CNASA-TM-111116)

~~(NIPS-95-05521)~~ RADIAL AND CIRCUMFERENTIAL FLOW SURVEYS AT THE INLET AND EXIT OF THE SPACE SHUTTLE MAIN ENGINE HIGH PRESSURE FUEL TURBINE MODEL (NASA. Marshall Space Flight Center) 4 p

N96-13163

Unclas

G3/20 0072797

NASA-TM-111116

IN-20-TM
5521
P-4

# Radial and Circumferential Flow Surveys at the Inlet and Exit of the Space Shuttle Main Engine High Pressure Fuel Turbine Model

S.T. Hudson, W.J. Bordelon, Jr., and A.W. Smith
NASA/Marshall Space Flight Center
Huntsville, AL 35812

N. Ramachandran
Universities Space Research Association
Huntsville, AL 35806

## Abstract

Previous papers described the Phase IA tests of the Rocketdyne configuration of the Space Shuttle Main Engine (SSME) High Pressure Fuel Turbopump (HPFTP) turbine with rough coated flight engine rotor blades and with polished coated rotor blades at Marshall Space Flight Center (MSFC). The testing involved using scaled performance parameters and model measurements to determine the performance of the turbine. The turbine's performance was measured over its operating range and at extreme off-design points. The overall performance has been the primary objective of the tests to date, but more detailed measurements are also of interest for this turbine. This paper reports the results of an experimental program designed to obtain radial and circumferential velocity, temperature, and pressure distributions at the turbine inlet and exit using various measurement methods.

The test was designed to meet several objectives. First, the techniques for making laser velocimeter, hot-film probe, and cobra probe measurements in turbine flows were developed and demonstrated. The ability to use the cobra probes to obtain static pressure and, therefore, velocity had to be verified; insertion techniques had to be established for the fragile hot-film probes; and a seeding method had to be established for the laser velocimetry. Once the measurement techniques were established, turbine inlet and exit velocity profiles, temperature profiles, pressure profiles, turbulence intensities, and boundary layer thicknesses were measured at the turbine design point. The blockage effect due to the model inlet and exit total pressure and total temperature rakes on the turbine performance was also studied. A small range of off-design points were run to obtain the profiles and to verify the rake blockage effects off-design. Finally, a range of different Reynolds numbers were run to study the effect of Reynolds number on the various measurements.

The test was conducted in the MSFC air flow Turbine Test Equipment (TTE) shown in figure 1. The TTE is a blowdown facility which operates by expanding high pressure air (420 psig) from one or two 6000 cubic feet air tanks to atmospheric conditions. Air

flows from the storage tanks through a heater section, quiet trim control valve, calibrated subsonic mass flow venturi, and into a plenum section. The air then passes through the test model and exhausts to atmosphere. This equipment can deliver 220 psia air to the test section for run times from 30 seconds to over 5 minutes. The heater allows a blowdown controlled temperature between 530° R and 830° R. The TTE has manual set point closed-loop control of the model inlet total pressure, inlet total temperature, shaft rotational speed, and pressure ratio. In addition to these control parameters, the facility can accurately measure mass flow, torque, and horsepower. The associated data acquisition system is capable of measuring 400 pressures, 120 temperatures, and various model health monitoring variables.

The model tested (the HPFTP Turbine Test Article (TTA)) was a full-scale model of the HPFTP turbine in the baseline Rocketdyne configuration (figure 2). It duplicated the gas path geometry of the prototype. HPFTP stator and rotor blade flight engine hardware was used, but the flight engine rotor blades were polished to a smooth surface finish. The mean line airfoil diameter was 10.069 inches. The model inlet and exit planes were defined by rotating rings containing eight instrumentation ports where total pressure and temperature rakes have been installed for the past tests. The rings could be rotated through 90° allowing the pressure and temperature rakes to cover 360°. All of the total pressure and temperature rakes were removed for this test. One of the instrumentation ports at the inlet and the exit was used to mount a window for optical access to the flow. Contoured plugs were installed in the remaining instrumentation ports. Two auto-nulling three-hole cobra probes have also been mounted on each ring 180° apart to measure flow angle, total pressure, and total temperature for the past tests. The cobra probe towers were used to mount cobra probes as well as various hot-film probes for the current test. The exit guide vanes, located downstream of the exit rotating ring, contained four total pressure sensors on six of the vanes, four total temperature sensors on the remaining six vanes, and twelve static pressure taps at the inlet and exit for both the outer and inner walls. The model was instrumented with eight equally spaced (circumferentially) static pressure taps on the annulus outer and inner diameters at six axial planes. The first and second stage vanes contained static pressure taps at 10%, 50%, and 90% span. Various health monitoring and special purpose instrumentation was also included.

The main objective of this test was to obtain detailed radial and circumferential flow surveys at the inlet and exit of the SSME High Pressure Fuel Turbine model using three-hole cobra probes, hot-film probes, and a laser velocimeter. The results using the various measurement techniques will be compared, and the accuracy of the different methods will be evaluated. These results will be compared to other test results and code predictions and will be used to improve the analytical tools used in the design and performance predictions of turbopump turbines. The paper will include a presentation and discussion of the results along with conclusions.

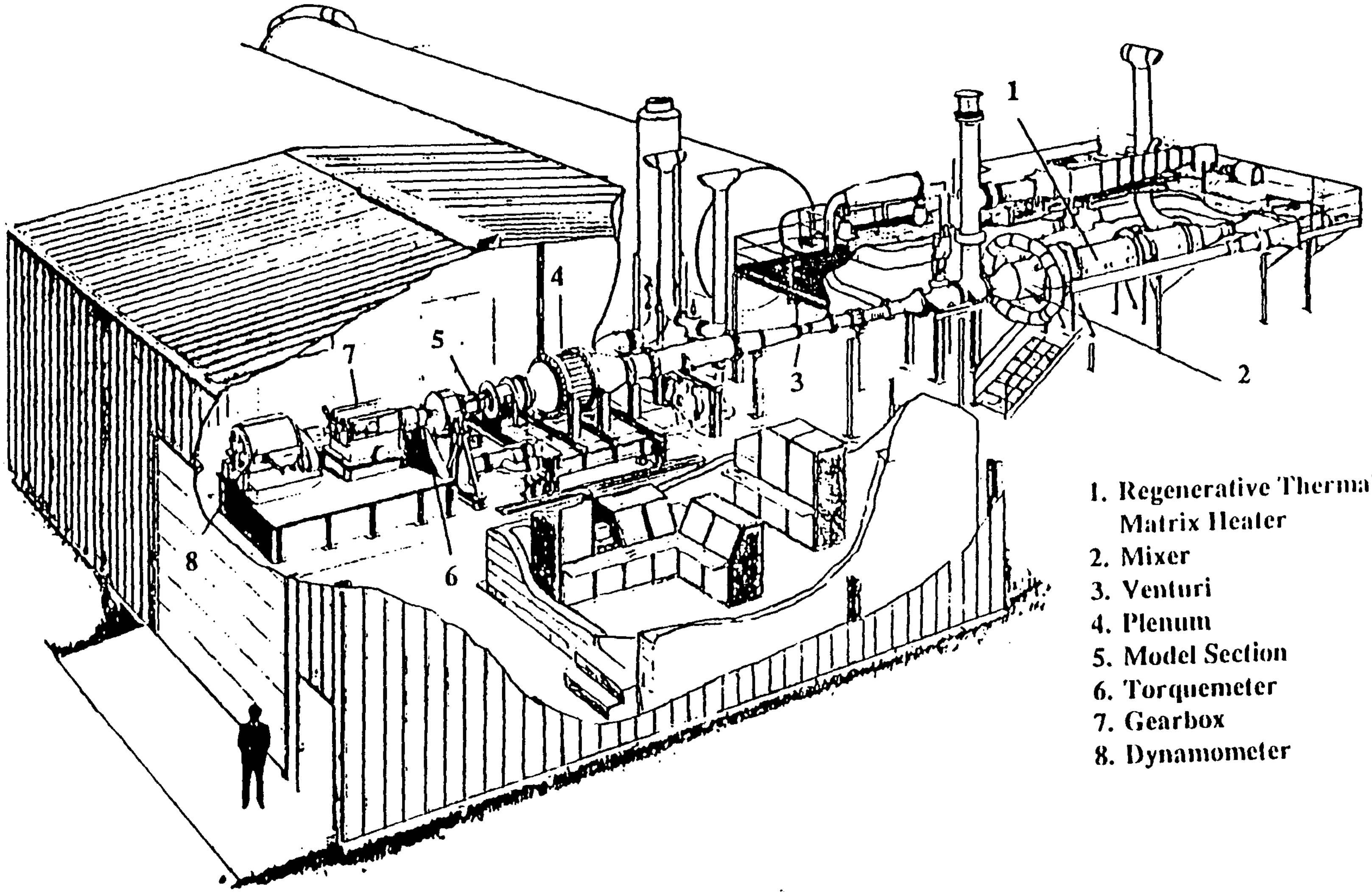


Fig. 1. Schematic of TTE

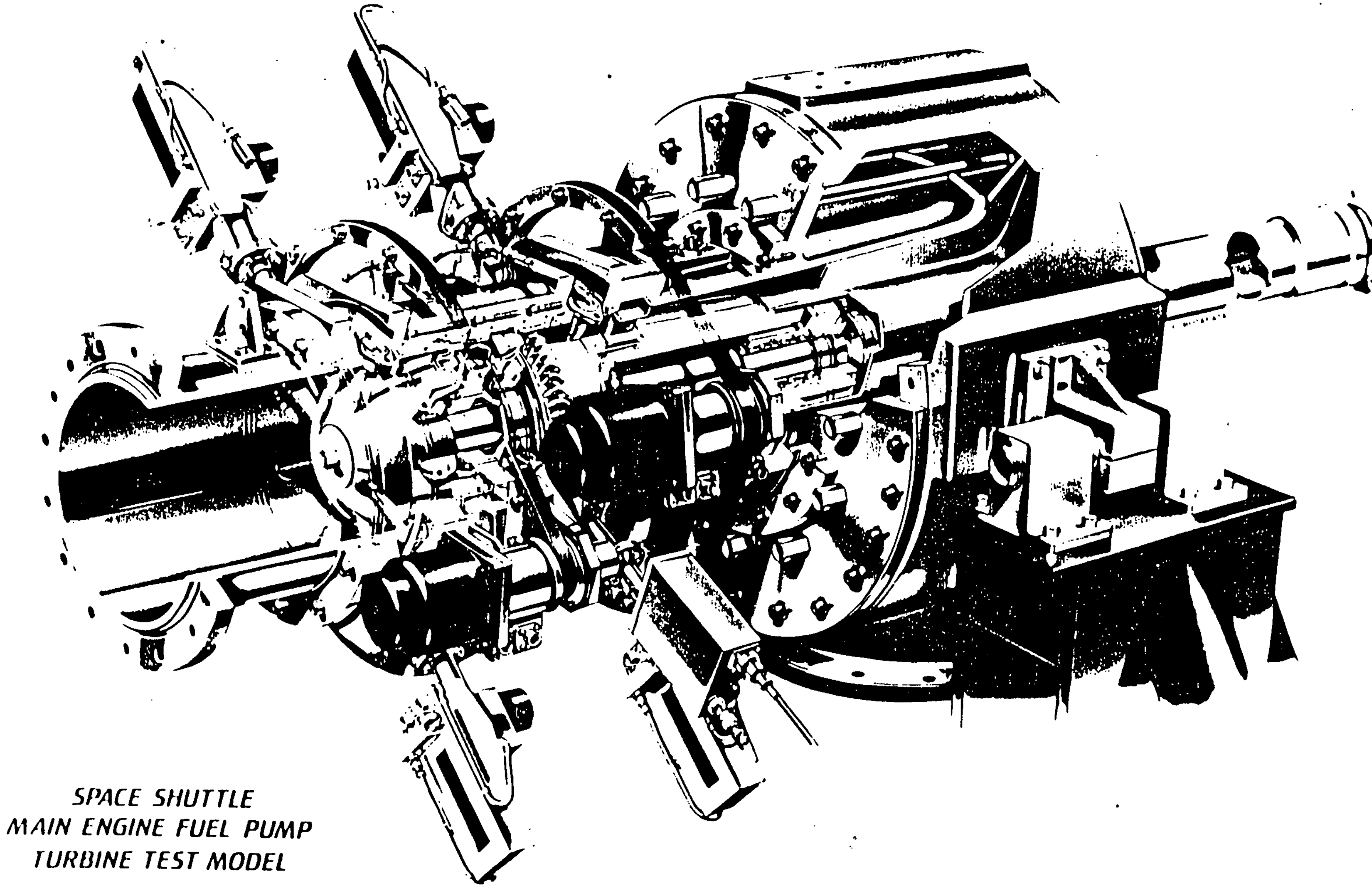


Fig. 2. Turbine Test Model