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INFRARED SUPPRESSOR EFFECT ON T63
TURBOSHAFT ENGINE PERFORMANCE

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SUMMARY

Tests were conducted to determine if there are performance penalties associated with the installation of infrared (IR) suppressors on the T63-A-700 turboshaft engine. The testing was done in a sea-level, static test cell at the NASA Lewis Research Center. The same engine (A-E402808 B) was run with the standard OH-58 aircraft exhaust stacks and with the Hughes-designed, ejector-type IR suppressors in order to make a valid comparison. Repeatability of the test results for the two configurations was verified by rerunning the conditions over a period of days. Test results showed no measurable difference in performance between the standard exhaust stacks and the IR suppressors.

INTRODUCTION

Recent U. S. Army combat experience with helicopters has shown a considerable threat to their survivability from infrared (IR) heat-seeking missiles. The prime source of IR radiation on a helicopter is, of course, the engine exhaust. One approach to the problem has been the development of devices that suppress the IR signature by either cooling the hot metal parts and the plume or shielding them from view. One such IR suppressor designed by Hughes for the T63 engine is an ejector-type device that simply replaces the standard OH-58 aircraft exhaust stacks. Although such devices improve survivability, they may impose performance penalties on the engine. In the tests described in this report, therefore, a T63 engine was run with and without suppressors to determine the performance penalties, if any. The testing was done at the NASA-Lewis Research Center.

APPARATUS

Engine

The T63-A-700 (fig. 1) is a small turboshaft engine used in the Army Kiowa OH-58 light observation helicopter. The engine has a pressure ratio of 8, a single-spool gas producer, and a free power turbine. At the takeoff rating, the engine develops a maximum of 236 kilowatts (317 hp) and has a gas-producer outlet temperature of 1022 K (1380° F). External controls consist of a gas-producer fuel control lever and a power-turbine governor lever. At power settings higher than ground idle, the engine is controlled by manipulating only the power-turbine governor lever. Exhaust is directed upward from the engine through two ducts. In the aircraft installation, two short, curved exhaust stacks mount directly on the engine. As shown in figure 1, the standard stacks are elliptic, smoothly curved ducts that direct the exhaust backward almost horizontally.

IR Suppressors

The IR suppressors shown mounted on the engine in figure 2 are ejector-type devices that consist of an inner duct with a surrounding outer ejector shroud. The inner duct is covered with insulating material, and the ejector shroud has external circumferential cooling fins. The insulation, the cooling fins, and the flow of secondary ambient air that is generated by the ejector shroud lower the surface temperature of the tailpipe. The partial mixing of secondary air with the exhaust plume further lowers the vulnerability of the aircraft to heat-seeking missiles. Tests were limited only to the effect of the suppressors on engine performance. One notable difference between the two installations is that the standard pipes exhaust nearly horizontally but the IR suppressors exhaust vertically.

Test Cell Installation

The test cell was a sea-level facility with a large, horizontal exhaust duct and was originally designed for jet engines. An exhaust hood was fabricated to fit over the T63 engine and accommodate both exhaust configurations. The engine was mounted in the frame of the Army's mobile engine test stand (METS), shown in figure 3. The water supply and control systems were designed at Lewis. The arrangement of the engine, the exhaust hood, and the facility exhaust duct are shown schematically in figure 4.

With the standard tailpipe configuration, the engine exhausts almost directly into the facility exhaust pipe - much as a jet engine would. With the IR suppressor configuration, however, there was concern that the angle of the engine exhaust and the proximity of the hood to the exhaust stacks might cause recirculation or, worse yet, bias the outcome of the tests. So that the exhaust gas would be completely removed from the cell, an aspirator was inserted into the exhaust hood downstream of the engine. Static pressures under the hood were monitored to insure that the aspirator did not create significantly different pressures at the exhaust stack exits.

Instrumentation

A relatively small number of parameters had to be monitored and/or recorded for these tests. The bellmouth inlet was instrumented with two iron-constantan thermocouples and four static-pressure taps located as shown in figure 5. Before installation on the engine, the instrumented bellmouth was calibrated for discharge coefficient variation with Reynolds number. This calibration curve was then used to measure engine airflow. The gas-producer outlet temperature (TOT) was measured with the standard engine thermocouple harness, which consisted of four Chromel-Alumel

thermocouples equally spaced around the gas-producer turbine outlet annulus. The four thermocouples were connected in parallel to give an average signal. Torque was measured with the strain-gage torquemeter that is built into the Lycoming dynamometer. A torque-sensing device in the engine generated a hydraulic pressure signal that was directly proportional to the output torque. The output from this device was also recorded as backup. Two flowmeters were installed in the fuel line to measure fuel flow. Gas-producer shaft speed N_1 and power-turbine shaft speed N_2 were obtained by counting teeth on the gears installed behind the tachometer generators. Compressor discharge conditions were measured with a combined total-temperature/static-pressure probe.

These primary parameters were recorded on the Lewis central automatic digital data encoder (CADDE) (ref. 1). For engine operating purposes, other parameters such as engine oil temperature, water brake temperature, oil scavenge pressure, and vibration were monitored. Two differential pressure probes were also installed inside the exhaust hood, near the exit plane of the engine exhaust stacks, to monitor the backpressure at the engine exhaust.

PROCEDURE

A typical run consisted of engine startup, warmup, datataking at various power settings, and shutdown. To simulate actual helicopter operation, N_2 was maintained constant at 35 000 rpm. Throughout the testing, the engine water brake combination was not easy to control and usually exhibited varying degrees of unsteadiness. Certain power settings were fairly steady; others were not. Typically, at a fixed throttle setting, random fluctuations of ± 50 rpm in N_2 and ± 11 K ($\pm 20^\circ$ F) in TOT often occurred. Because none of the parameters were recorded against time, the exact cause of the unsteadiness could not be determined. It was presumed to be related to the engine and water brake controls. The water brake was quite sensitive to slight changes in inlet pressure, and small perturbations in supply pressure were often evident. (It is worth noting that the Army includes a flywheel in the kit for running a T63 on the METS although larger engines that the stand also accommodates do not require one.) This operational unsteadiness was overcome by simply taking many data points along the operating line and taking several data recordings at each operating point. CADDE data would occasionally show an N_2 that differed from the monitored value (35 000 rpm) by more than ± 100 rpm. The reason for this is that the CADDE sampling rate was much faster than that of the digital counter being monitored in the control room. These data points were discarded on the basis that N_2 was probably unsteady during that data recording. Fuel flow and power were corrected to standard-day conditions by using the relationships

$$(WF)_{\text{corr}} = \frac{(WF)_{\text{act}}}{\sqrt{\theta \delta}}$$

and

$$(HP)_{\text{corr}} = \frac{(HP)_{\text{act}}}{\sqrt{\theta \delta}}$$

where θ and δ are the ratios of actual to standard temperature and pressure, respectively. Fuel flow was also scaled to a reference heating value of 42 831 joules per gram (18 400 Btu/lb).

RESULTS AND DISCUSSION

The results of the T63-A-700 performance tests with and without IR suppressors are presented in terms of corrected fuel flow and power. Least-squares linear regression lines are drawn through the data. The correlation coefficients for the linear regression fits are all better than 0.99. When the data are plotted in this manner, an increase in corrected fuel flow for the same corrected power indicates a loss in performance.

The results from three separate runs with the standard exhaust stacks installed are shown in figure 6. The total number of data points, the standard deviation of the data about the regression line, and the average percentage of deviation from the line are given in the figure. Individual regression lines through the data from each of the runs in this figure would show a maximum spread of about 0.75 percent in performance level. This is a measure of the repeatability achieved.

Test results from four runs with the IR suppressors installed are shown in figure 7. The same statistical information is given here as in figure 6. Approximately the same level of repeatability was achieved with the IR suppressors as with the standard exhaust stacks.

Figure 8 shows the results of a run with the IR suppressors installed but with the outer ejector shrouds removed. These results agree well with those of the complete IR suppressor installation shown in figure 7. In case of sizeable differences in performance between the standard and IR-suppressor stacks, this run was intended to separate the ejector effect from that of the IR suppressor primary nozzle alone.

The performance results with and without the IR suppressors, already presented in figures 6 and 7, are repeated in figure 9 for ease of comparison. The difference of less than 1/2 percent between the two configurations' levels of performance is well within the limits of repeatability for either configuration alone. Within the accuracy of the data, therefore, no measurable difference in performance was observed.

CONCLUDING REMARKS

A-T63-A-700 turboshaft engine was operated in a sea-level, static cell to test for effects of ejector-type IR suppressors on engine performance. The uninstalled performance of the T63-A-700 engine was not measurably affected by the IR suppressors.

REFERENCE

Central Automatic Data Processing System, NACA TN-1212, 1958.

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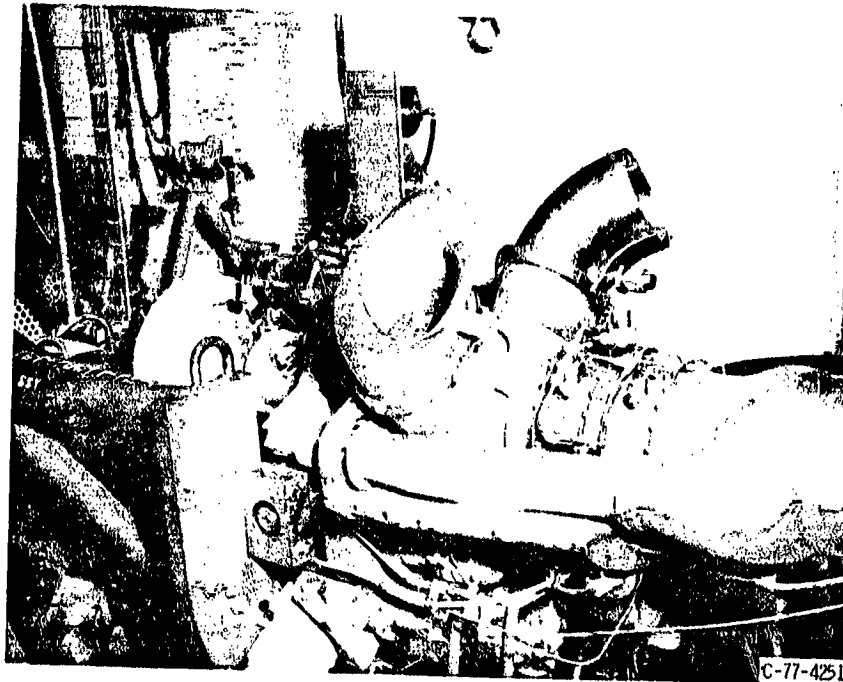


Figure 1 - T63 engine with standard exhaust stacks.

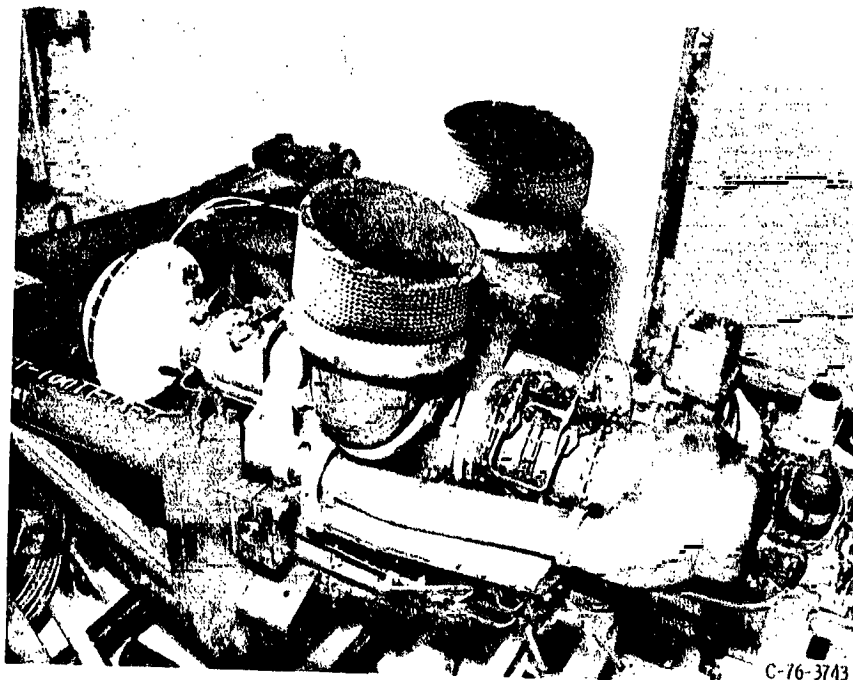


Figure 2 - T63 engine with IR suppressors.

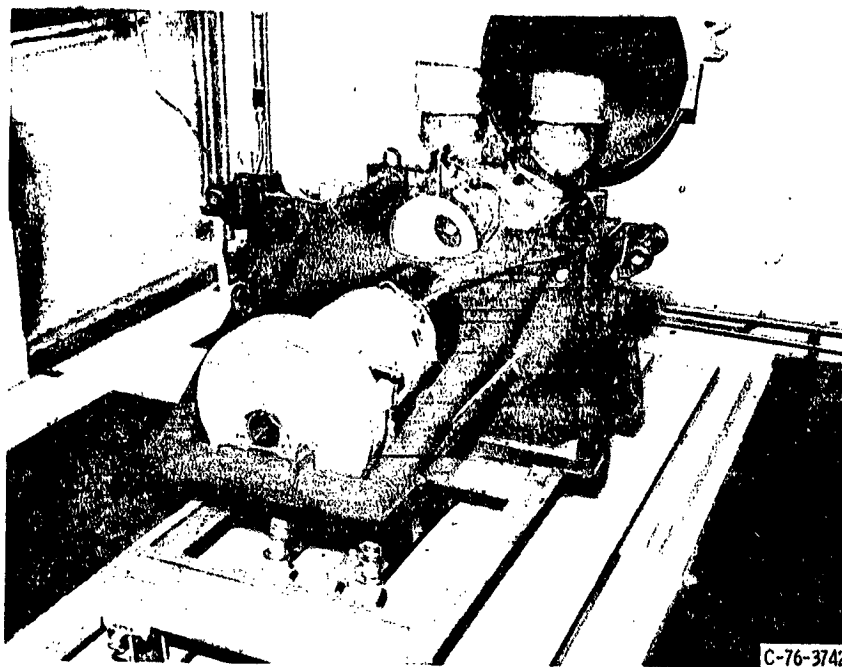


Figure 3 - T63 engine test stand showing flywheel, water brake, and facility exhaust duct.

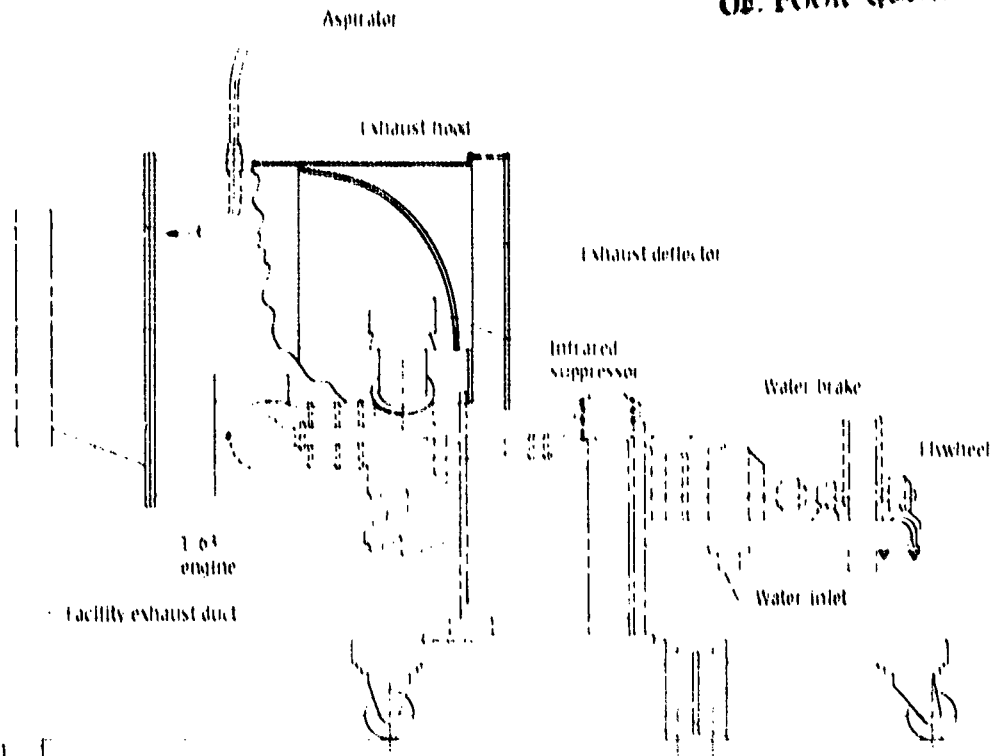


Figure 4 Schematic of 103 engine test stand

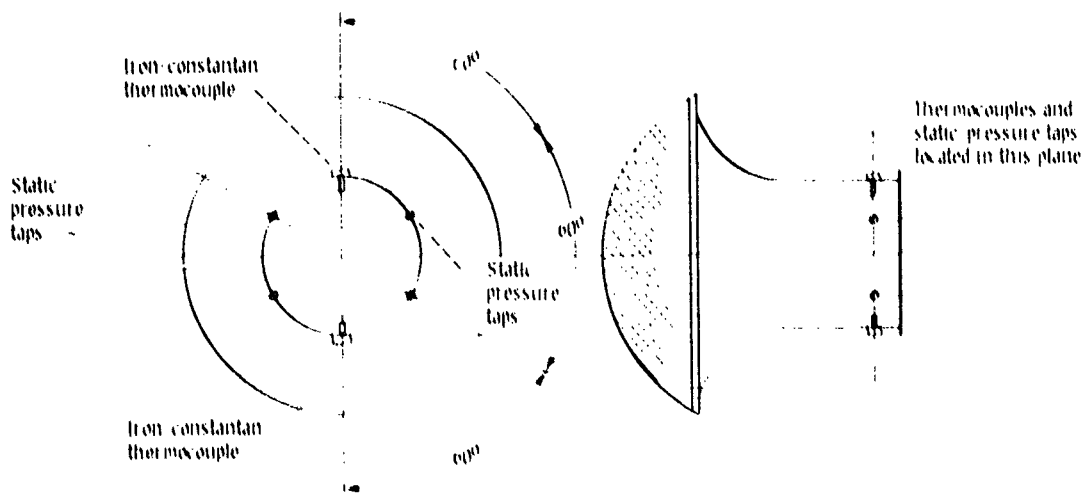


Figure 5 Inlet bellmouth instrumentation

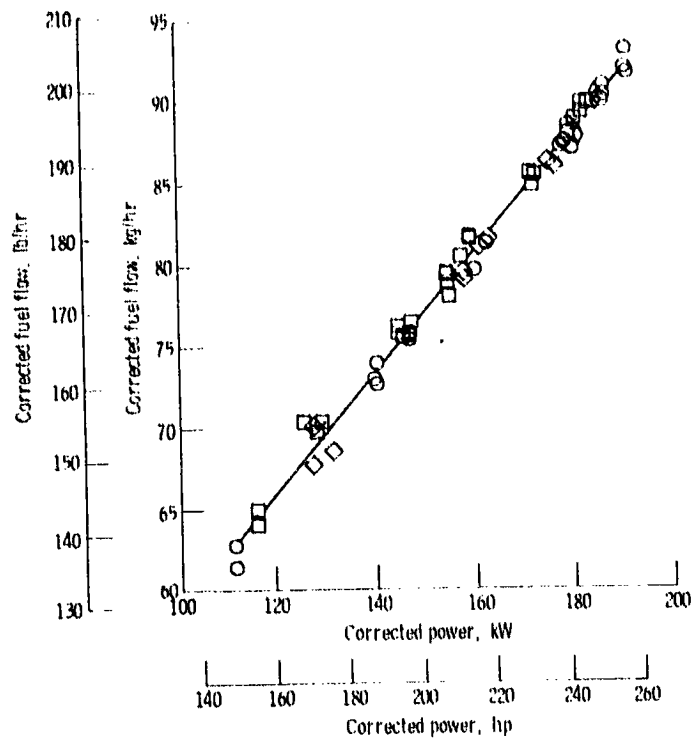


Figure 6. - Test results with standard exhaust stacks. Number of points, 58; standard deviation, 0.7702 kg/hr (1.698 lb/hr); average percentage of deviation, 0.793.

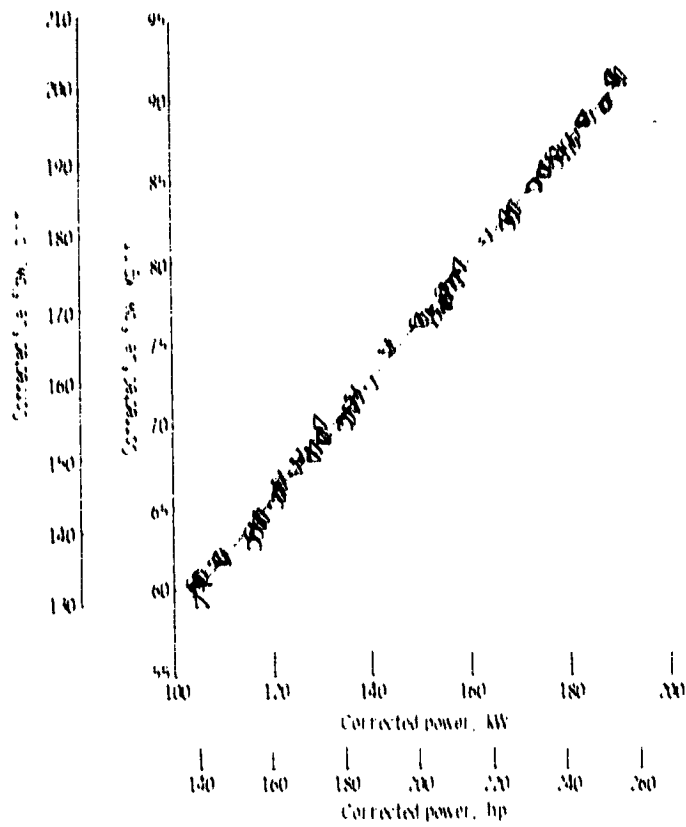


Figure 7. Test results with 18 suppressors. Number of points, 87, standard deviation, 0.4890 kJ/hr (1.078 lb/hr), average percentage of deviation, 0.518.

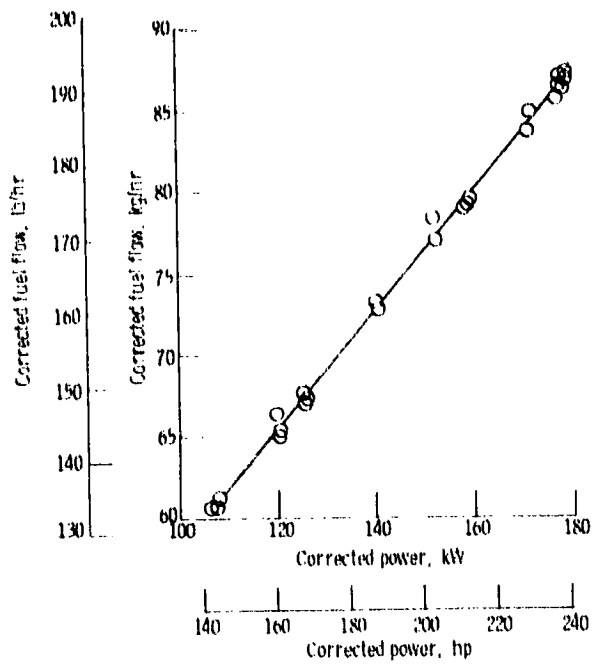


Figure 8. Test results with IR suppressors without ejector shrouds. Number of points, 25; standard deviation, 0.4813 kg/hr (1.061 lb/hr), average percentage of deviation, 0.483.

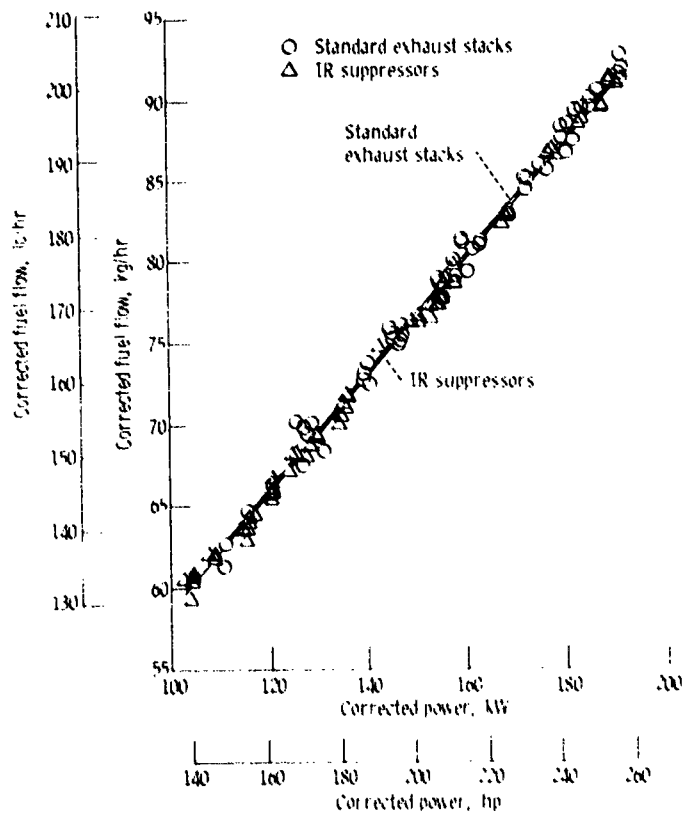


Figure 9. 168 A-700 engine performance with and without IR suppressors.