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HOT SECTION VIEWING SYSTEM

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The objective of the hot section viewing program is to develop a prototype optical system for viewing the interior of a gas turbine combustor during high temperature, high pressure operation in order to produce a visual record of some causes of premature hot section failures. The program began by identifying and analyzing system designs that would provide clearest images while being able to survive the hostile environment inside the combustion chamber. Different illumination methods and computer techniques for image enhancement and analysis were examined during a preliminary test phase. In the final phase of the program, which will be discussed in this presentation, the prototype system was designed and fabricated and is currently being tested on a high pressure combustor rig.

The combustor viewing system consists of a 12.7 mm diameter viewing probe with an actuator unit that mounts onto a rig or engine, an optical interface unit to transfer images to video and film cameras and provide illumination light, and two control chassis for remote operation of the probe and the optics interface unit. Probe actuation consists of a $\pm 180^{\circ}$ rotation from a downstream view and insertion radially along the combustor axis with a depth range of 7.6 cm. In order to cover a wide range of views, two viewing probes were constructed. One probe has a wide view, the other a narrow view. Both probes have their direction of view angled off the probe axis so that the view can be scanned on rotation. In addition, each probe has a choice of two lenses. The wide field probe has 90° and 60° field-of-view lenses, and the narrow field probe has 35° and 13° field-of-view lenses. For the wide field probe the view is oriented at 45° to the probe axis by bending the fiber optic image bundle. A cross section view of this probe is shown in figure 1. Since the lens focal lengths are much longer for a narrow field-of-view, the narrow field probe had to use a mirror to turn the view from the probe axis. Figure 2 shows a cross section of the narrow field probe.

Both probes are made of copper and have water-cooled walls. Four baffles in the probe walls guide cooling water to the distal end of the probe. Hot, soot-ladened combustor gas is kept from the probe interior and from the fiber and lens exposed surfaces with a flow of purge gas. The gas flows down the center of the probes and exits around the illuminating fibers and out of the lens aperture or across the mirror in the case of the narrow field probe and into the combustor. The probes were designed to handle the high heat fluxes expected in a primary combustion zone. A finite element analysis indicated that the probe tip temperatures were well within material limits and that cooling water at the probe tip should be below the boiling point. Measured temperatures were about $50^{\circ}C$ higher than calculated.

The image carrying fiber element is 3 mm in diameter and consists of a fused bundle of about 75,000, 10 μm diameter fibers. Each fiber corresponds to a picture element. The fused fiber bundle is 33 cm long and transfers the image from the viewing lens at the distal end of the probe to the opposite end of the probe where it is butt-coupled to a 3 m long flexible fiber bundle. The flexible bundle transfers the image to the optics interface unit for recording by video or film cameras. One millimeter diameter plastic clad fused quartz fibers, shown in the figures, were used for transferring the illumination light source. Two fibers were used in each probe. There are also two thermocouples mounted in each probe tip.

The viewing probe mounted in its actuator along with the remote control chassis is shown in figure 3. The purge gas line connects to the upright fitting on the left-hand side of the probe and the four bent tubes with connectors are for the probe water cooling. A separate line is used for cooling the actuator case and mounting plate. The remote control unit has a probe tip temperature indicator along with water, gas, and temperature interlocks. Probe depth is indicated with an LED bargraph meter. Rotation is indicated in degrees with a digital panel meter. The rotational speed can be varied. Another view of the probe and actuator with covers removed is shown in figure 4. The flexible fiber bundle can be seen leaving in the upper left-hand corner of the figure, and the actuator motors for depth and rotation can be easily identified along with their position indicating potentiometers.

The optics interface unit is shown in figure 5. The 3 m long fiber optic image bundle from the probe comes into a filter wheel in the upper left-hand corner of the figure. A series of eight different optical filters can be used such as neutral density, color, and interference filters to vary exposure and spectral range. A pneumatically-controlled slide positions a mirror that directs the image from the filter wheel to a video camera. When the mirror is positioned away from the line-of-view, the image can be seen with a film camera. A mercury arc lamp, its power supply, and the two illuminating fibers are on the right-hand side of the board. A second pneumatically-operated mirror directs the collimated and focused arc lamp light to the fiber ends. With the mirror out of position, a laser light beam can be focused into the fibers. There is also a control chassis that permits remote operation of the filter wheel, mirrors, and cameras with position indicators.

Tests are currently underway with the viewing system in a high pressure combustor rig. A modified JT-12 combustor liner is used in the rig as illustrated in figure 6. Three viewing ports on the side of the rig are available for mounting the probe. Two of the ports are shown in the figure with the probe attached to port 1. The depth range of the probe (7.6 cm) in relation to the combustor is also shown in the figure. Both film and video data of the combustor liner surfaces will be recorded along with probe temperature and operational conditions.

WIDE FIELD PROBE

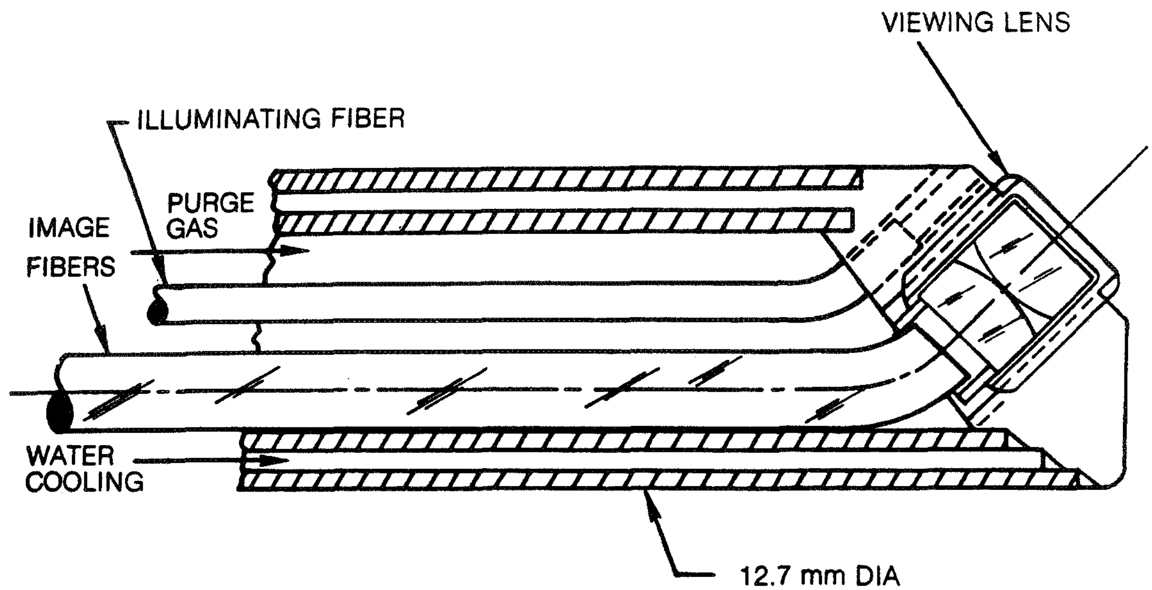

Figure 1

NARROW FIELD PROBE

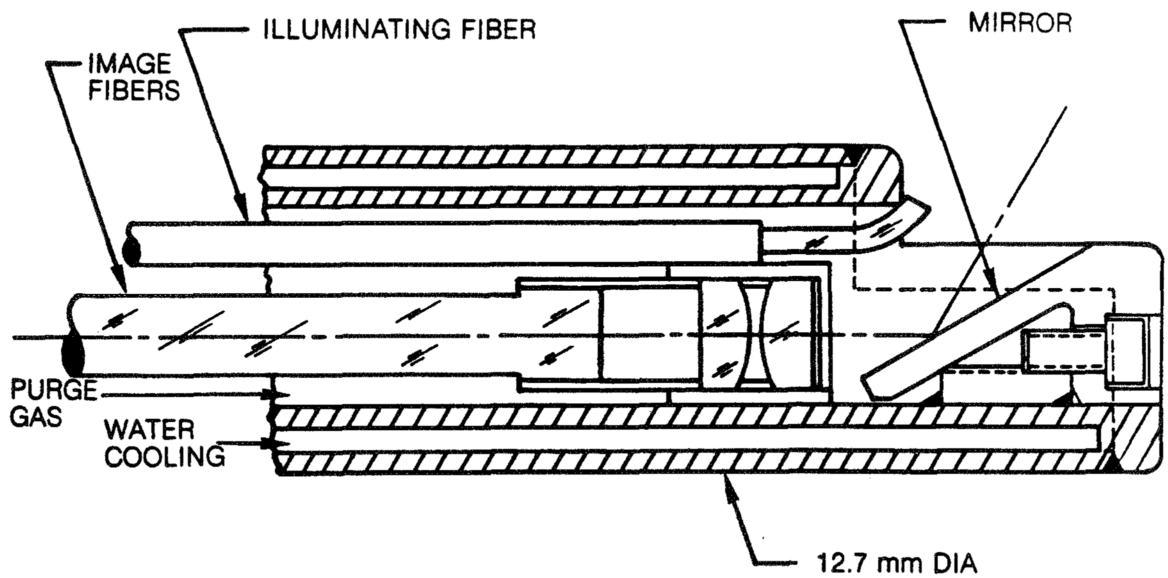

Figure 2

COMBUSTOR VIEWING PROBE AND CONTROL UNIT

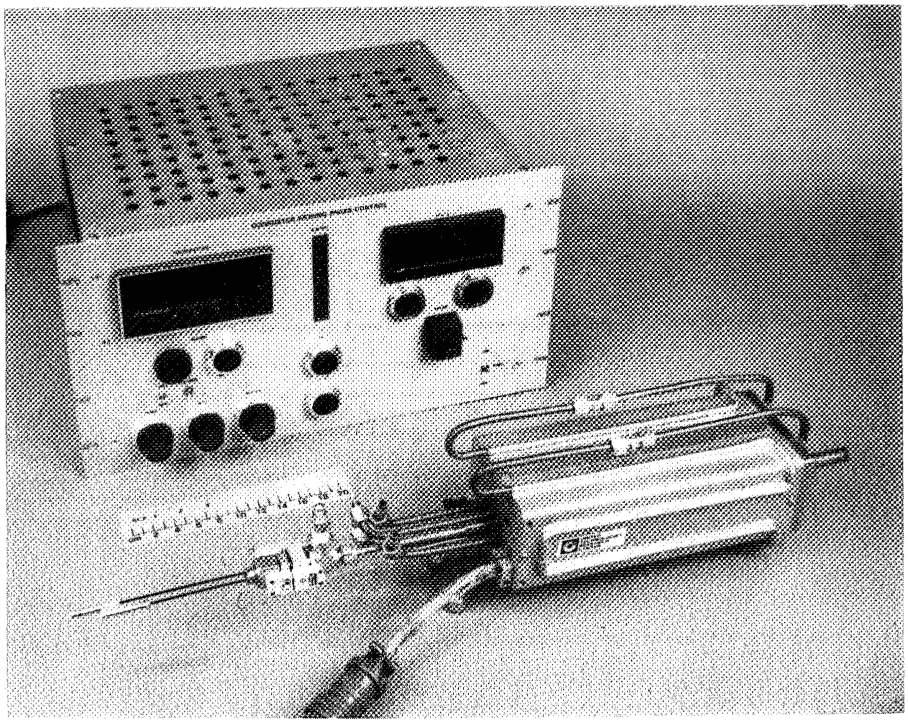

Figure 3

VIEWING PROBE AND ACTUATOR

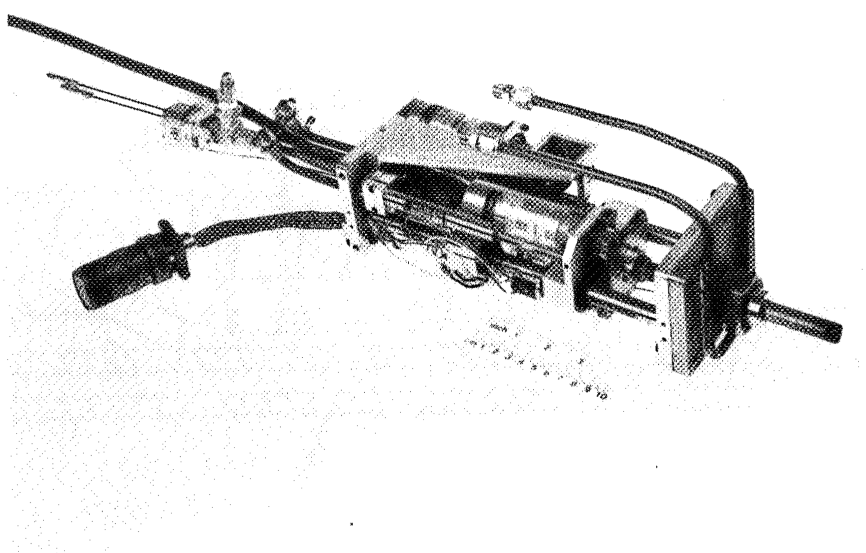

Figure 4

OPTICS INTERFACE BOARD

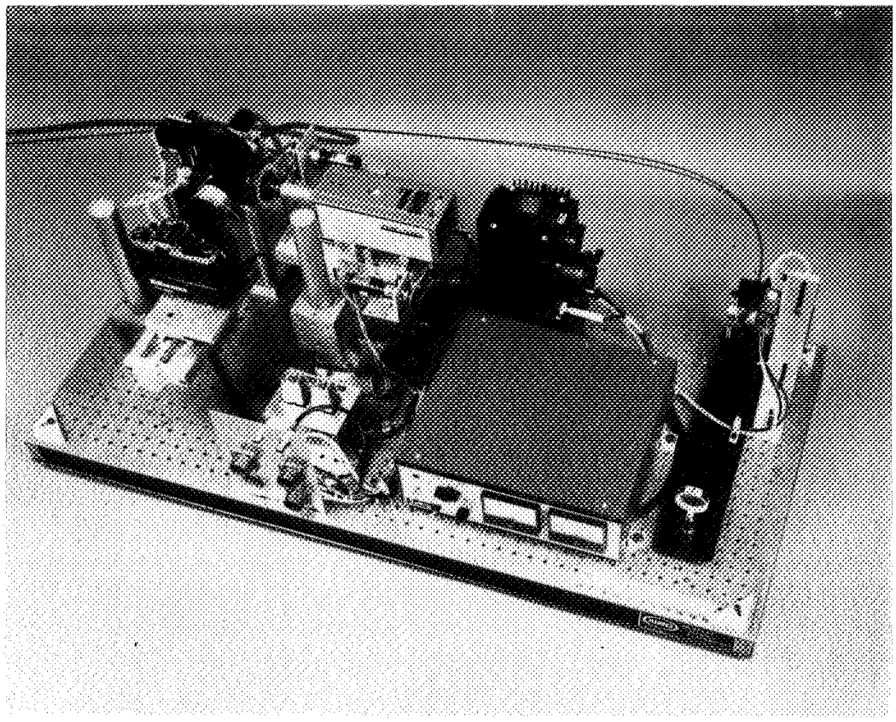

Figure 5

HIGH PRESSURE COMBUSTOR

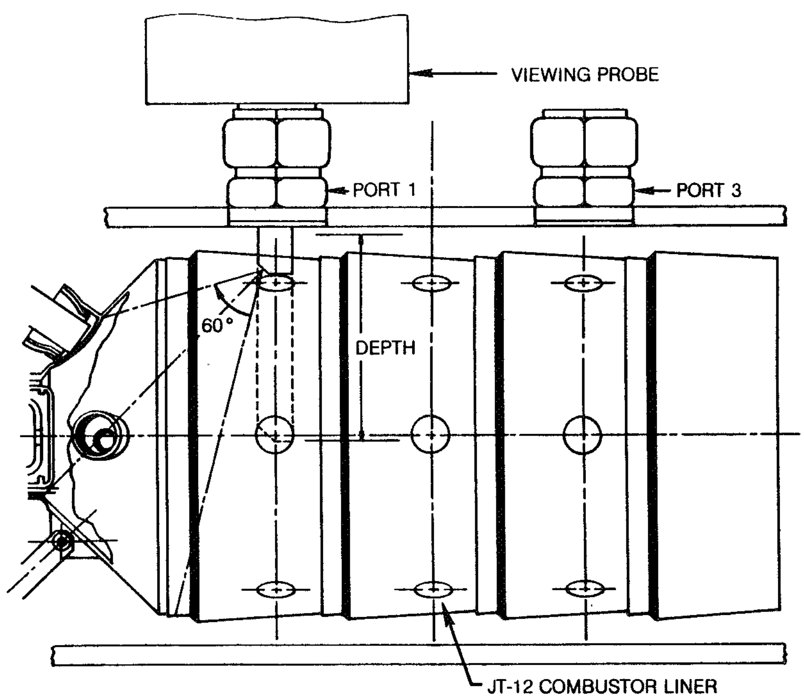

Figure 6