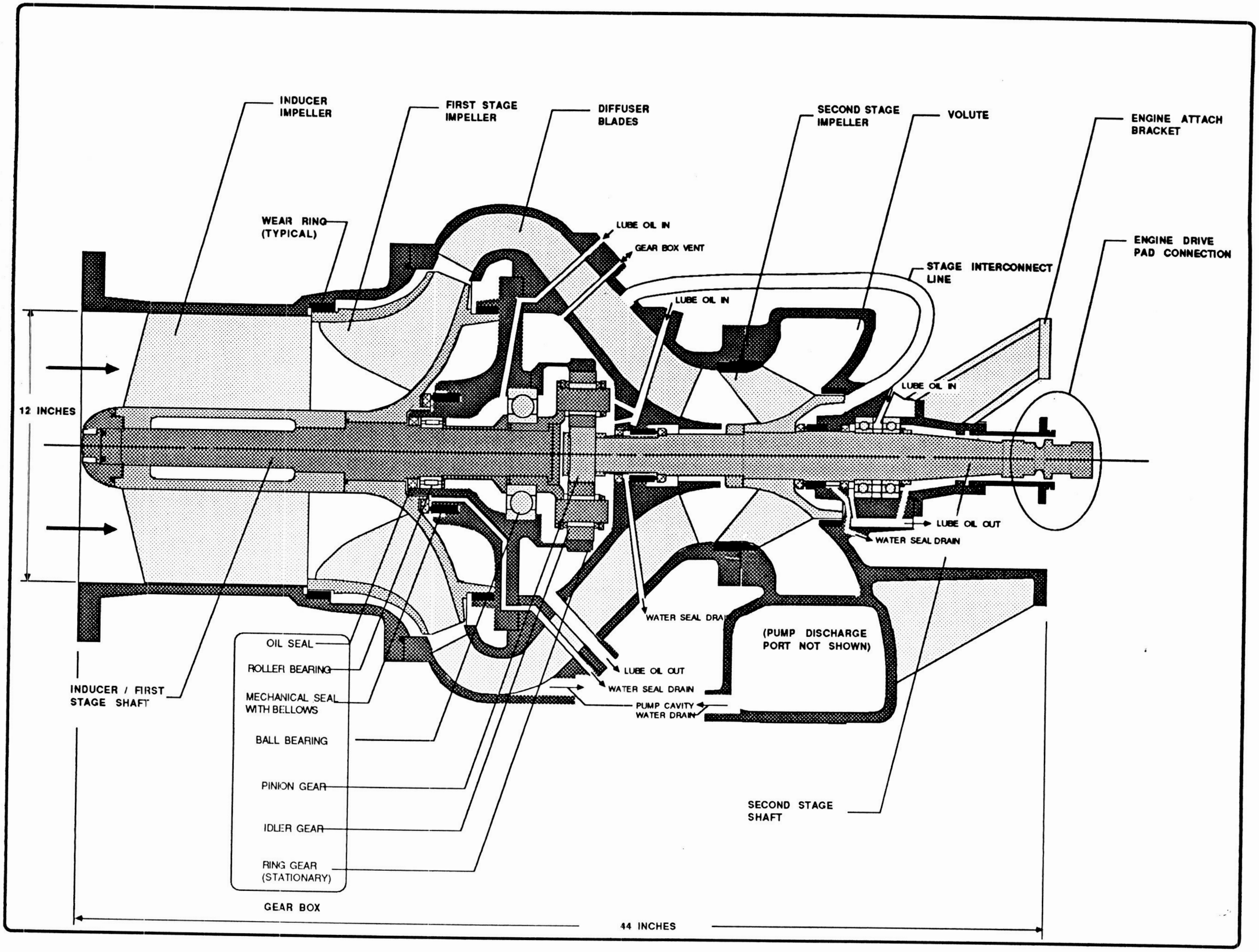
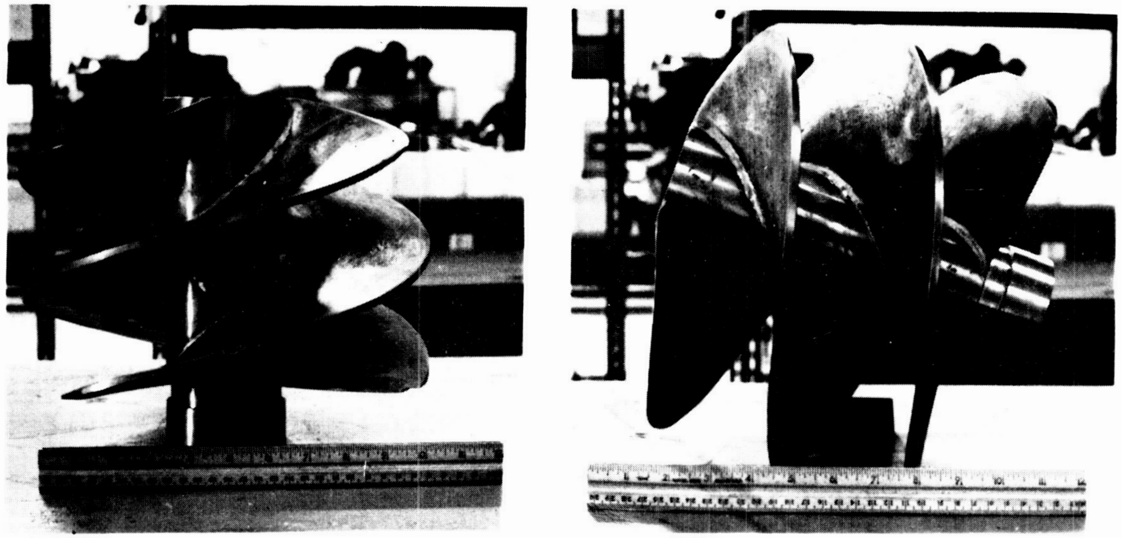


Figure 8. Pump schematic.



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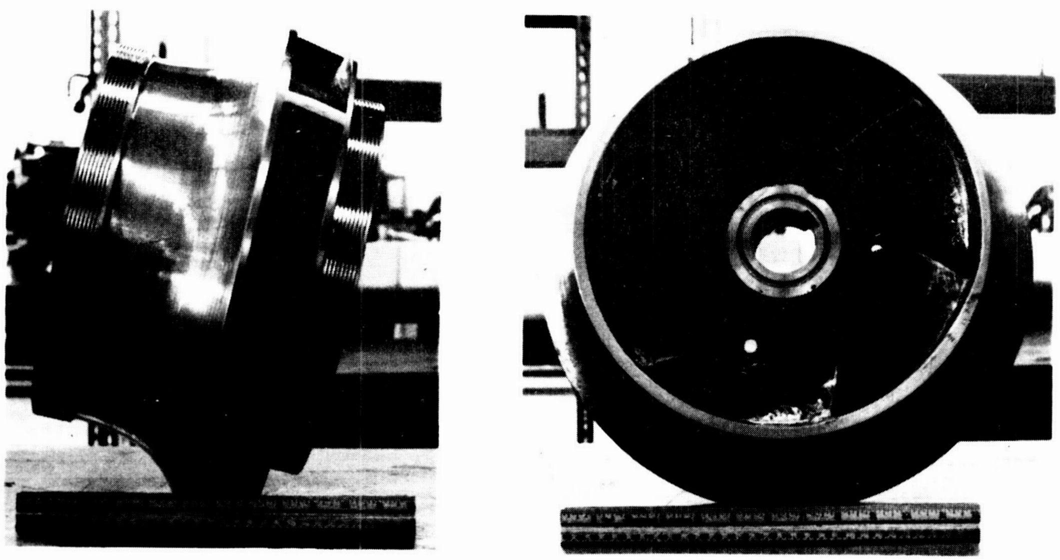
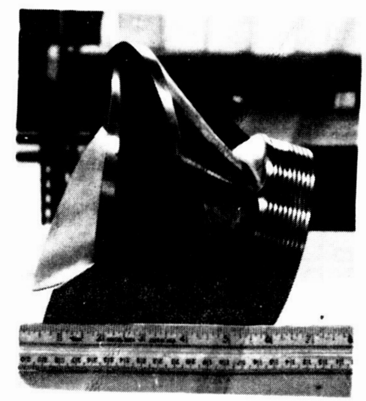


FIRST STAGE



SECOND STAGE

Figure 9. Pump impellers.

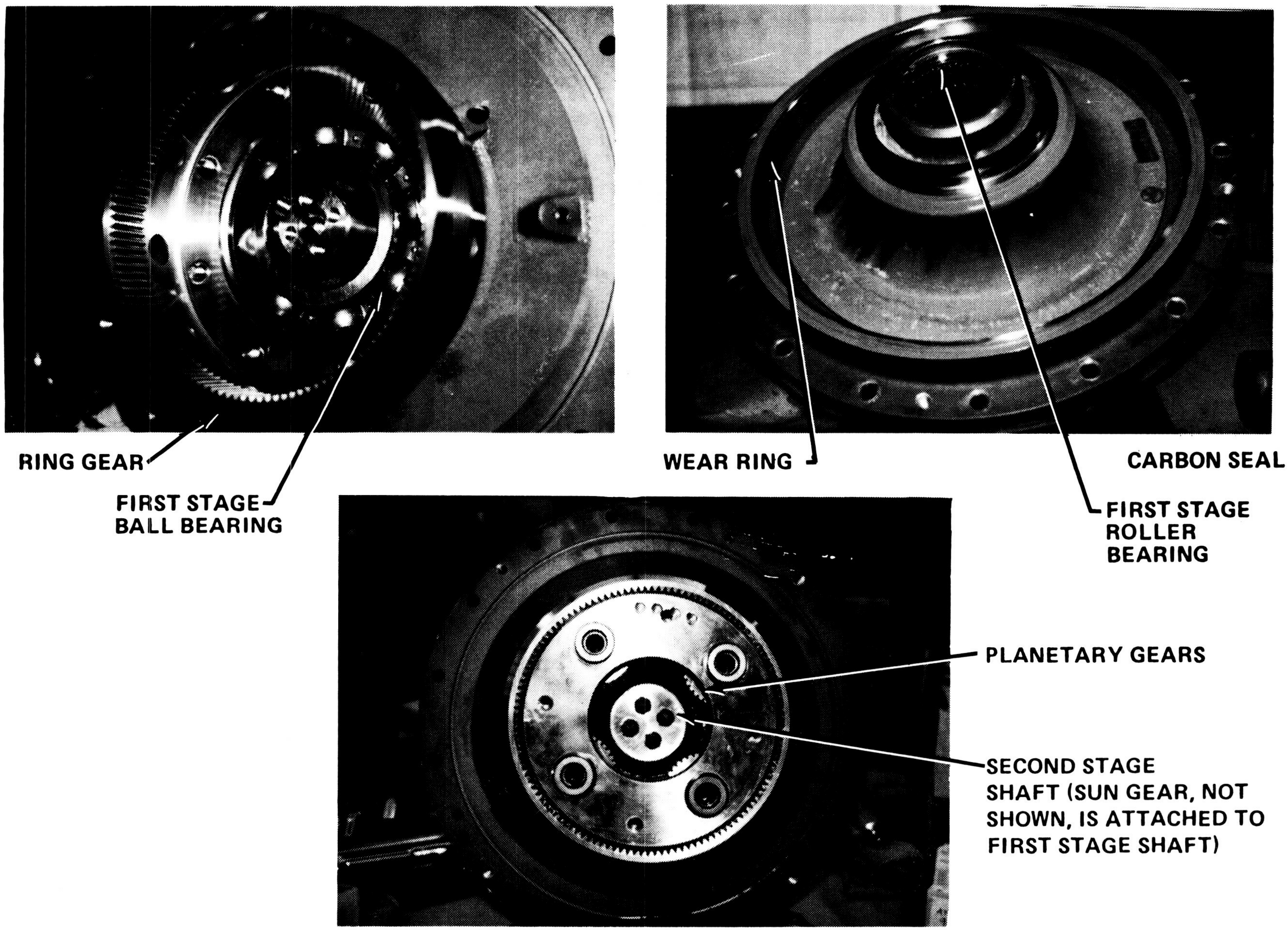


Figure 10. Pump gearbox.

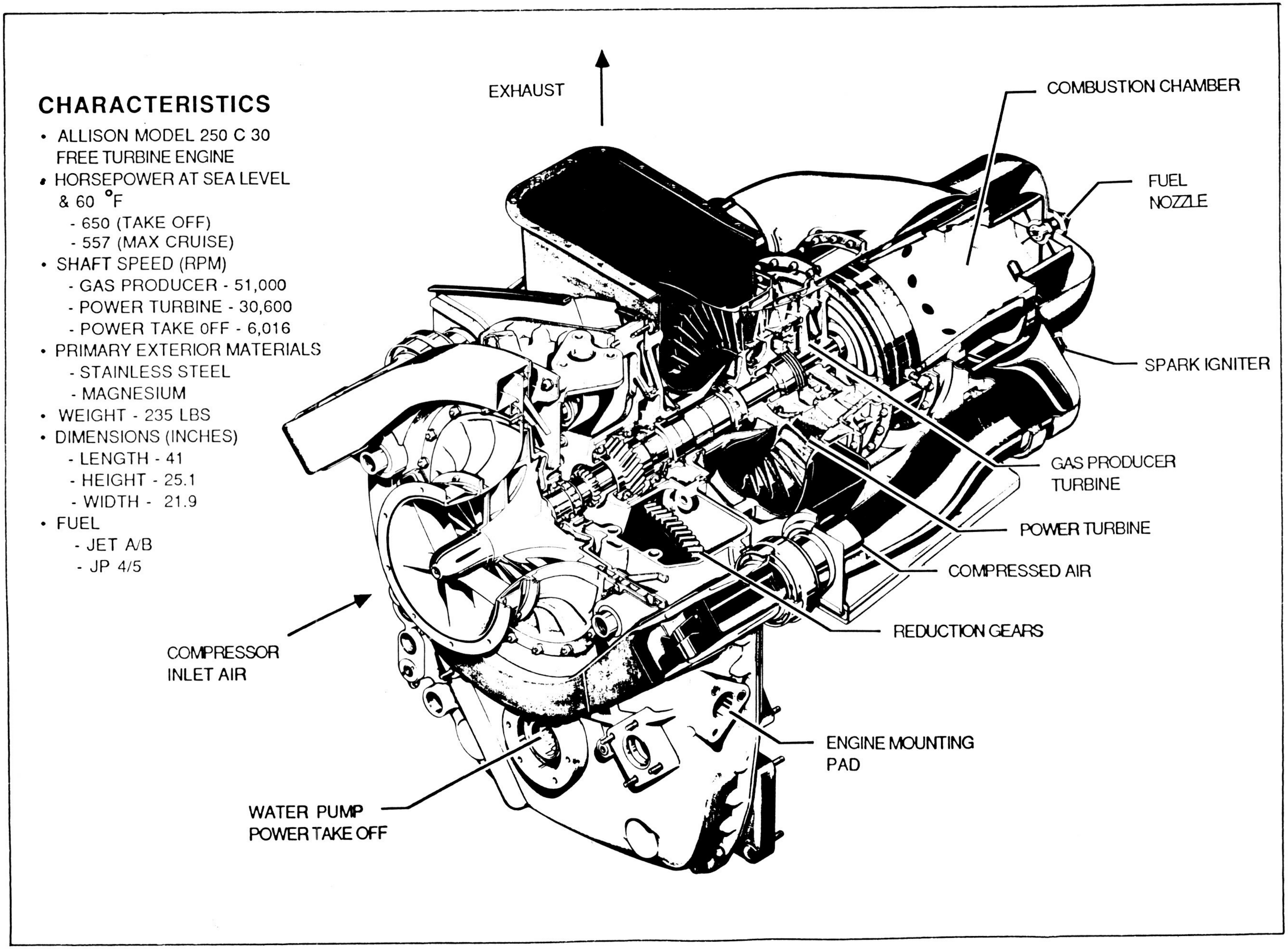


Figure 11. Engine schematic.

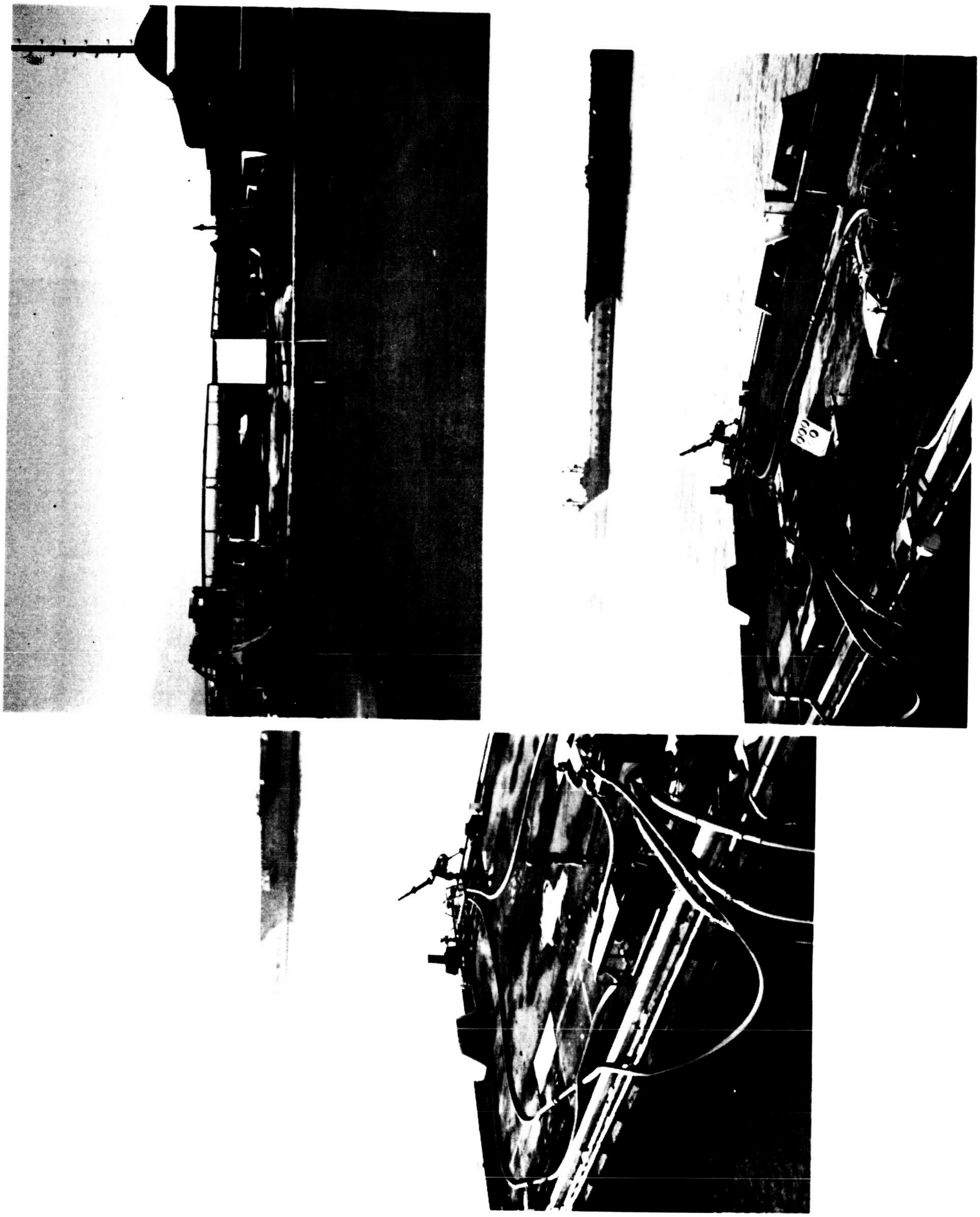


Figure 12. Module test setup.

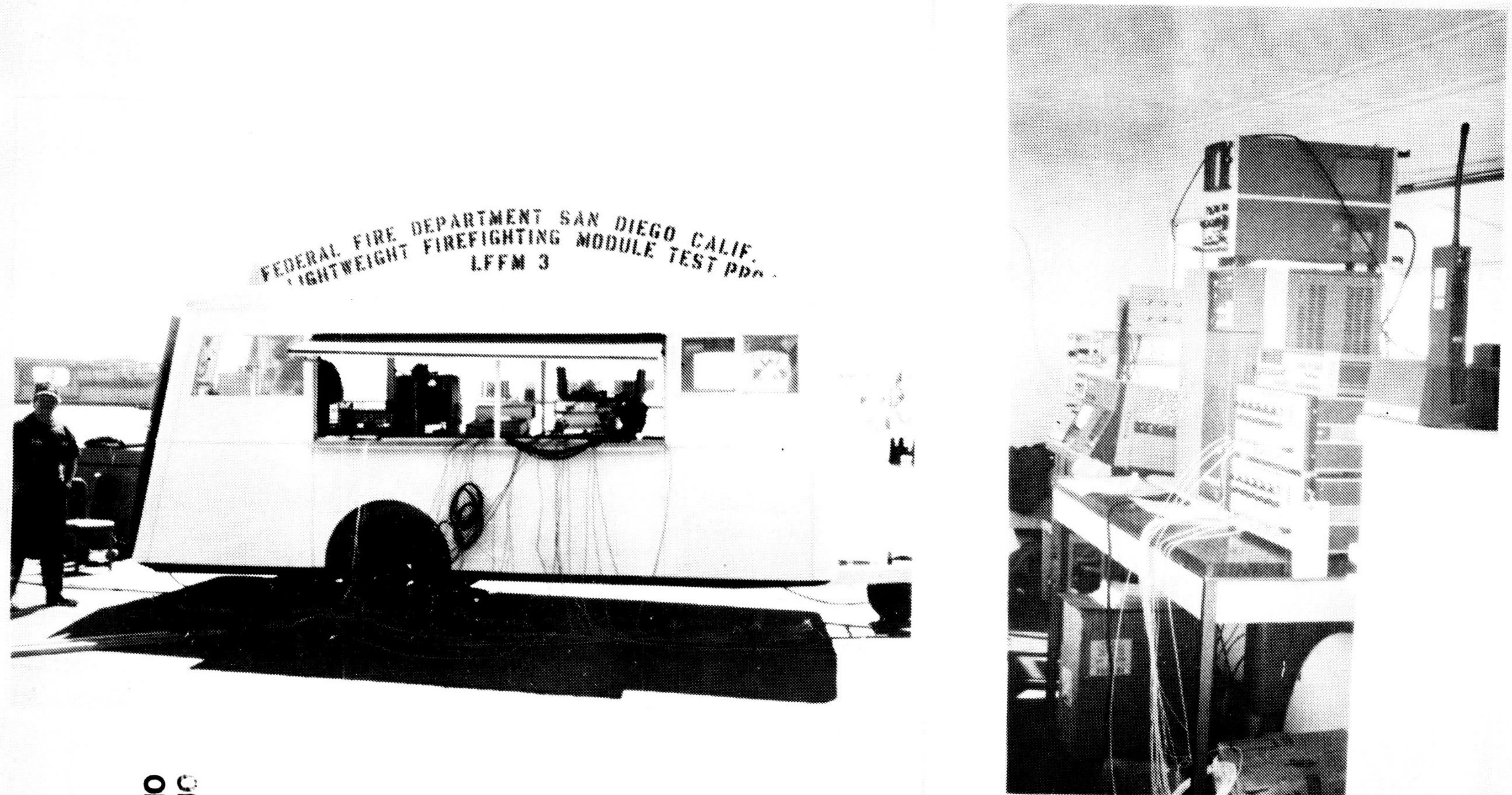


Figure 13. Instrumentation trailer.

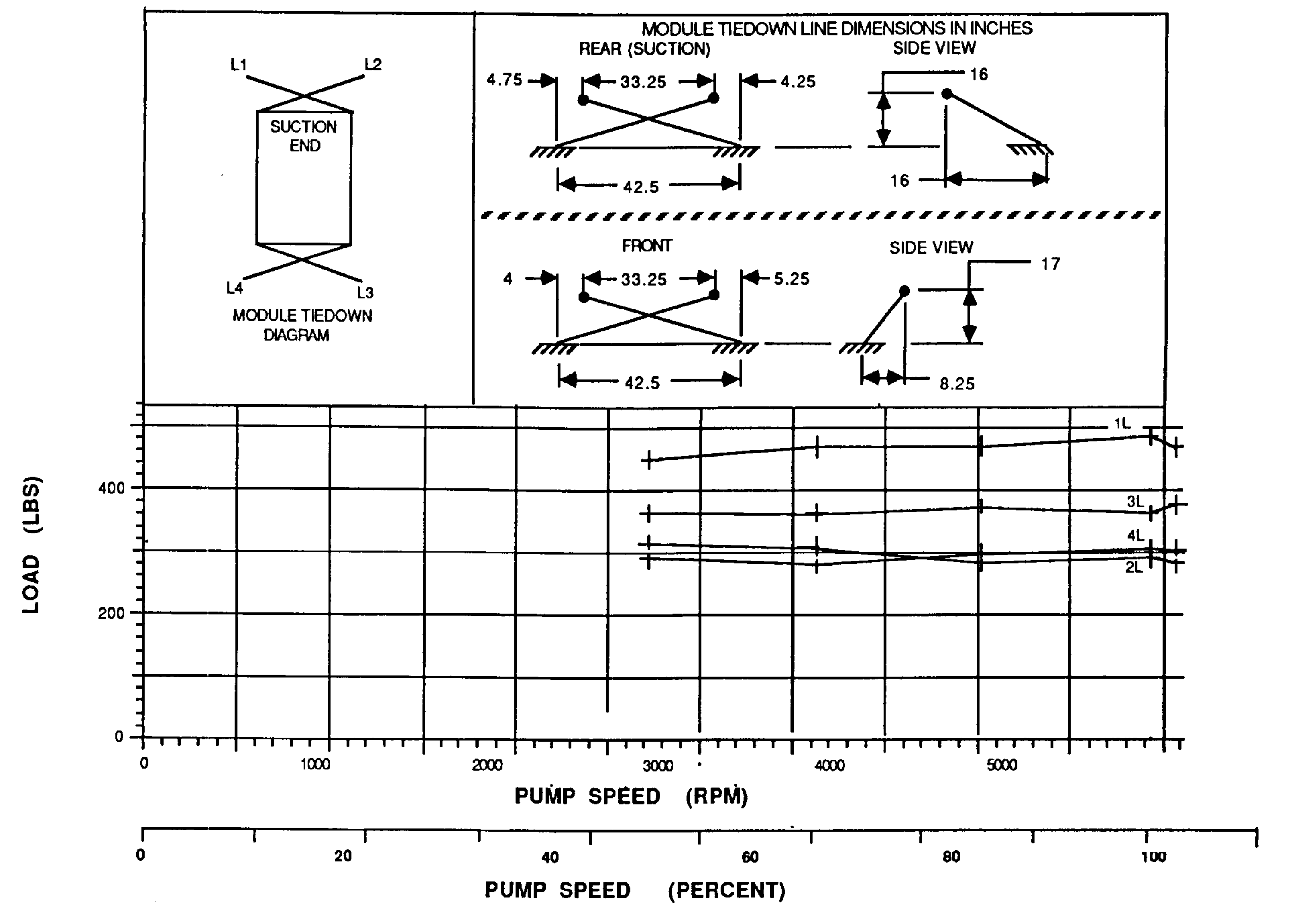


Figure 14. Tiedown loads — one side discharge open.

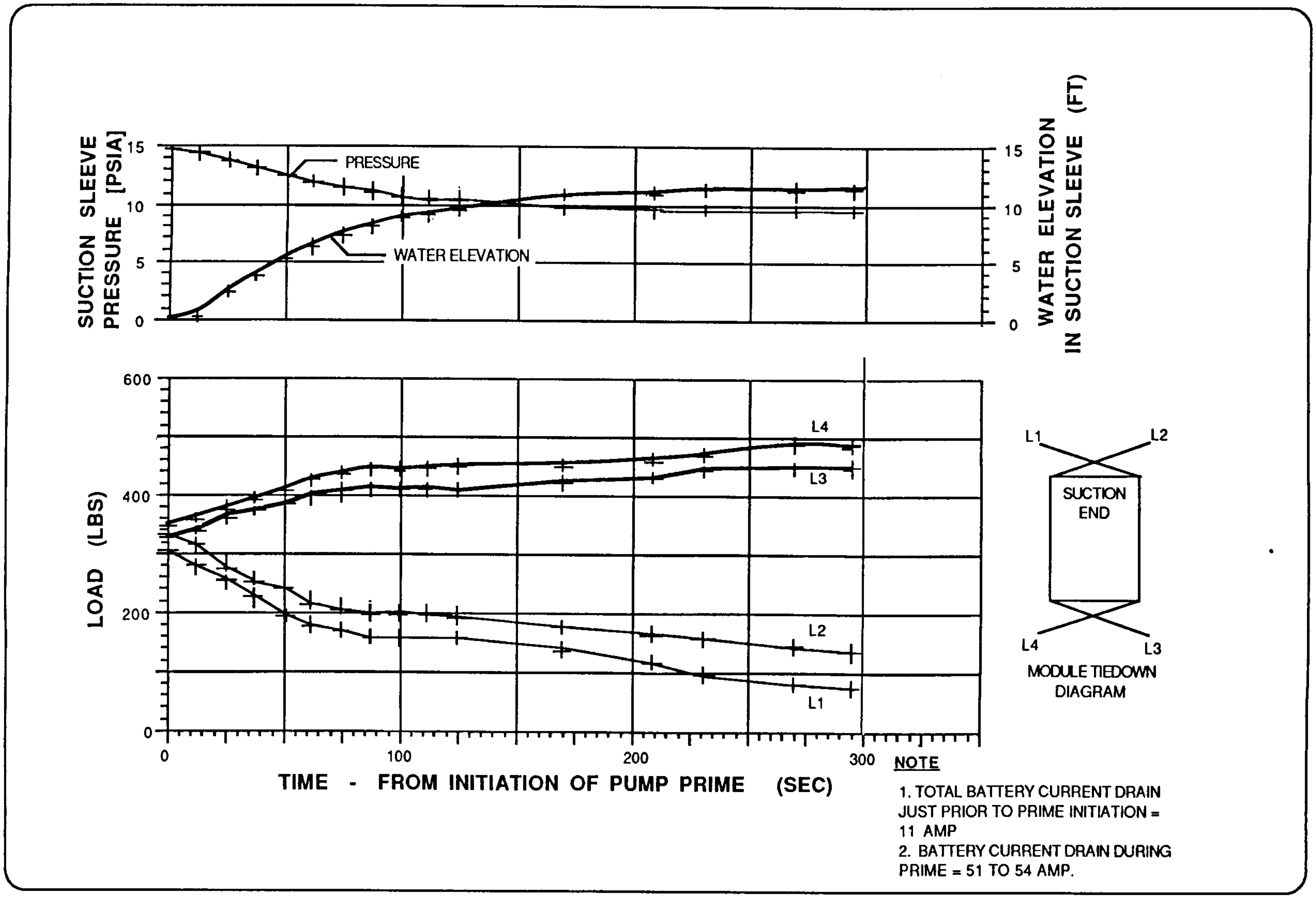


Figure 15. Prime/load test.

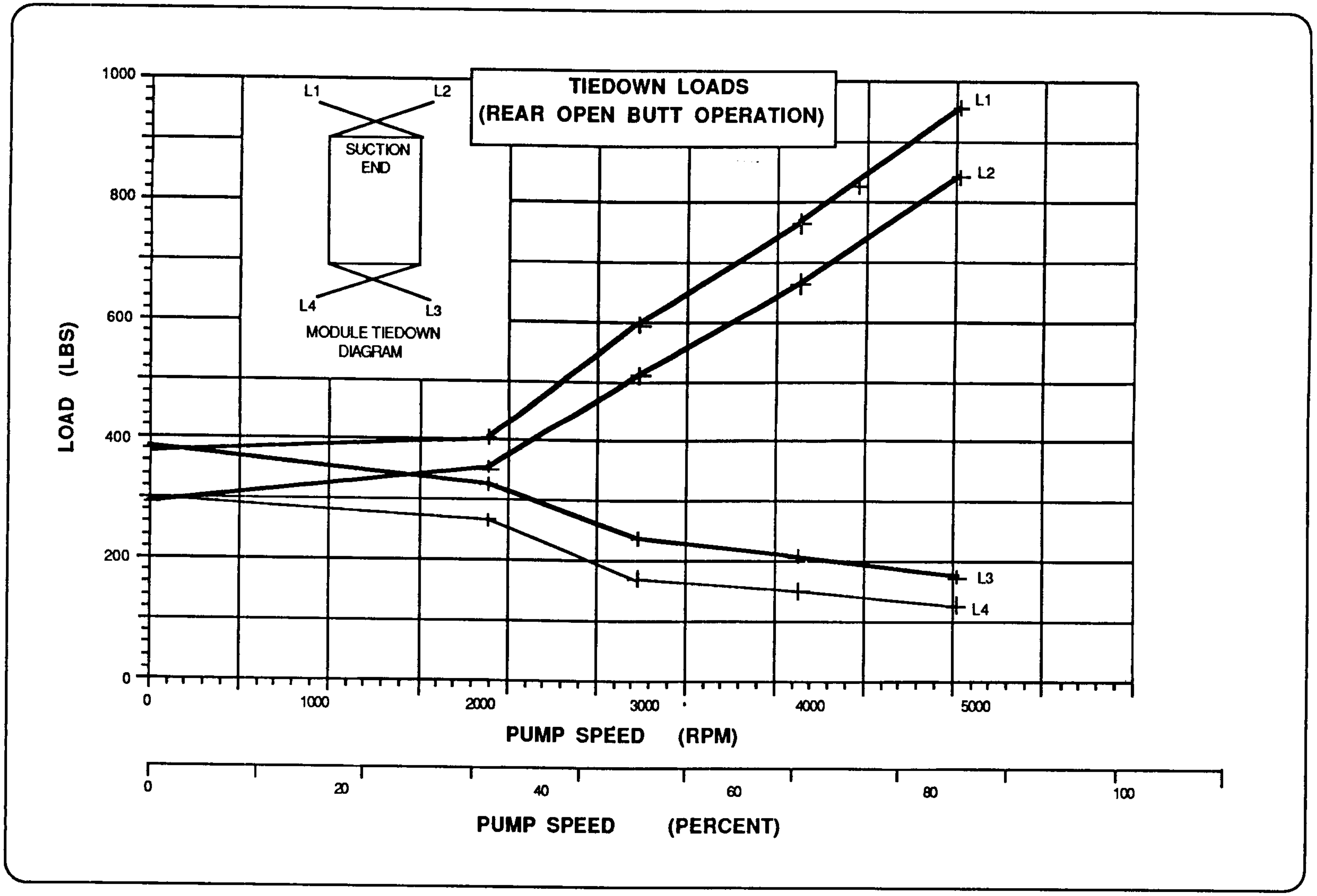


Figure 16. Tiedown loads — open butt.

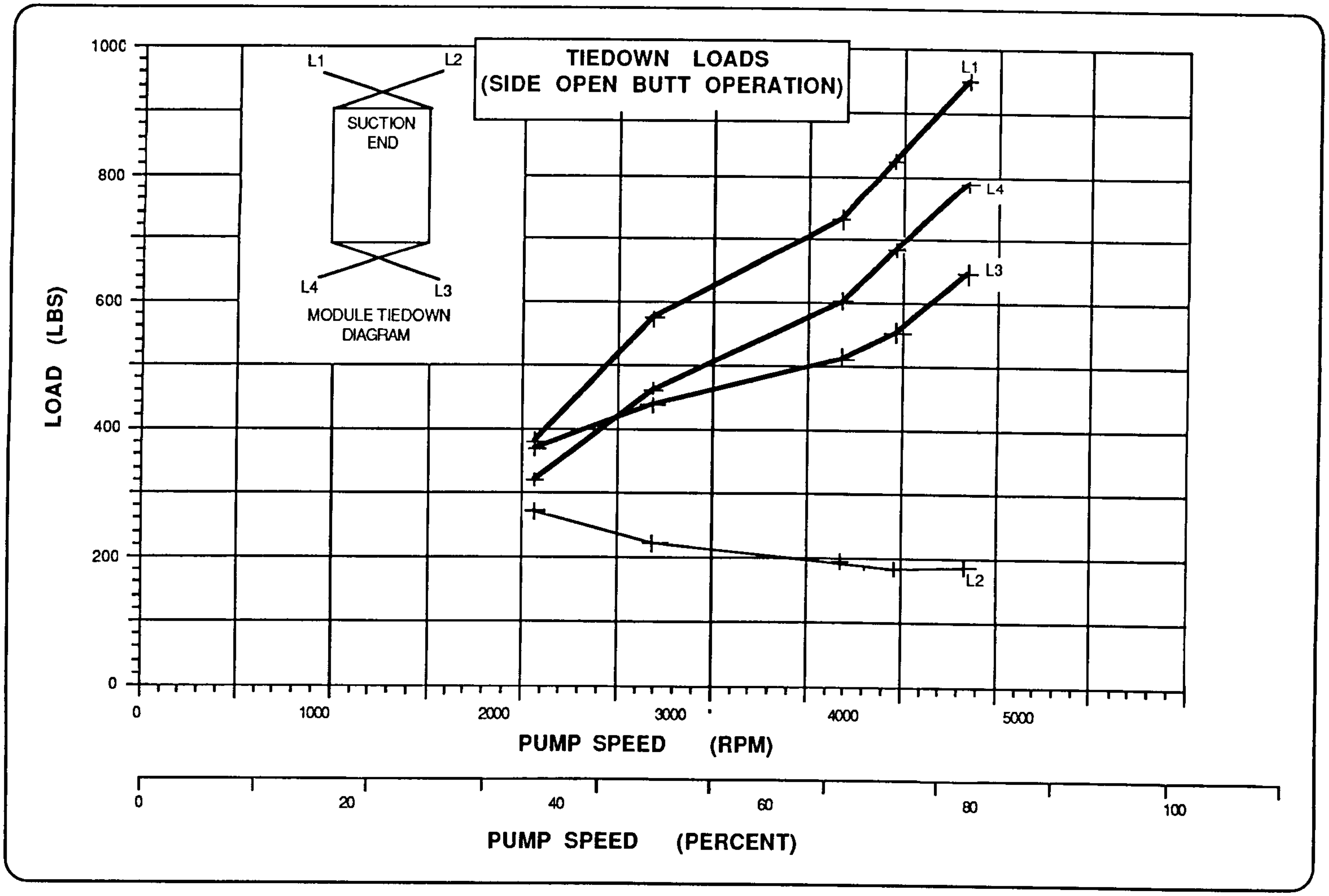


Figure 17. Tiedown loads — side open butt.

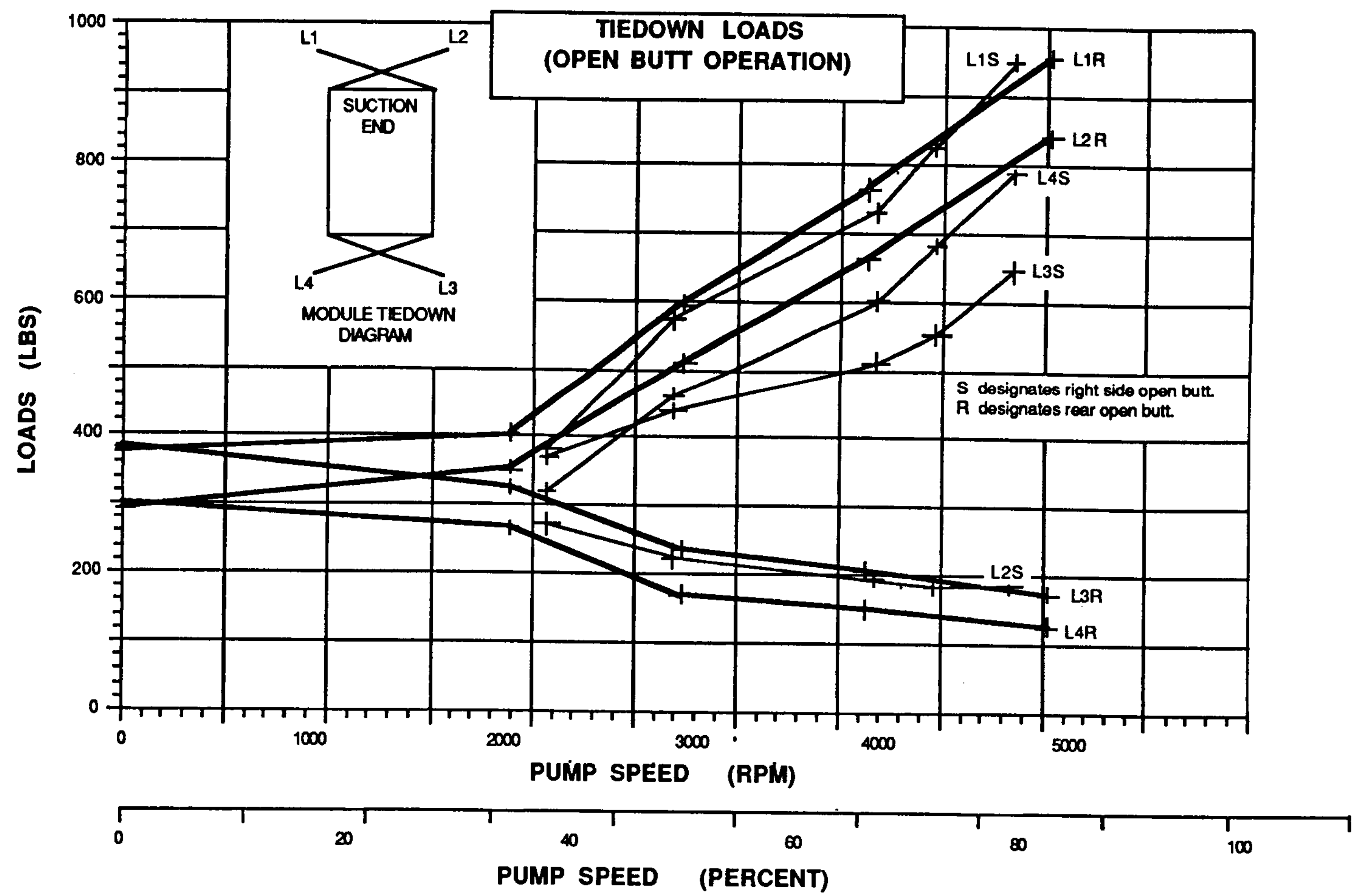


Figure 18. Tiedown loads — open butt.

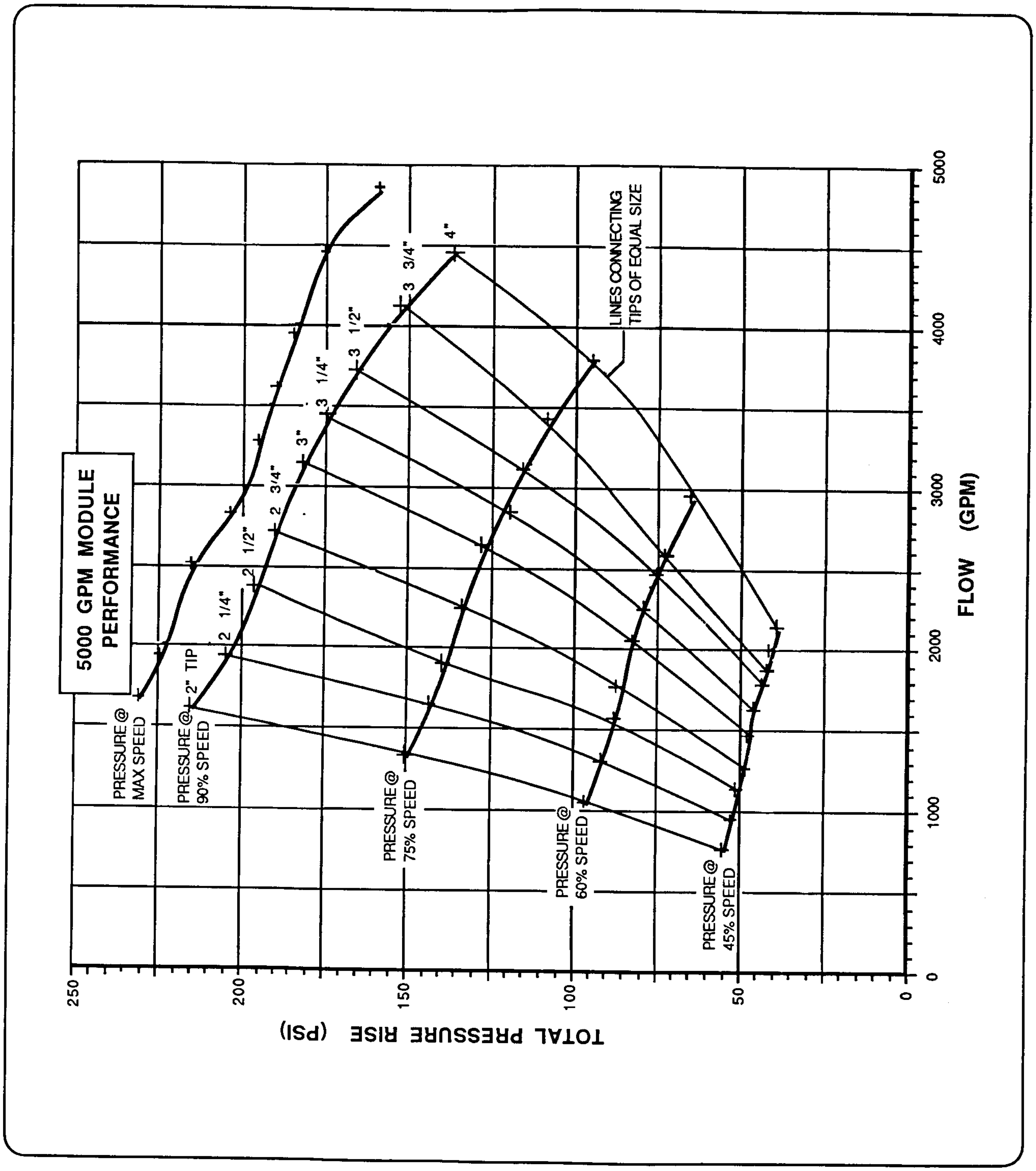


Figure 19. Performance.

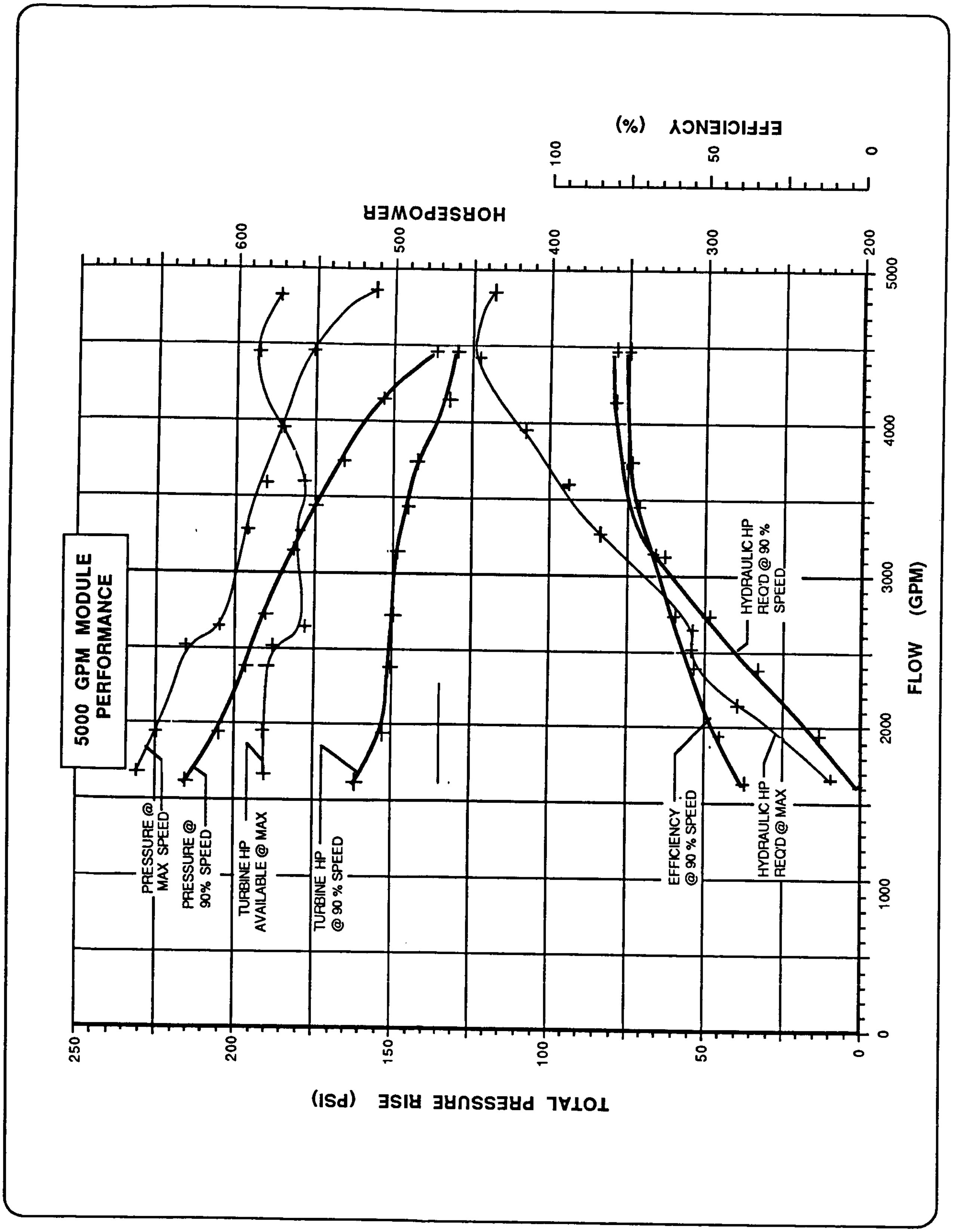


Figure 20. Performance.

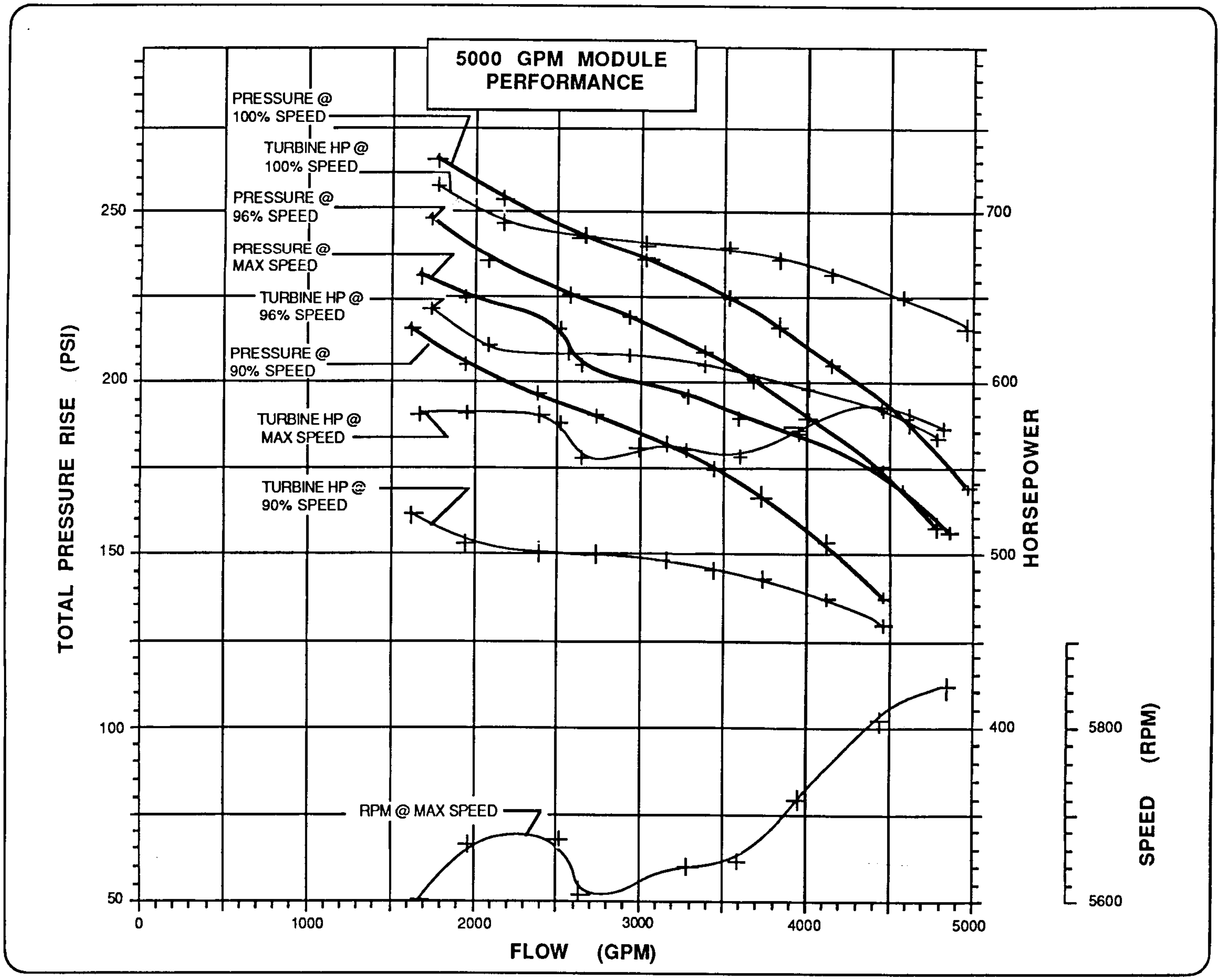


Figure 21. Performance.

SPEED %	DIGITAL TOT °C	GAUGE TOT °C
45	495.4	507.8
60	548.3	537.2
75	586.8	606.9
90	682	697.8
MAX	713.9	729.4

TOT ERROR
TABLE 1

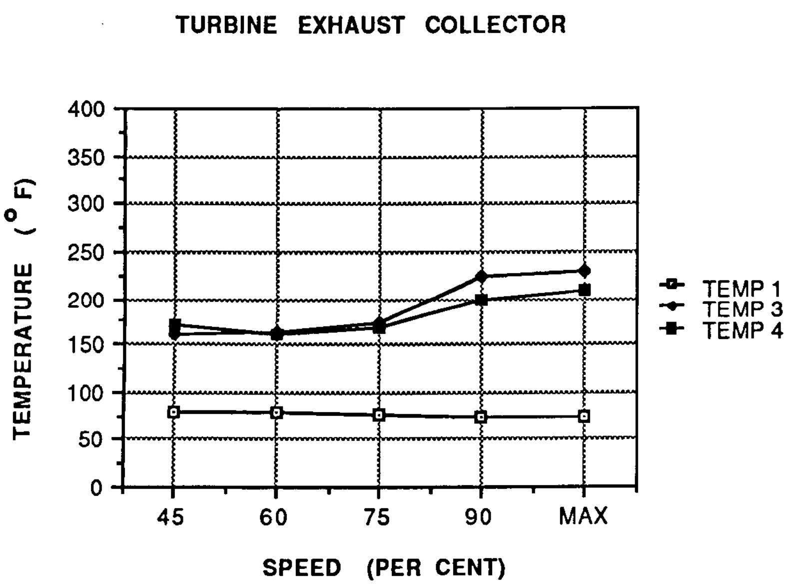
SPEED	TORQUE - PSI	
%	TRANSDUCER	PANEL GAUGE
45	20.1	25.3
60	35.5	41.2
75	54.3	63.4
90	78.1	89.2
MAX	86.0	97.7

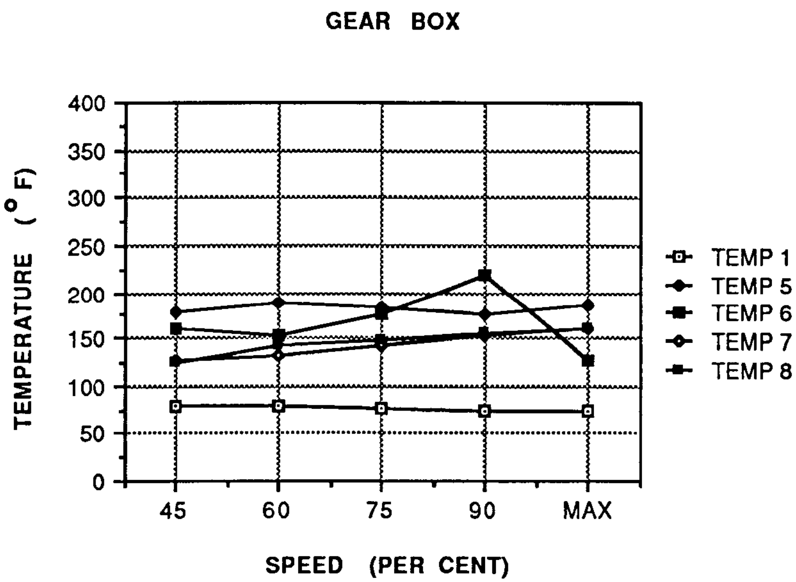
TORQUE ERROR
TABLE 2

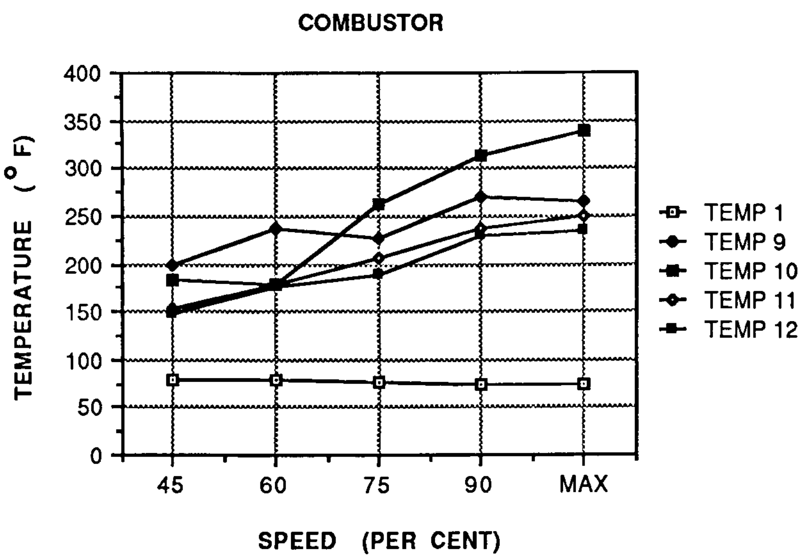
FLOW GPM	PUMP SPEED RPM	N1 %	N2 %	PUMP DISCHARGE PRESSURE PSI	CANNON MANIFOLD PRESSURE PSI	CANNON TIP PRESSURE TRANSDUCER PSI	CANNON TIP PRESSURE GAUGE PSI	TOT DIGITAL °C	ENGINE TORQUE PSI	TIP SIZE INCH
4830	5845	97.4	98.4	147	116.2	107.9	110	717	84	4.0
4437	5811	98.4	98.4	165.5	139.1	131.6	130	713	86.4	3.75
3952	5720	98.8	95.5	175.8	154.6	148.9	150	717	85.5	3.50
3597	5645	98.8	98.8	181.5	163.8	158.6	160	713	84.6	3.25
3286	5640	98.8	94.5	190.7	176	171	172	713	85.4	3.0
2827	5607	98.9	94.5	200.4	188.7	184.9	190	713	84.9	2.75
2508	5671	98.9	94.5	212.5	203.3	200.6	-	713	87.1	2.5
1959	5663	99.3	94.5	221.5	213.5	211.9	-	713	87.5	2.25
1672	5601	99.3	93.6	229.5	224.6	222	-	713	89	2.0

REPRESENTATIVE TEST PARAMETERS
TABLE 3

Figure 22. Representative test parameters.







MEASUREMENT LOCATIONS

TEMP 1	OUTSIDE AMBIENT AIR TEMPERATURE
TEMP 3	EXHAUST COLLECTOR - LEFT SIDE
TEMP 4	EXHAUST COLLECTOR - RIGHT SIDE
TEMP 5	ABOVE GEAR BOX - LEFT SIDE
TEMP 6	ABOVE GEAR BOX - RIGHT SIDE
TEMP 7	BELOW GEAR BOX - LEFT SIDE
TEMP 8	BELOW GEAR BOX - RIGHT SIDE
TEMP 9	ABOVE COMBUSTOR - LEFT SIDE
TEMP 10	ABOVE COMBUSTOR - RIGHT SIDE
TEMP 11	BELOW COMBUSTOR - LEFT SIDE
TEMP 12	BELOW COMBUSTOR - RIGHT SIDE

Figure 23. Engine compartment air temperatures.

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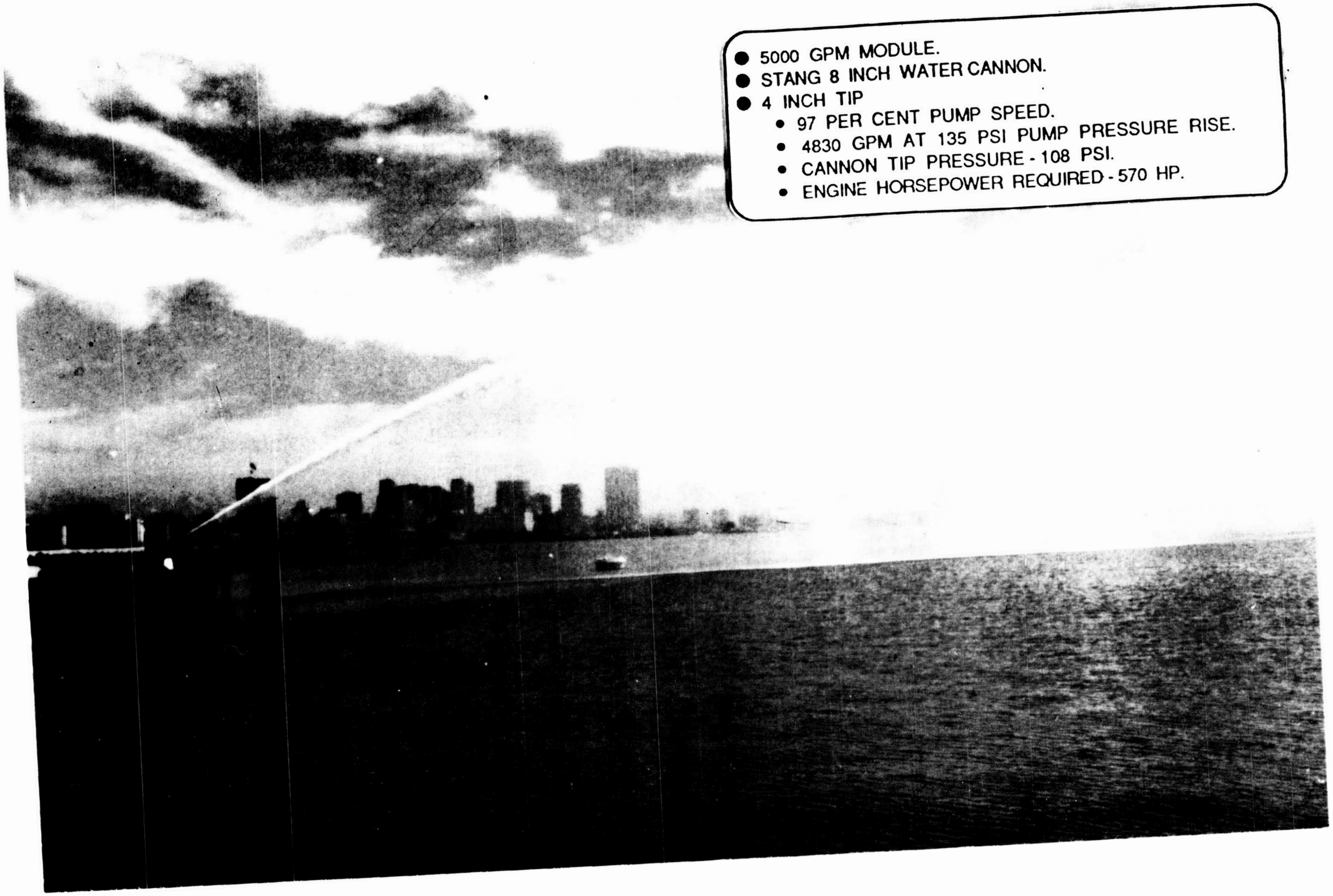

Figure 24. Water stream reach, 4-in. tip.

- 5000 GPM MODULE.
- STANG 8 INCH WATER CANNON.
- 3.75 INCH TIP
  - 97 PER CENT PUMP SPEED.
  - 4440 GPM AT 175 PSI PUMP PRESSURE RISE.
  - CANNON TIP PRESSURE - 132 PSI.
  - ENGINE HORSEPOWER REQUIRED - 585 HP.

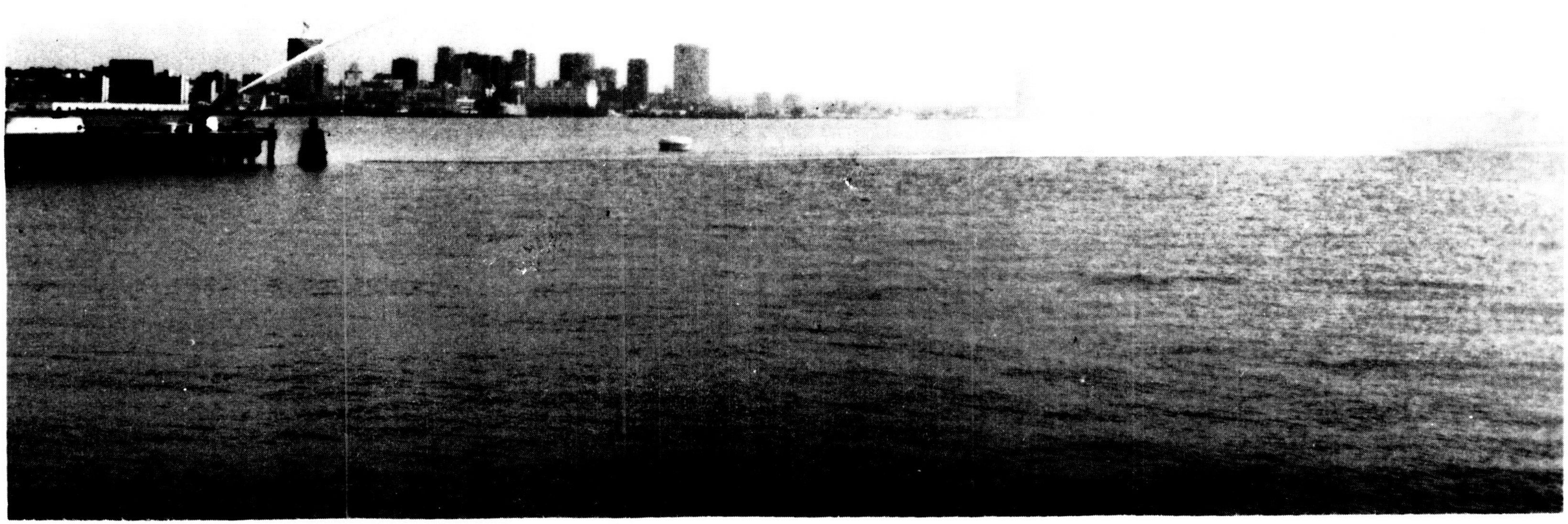

Figure 25. Water stream reach, 3.75-in. tip.

- 5000 GPM MODULE.
- STANG 8 INCH WATER CANNON.
- 3.50 INCH TIP
  - 95 PER CENT PUMP SPEED.
  - 3950 GPM AT 185 PSI PUMP PRESSURE RISE.
  - CANNON TIP PRESSURE - 149 PSI.
  - ENGINE HORSEPOWER REQUIRED - 570 HP.

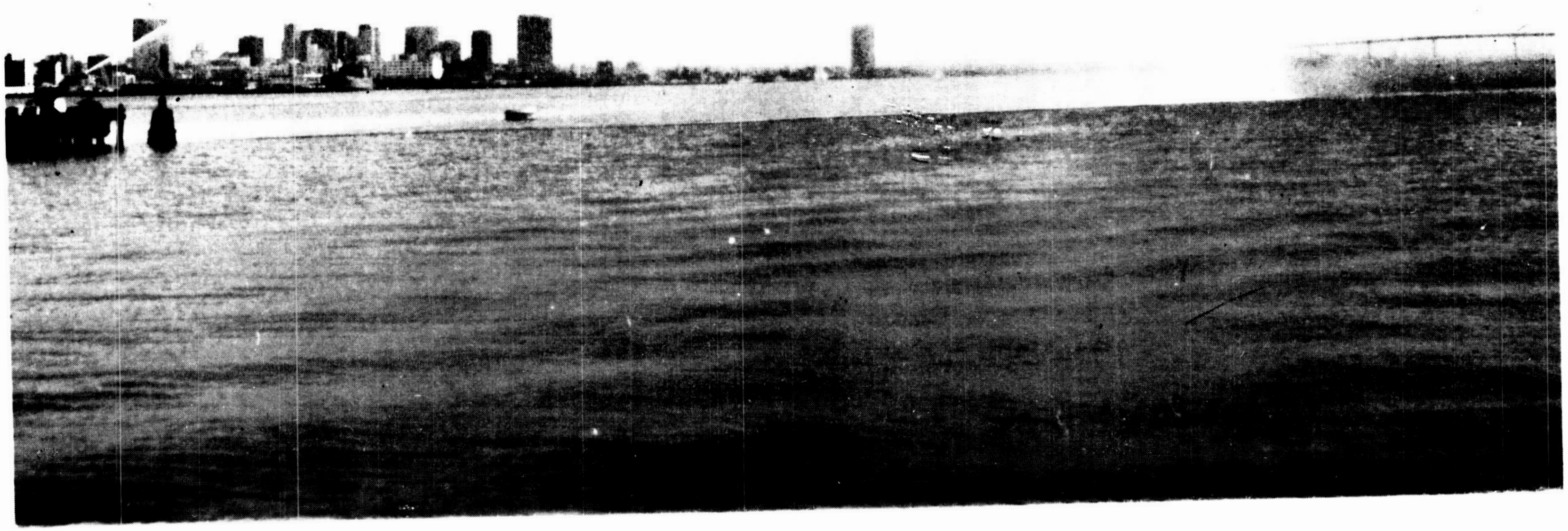

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Figure 26. Water stream reach, 3.50-in. tip.

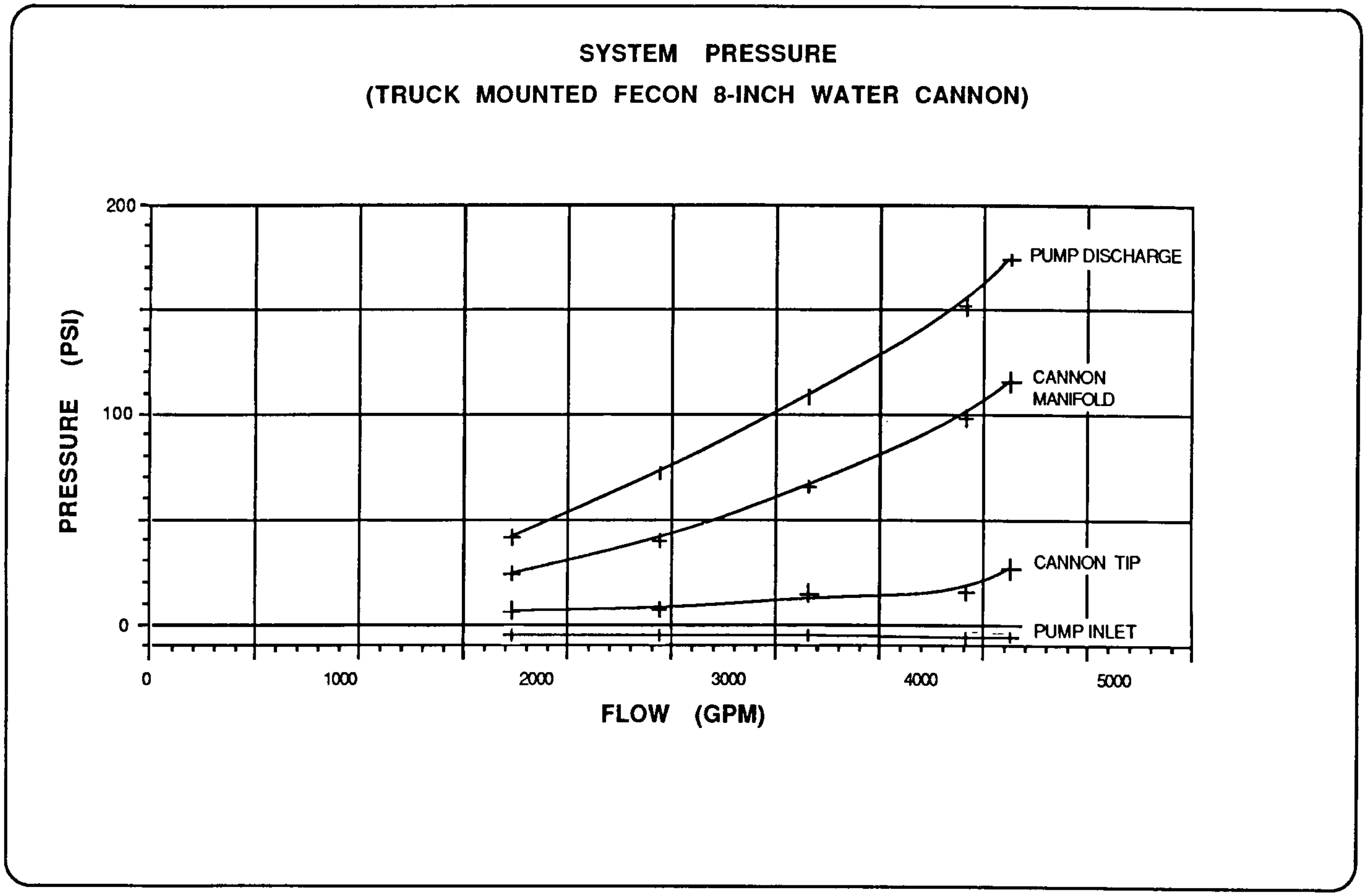

Figure 27. System pressure, Fecon.

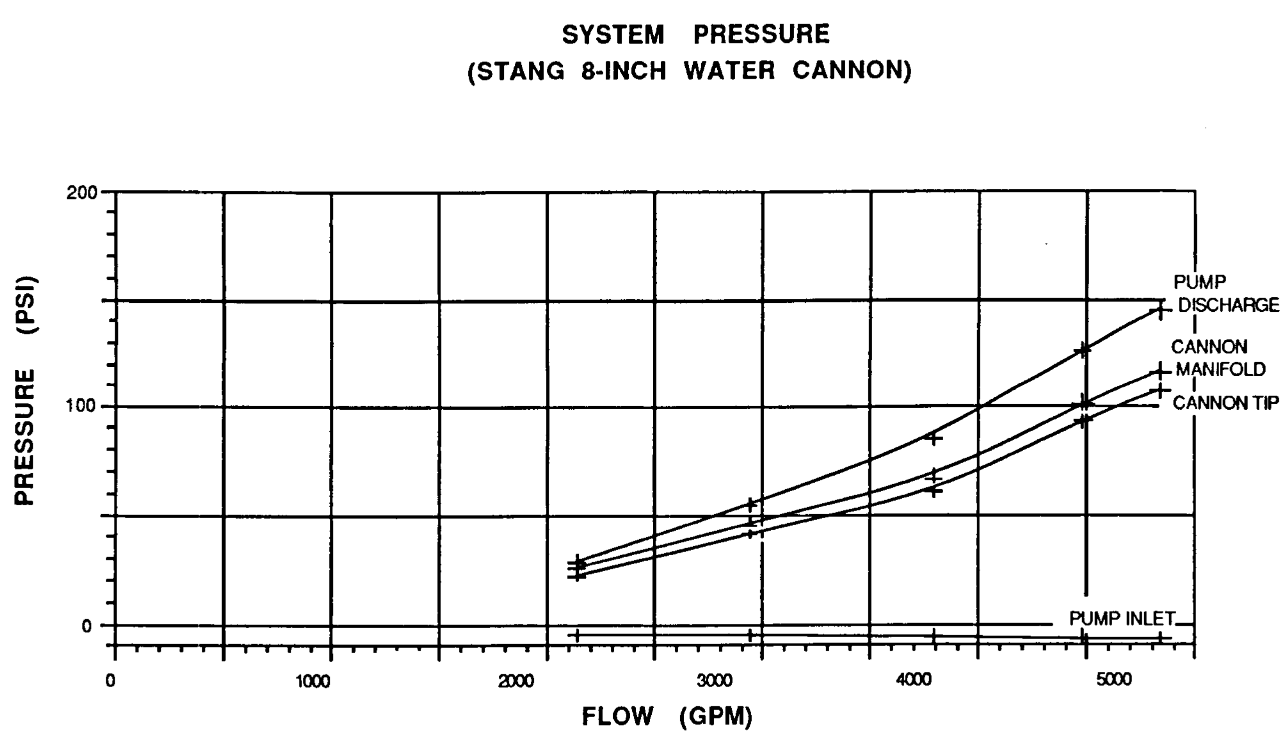

Figure 28. System pressure, Stang.

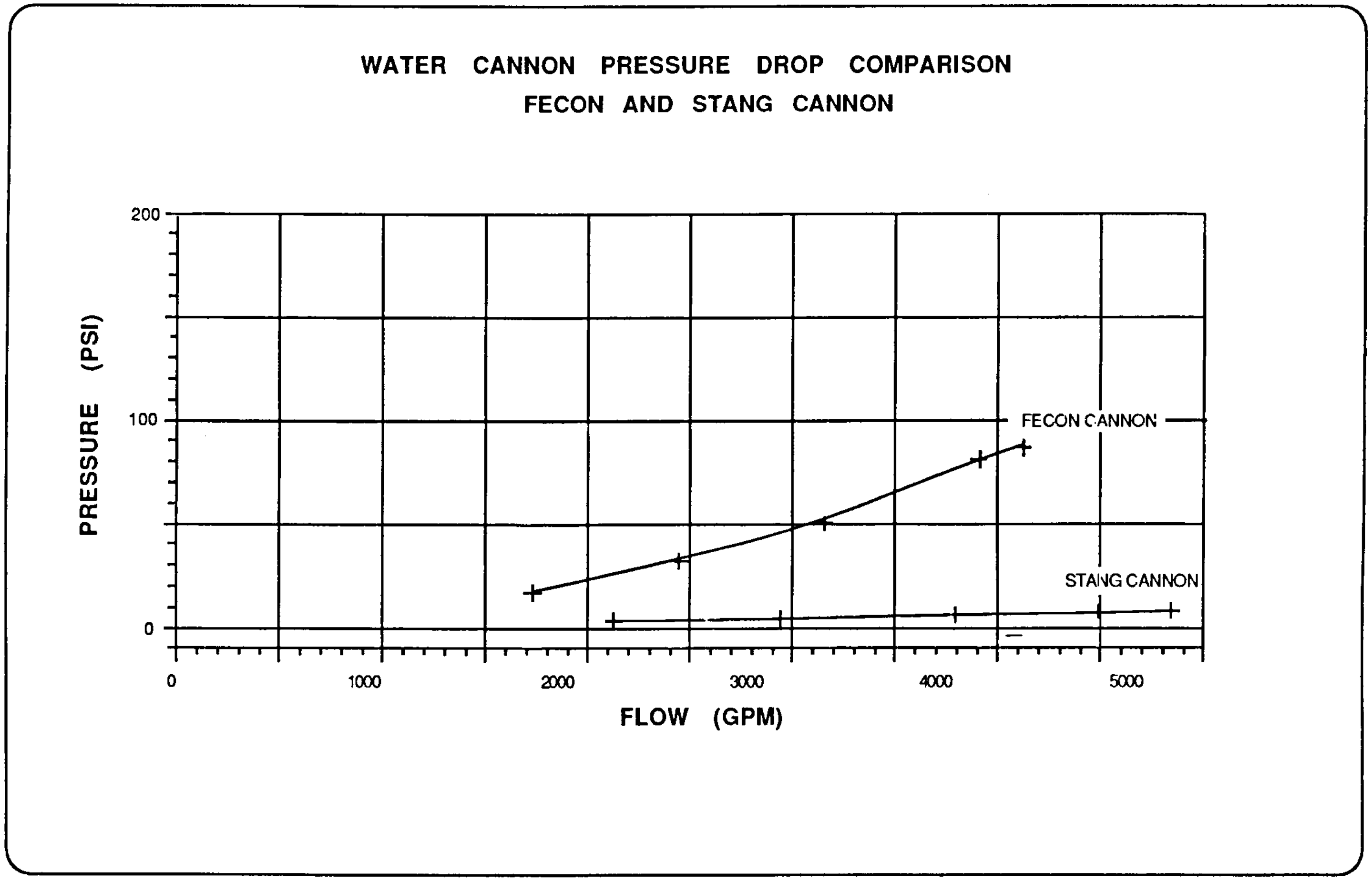

Figure 29. System pressure comparison.

APPROVAL

5000 GPM FIREFIGHTING MODULE EVALUATION TEST

By Ralph A. Burns

The information in this report has been reviewed for technical content. Review of any information concerning Department of Defense or nuclear energy activities or programs has been made by the MSFC Security Classification Officer. This report in its entirety has been determined to be unclassified.

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Chief, Mechanical Division

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TECHNICAL REPORT STANDARD TITLE PAGE

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16. ABSTRACT

The 5000 gpm Firefighting Module development was sponsored and shared by the Navy Facilities Engineering Command. It is a lightweight, compact, self-contained, helicopter-transportable unit for fighting harbor and other specialty fires as well as for use in emergency and shipboard water pumping applications. This unit is a more advanced model of the original 1500 GPM module developed for the U.S. Coast Guard.

This report describes the module and an evaluation test program conducted at the North Island Naval Air Station, San Diego, CA, by NASA and the U.S. Navy.

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