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OPAD 1991 - A STATUS REPORT

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The Optical Plume Anomaly Detection program, an experimental study in the attempt to create a rocket engine health monitor based on detection - and possible quantification - of anomalous atomic and molecular species in the exhaust plume, has been in existence for several years. The first year was used to acquire data allowing characterization of rocket plumes, specifically O_2/H_2, since no information was available in the literature for these engines. Equipment used was that available from the repertoire, available at the AEDC-a matter of economics and convenience. As many as 17 instruments were used during this time. We learned what an average plume appeared to spectroscopic analysis and we learned about the equipment needed to really do the job. Basically, instruments allowing both a wide spectral range and high spectral resolution were needed, and since such units were not available commercially, custom designs were required. Several stages were passed through to bring us to the current configuration, which is described below.

Two optical instruments are employed-the polychromator and the spectrometer. The polychromator is a 16 channel spectroradiometer having independent channels individually adjustable for center wavelength and pass bandwidth. Those values may be mechanically reset, with the aid of certain lab equipment. The spectrometer is a multichannel spectral analyser having two 2048 element linear photodiode arrays at the exit plane of the dispersing instrument, which-like the 16 channel device-is a 1/2 meter grating spectrograph. These instruments are equipped with UV grade multifiber optical input cables, allowing the instruments to be placed in a benign environment. Telescopes mounted on the test stand observe the plume keeping the shock structure (mach disc) in view.

The data acquisition and control system consists of four (4) 80386-33 mHz computers-two at the test stand for instrument control and data preconditioning, and two in the test support building providing data archiving and display and system control. A fiber optic data link connects the two sets. A real time display utilizing multiple high resolution CRT's is provided. A meter (bar chart) style display is provided for the polychromator and two CRT's provide the full spectrum in a "waterfall" plot. The bar chart is filtered such that the readout movement is slow enough for a human observer to follow it. The "waterfall" plot yields a 3-dimensional display-wavelength, amplitude, and time; thus, many spectral samples are visible at any given time with the most recent sample always at the front. These displays also make later examination of the data easy. Since the data is available at the support building, processing may be initiated as soon as the engine firing is completed (it may be as much as 30 minutes before stand access is available). Quick-look data is also immediately available via oscillographic type printouts. That quick data permits selecting the most desirable areas to examine prior to complete processing of the data-which will require anywhere from several days to a few weeks, depending upon the nature of the test. That processing is discussed below.

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DATA ANALYSIS

Currently, following each test, the data is studied for correlation to known engine activity, including instances of engine component erosion. This analysis is included as part of the post-test review. For example, in TTB016, we were asked to examine OPAD data to aid in identifying the time at which a pilot lip crack in the HPFTP occurred. Examination showed significant increases in Cr at approximately 5.838 sec. (Fig.1) TTB020 experienced significant faceplate erosion of the preburners. OPAD data, based on comparisons with previous SSME tests, indicated significant amounts of metallic elements, primarily Ni, Cr, Mn, and Fe throughout the test which was aborted at approximately 8 sec. (Fig.2).

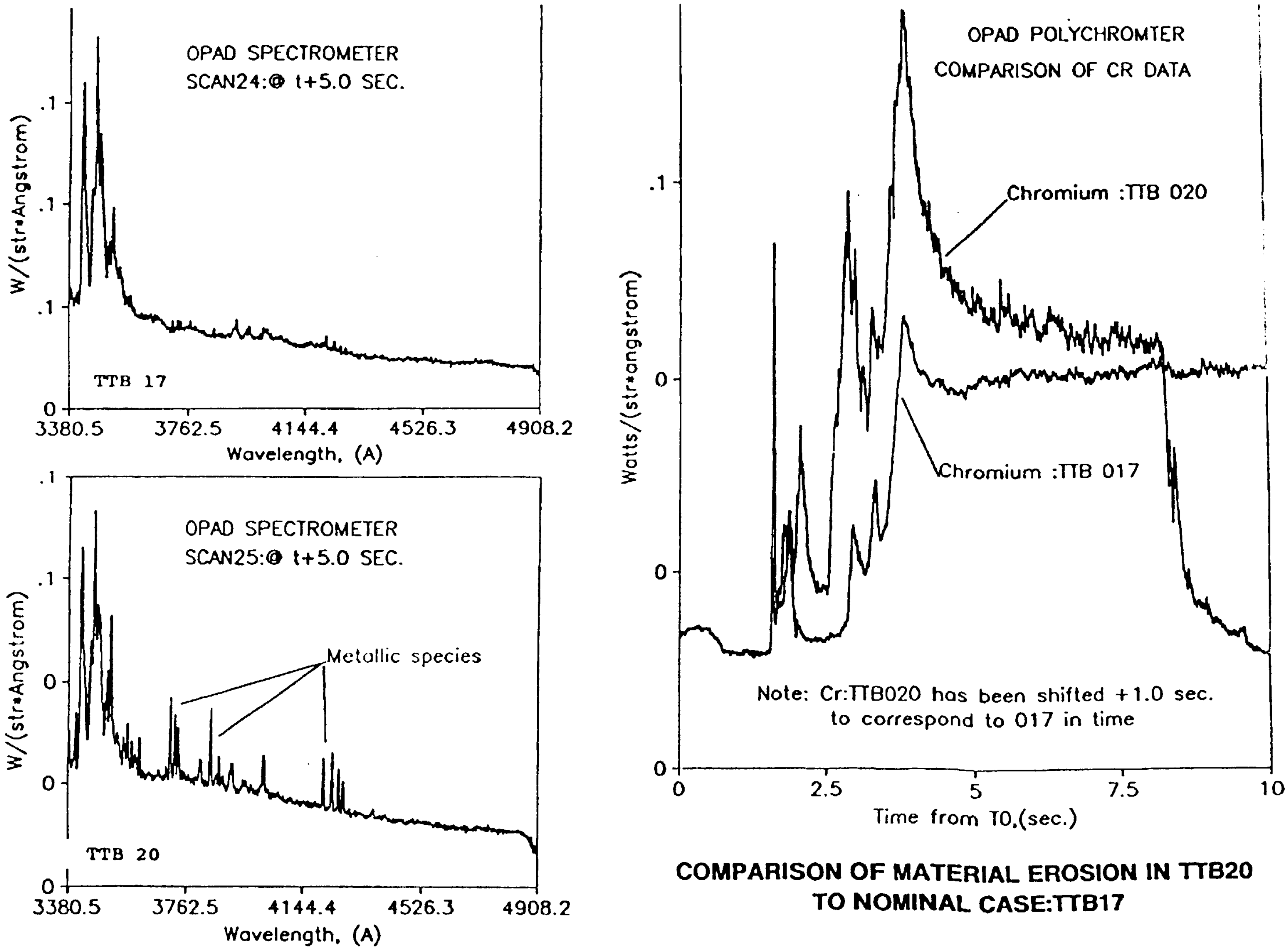
On a much broader basis, in the past year, an in-depth analysis of OPAD data collected on 21 tests of the SSME engine at the technology test bed stand at Marshall has begun. Some of the initial efforts include an investigation of spectral emissions at engine start-up, variations in baseline plume emissions due to changes in rated-power-level (RPL), variations of OH and continuum as a function of RPL, variations of Na as a function of RPL and an analysis of plume emissions at startup using a theoretical radiation model.

Correlation of spectral observations to engine operation at start-up is difficult because of the complexity of the SSME and the dynamic manner in which the exhaust plume evolves. However, in the polychromator data and to lesser degree in the spectrometer data, several events are clearly evident. Among these are the MCC prime time (the time at which initial combustion occurs), formation of the mach disk, and main stage operation.

An effort to understand and quantify the effects of changes in RPL on baseline plume emissions, on OH and continuum, and on atomic emission of Na is also underway. With increase in RPL the Mach disk moves away from the nozzle exit at a rate which is not linear with RPL (theoretically it is proportional to square-root of RPL). Total mass flow and chamber pressure are varied to achieve desired RPL, but the O/F ratio is held at constant value of 6.0. Hence, the chemistry should be somewhat independent of RPL. Findings also indicate that the movement of the Mach disk into the FOV of the OPAD instrument along with the change in pressure at the Mach disk is primarily responsible for the variations in the baseline OH and continuum. Surprisingly Na emission does not follow the movement in the Mach disk as does the OH and continuum. This will require further investigation.

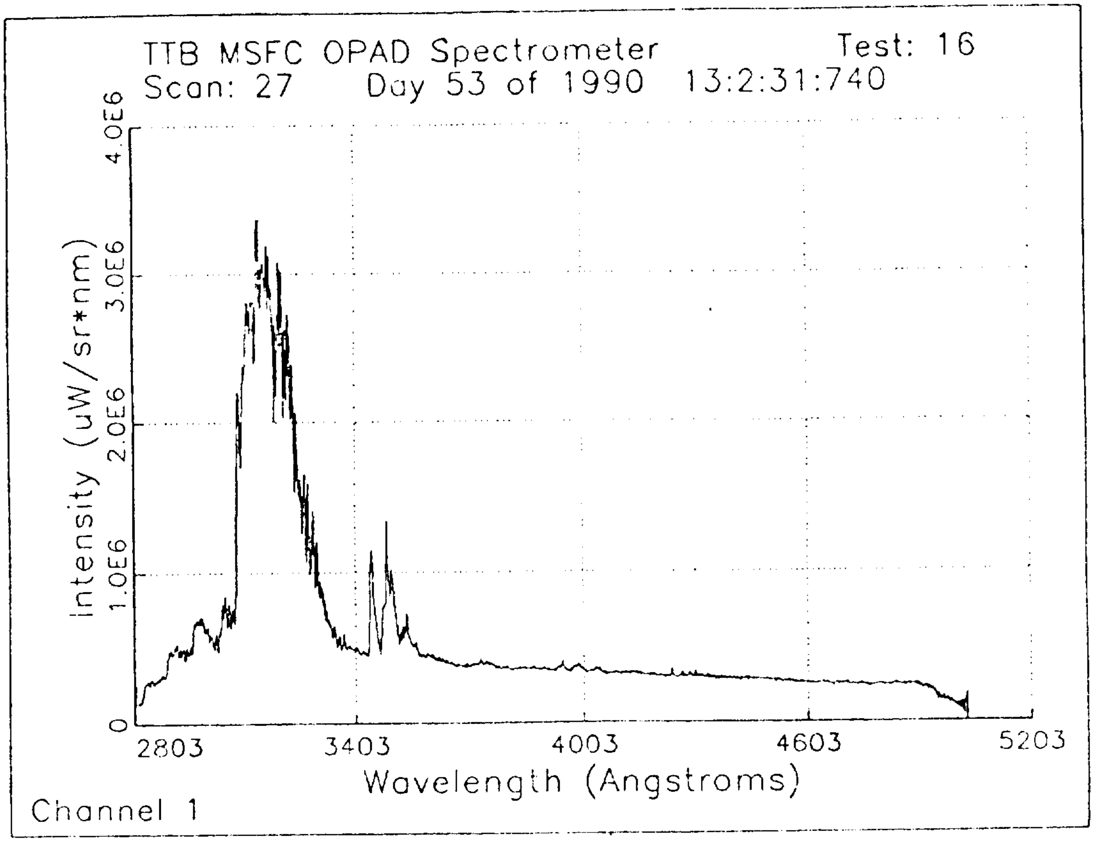
In a first attempt to determine element composition from spectral observations, an optically thin radiative model was developed by Tim Wallace of AEDC to predict absolute emission line intensities from a number of atomic species. While it assumes thermodynamic equilibrium and considers only collisional excitation of atoms, it will be a valuable tool in determining the spectral characterization of the plume.

Immediate plans for future data analysis include the development of radioactive transfer models which will enable us to determine material composition and erosion rates. It is believed that these models in combination with other experience gained from the OPAD project will provide us with a methodology to look at the data from an intelligent standpoint, permitting on-line judgments.



COMPARISON OF MATERIAL EROSION IN TTB20 TO NOMINAL CASE:TTB17

TYPICAL



HPFTP PILOT LIP CRACK