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THE INFRARED SIGNATURE OF THE HIGH ALTITUDE SUPERSONIC TARGET (HAST) AT SEA LEVEL

TARGETS BRANCH
GUIDED WEAPONS DIVISION

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Detailed measurements of the infrared signature of the High Altitude Supersonic Target (HAST) hybrid rocket engine have been obtained for the first time at sea level and at several measured O/F ratios representing its entire operating range. Secondary injection, as an infrared signature augmentation technique, has been evaluated on both the full-scale HAST engine and a special subscale model. The latter has also been operated with subsonic envelopes of inert gas (nitrogen) and air to eliminate or reduce the effect of afterburning as a radiation mechanism. The infrared measurements show excellent correlation between full-scale and subscale total radiation and also indicate that maximum radiation per unit area remains constant

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at beam aspect. It has been determined that the HAST hybrid engine infrared radiation is surface area dependent, varies linearly with flow rate, and is affected primarily by O/F ratio. These measurements have permitted closer evaluation of in-flight performance and have resulted in realistic recommendations for a HAST augmentation technique.

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PREFACE

This technical report describes the results of measurements and analyses performed by the Targets Branch (DLMQ) of the Air Force Armament Laboratory, Eglin Air Force Base, Florida, in simultaneous support of Program Element No. 62602F, Project No. 192103, "Infrared Plume Simulation Technology," and Program Element No. 63232F, Project No. 469A0501, "Plume Injection Infrared Augmentation." The effort was conducted during the period 20 January 1975 through 1 June 1975 by Dr. D. B. Ebeoglu, Lieutenant C. W. Martin, Mr. D. E. Fink, and Mr. I. W. Semmes (AFATL/DLMQ). The interferometer data were obtained and reduced by Captain W. B. Jollie (ADTC/TSGPA). The outstanding technical cooperation and support of Mr. A. L. Holzman, Mr. R. A. Jones, and Dr. B. L. Iwanciow of Chemical Systems Division (CSD), United Technologies, Sunnyvale, California, is gratefully acknowledged. The results of the experimental and analytical effort conducted by CSD are contained in technical report AFATL-TR-75-90, "High Altitude Supersonic Target (HAST) Infrared Augmentation," Eglin Air Force Base, Florida, July 1975.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

FENDRICK J. SMITH, JR., Colonel, USAF
Chief, Guided Weapons Division

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SECTION I

INTRODUCTION

The infrared data described in this report were obtained on two hybrid rocket engines developed by Chemical Systems Division (CSD), United Technologies (formerly United Technology Center, Division of United Aircraft), Sunnyvale, California. These engines utilize a case bonded solid fuel grain (80 percent polybutadiene and 20 percent polymethylmetacrylate) having a hollow core through which is injected an atomized liquid oxidizer [inhibited red fuming nitric acid (IRFNA)].

The full-scale engine operates at total flow rates of between 1000 and 2000 grams per second and is the propulsion system for the HAST. A subscale engine having the same general geometry and propellants, and operating at a flow rate of about 100 grams per second, was developed to permit the study of secondary injection as an infrared augmentation technique over a wide range of primary and secondary conditions.

The purpose of this effort was to obtain a set of detailed and unambiguous measurements of the infrared signature of the HAST engine at sea level, analyze infrared performance, evaluate and recommend viable augmentation techniques and extrapolate the data to determine inflight infrared performance. Previous analyses (Reference 1) had concluded that, to the maximum extent possible, the target propulsion system should be used as the infrared source. Experimental investigations (Reference 2) had established the major parameters affecting infrared radiation from rocket engine plumes. An experimental investigation was thus recommended and was undertaken by CSD to apply the fundamental knowledge gained in maximizing radiation from plumes to the specific details of the HAST hybrid engine configuration, temperature, and fuel chemistry.

The detailed IR signature measurements, which were conducted by AFATL, determined total radiant intensity between 4 and 5 micrometers, spectral radiant intensity between 2 and 5 micrometers and spatial radiant intensity distributions over its entire plume between 4 and 5.5 micrometers. These data were obtained for each operating condition. Both engines were operated by CSD using a complement of instrumentation to control, monitor, and record engine operating conditions.

This report describes the geometry for the measurements, the final reduced data from each instrument and the agreement between instruments. It discusses the infrared performance of the hybrid engine with and without augmentation, with and without subsonic co-flowing air envelope, and with and without a subsonic nitrogen envelope. This

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References

1. Report of the Plume Emissions Panel, Advisory Committee to the Air Force Systems Command, National Academy of Sciences, June 1973.

2. D. B. Ebeoglu, Fundamental Parameters Affecting Plume Infrared Radiation, AFATL-TR-74-84, Eglin Air Force Base, Florida, April 1974.

report also reviews previous infrared plume prediction calculations performed for the HAST, compares them against the measured data and evaluates their effectiveness. Based on the conclusions reached from all the data analysis, recommendations are made for implementing improved techniques to provide significant inflight infrared enhancement of the HAST engine exhaust plume.

SECTION II

MEASUREMENT CONDITIONS

1. EXPERIMENTAL GEOMETRY

Figures 1 and 2 show the geometry chosen for the subscale and full-scale engine measurements, respectively. Corresponding photographs of the engine/instrumentation arrangements are shown in Figures 3 and 4. Both engines were operated at a height of 39.4 centimeters from ground to centerline.

There was a vertical wall approximately 69.9 centimeters from the subscale engine parallel to the centerline (off the right-hand side of Figure 3). The scanner measurements detected an infrared reflection of the plume from this wall during the subscale engine tests and from the ground plane[1] during the full-scale engine tests. However, the reflected radiation in each case contributed an apparent increase in total radiation of less than 20 percent. In view of the low levels encountered, no serious attempts were undertaken to eliminate reflections. [These conclusions become apparent from the infrared scanner data on the subscale engine (Tables 5 through 14) and on the full-scale engine (Tables 16 and 18 through 24)].

For the subscale measurements, the AFATL and CSD radiometers were placed next to each other at a point approximately 30 degrees from the plume axis (tail-on angle being 0 degree). Agreement between the radiometers was repeatedly found to be within 6 percent. Thus, for the full-scale measurements, the radiometers were placed at separate locations in order to gain another data point. In the latter case, the AFATL unit was placed at 60 degrees and the CSD unit at 30 degrees. (However, due to the lay of the land, the CSD unit had to be at a height of approximately 10 meters above the engine axis.) The interferometer and the scanner were always operated at 90 degrees aspect angle, care being taken to ensure that they did not fall within each other's field of view.

2. INSTRUMENTATION

Most of the infrared instrumentation has been described in detail previously and thus only salient points are reviewed here. The AFATL radiometer is a Hewlett Packard 8330A/8334A thermopile with a 3.92- to 5.1-micrometer bandpass filter, a 7-½-degree non-attenuated field of view and a CaF_2 window. The CSD radiometer, designed and fabricated by CSD, uses a pyroelectric detector with a 3.86- to 5.31-micrometer bandpass filter, a non-attenuated field of view of approximately 7.2 degrees, and a germanium window. Both radiometers have a flat spectral response and were operated over a flat field of view.

Footnote

[1]The full-scale measurements were conducted on a rainy day, and the wet pavement might have enhanced the amount of radiation reflected in that instance.

A BOFORS scanner with a Barnes digital data acquisition system (Reference 3) was used to obtain infrared spatial distributions. The instrument has a 25-degree (horizontal) by 12.5-degree (vertical) field of view, giving a two-dimensional matrix of 56 (horizontal) by 94 (vertical) total digital picture elements over this field of view, with a digital dynamic range of each picture element from 0 to 127. The bandpass selected was 4 to 5.5 micrometers.

A Block Model 600 interferometer spectrometer was used to measure spectral distributions between 2 and 5 micrometers. Data were collected at a resolution of 4 cm^{-1} at a rate of 16 scans per second, generally, over a 1-second duration. The instrument was operated with about a 25-degree field of view (of which approximately 16 degrees were taken up by the full-scale plume).

An automatic sequencing system developed by CSD was used with both the engines to control the duration of each sequence of operation during a given firing. Figure 5 shows the time sequences used for the subscale HAST firing. The standard time sequence shown in Figure 5(a) allowed the examination of (a) the static plume, (b) the static plume with fuel augmentation, (c) the static plume with oxygen augmentation, (d) the dynamic plume (with subsonic air or nitrogen envelope), (e) the dynamic plume with fuel augmentation, and (f) the dynamic plume with oxygen augmentation. The sequence was changed only once, as shown in Figure 5(b), to allow the evaluation of the Atlantic Research Corporation Pyrotechnic Optical Plume Simulator (POPS) as a HAST plume augmentation device.

Table 1 shows the sequences for both the boost and sustain phases of the full-scale HAST firing. The infrared instruments were operated continuously from a point in time preceding engine firing to after the end of a complete set of sequences. The sequencer was used to produce time marks in conjunction with an IRIG time-code generator. The full-scale engine could only be evaluated at static conditions; thus, time sequences were selected to allow infrared measurements of the plume with and without fuel augmentation and with and without oxygen augmentation at set intervals. These intervals encompassed a range of engine O/F ratios and total mass flow rates for all the missions contemplated for the HAST.

The interferometer data were collected in two ways. First, interferograms were recorded on analog tape (using a Bell & Howell CPR-4040 Instrumentation Recorder) along with IRIG time code, the automatic sequencer sync pulse, and voice annotation. In this way, the entire spectral history of each rocket motor firing was preserved. Second, interferograms were randomly digitized and recorded in real time using the data system of the spectrometer to provide spectral information free from any possible recorder noise. This real time data provided a check on the quality of the recorded data and provided a means of on-the-spot data evaluation.

Reference

3. C. W. Martin, R. F. Askew, and D. B. Ebeoglu, Operation of an Infrared Thermal Scanner for Plume Measurements, AFATL-TR-74-204, Eglin Air Force Base, Florida, December 1974.

For each run, data were reduced over the intervals of time shown in Figure 5 and Table 1. The data system digitized and co-added 16 interferograms to create the final data interferogram for each specified time. It then performed a Fourier transform on the final interferogram to produce a raw target spectrum. This spectrum was corrected with the instrument response curve and plotted as a fully calibrated spectrum. Each spectrum was then recorded on digital magnetic tape to make a permanent record of the final data. The same procedures were used to reduce the data collected in real time, except that a separate real time instrument response curve was used to correct the raw data.

The thermal scanner data were continuously recorded on digital tape and the time sequences shown in Figure 5 and Table 1 used for final data reduction. Frames were selected using timing pulses from the firing sequencer on a strip chart recorder and the octal frame counter on the scanner. (The scanner operates at a scan rate of 2.87 frames per second.) The radiant intensity figures presented for each sequence are averages of the total radiant intensity measured in three frames. The data recorded from the scanner were visually reviewed on an oscilloscope and gross effects, such as saturation or reflections, noted for correction. Final numerical data reduction was performed on a CDC 6600 computer.

3. CALIBRATION AND DATA VERIFICATION

A 1.25-square-centimeter blackbody source at 900 degrees Centigrade was used at the test locations to obtain the response of each instrument configuration. Interferograms from the blackbody were collected on both analog tape and in real time. These data were reduced to provide an instrument response curve in order to calibrate the spectral information from the target. Analog voltages from the scanner due to the blackbody radiation were checked on-site and the radiation recorded on digital tape.

Full calibration procedures were performed at the Air Force Armament Laboratory using the same blackbody source at different locations, an extended blackbody source, a propane/oxygen torch, and all three infrared instruments. Data were taken for a number of extended sources having about a 10:1 range of radiance and radiant intensity levels. Total radiant intensity between 4 and 5 micrometers, as measured by the thermopile radiometer, and total radiant intensity between 4 and 5.5 micrometers, as summed by the scanner (operated at the same sensitivity and attenuator levels used for the HAST plume measurements) were found to agree within 18 percent.

The comparison of these data against integrated radiant intensity between 4 and 5 micrometers, as measured by the interferometer, showed the latter, in certain configurations, to yield approximately one-half the radiant intensity measured by the other two instruments. This occurred consistently for all cases in which the interferometer viewed an extended source filling the field of view. It was determined that better than 20 percent agreement could be obtained for a small extended source placed in the center of the field of view.

The interferometer has a sharp drop-off in sensitivity beyond a central solid angle of 5 degrees with the optical configuration used in the HAST measurements. This drop-off causes integrated values of radiant intensity between 4 and 5 micrometers to be, very roughly, halved. This factor applied for all the spectral radiant intensity data collected on the full-scale HAST. The interferometer was only used to measure the relative radiant intensity of the subscale HAST. This correction factor, therefore, is not relevant to the latter data.

The radiometric data comparison described above is summarized in Table 2. Runs 1 through 5 were performed with the interferometer viewing sources filling its field of view. In runs 6 through 9 the extended sources did not fill the field of view of the interferometer. The result was better than 20 percent agreement between the interferometer and the thermopile radiometer.

SECTION III

EXPERIMENTAL RESULTS

1. SUBSCALE HAST MEASUREMENTS

Infrared measurements were performed at sea level on the subscale HAST engine during 18 firings, two of which included augmentation by the Atlantic Research Corporation POPS device. The engine was operated at O/F ratios between 1.95 and 4.01 and at total mass flow rates between 86 and 172 grams per second. Chamber pressures varied between 4.86 and 10.2 kg/cm^2. Six data points were taken at each firing (except for the POPS run, which only required four). Oxygen (O_2) and methane (CH_4) augmentation were evaluated at static conditions and also with a co-flowing airstream at Mach 0.7 or with a co-flowing nitrogen stream at Mach 0.3.

This procedure resulted in approximately 100 data points being taken by each instrument and allowed the infrared signature of the engine to be verified several ways. Since the data are similar in many respects, data taken by these instruments are presented in their entirety for only a few representative firings.

a. Radiometric Data

The complete set of data collected with the radiometers and the radiometric data from the scanner are presented in Table 3 which relates them to key engine parameters. Additional diagnostic engine data taken for each firing included fuel grain size, nozzle diameter and expansion ratio, chamber pressure, characteristic velocity, IRFNA mass flow rate, total mass flow rate and thrust. These may be found in the CSD final report (Reference 4) and can be cross-referenced by using the run number. They are not repeated here since analyses of the data have shown them to have a relatively minor effect on the infrared performance of the engine.

For each firing of the subscale HAST, Table 3 shows:

(1) O/F ratio

(2) Secondary material injected

Reference

4. A. L. Holzman and R. A. Jones, High Altitude Supersonic Target (HAST) Infrared Augmentation, AFATL-TR-75-90, Eglin Air Force Base, Florida, July 1975.

(3) Ratio of secondary to primary mass flow rate ($\dot{m}_s/\dot{m}_p$)

(4) Co-flowing air or nitrogen Mach number (M_∞); with the latter flow condition being designated by the symbol N_2 following the Mach number

(5) The radiant intensity, J, in watts/steradian, between 4 and 5 micrometers measured by the radiometers

(6) The radiant intensity, J, in watts/steradian, between 4 and 5.5 micrometers measured by the scanner

(7) The figure of merit, $\bar{J}$, in watts/steradian/gram/second, computed from the radiometer data

(8) The infrared augmentation ratio $(J_{aug}/J)_{flow}$ is the ratio of the radiant intensity of the plume with and without secondary injection, based on the radiometer data obtained with air or nitrogen flow

(9) Injection mode, whether via a discrete number of holes or an annular slot

The radiometric data shown in Table 3 are those measured by the CSD radiometer. The latter numerical values were used directly since agreement with the AFATL radiometer was within 10 percent for every single data point. These radiometric data therefore provide a consistent standard of comparison for previous and subsequent measurements performed by CSD.

The static data consistently show O_2 injection to produce a fraction of the augmentation produced by CH_4 injection, the latter in some cases exceeding 100 percent. It is quite certain, however, that these data merely show the enhancement of afterburning by hot CH_4 rather than augmentation of the exhaust plume itself. The static augmentation data is only recommended for use in determining the extent to which the subscale infrared plume is an extrapolation of the full-scale infrared plume.

Afterburning is the primary radiation mechanism in a rocket engine exhaust plume at static altitude conditions (Reference 5). Afterburning increases when the O/F ratio is decreased as more hot unburned fuel is released into the ambient air, causing the large increase in radiant intensity noted at low O/F ratios. The HAST engine operates below

Reference

5. D. B. Ebeoglu and C. W. Martin, Effect of Mixture Ratio on UV, Visible and Infrared Radiation for Exhaust Plumes, AFATL-TR-75-79, Eglin Air Force Base, Florida, May 1975.

stoichiometry for all presently postulated mission profiles, resulting in significant afterburning at static altitude conditions. Oxygen injection at static conditions produces minimal infrared augmentation probably by permitting slightly more efficient combustion of the fuel rich exhaust than with stagnant air. Methane injection, at static conditions. on the other hand, directly increases afterburning. The effect of fuel injection is the same as lowering the O/F ratio and thus large increases of infrared radiant intensity are produced.

Afterburning is reduced significantly in an airstream. In the case of an unchoked exhaust the attenuation is quite severe; reductions of two orders of magnitude are possible at low subsonic air velocities (Reference 6). In the case of a choked rocket engine exhaust in a supersonic airstream, radiant intensity may be reduced by a factor as high as 20.

The air or nitrogen ambient flow data were thus used as the basis for evaluating the secondary injection plume augmentation technique. The ratio of J_{flow}/J_{static} gives a direct indication of the operational HAST plume signature attenuation by air velocity in flight. Normalizing the radiant intensity data of the subscale HAST engine with ambient flow, so that J for the plume without augmentation becomes 1.0, permits a direct indication of the effectivess of O_2 and CH_4 augmentation

The ratio of the plume radiant intensity at static sea level conditions to that in a subsonic airstream gives an optimistic indication of the attenuation that can be expected in flight since (a) the air is only at subsonic velocity and (b) the airflow does not fully encompass the plume. The data collected with the plume in a subsonic co-flowing nitrogen stream give a more pessimistic approximation of the ultimate airborne radiant intensity. Although signature attenuation due to the kinetic effects of a supersonic airstream are not simulated, the nitrogen stream overcompensates by eliminating all the afterburning that the HAST engine exhaust could be expected to produce in actual flight at altitude. On the other hand, it has been shown that radiant intensity increases with altitude (Reference 2) in inverse proportion to the square root of ambient pressure due to the expansion and increase in length of the exhaust plume.

Using these criteria for evaluation, the data show that:

(1) Augmentation by fuel or oxygen injection depends on the engine O/F ratio at any ambient condition. With either a co-flowing air or nitrogen stream the data show that fuel injection produces more augmentation at rocket engine O/F ratios larger than about 3.0,

Reference

6. D. B. Ebeoglu, The Infrared Signature of Pyrophorics, AFATL-TR-74-92, Eglin Air Force Base, Florida, May 1974.

whereas oxygen injection is more effective for O/F ratios less than 3.0. The POPS device, which produces an exhaust rich in carbon particulates, gives about the same augmentation as CH_4.

(2) Maximum augmentation of about 50 to 60 percent is possible, albeit at different O/F ratios, for either O_2, CH_4, or POPS injection. These measurements are all in co-flowing subsonic streams, and require secondary total mass flow rates of about 5 to 10 percent of that of the HAST engine total propellant flow rate. Further increases of the secondary mass flow rate, of either oxidizer or fuel, do not measurably increase the enhancement.

(3) Annular or multipoint secondary injection produces higher augmentation than single hole injection at any condition.

b. Spectral Data

Spectral radiant intensity distributions for either of the HAST engines, for any operating condition, and for any augmentation condition, bear striking resemblances to each other. Spectra are presented in Figures 6 through 11 for the subscale engine for all six conditions of one run (number 5579) illustrating O_2/CH_4 injection, with and without Mach 0.3 nitrogen flow. Figures 12 through 15 show all four conditions of one run (number 5587) with POPS injection, with and without Mach 0.7 airflow.

The spectra show CO_2 radiation between 4 and 5 micrometers, CO_2 and H_2O radiation between 2.5 and 3 micrometers, superimposed on a strong graybody continuum peaking below 2 micrometers. POPS injection does not alter the spectral distribution in any appreciable fashion. The exhaust plume spectra are quite similar to those produced by a highly fuel rich combustion at which the point of carbon luminosity has been reached. [For example, the spectrum of freeburning kerosene (Reference 5)].

In general, the graybody contribution is more pronounced with air or nitrogen flow than at static conditions. Run 5579 was chosen as an example because it exhibits the largest difference in graybody level from static to dynamic condition than any other run and thus best illustrates this point. The change in spectral distribution indicates that afterburning (which predominates in a static environment) produces more CO_2 and H_2O emission than hot carbon emission. As with the radiometric data, the ambient flow measurements give a fairly realistic representation of spectral distributions that can be expected from this engine in flight.

Relative radiation emitted in three spectral bands, 2.2 to 3, 2.2 to 4, and 4 to 5 micrometers are presented in Table 4 for each sequence of each firing of the subscale HAST engine. These data can be used to assess the distribution of radiation within the 2- to 5-micrometer band. The data with nitrogen or airflow show that secondary injection of CH_4

and O_2 affect infrared radiation in any of these three bandpasses in nearly the same amounts. The 4- to 5-micrometer band data are generally proportional to the radiometric data presented in Table 3, although no attempt was made to ensure that the interferometer viewed the entire plume.

In the case of the POPS tests the interferometer data for the 4- to 5-micrometer band are directly proportional to the radiometer readings. The spectral data with airflow show the POPS to augment primarily by increasing graybody radiation when injected into a high O/F ratio exhaust. Table 4 shows that at an O/F ratio of 2.46 (Run 5587) POPS is not effective in any band; on the other hand, at an O/F ratio of 3.99 (Run 5588), augmentation in the 2.2- to 3- and 2.2- to 4-micrometer bands is significantly higher than in the 4- to 5-micrometer band. This suggests that at the lower O/F ratio, the graybody radiation from the engine plume is too high for augmentation by particulates from the POPS device. At the higher O/F ratio, POPS injection doubles the graybody radiation from the plume and consequently increases radiant intensity in the 4- to 5-micrometer band.

c. Spatial Data

Typical infrared plume spatial distributions for the subscale HAST exhaust are shown in Tables 5 through 14. These cover the same two runs which were used to describe the interferometer data. These data represent one file out of the data recorded on a continuous time base during each firing sequence. The horizontal increment is 2.54 cm, the vertical increment is 0.72 cm, and the unit of radiation in each spatial element is 0.01 watt/steradian.

The radiation reflected from the wall behind the engine is evident at the top of the static plume scans. In order to determine the radiation from the plume alone and assess quantitatively the contribution of the reflected radiation, a special data reduction computer program for line subtraction was written and applied to the data. Table 15 compares radiant intensity with and without reflection for all the subscale engine runs and lists the percent contribution due to the reflection.

The spatial measurements were all made at the same attenuator and sensitivity settings in order to obtain a direct comparison of data. The difference between the spatial distributions of plumes in a static and in a subsonic flow environment are significant. As Tables 5 through 14 typically show, the subsonic ambient flow causes plumes to be reduced by at least a third in each dimension, and plume maximum intensity per unit area to drop at least one-half. Secondary injection without airflow produces augmentation by increasing plume dimensions as well as increasing radiance, indicating augmentation to be due to a large extent to afterburning. Secondary injection with ambient flow, on the other hand, does not appreciably increase plume dimensions - primarily, the magnitude of the scanned matrix elements increase.

POPS produces a spatially skewed augmented plume due to its being injected at a relatively high velocity through a single point in the subscale HAST engine exit nozzle. The POPS injection data also show the low radiant intensity of its own exhaust as it is injected into the subscale HAST engine plume. The POPS exhaust can be seen in a single vertical column in the top left-hand side of Tables 13 and 14 (the scanner data being inverted).

For all the ambient flow conditions, Table 15 shows that the subscale HAST scanner radiometric data agree closely with the thermopile and pyroelectric radiometer data; whereas, in the static case, the scanner and radiometer data differ by a constant amount. This is due entirely to aspect angle. The HAST propellant exhaust is highly rich in fuel and particulates and thus is quite likely to be optically opaque. Therefore, it is postulated that the radiation emitted by the plume is proportional to the plume surface area rather than the plume volume. The radiometers placed at 30 degrees and the scanner placed at 90 degrees view different aspects, and thus different size surface areas, of the plume. At static conditions the surface area of the plume at beam aspect is much larger than that at 30-degree aspect. With a co-flowing stream the plume length is decreased and the surface area projected at 90 degrees becomes closer to that at 30 degrees.

2. FULL-SCALE HAST MEASUREMENTS

The full-scale engine infrared measurements were performed over a set of mixture ratios covering the full HAST inflight operating range. Data were obtained continuously during operating conditions representing both boost and sustain phase. The secondary injection cycle is shown in Figures 16 and 17 together with the actual O/F ratios at those points. O/F ratios were obtained by an indirect measurement of the solid fuel flow rate during firings via a continuous engine-weighing process developed by CSD.

O/F ratios varied between 1.5 and 3.2 during boost and between 3.1 and 2.0 during sustain phase. Total propellant flow rates were between 1500 and 2200 grams per second during boost and from approximately 1200 down to 500 grams per second during sustain phase. Either methane (CH_4) or oxygen (O_2) were injected, both symmetrically and unsymmetrically, at two flow rates of approximately 23 and 53 grams per second. Chamber pressures increased from about 15 to 27 kg/cm^2 during boost and decreased from about 13 to 3.5 kg/cm^2 during sustain phase.

The only infrared anomaly noted occurred in the first 10 seconds of boost phase. The initial 10 seconds of boost phase is not representative of conditions that can be reproduced during significant time periods in which the HAST would be presented as an inflight infrared target. During the first 10 seconds, extra fuel is used for reliable ignition producing an O/F of 1.5. The high infrared radiant intensity produced during this period is due to this extremely low O/F ratio and also to the exhaust of burned igniter material.

a. Radiometric Data

Figure 28 shows infrared radiant intensity versus time for the boost phase. The data shown were taken with the AFATL thermopile detector at the 60-degree aspect angle position. The time profile agrees extremely well with that observed at the 30-degree aspect angle by the CSD pyroelectric detector. Variations in infrared radiant intensity with O/F ratio and with secondary injection are clearly evident.

Figure 18 shows secondary injection to produce the same effect on the full-scale HAST engine plume radiation as on the subscale engine at static conditions. Significant augmentation occurs during CH_4 injection, with negligible or negative effects being produced with O_2 injection. As has been indicated, however, these effects are solely manifestations of afterburning which predominates at static conditions. They are not representative of in-flight performance.

Table 16 presents the radiometric data obtained between 4 and 5 micrometers by all of the infrared instruments during boost phase. The injection mode is designated at Hi O (high oxygen), Lo F (low methane), etc. Thermal scanner data were lost due to saturation during 10 seconds of the run (Figure 18) when its sensitivity setting was erroneously changed from 50 to 20. Interferometer data were not taken during the initial 10 seconds. The integrated interferometer readings have been corrected grossly for spatial non-linearity. The integrated thermal scanner data is presented with and without the reflection from the ground, as is the percent reflection. The contribution of reflection differs with aspect angle and, therefore, these corrections only apply to the scanner and interferometer data which were taken at 90 degrees. Table 16 shows reflection corrected data only in the scanner column so marked.

Table 16 generally illustrates the variation of radiant intensity with aspect angle in boost phase. This distribution is quite similar to the cardioid pattern observed in a turbojet engine exhaust. Maximum radiant intensity is observed at 60 degrees. Beam aspect is somewhat lower, with 30-degree aspect radiation being lower still. As has been discussed, however, it is believed that the HAST rocket engine produces a plume that is optically thick, and that it thus emits infrared radiation which is surface, rather than volume, dependent. Turbojets, on the other hand, generally emit optically thin, and thus volume dependent, radiation, with the possible exception being those engines operating at high afterburner power. The variation of radiant intensity with aspect angle of the full-scale HAST plume, therefore, may not always exhibit the familiar cardioid pattern in flight.

Figure 19 shows the radiometric performance versus time during the sustain phase, as observed with the AFATL radiometer at 60 degrees aspect angle. As in boost phase, the initial 10 seconds are not representative of long-term performance. The infrared time profile shown, tracks all the variations in engine and injection operation cycles at this aspect

angle. On the other hand, the output of the CSD radiometer at 30 degrees did not follow these variations and did not maintain relative agreement with the 60-degree readings. After other possibilities were eliminated, it was concluded that these anomalies were due to plume separation in the nozzle. Separation will occur when the full-scale engine is operated at sea level and at low chamber pressures during the sustain phase.

Table 17 summarizes all the useful radiometric data obtained during the sustain phase. Injection modes are designated as in Table 16, with the exception of Asy to mean asymmetric secondary injection. The interferometer data shown has been corrected roughly for its non-flat field of view. The 30-degree aspect angle data were discarded since they were dominated by the separated plume; scanner data were not collected in usable form due to operator error. The data are consistent with the boost data and subscale engine infrared performance. $\bar{J}$ appears to be reasonably constant at a given O/F ratio for this range of operating conditions indicating that plume radiant intensity varies fairly linearly with total flow rate over a fairly wide range of flow rates between about 90 and 2200 grams per second.

b. Spectral Data

The spectral variant intensity distribution of the full-scale HAST engine was determined to be very similar to that observed with the subscale engine. A representative spectrum for boost and sustain phase, respectively, are presented in Figures 20 and 21. Relative radiation emitted in the three subdivisions of the 2- and 5-micrometer band are equally similar to that observed with the subscale engine.

These data support the thesis presented earlier (Reference 5) that all hydrocarbon exhausts emit infrared energy within a very limited number of spectral distributions, which change noticeably only at the extremes of O/F ratio. The HAST engine spectra show that changing engine size has no effect on infrared spectral distribution. In this case, it can also be postulated that even changing the oxidizer (from IRFNA to O_2, for example) might not have had an appreciable effect on the spectrum.

c. Spatial Data

The BOFORS infrared scanner has two controls which permit gain to be changed in steps varying between 2 and 3, provided both controls are set properly. One of these is electronic and can be controlled from the control panel. The other is in the form of neutral density attenuators which have to be physically replaced on the camera head itself. These gain settings determine the size signal that will be registered by each cell in the matrix of 56 by 94. If the controls are set too low, some cells become saturated, i.e, their output becomes pegged at a maximum level that might be any fraction of the actual radiant intensity falling on the detector. The data in those cells, and probably for the total plume, become numerically unusable. If, on the other hand, the controls are set too high, dynamic range is lost since the output signal from each cell remains well below the maximum possible.

Usually, these instrument idiosyncrasies do not pose difficulties in that test runs can be performed in the beginning of a set of measurements to select the controls for optimum signal output. In the case of the full-scale HAST measurements test runs could obviously not be made and, since the first phase, boost, was only 45 seconds long, controls had to be preset based on extrapolations from the subscale data.

The assumptions that had to be made were (1) full-scale engine plume length (to determine the distance at which to place the detector), and (2) the maximum radiation expected within a rectangle Δx by Δy on the plume (represented by each cell of the matrix). These required further assumptions of (1) J, (2) the area or volume dependence of the radiation from the plume, and (3) the relative shape of the visible versus the infrared plume at sea level. Calculations were then performed using equations developed earlier (Reference 3) to estimate control settings.

Maximum infrared plume length during boost phase was estimated to be not more than 3.66 meters (12 feet), based on linear extrapolations of the subscale engine infrared and visible plumes, and previous photographs of a full-scale engine plume. A plume-to-detector distance of 9.14 meters (30 feet) was selected that would provide for a small margin of error by allowing plumes up to 4.27 meters (14 feet) to be imaged. The scanner was positioned at a point about 2 meters downstream perpendicular to the plume axis.

At this distance, Δx = 7.5 cm by Δy = 2.13 cm on the plume, producing a cell having an area of 16.26 cm^2. The subscale engine data, for an O/F similar to boost phase, showed plume radiation per unit area to be 1.06 $w/st/cm^2$. The estimated maximum radiation for the full-scale HAST in the above geometry is then 17.23 w/st per cell. Next, at 9.14 meters the solid angle subtended by the camera can be shown to be 1.33 by 10^{-4} steradians, and the latter two parameters combined to give:

$$CF_{max} = 4.36 \times 10^4$$

which corresponds to an amplifier setting of 50 in conjunction with neutral density attenuator $1/K_o$ factor of 2465.

It was thus decided to use an attenuator setting of 75 during the first 10 seconds of the boost, when unusually high exhaust radiation would prevail which did not correspond to a normal engine cycle, and set the control at 50 after the first 10 seconds.

A second estimate was also performed assuming volume dependent radiation and radiation per unit volume. Naturally, this assumption defined a different set of scanner gain control settings. This estimate was performed as backup to be used in the sustain phase in case the assumption of surface area dependent radiation proved to be inaccurate.

The boost phase data for the HAST were successfully obtained at these specific control settings, indicating the accuracy of the estimates. Conversely, they also proved that (1) the subscale engine plume data could be accurately extrapolated to predict full-scale engine total radiant intensity, (2) the radiation from HAST engine plumes was surface area dependent, and (3) the maximum radiation per unit area for the subscale plume was the same as that emitted by the full-scale plume.

The basic scanner data obtained during the boost phase of the HAST are presented in Tables 18 through 23. These correspond to the time frames shown in Table 16. The accuracy of the extrapolation was explicitly proven further when the operator attempted to obtain data at an attenuator setting of 20 (instead of 50) during the 10 seconds of the run shown in Figure 18. The four scanner matrices obtained during this brief period had a sizeable number of saturated cells. One of these matrices (taken at t = 29 to 30 seconds) is shown as an example in Table 24 with saturated cells indicated by asterisks. These four scanner plots could not be numerically reduced with any accuracy and were discarded from the final data.

The scanner data just presented were treated additionally to obtain further displays that can be used for the verification of analytical predictions and for direct comparisons against the airborne turbojet plume data format. These corresponding displays are presented in the Appendix. The first displays show radiant intensity versus axial distance along the plume (also known as station radiation). The second displays present a compact two-dimensional display of plume geometry, with radiant intensity shown as a quasi-gray level. The third displays give a three-dimensional format with length, width, and radiant intensity projected on the three axes. The latter display format is presently used to present all BASES (Beam Approach Seeker Evaluation System) airborne data.

SECTION IV

COMPARISON AGAINST ANALYTIC PREDICTIONS

A variety of models were previously used to calculate plume infrared properties from propellant and engine design parameters (References 7 and 8). Emissions from hot CO_2, H_2O, CO and, in one case, particulates, were calculated over a band of infrared wavelengths between 1 and 8 micrometers, ignoring atmospheric absorption.

Briefly, the first prediction calculations (Reference 9) used a chemical equilibrium program called Isp, followed by the Dynamic Sciences Generalized Kinetics Program (GKP) (Reference 10). The output was fed into a Low Altitude Plume Program (LAPP) (Reference 11) as well as a Naval Weapons Center/Brigham Young University plume model (Reference 12). The plumes predicted by these codes were then used as the basis for plume IR predictions for the HAST engine using two different gaseous radiation band models. These were a code developed to predict radiant base heating from the plume of NASA's Saturn IV rocket (Reference 13) and one developed by the Army Missile Command to predict plume IR signatures of jet aircraft engines (Reference 14).

The first set of predictions were all made for an O/F ratio of 3.2 and cruise mode for a number of altitude/flight velocity conditions. A valid comparison can be made between the predictions for sea level static ambient conditions and the radiometric, spatial, and spectral measurement data for the unaugmented engine operating at an O/F of 3.1 in the sustain phase.

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14. H. T. Jackson, An Analytical Model for Predicting the Radiation from Jet Plumes, Army Missile Command, RE-TR-70-7, April 1970.

Table 25 compares two of the predicted variations of total radiant intensity (in the nominal 4- to 5-micrometer band) with aspect angle with the measured data. The radiometric predictions compare within a factor of 2 with the worst error occurring in the extrapolated calculation. There is no discernible trend to the calculations; they are neither consistently high nor consistently low.

The predicted plume spatial radiation distributions are in the form of isothermal contours as shown in Figure 22. It is thus possible only to compare approximate plume lengths and widths; it is not possible to make station radiation comparisons. The predicted plume boundary (600 degrees Kelvin contour) is 47 feet long by 2.4 feet in diameter. Even if the plume boundary is assumed to be at a higher temperature (1000 degrees Kelvin), the calculations predict a plume of 22 feet long by 0.75 foot in diameter. The actual plume is considerably shorter (about 8 feet at an O/F = 3.1 in sustain phase with an absolute measured maximum of 12 feet even in boost phase) and somewhat wider (about 2.6 feet) in both sustain and boost. Some of the discrepancy may be due to flow separation within the nozzle that is believed to occur during sustain mode at sea level. However, the predictions differ from the boost data at an O/F of 3.2 where separation is not a problem, and where the flow rates are higher. There is thus some question as to the validity of more detailed spatial distribution calculations that could be made based on these predictions.

The spectrum between 1 and 8 micrometers predicted for the HAST engine at sea level static conditions for a 30-degree aspect angle is shown in Figure 23. These calculations ignored the contribution of emission by particulates and thus this spectrum differs significantly from any of the measured spectra. Abundant graybody radiation is emitted by the HAST propellant at any flow rate over a fairly wide range of O/F ratios including the one at which the predictions were performed. This is evident from all the spectra presented in this report and also from Figure 24 which shows a measured spectrum for this type of fuel and particulate-rich exhaust carried forward to 14 micrometers.

Another prediction of the HAST infrared signature was also previously made (Reference 8), this time with graybody radiation included in the calculations. In this instance the signature was calculated at sea level in boost phase at an O/F believed to be 3.5.

This prediction is based on an equilibrium thermochemical program developed at Naval Weapons Center (Reference 15) which was input to an equilibrium method of

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Reference

15. H. N. Browne, D. R. Cruise, and M. M. Williams, The Theoretical Computation of Equilibrium Compositions, Thermodynamic Properties and Performance Characteristics of Propellant Systems, NAVWEPS Report No. 7043, June 1960.

characteristics (Reference 16) and an equilibrium mixing (Reference 17) program. The results of the plume flow-field analyses were finally used to predict spectral radiant intensity distributions using the computer solution described in Reference 13.

The radiometric comparison of the data is shown in Table 26. The predicted radiation at 30 degrees aspect angle is off by a factor of 2; otherwise, there is reasonable agreement. It is again, however, misleading to compare single radiometric values to see if valid plume predictions have been made.

Spatial estimates in this instance are limited to a prediction of a maximum plume diameter of about 11 inches, and the determination that the first Mach disc would occur at about 9.9 inches with a shock at about 17.5 inches. This prediction is shown in Figure 25. The prediction of plume boundary does not agree with the measured diameter of about 29 inches. The Mach discs and shocks at sea level do not show up in infrared or visible imagery at discrete locations but tend to run into each other creating a luminous core, as shown in the thermalscanner displays in Section III and in the Appendix. The prediction of a precise location for only the first Mach disc and the first shock, therefore, is of little practical value and almost impossible to verify.

The last prediction at sea level is of spectral distribution. Spectral radiant intensity distributions were predicted for two bands, 1.8 to 2.5 and 4.0 to 5.6 micrometers (as shown in Figures 26 and 27) for the 90-degree aspect angle. These data show more graybody radiation than do the first set of predictions. However, the beginning of the H_2O and CO_2 band emissions in the 2.2 to 2.5-micrometer region is much too high and the prediction of graybody radiation increasing at wavelengths beyond 5 micrometers is wrong; graybody radiation monotonically decreases beyond 5 micrometers.

Taking also into account the gap in the predictions between 2.5 and 4.0 micrometers can only lead to the inevitable conclusion that these predictions are unsatisfactory. The method of characteristics prediction technique is really only useful for very high altitude (well above 100,000 feet) rocket engines exhausts where there is a large distance between shocks, and the length of the plume to the first Mach disc and shock is of interest. Its use for sea level or even low altitude plume prediction is questionable.

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16. M. W. Garbrick, Analysis of an Inviscid Exhaust Plume, Martin Marietta Corporation Report No. OR 9171, December 1967.

17. M. W. Dowdy, et. al., Missile Exhaust Plume and Shock Layer Studies, Martin Marietta Corporation Report No. OR 10,338, December 1969.

The lack of agreement between predictions and measurements at static altitude has also been previously reported for a kerosene/oxygen rocket engine (Reference 18). Causes for some of the discrepancies have been suggested in this reference. The HAST engine case points up another major deficiency in the codes used: incorrect predictions of graybody radiation emission. This point was not evident in the case of the simple kerosene/oxygen engine exhaust which primarily emitted molecular radiation.

Reference

18. D. B. Ebeoglu and C. W. Martin, Experimental Verification of Infrared Plume Predictions for a Rocket Engine, AFATL-TR-74-191, Eglin Air Force Base, Florida, November 1974.

SECTION V

CONCLUSIONS AND RECOMMENDATIONS

1. CONCLUSIONS

A detailed discussion of the conclusions reached from the infrared measurements and analysis performed on the subscale and full-scale HAST engines accompany the data presented in Sections III and IV. Following is a summary of these conclusions:

(1) The subscale engine provides a valid spatial and spectral infrared simulation of the exhaust plume of the full-scale HAST.

(2) The full-scale infrared plume performance can be linearly extrapolated from the subscale data.

(3) Co-flowing streams of air or nitrogen provide more valid ambient conditions for testing the effectiveness of augmentation techniques than do static sea level conditions.

(4) Oxygen injection produces about a 50 percent increase in radiant intensity with a Mach 0.5 nitrogen ambient at an O/F less than 3.0 at less than 6 percent primary flow rate.

(5) Methane injection produces about a 50 percent increase in radiant intensity with a Mach 0.5 air ambient at an O/F greater than 3.0 at less than 6 percent primary flow rate.

(6) Atlantic Research Corporation POPS device produces approximately the same performance as methane.

(7) Multi-point (or preferably annular) secondary injection is required to achieve the augmentation cited. One-point and even two-point injections do not give consistent or satisfactory results.

(8) The analytic predictions of the HAST infrared performance made to date are not valid.

(9) A problem of flow separation exists when the full-scale engine is operated in sustain mode at static sea level conditions.

2. RECOMMENDATIONS

On the basis of the data presented in previous sections and the conclusions reached from them, the following recommendations were made immediately after the measurements:

(1) Perform remaining infrared augmentation experimentation on the subscale engine with co-flowing air or nitrogen streams; do not perform any further static tests.

(2) Determine the capability of bi-propellant injection (simultaneous injection of gaseous fuel and oxidizer) to increase secondary combustion.

(3) Determine the capability of high temperature fuel injection to increase secondary combustion.

(4) Determine the capability of hydrogen injection to increase the energy level of emission from the exhaust plume.

(5) Determine the capability of CO_2 injection (as CO plus O_2 bi-propellant) on augmenting CO_2 radiation.

(6) Increase the ratio of secondary to primary propellant flow rate for all techniques to determine optimum augmentation, i.e., beyond the 3 to 6 percent originally proposed for fuel or oxidizer injection.

(7) Determine the capabilities of IRFNA as well as O_2 injection (in order to make use of on-board oxidizer and thus reduce HAST payload).

(8) Establish a verified analytic prediction capability in line with previous recommendations (References 1, 18).

Most of the steps recommended above were performed between February and May 1975. The results of these experiments are reported in the CSD report (Reference 4). In summary the data show that:

(1) Bi-propellant injection [high temperature methyl acetylene-propadiene (MAPP) gas and oxygen as well as methane and oxygen] produces 300 to 600 percent augmentation with Mach 0.5 airflow.

(2) Hydrogen injection gives quite similar performance.

(3) These performances are achieved for approximately 20 percent secondary to primary ratio of flow rates. Augmentation does not increase appreciably

at higher secondary flow rates; augmentation is reduced at lower secondary flow rates to about the monopropellant performance at 3 to 6 percent secondary to primary ratios.

(4) Increasing monopropellant injection flow rates does not increase augmentation measurably.

(5) High temperature fuel (MAPP) injection by itself gives about the same augmentation performance as methane.

(6) MAPP/oxygen injection produces approximately twice as much augmentation as methane/oxygen.

(7) CO_2 injection does not give appreciable augmentation.

(8) IRFNA injection decreases the infrared radiant intensity as does any liquid fuel or oxidizer injection tested to date.

The bi-propellant and hydrogen injection results show the feasibility of producing significant augmentation by maximizing secondary combustion in the plume. Augmentation improves by an order of magnitude in a non-afterburning environment indicating that the same performance can be sustained during flight. Bi-propellant injection can therefore be considered a possible major breakthrough in infrared augmentation technology.

It is thus finally recommended that the technique be evaluated on a subscale HAST engine in an environment simulating flight altitude as well as air velocity. It is also recommended that the applicability of the technique to augment other primary propellants and engines be investigated. The feasibility of the concept of augmenting through secondary combustion has been shown. The technique of bi-propellant injection should be exploited for as many other target systems as possible.

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5. D. B. Ebeoglu and C. W. Martin, Effect of Mixture Ratio on UV, Visible and Infrared Radiation for Exhaust Plumes, AFATL-TR-75-79, Eglin Air Force Base, Florida, May 1975.

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7. W. L. Rothschild, Analysis of the HAST Rocket Exhaust Plume Infrared and Radar Characteristics, AFRPL-TR-73-16, Edwards Air Force Base, California, May 1973.

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18. D. B. Ebeoglu and C. W. Martin, Experimental Verification of Infrared Plume Predictions for a Rocket Engine, AFATL-TR-74-191, Eglin Air Force Base, Florida, November 1974.

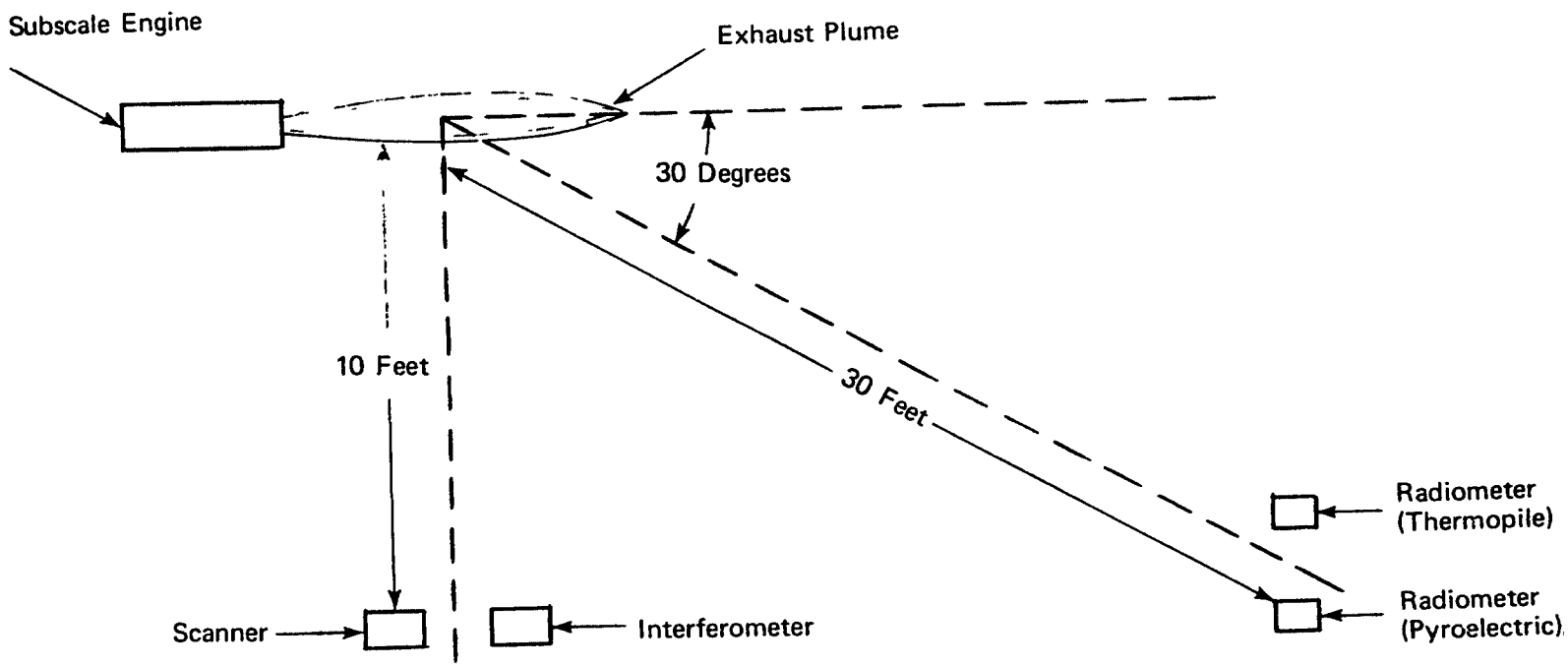

Figure 1. Subscale HAST Infrared Measurements Geometry

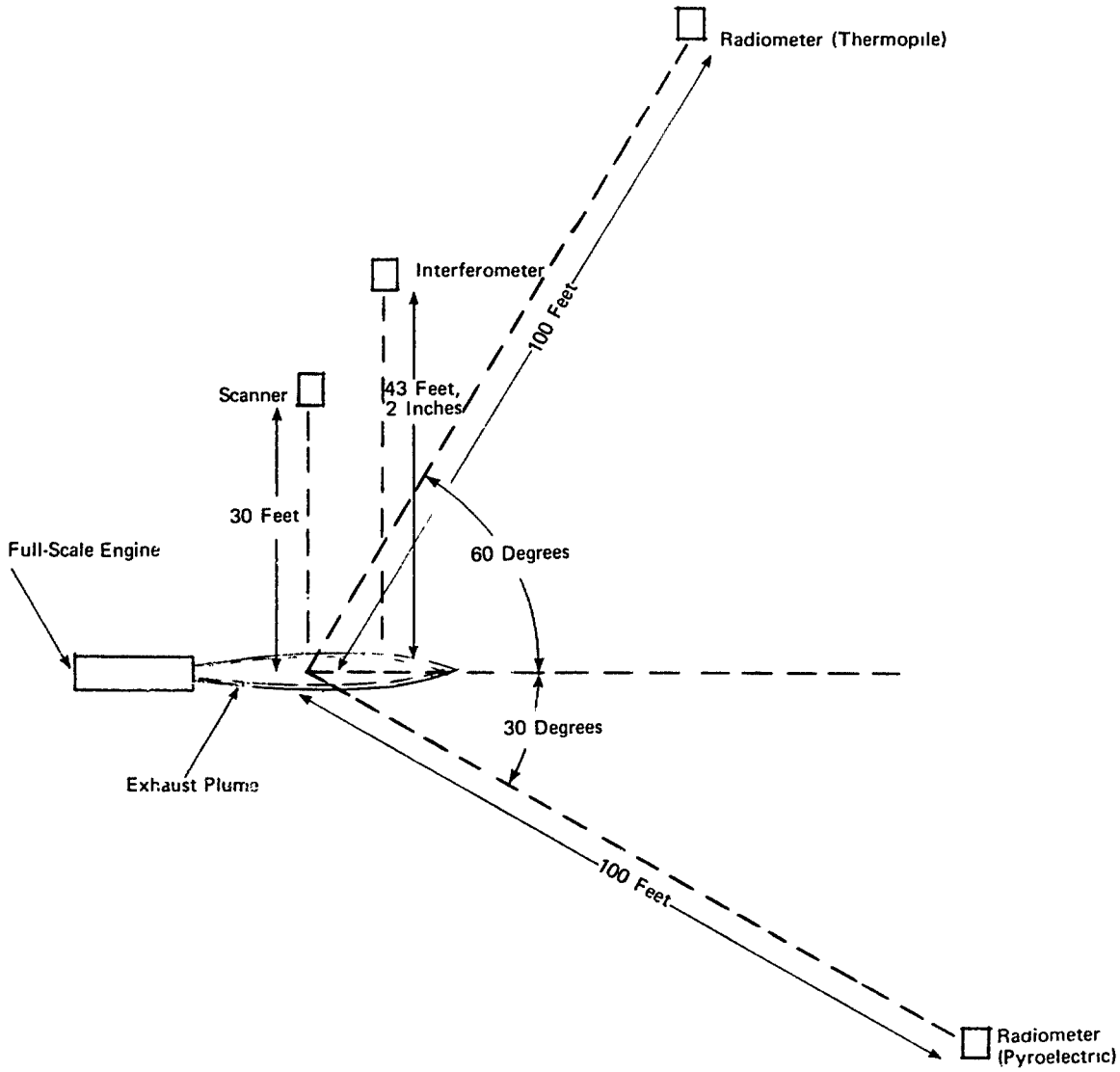

Figure 2. Full-Scale HAST Infrared Measurements Geometry

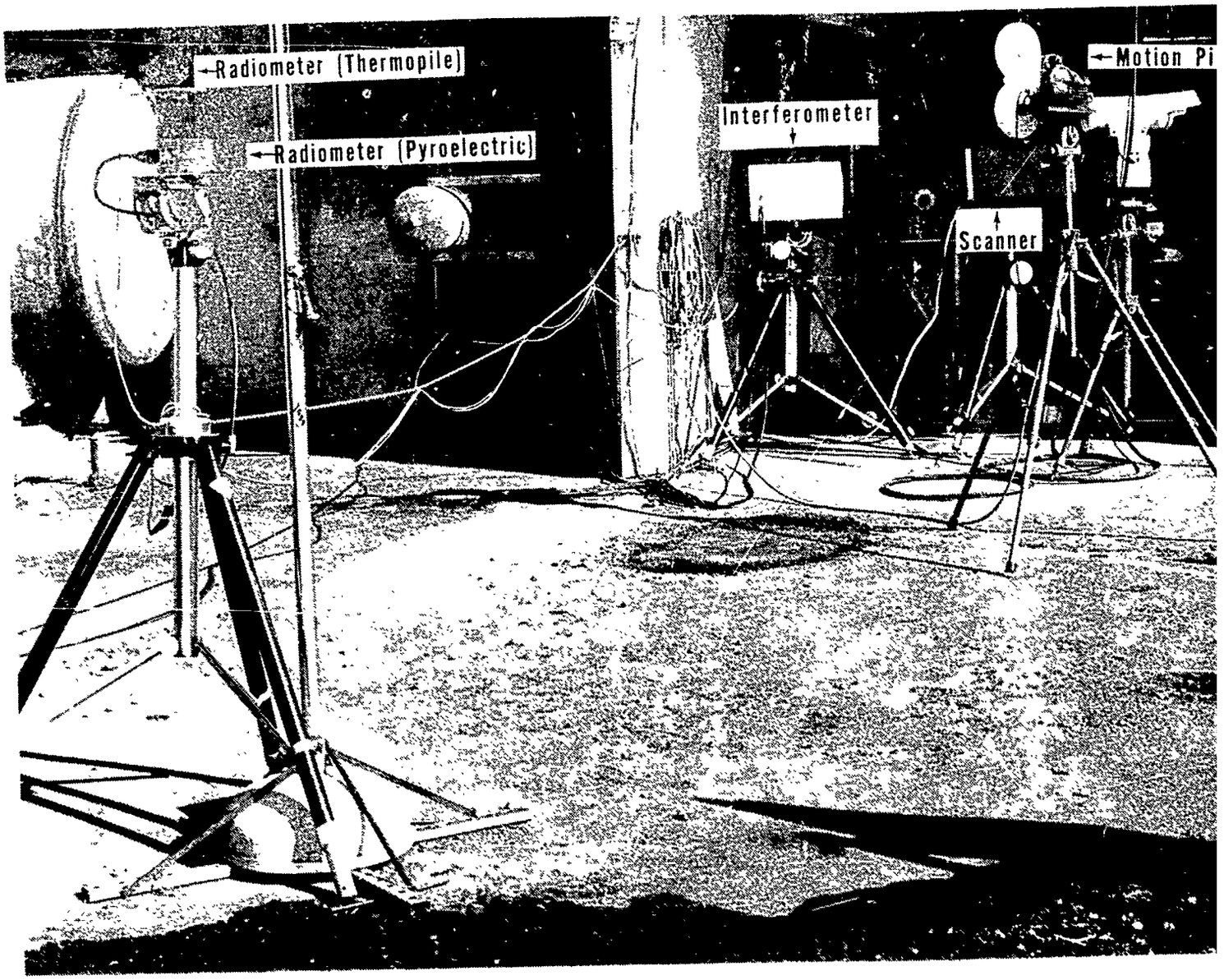
Radiometer (Thermopile)
Radiometer (Pyroelectric)
Interferometer
Scanner
Motion Pi

Figure 3.

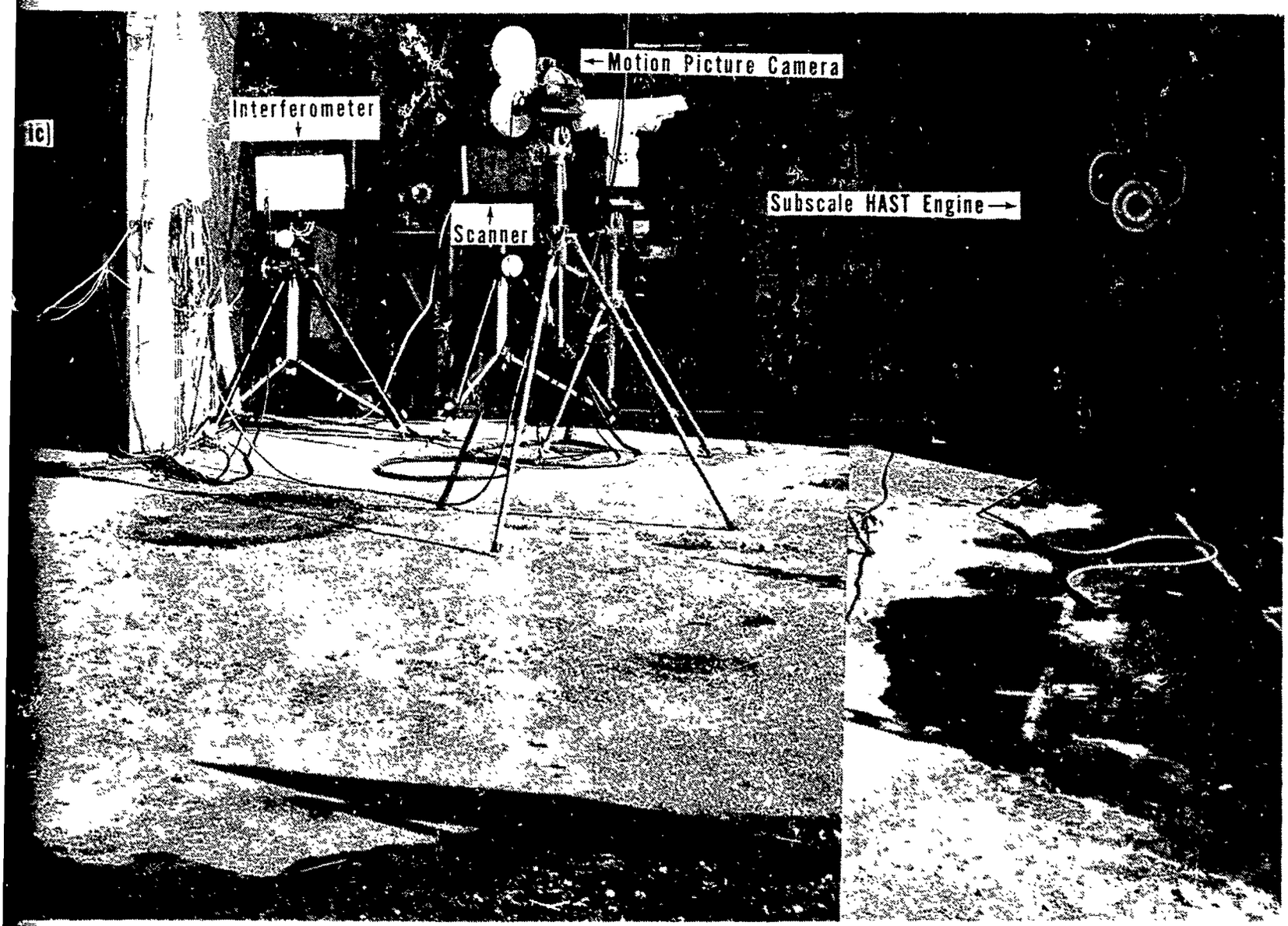

Figure 3. Subscale HAST Engine/Infrared Instrumentation Arrangement

2

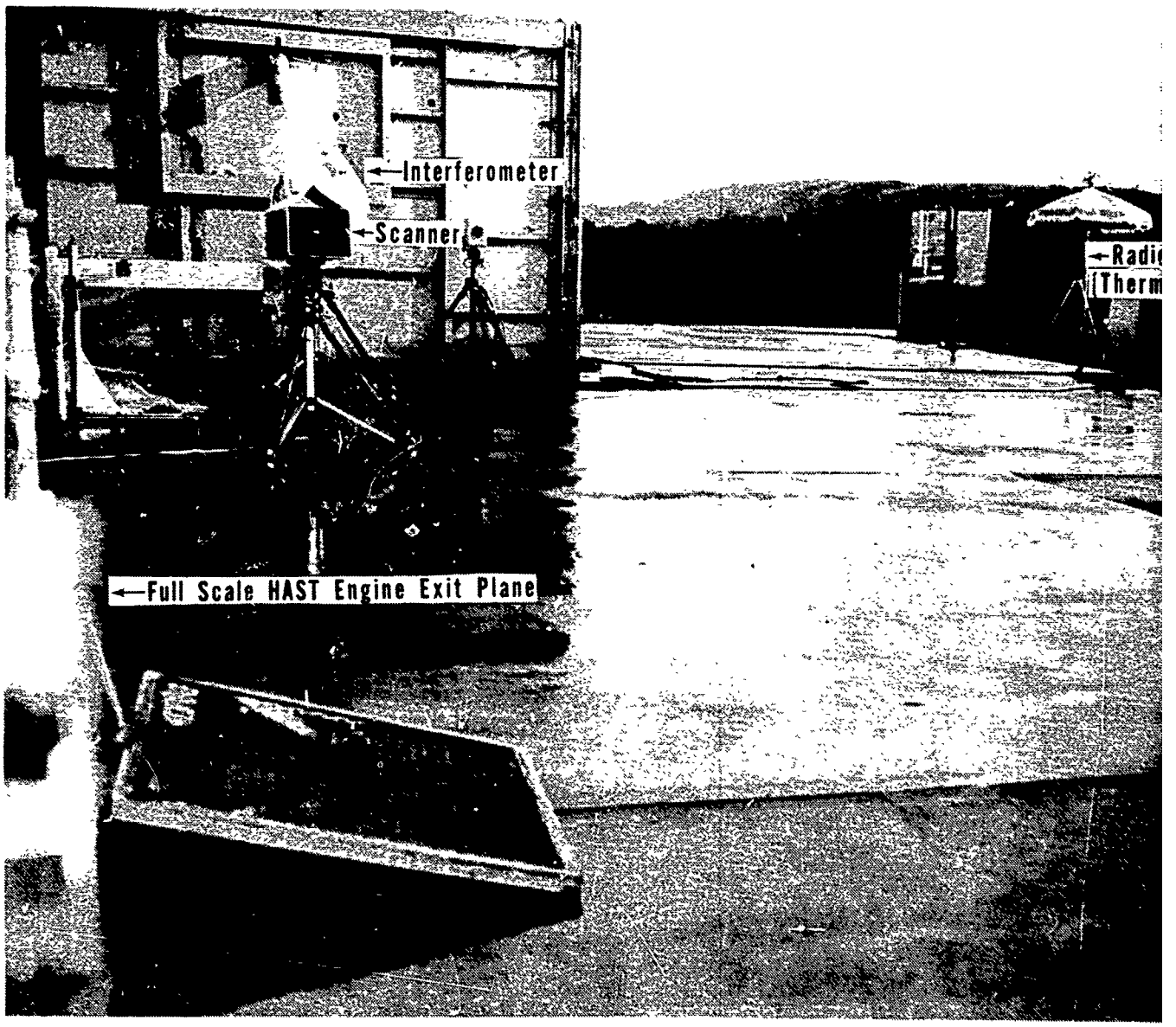

Figure 4. Full-Scale HAST Engine/Infrare

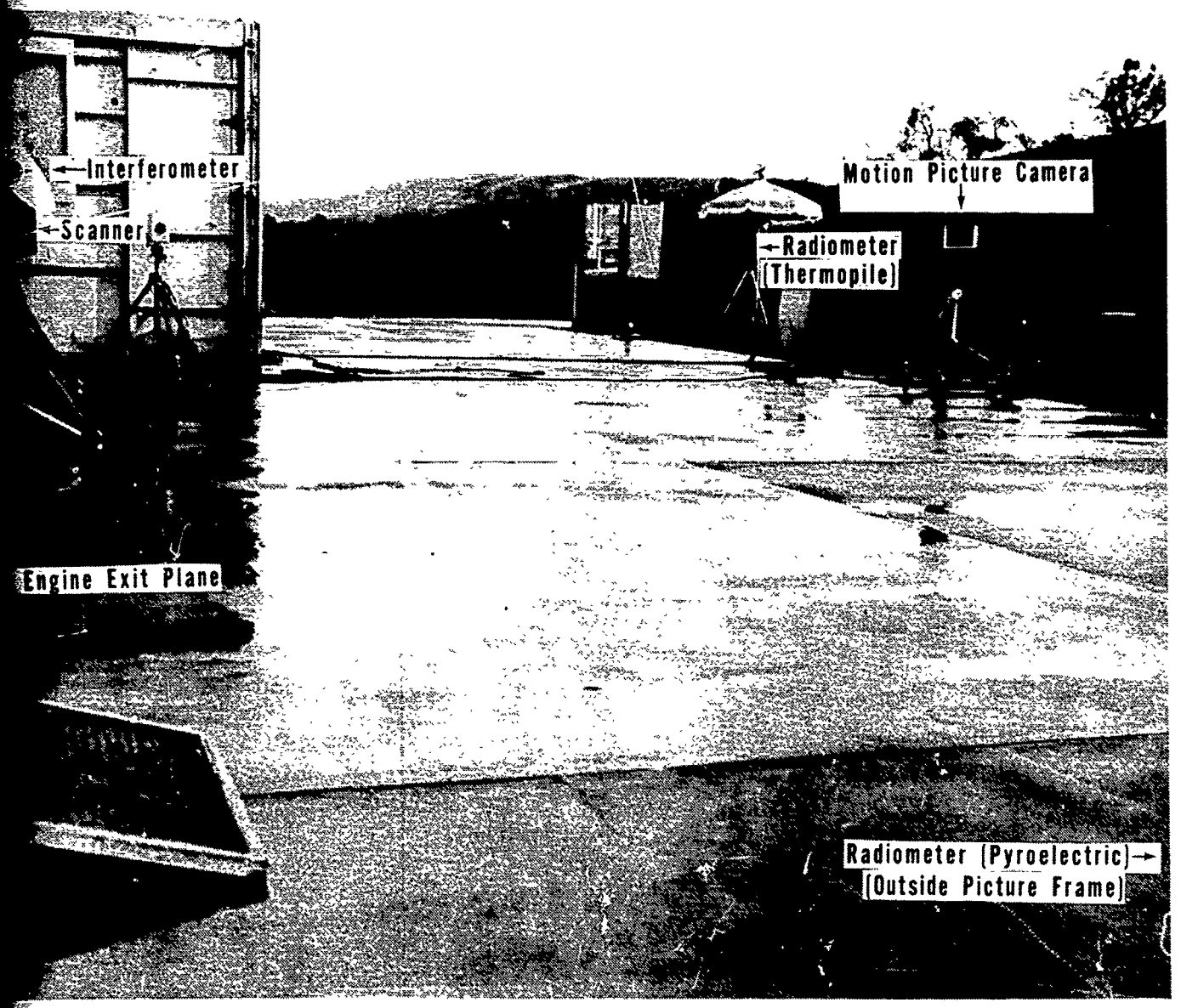

Figure 4. Full-Scale HAST Engine/Infrared Instrumentation Arrangement

2

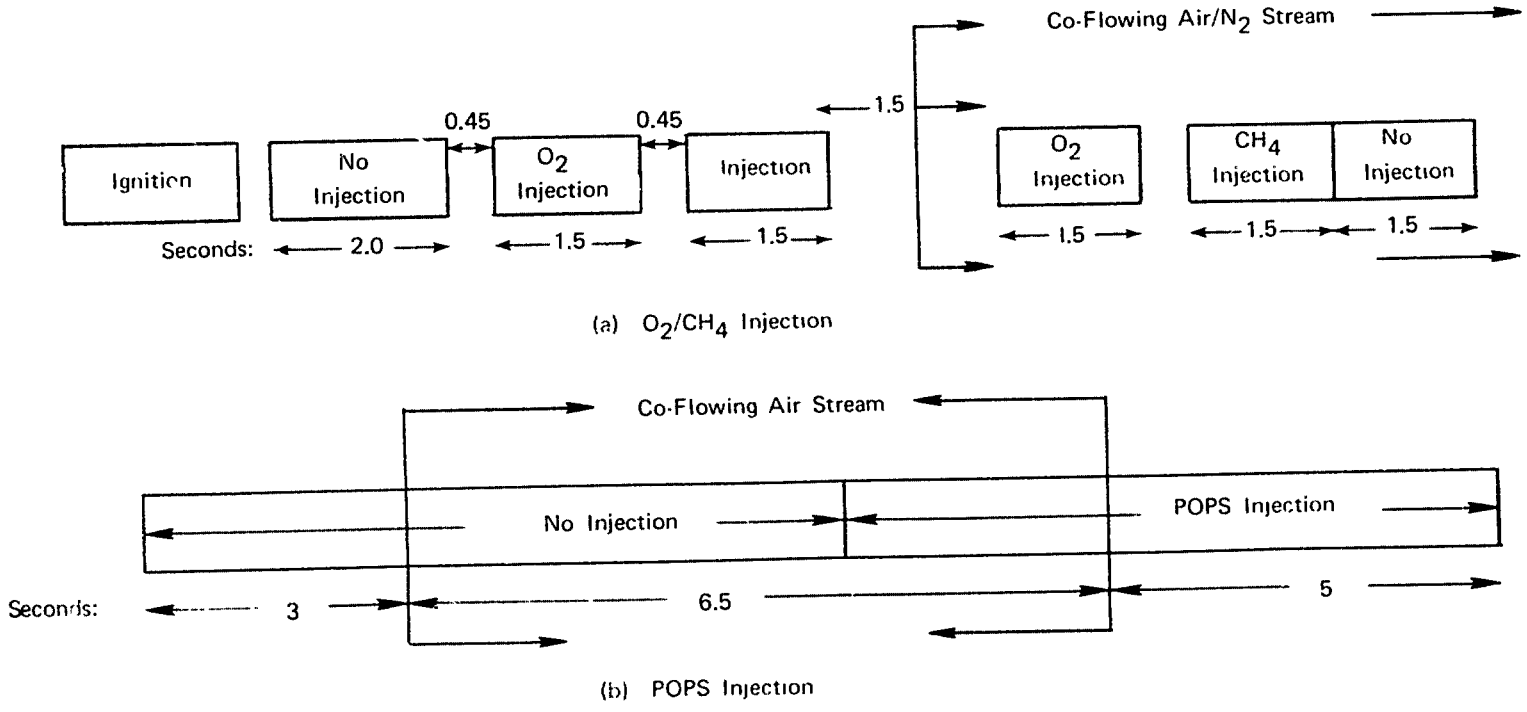

Figure 5. Time Sequences for Subscale HAST Engine Secondary Injection

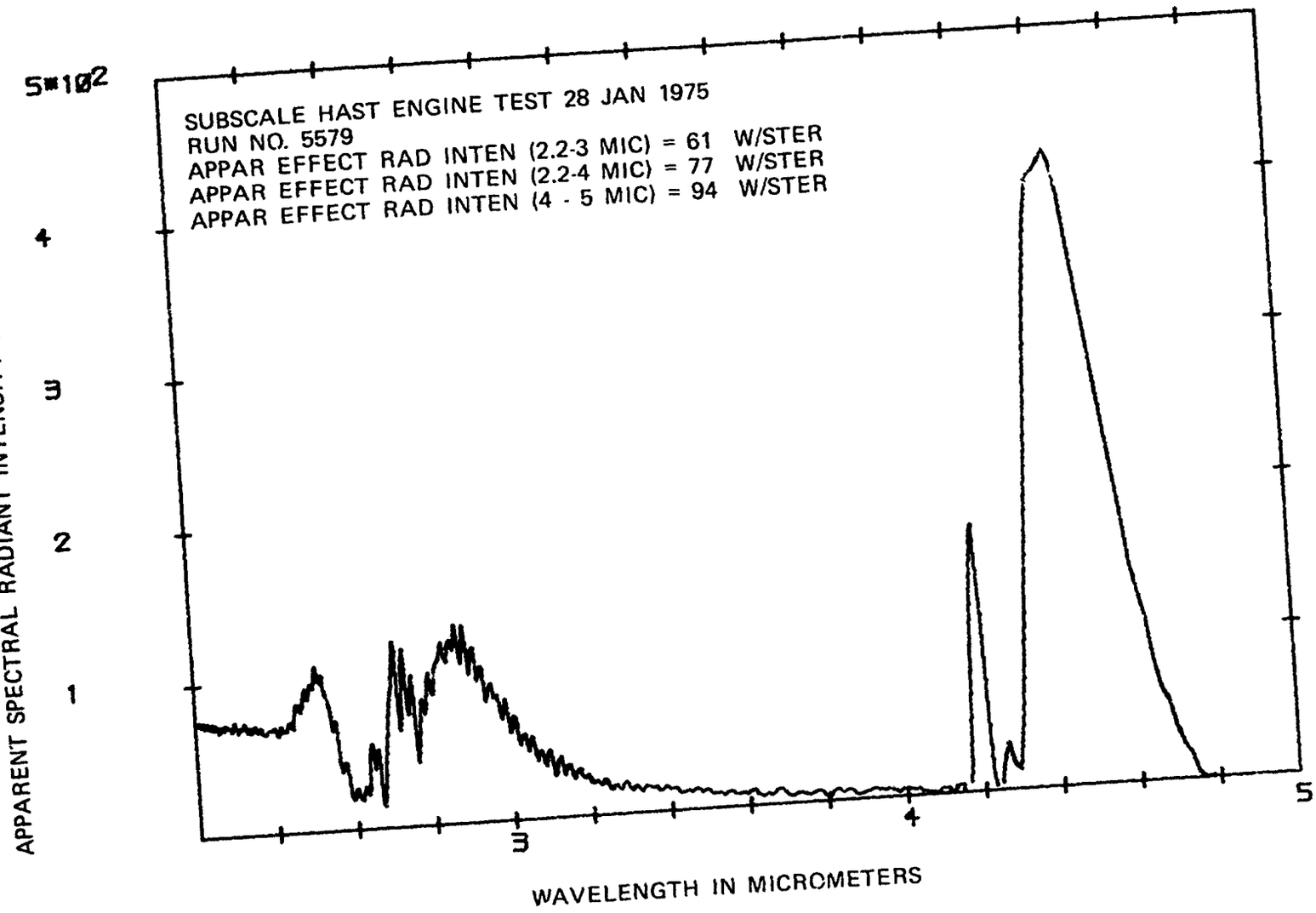

Figure 6. Subscale Engine Spectrum - No Injection, No Flow

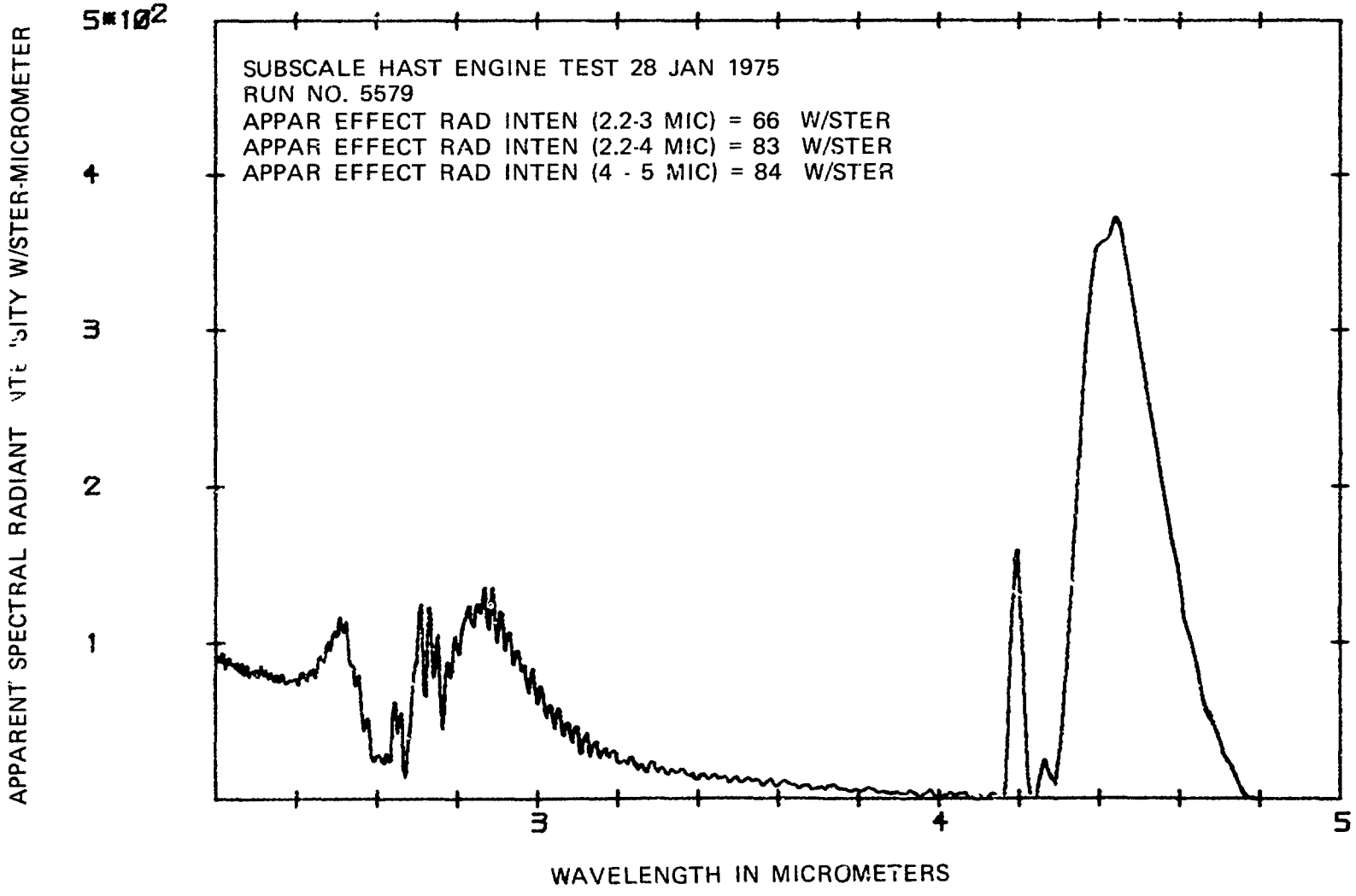

Figure 7. Subscale Engine Spectrum - O_2 Injection, No Flow

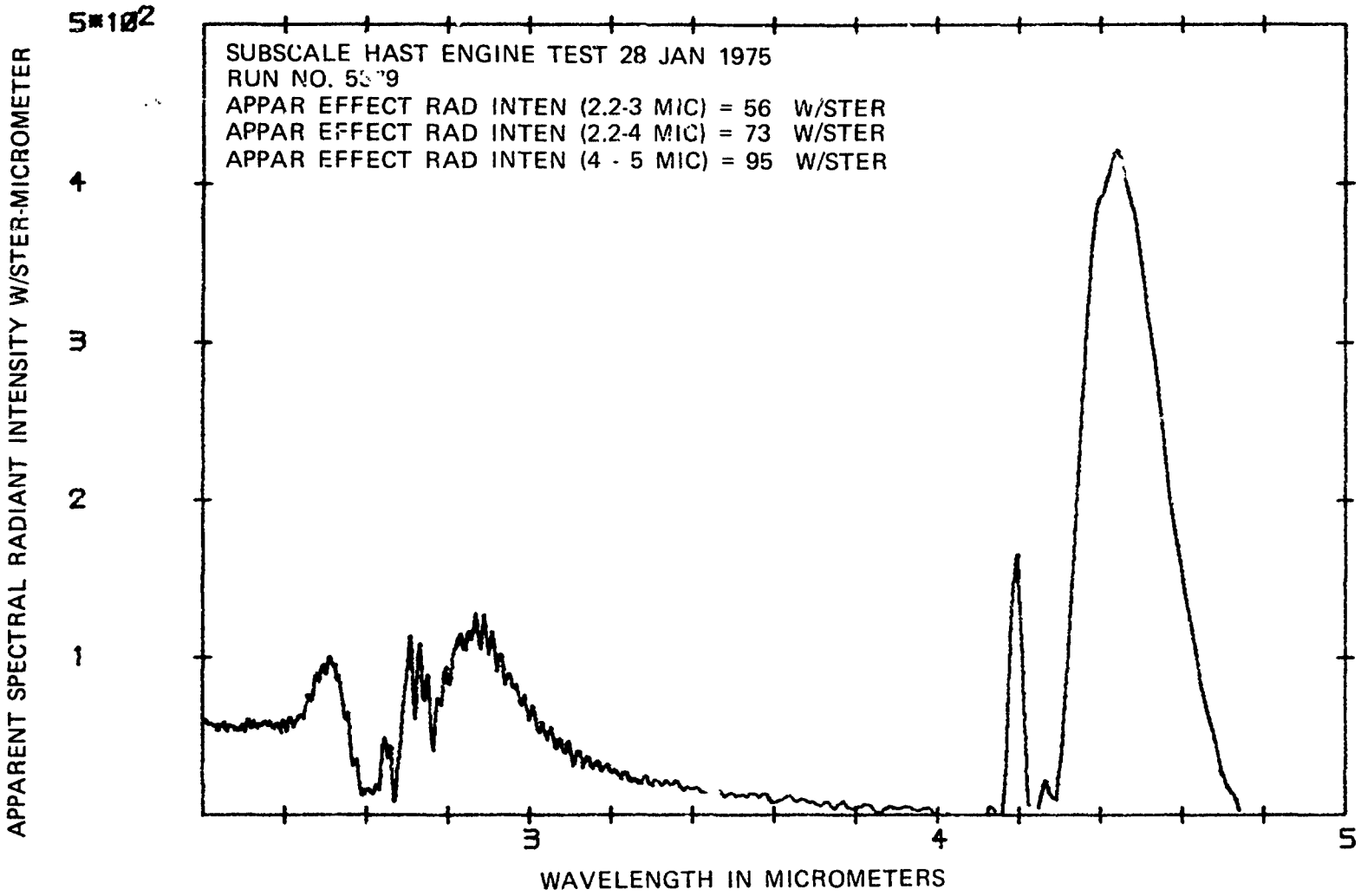

Figure 8. Subscale Engine Spectrum - CH_4 Injection, No Flow

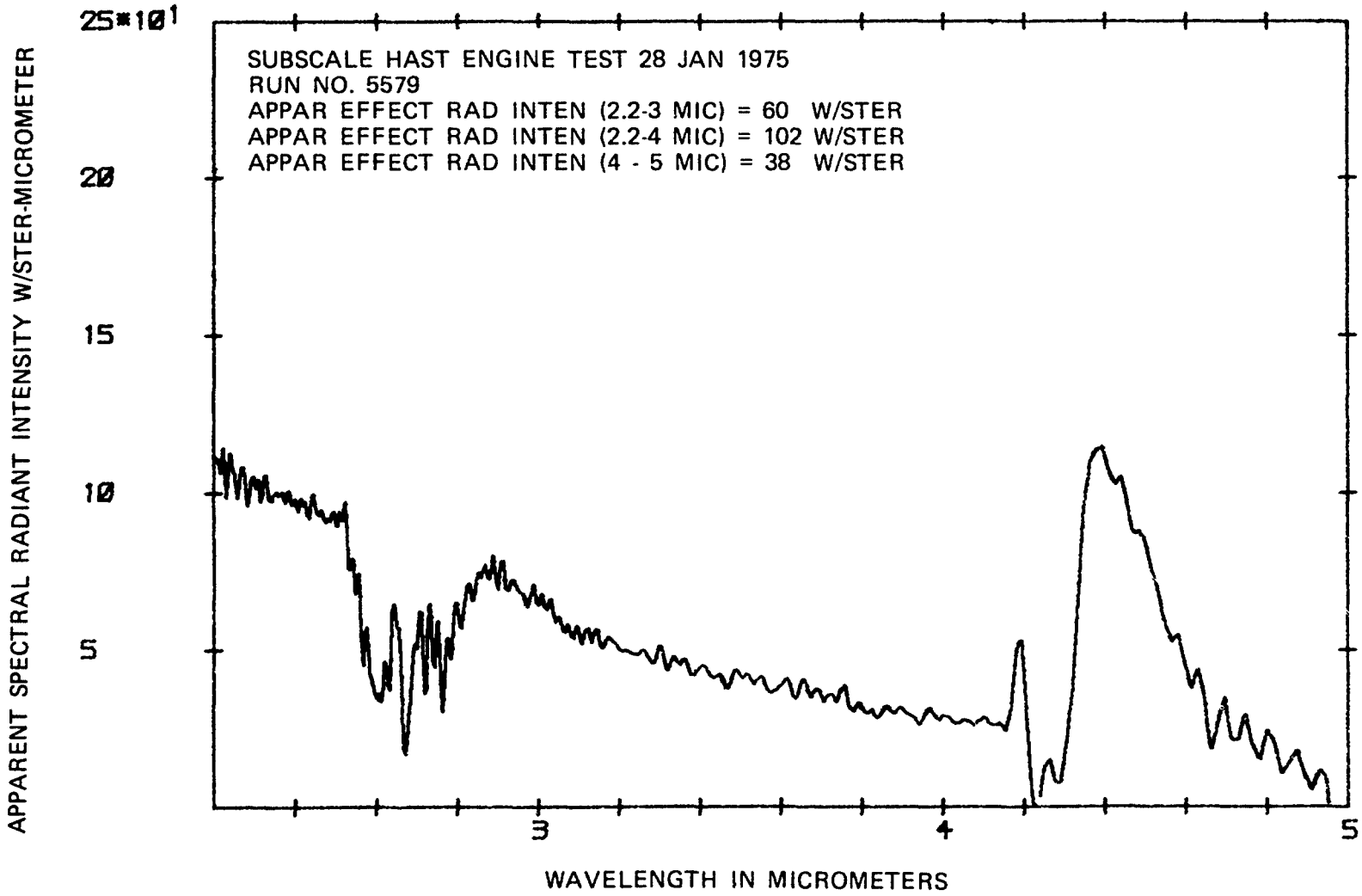

Figure 9. Subscale Engine Spectrum - O_2 Injection, Mach 0.3 N_2 Flow

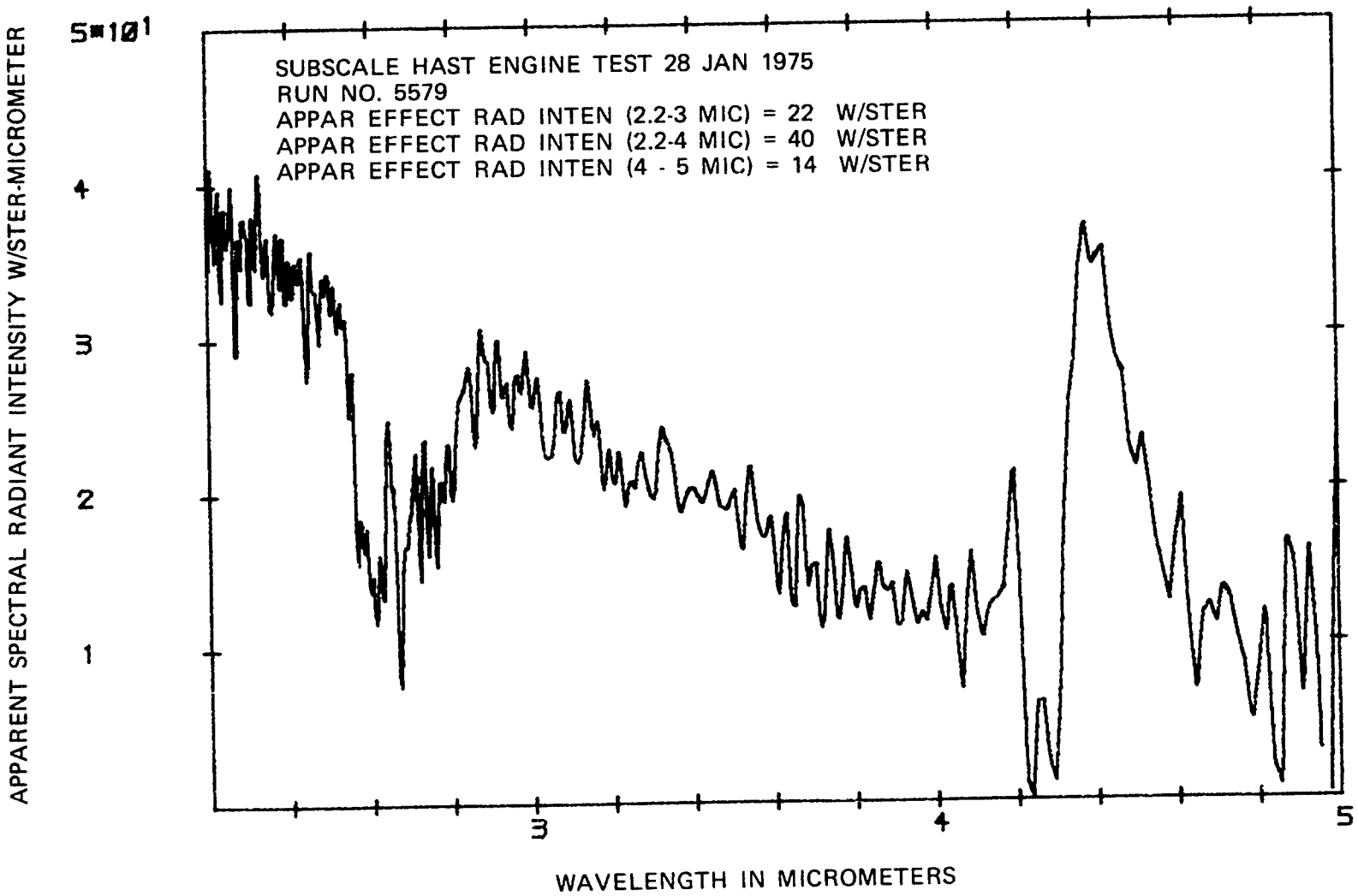

Figure 10. Subscale Engine Spectrum - CH_4 Injection, Mach 0.3 N_2 Flow

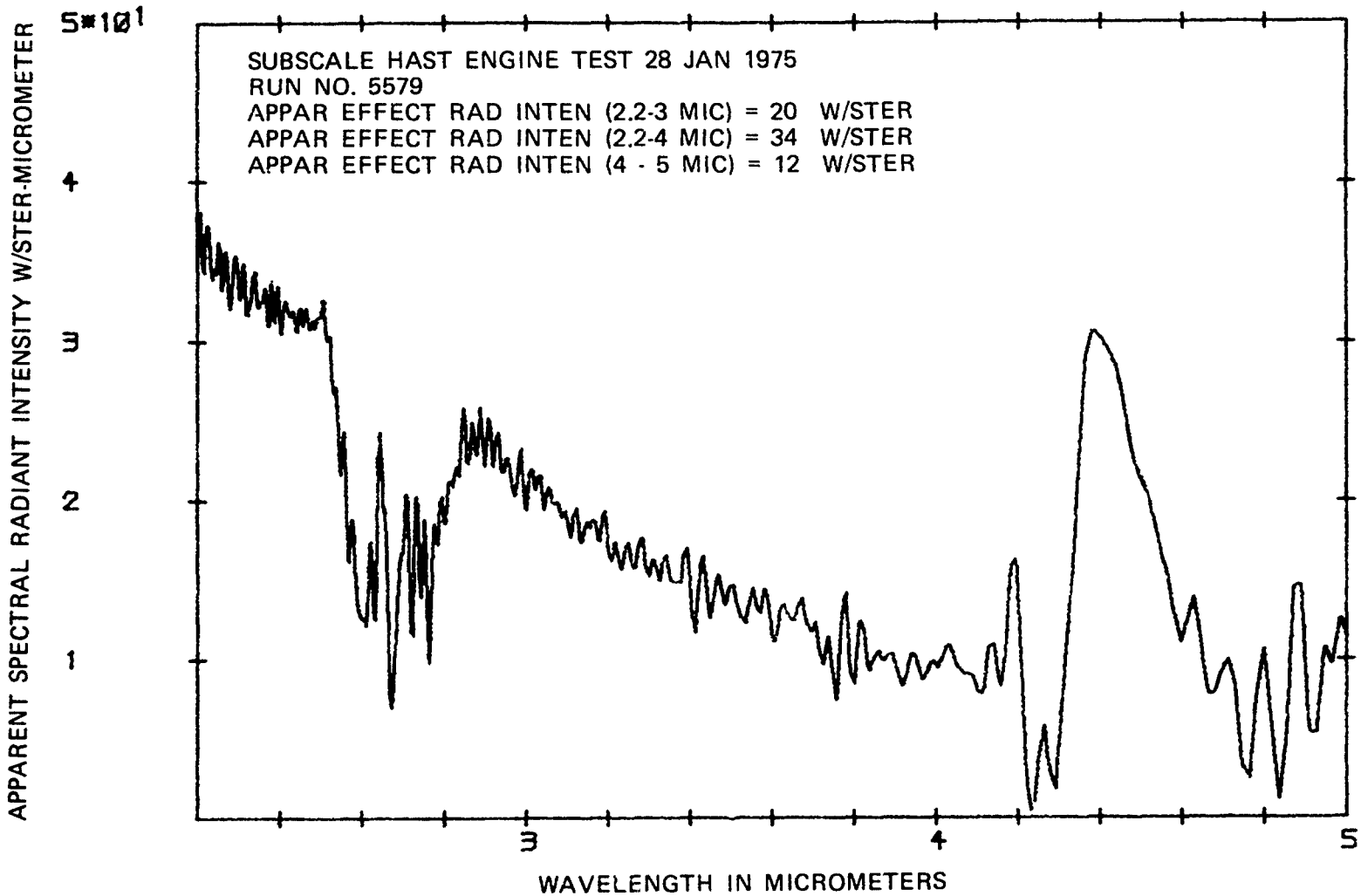

Figure 11. Subscale Engine Spectrum, No Injection, Mach 0.3 N_2 Flow

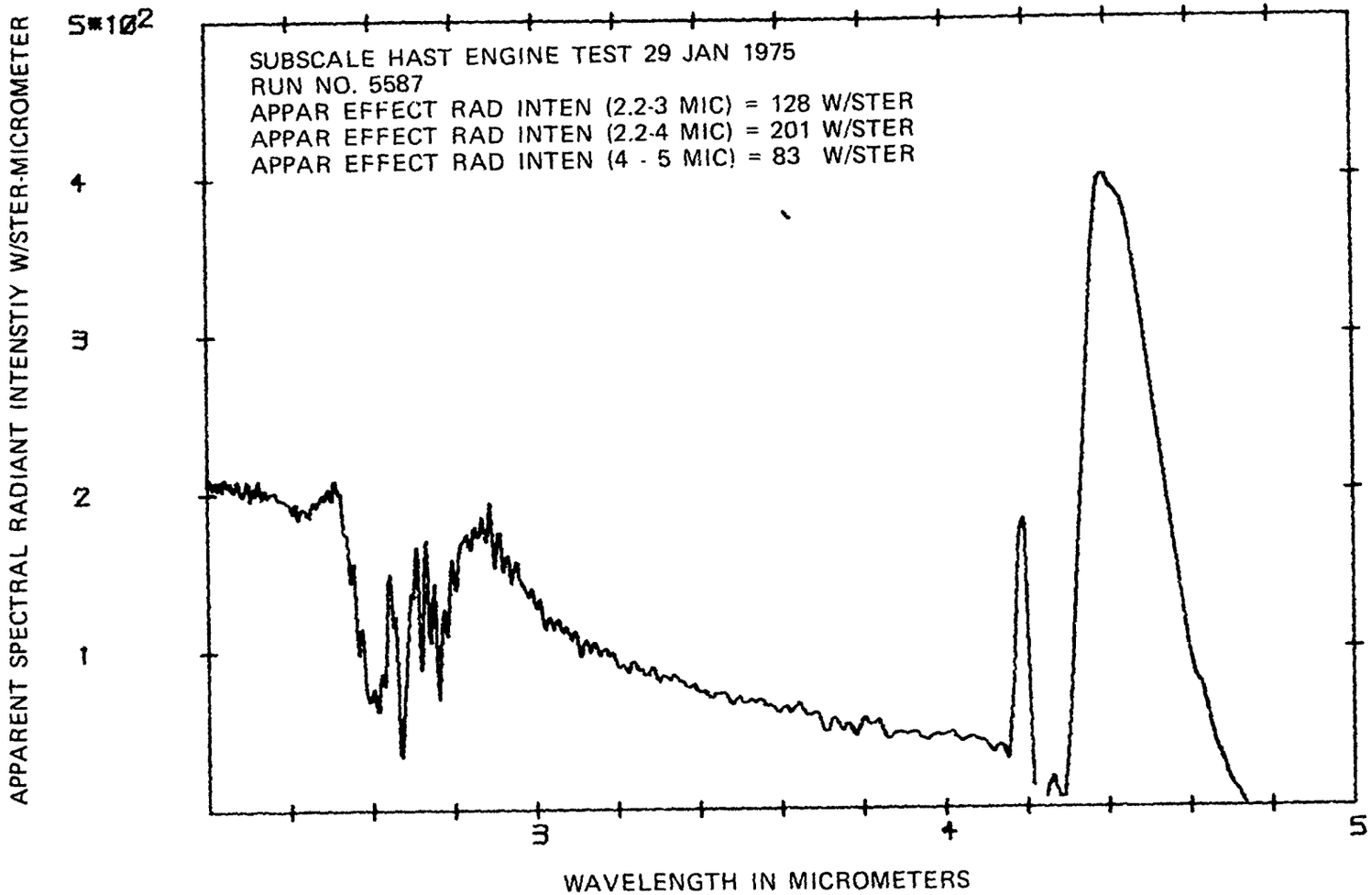

Figure 12. Subscale Engine Spectrum, No Injection, No Flow

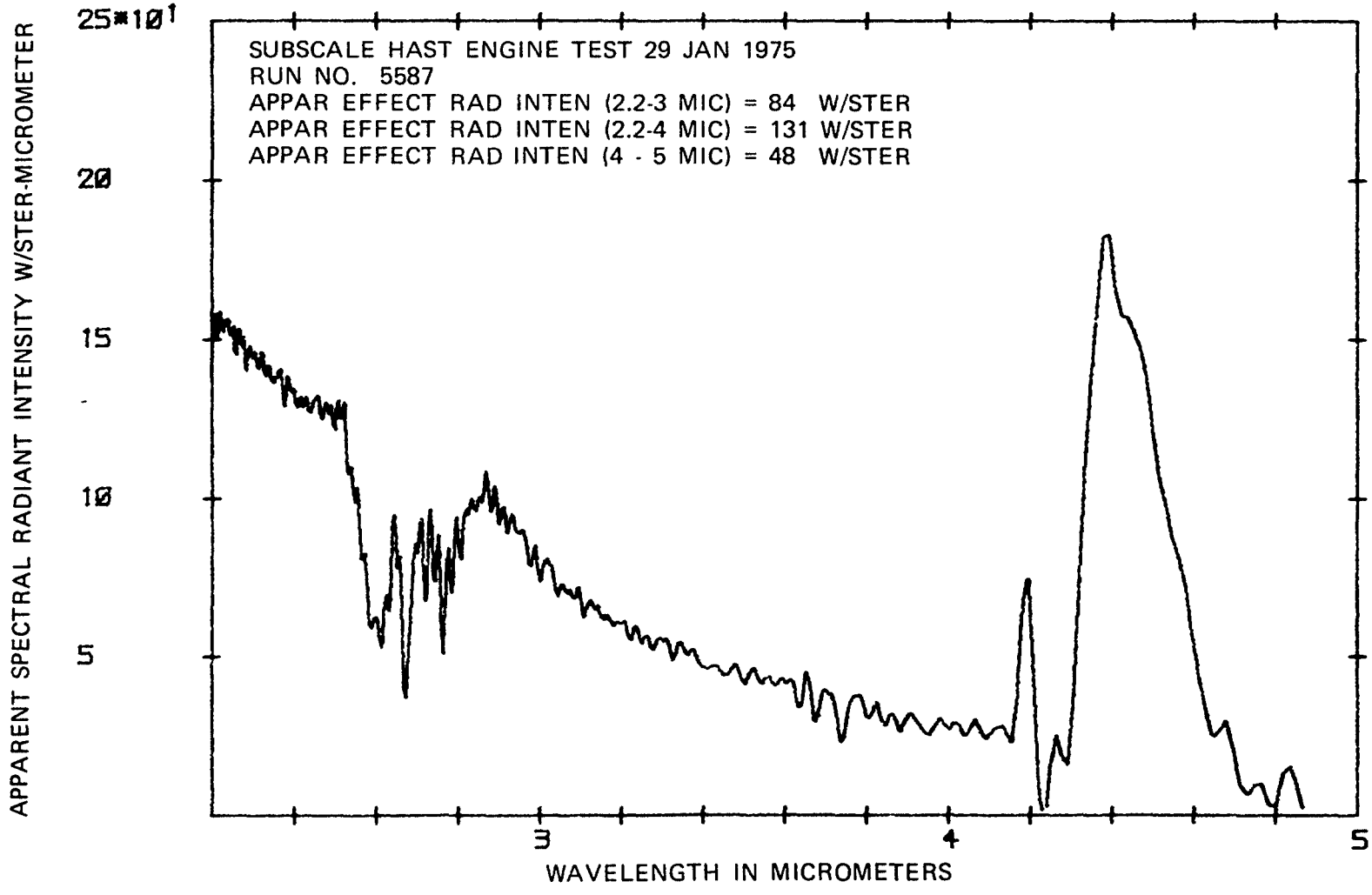

Figure 13. Subscale Engine Spectrum, No Injection, Mach 0.7 Airflow

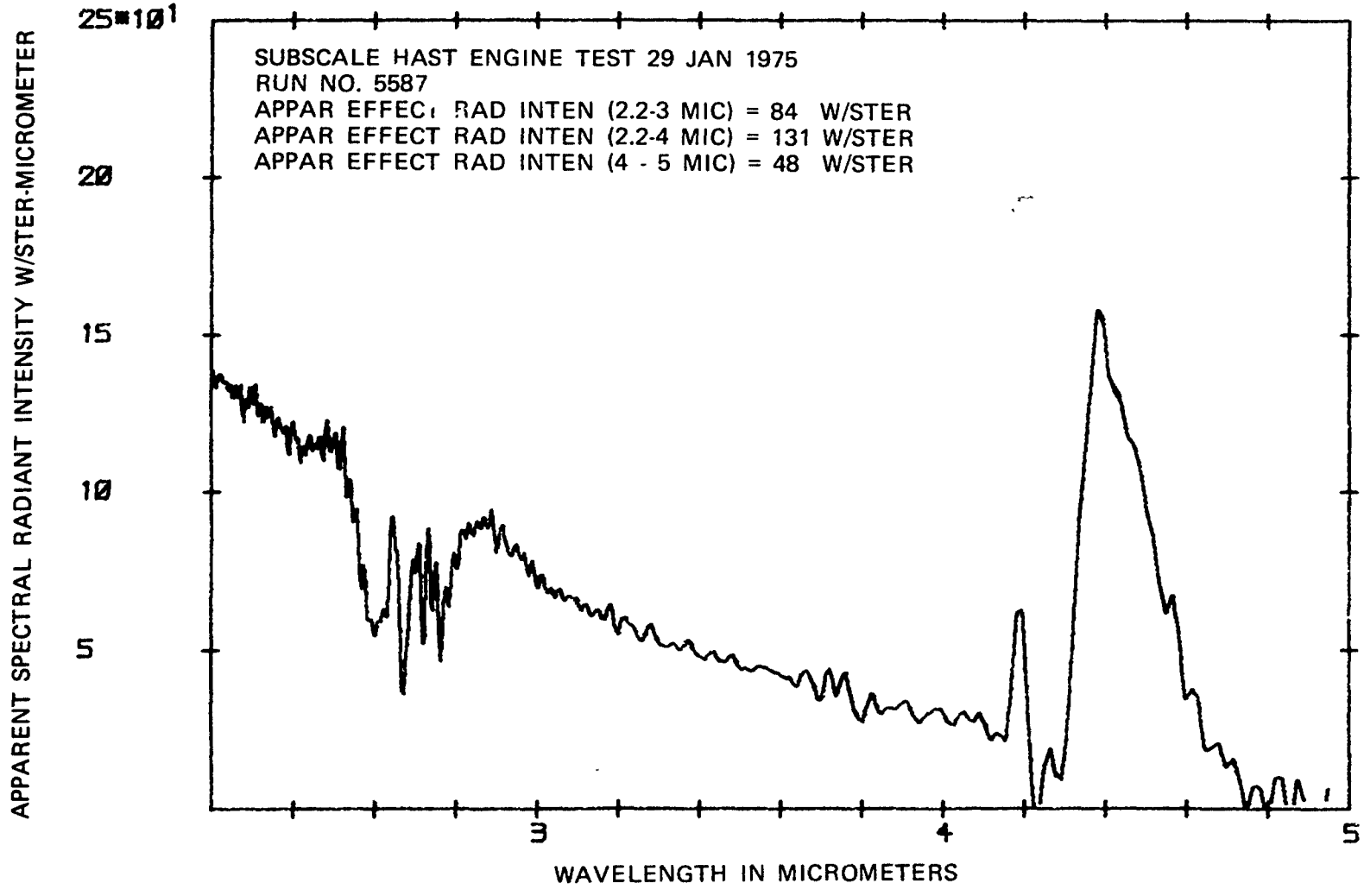

Figure 14. Subscale Engine Spectrum, POPS Injection, Mach 0.7 Airflow

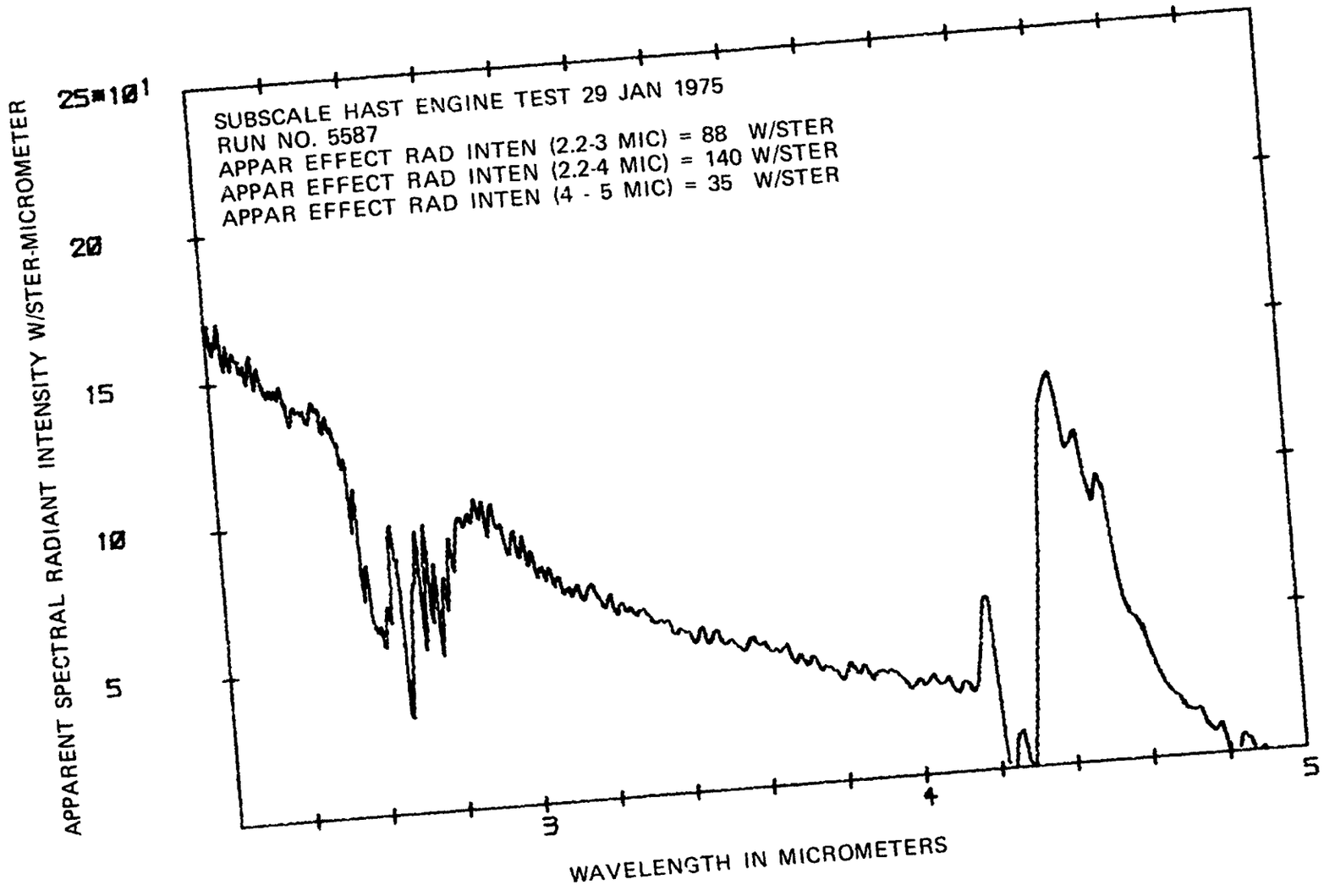

Figure 15. Subscale Engine Spectrum, POPS Injection, No Flow

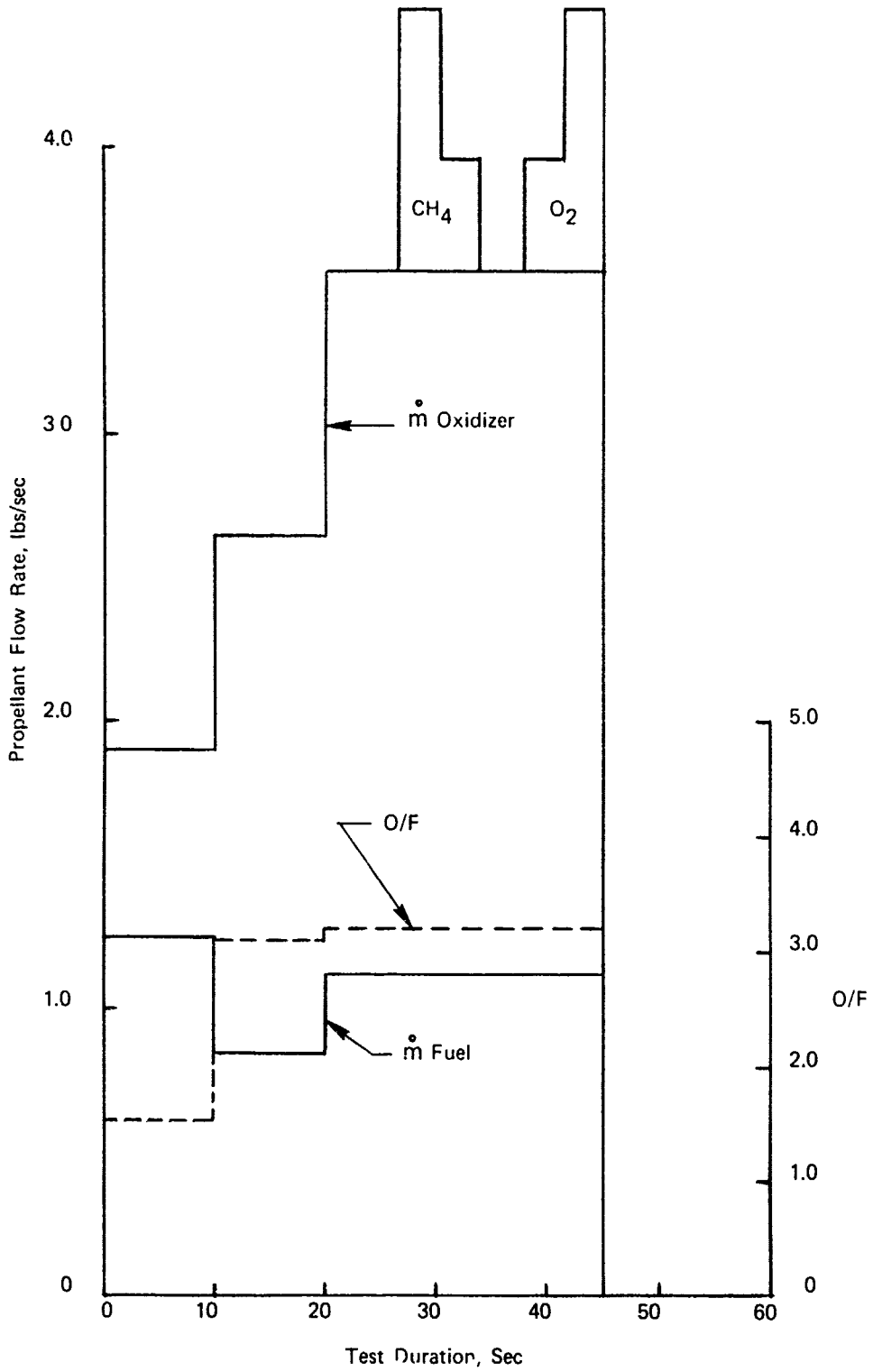

Figure 16. Full-Scale HAST Engine - Boost Phase Duty Cycle

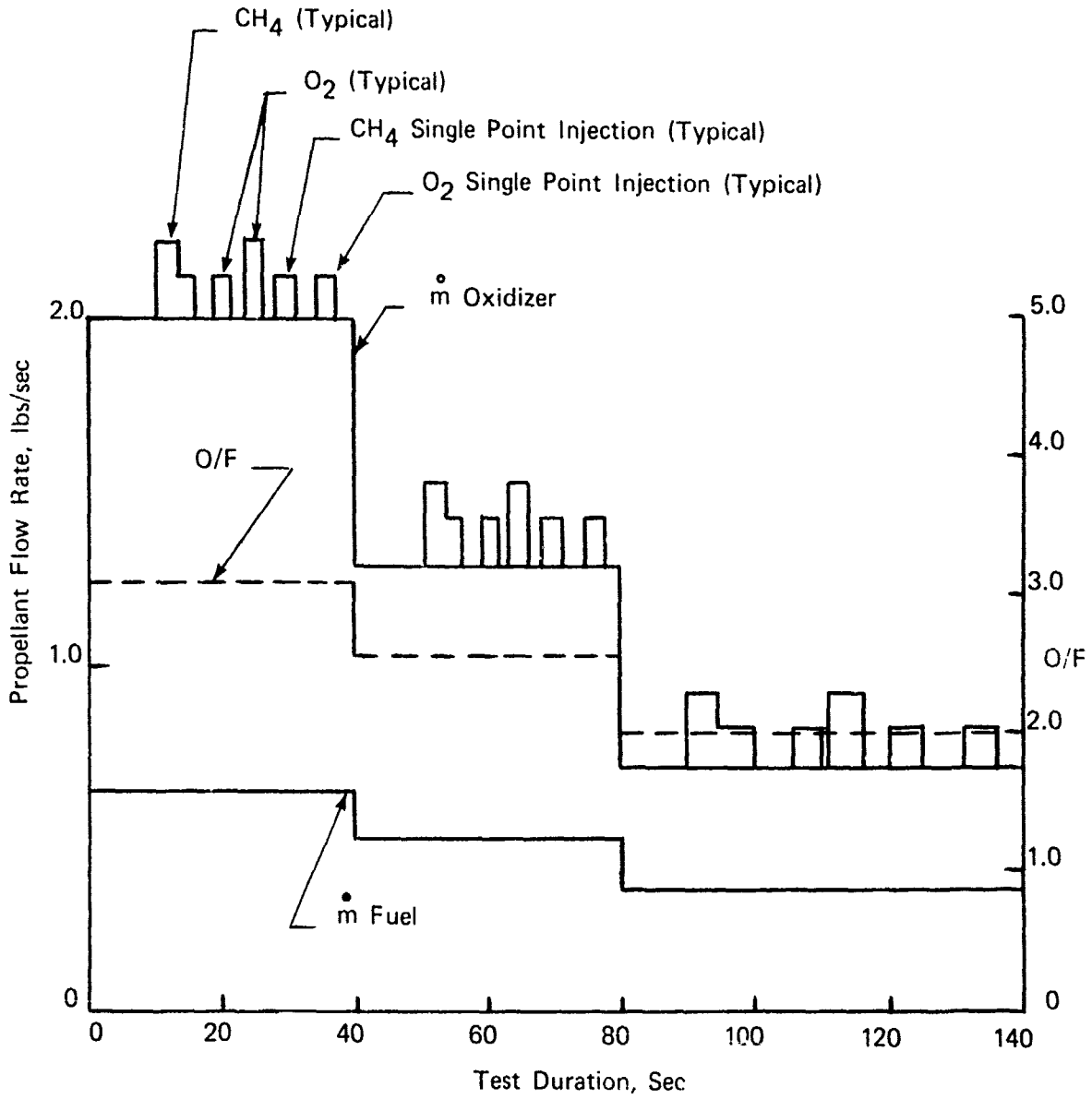

Figure 17. Full-Scale HAST Engine - Sustain Phase Duty Cycle

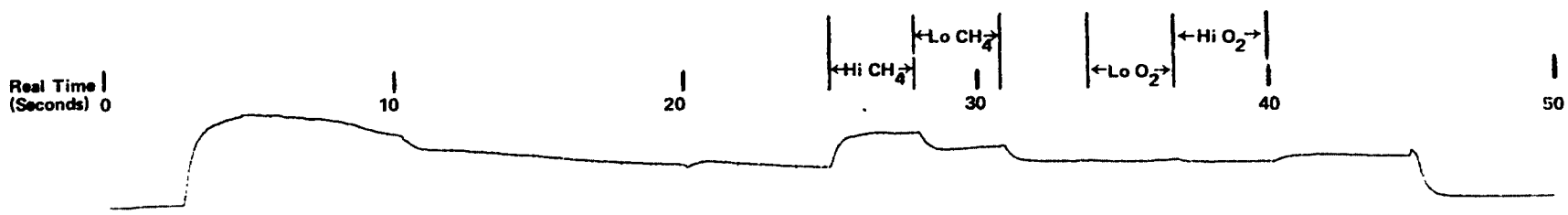

Figure 18. Full-Scale HAST Engine Boost Phase - J (4 to 5 Micrometers) Versus Time

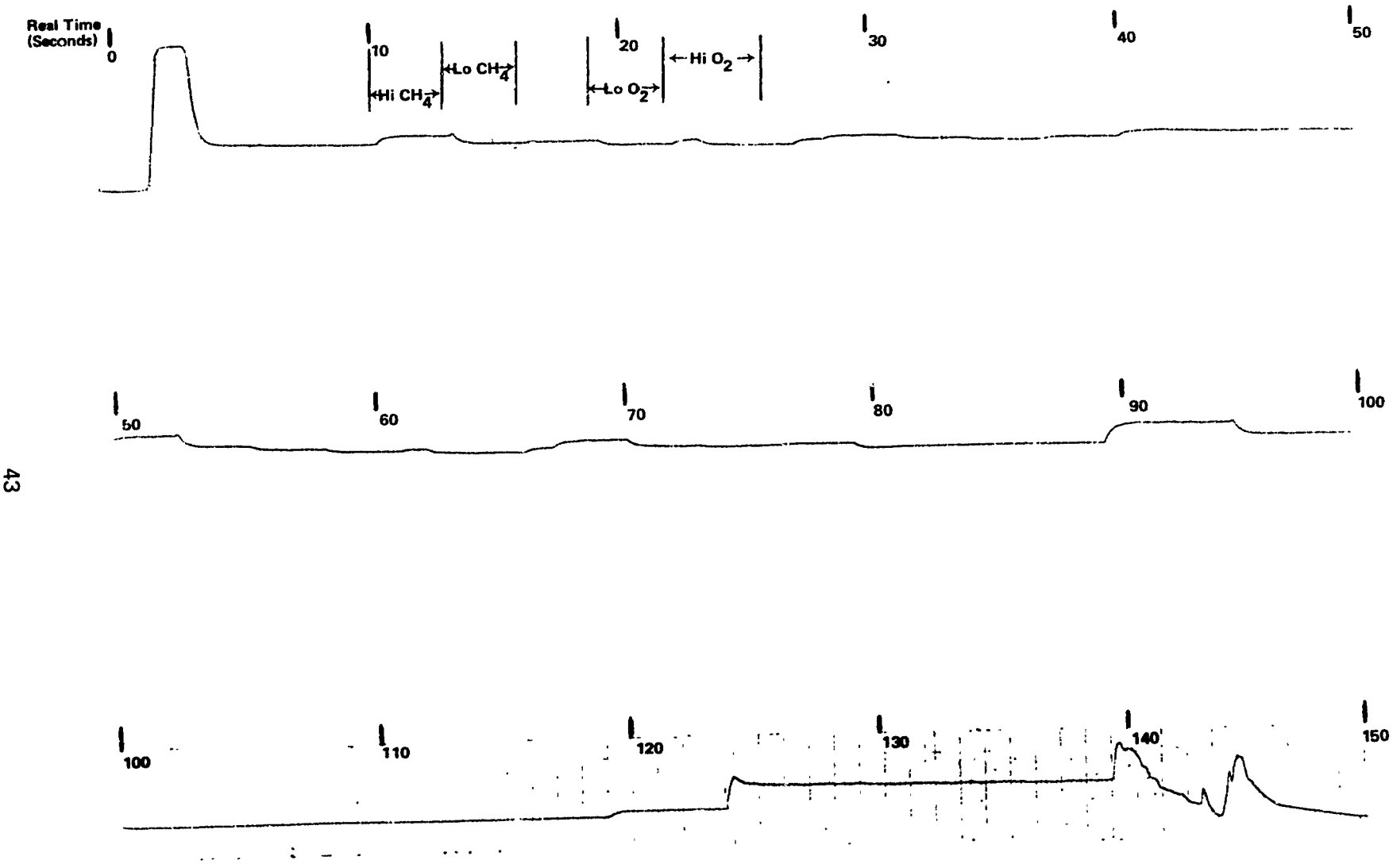

Figure 19. Full-Scale HAST Engine Sustain Phase - J (4 to 5 Micrometers) Versus Time

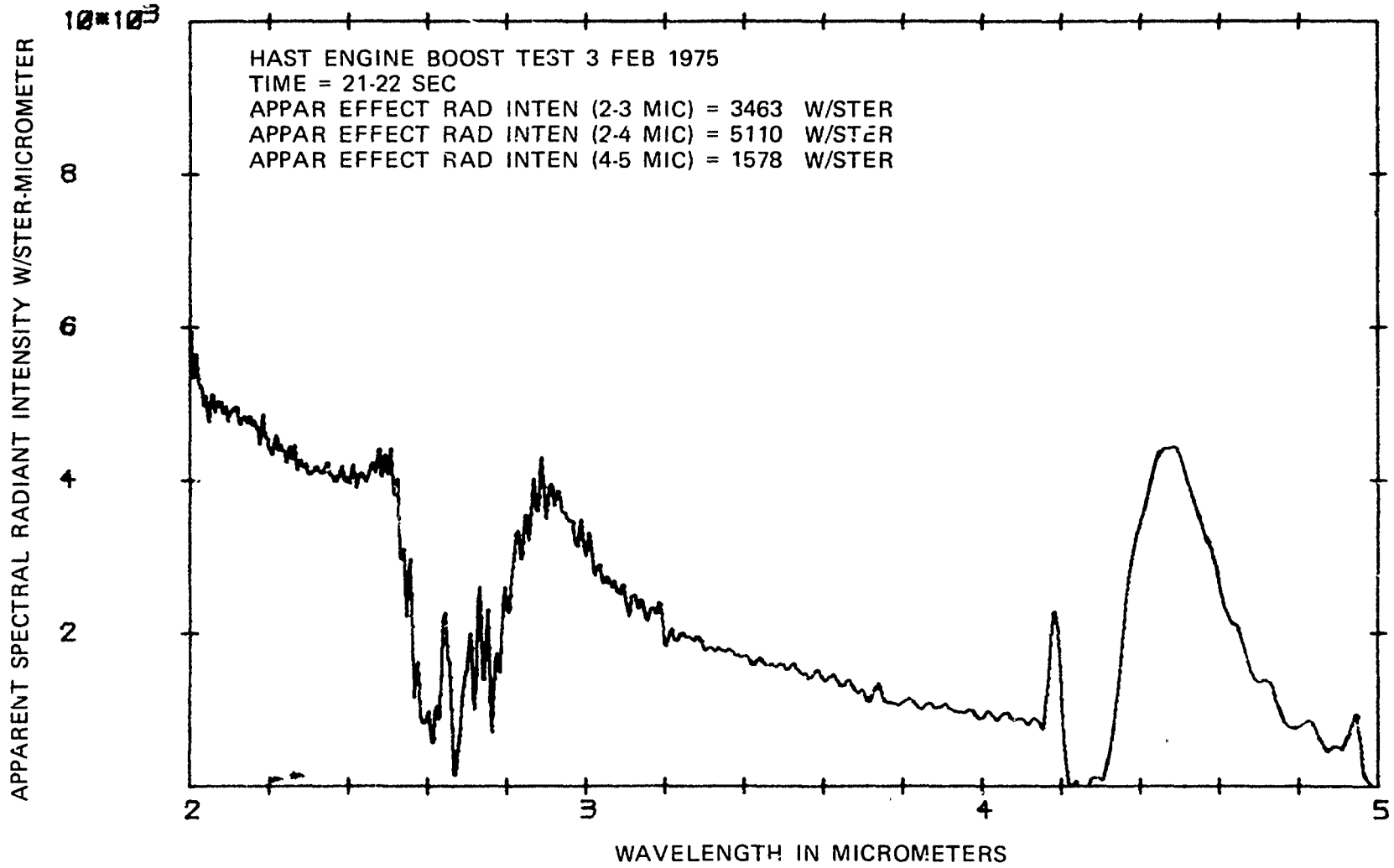

Figure 20. Full-Scale HAST Engine Boost Phase - Typical Spectrum

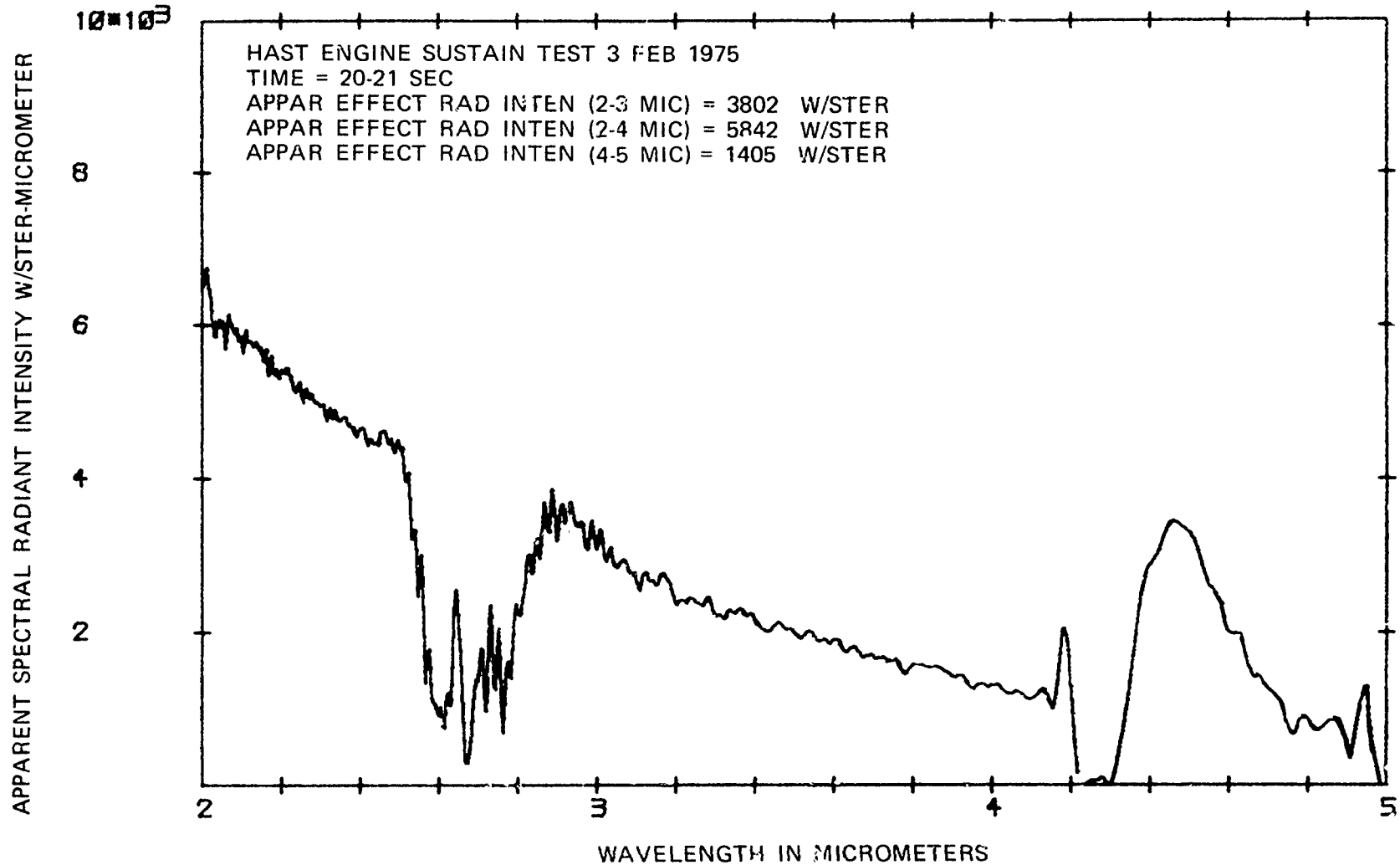

Figure 21 Full-Scale HAST Engine Sustain Phase - Typical Spectrum

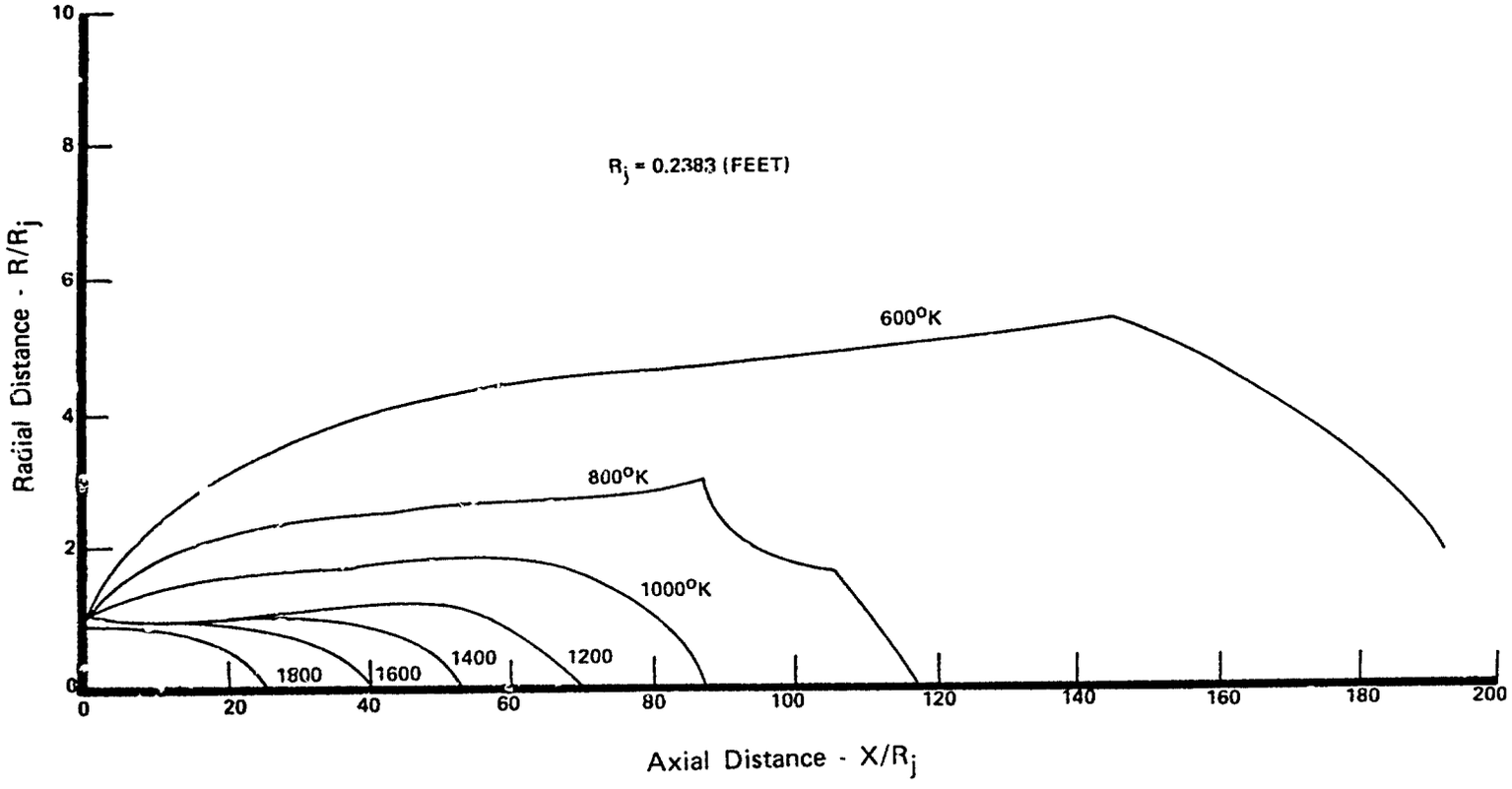

Figure 22. Predicted HAST Plume Isothermal Contours (Sea Level Static)-Non-Equilibrium Chemistry

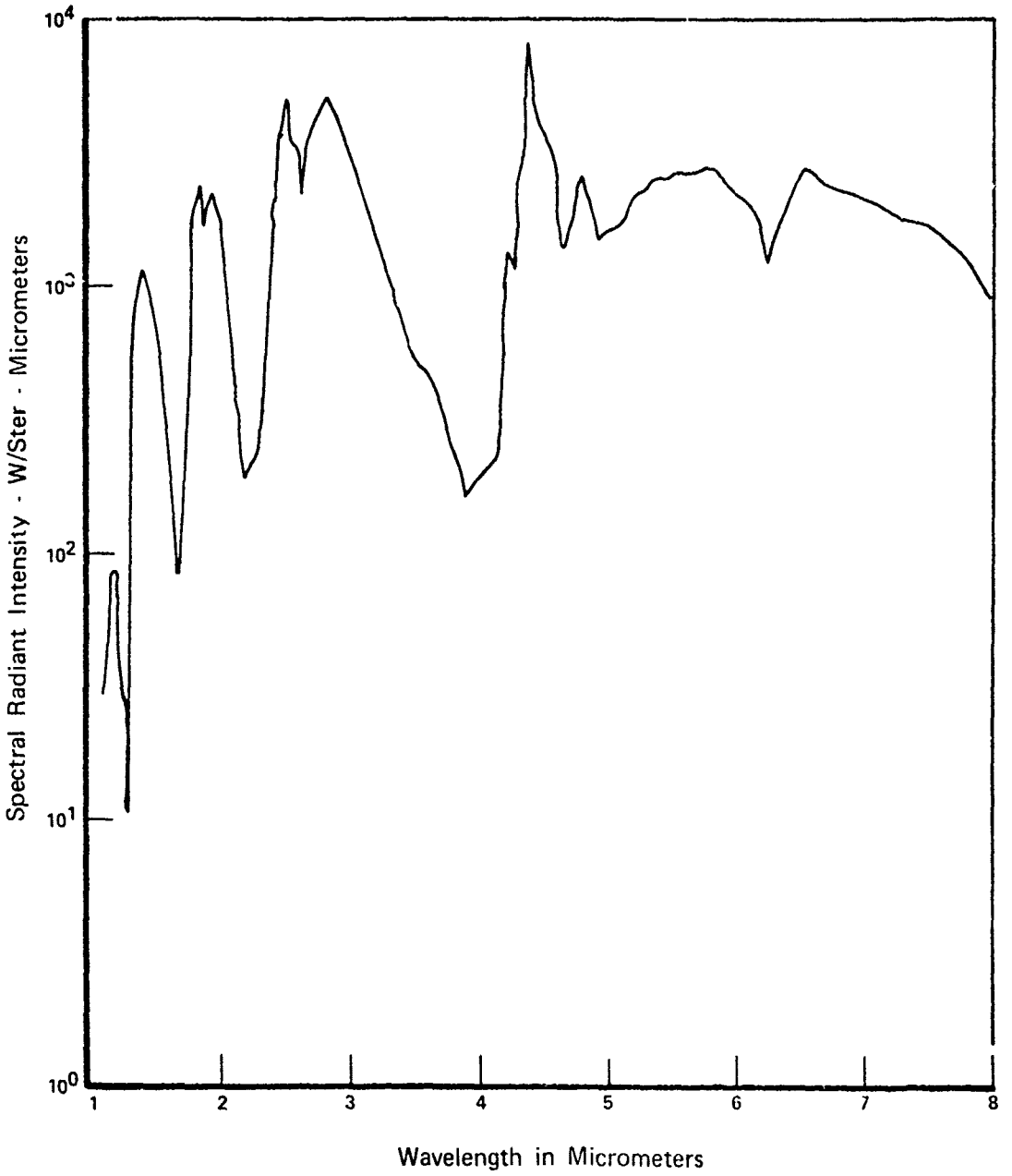

Figure 23. Predicted HAST Plume Spectral Radiant Intensity at 30 Degrees from Tail - 1 to 8 Micrometers

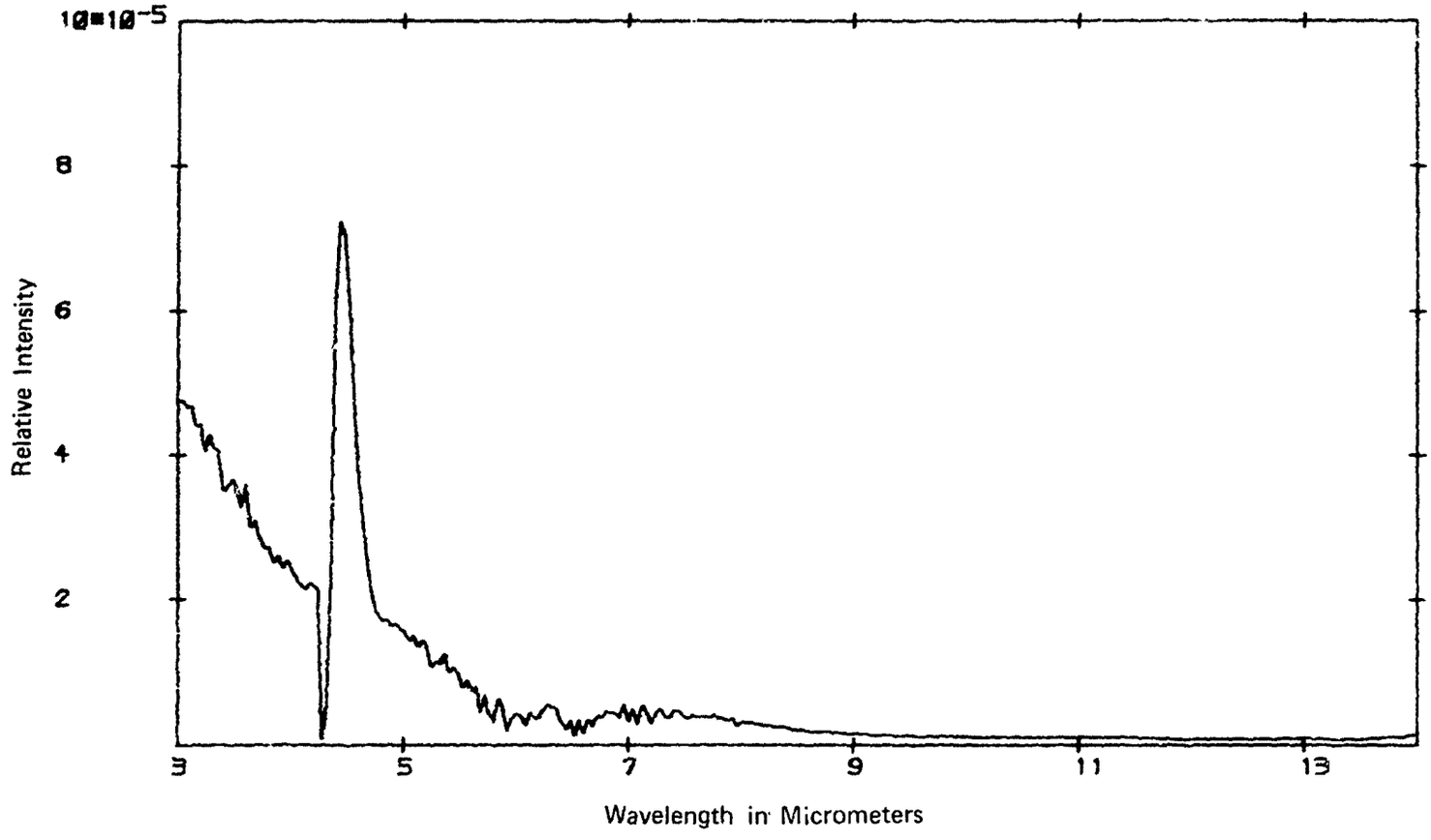

Figure 24. Measured Fuel/Particulate Rich Spectral Distribution from 3 to 14 Micrometers

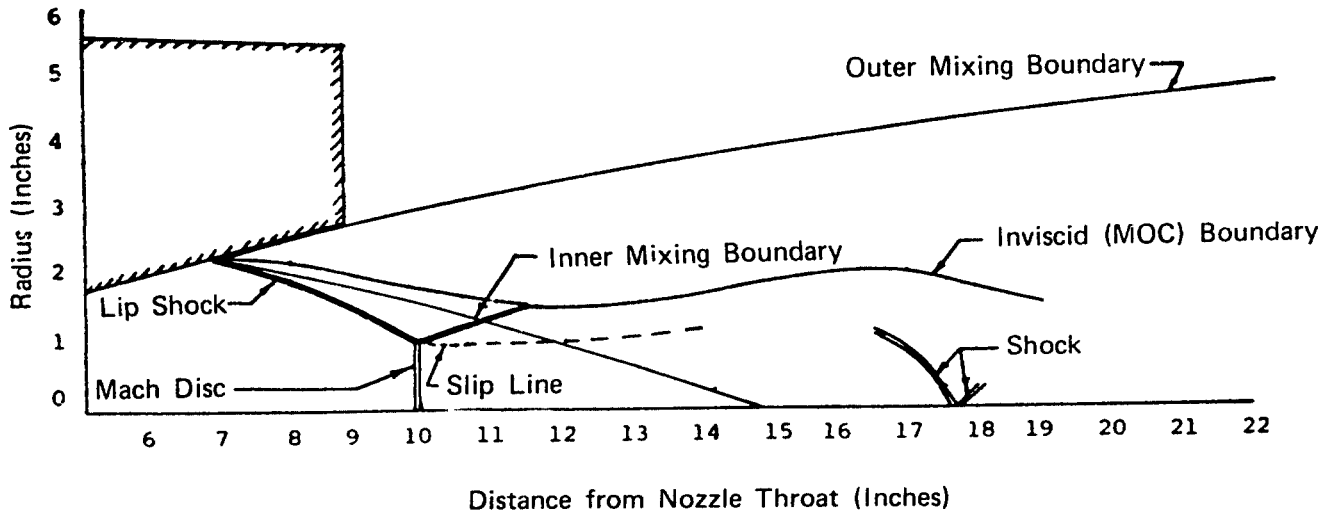

Figure 25. Predicted HAST Plume at Sea Level Static Conditions

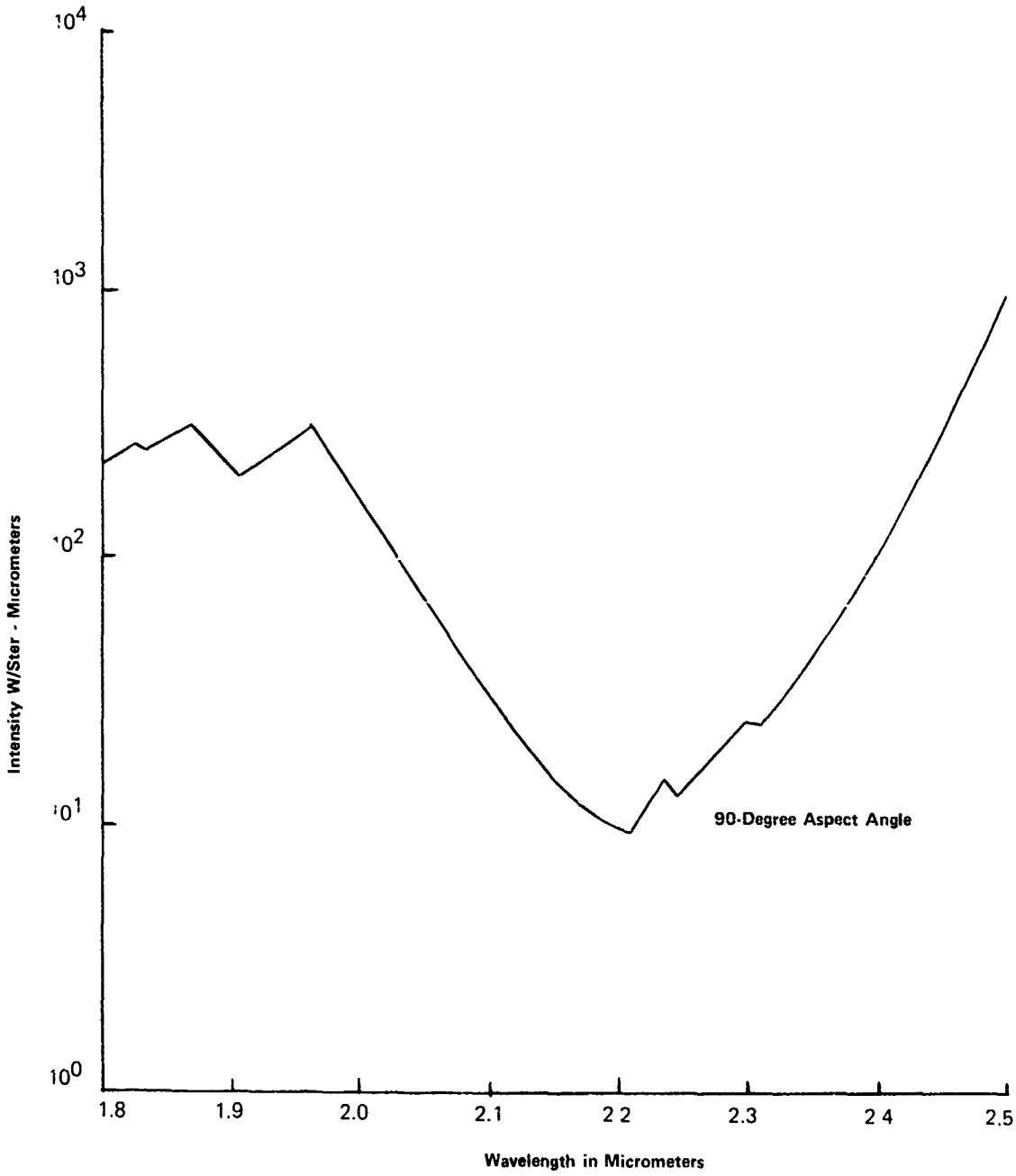

Figure 26. Predicted HAST Plume Spectral Radiant Intensity 1.8 to 2.5 Micrometers (Sea Level Static)

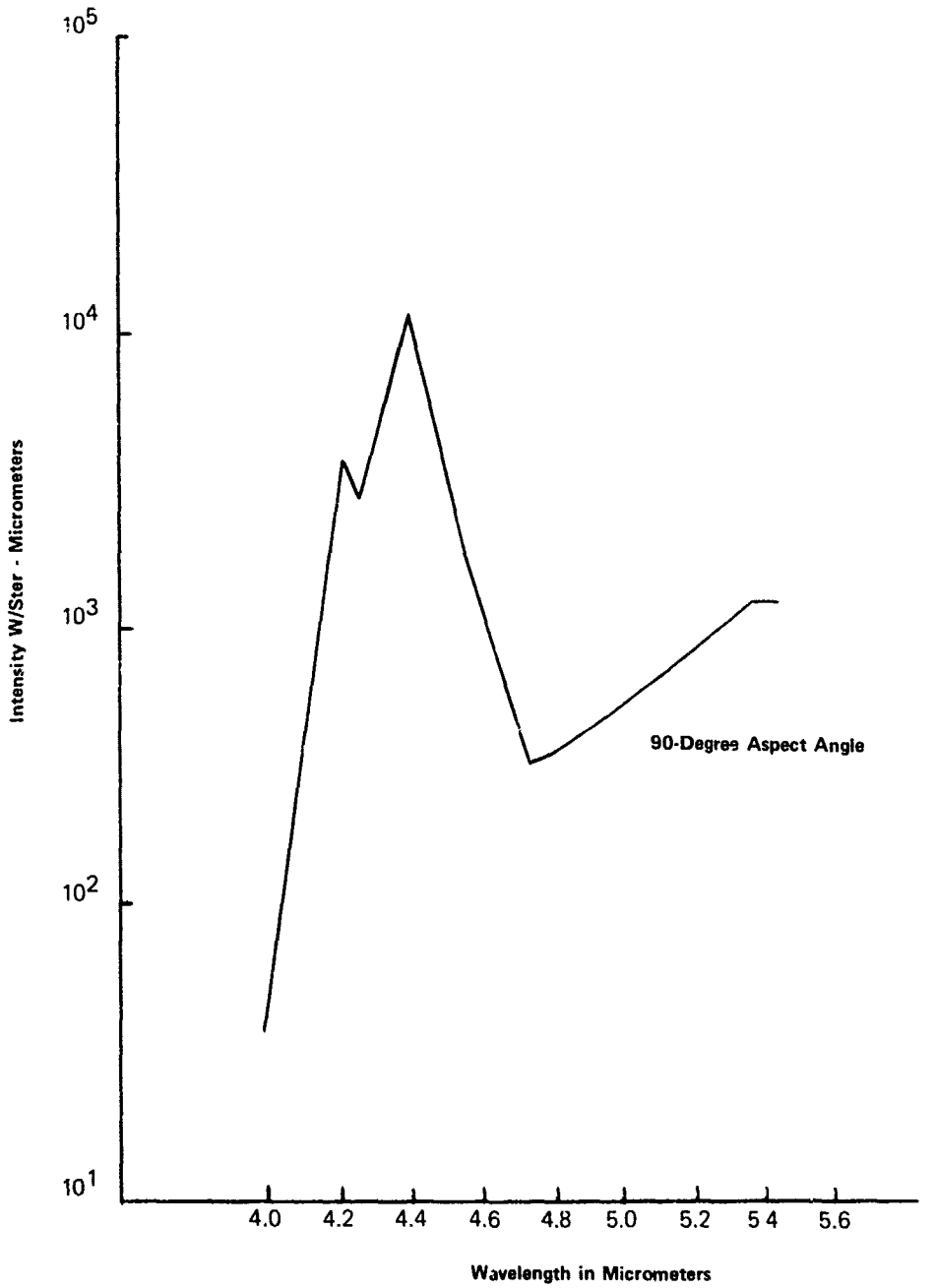

Figure 27. Predicted HAST Plume Spectral Radiant Intensity 4.0 to 5.5 Micrometers (Sea Level Static)

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TABLE 1. TIME SEQUENCES FOR FULL-SCALE HAST ENGINE SECONDARY INJECTION FOR BOOST AND SUSTAIN PHASES

Time (Sec)	Sym Valve	Hi CH_4	Lo CH_4	Lo O_2	Hi O_2
		BOOST SEQUENCE			
5 to 6	*	*	*	*	*
7 to 8	*	*	*	*	*
14 to 15	On	*	*	*	*
21 to 22	On	*	*	*	*
26 to 27	*	On	*	*	*
29 to 30	*	*	On	*	*
32 to 33	*	*	*	*	*
35 to 36	*	*	*	On	*
38 to 39	*	*	*	*	On
41 to 42	*	*	*	*	*
		SUSTAIN SEQUENCE			
0 to 2	*	*	*	*	*
2 to 9	*	*	*	*	*
9 to 10	On	*	*	*	*
10 to 13	On	On	*	*	*
13 to 16	On	*	On		
16 to 19	On	*	*	*	*
19 to 22	On	*	*	On	
22 to 23	On	*	*	*	*
23 to 26	On	*	*	*	On
26 to 27	On	*	*	*	*
27 to 28	*	*	*	*	*
28 to 31	*	*	On	*	*
31 to 34	*	*	*	*	*
34 to 37	*	*	*	On	*
37 to 49	*	*	*	*	*
49 to 50	On	*	*	*	*
50 to 53	On	On	*	*	*
53 to 56	On	*	On	*	*
56 to 59	On	*	*	*	*
59 to 62	On	*	*	On	*
62 to 63	On	*	*	*	*
63 to 66	On	*	*	*	On
66 to 67	On	*	*	*	*
67 to 68	*	*	*	*	*
68 to 71	*	*	On	*	*
71 to 74	*	*	*	*	*
74 to 77	*	*	*	*	*
77 to 89	*	*	*	*	*
89 to 90	On	*	*	*	*

TABLE 1. TIME SEQUENCES FOR FULL-SCALE HAST ENGINE SECONDARY INJECTION FOR BOOST AND SUSTAIN PHASES (CONCLUDED)

Time (Sec)	Sym Valve	Hi CH_4	Lo CH_4	Lo O_2	Hi O_2
		SUSTAIN SEQUENCE			
90 to 95	On	On	*	*	*
95 to 100	On	*	On	*	*
100 to 105	On	*	*	*	*
105 to 110	On	*	*	On	*
110 to 111	On	*	*	*	*
111 to 116	On	*	*	*	On
116 to 117	On	*	*	*	*
117 to 120	*	*	*	*	*
120 to 125	*	*	*	*	*
125 to 130	*	*	*	*	*
130 to 135	*	*	*	*	*
135 to 140	*	*	*	*	*

*Off

TABLE 2. INFRARED MEASUREMENT COMPARISONS AGAINST AN EXTENDED SOURCE

	BOFORS Scanner	Radiometer (Thermopile)	Interferometer Spectrometer
	4 to 5.5μ	3.9 to 5.0μ	4 to 5μ
Plume 1	5.85	5.49	2.79
Plume 2	6.29	5.89	2.91
Plume 3	11.3	9.63	4.49
Plume 4	17.1	14.5	5.57
Plume 5	2.64	2.73	1.16
Plume 6	29.3	25.8	21.72
Plume 7	52.0	52.4	46.86
Plume 8	19.2	17.2	14.42
Plume 9	33.9	30.4	24.71

All units are radiant intensity (W/Ster).
Plume size of propane/oxygen torch was 1 to 3 feet.

TABLE 3. RADIOMETRIC DATA FOR SUBSCALE HAST ENGINE

Run No.	O/F	Injection	$\dot{m}_s/\dot{m}_p$	M_∞	Rad J	Scanner J	$\bar{J}$	$(J_{aug}/J)_{flow}$	Injection Mode	J_{static}/J_{flow}
5570	2.66	*	0	0	139	SAT	1.40			2.57
		O_2	0.056	0	151	SAT	1.43		SLOT	
		CH_4	0.058	0	216	SAT	2.05			
		*	0	0.7	54	SAT	0.54	1		
		O_2	0.056	0.7	82	SAT	0.78	1.52		
		CH_4	0.058	0.7	66	SAT	0.63	1.22		
5571	2.42	*	0	0	154	185	1.51			2.44
		O_2	0.055	0	170	216	1.57		SLOT	
		CH_4	0.056	0	232	282	2.15			
		*	0	0.7	63	62	0.62	1		
		O_2	0.055	0.7	92	105	0.85	1.46		
		CH_4	0.056	0.7	85	64	0.79	1.34		
5572	2.59	*	0	0	135	163	1.23			2.45
		O_2	0.073	0	145	178	1.23		SLOT	
		CH_4	0.076	0	224	271	1.90			
		*	0	0.7	55	57	0.50	1		
		O_2	0.073	0.7	88	101	0.75	1.60		
		CH_4	0.076	0.7	65	65	0.55	1.18		

TABLE 3. RADIOMETRIC DATA FOR SUBSCALE HAST ENGINE (CONTINUED)

Run No.	O/F	Injection	$\dot{m}_s/\dot{m}_p$	M_∞	Rad J	Scanner J	$\bar{J}$	$(J_{aug}/J)_{flow}$	Injection Mode	J_{static}/J_{flow}
5573	2.28	*	0	0	151	207	1.58			2.60
		O_2	0.084	0	161	250	1.56		SLOT	
		CH_4	0.087	0	268	369	2.59			
		*	0	0.7	58	81	0.61	1		
		O_2	0.084	0.7	91	129	0.88	1.57		
		CH_4	0.087	0.7	75	108	0.73	1.29		
5574	3.40	*	0	0	68	116	0.71			2.28
		O_2	0.083	0	75	121	0.72		SLOT	
		CH_4	0.085	0	139	221	1.32			
		*	0	0.7	30	54	0.31	1		
		O_2	0.083	0.7	38	52	0.36	1.26		
		CH_4	0.085	0.7	47	78	0.44	1.54		
5575	2.96	*	0	0	75	SAT	0.79			3.95
		O_2	0.084	0	79	SAT	0.76		SLOT	
		CH_4	0.086	0	139	SAT	1.34			
		*	0	0.3 N_2	19	SAT	0.20	1		
		O_2	0.084	0.3 N_2	22	SAT	0.21	1.14		
		CH_4	0.086	0.3 N_2	14	SAT	0.13	0.72		

TABLE 3. RADIOMETRIC DATA FOR SUBSCALE HAST ENGINE (CONTINUED)

Run No.	O/F	Injection	$\dot{m}_s/\dot{m}_p$	M_∞	Rad J	Scanner J	$\bar{J}$	$(J_{aug}/J)_{flow}$	Injection Mode	J_{static}/J_{flow}
5576	2.33	*	0	0	126	SAT	1.32			7.68
		O_2	0.084	0	130	SAT	1.25		SLOT	
		CH_4	0.086	0	214	SAT	2.07			
		*	0	0.3 N_2	16	19	0.17	1		
		O_2	0.084	0.3 N_2	24	27	0.23	1.44		
		CH_4	0.086	0.3 N_2	14	17	0.13	0.84		
5577	ABORT									
5578	ABORT									
5579	2.72	*	0	0	162	343	1.46			5.64
		O_2	0.072	0	162	324	1.36		8 Holes	
		CH_4	0.074	0	236	461	1.97			
		*	0	0.3 N_2	29	42	0.26	1		
		O_2	0.072	0.3 N_2	44	57	0.37	1.53		
		CH_4	0.074	0.3 N_2	19	18	0.16	0.64		
5580	ABORT									
5581	ABORT									
5582	ABORT									
5583	2.52	*	0	0	123	163	1.28			2.72
		O_2	0.084	0	124	175	1.19		SLOT	

TABLE 3. RADIOMETRIC DATA FOR SUBSCALE HAST ENGINE (CONTINUED)

Run No.	O/F	Injection	$\dot{m}_s/\dot{m}_p$	M_∞	Rad J	Scanner J	$\bar{J}$	$(J_{aug}/J)_{flow}$	Injection Mode	J_{static}/J_{flow}
		CO	0.085	0	135	197	1.30			
		*	0	0.7	45	59	0.47	1		
		O_2	0.084	0.7	71	99	0.69	1.57		
		CO	0.085	0.7	53	52	0.51	1.17		
5584	2.64	*	0	0	107	144	1.13			2.52
		O_2	0.133	0	93	110	0.87		SLOT	
		CO	0.135	0	128	139	1.20			
		*	0	0.7	43	51	0.45	1		
		O_2	0.133	0.7	66	96	0.61	1.54		
		CO	0.135	0.7	52	64	0.49	1.23		
5585	2.56	*	0	0	118	198	1.23			2.91
		O_2	0.084	0	82	111	0.79		1 Hole	
		CH_4	0.081	0	62	79	0.60			
		*	0	0.7	41	66	0.42	1		
		O_2	0.084	0.7	39	57	0.38	0.97		
		CH_4	0.081	0.7	30	35	0.28	0.72		
5586 (POPS)		*		0	2		0.14			
5587	2.46	*	0	0	133	226	1.39			2.86
		POPS	0.145	0	114	85	1.04		1 Hole	

TABLE 3. RADIOMETRIC DATA FOR SUBSCALE HAST ENGINE (CONCLUDED)

Run No.	O/F	Injection	$\dot{m}_s/\dot{m}_p$	M_∞	Rad J	Scanner J	$\bar{J}$	$(J_{aug}/J)_{flow}$	Injection Mode	J_{static}/J_{flow}
		*	0	0.7	4[illegible]	77	0.49	1		
		POPS	0.145	0.7	51	38	0.47	1.10		
5588	3.99	*	0	0	49	47	0.56			1.91
		POPS	0.138	0	74	25	0.73		1 Hole	
		*	0	0.7	25	25	0.29	1		
		POPS	0.138	0.7	39	SAT	0.39	1.55		
5589	3.88	*	0	0	41	59	0.47			2.04
		O_2	0.144	0	32	27	0.32		1 Hole	
		CH_4	0.154	0	55	54	0.55			
		*	0	0.7	20	20	0.22	1		
		O_2	0.144	0.7	18	21	0.18	0.88		
		CH_4	0.154	0.7	24	20	0.24	1.21		
5590	4.01	*	0	0	85	159	0.53			5.90
		O_2	0.079	0	47	82	0.28		1 Hole	
		CH_4	0.084	0	33	67	0.19			
		*	0	0.7	14	11	0.09	1		
		O_2	0.079	0.7	13	15	0.08	0.91		
		CH_4	0.084	0.7	9	7	0.05	0.64		

*No injection

TABLE 4. RELATIVE RADIATION EMITTED BY SUBSCALE HAST ENGINE IN THREE SPECTRAL BANDS

Run No.	Injection	M_∞	(2.2 to 3.0μ)	(2.2 to 4.0)	(4.0 to 5.0)
5570	*	0	**	**	**
	O_2	0	**	**	**
	CH_4	0	**	**	**
	*	0.7	**	**	**
	O_2	0.7	**	**	**
	CH_4	0.7	**	**	**
5571	*	0	145	210	96
	O_2	0	88	119	51
	CH_4	0	196	277	127
	*	0.7	122	172	48
	O_2	0.7	120	177	58
	CH_4	0.7	84	127	39
5572	*	0	83	121	56
	O_2	0	181	252	124
	CH_4	0	89	130	80
	*	0.7	143	202	67
	O_2	0.7	116	176	56
	CH_4	0.7	87	137	43

TABLE 4. RELATIVE RADIATION EMITTED BY SUBSCALE HAST ENGINE IN THREE SPECTRAL BANDS (CONTINUED)

Run No.	Injection	M_∞	(2.2 to 3.0 μ)	(2.2 to 4.0)	(4.0 to 5.0)
5573	*	0	126	186	106
	O_2	0	141	201	127
	CH_4	0	171	246	199
	*	0.7	147	208	66
	O_2	0.7	105	157	65
	CH_4	0.7	92	146	45
5574	*	0	94	150	73
	O_2	0	95	144	79
	CH_4	0	56	87	30
	*	0.7	44	70	29
	O_2	0.7	33	51	24
	CH_4	0.7	64	101	30
5575	*	0	42	64	25
	O_2	0	41	60	31
	CH_4	0	106	150	92
	*	0.3 N_2	17	30	9
	O_2	0.3 N_2	18	32	11
	CH_4	0.3 N_2	37	62	17

TABLE 4. RELATIVE RADIATION EMITTED BY SUBSCALE HAST ENGINE IN THREE SPECTRAL BANDS (CONTINUED)

Run No.	Injection	M_∞	(2.2 to 3.0μ)	(2.2 to 4.0)	(4.0 to 5.0)
5576	*	0	64	98	52
	O_2	0	110	167	104
	CH_4	0	165	249	133
	*	0.3 N_2	42	73	23
	O_2	0.3 N_2	15	27	8
	CH_4	0.3 N_2	18	31	9
5577 ABORT					
5578 ABORT					
5579	*	0	61	77	94
	O_2	0	66	83	84
	CH_4	0	56	73	95
	*	0.3 N_2	60	102	38
	O_2	0.3 N_2	22	40	14
	CH_4	0.3 N_2	20	34	12
5583	*	0	78	117	39
	O_2	0	178	257	85
	CO	0	138	216	75
	*	0.7	129	192	40

TABLE 4. RELATIVE RADIATION EMITTED BY SUBSCALE HAST ENGINE IN THREE SPECTRAL BANDS (CONTINUED)

Run No.	Injection	M_∞	(2.2 to 3.0μ)	(2.2 to 4.0)	(4.0 to 5.0)
	O_2	0.7	123	184	46
	CO	0.7	95	150	40
5584	*	0	145	223	80
	O_2	0	146	220	73
	CO	0	149	234	82
	*	0.7	145	211	45
	O_2	0.7	52	80	24
	CO	0.7	100	154	40
5585	*	0	135	204	88
	O_2	0	113	181	58
	CH_4	0	112	186	65
	*	0.7	86	131	38
	O_2	0.7	64	102	32
	CH_4	0.7	66	104	32
5589	*	0	74	118	52
	O_2	0	50	82	30
	CH_4	0	74	119	54
	*	0.7	46	70	21

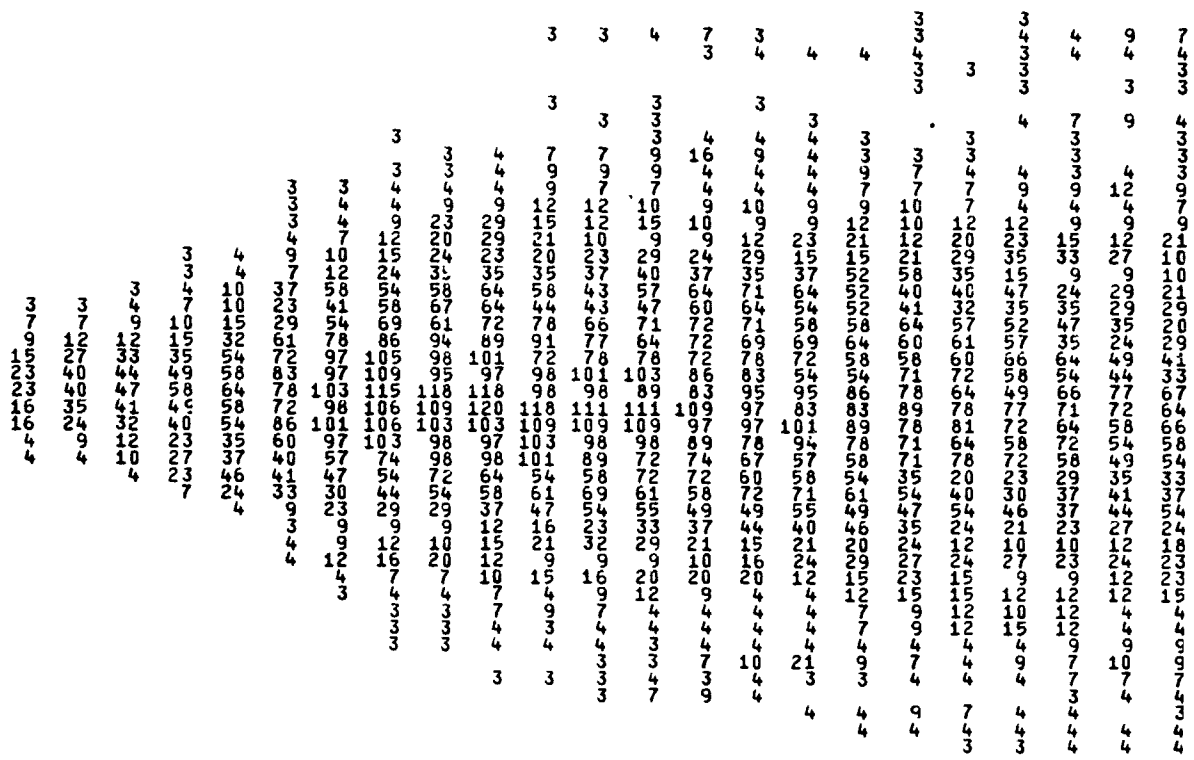
TABLE 4. RELATIVE RADIATION EMITTED BY SUBSCALE HAST ENGINE IN THREE SPECTRAL BANDS (CONCLUDED)

Run No.	Injection	M_∞	(2.2 to 3.0μ)	(2.2 to 4.0)	(4.0 to 5.0)
	O_2	0.7	39	63	24
	CH_4	0.7	58	86	26
5590	*	0	137	209	96
	O_2	0	181	136	53
	CH_4	0	88	150	58
	*	0.7	28	43	14
	O_2	0.7	30	46	14
	CH_4	0.7	17	26	9

*No injection
**No data

SUBSCALE HAST RANGE(DET)= 3.513 M

RUN=579 FILE=477 RANGE (FROM OF CAMERA)= 3.05 M SENSITIVITY= 75 ATTENUATION= 620 POWER=2.72



COLUMN NO.=

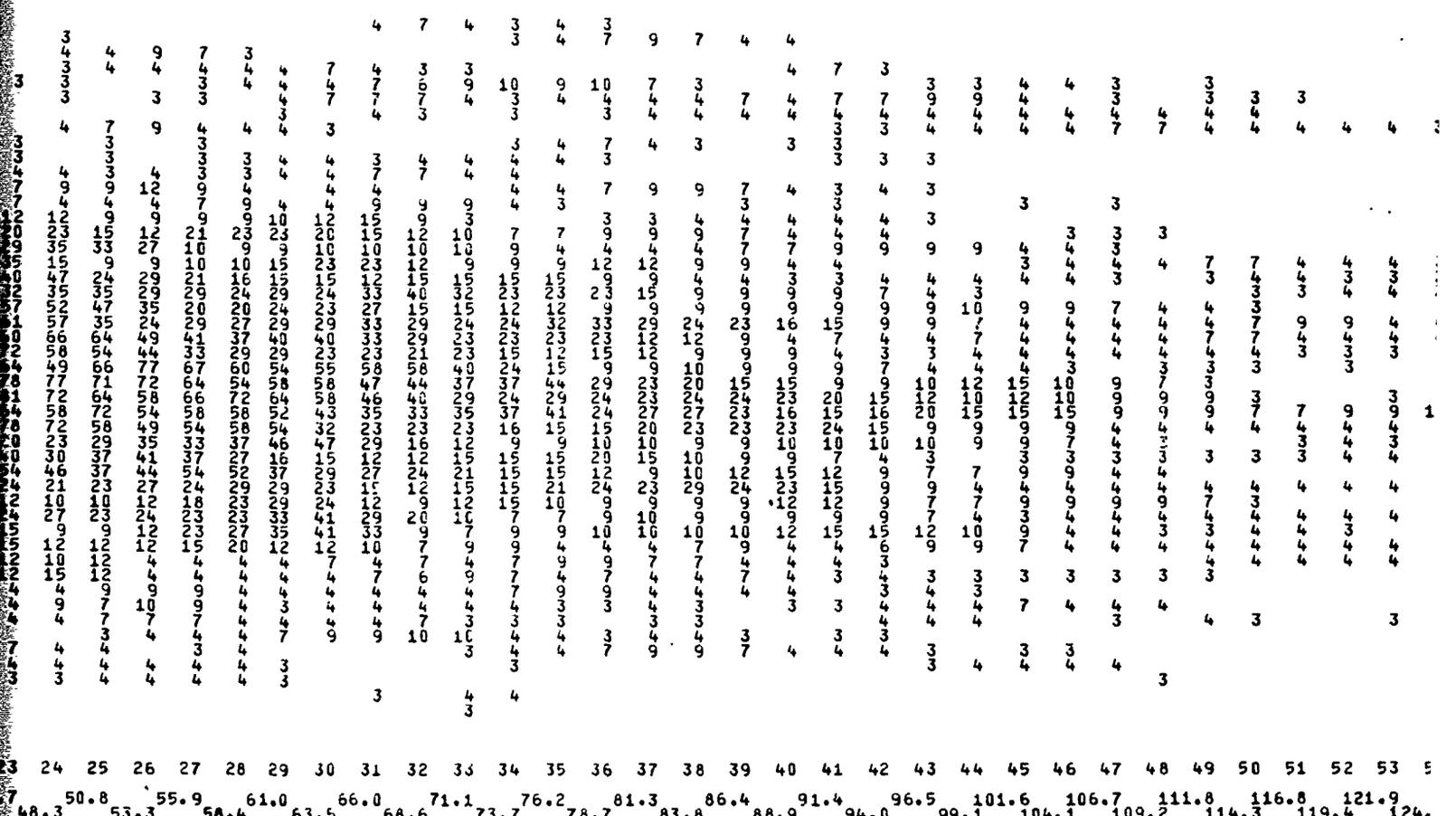
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
0.0	0.0	0.0	0.0	0.0	2.5	5.1	7.6	10.2	12.7	15.2	17.8	20.3	22.9	25.4	27.9	30.5	33.0	35.6	38.1	40.6	43.2	45.7	48.3	50.8	53.3	55.9

EXIT PLANE IS IN COLUMN 5,FIELD OF VIEW CENTER IS IN COLUMN 28 HORZ INCREMENT= 2.54 CM VERT INCREMENT= .

TABLE 5. SUBSCALE ENGINE PLUME SPATIAL DISTRIBUTION - NO INJE

= 3.513 M

MER=2.72 BACK



ERT INCREMENT= .72 CM

TABLE 5. SUBSCALE ENGINE PLUME SPATIAL DISTRIBUTION - NO INJECTION, NO FLOW

UNITS=WATTS/STER X

BACKGROUND= 153

7	4	3	4	3																				25	27
		3	4	7	9	7	4	4																44	28
																								50	29
3	3							4	7	3														73	30
6	9	10	9	10	7	3					3	3	4	4	3		3							105	31
7	4	3	4	4	4	4	7	4	7	7	9	9	4		3		3	3	3					119	32
3		3		3	4	4	4	4	4	4	4	4	4	4	4	4	4	4						81	33
									3	3	4	4	4	4	7	7	4	4	4	4	4	3	3	106	34
		3	4	7	4	3		3	3														3	60	35
4	4	4	4	3					3	3	3													116	36
7	4	4																						116	37
		4	4	7	9	9	7	4	3	4	3													179	38
9	9	4	3				3		3				3		3									199	39
9	3			3	3	4	4	4	4	4	3													298	40
12	10	7	7	9	9	9	7	4	4	4				3	3	3								452	41
10	10	9	4	4	4	4	7	7	9	9	9	9	4	4	3									542	42
12	9	9	9	12	12	9	9	4	4				3	4	4	4	7	7	4	4	4	3		733	43
15	15	15	15	9	9	4	4	3	3	4	4	4	4	4	3		3	4	4	3	3	3		1091	44
40	32	23	23	23	15	9	9	9	9	7	4	3						3	3	4	4	3		1178	45
15	15	12	12	9	9	9	9	9	9	9	9	10	9	9	7	4	4	3						1348	46
29	24	24	32	33	29	24	23	16	15	9	9	7	4	4	4	4	4	7	9	9	4	4		1705	47
29	23	23	23	23	12	12	9	4	7	4	4	7	4	4	4	4	7	7	4	4	4	4	4	1863	48
21	23	15	12	15	12	9	9	9	4	3	3	4	4	4	4	4	4	4	3	3	3			1882	49
58	40	24	15	9	9	10	9	9	9	7	4	4	4	3		3	3	3		3		3	3	2268	50
44	37	37	44	29	23	20	15	15	9	9	10	12	15	10	9	7	3					3		2435	51
40	29	24	29	24	23	24	24	23	20	15	12	10	12	10	9	9	9	3			3		3	2390	52
33	35	37	41	24	27	27	23	16	15	16	20	15	15	15	9	9	9	7	7	9	9	10	12	2181	53
23	23	16	15	15	20	23	23	23	24	15	9	9	9	9	4	4	4	4	4	4	4	4	4	1808	54
16	12	9	9	10	10	9	9	10	10	10	10	9	9	7	4	3			3	4	3		3	1282	55
12	15	15	15	20	15	10	9	9	7	4	3		3	3	3	3	3	3	3	4	4	4	3	1182	56
24	21	15	15	12	9	10	12	15	12	9	7	7	9	9	4	4								1110	57
12	15	15	21	24	23	29	24	23	15	9	9	4	4	4	4	4	4	4	4	4	4	4		794	58
9	12	15	10	9	9	9	9	12	12	9	7	7	9	9	9	9	7	3						558	59
20	10	7	7	9	10	9	9	9	9	9	7	4	3	4	4	4	4	4	4	4	4	4	4	606	60
9	7	9	9	10	10	10	10	12	15	15	12	10	9	4	4	3	3	4	4	3				545	61
7	9	9	4	4	4	7	9	4	4	6	9	9	7	4	4	4	4	4	4	4	4	4	4	339	62
7	4	7	9	9	7	7	4	4	4	3							4	4	4	4	4	4	4	215	63
6	9	7	4	7	4	4	7	4	3	4	3	3	3	3	3	3	3							195	64
4	4	7	9	9	4	4	4	4		3	4	3												151	65
4	4	4	3	3	4	3		3	3	4	4	4	7	4	4	4								176	66
7	3	3	3		3	3				4	4	4			3		4	3			3			122	67
10	10	4	4	3	4	4	3		3	3														111	68
	3	4	4	7	9	9	7	4	4	4	3		3	3										103	69
		3									3	4	4	4	4									57	70
																3								28	71
	4	4																						11	72
	3																							3	75
32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	

71.1 76.2 81.3 86.4 91.4 96.5 101.6 106.7 111.8 116.8 121.9 127.0

73.7 78.7 83.8 88.9 94.0 99.1 104.1 109.2 114.3 119.4 124.5 129.5

SUBSCALE HAST RANGE(DET)= 3.513 M

RUN=579 FILE=483 RANGE (FRONT OF CAMERA)= 3.05 M SENSITIVITY= 75 ATTENUATION= 620 POWER=2.72

																														3
																	4	4					3	4	3				
															3		3	3	4	3	3	3		4	4	3		3
														3			3	3	3	3	3			4	4	4	4	4
										3	3	3	3	4	4	3	4	4	4	4	3	4	9	4	4	3	3	
									3	3	4	4	4	4	4	7	4	4	4	4	4	4	4	4	4	3	3	4
									3	4	4	4	4	4	4	9	9	7	4	7	9	7	9	9	9	7	7	4
								3	4	4	7	9	9	9	10	7	9	12	15	9	10	21	21	15	9	9	9	7
							3	4	4	7	9	9	9	9	10	15	15	18	23	20	29	23	9	9	9	10	12	10	1
							3	4	7	9	12	15	15	21	24	20	23	24	23	23	23	23	24	30	23	23	20	9	
							4	9	9	10	15	23	29	35	46	29	29	35	32	23	21	20	12	20	23	23	21	23	2
			3	4	12	23	23	32	33	40	32	27	30	37	35	27	21	16	23	23	27	35	23	15	23	23	1		
		3	4	4	12	44	52	47	47	46	57	49	58	54	35	35	35	47	52	64	54	35	23	15	15	1			
		4	7	9	21	58	66	72	83	78	64	64	89	83	58	32	33	41	35	35	27	33	35	33	35	2			
		7	10	23	49	86	94	91	81	74	83	83	69	74	66	64	61	58	46	47	40	40	37	40	40	3			
		12	32	54	83	98	103	108	109	101	97	108	83	60	69	72	69	61	54	54	46	40	35	27	24	2			
9		29	47	64	103	120	123	106	109	118	118	114	95	66	69	72	72	64	64	58	58	78	64	37	35	3			
		23	46	84	108	134	128	123	134	134	108	103	109	126	108	78	78	72	72	91	81	72	61	40	33	2			
		23	41	77	95	109	115	109	114	111	114	122	115	109	94	78	69	72	81	72	61	60	61	57	37	3			
		15	30	58	84	103	128	106	98	103	111	111	111	109	89	84	83	72	71	61	60	57	47	29	29	3			
		4	15	35	69	72	86	103	98	106	89	86	89	83	89	86	72	58	72	77	47	46	46	46	40	3			
		3	9	12	35	61	61	78	83	89	84	84	77	83	89	83	58	58	71	72	69	58	54	54	37	2			
			3	7	15	37	49	54	49	64	72	71	60	69	74	78	89	86	58	47	35	37	44	40	33	4			
				4	12	23	35	40	46	49	49	41	46	58	64	58	64	54	52	52	49	44	33	33	33	4			
				3	4	15	29	29	33	37	60	54	37	35	29	35	33	46	47	58	72	54	33	37	29	2			
					3	4	9	12	23	23	29	33	37	29	29	24	23	32	40	46	54	60	54	29	21	1			
						3	4	4	7	9	10	23	23	23	33	23	37	47	47	40	24	29	35	23	21	2			
							3	4	4	9	9	9	10	9	9	7	9	23	24	15	10	9	9	10	15	1			
								4	4	4	4	4	10	9	4	4	9	10	15	27	40	41	32	23	7				
									3	3	3	4	4	7	9	9	21	16	15	9	9	9	7	9	12	1			
										3	3	3	3	3	4	4	4	4	4	7	10	9	9	4	4				
										3		3	3	3	4	4	3	4	3		3		4	4	7				
										3		3	3	3	4	7	4	9	10	21	9	7	4	9	10				
											3							3	4	4	7	4	4	9	16	1			
																		3		3	3	3	4	4	4				
																									3				
																									3				

COLUMN NO.=

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	2
0.0	0.0	0.0	0.0	0.0	2.5	5.1	7.6	10.2	12.7	15.2	17.8	20.3	22.9	25.4	27.9	30.5	33.0	35.6	38.1	40.6	43.2	45.7	48.3	50.8	53.3	55.9	58.4	61.

EXIT PLANE IS IN COLUMN 5,FIELD OF VIEW CENTER IS IN COLUMN 28 HORZ INCREMENT= 2.54 CM VERT INCREMENT= .72 CM

TABLE 6. SUBSCALE ENGINE PLUME SPATIAL DISTRIBUTION - O_2 INJECTIO

UN

BACKGR

.513 M

=2.72

	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
					3	4	3																	3							
	4	3				3	3	4	3									4	4	3											
	4	4	3		3				3	4	4	7	4	4	4	3		4	7	7	7	7	4	3							
	4	4	4	4	4	4	4	7	4		3			3		4	4	4		3	4	7	3	3		4	4	4	4	3	
	9	4	3	3		3	4	4	4	4	4	4	4	7	9	9	4	4	3						3	3	4	3			
	4	4	3	3	4	4	4	7	4	4	3					3	4	3	4	4	4	4	3	3							
	9	9	7	7	4	4	4	3		3	4	3	4	4	3	4	3	4	4	3						3		3			
	15	9	9	9	7	4	7	4	4	9	4	4							4	4	4	4						3			
	9	9	10	12	10	12	12	12	12	9	4	3	3	3	4	4	4	4	4		3				3	3	4	3			
	30	23	23	20	9	9	10	10	9	9	9	4	7	4	4	3	4	3		3	3	3									
	20	23	23	21	23	27	24	9	9	10	9	9	4	4	4	4	4	4	4	3	3	3			3	4	4	3			3
	35	23	15	23	23	12	15	12	12	15	12	9	4	4	4	4	4	3	4	4	3										
	54	35	23	15	15	15	15	16	27	23	10	9	7	9	9	9	9	9	4	4											
	27	33	35	33	35	29	23	29	29	20	16	15	12	12	9	9	4	4	4	4	4	4	7	7	7	4					
	40	40	37	40	40	37	29	29	15	10	9	9	9	9	12	10	9	9	10	10	9	7	4	3	3				3	3	3
	46	40	35	27	24	23	23	23	23	29	27	24	23	23	15	12	10	7	7	7	4	4	4	4	4	7	4	4	4	3	
	58	78	64	37	35	35	24	16	16	23	16	10	9	4	7	4	4	4	7	7	4	4	4	7	9	7	7	7	9	4	4
	81	72	61	40	33	27	23	24	23	15	16	23	29	33	16	10	10	10	10	12	9	9	4	3	3	3					
	61	60	61	57	37	37	35	35	24	29	20	20	16	9	4	4	4	4	4	4	7	9	9	10	10	9	9	7	4	3	3
	67	57	47	29	29	30	29	33	32	24	20	16	23	24	23	20	16	15	12	9	4	3				3	4	3	4	4	4
	47	46	46	46	40	35	35	35	32	29	23	15	15	10	9	9	9	9	7	4	3	4	4	7	4	4	3				
	69	58	54	54	37	27	29	32	35	24	21	23	23	15	15	12	12	10	7	7	4	4	4	4	9	9	3	3		3	
	35	37	44	40	33	40	33	24	23	21	20	16	15	12	9	4	4	4	4	9	9	9	4	4	4	7	4	7	4	4	4
	49	44	33	33	33	44	35	27	15	12	9	9	10	15	16	15	7	4	4	7	7	7	4	4	3	3	3	4	4	3	
	72	54	33	37	29	24	15	10	10	10	12	15	21	21	15	10	15	9	4	3	4	7	4	4	7	4	4	4	4	4	3
	54	60	54	29	21	16	15	18	21	24	29	33	33	21	10	7	7	7	7	4	4	4	4	3							3
	24	29	35	23	21	24	24	16	7	4	9	9	9	10	10	10	9	9	9	9	9	9	9	9		4	4	4			
	10	9	9	10	15	16	23	15	15	16	23	23	23	21	9	4	4	3		3	4	4	4	4	4	4	3		3	3	4
	40	41	32	23	7	4	4	4	4		3	4	4	7	9	10	10	12	9	9	4	3									
	9	9	7	9	12	12	15	23	16	9	9	7	7	4				4	3					3	4	4	3				
	10	9	9	4	4	4	4	7	9	9	9	4	4	7	9	9	9	9	4	4											
	3		4	4	7	9	10	12	20	16	12	10	7	4	3	3										3					
	9	7	4	9	10	4		3	4	4	4	4		3	4	4	9	9	9	4	4	4	4	4							
	7	4	4	9	16	15	9	7	4	3		4	7	9	9	9	7									3	4	4	3		
	3	3	4	4	4	9	9	4	7	7	10	7	3		3	4	4	4	7	7	9	7	7	4	4	3					
									3		4	4	4	7	6	7	4		3	4	3					3	3	3	3		
					3		3	4	4								3						3								
					3									3	3	4									3						

63. 50.8 55.9 61.0 66.0 71.1 76.2 81.3 86.4 91.4 96.5 101.6 106.7 111.8 116.8 121.9 12

8.3 53.3 58.4 63.5 68.6 73.7 78.7 83.8 88.9 94.0 99.1 104.1 109.2 114.3 119.4 124.5

T INCREMENT= .72 CM

TABLE 6. SUBSCALE ENGINE PLUME SPATIAL DISTRIBUTION - O_2 INJECTION, NO FLOW

UNITS=WATTS/STER X

BACKGROUND= 153

4	3																3										10	31
	3	4	4	7	4	4	4	3		4	4	3															16	32
			3			3		4	4	4	7	7	7	7	4	3											62	33
7	4		3							3		3	4	7	3	3		4	4	4	4	3					89	34
4	4	4	4	4	4	7	9	9	4	4	3						3	3	4	3							105	35
7	4	4	3					3	4	3	4	4	4	3	3	3											146	36
3		3	4	3	4	4	3	4	3	4	4	3						3		3							136	37
4	4	9	4	4							4	4	4	4						3							178	38
2	12	9	4	3	3	3	4	4	4	4	4		3				3	3	4	3							257	39
0	9	9	9	4	7	4	4	3	4	3		3	3	3													372	40
9	9	10	9	9	4	4	4	4	4	4	4	3		3			3	4	4	3							492	41
2	12	15	12	9	4	4	4	4	4	3	4	4	3	3										3	3		636	42
6	27	23	10	9	7	9	9	9	9	9	4	4	3														694	43
9	29	20	16	15	12	12	9	9	4	4	4	4	4	4	7	7	7	4									1065	44
9	15	10	9	9	9	9	12	10	9	9	10	10	9	7	4	3	3				3	3	3	3			1347	45
3	23	29	27	24	23	23	15	12	10	7	7	7	4	4	4	4	4	7	4	4	4	3					1617	46
6	16	23	16	10	9	4	7	4	4	4	7	7	4	4	4	7	9	7	7	7	9	4	4	4			1917	47
4	23	15	16	23	29	33	16	10	10	10	10	12	9	9	4	3	3	3							3		2148	48
5	24	29	20	20	16	9	4	4	4	4	4	4	7	9	9	10	10	9	9	7	4	3	3	4			2461	49
3	32	24	20	16	23	24	23	20	16	15	12	9	4	3				3	4	3	4	4	4	4			2329	50
5	32	29	23	15	15	10	9	9	9	9	7	4	3	4	4	7	4	4	3								2208	51
2	35	24	21	23	23	15	15	12	12	10	7	7	4	4	4	4	9	9	3	3		3					1919	52
4	23	21	20	16	15	12	9	4	4	4	4	9	9	9	4	4	4	7	4	7	4	4	4	3			1797	53
7	15	12	9	9	10	15	16	15	7	4	4	7	7	7	4	4	3	3	3	4	4	3		3			1472	54
0	10	10	12	15	21	21	15	10	15	9	4	3	4	7	4	4	7	4	4	4	4	4	3				1213	55
8	21	24	29	33	33	21	10	7	7	7	7	4	4	4	4	3							3	3			1052	56
6	7	4	9	9	9	10	10	10	9	9	9	9	9	9	9	9	4	4	4	4							887	57
5	15	16	23	23	23	21	9	4	4	3		3	4	4	4	4	4	4	3		3	3	4	4			685	58
4	4		3	4	4	7	9	10	10	12	9	9	4	3													436	59
3	16	9	9	7	7	4				4	3					3	4	4	3								351	60
7	9	9	9	4	4	7	9	9	9	9	4	4															272	61
2	20	16	12	10	7	4	3	3										3									179	62
3	4	4	4	4		3	4	4	9	9	9	4	4	4	4	4											157	63
7	4	3		4	7	9	9	9	7									3	4	4	3						193	64
4	7	7	10	7	3		3	4	4	4	7	7	9	7	7	4	4	3									151	65
	3		4	4	4	7	6	7	4		3	4	3					3	3	3	3						143	66
4	4								3						3												61	67
						3	3	4									3										20	68
																											16	69

1 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56

0 71.1 76.2 81.3 86.4 91.4 96.5 101.6 106.7 111.8 116.8 121.9 127.0

68.6 73.7 78.7 83.8 88.9 94.0 99.1 104.1 109.2 114.3 119.4 124.5 129.5

3

SUBSCALE HAST RANGE(DET)= 3.513 M

RUN=579 FILE=488 RANGE (FRONT OF CAMERA)= 3.05 M SENSITIVITY= 75 ATTENUATION= 620 POWER=2.72

																												3
																											3	
																		3	3	3	3	4	3	3	3			
																			3	4	7	4	3	4	4	7	4	4
																				3	4	4	7	7	7	4	7	4
																				3	4	4	7	9	10	15	21	24
																			3	3	4	9	9	9	9	7	7	4
																				3	3	4	4	9	9	15	21	29
																	4	9	9	9	7	9	9	12	12	9	9	9
															3	4	7	9	12	12	12	12	10	15	9	9	12	20
															4	16	15	10	12	15	23	16	20	23	15	12	12	12
																4	4	10	15	20	23	29	23	27	35	40	41	29
												3	10	9	12	20	27	24	21	27	24	32	37	29	29	29	15
													7	21	21	23	29	47	54	58	66	71	60	60	37	27	47
													3	4	7	15	35	47	64	60	47	47	40	54	47	54	64
								3	4	4			4	12	9	23	57	74	81	72	71	77	64	47	47	47	44
		3			3		4	3	4	3			3	4	3	3	15	41	49	52	67	72	83	67	58	54	23
		4	7	7	7	4	4	7	7	7			9	9	4	3	4	4	4	9	16	9	4	4	4	9	15
4		10	15	15	15	12	12	16	21	33			23	20	15	29	41	47	78	86	94	103	98	78	71	54	33
		23	27	24	29	32	23	12	16	21			35	54	60	64	64	72	94	101	114	109	101	103	108	106	103
		15	32	29	29	40	35	27	21	29			23	33	58	83	103	109	109	114	103	83	83	97	80	72	64
		16	27	29	33	29	37	27	24	24			29	60	83	109	118	122	118	83	89	89	83	74	72	83	83
		9	16	21	23	23	32	33	35	46			54	58	71	83	101	126	117	111	111	98	74	74	78	89	94
		4	9	9	12	12	15	23	29	32			47	64	78	89	103	111	111	97	72	72	72	69	72	77	89
		3	4	4	4	9	4	9	12	10			15	23	54	83	91	89	86	91	83	71	64	72	64	64	72
				3		3	9	9	9	21			47	54	37	40	46	64	78	83	92	111	109	114	111	89	71
							3	3	3	4			7	12	35	64	83	97	97	83	84	89	97	95	83	74	74
										4			4	16	32	46	49	54	60	64	72	64	60	71	83	101	98
													3		7	12	23	47	66	74	78	74	60	54	46	46	54
										4		35	57	66	64	47	35	47	47	58	71	60	57	49	60	58
												4	10	24	35	40	47	40	40	40	37	54	61	52	47	58
													4	9	20	37	33	32	46	44	52	54	29	15	12	12
															4	10	15	24	41	52	55	54	52	37	32	33
														9	9	9	9	15	16	9	12	23	35	37	35	35
													4	9	12	15	15	21	23	15	20	23	24	23	35	40
													3	4	7	9	9	9	12	15	21	21	23	29	27	23
															4	9	9	7	7	10	12	15	9	9	9	9
														3	3	3	4	9	12	10	9	10	15	16	10	10
																3	4	4	4	7	4	3	4	7	9	15
																						3	3	4	4	3
																						4				
																						3	4			

COLUMN NO.=

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
0.0		0.0		0.0		5.1		10.2		15.2		20.3		25.4		30.5		35.6		40.6		45.7		50.8		55.9	
	0.0		0.0		2.5		7.6		12.7		17.8		22.9		27.9		33.0		38.1		43.2		48.3		53.3		58.4

EXIT PLANE IS IN COLUMN 5,FIELD OF VIEW CENTER IS IN COLUMN 28 HORZ INCREMENT= 2.54 CM VERT INCREMENT= .72 CM

TABLE 7. SUBSCALE ENGINE PLUME SPATIAL DISTRIBUTION - CH_4 INJECTION

M

UNITS=W

BACKGROUND=

																			3	4	3					3				
													3		3	3	4	4	4	4	3									
						3	3							3	4	4	4	4	4	4	3		3							
			3	4	4	3	3	4	9	9	7				3	4	4	4	4	4	4	4	4	4	4	4	3			
		3		3		4	3	4	4	4	4	9	10	9	4	4	4	3	4	4	3						3	3	4	4
3					3	4	4	3	4	4	4	4	4	4	4	7	9	4	4	4	9	9	12	9	4					
4	7	4	4	4	3								3	4	7	9	9	7	4	4	4	4	4	4	4	9	9	9	7	9
7	4	7	4	4	3		3	4	9	12	9	3			3			3	4	4	9	9	9	10	12	15	21	18	12	9
10	15	21	24	35	35	29	23	23	10	7	4	4	3	3	7	4	4			3		3			3	4	4	4	4	7
9	7	7	4	7	9	15	12	12	15	12	12	9	9	9	9	4	3											3	4	4
9	15	21	29	33	47	54	29	23	15	12	10	9	9	9	9	9	7	4	3											
12	9	9	9	9	4	4	4	7	9	10	15	23	24	23	9	7	4	7	9	10	9	4								
9	9	12	20	15	9	9	9	4	4	4	7	9	15	20	20	23	23	23	23	20	10	7	4	3						
15	12	12	12	20	16	9	9	12	20	15	12	9	9	9	9	9	9	9	9	9	9	9	10	12	15	12	12	9	3	
35	40	41	29	21	10	9	9	9	9	10	9	12	10	12	15	12	9	9	9	9	9	9	9	10	9	9	9	9	10	9
29	29	29	15	15	24	29	35	47	58	60	52	29	9	7	7	9	9	7	4	7	9	9	9	9	9	9	7	7	9	9
60	37	27	47	35	23	20	21	23	27	33	23	15	10	10	15	24	29	21	9	9	15	15	12	7	4	4	4	4	4	4
54	47	54	64	69	44	29	23	21	15	12	12	15	12	10	12	10	12	15	12	15	15	10	9	9	9	9	7	7	4	7
47	47	47	44	37	40	44	54	58	54	47	35	23	21	21	21	20	12	9	9	9	9	9	4	4	4	4	4	7	7	7
67	58	54	23	23	29	52	54	37	37	32	29	33	32	29	29	23	16	12	10	9	12	12	9	9	7	7	4	4	3	
4	4	9	15	21	15	15	20	15	15	15	15	15	16	16	20	21	16	15	15	12	7	4	7	9	4	3		3	3	3
78	71	54	33	37	47	49	49	47	37	29	23	16	15	9	7	7	9	9	10	9	10	9	9	9	4	7	9	4	4	3
03	108	106	103	91	72	57	54	46	32	35	35	20	23	23	23	23	21	23	23	23	15	9	4	4	4	4	4	4	4	4
97	80	72	64	58	58	49	52	54	52	49	47	49	47	46	44	40	37	40	32	24	23	15	10	10	9	9	4			
74	72	83	83	94	98	97	89	80	54	49	40	35	35	33	35	37	37	35	29	23	23	23	23	23	23	24	24	15	12	9
74	78	89	94	61	58	60	61	66	69	72	74	58	46	40	37	29	29	23	21	12	15	12	9	7	9	10	12	15	10	10
69	72	77	89	77	61	72	74	78	83	71	54	41	37	41	33	37	33	29	24	23	23	23	23	21	15	12	9	9	9	9
72	64	64	72	74	78	72	66	69	55	40	37	33	35	35	44	47	49	49	35	27	24	23	20	21	21	15	12	9	9	9
14	111	89	71	66	61	54	47	46	46	40	35	40	40	37	40	40	29	20	15	15	20	21	15	10	9	9	9	10	12	10
95	83	74	74	72	69	69	72	71	71	58	49	44	24	20	20	23	24	24	23	23	12	12	15	15	15	12	9	9	7	4
71	83	101	98	71	58	44	37	40	44	47	54	58	60	57	37	32	35	44	41	32	23	12	9	10	9	9	9	9	9	4
54	46	46	54	47	47	54	56	61	58	40	29	32	29	33	37	35	33	29	29	24	27	27	27	23	15	12	9	9	9	9
57	49	60	58	52	54	54	58	58	40	40	41	32	21	15	15	23	22	16	15	16	16	21	23	23	23	23	15	9	9	7
61	52	47	58	71	64	58	60	49	37	35	40	41	44	41	37	24	29	24	24	23	12	9	10	15	12	9	9	9	9	7
29	15	12	12	21	21	23	24	29	46	57	57	58	57	49	46	33	27	27	29	29	32	23	21	16	15	9	9	9	9	4
52	37	32	33	35	33	47	58	61	64	47	27	20	15	9	10	15	23	24	23	23	23	23	23	9	9	12	15	15	15	15
35	37	35	35	35	40	40	40	37	37	23	20	21	21	15	16	15	20	20	23	23	23	20	15	12	10	10	10	10	9	9
24	23	35	40	41	37	35	27	29	32	35	40	44	47	47	35	35	32	33	23	10	7	7	9	9	9	9	9	9	10	9
23	29	27	23	21	16	15	9	15	29	46	71	72	47	33	24	12	10	12	12	15	21	21	23	29	29	27	23	15	12	10
9	9	9	9	16	15	15	23	23	23	23	32	35	41	40	35	40	35	23	12	9	12	21	21	20	16	21	15	15	15	9
15	16	10	10	24	27	7	4	4	4	4	7	9	10	10	12	10	15	23	23	21	15	12	10	9	9	10	12	12	10	9
4	7	9	15	28	15	23	29	29	35	41	40	12	4	3		3	4	4	4	4	4	4	9	10	12	15	15	15	15	9
3	4	4	3	3	4	7	7	9	12	10	10	10	12	12	12	10	15	20	21	23	23	7			3	4	4	4	7	7
				3							3	4	4	9	9	10	9	9	10	9	7	9	9	7	4	4	4	3		3
																				4	4	4	3	3		3	4	4	3	
4																														
25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55
.8	53.3	55.9	58.4	61.0	63.5	66.0	68.6	71.1	73.7	76.2	78.7	81.3	83.8	86.4	88.9	91.4	94.0	96.5	99.1	101.6	104.1	106.7	109.2	111.8	114.3	116.8	119.4	121.9	124.5	127.0

CREMENT= .72 CM

TABLE 7. SUBSCALE ENGINE PLUME SPATIAL DISTRIBUTION - CH_4 INJECTION, NO FLOW

UNITS=WATTS/STER X

BACKGROUND= 153

											3	4	3					3						13	26
					3		3	3	4	4	4	4	3											28	27
						3	4	4	4	4	4	4	3		3									39	28
4	9	9	7				3	4	4	4	4	4	4	4	4	4	4	4	3					96	29
4	4	4	4	9	10	9	4	4	4	3	4	4	3						3	3	4	4		97	30
3	4	4	4	4	4	4	4	7	9	4	4	4	9	9	12	9	4							138	31
					3	4	7	9	9	7	4	4	4	4	4	4	9	9	9	9	7	9		161	32
4	9	12	9	3			3			3	4	4	9	9	9	10	12	15	21	18	12	9		232	33
23	10	7	4	4	3	3	7	4	4			3		3			3	4	4	4	4	7		320	34
12	15	12	12	9	9	9	9	4	3											3	4	4		212	35
23	15	12	10	9	9	9	9	9	7	4	3													379	36
7	9	10	15	23	24	23	9	7	4	7	9	10	9	4										298	37
4	4	4	7	9	15	20	20	23	23	23	23	20	10	7	4	3								407	38
12	20	15	12	9	9	9	9	9	9	9	9	9	9	9	10	12	15	12	12	9	3			490	39
9	9	10	9	12	10	12	15	12	9	9	9	9	9	9	9	10	9	9	9	9	10	9		575	40
47	58	60	52	29	9	7	7	9	9	7	4	7	9	9	9	9	9	9	7	7	9	9		842	41
23	27	33	23	15	10	10	15	24	29	21	9	9	15	15	12	7	4	4	4	4	4	4		1048	42
21	15	12	12	15	12	10	12	10	12	15	12	15	15	10	9	9	9	9	7	7	4	7		1012	43
58	54	47	35	23	21	21	21	20	12	9	9	9	9	9	4	4	4	4	4	7	7	7		1313	44
37	37	32	29	33	32	29	29	23	16	12	10	9	12	12	9	9	7	7	4	4	3			1167	45
15	15	15	15	15	16	16	20	21	16	15	15	12	7	4	7	9	4	3		3	3	3		481	46
47	37	29	23	16	15	9	7	7	9	9	10	9	10	9	9	9	4	7	9	4	4	3		1496	47
46	32	35	35	20	23	23	23	23	21	23	23	23	15	9	4	4	4	4	4	4	4	4		2179	48
54	52	49	47	49	47	46	44	40	37	40	32	24	23	15	10	10	9	9	4					2329	49
80	54	49	40	35	35	33	35	37	37	35	29	23	23	23	23	23	23	24	24	15	12	9		2640	50
66	69	72	74	58	46	40	37	29	29	23	21	12	15	12	9	7	9	10	12	15	10	10		2502	51
78	83	71	54	41	37	41	33	37	33	29	24	23	23	23	23	21	15	12	9	9	9	9		2389	52
69	55	40	37	33	35	35	44	47	49	49	35	27	24	23	20	21	21	15	12	9	9	9		2089	53
46	46	40	35	40	40	37	40	40	29	20	15	15	20	21	15	10	9	9	9	10	12	10		1996	54
71	71	58	49	44	24	20	20	23	24	24	23	23	12	12	15	15	15	12	9	9	7	4		1953	55
40	44	47	54	58	60	57	37	32	35	44	41	32	23	12	9	10	9	9	9	9	9	4		1772	56
61	58	40	29	32	29	33	37	35	33	29	29	24	27	27	27	23	15	12	9	9	9	9		1486	57
58	40	40	41	32	21	15	15	23	23	16	15	16	16	21	23	23	23	23	15	9	9	7		1557	58
49	37	35	40	41	44	41	37	24	29	24	24	23	12	9	10	15	12	9	9	9	9	7		1391	59
29	46	57	57	58	57	49	46	33	27	27	29	29	32	23	21	16	15	9	9	9	9	4		1179	60
61	64	47	27	20	15	9	10	15	23	24	23	23	23	23	23	9	9	12	15	15	15	15		1102	61
37	37	23	20	21	21	15	16	15	20	20	23	23	23	20	15	12	10	10	10	10	9	9		827	62
29	32	35	40	44	47	47	35	35	32	33	23	10	7	7	9	9	9	9	9	9	10	9		948	63
15	29	46	71	72	47	33	24	12	10	12	12	15	21	21	23	29	29	27	23	15	12	10		881	64
23	23	23	32	35	41	40	35	40	35	23	12	9	12	21	21	20	16	21	15	15	15	9		714	65
4	4	4	7	9	10	10	12	10	15	23	23	21	15	12	10	9	9	10	12	12	10	9		436	66
29	35	41	40	12	4	3		3	4	4	4	4	4	4	9	10	12	15	15	15	15	9		442	67
9	12	10	10	10	12	12	12	10	15	20	21	23	23	7			3	4	4	4	7	7		273	68
			3	4	4	9	9	10	9	9	10	9	7	9	9	7	4	4	4	3		3		133	69
												4	4	4	3	3		3	4	4	3			32	70
																								7	71

33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56

71.1 76.2 81.3 86.4 91.4 96.5 101.6 106.7 111.8 116.8 121.9 127.0

73.7 78.7 83.8 88.9 94.0 99.1 104.1 109.2 114.3 119.4 124.5 129.5

SUBSCALE HAST RANGE(DET)= 3.513 M

RUN=579 FILE=497 RANGE (FRONT OF CAMERA)= 3.05 M SENSITIVITY= 75 ATTENUATION= 620 POWER=2.72

										3		3															
						3	3	3	3	3	3	3	3			3		3	3	3							
			3	3	4	4	4	4	4	4	4	3		4	4	3	3	3	3	3		3	3				
		3	4	4	4	4	4	4	9	4	4	4	4	4	7	4	4	3	4	4							
		3	4	7	9	4	7	9	9	9	12	9	7	4	9	15	10	9	4	3	3	3	3	4			
		4	12	15	12	16	23	15	15	15	16	12	10	15	12	9	7	4	4	4	4	4	4	3			
		10	24	29	29	37	35	37	37	27	16	20	23	29	15	9	4	7	9	9	4	3	3	4			
	3	23	37	41	47	47	47	47	46	37	33	29	23	15	12	20	12	10	10	9	9	4	7	4			
		20	37	47	47	54	57	58	58	47	44	43	41	35	27	20	15	15	12	15	9	7	4	4			
		23	35	44	47	58	54	49	58	54	47	40	41	37	23	21	12	9	10	12	12	9	4	4			
		9	23	29	33	47	41	49	49	45	46	47	35	29	29	21	20	10	12	9	12	9	7	9			
		4	12	20	23	29	35	32	37	37	40	29	24	27	15	15	15	10	9	4	4	4	4	7			
		4	7	9	12	12	15	15	23	23	16	23	24	15	15	15	12	9	9	4	7	9	9	9			
			3	4	4	7	9	9	10	12	10	12	16	9	12	23	10	9	9	9	9	7	4	4			
					3	3	4	4	7	9	9	4	4	4	4	9	9	9	4	4	4	4	4	4			
							3	3	3	4	4	4	3	4	4	4	9	4	4	3	4	4	4	4			
								3					3	3	4	4	4	7	4								
																3	3		3								

COLUMN NO.=

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
0.0		0.0		0.0		5.1		10.2		15.2		20.3		25.4		30.5		35.6		40.6		45.7		50.8		55.9
	0.0		0.0		2.5		7.6		12.7		17.8		22.9		27.9		33.0		38.1		43.2		48.3		53.3	5

EXIT PLANE IS IN COLUMN 5,FIELD OF VIEW CENTER IS IN COLUMN 28 HORZ INCREMENT= 2.54 CM VERT INCREMENT= .7

TABLE 8. SUBSCALE ENGINE PLUME SPATIAL DISTRIBUTION - O_2 INJECTION,

= 3.513 M

ER=2.72

BA

	23	24	25	26	27	28	29	30	31	32	33	34	35	36
		3	3											
4	4													
3	3	3	3	3	4									
4	4	4	4	4	3		3	3						
4	9	4	3	3	4	4	4	3		3	3			
4	9	9	4	7	4	3	3				3			
4	15	9	7	4	4	4	4	3	3					
4	12	12	9	4	4	3	4	4	3					
9	9	12	9	7	9	4	4	3	4	3		3	3	
7	4	4	4	4	7	4	3		3	4	3			
9	4	7	9	9	9	4	3	3	3					3
4	9	9	7	4	4	4	3	3	3					
4	4	4	4	4	4	4	3	3	3					
	3	4	4	4	4									

7 2 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53

9 7 50.8 55.9 61.0 66.0 71.1 76.2 81.3 86.4 91.4 96.5 101.6 106.7 111.8 116.8 121.9

58.4 48.3 53.3 58.4 63.5 68.6 73.7 78.7 83.8 88.9 94.0 99.1 104.1 109.2 114.3 119.4 124

.72 C ERT INCREMENT= .72 CM

TABLE 8. SUBSCALE ENGINE PLUME SPATIAL DISTRIBUTION - O_2 INJECTION, MACH 0.3 N_2 FLOW

UNITS=WATTS/STER X

BACKGROUND= 153

6	41
33	42
66	43
82	44
156	45
241	46
437	47
581	48
730	49
717	50
645	51
453	52
312	53
214	54
119	55
72	56
32	57
9	58

	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56
		3	3																							
			3																							
		3		3	3																					
		4	3			3																				

68.6 71.1 73.7 76.2 78.7 81.3 83.8 86.4 88.9 91.4 94.0 96.5 99.1 101.6 104.1 106.7 109.2 111.8 114.3 116.8 119.4 121.9 124.5 127.0 129.5

SUBSCALE HAST RANGE(DET)= 3.513 M

RUN=579 FILE=502 RANGE (FRONT OF CAMERA)= 3.05 M SENSITIVITY= 75 ATTENUATION= 620 POWER=2.72

			3	3	4	3	4	4	3	3		3		3	3												
			7	9	9	7	7	4	4	4	4	4	4	4	4	3	4	3									
			15	15	15	10	12	9	9	10	10	4	4	3	4	4	4	4	3						3		
4			12	29	24	23	23	20	15	12	12	9	4	4	4	4	4	3	3	3	3						
			15	32	29	29	27	24	24	15	10	9	9	9	9	4	4	3	4	4							
			10	32	32	35	32	29	29	29	16	9	10	15	12	4	4	3	3			3				
			10	24	23	23	24	21	23	23	9	10	15	9	4	4	4	4	4	4							
			7	10	12	12	10	10	9	9	9	9	9	10	7	4	7	4	4	3		3					
			4	4	7	4	9	7	9	9	9	9	4	3	4	4	4	4									
				4	4	4	4	4	4	7	9	4	4	3	3	4	4	3	4	4	3						
						3	3	4	3	3	3	4	4	4	4	4	3	3	4	3		3					

COLUMN NO.=

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
0.0	0.0	0.0	0.0	0.0	2.5	5.1	7.6	10.2	12.7	15.2	17.8	20.3	22.9	25.4	27.9	30.5	33.0	35.6	38.1	40.6	43.2	45.7	48.3	50.8	53.3	55.3

EXIT PLANE IS IN COLUMN 5,FIELD OF VIEW CENTER IS IN COLUMN 28 HORZ INCREMENT= 2.54 CM VERT INCREMENT= .7

TABLE 9. SUBSCALE ENGINE PLUME SPATIAL DISTRIBUTION - CH_4 INJE

```
E(DET)= 3.513 M
20  POWER=2.72

                3
  3   3
  4                                                  3
          3
  4
  3       3
  4   3
  3       3

  22  23  24  25  26  27  28  29  30  31  32  33  34  35  36  37  38  39  40  41  42  43  44  45  46  47  48  49  50  51  52
     45.7    50.8    55.9    61.0    66.0    71.1    76.2    81.3    86.4    91.4    96.5   101.6   106.7   111.8   116.8   1
43.2    48.3    53.3    58.4    63.5    68.6    73.7    78.7    83.8    88.9    94.0    99.1   104.1   109.2   114.3   119.4
CM   VERT INCREMENT=  .72 CM
```

TABLE 9. SUBSCALE ENGINE PLUME SPATIAL DISTRIBUTION - CH_4 INJECTION, MACH 0.3 N_2 FLOW

UNITS=WATTS/STER X

BACKGROUND= 153

36	45
81	46
138	47
215	48
263	49
307	50
238	51
148	52
94	53
76	54
55	55

3

30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56

66.0 71.1 76.2 81.3 86.4 91.4 96.5 101.6 106.7 111.8 116.8 121.9 127.0

.5 68.6 73.7 78.7 83.8 88.9 94.0 99.1 104.1 109.2 114.3 119.4 124.5 129.5

3

SUBSCALE HAST RANGE(DET)= 3.513 M

RUN=579 FILE=505 RANGE (FRONT OF CAMERA)= 3.05 M SENSITIVITY= 75 ATTENUATION= 620 POWER=2.72

											3															
					3	3	4	3	4	4	4															
		3	3		4	4	4	4	4	4	4	4				3	3									
3	4	4	4	4	9	9	4	4	4	4	4	4	4	4	4	4	3	3	3							
4	9	9	9	9	9	9	10	10	10	9	9	4	9	9	9	4	3			4						
10	21	21	23	23	20	21	24	15	12	12	10	9	4	4	4	4	4	4	4	4	4	4				
15	37	37	40	37	37	29	23	35	37	29	23	10	10	12	12	12	7	4	4	4	4	4				
16	40	40	46	54	47	46	49	47	37	29	27	24	23	23	20	9	7	4	4	4	4	7				
23	32	35	40	47	46	47	44	52	57	44	29	24	21	21	15	9	7	7	9	9	9	9				
9	23	24	29	32	37	46	35	32	29	29	15	20	29	23	10	9	9	9	9	9	9	4				
7	16	21	23	23	33	40	37	29	27	24	24	23	21	16	20	12	9	4	4	4						
4	9	10	12	23	20	15	21	24	27	29	23	21	20	12	7	9	7	4	4	4	4	4				
3	4	7	7	9	9	15	15	15	10	20	9	9	9	7	7	4	4	4	7	4	3					
	3	3	4	4	4	4	7	9	9	9	9	9	9	9	4	3			3	3	3					
			3	3	4	4	4	4	4	4	4	4	4	7	4	3	4	4	4							
						3		3	3		3	3	4	3								3	4			

COLUMN NO.=

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
0.0		0.0		0.0		5.1		10.2		15.2		20.3		25.4		30.5		35.6		40.6		45.7		50.8		55.9
	0.0		0.0		2.5		7.6		12.7		17.8		22.9		27.9		33.0		38.1		43.2		48.3		53.3	

EXIT PLANE IS IN COLUMN 5,FIELD OF VIEW CENTER IS IN COLUMN 28 HORZ INCREMENT= 2.54 CM VERT INCREMENT= .

TABLE 10. SUBSCALE ENGINE PLUME SPATIAL DISTRIBUTION, - NO INJECTION, MAC

UNI

BACKGRO

513 M

2.72

```
4                   3
4   4   4   3       4   3       3
4   4   4   3                   3   3
4   4   7   3       3       3       3
9   9   9   4       3
9   9   4   3       4   4
4   4               4   3
4   4   4   3
7   4   3   3       4   3
3   3   3   3
4                   3       3
            3   4
```

```
24  25  26  27  28  29  30  31  32  33  34  35  36  37  38  39  40  41  42  43  44  45  46  47  48  49  50  51  52  53  54
    50.8    55.9    61.0    66.0    71.1    76.2    81.3    86.4    91.4    96.5   101.6   106.7   111.8   116.8   121.9   127
3       53.3    58.4    63.5    68.6    73.7    78.7    83.8    88.9    94.0    99.1   104.1   109.2   114.3   119.4   124.5
```

INCREMENT= .72 CM

TABLE 10. SUBSCALE ENGINE PLUME SPATIAL DISTRIBUTION, - NO INJECTION, MACH 0.3 N_2 FLOW

UNITS=WATTS/STER X

BACKGROUND= 153

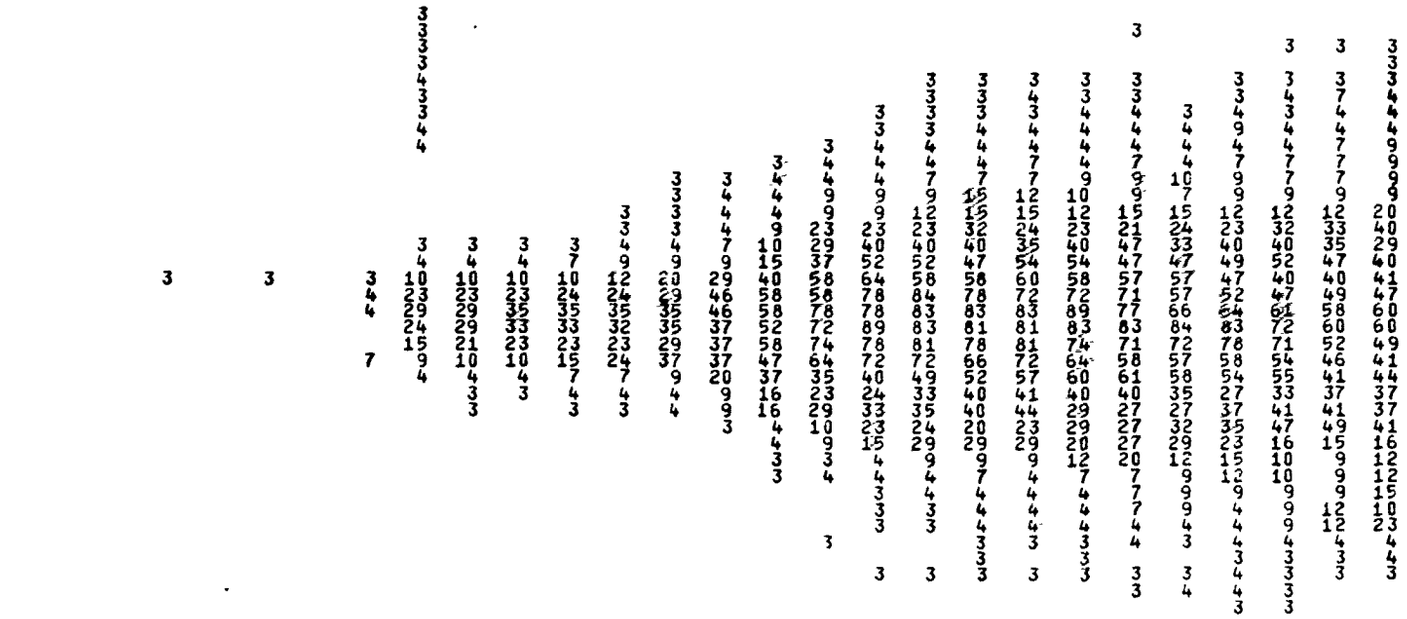
3	41
25	43
44	44
78	45
151	46
270	47
467	48
615	49
634	50
482	51
427	52
312	53
191	54
111	55
74	56
22	57
7	59

2	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	
	71.1		76.2		81.3		86.4		91.4		96.5		101.6		106.7		111.8		116.8		121.9		127.0		
6		73.7		78.7		83.8		88.9		94.0		99.1		104.1		109.2		114.3		119.4		124.5		129.5	

3

SUBSCALE HAST RANGE(DET)= 3.513 M

RUN=507 FILE=281 RANGE (FRONT OF CAMERA)= 3.05 M SENSITIVITY= 75 ATTENUATION= 620 POWER=2.46



COLUMN NO.=

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	5.1	7.6	10.2	12.7	15.2	17.8	20.3	22.9	25.4	27.9	30.5	33.0	35.6	38.1	40.6	43.2	45.7	48.3	50.8

EXIT PLANE IS IN COLUMN 7, FIELD OF VIEW CENTER IS IN COLUMN 28 HORZ INCREMENT= 2.54 CM VERT INCREMENT= .7

TABLE 11. SUBSCALE ENGINE PLUME SPATIAL DISTRIBUTION - NO INJEC

3.513 M

R=2.46

UN

BACKGR

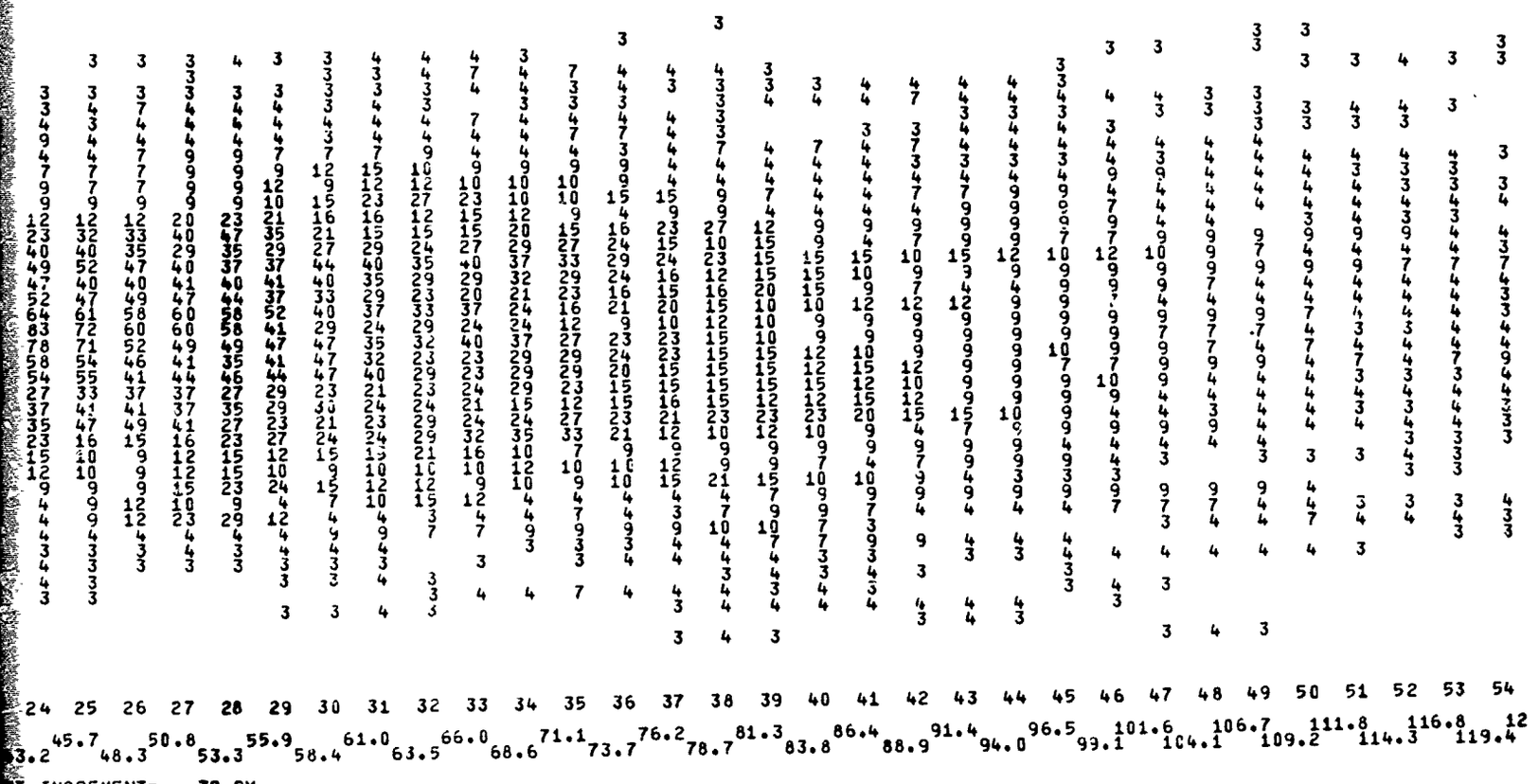


TABLE 11. SUBSCALE ENGINE PLUME SPATIAL DISTRIBUTION - NO INJECTION, NO FLOW

UNITS=WATTS/STER X

BACKGROUND= 153

				3																		6	31
3		3													3	3						15	32
3												3	3		3					3		49	33
4	7	4	4	4	3						3					3	3	4	3	3	3	71	34
4	3	4	3	3	3	3	4	4	4	4	3											92	35
3	3	3		3	4	4	4	7	4	4	4	4	4	3	3							112	36
3	4	4	4	3					3	3	3		3	3	3	3	4	4	3			119	37
4	7	7	4	3			3	3	4	4	4	3			3	3	3	3			3	135	38
4	4	3	4	7	4	7	4	7	4	4	4	4	4	4	4						3	177	39
3	9	9	4	4	4	4	4	3	3	3	3	4	3	4	4	4	4	4	4	3	4	232	40
3	10	9	4	4	4	4	4	4	4	4	4	9	9	4	4	4	3	3	3			267	41
3	10	15	15	9	7	4	4	7	7	9	9	4	4	4	4	4	4	3	3	3	3	376	42
4	12	9	9	9	4	4	4	4	9	9	9	7	4	4	4	4	4	4	4	4	3	403	43
3	20	15	16	23	27	12	9	9	9	9	9	9	4	4		3	4	3	3		3	688	44
4	29	27	24	15	10	15	9	4	7	9	9	7	7	9	9	9	9	9	4	4	4	894	45
4	37	33	29	24	23	15	15	15	10	15	12	10	12	10	9	7	4	4	4	4	3	1170	46
4	32	29	24	16	12	15	15	10	9	9	9	9	9	9	9	9	9	9	7	7	7	1270	47
4	21	23	16	15	16	20	15	9	7	4	4	9	9	9	7	4	4	4	4	4	4	1417	48
3	24	16	21	20	15	10	10	12	12	12	9	9	7	4	4	4	4	4	4	4	3	1655	49
4	24	12	9	10	12	10	9	9	9	9	9	9	9	9	9	7	4	4	4	4	3	1604	50
7	37	27	23	23	15	10	9	9	9	9	9	9	9	7	7	4	3	3	4	4	3	1578	51
4	29	29	24	23	15	15	12	10	9	9	9	10	9	9	7	4	7	4	4	4	4	1371	52
4	29	29	20	15	15	15	12	15	12	9	9	7	7	9	9	9	4	7	4	7	9	1186	53
	29	23	15	15	15	15	15	12	10	9	9	9	10	9	4	4	4	3	3	3	4	824	54
1	15	12	15	16	15	12	12	15	12	9	9	9	9	4	4	4	4	4	4	4	4	817	55
3	24	27	23	21	23	23	23	20	15	15	10	9	4	4	3	4	4	3	3	4	3	779	56
	35	33	21	12	10	12	10	9	4	7	9	9	9	9	9	4	4	4	4	4	3	644	57
3	10	7	9	9	9	9	9	9	9	9	9	4	4	4	4	4			3	3	3	351	58
	12	10	10	12	9	9	7	4	7	9	9	9	3	3		3	3	3	4	3		286	59
4	10	9	10	15	21	15	14	10	9	4	3	3	3						3	3	3	303	60
3	4	4	4	4	4	7	9	9	9	9	9	9	9	9	9	4						247	61
3	4	7	4	3	7	9	9	7	4	4	4	4	7	7	7	4	4	3	3	3	4	242	62
	9	9	9	9	10	10	7	3						3	4	4	7	4	4	4	3	177	63
3	3	3	4	4	4	7	7	9	9	4	4	4								3	3	104	64
		3	4	4	4	4	3	3		3	3	4	4	4	4	4	4	3				107	65
				3	4	3	4	3				3									3	50	66
	4	7	4	4	4	3	4	3				3	4	3								56	67
				3	4	4	4	4	4	4	4		3									47	68
									3	4	3											10	69
				3	4	3								3	4	3						20	70
55																							
1.9	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56
1		71.1		76.2		81.3		86.4		91.4		96.5		101.6		106.7		111.8		116.8		121.9	
	.6		73.7		78.7		83.8		88.9		94.0		99.1		104.1		109.2		114.3		119.4		124.5

3

SUBSCALE HAST RANGE(DET)= 3.513 M

RUN=587 FILE=292 RANGE (FRONT OF CAMERA)= 3.05 M SENSITIVITY= 75 ATTENUATION= 620 POWER=2.46

																3								3				3
																3	3		3				3		3	3	3	
													3	3	3	4	4	4	3	4	3	3	3	3	3	3	3
													3	3	4	7	4	4	7	4	3	3	3	3	3	4	3
													3	4	4	7	10	9	10	9	4	4	4	4	4	4	4
								3		3	4	4	4	9	9	9	12	9	15	9	4	9	9	7	9	10	12
							3	3		3	4	4	4	7	9	12	9	9	9	9	12	10	15	9	4	4	4
						3	3	3	3	4	7	9	10	21	23	27	23	20	10	12	15	12	9	9	9	9	9
					3	4	4	4	9	15	23	24	24	21	15	21	24	24	23	16	9	9	9	12	9	9	9
3				3	7	9	9	12	20	23	29	44	44	40	35	35	29	35	33	29	24	23	23	15	12	10	10
				4	12	15	15	16	23	29	40	37	37	41	35	37	35	32	35	27	23	15	15	9	24	9	9
			3		20	24	27	24	24	35	52	54	54	52	46	35	35	35	32	23	24	21	16	15	12	9	9
				3	24	29	32	29	29	35	44	46	46	47	49	49	52	47	47	47	37	15	12	15	12	10	10
				7	24	24	24	24	24	35	35	47	47	52	49	37	27	24	29	37	33	23	21	10	10	9	9
				9	16	16	16	20	24	35	40	47	47	47	47	33	23	23	24	23	20	12	12	15	9	7	7
				4	9	9	9	12	23	29	37	32	37	37	40	29	24	29	21	23	27	16	9	12	12	7	7
				3	4	4	7	7	9	12	23	29	27	27	35	40	40	29	24	15	15	12	9	9	10	9	9
					3	4	4	4	4	4	9	15	20	20	16	21	29	16	12	16	23	23	15	9	10	10	10
						3	3	3	3	4	4	7	12	12	9	7	9	15	21	9	9	15	15	12	4	4	4
										3	4	4	4	4	4	7	4	4	4	4	9	9	7	4	4	4	4
										3	3	4	4	4	4	3	4	3	3				3	3			4
												3	3	4	4	4	4	3	3	7	9	4	4	4			
															3	3									3		
																3		3									4
														3													

COLUMN NO.=

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
0.0		0.0		0.0		0.0		5.1		10.2		15.2		20.3		25.4		30.5		35.6		40.6		45.7		50.8	
	0.0		0.0		0.0		2.5		7.6		12.7		17.8		22.9		27.9		33.0		38.1		43.2		48.3		53.3

EXIT PLANE IS IN COLUMN 7,FIELD OF VIEW CENTER IS IN COLUMN 28 HORZ INCREMENT= 2.54 CM VERT INCREMENT= .72 C

TABLE 12. SUBSCALE ENGINE PLUME SPATIAL DISTRIBUTION - NO INJECTION, I

3.513 M

ER=2.46

BAC

											3	3																							
	3				3		3																												
		3	3	3																															
3	3	3	3	3	3			3	3	4	3	3																							
3	3	3	3	4	3	3	3	3	3	3	3																								
4	4	4	4	4	4	4	3	3	3		3	3	3	3																					
9	9	7	9	10	12	10	9	4	3		3	3		3																					
0	15	9	4	4	4	4	4	4	3	3	3	3	3																						
5	12	9	9	9	9	4	7	4	4	3			3	4	3																				
9	9	9	12	9	9	10	4	3	3	4	4	3	3																						
4	23	23	15	12	10	9	9	7	7	9	4	3		3						3															
3	15	15	9	24	9	4	4	4	4	3	4	7	4	4		3																			
4	21	16	15	12	9	4	4	4	4	3		3	3	3	3	4																			
7	15	12	15	12	10	9	9	4	4	3	4	3			3	3																			
3	23	21	10	10	9	7	7	7	9	4	3																								
0	12	12	15	9	7	9	9	4	4	4	3	3		3	3	3																			
7	16	9	12	12	7	4	4	7	4	4	4																								
5	12	9	9	10	9	4	3	3	3		4	4	3	3																					
3	23	15	9	10	10	7	4	4	3						3	3																			
9	15	15	12	4	4	9	9	4	7	4																									
9	9	7	4	4	4	4	4	3		3		3		3																					
		3	3		4	7	4																												
9	4	4	4							3	4	3																							
				3								3																							
					4																														

23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 5

46 45.7 50.8 55.9 61.0 66.0 71.1 76.2 81.3 86.4 91.4 96.5 101.6 106.7 111.8 116.8

43.2 48.3 53.3 58.4 63.5 68.6 73.7 78.7 83.8 88.9 94.0 99.1 104.1 109.2 114.3 119.

ERT INCREMENT= .72 CM

2

BLE 12. SUBSCALE ENGINE PLUME SPATIAL DISTRIBUTION - NO INJECTION, MACH 0.7 AIRFLOW

UNITS=WATTS/STER X

BACKGROUND= 153

																								6	35
																								12	36
																								21	37
3	3																							65	38
3																								77	39
3	3	3	3																					109	40
3	3		3																					181	41
3	3	3																						166	42
		3	4	3																				270	43
4	3	3																						321	44
4	3		3					3																556	45
4	7	4	4		3																			569	46
	3	3	3	3	4																			653	47
4	3			3	3																			752	48
3																								642	49
3	3		3	3	3																			563	50
4																								477	51
4	4	3	3																					399	52
				3	3																			231	53
																								201	54
	3		3																					99	55
																								52	56
4	3																							62	57
	3																							12	58
																								10	60
																								3	61

34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56

71.1 76.2 81.3 86.4 91.4 96.5 101.6 106.7 111.8 116.8 121.9

.6 73.7 78.7 83.8 88.9 94.0 99.1 104.1 109.2 114.3 119.4 124.5

3

SUBSCALE HAST RANGE(DET)= 3.513 M

RUN=587 FILE=299 RANGE (FRONT OF CAMERA)= 3.05 M SENSITIVITY= 75 ATTENUATION= 620 POWER=2.46

							3																			
							3					3		3	3	3	3	3	3	3						
							3						3	3	3	3		3	3		3		3		3	
							3					3	3	3	3	3	4	4	3	4	4		3	4	4	
										3	3	4	4	4	4	4	4	7	4	4	4	3	3	3		
										3	4	4	7	9	10	7	4	9	15	9	7		3			
							3		3	3	4	7	9	12	10	20	23	23	15	12	9	3	3		3	
							3	3	4	4	7	15	15	12	15	10	12	9	10	7	4	4	4	4	4	3
							3	4	4	4	9	10	10	12	20	23	15	15	15	15	21	9	9	4	4	4
							3	7	4	7	9	15	15	24	23	9	15	9	9	9	4	3	3	3		4
		3	6	9	9	10	23	33	20	20	23	23	23	16	7	4	7	4	7	7	4	3				
		4	15	15	12	15	27	40	29	29	23	29	23	10	10	10	12	9	12	9	4	3				
		4	21	23	15	15	23	24	15	23	29	20	21	10	9	9	9	7	4	4	4	4				
		4	27	32	24	27	32	35	29	35	41	21	23	15	15	12	9	10	9	4	3	3				
		3	32	40	46	37	40	49	54	47	41	40	35	32	24	23	27	21	16	9	4	4				
		9	32	32	35	32	46	60	47	47	44	41	41	29	23	15	15	10	10	9	9	9				
			16	27	29	35	33	41	57	60	54	47	40	37	40	33	35	32	27	27	16	16				
		3	9	15	16	21	29	47	54	64	74	64	47	40	44	47	46	52	35	24	9	4				
			7	9	9	15	24	24	29	41	58	57	54	46	44	46	32	23	21	15	12	10				
			4	4	7	7	10	23	40	41	40	40	47	33	29	37	37	23	21	15	12	10				
			3	3	4	4	7	9	12	15	24	24	29	37	35	33	23	12	10	9	9	9				
				3		3	4	9	21	29	23	15	15	15	12	12	10	9	10	9	4	4				
							3	4	4	4	4	9	20	35	46	24	10	4	9	12	15	10				
							3	3	4	4	4	4	9	10	7	7	9	4	4	4	4	7				
								3	4	4	7	7	4	7	9	10	9	4	4	4	4	3				
								3	3	3	4	4	4	4	4	4	4	4	4	4	4	4				
										3	3	3	4	3	3	3	3	3	4	4	4	3				
									3		3	3		3	3	4	4	4	4	3	3	3				
										3	3	3														
											3				3	4	4		3	3	3	3				
										3		3														
									3	3		3														

COLUMN NO.=

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	5.1	7.6	10.2	12.7	15.2	17.8	20.3	22.9	25.4	27.9	30.5	33.0	35.6	38.1	40.6	43.2	45.7	48.3	50.8

EXIT PLANE IS IN COLUMN 7,FIELD OF VIEW CENTER IS IN COLUMN 28 HORZ INCREMENT= 2.54 CM VERT INCREMENT= .7

TABLE 13. SUBSCALE ENGINE PLUME SPATIAL DISTRIBUTION - POPS INJECTION, MACH (

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13 M                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                
```

UNITS

BACKGROUI

```
3         3
3    4    4
3    3
3
3         3
4    4    4    3    3         3
6    4    4    4    3
3    3         4
7    7    4    3    4    3
2    9    4    3
4    4    4    4    3
9    4    3    3    3
6    9    4    4    4    4    4    3
0    9    9    9    9    4    4
7   27   16   16    9    4    3         3         3         3
5   24    9    4    4    4    3    4    4    3    3
1   15   12   10    9    3         3
1   15   12   10    9    4    4    3                        3    4    4    4
0    9    9    9    7    4    3    3    3
0    9    4    4    3    3
9   12   15   10   15    4    3
4    4    4    7    9   12    7    4    3
4    4    4    3    3         3    4    4
4    4    4    4    3                   3         3
4    4    4    3                        3         3    3    3    4    3    3
4    3    3    3    4    4                   3         3
     3    4                   3         3
3    3    3    3    3    4    3                                                  3

24  25   26   27   28   29   30   31   32   33   34   35   36   37   38   39   40   41   42   43   44   45   46   47   48   49   50   51   52   53   54   5
    45.7      50.8      55.9      61.0      66.0      71.1      76.2      81.3      86.4      91.4      96.5      101.6     106.7     1.1.8     116.8     121.
2        48.3      53.3      58.4      63.5      68.6      73.7      78.7      83.8      88.9      94.0      99.1      104.1     109.2     114.3     119.4
INCREMENT=   .72 CM
```

TABLE 13. SUBSCALE ENGINE PLUME SPATIAL DISTRIBUTION - POPS INJECTION, MACH 0.7 AIRFLOW

UNITS=WATTS/STER X

BACKGROUND= 153

																									3 32
																									27 37
																									30 38
																									49 39
																									58 40
																									91 41
																									162 42
																									155 43
																									213 44
																									175 45
																									271 46
																									340 47
																									296 48
																									413 49
																									639 50
																									612 51
		3			3																				727 52
3		3																							769 53
					3	4	4	4																	591 54
																									515 55
																									331 56
																									213 57
																									235 58
																									122 59
																									97 60
		3																							66 61
		3	3		3	4	3	3																	66 62
		3																							48 63
																									22 64
																									33 65
											3														9 66
																									9 68

33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56

66.0 68.6 71.1 73.7 76.2 78.7 81.3 83.8 86.4 88.9 91.4 94.0 96.5 99.1 101.6 104.1 106.7 109.2 111.8 114.3 116.8 119.4 121.9 124.5

3

SUBSCALE HAST RANGE(DET)= 3.513 M

RUN=587 FILE=312 RANGE (FRONT OF CAMERA)= 3.05 M SENSITIVITY= 75 ATTENUATION= 620 POWER=2.46

						3	3																				
						3			3					3	3												
						3	3	3	3	3		3															
						3	4	4	4	3	3	4	4	3	3	3											
						3	9	9	7	4	4	4	4	4	4			4	4	3	3			3			
						7	15	12	10	10	4	7	9	4	4	4	4	3	3	3	4	3	4	4	3		
						7	29	23	16	15	9	9	9	9	9	9	9	9	9	7	4	3	3	3		3	3
						3	33	32	27	23	20	16	9	7	4	7	4	4	7	4							
						7	35	35	35	29	23	16	23	23	12	10	10	7	4	4	4		3		3		
						3	23	32	35	46	37	23	23	15	21	23	27	29	12	7	9	10	10	7	3		
						3	12	20	24	40	40	35	47	35	40	35	24	20	16	10	10	9	9	9	7	4	3
							7	10	15	29	29	29	32	37	35	33	23	20	18	12	9	4	3	3	3	3	4
							3	4	7	9	10	29	37	29	10	9	10	10	9	9	4	3	4	3	4	4	4
							3	3	4	4	9	16	20	9	10	9	9	9	10	10	15	15	12	7	4	7	4
								3	3	4	7	4	4	7	9	9	12	7	4	4	4	7	4				3
									3	3	3	3	3	4	7	16	16	9	4	3			3	3	3	3	
												3	4	9	10	9	3	3	4	7	4	4	4	4	3	3	3
													3		4	7	4	3		3	3	3	4	4	4	4	3
																		3	3						3		3

COLUMN NO.=

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
0.0	0.0	0.0	0.0	0.0	0.0	2.5	5.1	7.6	10.2	12.7	15.2	17.8	20.3	22.9	25.4	27.9	30.5	33.0	35.6	38.1	40.6	43.2	45.7	48.3	50.8	53.3	55

EXIT PLANE IS IN COLUMN 7,FIELD OF VIEW CENTER IS IN COLUMN 28 HORZ INCREMENT= 2.54 CM VERT INCREMENT= .72 CM

TABLE 14. SUBSCALE ENGINE PLUME SPATIAL DISTRIBUTION - POPS INJECTIO

UNITS

BACKGROUN

```
3 M
46

 3
 4   3
 3       3   3   3

     3
 7   3
 9   7   4   3           3
 3   3   3   4   3       4   3
 3   4   4   4   4
 7   4   7   4   4   3   4   3
             3   4   3   4   3
 3   3   3
 4   3   3   3
 4   4   4   3   3
         3   3

 25  26  27  28  29  30  31  32  33  34  35  36  37  38  39  40  41  42  43  44  45  46  47  48  49  50  51  52  53  54  55
45.7    50.8    55.9    61.0    66.0    71.1    76.2    81.3    86.4    91.4    96.5   101.6   106.7   111.8   116.8   121.9
  48.3    53.3    58.4    63.5    68.6    73.7    78.7    83.8    88.9    94.0    99.1   104.1   109.2   114.3   119.4

INCREMENT=  .72 CM
```


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TABLE 14. SUBSCALE ENGINE PLUME SPATIAL DISTRIBUTION - POPS INJECTION, NO FLOW

UNITS=WATTS/STER X
BACKGROUND= 153

6	43
12	44
18	45
38	46
69	47
117	48
208	49
200	50
283	51
395	52
455	53
368	54
215	55
203	56
109	57
86	58
77	59
52	60
12	61

33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	
0	71.1	76.2	81.3	86.4	91.4	96.5	101.6	106.7	111.8	116.8	121.9													
68.6	73.7	78.7	83.8	88.9	94.0	99.1	104.1	109.2	114.3	119.4	124.5													

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TABLE 15. SUBSCALE HAST ENGINE SCANNER, RADIOMETRIC DATA WITH AND WITHOUT REFLECTED RADIATION

Run No.	Injection	M_∞	J (With Reflection)	J (Without Reflection)	Percent Reflection
5570	*	0	SAT	SAT	
	O_2	0	SAT	SAT	
	CH_4	0	SAT	SAT	
	*	0.7	SAT	SAT	
	O_2	0.7	SAT	SAT	
	CH_4	0.7	SAT	SAT	
5571	*	0	185	173	6
	O_2	0	216	201	7
	CH_4	0	282	256	9
	*	0.7	62	59	5
	O_2	0.7	105	100	5
	CH_4	0.7	64	59	8
5572	*	0	163	155	5
	O_2	0	178	167	6
	CH_4	0	271	259	4
	*	0.7	53	51	4
	O_2	0.7	101	94	7
	CH_4	0.7	65	62	5

TABLE 15. SUBSCALE HAST ENGINE SCANNER, RADIOMETRIC DATA WITH AND WITHOUT REFLECTED RADIATION (CONTINUED)

Run No.	Injection	M_∞	J (With Reflection)	J (Without Reflection)	Percent Reflection
5573	*	0	207	190	8
	O_2	0	250	226	10
	CH_4	0	369	343	7
	*	0.7	81	74	8
	O_2	0.7	129	116	10
	CH_4	0.7	108	99	8
5574	*	0	116	104	10
	O_2	0	121	109	10
	CH_4	0	221	199	10
	*	0.7	54	48	11
	O_2	0.7	52	45	13
	CH_4	0.7	78	72	8
5575	*	0	SAT	SAT	
	O_2	0	SAT	SAT	
	CH_4	0	SAT	SAT	
	*	0.3 N_2	SAT	SAT	
	O_2	0.3 N_2	SAT	SAT	
	CH_4	0.3 N_2	SAT	SAT	

TABLE 15. SUBSCALE HAST ENGINE SCANNER, RADIOMETRIC DATA WITH AND WITHOUT REFLECTED RADIATION (CONTINUED)

Run No.	Injection	M_∞	J (With Reflection)	J (Withcut Reflection)	Percent Reflection
5576	*	0	SAT	SAT	
	O_2	0	SAT	SAT	
	CH_4	0	SAT	SAT	
	*	0.3 N_2	19	18	5
	O_2	0.3 N_2	27	25	7
	CH_4	0.3 N_2	17	16	6
5577	ABORT				
5578	ABORT				
5579	*	0	343	310	10
	O_2	0	324	293	10
	CH_4	0	461	421	9
	*	0.3 N_2	43	39	9
	O_2	0.3 N_2	57	49	14
	CH_4	0.3 N_2	18	16½	8
5580	ABORT				
5581	ABORT				
5582	ABORT				
5583	*	0	163	150	8
	O_2	0	175	163	7

TABLE 15. SUBSCALE HAST ENGINE SCANNER, RADIOMETRIC DATA WITH AND WITHOUT REFLECTED RADIATION (CONTINUED)

Run No.	Injection	M_∞	J (With Reflection)	J (Without Reflection)	Percent Reflection
	CO	0	197	183	7
	*	0.7	60	57	5
	O_2	0.7	99	91	8
	CO	0.7	52	49	6
5584	*	0	144	135	6
	O_2	0	110	102	7
	CO	0	139	130	6
	*	0.7	51	50	2
	O_2	0.7	96	90	6
	CO	0.7	64	60	6
5585	*	0	198	177	11
	O_2	0	111	101	10
	CH_4	0	79	76	4
	*	0.7	66	59	11
	O_2	0.7	57	52	9
	CH_4	0.7	35	32	9
5586	(POPS)		**		
5587	*	0	226	200	12
	POPS	0	85	74	13

TABLE 15. SUBSCALE HAST ENGINE SCANNER, RADIOMETRIC DATA WITH AND WITHOUT REFLECTED RADIATION (CONCLUDED)

Run No.	Injection	M_∞	J (With Reflection)	J (Without Reflection)	Percent Reflection
	*	0.7	77	66	14
	POPS	0.7	38	29	24
5588	*	0	47	45	4
	POPS	0	25	23	8
	*	0.7	25	24	4
	POPS	0.7	SAT	SAT	
5589	*	0	59	57	3
	O_2	0	27	25	7
	CH_4	0	54	47	13
	*	0.7	20	19	5
	O_2	0.7	21	20	5
	CH_4	0.7	20	19	5
5590	*	0	159	141	11
	O_2	0	82	74	10
	CH_4	0	67	48	28
	*	0.7	11	10	9
	O_2	0.7	15	14	7
	CH_4	0.7	7	6	14

*No injection
**No data

TABLE 16. FULL-SCALE HAST ENGINE BOOST PHASE - INFRARED RADIANT INTENSITY BETWEEN 4 AND 5μ

$\dot{\omega}_t$ gm/sec	Time from t = 0 (sec)	$J^{60°}$ W/Ster	$J^{30°}$ W/Ster	Scanner $J^{90°}$ With Reflection	Scanner $J^{90°}$ Without Reflection	Percent Reflection	Interferometer $J^{90°}$
1429	5 to 6	8734	4100	7710	7000	13	*
1429	7 to 8	8353 to 8135	3985	7440	6650	16	*
1528	14 to 15	4914 to 4641	2930	3390	3050	17	3606
2132	21 to 22	3986 to 3822	2348	3040	2360	18	3156
(2278) Hi F	26 to 27	6552	4226	4910	4540	13	5032
(2192) Lo F	29 to 30	4914 to 5078	3228	*	*	*	4342
2132	32 to 33	3822	2583	*	*	*	3334
(2191) Lo O	35 to 36	3713	2524	*	*	*	3186
(2273) Hi O	38 to 39	3549	2348	*	*	*	3094
2132	41 to 42	4204	2583	*	*	*	3648

*No measurements were taken.

TABLE 17. FULL-SCALE HAST ENGINE SUSTAIN PHASE - INFRARED RADIANT INTENSITY BETWEEN 4 AND 5μ

$\dot{\omega}_t$ gm/sec	Time from t = 0 (sec)	$J^{60°}$ W/Ster	Interferometer $J^{90°}$	$J^{60°}$ W/Ster/gm/sec
1197	5 to 6	4368	*	3.65
(1240) Hi F	11 to 12	4859	4438	3.89
(1220) Lo F	15 to 16	3549	3370	2.91
1197	18 to 19	3549	3296	2.96
(1221) Lo O	20 to 21	2894	2810	2.37
(1250) Hi O	24 to 25	2675	2356	2.14
(1220) Asy F	29 to 30	3385	3454	2.77
1197	32 to 33	2894	2888	2.42
(1221) Asy F	35 to 36	2730	2508	2.24
(869) Hi F	51 to 52	4696	4652	5.4
(834) Lo F	54 to 55	3385	3474	4.03
816	56 to 57	3003	*	3.68
(840) Lo O	60 to 61	2675	2594	3.19
(869) Hi O	64 to 65	2184	2196	2.51
(840) Asy F	69 to 70	3330	3324	3.97
816	72 to 73	2675	2574	3.28
(840) Asy F	75 to 76	2348	2470	2.80
(529) Hi F	91 to 92	4095	3544	7.74
(499) Lo F	96 to 97	2730	2338	5.47
476	101 to 102	1801	1628	3.79
(500) Lo O	106 to 107	1801	1674	3.61
(528) Hi O	112 to 113	1692	1574	3.21
(499) Asy F	121 to 122	2238	2156	4.48
476	126 to 127	1557	1556	3.27
(500) Lo O	131 to 132	1539	1512	3.08
476	136 to 137	1470	1576	3.09

*No data taken.

FULL SCALE HAST "BOOST" FIRING STATIC 1400 FT ALTITUDE MODIFIED A(E)/A(T)RANGE(DFT)= 9.609 M

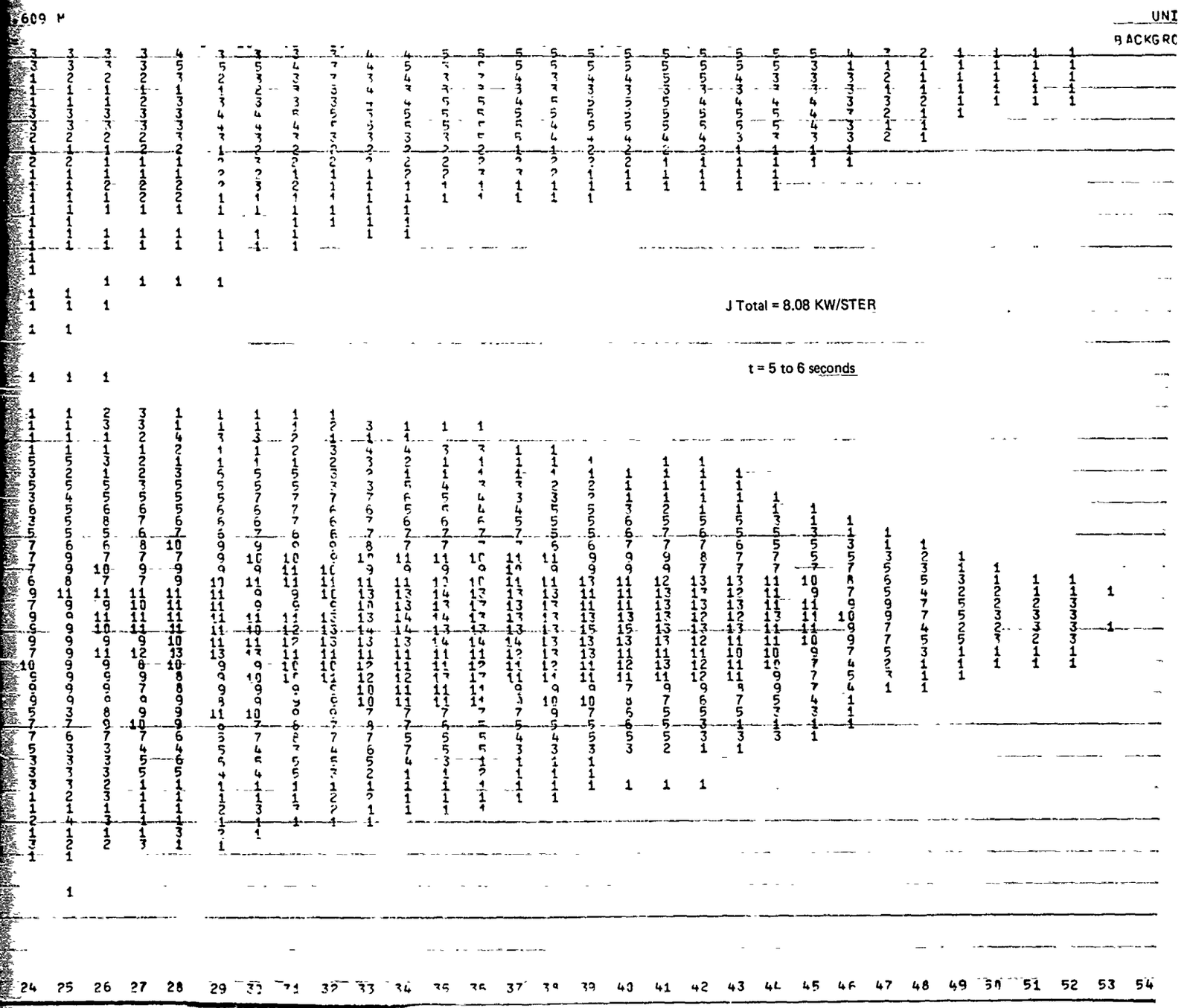
RUN= 10 FILE= 29 RANGE (FRONT OF CAMERA)= 9.14 M SENSITIVITY= 75 ATTENUATION=2465 POWER=

1		1	1	1	1	1	1	2	2	1	1	1	1	1	1	1	2	2	2	1	2	3	3	3	3	3	4
	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	3	3	3	3	3	3	5
1	1	1	1	1	1							1	1	1	1	1	1	1	1	3	3	3	1	2	2	2	3
												1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
			1	1	1					1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	2	3
	1				1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	2	2	2	3	3	3	3	3
						1	1	1	1	1	1	1	1	1	1	2	3	2	1	1	1	3	3	3	3	3	3
		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	3	3	2	2	2	2	3
																1	1	1	1	1	1	1	1	1	1	2	2
										1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	1	1
							1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1								1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	2	2
								1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2
																1	1	1	1	1	1	1	1	1	1	1	1
												1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
													1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
						1	1	1	1	1	1							1	1	1	1	1	1	1			
												1	1	1	1	1	1	1	1	1	1	1	1	1			
				1	1	1	1	1								1	1	1	1	1					1	1	1
1													1	1								1	1	1	1			
														1	1	1	1	1	1	1	1	1	1	1	1		
								1	1	1	1	1	1	1	1	1		1				1	1				
				1	1	1	1	1	1	1	1	1	1	1				1	1	1	1	1	1	1	1		
1	1	1	1	1	1	1	1	1							1	1	1										
								1		1	1	1	1	1													
	1	1	1	1	1	1	1	1	1	1	1	1	1	1													
			1	1	1			1													1	1		1	1	1	
1	1		1												1	2	1	1	1	1	1						
									1	1	3	2	1	1	1	1	1										
							1	1	1	1				1	1	1	1				1	1	1	1	2	3	1
						1	1	1				1	1	1	2	1	1	1			1	1	1	1	3	3	1
									1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	2	4
1	1				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	2
1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	3	5	5	3	2
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	5	3	2	1	1
1		1	1	1	1	1	1	1	1	1	1	1	2	3	2	2	1	1	3	3	3	3	3	5	5	5	3
1	1	1	1	1	1	1	1	1	1	1	2	2	1	1	1	2	3	2	3	5	5	3	3	4	5	5	5
1	1	1	1	1	1	1	3	2	1	1	1	1	2	3	4	3	3	3	3	1	2	3	3	3	5	8	7
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	5	5	6	5	3	5	5	5	5	6
1	1	1	1	1	1	1	1	1	1	1	1	3	5	5	3	3	5	4	5	5	5	5	5	7	6	6	8
1	1	1	1	3	2	2	1	1	2	3	1	1	3	5	4	5	5	5	5	5	5	5	7	9	7	7	7
1	1	1	1	1	1	1	1	1	1	1	1	1	3	3	3	3	4	4	4	6	6	6	7	9	10	9	9
1	1	1	1	1	1	1	1	1	1	1	1	1	2	3	5	5	5	6	7	7	5	5	6	8	7	7	9
1	1	1	1	1	1			1	1	3	3	3	2	2	2	1	3	6	7	8	7	7	9	11	11	11	11
			1	1	1	1	1	1	1	1	1	1	2	3	4	5	5	5	6	7	9	10	7	7	9	9	10
1	1	1	1	1	1	1	1	1	1	1	1	1	2	3	5	5	5	7	9	9	8	9	9	9	9	11	11
1	1			1		1	1	1	3	3	3	3	3	4	5	7	7	6	7	7	7	7	7	9	9	10	11
			1	1	1	1	1	3	3	3	3	3	3	3	5	5	5	5	5	5	6	9	9	9	9	9	9
1	1	1	1	1	1	1	1	2	4	5	5	5	4	5	5	7	7	9	9	9	7	7	7	9	11	12	13
	1	1	1	1	1	1	2	3	2	3	3	3	3	5	5	7	9	9	8	7	9	10	10	9	9	8	10
1			1	1	3	3	3	5	3	3	3	3	2	3	4	5	8	8	9	7	7	9	9	9	9	9	8
1	1	2	2	1	1	1	1	1	1	3	5	5	5	5	5	4	5	5	6	9	10	9	9	9	9	7	8
1		1	1	1	1	2	3	3	3	3	3	4	3	5	5	5	6	7	6	7	8	7	9	9	9	9	9
	1	1	1	2	3	3	3	3	5	5	4	4	3	3	3	4	5	6	7	5	7	7	5	3	8	9	9
3	3	3	2	2	2	1	1	2	2	1	1	1	1	3	3	3	3	2	1	3	5	6	7	7	9	10	9
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	4	7	7	7	7	7	7	7	6	7	7	6
1	1	1	1	1						1	2	4	3	3	5	6	7	7	7	7	5	5	5	3	3	4	4
						1	1	2	2	2	1	2	3	5	5	4	3	3	3	4	3	3	3	3	3	5	6
			1	1	1	1	3	3	3	2	2	2	1	1	1	2	3	4	3	3	3	3	3	3	3	5	5
	1	1	1	1	1	1	1	1	1	1	3	3	3	2	2	3	2	2	3	3	3	2	3	3	2	1	1
1	1	1	1	1	1	2	3	2	1	1	1	1	2	3	2	1	1	1	1	1	1	1	1	2	3	1	1
1	1	1	1	1	1	1	1	1	1	1	1				1	2	2	4	3	3	3	2	1	1	1	1	1
1	1	1	1	1			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	4	3	1	1
								1	1	1	1	1	1	1		1	1	1	1	3	2	1	1	1	1	1	3
				1	1	1	1	1					1	1	2	2	2	1	1	1	1	3	3	2	2	3	1
									1	1	1	1	2	1	1	1	2	3	3	1	1	1	1	1			
				1	1	1	1	1	1	1	1	1	1	1	2	2	1	1	1	1	1						
		1		1	1	1			1	1	1	1												1			
							1	1												1							
					1	1	1	1										1	1								
			1	1																							

COLUMN NO.=

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28

TABLE 18. FULL-SCALE HAST ENGINE BOOST PHASE SPATIAL DISTRIBUTION, T = 5 TO 6 S



18. FULL-SCALE HAST ENGINE BOOST PHASE SPATIAL DISTRIBUTION, T = 5 TO 6 SECONDS

UNITS=WATTS/STER X

BACKGROUND= 156

7	4	4	5	5	5	5	5	5	5	5	5	5	5	4	3	2	1	1	1	1					134
7	4	5	5	5	5	5	5	5	5	5	5	5	3	1	1	1	1	1	1	1					130
7	3	4	3	3	4	3	4	4	5	5	4	3	3	3	2	1	1	1	1	1					102
5	4	3	3	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1					75
3	4	4	5	5	4	5	5	5	5	4	4	4	4	3	3	2	1	1	1	1					107
5	3	5	5	5	5	5	5	5	5	5	5	5	4	3	2	1	1								127
6	5	5	5	5	5	4	5	5	5	5	5	5	4	3	1	1									125
3	3	3	3	5	5	4	4	4	4	4	3	3	3	3	2	1									104
2	2	2	2	2	1	1	2	2	2	2	1	1	1	1											44
2	2	2	2	2	2	2	2	2	1	1	1	1	1	1											50
1	1	2	2	2	2	2	1	1	1	1	1	1													46
1	1	1	1	1	1	1	1	1	1	1	1	1													42
1	1	1	1	1	1	1																			33
1	1	1																							19
1	1	1																							13
	1	1																							22
																									19
																									13
																									13
																									14
																									7
																									13
																									11
																									18
																									13
																									6
																									14
																									9
																									11
																									12
1																									22
2	3	1	1	1																					34
1	1	1																							35
3	4	4	3	3	1	1																			50
2	3	2	1	1	1	1	1		1	1															59
3	2	1	1	1	1	1	1	1	1	1	1														78
3	3	5	4	3	3	2	2	1	1	1	1														104
7	7	6	5	4	3	3	2	1	1	1	1	1													129
6	6	5	6	4	4	5	5	3	2	1	1	1	1												156
6	7	6	6	6	5	5	5	6	5	5	5	3	1	1											161
6	7	7	7	7	7	5	5	6	7	6	5	5	3	1	1										180
9	8	7	7	7	7	6	6	7	7	7	6	5	5	3	1	1									226
9	10	11	11	10	11	11	9	9	9	8	7	7	5	5	3	2	1								271
10	9	9	9	9	10	9	9	9	9	7	7	7	7	7	5	3	1	1							265
11	11	11	10	10	11	11	13	11	12	13	13	11	10	8	6	5	3	1	1	1					315
10	13	13	14	13	13	13	11	11	13	13	12	11	9	7	5	4	2	2	1	1	1				336
12	10	13	13	13	13	13	11	11	13	13	13	11	11	9	9	7	5	2	2	3					351
12	13	14	14	13	13	13	13	13	13	12	12	13	11	10	9	7	5	3	3	3					387
13	14	14	13	13	13	13	15	15	13	13	13	11	11	9	7	4	2	2	3	3	1				380
13	13	13	14	14	14	13	13	13	13	12	11	11	10	9	7	5	5	3	2	3					368
11	11	11	11	11	12	13	13	11	11	11	10	10	9	7	5	3	1	1	1	1					359
10	12	11	11	12	11	12	11	12	13	12	11	10	7	4	2	1	1	1	1	1					334
11	12	12	12	12	11	11	11	11	11	12	11	9	7	5	3	1	1								323
9	10	11	11	11	9	9	9	7	9	9	9	9	7	4	1	1									291
9	10	11	11	9	10	10	8	7	6	7	5	4	1												275
9	7	7	7	7	9	7	6	5	5	5	3	3	1												237
7	8	7	6	5	5	5	6	5	3	1	1	1	1												185
7	7	5	5	5	4	4	5	5	5	3	3	3	1												177
4	6	7	5	5	3	3	3	3	2	1	1														141
5	5	4	3	1	1	1	1																		104
3	2	1	1	2	1	1	1																		87
1	1	1	1	1	1	1	1	1	1	1															67
2	2	1	1	1	1	1																			51
2	1	1	1	1																					51
1	1																								37
																									27
																									32
																									22
																									19
																									7
																									1
																									3
																									6
																									2
																									0
32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	

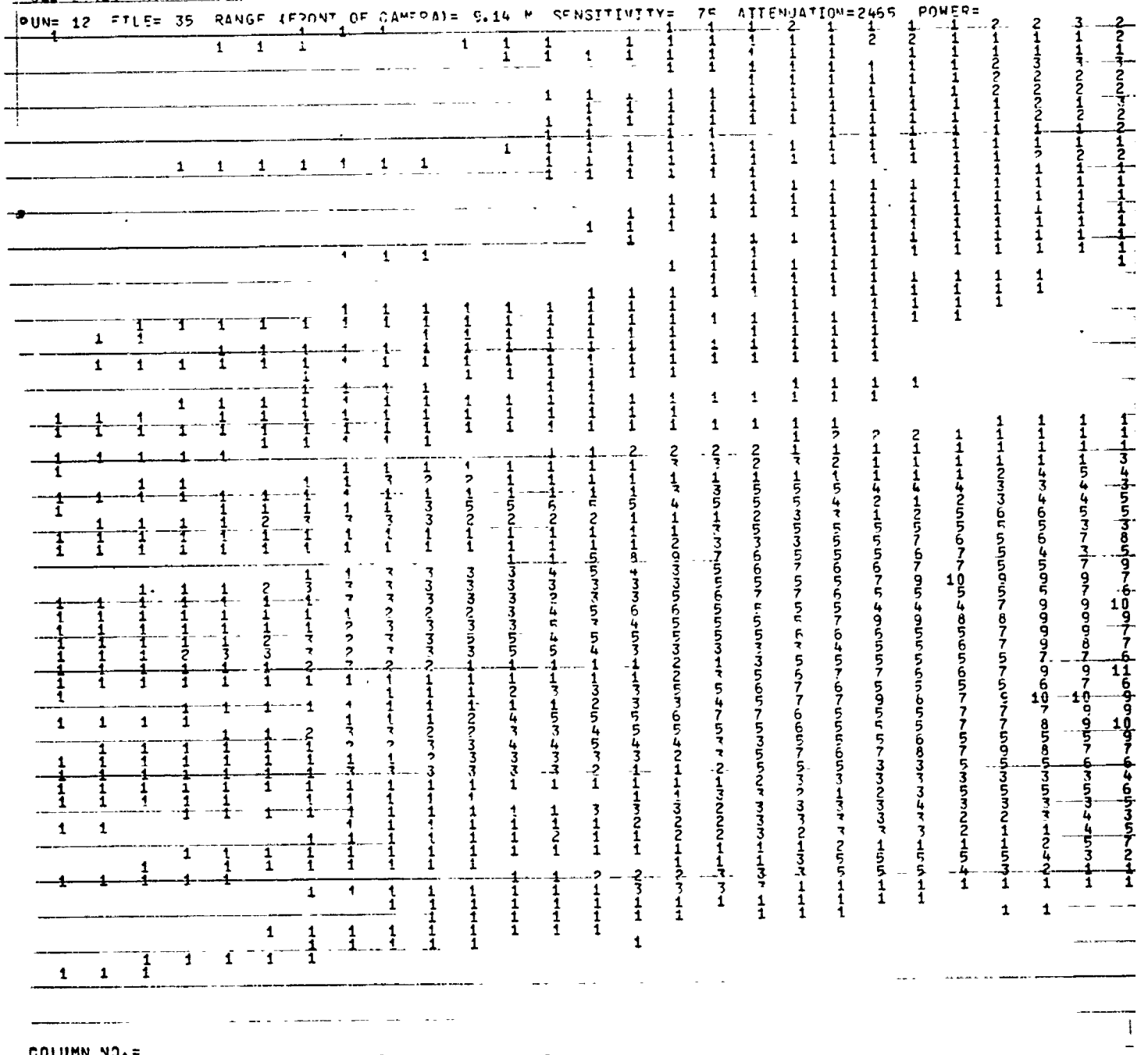
J Total = 8.08 KW/STER

t = 5 to 6 seconds

3

FULL SCALE HAST "300SI" FIRING STATIC 1400 FT ALTITUDE MODIFIED A(F)/A(T)RANGE(DFT)= 9.609 M

RUN= 12 FILE= 35 RANGE (FRONT OF CAMERA)= 9.14 M SENSITIVITY= 75 ATTENUATION=2465 POWER=



COLUMN NO.=

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27

TABLE 19. FULL-SCALE HAST ENGINE BOOST PHASE SPATIAL DISTRIBUTION

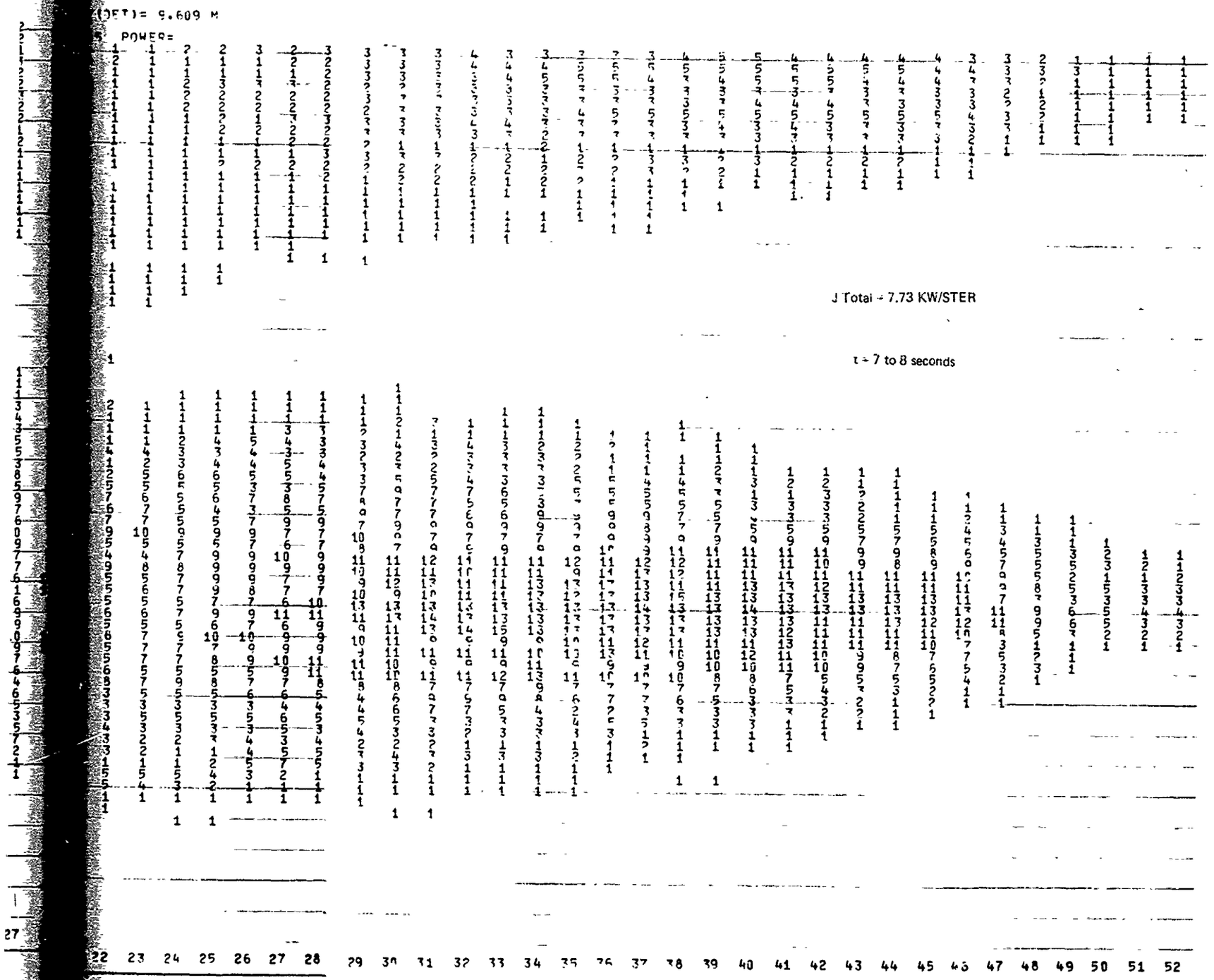


TABLE 19. FULL-SCALE HAST ENGINE BOOST PHASE SPATIAL DISTRIBUTION, T = 7 TO 8 SECONDS

.UNITS=WATTS/STER X

BACKGROUND= 156

3	4	3	3	3	3	3	4	5	5	4	4	4	4	4	3	3	2	1	1	1	1						99
3	4	4	4	5	5	5	5	5	5	5	5	5	5	4	4	3	3	3	1	1	1						115
3	3	4	5	5	5	4	3	4	5	5	5	4	4	4	3	3	2	1	1	1	1	1					99
3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	1	1	1	1	1						80
3	3	3	3	3	3	3	3	3	4	4	4	3	3	3	3	2	2	1	1	1	1						81
3	3	3	3	4	5	5	5	5	5	5	5	5	5	5	4	3	2	1	1	1	1						105
3	4	4	3	3	3	3	3	4	3	4	3	3	3	3	3	3	1	1	1								84
3	3	3	2	3	3	3	3	3	3	3	3	3	3	3	2	1	1	1	1								76
1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1											36
2	2	2	1	2	2	3	3	2	3	2	2	2	2	1	1												58
2	2	2	2	2	2	3	2	2	1	1	1	1	1	1	1												58
2	2	1	2	2	1	1	1	1	1	1	1	1	1														34
1	1	1	1	1	1	1	1			1	1																23
1			1	1	1	1	1																				22
1	1	1	1	1	1																						23
1	1	1		1	1																						20
1	1																										18
																											13
																											9
																											9
																											12
																											14
																											21
																											13
																											17
																											20
																											7
																											18
																											18
																											16
																											27
																											22
																											36
																											46
																											67
																											86
																											112
																											124
																											144
																											155
																											149
																											240
																											272
																											289
																											329
																											347
																											372
																											354
																											362
																											369
																											333
																											306
																											306
																											287
																											253
																											216
																											176
																											109
																											106
																											87
																											65
																											70
																											54
																											58
																											56
																											31
																											16
																											12
																											9
																											6
																											5
																											3
																											0
																											0
																											0
																											0
31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56		

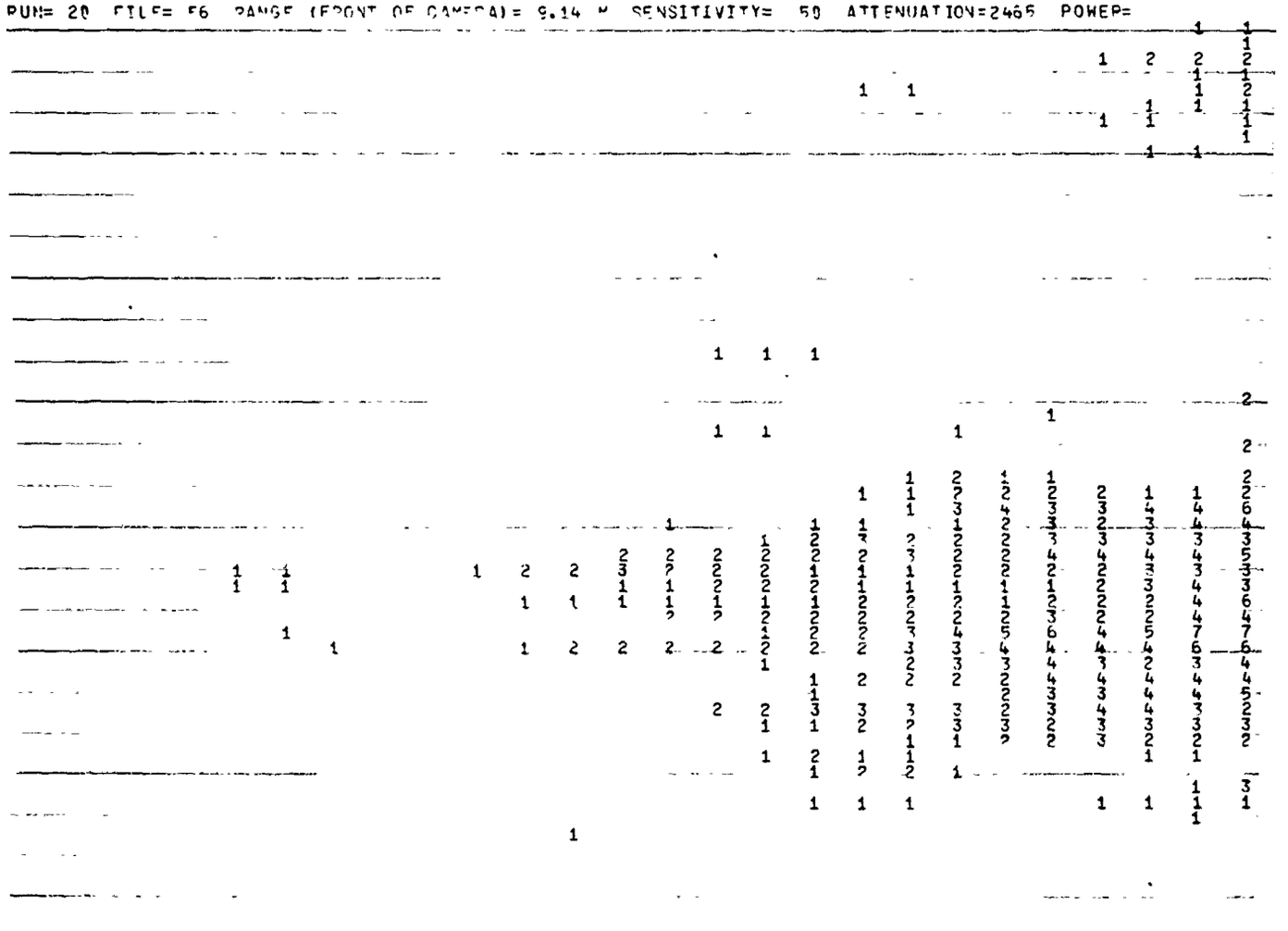
J Total = 7.73 KW/STER

t = 7 to 8 seconds

3

FULL SCALE MAST "BOOST" FIRING STATIC 1400 FT ALTITUDE MODIFIED A(E)/A(T)RANGE(JET)= 9.609

RUN= 20 FILE= F6 RANGE (FRONT OF CAMERA)= 9.14 M SENSITIVITY= 50 ATTENUATION=2465 POWER=



COLUMN NO.=

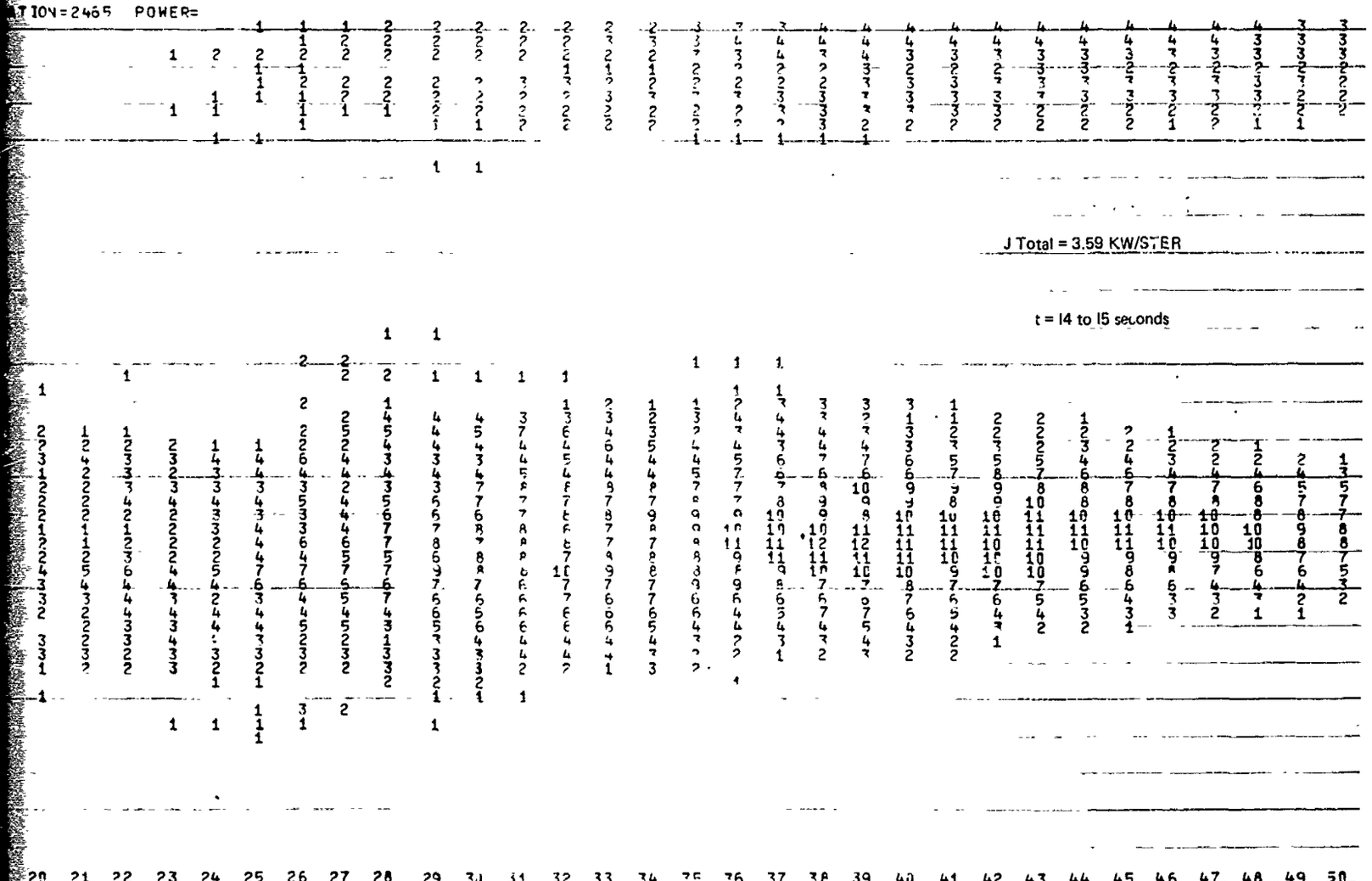
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

EXIT PLANE IS IN COLUMN53,FIELD OF VIEW CENTER IS IN COLUMN 28 HORZ INCREMENT= 7.62 CM VERT INCREMENT

TABLE 20. FULL-SCALE HAST ENGINE BOOST PHASE SPATIAL DISTRI

(T)RANGE(DET)= 9.609

TION=2465 POWER=



J Total = 3.59 KW/STER

t = 14 to 15 seconds

20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50

0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

T= 7.62 CM VERT INCPEMENT= 2.14 C

TABLE 20. FULL-SCALE HAST ENGINE BOOST PHASE SPATIAL DISTRIBUTION, T = 14 TO 15 SECONDS

UNITS=WATTS/STER Y

BACKGROUND= 159

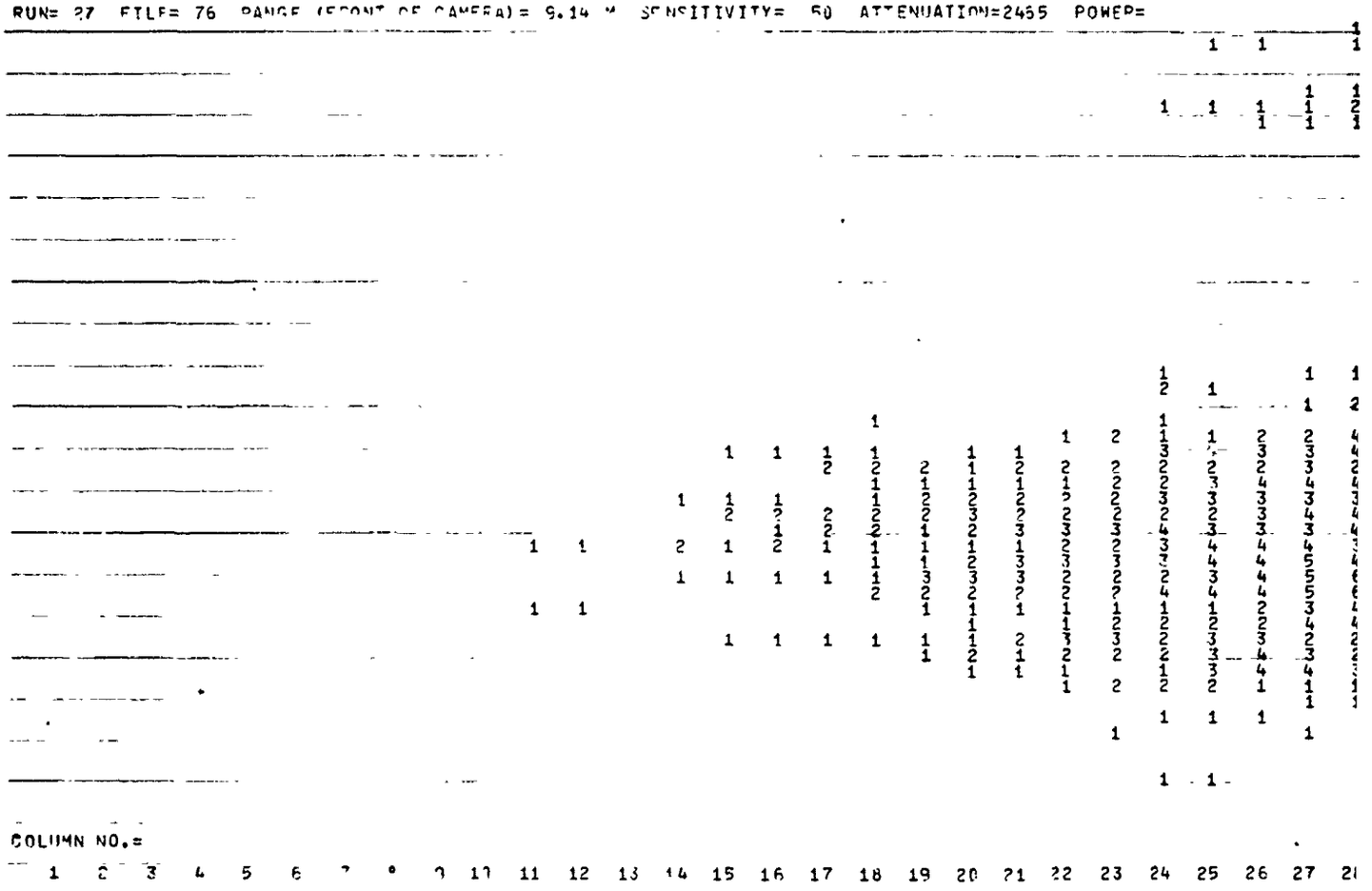
J Total = 3.59 KW/STER

t = 14 to 15 seconds

2	2	2	2	2	3	3	3	4	4	4	4	4	4	4	4	4	4	4	3	3	3	3					82
2	2	2	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	3	3	3	3	3					85
2	2	2	2	2	3	3	4	3	4	3	3	3	3	3	3	3	3	3	3	3	2	2					77
		1	1	1	2	2	2	2	3	2	2	2	3	3	2	2	2	2	2	2	2	2					44
2	3	3	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	2	2	2					70
2	2	2	3	3	2	3	3	3	3	3	3	3	3	3	3	3	3	3	2	2	2	1					70
2	2	2	2	2	2	2	3	3	3	3	3	3	2	2	3	2	2	2	2	2	1	1					57
1	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	1	2	1	1								39
					1	1	1	1	1																		7
																											0
1																											2
																											0
																											0
																											0
																											0
																											0
																											0
																											0
																											0
																											0
																											0
																											0
																											3
																											2
																											0
					1	1	1																				7
1	1	1																									9
						1	1																				5
		1	2	1	1	2	3	3	3	3	1																23
4	3	3	3	2	3	4	4	3	2	1	1	2	2	1													48
5	7	6	4	3	2	3	4	4	3	3	2	2	2	2	2	1											76
4	4	4	6	5	4	4	3	4	4	3	3	3	2	3	2	2	2	1									87
3	4	5	4	4	4	5	6	7	7	6	5	5	5	4	4	3	2	2	2	1							126
4	5	4	4	4	5	7	6	6	6	6	7	8	7	6	6	4	4	4	4	3	2	1					147
7	8	8	9	8	7	7	7	9	10	9	9	9	8	8	7	7	7	6	5	5	4	2					199
7	7	7	7	7	8	7	8	9	9	9	8	9	10	8	8	8	8	8	7	7	6	4	2				233
6	7	6	8	9	9	9	10	9	8	10	10	10	11	10	10	10	10	8	8	7	7	4	1				251
8	8	8	7	8	9	10	10	10	11	11	11	11	11	11	11	11	10	10	9	8	8	6	2				262
7	8	6	7	7	8	11	11	12	12	11	11	10	11	10	11	10	10	10	8	8	7	5	2				266
8	8	7	9	8	9	9	11	11	11	11	10	10	10	9	9	9	9	8	7	7	6	4	2				247
8	6	10	9	8	3	8	9	10	10	10	9	10	10	9	8	8	7	6	6	5	4	2					252
7	6	7	7	7	9	9	8	7	7	8	7	7	7	6	6	6	4	4	4	3	2	2					209
6	6	7	6	7	6	6	6	6	[illegible]	7	6	6	5	5	4	3	3	3	2	2	1						152
5	6	6	6	6	6	4	5	7	7	6	5	4	4	3	3	3	2	1	1								133
6	6	6	5	5	4	4	4	4	5	4	4	3	2	2	1												101
4	4	4	4	4	3	2	3	3	4	3	2	1															81
3	4	4	4	3	2	2	1	2	3	2	2																67
3	2	2	1	3	2																						36
2																											14
1	1																										9
																											6
																											8
																											1
																											1
																											0
																											0
																											0
																											0
																											0
30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.6	15.2	22.9	

FULL SCALE HAST "BOOST" FIRING STATIC 14;0 FT ALTITUDE MODIFIED A(E)/A(T)RANGE(DET)= 9.609 M

RUN= 27 FILE= 76 RANGE (FRONT OF CAMERA)= 9.14 M SENSITIVITY= 50 ATTENUATION=2455 POWER=



COLUMN NO.=

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

EXIT PLANE IS IN COLUMN#2,FIELD OF VIEW CENTER IS IN COLUMN 28 HORZ INCREMENT= 7.62 CM VERT INCREMENT= 2.14 C

TABLE 21. FULL-SCALE HAST ENGINE BOOST PHASE SPATIAL DISTRIBUTION, T = 21 TO

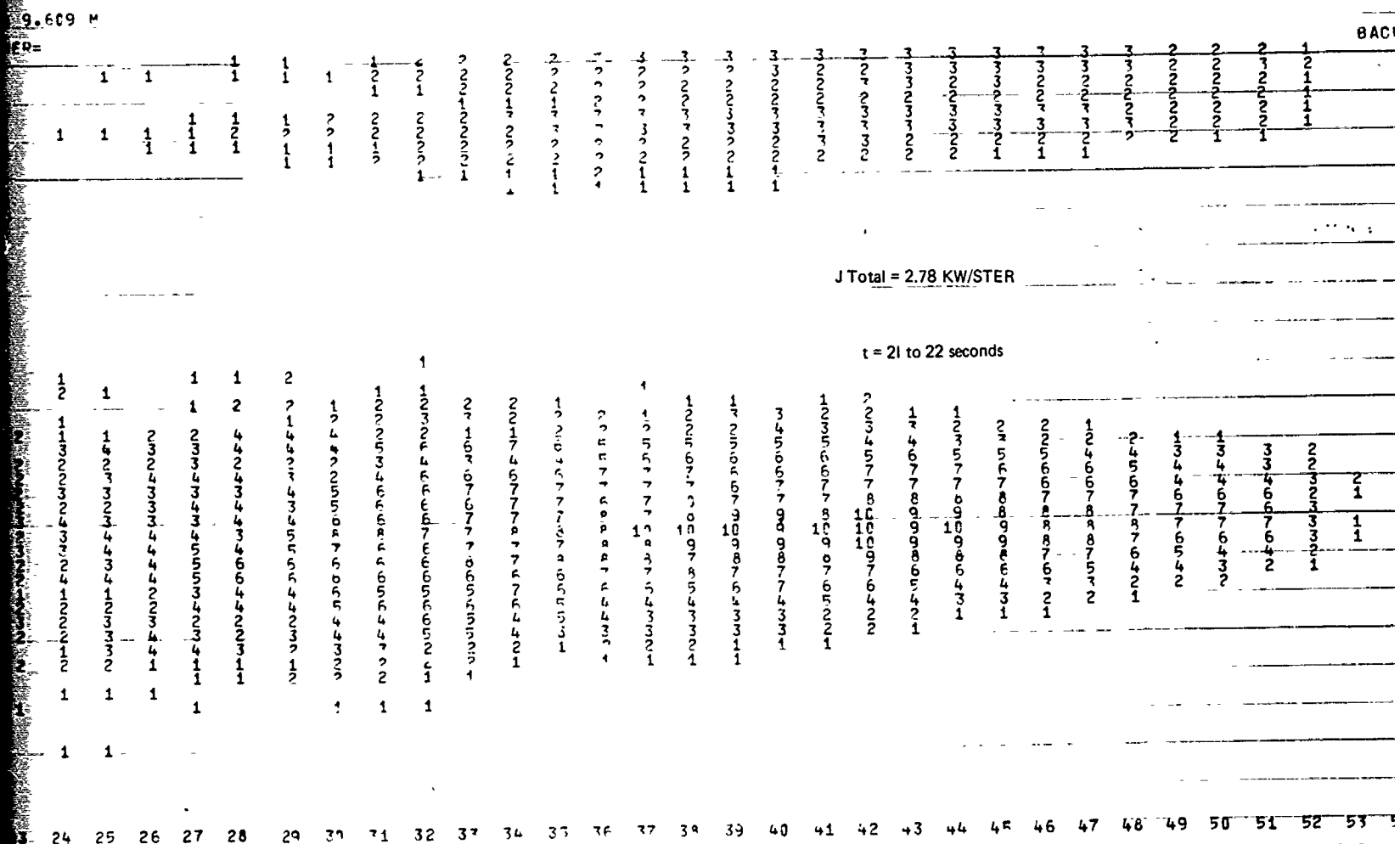


TABLE 21. FULL-SCALE HAST ENGINE BOOST PHASE SPATIAL DISTRIBUTION, T = 21 TO 22 SECONDS

UNITS=WATTS/STER X

BACKGROUND= 159

1	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	2	2	2	1							57
2	2	2	2	2	2	2	2	2	3	2	2	3	3	3	3	3	3	2	2	3	2							57
1	1	2	2	2	2	2	2	2	2	2	2	3	2	3	2	2	2	2	2	2	1							44
		1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1							36
2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	2	2	2	2	1							62
2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	2	2	2	1							67
1	2	2	2	2	2	2	2	2	2	3	3	2	2	2	2	2	2	2	1	1								46
2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1												33
	1	1	1	1	2	1	1	1	1																			10
			1	1	1	1	1	1	1																			7
																												0
																												0
																												0
																												0
																												0
																												0
																												0
																												0
																												0
																												0
	1																											1
																												5
1	1					1																						6
2	2	2	2	1			1	1		1	2																	20
2	3	2	2	2	2	1	2	2	3	2	2	1	1															34
2	2	1	1	2	2	2	2	2	4	3	3	2	2	2	2	1												57
5	6	6	7	6	6	5	5	5	5	5	4	4	3	2	2	2	2	1	1									113
3	4	3	4	4	5	6	6	6	6	6	5	6	5	5	5	4	4	3	3	3	2							126
7	6	6	6	6	7	7	7	6	6	6	7	7	7	6	6	6	5	4	4	3	2							153
6	6	7	7	7	7	7	7	6	7	7	7	7	7	7	6	6	6	4	4	4	3	2						175
6	6	6	7	7	6	7	8	7	7	7	8	8	6	8	7	7	7	6	6	6	2	1						190
6	6	7	7	7	8	7	8	9	9	8	10	9	9	8	8	8	7	7	7	6	3							208
8	7	7	8	8	8	10	10	10	9	10	10	9	10	9	8	8	8	7	7	7	3	1						229
6	6	7	7	7	8	9	9	9	9	9	10	9	9	9	8	8	7	6	6	6	3	1						212
6	6	6	7	8	8	8	7	8	8	8	9	8	8	8	7	7	6	5	4	4	2							200
6	6	6	6	6	7	7	8	7	7	7	7	6	6	6	6	5	4	4	3	2	1							170
5	5	5	7	5	6	5	5	6	7	6	6	5	4	4	3	3	2	2	2									123
6	6	6	6	5	4	4	4	4	4	5	4	4	3	3	2	2	1											100
4	6	5	4	5	4	3	3	3	3	2	2	2	1	1	1													81
4	5	5	4	3	3	3	3	3	3	2	2	1																70
3	2	2	2	1	3	2	2	1	1	1																		42
2	2	2	1		1	1	1	1																				24
2	1	1																										10
																												3
1	1																											5
																												0
																												0
																												2
																												0
																												0

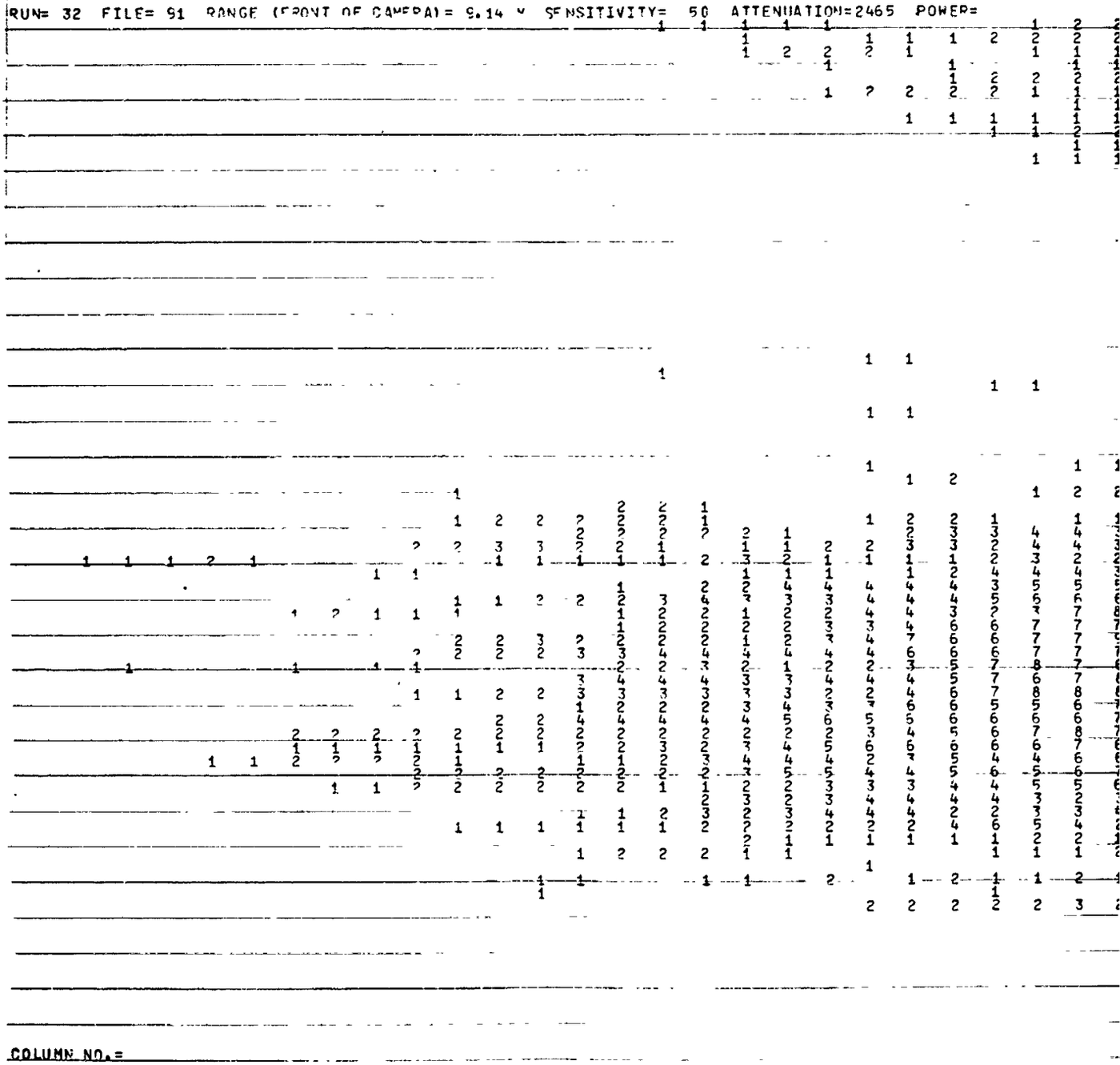
J Total = 2.78 KW/STER

t = 21 to 22 seconds

31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56
0.0		0.0		0.0		0.0		0.0		0.0		0.0		0.0		0.0		0.0		0.0		0.0		15.2	
	0.0		0.0		0.0		0.0		0.0		0.0		0.0		0.0		0.0		0.0		0.0		7.6		22.9

FULL SCALE HAST "BOOST" FIRING STATIC 14.0 FT ALTITUDE MODIFIED A(F)/A(T)RANGE(DET)= 9.609 M

RUN= 32 FILE= 91 RANGE (FRONT OF CAMERA)= 9.14 M SENSITIVITY= 50 ATTENUATION=2465 POWER=



COLUMN NO.=

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27

TABLE 22. FULL-SCALE HAST ENGINE BOOST PHASE SPATIAL DISTRIBUTION,

(DET)= 9.609 M

POWER=

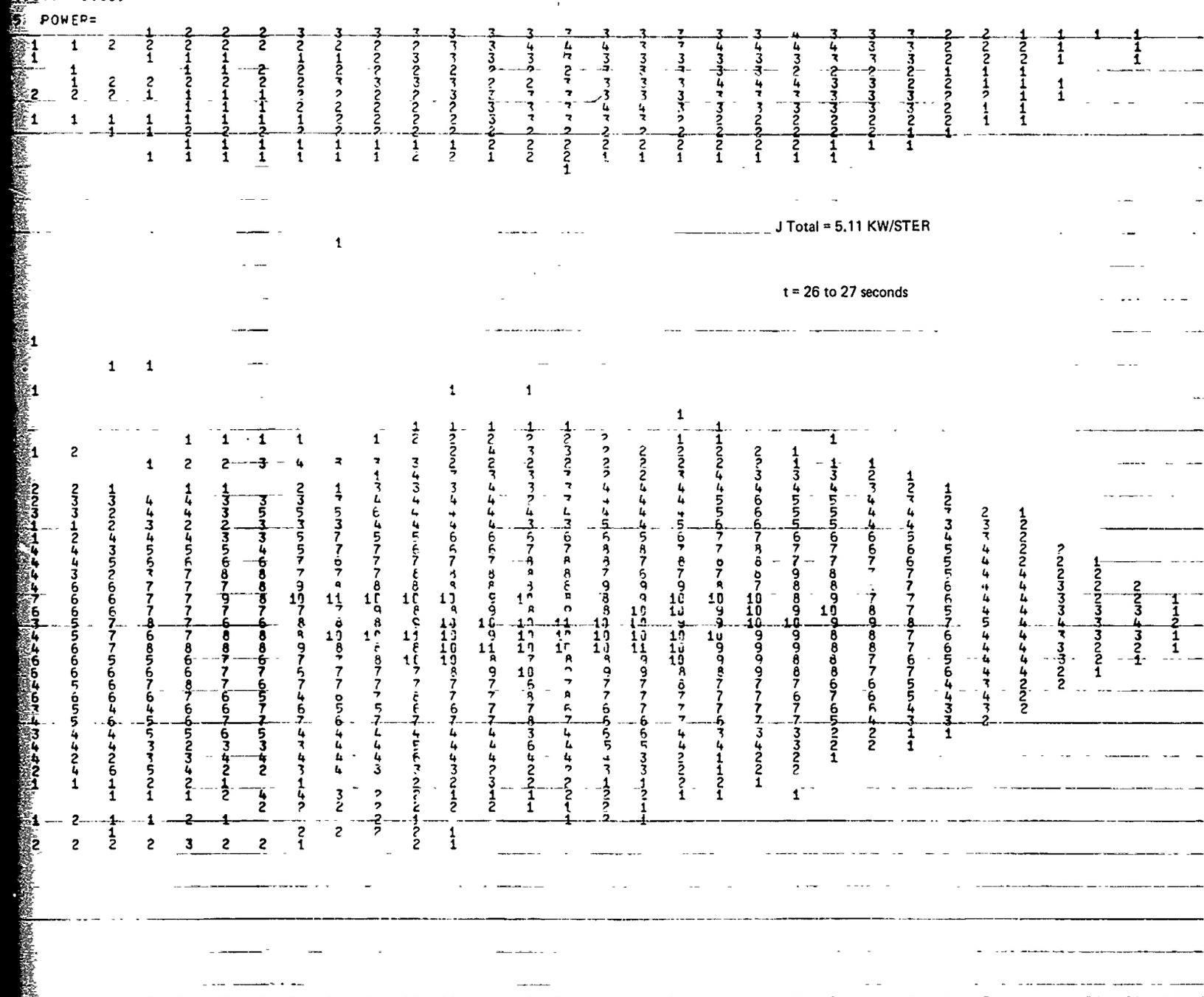


TABLE 22. FULL-SCALE HAST ENGINE BOOST PHASE SPATIAL DISTRIBUTION, T = 26 TO 27 SECONDS

UNITS=WATTS/STER X

BACKGROUND= 159

	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	
8	3	3	3	3	3	3	3	3	3	3	4	3	3	3	2	2	1	1	1	1						72
	2	3	3	4	4	4	3	3	4	4	4	4	3	3	2	2	2	1		1						76
	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	2	2	1		1						65
	2	2	2	2	2	3	3	3	3	3	2	2	2	2	1	1	1									48
	3	3	2	2	3	3	3	3	4	4	4	3	3	2	2	1	1	1								66
	2	3	3	3	3	3	3	3	3	3	3	3	3	3	2	2	1	1								66
	2	2	3	3	3	4	4	3	3	3	3	3	3	3	2	1	1									55
	2	2	3	3	3	3	3	2	2	2	2	2	2	2	2	1	1									49
	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1											42
	1	1	2	2	2	2	2	2	2	2	2	1	1	1												29
	2	2	1	2	2	1	1	1	1	1	1	1														23
					1																					1
																										0
																										0
																										0
																										0
																										1
																										0
																										0
																										0
																										0
																										0
																										0
																										2
																										1
																										2
																										0
		1		1																						4
								1																		0
																										1
	1	1	1	1	1				1																	6
	2	2	2	2	2	2		1	1			1														21
		2	4	3	3	2	2	2	2	2	1															26
	3	2	2	2	2	2	2	2	2	2	1	1	1													43
	4	3	3	3	3	2	2	3	4	3	3	3	2	1												45
	3	3	4	3	3	4	4	4	4	4	4	4	3	2	1											76
	4	4	4	3	3	4	4	4	5	6	5	5	4	3	2											102
	4	4	4	4	4	4	4	4	5	6	5	5	4	4	3	2	1									128
	4	4	4	3	3	5	4	5	6	6	5	5	4	4	3	3	2									114
	5	6	6	6	6	6	5	6	7	7	6	6	6	5	4	3	2									135
	6	6	6	7	7	8	8	7	7	8	7	7	6	6	5	4	2	2								175
	7	7	7	8	8	8	7	8	8	8	7	7	7	6	5	4	2	2	1							202
	8	8	8	8	8	7	6	7	7	8	9	8	7	7	5	4	4	2	2							199
	8	9	8	9	8	9	9	9	8	7	8	8	8	7	6	4	4	3	2	2						219
	10	10	9	10	8	8	9	10	10	10	8	9	7	7	6	4	4	3	2	2	1					253
	8	9	9	8	8	8	10	10	9	10	9	10	8	7	5	4	4	3	3	3	1					253
1	9	10	10	10	11	10	10	9	9	10	10	9	9	8	7	5	4	4	3	4	2	1				248
	11	10	9	10	10	10	10	10	10	9	9	8	8	7	6	4	4	3	3	3	1					257
	8	10	11	10	10	10	11	10	9	9	9	8	8	7	6	4	4	3	2	2	1					254
	10	10	8	7	8	9	9	10	9	9	8	8	7	6	5	4	4	3	2	1						219
	7	8	9	10	9	9	9	8	8	9	8	8	7	7	6	4	4	2	1							237
	7	7	7	6	7	7	7	8	7	7	7	6	6	5	4	3	2	2								200
	6	7	7	8	8	7	7	7	7	7	6	7	6	5	4	4	2									200
	6	6	7	7	6	6	7	7	7	7	7	6	6	4	3	3	2									180
	7	7	7	8	7	6	6	7	6	7	7	5	4	3	3	2										185
	4	4	4	3	4	6	6	4	3	3	3	2	2	1	1											120
	5	4	4	6	4	5	5	4	4	4	3	2	2	1												101
	6	4	4	4	4	4	3	2	1	2	2	1														91
	3	3	2	2	2	3	3	2	1	2	2															76
	2	2	3	2	2	1	1	2	2	1																32
	2	1	1	1	2	2	2	1	1		1															41
	2	2	2	1	1	2	1																			20
	1				1	2	1																			21
	2	1																								11
	2	1																								21
																										0
																										0
																										0
																										0
																										0
																										0
																										0
																										0
																										0
53	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	

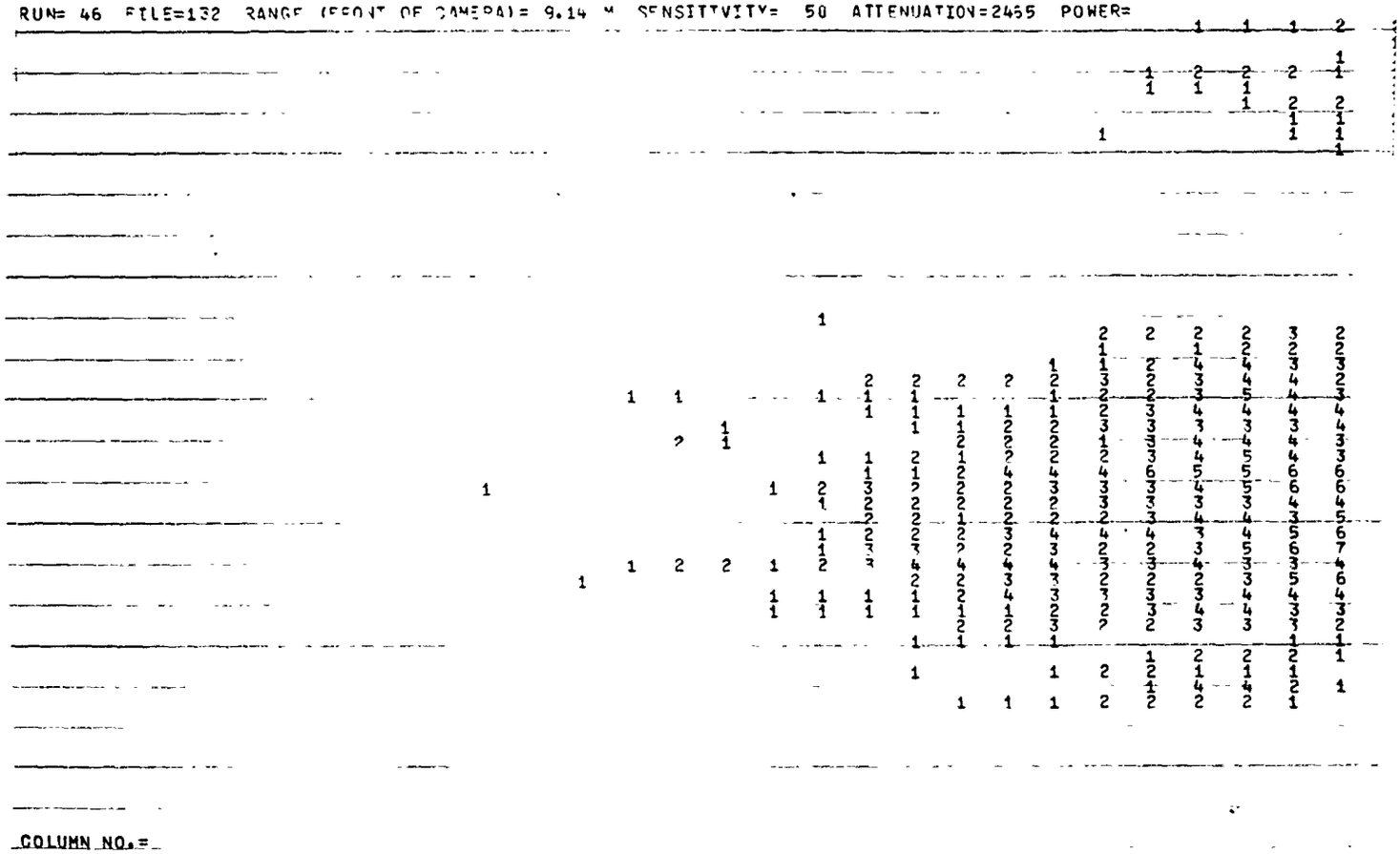
J Total = 5.11 KW/STER

t = 26 to 27 seconds

3

FULL SCALE HAST "BOOST" FIRING ___STATIC 14__ FT ALTITUDE MODIFIED A(F)/A(T)RANGE(JET)= 9.609 M

RUN= 46 FILE=132 RANGE (FRONT OF CAMERA)= 9.14 M SENSITIVITY= 50 ATTENUATION=2455 POWER=

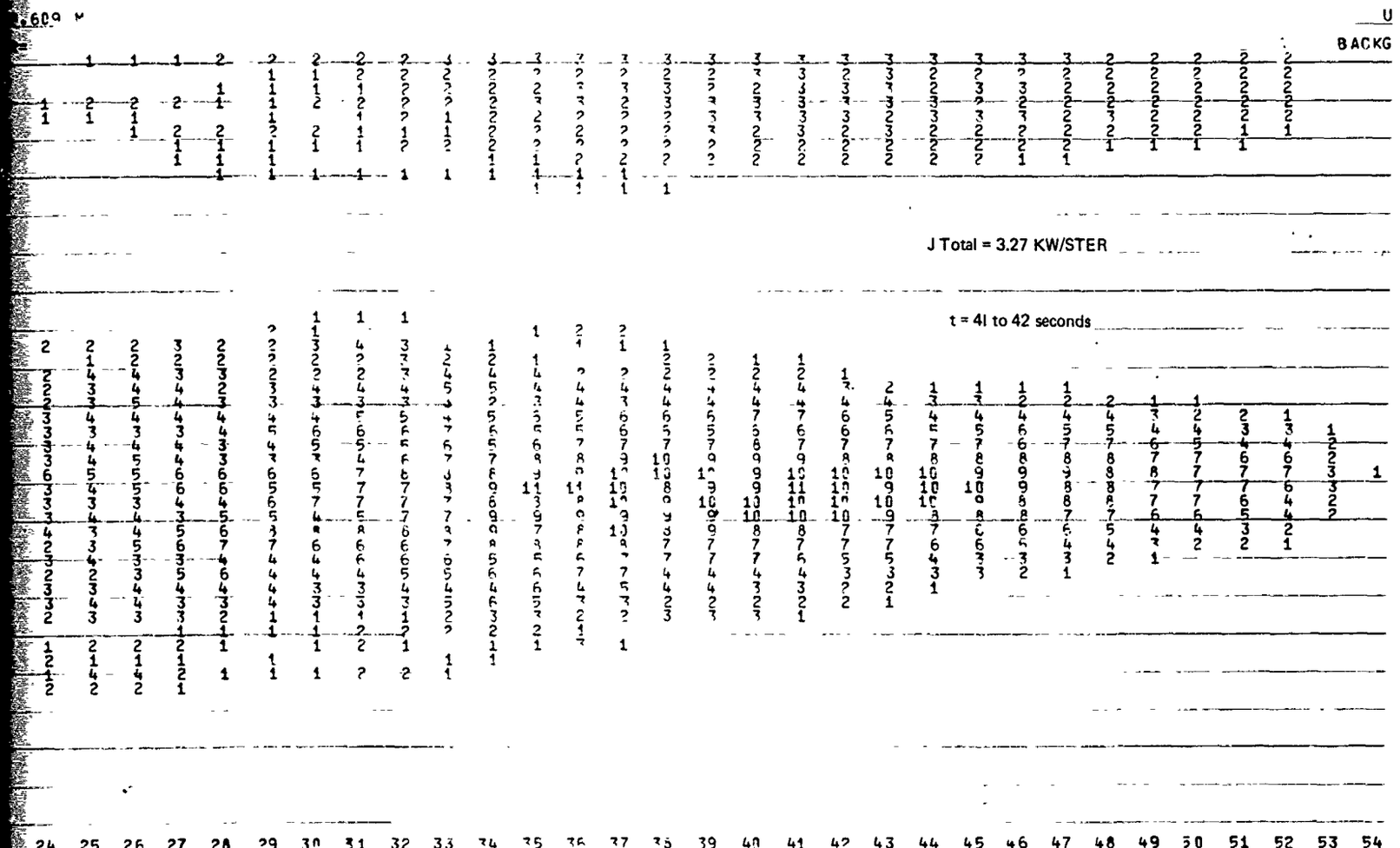


COLUMN NO.=

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

EXIT PLANE IS IN COLUMN57,FIELD OF VIEW CENTER IS IN COLUMN 28 HORZ INCREMENT= 7.62 CM VERT INCREMENT= 2.14 C

TABLE 23. FULL-SCALE HAST ENGINE BOOST PHASE SPATIAL DISTRIBUTION, T = 41



BLE 23. FULL-SCALE HAST ENGINE BOOST PHASE SPATIAL DISTRIBUTION, T = 41 TO 42 SECONDS

UNITS=WATTS/STER X

BACKGROUND= 159

J Total = 3.27 KW/STER

t = 41 to 42 seconds

2	3	3	3	2	3	3	3	3	3	3	3	3	3	3	3	2	2	2	2	2				68
2	2	2	2	2	2	2	2	3	3	2	3	2	2	2	2	2	2	2	2	2				49
2	2	2	2	2	3	3	2	2	3	3	3	2	3	3	2	2	2	2	2	2				54
2	2	2	3	3	2	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2				64
2	1	2	2	2	2	2	3	3	3	3	2	3	3	3	2	3	2	2	2	2				54
1	1	2	2	2	2	2	3	2	3	2	3	2	2	2	2	2	2	2	1	1				51
2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1					41
		1	1	2	2	2	2	2	2	2	2	2	2	1	1									28
1	1	1	1	1	1																			10
			1	1	1	1																		4
																								0
																								0
																								0
																								0
																								0
																								0
																								0
																								0
1																								3
			1	2	2																			9
3	1			1	1	1																		30
3	2	2	1			2	2	1	1															28
3	4	4	4	2	2	2	2	2	2	1														52
4	5	5	4	4	4	4	4	4	4	3	2	1	1	1	1									98
3	3	2	3	4	3	4	4	4	4	4	4	3	3	2	2	2	1	1						90
5	4	5	5	5	6	6	6	7	7	6	5	4	4	4	4	4	3	2	2	1				135
6	7	6	6	6	6	5	5	5	6	6	6	5	5	6	5	5	4	4	3	3	1			154
6	6	6	6	7	7	7	7	8	7	7	7	7	7	6	7	7	6	5	4	4	2			176
6	7	7	8	8	9	10	9	9	9	8	8	8	8	8	8	8	7	7	6	6	2			206
6	8	8	9	9	10	10	10	9	10	10	10	10	9	9	9	8	8	7	7	7	3	1		252
7	8	9	11	11	10	8	9	9	11	10	9	10	10	9	8	8	7	7	7	6	3			247
7	7	8	8	8	10	9	10	10	10	10	10	10	9	8	8	8	7	7	6	4	2			227
7	7	9	9	9	9	9	9	10	10	10	9	8	8	8	7	7	6	6	5	4	2			212
6	8	9	7	8	10	8	9	8	8	7	7	7	6	6	6	5	4	4	3	2				204
6	7	8	8	8	9	7	7	7	7	7	7	6	6	5	4	4	3	2	2	1				178
6	6	5	5	6	7	7	7	7	6	5	5	4	3	3	3	2	1							149
5	5	6	6	7	7	4	4	4	4	3	3	3	3	2	1									110
4	4	4	6	4	5	4	4	3	3	2	2	1												90
3	5	6	5	3	3	2	2	2	2	2	1													73
1	2	3	3	2	2	3	3	3	1															48
2	2	2	2	1																				19
1		1	1	2	1																			18
	1	1																						12
2	1																							19
																								12
																								0
																								0
																								0
																								0
																								0
																								0

32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56
	0.0		0.0		0.0		0.0		0.0		0.0		0.0		0.0		0.0		0.0		0.0		15.2	
0.0		0.0		0.0		0.0		0.0		0.0		0.0		0.0		0.0		0.0		0.0		7.6		22.9

3

EXIT PLANE IS IN COLUMN-0,FIELD OF VIEW CENTER IS IN COLUMN 28 HORZ INCREMENT=-0.00 CM VERT INCREMENT=-0

EXPERIMENT DATE 3 FEB 75

FULL SCALE HAST BOOST FIRING RANGE(DET)= .465 M

RUN= -0 FILE= 98 RANGE (FRONT OF CAMERA)= 0.00 M SENSITIVITY= -0 ATTENUATION= -0 POWER=

4	4	1					5	5	8	6	6	5	6	14	14	16	19	21	25	30	37	38	30	28	30		
	4	3	1	1	4	5	6	6	9	11	14	13	12	9	6	9	13	20	27	28	25	29	32	41	43		
5	5	4	5	4	5	5	5	6	5	5	5	5	5	8	6	9	19	25	25	16	21	28	30	29	28		
5	4	5	5	5	3	1	1	5	8	6	9	6	6	5	5	12	14	14	16	19	26	32	29	25	25		
5	4	5	5	4		5	9	12	10	9	9	11	9	11	10	13	13	20	25	32	30	27	25	25	27		
	1		1		4	5	1						1	4	9	14	20	14	13	14	16	21	27	32	37		
1							1	3	5	5	5	5		3	5	5	9	14	21	24	25	27	30	32	30		
										1	4	9	9	11	9	9	12	9	12	14	21	28	30	32	32		
5	4	4	4	5	5	5	5	8	11	12	12	14	19	19	21	17	22	28	27	25	25	25	25	25	30		
6	9	10	11	9	6	9	9	9	6	6	9	6	5	8	9	13	16	21	16	12	13	16	27	28	33		
	3	3	4	4	3	5	5	5	5	5	5	6	6	6	6	5	8	13	9	9	9	13	13	14	16		
5	5	4	4	4	3	5	5	5	5	9	14	17	17	20	20	14	16	20	21	20	16	13	16	13	20		
5	5	4	5	5	6	9	8	8	5	8	6	9	11	9	6	9	16	17	16	14	11	6	5	5	12		
		1	3		3	1	1	1	3	3	5	9	9	8	5	5	9	6	9	8	5	3		5	9		
5	5	5	5	6	6	6	5	9	11	11	9	9	5	8	5	5	8	9	9	8	6	10	12	13	14		
5	5	3	4	5	5	4	4	5	4	4	5	4	6	6	5	5	8	6	9	12	14	13	13	11	9		
4	5	4	6	6	11	9	9	6	6	5	4	5	5	6	6	4	3	1				1	5	9	8		
5	5	4	3	4	5	4	4				3	3	5	5	5	5	5	3		3	4	3					
5	5	5	5	6	6	5	5	9	13	12	5	5	4	3				1			4	4			3		
6	6	6	6	6	6	5	4	1				1	3														
5	5	3	3		1		1	4	4	1	3	4	4	4	1		1	3	1								
5	4	5	9	12	6	6	3	5	3	5	5	5	5	4													
4	5	5	1			1	5	4																			
4	4	3	1											1	3		3						9	4			
5	5																4	6	3	2							
																									5		
5	6	1		1																	5	6	13	12	9		
	1													5	6	9	4	3	5	9	9	9	13	11	9		
5	6	5	6	6	6	6	5	5	5	5	6	5	5	5	6	5	6	5	9	16	14	9	9	6	11		
3	4	1	1		5	3		1	1				1	5	6	9	8	9	9	6	6	6	9	13	11		
	3	1		1			1	5	9	16	14	9	4	4	8	9	12	13	13	12	13	12	9	5	5		
1	3			1	8	6	6	6	9	9	9	8	6	8	6	6	5	5	5	4	1	4	5	13	16		
5	8	9	11	10	12	12	9	9	11	14	16	14	13	12	13	6	6	8	9	12	9	5		4	4		
5	5	5	11	10	13	13	13	13	16	14	12	11	9	9	9	16	16	9	5	3	11	14	19	13	11		
12	13	16	14	16	14	13	13	13	13	9	14	25	32	21	17	11	11	13	19	25	25	28	28	28	25		
6	9	8	9	9	12	13	12	10	13	14	11	6	12	13	13	13	8	12	10	13	41	48	40	27	21		
12	13	13	13	13	12	13	9	12	13	12	9	6	16	16	20	13	19	14	13	13	14	17	12	12	28		
6	6	8	6	9	5	5	4	5	4	5	11	13	13	6	4	4	4	13	25	32	37	28	27	29	28		
5	5	5	6	5	4	5				1						1	21	29	28	19	16	14	12	25	32		
														5	16	16	19	22	25	19	22	21	21	37	56		
5	5	4	3	4	8	13	11	16	13	9	8	5	16	29	25	25	46	54	48	29	28	40	41	41	48		
5	5	5	5	5	5	12	11	13	12	9	13	21	21	16	14	21	25	29	41	38	33	32	32	41	76		
3	6	4	1					8	9	9	12	5	9	14	19	28	38	32	32	33	43	41	41	44	54		
		3	1	1				5	8	6	4	1	6	11	27	36	25	21	28	32	29	43	86	91	******		
5	3	1	3				3	5	6	6	9	6	12	27	30	21	22	30	41	38	37	37	48	73	******		
							1	5	11	14	9	9	14	11	12	16	12	21	48	53	56	73	65	77	64		
						1		1	1	5	6	6	9	20	37	37	44	45	37	35	57	77	77	78	70		
3		5	4	4	9	20	21	25	22	20	21	21	25	21	22	27	37	64	60	49	57	83	65	64	80**		
	4	14	16			3	9		6	16	13	13	13	20	18	32	29	27	48	**********							
					5	9	9	5		4	9	25	40	45	48	64	69	57	65	**********			77	70	******		
	3	5	5	5	4	1	4	6	9	20	37	45	45	35	37	37	48	60	69	72	89	**********			88**		
	1				5	11	17	19	16	16	14	13	20	28	30	28	37	53	56	72	61	83	**********				
		5	3	1	5	5	6	13	16	21	29	28	25	21	24	30	51	56	52	57	61	67	80	**********			
				3	8	13	13	13	13	16	30	37	33	41	51	46	53	57	60	76	84	81	77	76	80		
1	5	9	13	14	12	13	19	20	16	16	14	16	25	29	35	49	56	54	76	68	57	53	59	60	67		
5	5	5	3	1	8	16	16	21	16	13	13	21	27	26	28	29	29	32	28	28	24	21	21	37	53		
5	3	3	5	4	4	6	12	11	13	13	11	12	9	13	37	54	57	53	44	41	41	60	64	64	60		
	1			3	8	12	14	12	6	20	33	48	41	40	41	37	32	29	32	21	16	28	40	67	******		
			5	9	9	4	12	13	9	9	9	16	13	9	13	11	28	32	28	37	38	48	46	46	40		
	5	1	1	3	3			5	6	5	5	25	28	32	28	25	30	32	29	28	37	32	36	53	45		
				6	6	6	5	5	9	5	4	5	16	36	33	24	16	21	25	37	41	51	53	45	56		
		3	5	6	4	9	15	9	4	5	16	21	19	13	13	13	22	40	40	38	37	30	24	28	25		
5	5	5	12	11	9	5	8	5	5	6	13	21	37	36	28	30	28	29	32	29	32	28	27	44	53		
4	3	8	9	9	10	21	24	17	20	19	13	12	14	21	12	5	5	14	21	20	16	13	19	28	32		
9	6	5	5	4	3	4	1	8	9	9	6	13	19	19	16	22	41	46	40	27	21	19	17	22	11		
1		5	8	9	9	16	22	21	17	9	5	9	29	28	25	21	16	11	9	9	4			1			
12	16	13	13	9	9	9	12	17	22	21	19	14	12	9	4												
5	6	13	14	12	5	5	6	9	5	5			4														
6	5	6	6	5	5	4	5					4							9	16	11	5	4				
4	5	4	4	5	5								1	3													
1	5	5	3																		5	8	5				
																									1		
									4	5	3																
5	1	1	3	4	6	6	1																				
4	5	4	3	1																							
5	3	1																									
		1	1		5	1																					
1																											

TABLE 24. FULL-SCALE HAST ENGINE BOOST PHASE SPATIAL DISTRIBUTION, T =

VERT INCREMENT=-0.00 C

ETI= .465 M

POWER=

38	30	28	30	32	37	44	52	59	57	57	60	59	56	54	57	56	50	60	62	60	57	61	57	61	61	44	37	37	24	16
29	32	41	43	41	43	41	41	38	45	48	53	59	57	62	62	61	64	69	64	64	62	70	73	65	64	48	41	44	29	19
28	30	29	28	30	28	30	37	48	48	48	46	49	48	52	59	59	60	59	60	57	53	59	56	54	48	37	36	35	19	9
32	29	25	25	28	33	43	49	51	48	53	57	59	60	57	54	48	52	59	59	60	56	59	57	54	53	38	32	32	21	13
27	25	25	27	37	44	48	41	43	49	53	53	53	53	57	54	60	64	65	65	69	62	64	61	57	56	41	37	37	22	14
21	27	32	37	39	43	41	48	54	56	53	52	53	53	51	53	53	57	54	53	53	52	53	57	46	48	36	29	28	16	9
27	30	32	30	32	35	37	40	38	37	36	33	32	33	38	37	37	44	44	45	45	41	41	37	38	33	25	21	20	10	5
28	30	32	32	37	37	37	36	38	44	44	37	44	49	48	49	49	48	46	44	45	41	41	41	38	37	28	21	16	12	5
25	25	25	30	37	32	29	30	32	38	44	46	44	43	44	48	52	46	44	44	44	40	37	37	32	28	21	13	11	5	
16	27	28	33	37	32	32	32	30	32	33	32	33	36	32	28	28	25	22	22	22	21	16	13	14	12	6	1			
13	13	14	16	20	25	24	22	20	20	22	22	21	21	19	19	19	16	17	16	14	9	9	6	8	5	1				
16	13	20	21	22	21	14	13	13	16	17	20	19	17	13	9	6	9	6	5	6	5	5	5	4	4	1				
6	5	5	12	13	12	14	13	9	6	5	6	6	8	9	9	9	6	9	9	12	9	5	3	1						
3		5	9	6	5	6	6	5	5	6	9	9	6	4	4				1	1	1	3								
10	12	13	14	12	13	16	10	9	13	9	8	6	9	6	5	5	4													
13	13	11	9	4	1	4	6	6	5	8	6	5	5	1																
1	5	9	8	5	4	5	3																							
3					4	1	6	3	1																					
4			3	1	5	5	3	1																						

NOT REDUCED

9	4								3			1		1	1															
		5	4	3	5	5	1				3																			
6	13	12	9	6	9	5	6	5	3																					
9	13	11	9	5	5	5	5	4	3	5	9	1	4																	
9	9	6	11	14	11	12	13	12	11	5	5	3																		
6	9	13	11	9	6	5	5	1	3																					
12	9	5	5	1																										
4	5	13	16	6	1	9	11	5	5	9	5	1																		
5		4	4	1	6	6	3	3	5	9	6	5	1	3	4	4	1													
14	19	13	11	13	16	16	13	16	25	12	13	20	14	13	12	9	6	5	5	5	5	3	1	1						
28	28	28	25	22	21	25	28	17	16	17	20	20	15	12	13	13	13	12	9	5	5	4	4							
48	40	27	21	21	13	16	21	21	20	29	32	26	25	22	17	13	10	9	11	9	6	8	6	4						
17	12	12	28	37	32	22	35	37	36	57	46	35	30	27	27	30	29	27	20	12	10	6	5	5	1					
28	27	29	28	24	21	44	52	60	54	57	48	38	33	29	41	38	38	33	28	25	21	17	13	13	6	5	5			
14	12	25	32	37	44	61	53	52	74	77	73	68	61	60	60	53	37	48	44	38	32	17	14	16	9					
21	21	37	56	69	59	51	45	41	33	33	56	69	67	57	60	70	68	61	54	46	35	28	19	16	10	5				
40	41	41	48	46	64	69	61	69	77	88	*	*	86	81	80	69	64	68	60	61	61	44	35	28	21	13	5			
32	32	41	76	78	77	*	*	*	*	*	*	*	*	*	*	84	84	84	84	67	57	54	54	51	32	21	12	1		
41	41	44	54	67	72	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	89	86	65	59	38	20	9	5	
43	86	91	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	85	60	42	27	12	2
37	48	73	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	77	59	44	27	
73	65	77	64	84	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	85	70	62	33	16
77	77	78	70	64	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	74	83	44	22
83	65	64	80	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	88	84	41	17
*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	85	84	41	2
*	77	70	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	86	76	38	14
*	*	*	88	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	77	62	60	33	14
83	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	77	64	48	28	14
67	80	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	78	62	44	28	16	3
81	77	76	80	83	*	*	*	*	84	76	*	*	*	*	*	*	*	*	*	*	*	*	86	77	57	43	28	13	3	
53	59	60	67	78	60	40	61	73	73	57	60	62	67	77	89	84	81	77	76	74	73	64	62	38	28	21	9	1		
21	21	37	53	57	*	*	80	69	77	*	78	70	69	62	73	83	70	53	44	44	51	49	44	25	20	13	3			
60	64	64	60	72	76	70	72	40	38	57	60	49	41	44	48	48	37	29	37	32	35	32	22	16	13	8				
28	40	67	*	*	83	64	57	56	61	56	49	53	43	37	44	49	48	25	25	21	21	17	5	5	1					
48	46	46	40	61	69	46	41	38	51	56	41	38	37	27	19	22	30	35	21	14	16	6	5	1						
32	36	53	45	43	73	62	48	69	85	60	46	37	28	30	25	28	17	14	5	1										
51	53	45	56	59	65	67	46	36	32	25	22	22	14	9	8	16	9	12	13	6	4	1								
30	24	28	25	25	44	45	60	48	37	30	21	14	12	9	17	16	13	9	5											
28	27	44	53	32	20	13	13	11	12	16	14	17	13	5	1			1	1											
13	19	28	32	19	21	28	30	21	25	9	3	1	1																	
19	17	22	11	1	1	4				1	1																			
		1																												
					3	3			1	3																				
5	4																													
8	5					3	6	4																						
			1																											

t = 29 to 30 seconds

TABLE 24. FULL-SCALE HAST ENGINE BOOST PHASE SPATIAL DISTRIBUTION, T = 29 TO 30 SECONDS

BACKGROUND: 163

57	57	60	59	56	54	57	56	59	60	62	60	57	61	57	61	61	44	37	37	24	16	5	5		1739
45	48	53	59	57	62	62	61	64	69	64	64	62	70	73	65	64	48	41	44	29	19	6	4		1808
48	48	46	49	48	52	59	59	50	59	60	57	53	59	56	54	48	37	36	35	19	9				1537
48	53	57	59	60	57	54	41	52	59	59	60	56	59	57	54	53	38	32	32	21	13	1			1577
49	53	53	53	53	57	54	60	64	65	65	69	62	64	61	57	56	41	37	37	22	14				1714
56	53	52	53	53	51	53	53	57	54	53	53	52	53	57	46	40	36	29	28	16	9				1455
37	36	33	32	33	38	37	37	44	44	45	45	41	41	37	38	33	25	21	20	10	5				1164
44	44	37	44	49	48	49	49	48	46	44	45	41	41	41	38	37	28	21	16	12	5				1254
38	44	46	44	43	44	48	52	46	44	44	44	40	37	37	32	28	21	13	11	5					1323
32	33	32	33	36	32	28	28	25	22	22	22	21	16	13	14	12	6	1							913
20	22	22	21	21	19	19	19	16	17	16	14	9	9	6	8	5	1								555
13	16	17	20	19	17	13	9	6	9	6	5	6	5	5	4	4	1								577
6	5	6	6	8	9	9	9	6	9	9	12	9	5	3	1										393
5	6	9	9	6	4	4				1	1	1	3												188
13	9	8	6	9	6	5	5	4																	329
5	8	6	5	5	1																				225
																									145
1																									93
																									121
																									50
																									48
																									82
																									25
																									38
3			1		1	1																			25
																									26
		3																							92
3																									139
3	5	9	1	4																					263
11	5	5	3																						146
3																									179
																									202
5	9	5	1																						298
5	9	6	5	1	3	4	4	1																	508
25	12	13	20	14	13	12	9	6	5	5	5	5	3	1	1										760
16	17	20	20	15	12	13	13	13	12	9	5	5	4	4											742
20	29	32	26	25	22	17	13	10	9	11	9	6	8	6	4										923
36	57	46	35	30	27	27	30	29	27	20	12	10	6	5	5	1									1000
54	57	48	38	33	29	41	38	36	33	28	25	21	17	13	13	9	5	5							1261
74	77	73	68	61	60	60	53	37	48	44	38	32	17	14	16	9									1331
33	33	56	69	67	57	60	70	68	61	54	46	35	28	19	16	10	5								1824
77	88	*****	86	81	80	69	64	68	60	61	61	44	35	28	21	13	5								1380
*****	*****	*****	*****	*****	*****	84	84	84	84	67	57	54	54	51	32	21	12	1							1001
*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	89	86	65	59	38	20	9	5						692
*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	85	60	42	27	12	2					679
*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	77	59	44	27	9					921
*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	85	70	62	33	16					931
*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	74	83	44	22	1				1059
*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	88	84	41	17					519
*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	85	84	41	21	3	4			815
*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	86	76	38	14					970
*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	77	62	60	33	14					811
*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	77	64	48	28	14					887
*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	78	62	44	28	16	3					1511
*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	86	77	57	43	28	13	3					2341
76	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****					1660
73	57	60	62	67	77	89	84	81	77	76	74	73	64	62	38	28	21	9	1						1675
77	*****	78	70	69	62	73	83	70	53	44	44	51	49	44	25	20	13	3							1401
38	57	60	49	41	44	48	48	37	29	37	32	35	32	22	16	13	8								1158
61	56	49	53	43	37	44	49	48	25	25	21	21	17	5	5	1									1165
51	56	41	38	37	27	19	22	30	35	21	14	16	6	5	1										971
85	60	46	37	26	30	25	28	17	14	5	1														845
32	25	22	22	14	9	8	16	9	12	13	6	4	1												712
37	30	21	14	12	9	17	16	13	9	5															547
12	16	14	17	13	5	1			1	1															410
25	9	3	1	1																					284
	1	1																							221
1	3																								89
																									91
																									31
																									45
4																									1
																									12
																									27
																									17
																									9
																									6
																									2
																									1

NOT REDUCED

t = 29 to 30 seconds

TABLE 25. COMPARISON BETWEEN CALCULATED AND MEASURED DATA (SEA LEVEL STATIC CONDITIONS - SUSTAIN PHASE)

	J (W/STER)		
Degrees	O/F = 3.2 Calculation 1 (4.17 to 4.88μ)	O/F = 3.2 Calculation 2 (4.0 to 5.56μ)	O/F = 3.1 Measurement (4 to 5μ)
30	2220	3440	Not observed
60	2540	3060	2900 to 3500
90	3770	5600*	3000 to 3300
120	4110	6100*	Not observed

*Extrapolated

TABLE 26. COMPARISON BETWEEN CALCULATED AND MEASURED DATA (SEA LEVEL STATIC - BOOST PHASE)

	J (W/STER)	
Degrees	O/F = 3.5 Calculation 3 (4.0 to 5.5μ)	O/F = 3.2 Measurement (4.0 to 5μ)
30	5910	2400 to 2900
60	3660	3800 to 4000
90	3410	2800 to 3600

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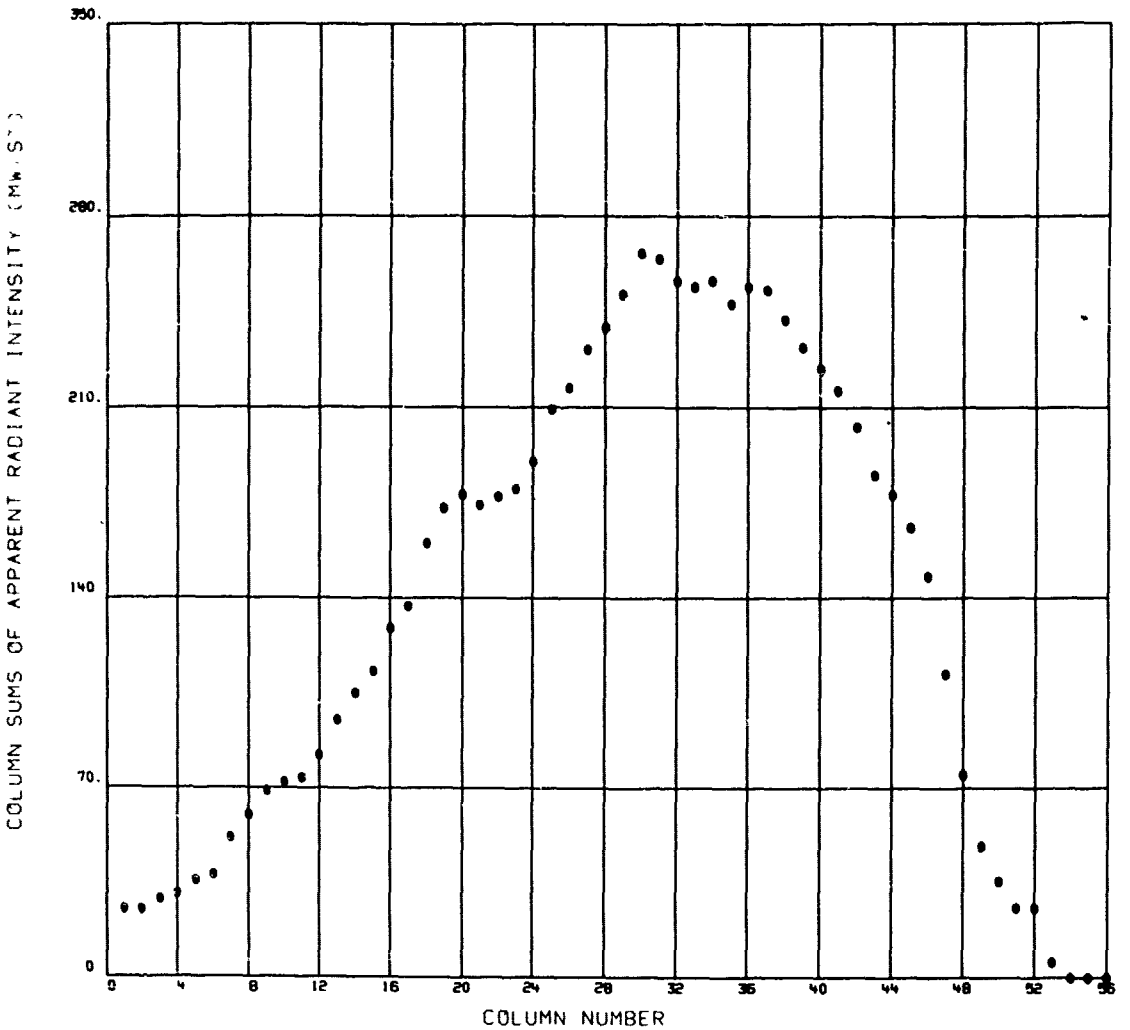
APPENDIX A

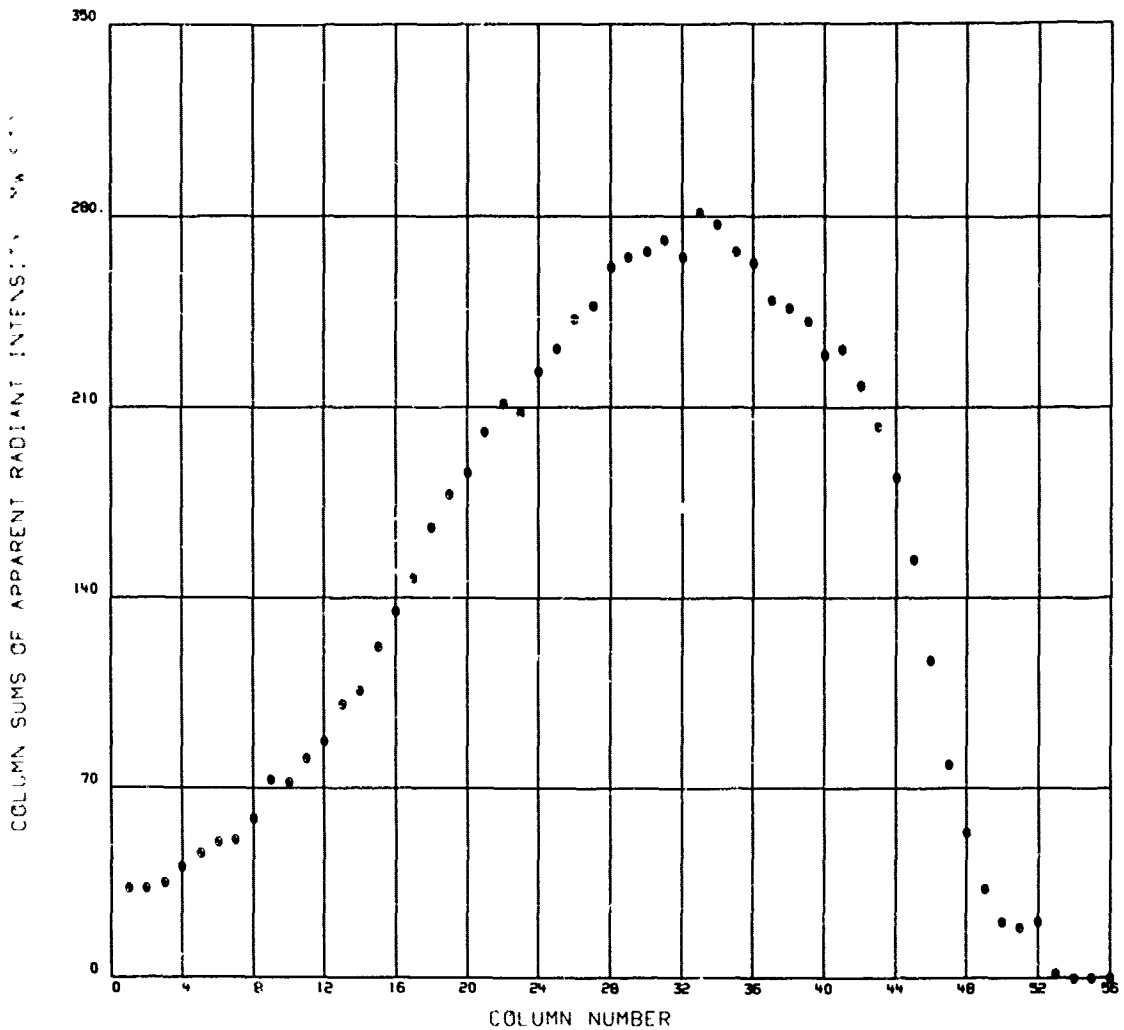
ADDITIONAL FULL-SCALE HAST ENGINE PLUME THERMAL SCANNER DATA DISPLAYS

ONE DIMENSIONAL DISPLAYS

FULL SCALE HAST BBOOSTB FIRING STATIC 1400 FT ALTITUDE MODIFIED A(E)/A(
FILE 35 RUN NO.= 12 POWER50000

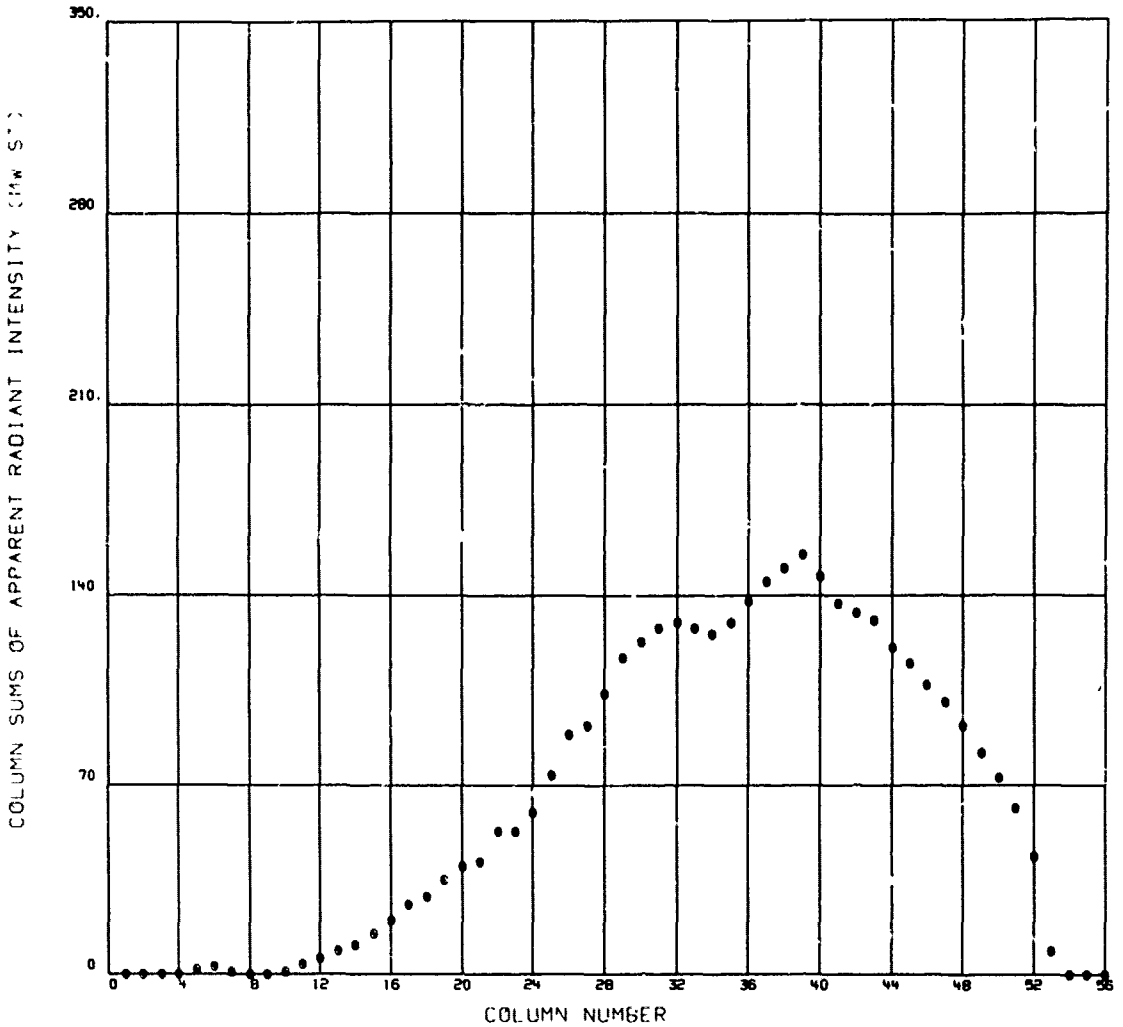


ONE DIMENSIONAL DISPLAYS (CONTINUED)



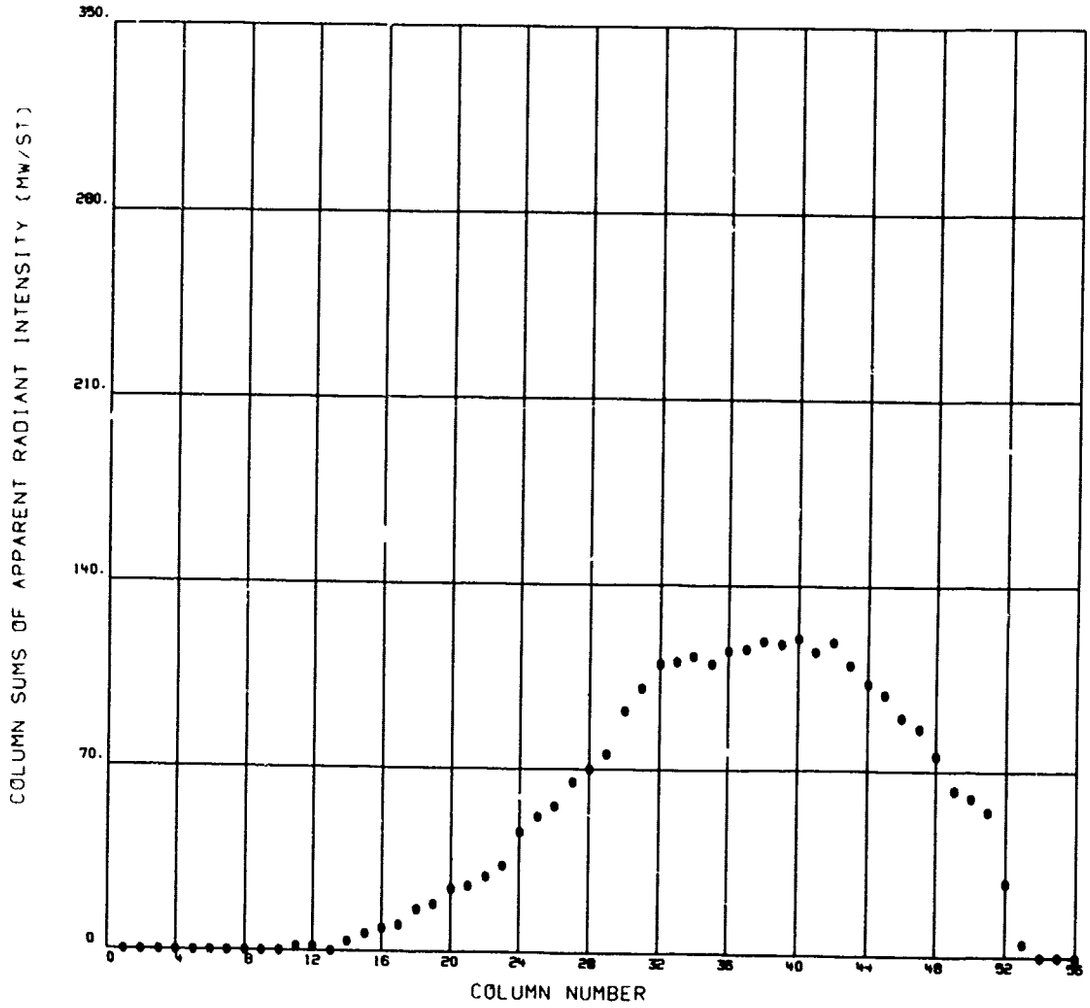
ONE DIMENSIONAL DISPLAYS (CONTINUED)

FULL SCALE HAST ßBOOSTß FIRING STATIC 1400 FT ALTITUDE MODIFIED ALT AT
FILE 56 RUN NO. - 20 POWER90000



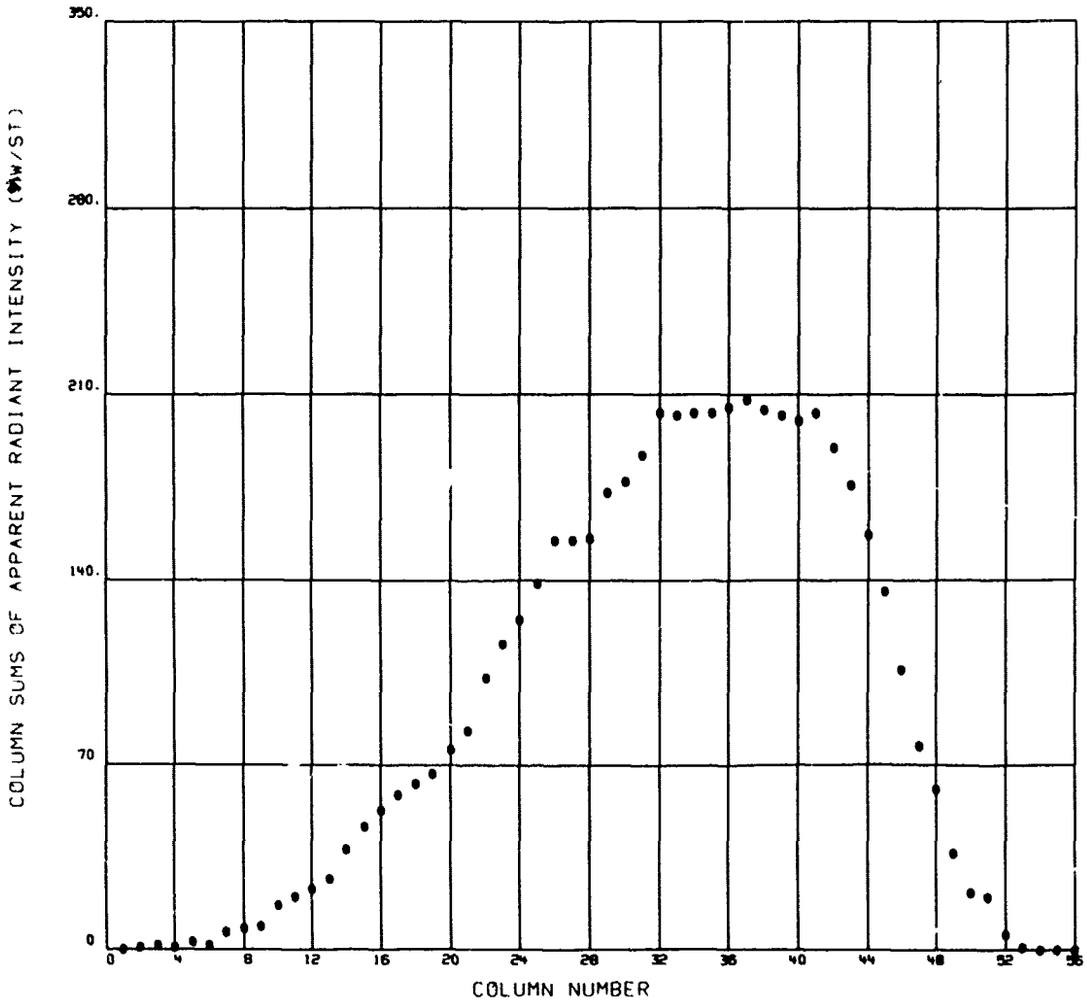
ONE DIMENSIONAL DISPLAYS (CONTINUED)

FULL SCALE HAST ØBOOSTØ FIRING STATIC 1400 FT ALTITUDE MODIFIED A(E)/A(
FILE '6 RUN NO. 27 POWER$0000

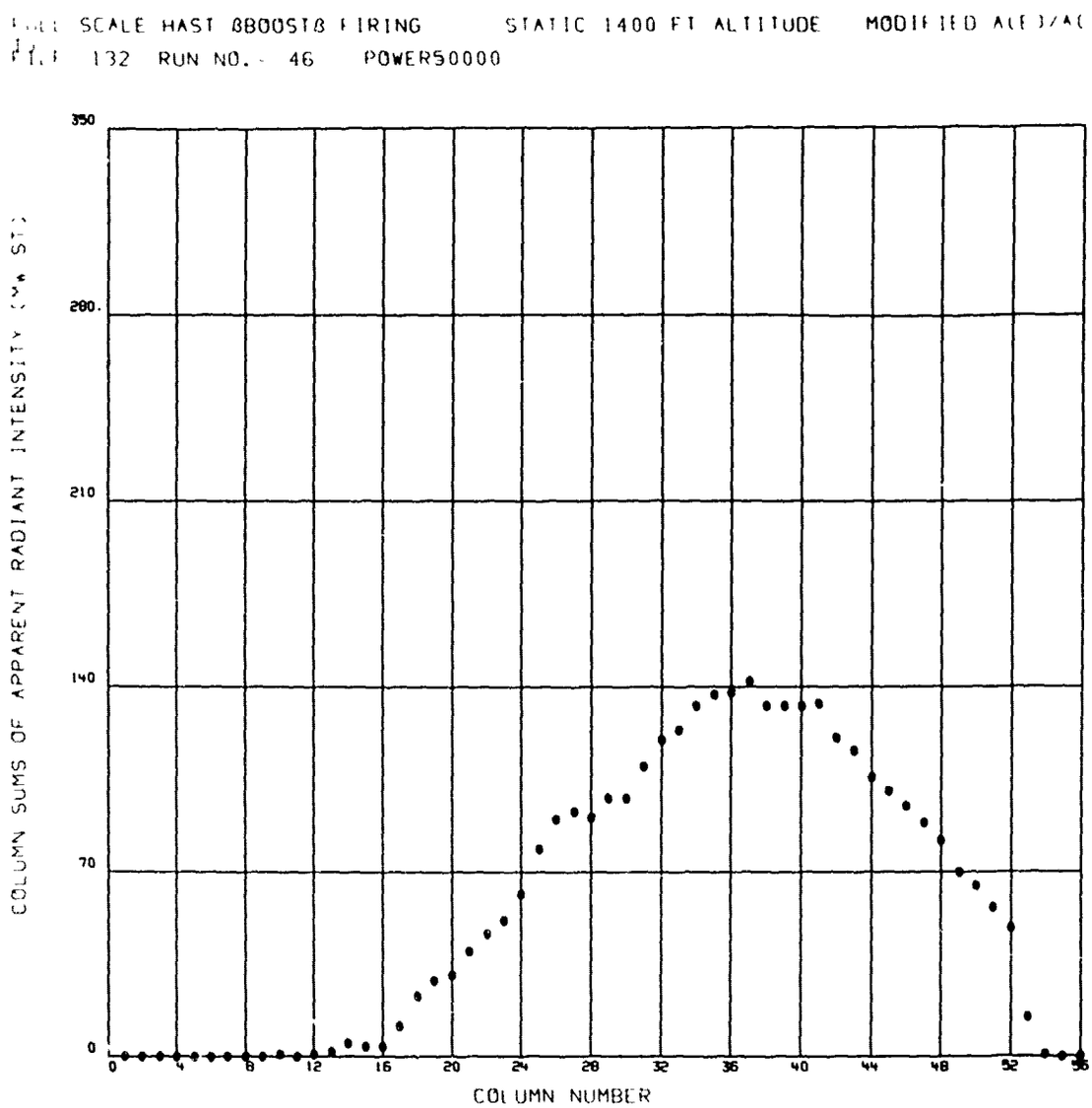


ONE DIMENSIONAL DISPLAYS (CONTINUED)

FULL SCALE HAST ßBOOSTß FIRING STATIC 1400 FT ALTITUDE MODIFIED A(E)/A(I)
FILE 91 RUN NO.= 32 POWER$0000

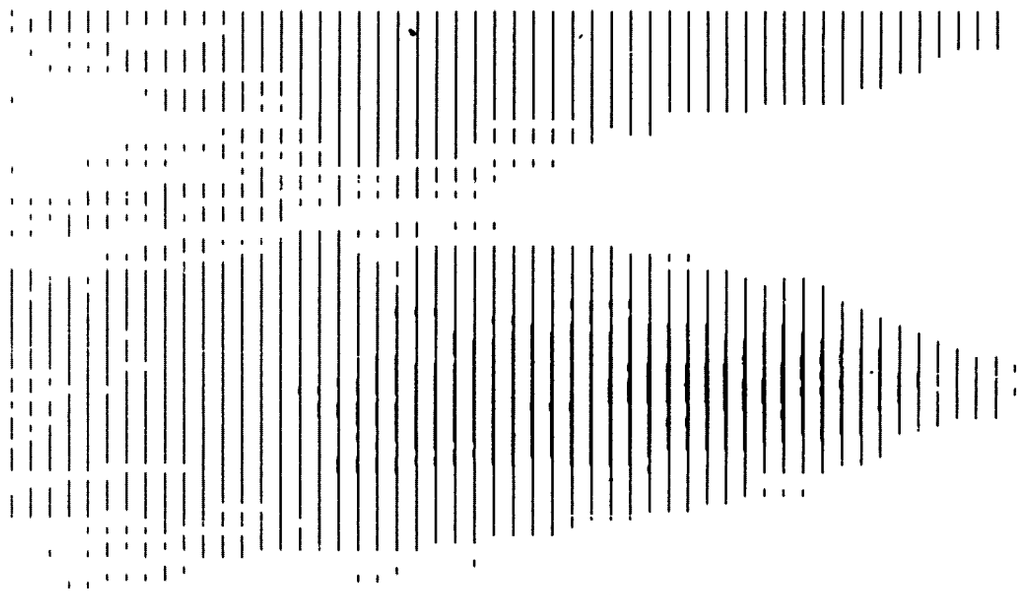


ONE DIMENSIONAL DISPLAYS (CONCLUDED)



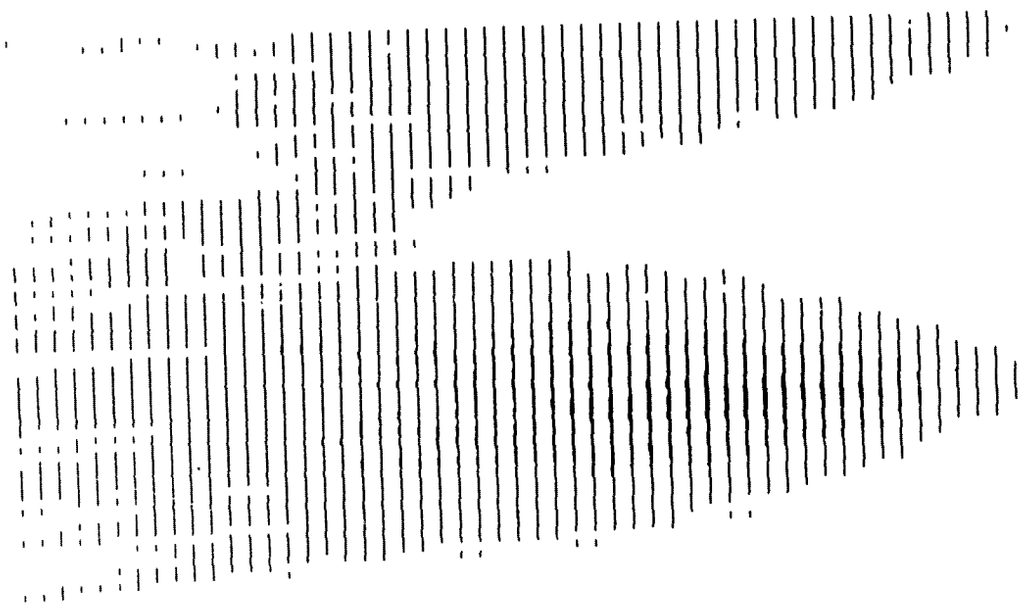
TWO DIMENSIONAL DISPLAYS

FULL SCALE HAST @BOOST@ FIRING STATIC 1400 FT ALTITUDE MODIFIED A(E)/A(I)
FILE= 29 RUN NO.= 10 POWER50000
MINIMUM VALUE= 1 MAXIMUM VALUE= 101 INCREMENT= 6



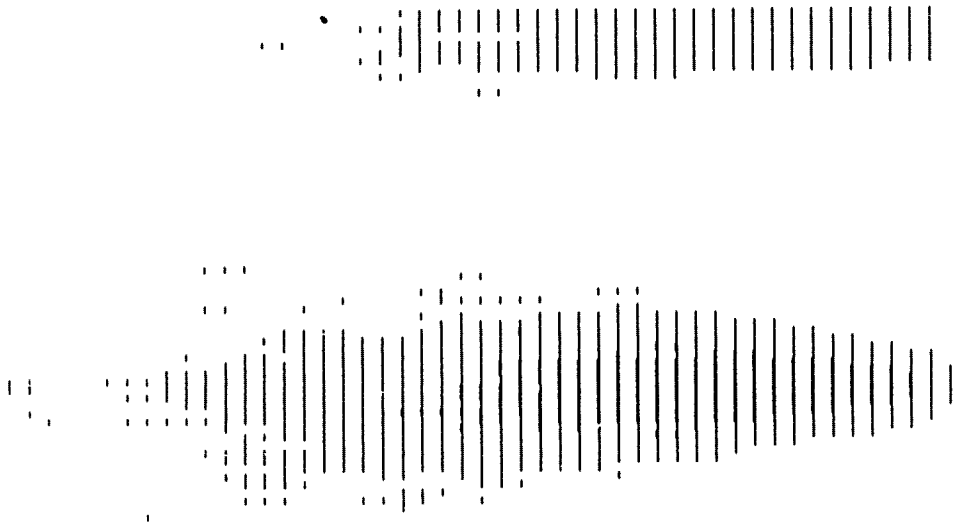
TWO DIMENSIONAL DISPLAYS (CONTINUED)

FULL SCALE HAST 8BOOST8 FIRING STATIC 1400 FT ALTITUDE MODIFIED A(E)/A(
FILE= 35 RUN NO.= 12 POWER50000
MINIMUM VALUE= 1 MAXIMUM VALUE= 101 INCREMENT= 6



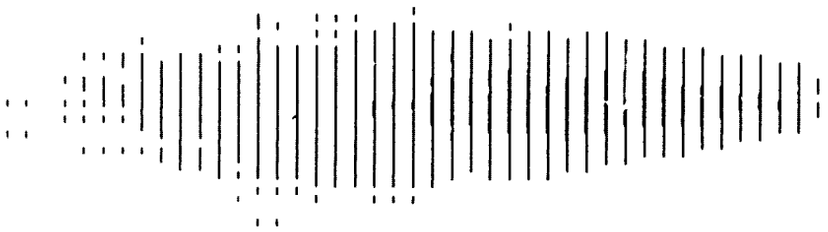
TWO DIMENSIONAL DISPLAYS (CONTINUED)

FULL SCALE HAST ØBOOSTØ FIRING STATIC 1400 FT ALTITUDE MODIFIED A(E)/A(I)
FILE= 56 RUN NO.= 20 POWER50000
MINIMUM VALUE= 1 MAXIMUM VALUE= 101 INCREMENT= 6



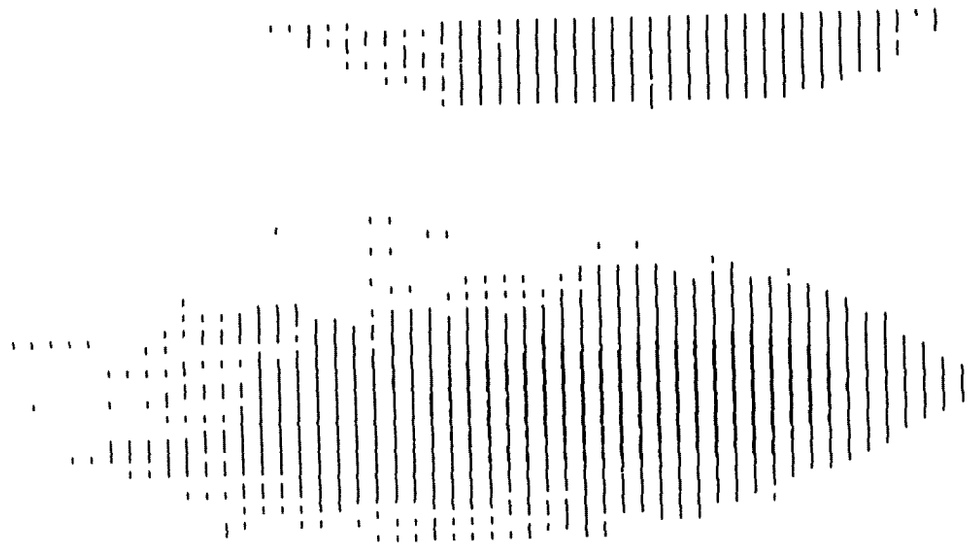
TWO DIMENSIONAL DISPLAYS (CONTINUED)

FULL SCALE HAST ØBOOSTØ FIRING STATIC 1400 FT ALTITUDE MODIFIED A(E)/A(I)
FILE= 76 RUN NO.= 27 POWER50000
MINIMUM VALUE= 1 MAXIMUM VALUE= 101 INCREMENT= 6



TWO DIMENSIONAL DISPLAYS (CONTINUED)

FULL SCALE HAST 8BOOST8 FIRING STATIC 1400 FT ALTITUDE MODIFIED A(E)/A(I)
FILE= 91 RUN NO.= 32 POWER50000
MINIMUM VALUE= 1 MAXIMUM VALUE= 101 INCREMENT= 6

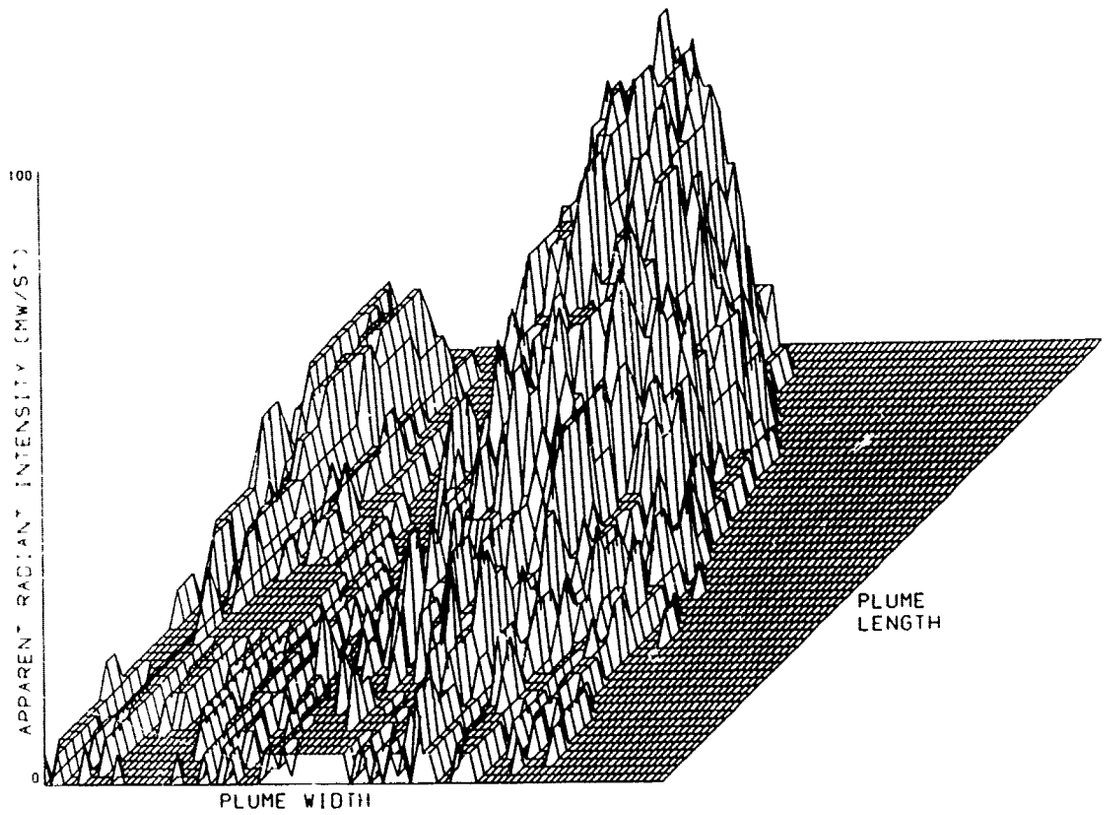


TWO DIMENSIONAL DISPLAYS (CONCLUDED)

FULL SCALE HAST 8BOOST8 FIRING STATIC 1400 FT ALTITUDE MODIFIED A(E)/A(I)
FILE= 132 RUN NO.= 46 POWER50000
MINIMUM VALUE= 1 MAXIMUM VALUE= 101 INCREMENT= 6

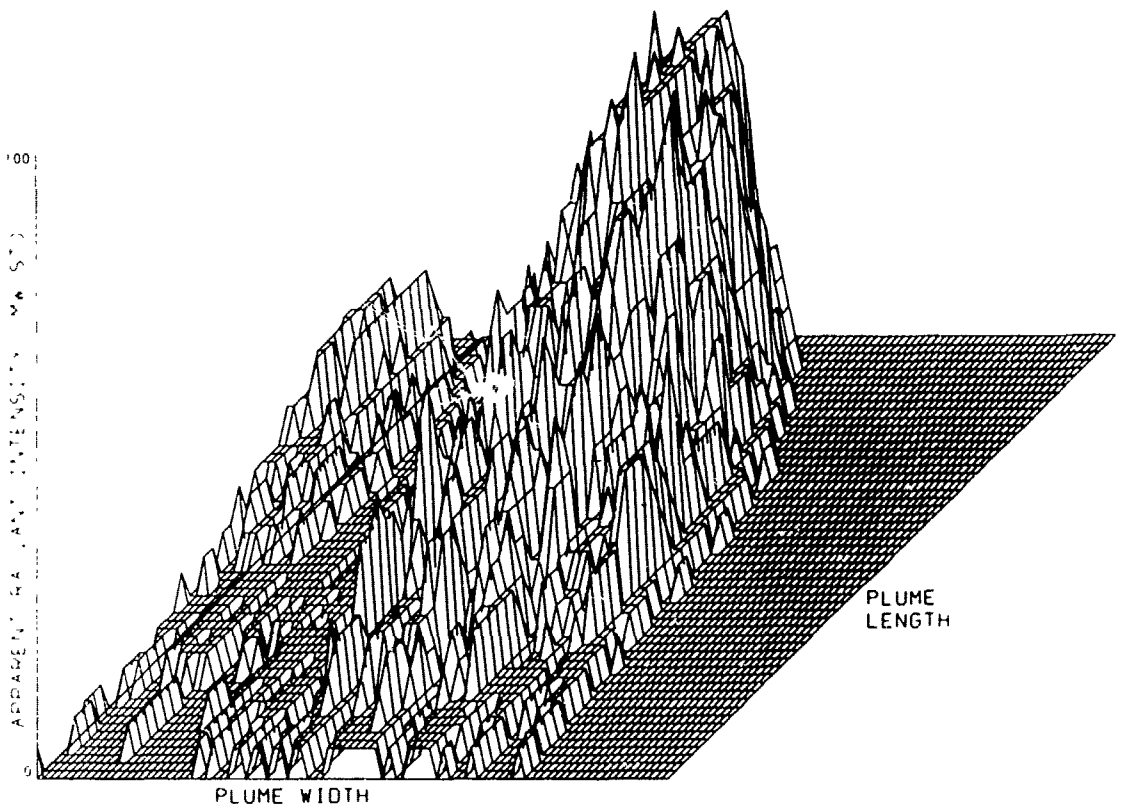
THREE DIMENSIONAL DISPLAYS

FULL SCALE HAST 8BOOST8 FIRING STA IC 1400 FT ALTITUDE MODIFIED A(E) AC
FILE .9 RUN NO. 10 O + 50000

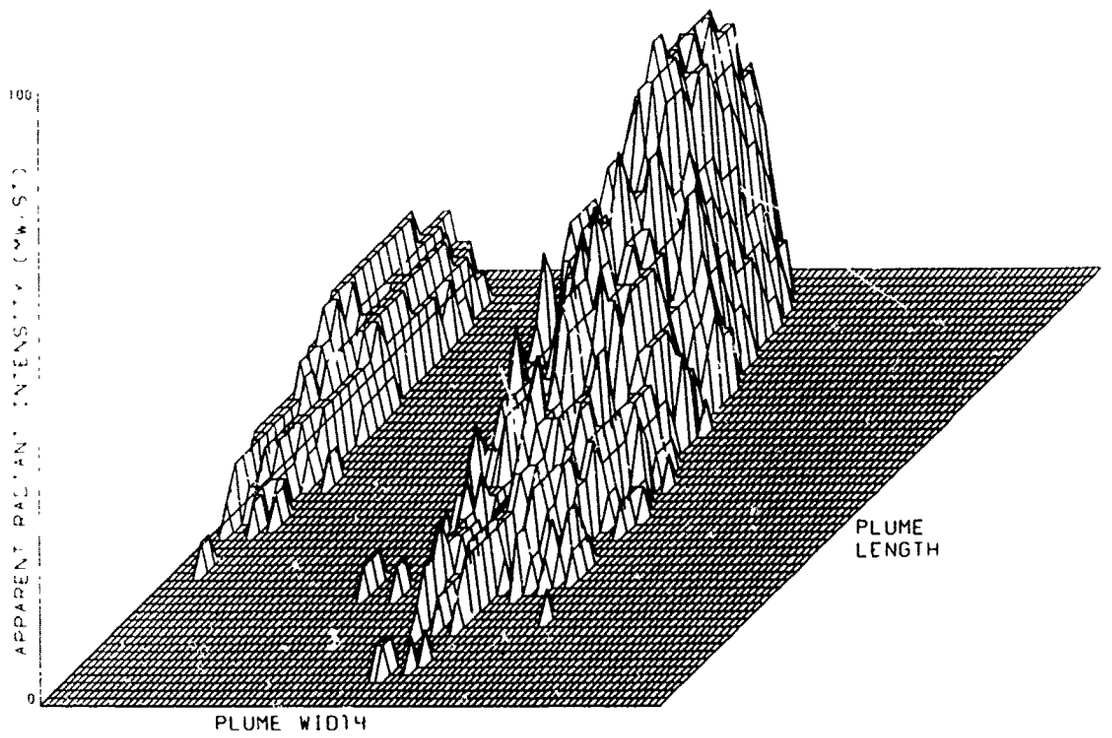


THREE DIMENSIONAL DISPLAYS (CONTINUED)

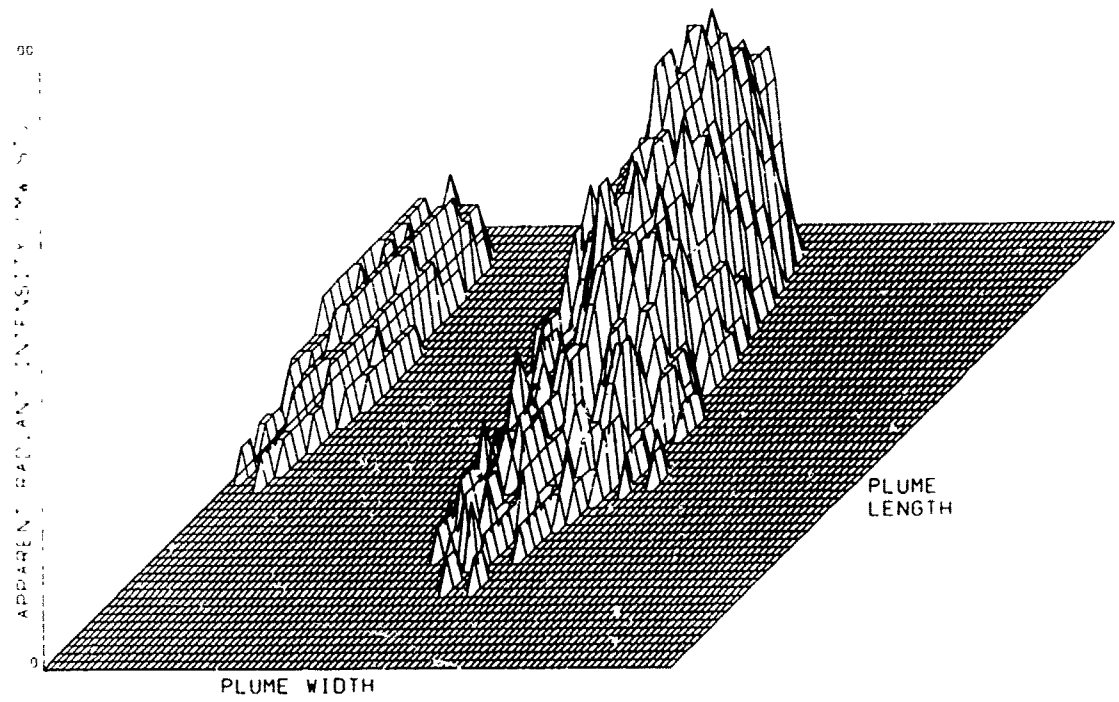
FULL SCALE MAST BBOOSTB FIRING STATIC 1400 FT ALTITUDE MODIFIED A(E)/A(
FIG. 35 RUN NO. 12 O/F 50000



THREE DIMENSIONAL DISPLAYS (CONTINUED)

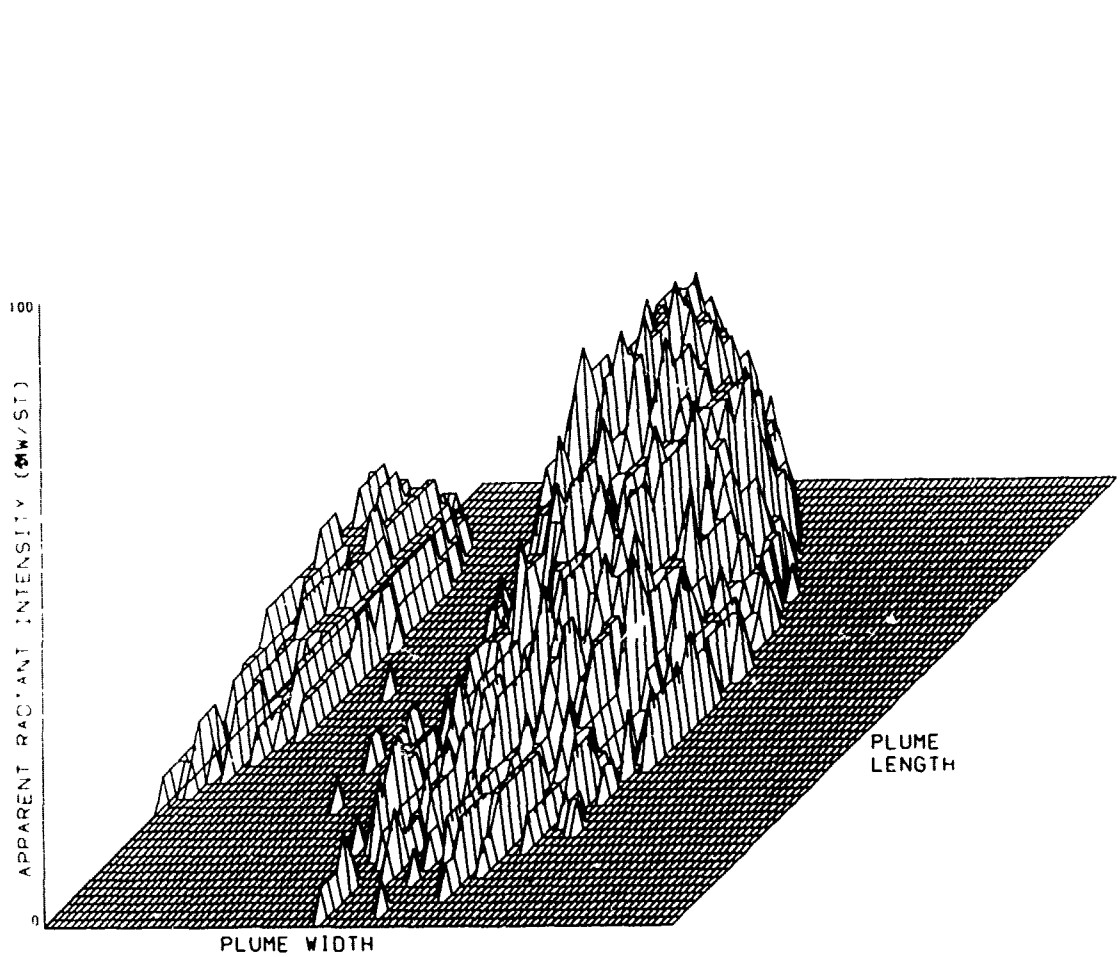


THREE DIMENSIONAL DISPLAYS (CONTINUED)



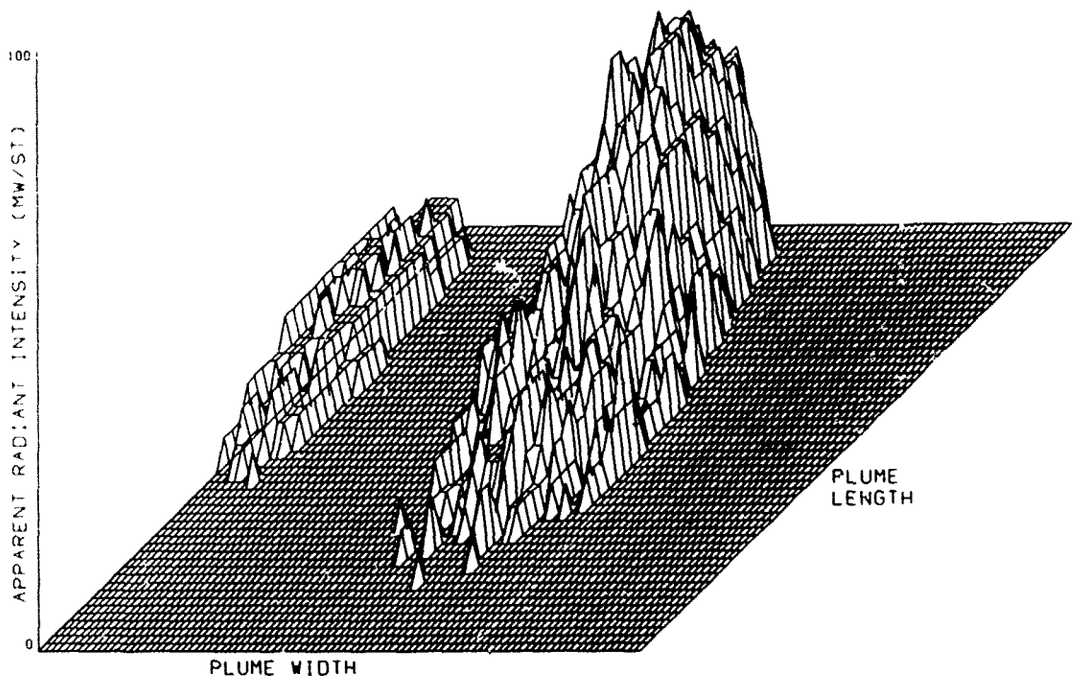
THREE DIMENSIONAL DISPLAYS (CONTINUED)

FULL SCALE HAST 8800STB FIRING STATIC 1400 FT ALTITUDE MODIFIED ACE A
FILE 91 RUN NO. 32 0/F 50000



THREE DIMENSIONAL DISPLAYS (CONCLUDED)

FULL SCALE HAST BBOOSTB FIRING STATIC 1400 FT ALTITUDE MODIFIED A(E)/A(
FILE= 132 RUN NO.= 46 O/F= 50000



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AFAL/NV	1
ASD/ENYS	1
ASD/RYE	2
AUL/AUL-LSE-70-239	1
ODDR&E/TST&E	1
DARPA/TIO	1
DDC	2
ADTC/PMR	1
TAWC/TRADOCLO	1
TAWC/TERR	1
ADTC/XR	1
AFATL/DL	1
AFATL/DLB	1
AFATL/DLM	1
AFATL/DLMI	1
AFATL/DLMH	3
AFATL/DLMQ	10
AFATL/DLOSL	2
AFTEC/XR	1
AFTEC/TET	1
4950 Test W/TIHM	1
Ogden ALC/MMNOP	2
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Redstone Arsenal (AMSMI–TM)	2
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FTD/ENDA	1
ASD/XR	1
AFAPL/RJT	1
AFCRL/OPS	1
AFCRL/OPI	1
AFRPL/DYSP	1
AEDC (Aro Inc/Lib/Doc)	1
Aro Inc/McGregor	1
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NRL/Code 4004B/Balwanz	1
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Aerodyne/Draper	1
Aerodyne/Mann	1
Aeronautical RA/Fishburne	1
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Aerospace Corp/Thomas	1
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SAMSO/RSSP	1
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Motorola, Inc	1
DARPA	1

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