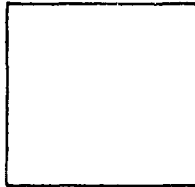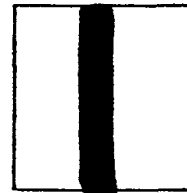PHOTOGRAPH THIS SHEET

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OPERATION CASTLE

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COLOR TEMPERATURES AT OPERATION CASTLE

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July 1955

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ABSTRACT

Color temperatures were calculated from measurements of the relative spectral intensities of the fireball of one explosion of the CASTLE series, shot Nectar. Spectral irradiances were measured over the wavelength interval 3500-5500A with a high speed spectrograph operating at a speed of 500 frames per second. Light from all portions of the fireball within the field of view of the spectrograph was integrated in each exposure. By means of a neutral density step wedge in the spectrograph and comparison spectra of a calibrated tungsten lamp, color temperatures over the above wavelength interval could be calculated with a fair degree of accuracy; viz., about 15 percent.

Only one shot of the CASTLE series was analyzed because the spectral irradiances between 3500-5500A for the other shots were too low to produce usable photographic densities, except during the first maximum.

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PREFACE

The data used in this report were taken and reduced by W. B. Fussell.

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COLOR TEMPERATURES AT OPERATION CASTLE

1 OBJECTIVE

The objective of these experiments was to measure the spectral characteristics of atomic fireballs of the CASTLE series over the range 3500-5500A as a function of time and with a time resolution of about 2msec. It was desired to obtain the effective color temperatures as a function of time over the above wavelength interval, assuming the data indicated that the fireballs acted approximately as grey-bodies.

2 BACKGROUND

The temperature of a radiant source may be described in several ways. Since in most cases it is difficult to measure the temperature of the source in the kinetic energy sense, it is necessary to determine the temperature from the characteristics of the radiation emitted by the source. The value of temperature found will usually depend upon the method of measurement, except in the case of a black-body. If the relative spectral intensity curve of the source is known, and the source is a grey-body, then the color temperature can be found from the Wien region of this curve by plotting $\log(J_w W^5)$ vs. W^{-1}, where J_w is the relative spectral intensity at wavelength W. This gives a straight line

whose slope is inversely proportional to the color temperature. Even

if the source is only approximately a grey-body, over a limited wave-

length region an effective color temperature can be obtained. This was

the procedure used in finding the color temperatures given in this report.

Measurements of relative spectral intensities in the region 3500-5500A

were made, specifically at 3500, 4000, 4500, 5000, and 5500A. These

relative intensities were then corrected approximately for the varying

attenuation of the atmosphere with wavelength. This was done by apply-

ing the results of measurements of atmospheric attenuation as a function

of wavelength which had been made by the Optics Division of NRL both in

Nevada and the Pacific.[1] From these data, spectral intensities at the

spectrograph were corrected to give the intensities which would have

been measured through a neutral atmosphere; i.e., one which has a con-

stant attenuation for all wavelengths. Thus the color temperature varia-

tion as a function of time was found, each data point on the color

temperature-vs.-time curve representing an exposure of about 2msec.

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[1] L. Dunkelman, Horizontal Attenuation of Ultraviolet and Visible Light
by the Lower Atmosphere, NRL Report 4031, Sept. 1952 (Unclassified).

Generally, when $\log(J_w W^5)$ was plotted against W^{-1}, the data points formed nearly a straight line (see Fig. 1). In some instances, however, the scatter was appreciable, showing that the source departed significantly from a grey-body for these exposures. In these cases, the best straight line through all the points was taken as giving an average value of the color temperature.

The color temperatures in this report are estimated to be accurate to within 15 percent.

3   INSTRUMENTATION

The high speed spectrograph used in these experiments has been described in a published report.[2] As used to collect the data in this report, the spectrograph operated at a film speed of about 10 fps. The slit height was such as to give an exposure time of 2msec. The optical system was f/11 and the dispersion was 95A/mm at 4000A. The slit width of 15μ was about three times the theoretical resolving power of the spectrograph at 4000A. However, the limiting factor in this case is the resolving power of the photographic emulsion used, Tri-X-AR. This emulsion has a resolving power of about 30 lines/mm (33μ). Thus the actual resolving power of the spectrograph was about 3A at 4000A.

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[2]D. J. Lovell, H. S. Stewart, and Seymour Rosin, Cine Spectrograph, J. Opt. Soc. Am. 44:799 (1954).

Figure 2 is a sample of the spectra obtained with one of the high speed spectrographs. The film was travelling at about 10fps when these exposures were made, giving an exposure time of about 2msec. The four multiple exposures composing each spectrum are clearly visible. These exposures are made simultaneously by means of a slotted drum which sweeps a series of slots, 1mm high and inclined at an angle of 45 deg, across four slits, each 6mm high and 15µ wide. Each exposure is displaced laterally 1mm from these that adjoin it. The speed of the film at any instant could be determined by a series of timing marks along "blue" edge of the film. The timing marks occurred at the rate of 1000 cps.

In all cases a front surface, concave parabolic mirror was used to receive and converge the light from the fireball (see Fig. 3). The position of the slit of the spectrograph along the optical axis of the cone of convergent light reflected from the mirror determined the field of view of the instrument. The field of view was generally less than 2 deg. A small optical flat deflected the light from the parabolic mirror into the slit of the spectrograph.

At Bikini a fairly involved optical system was used to reflect the light from the fireball down to the parabolic mirror mentioned above (see Fig. 4). This was due to the great distance of ground zero from

the spectrograph station for most of the shots of the CASTLE series. Thus the curvature of the earth necessitated that mirrors be placed at the 200 ft level of the steel tower on Nan to receive the light from the fireballs of the shots of the CASTLE series which were exploded at Bikini.

For the Nectar shot at Eniwetok, the spectrograph station was on Engebi, and a different system was used to illuminate the parabolic mirror nearest to the spectrograph (see Fig. 5).

4 RESULTS

Figure 6 gives the color temperature-vs.-time curve for the CASTLE Nectar shot. Table 1 gives the coordinates of the stationary points of this curve; that is, the minimum and the second maximum.

TABLE 1 - Coordinates of Stationary Points of Color Temperature-vs.-Time Curve

	Color Temp., 10^3 °K	Time, 10^2 msec	Tonnage, 10^2 KT
Values at the Minimum	1.2	1.3	
			16
Values at the Second Maximum	2.7	12	
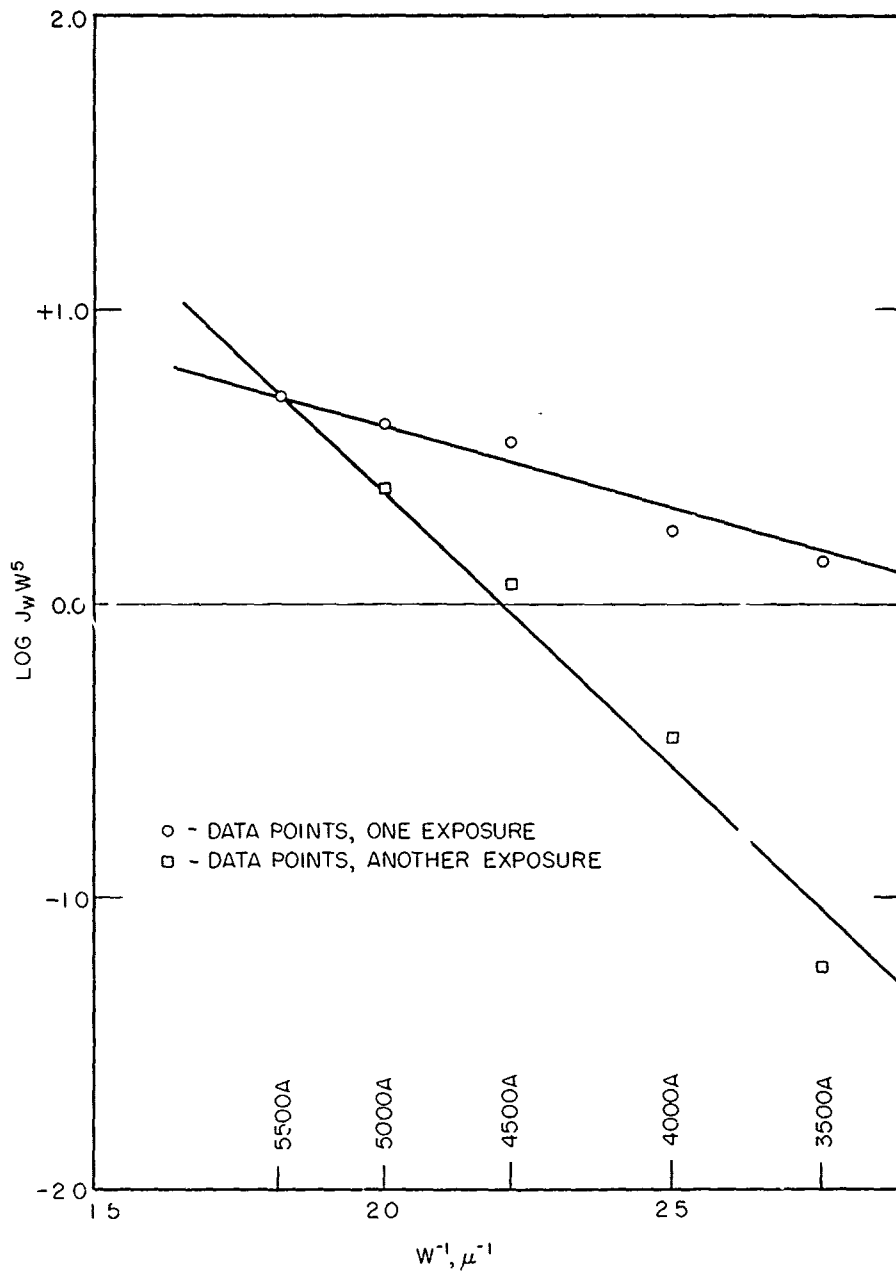
Fig. 1 - Sample plot of $\log(J_w W^5)$ vs. W^{-1}

Figure 2

12

LIGHT FROM FIREBALL →

M₁

M₂

O.A.

× S

HIGH SPEED SPECTROGRAPH

M₁ – PARABOLIC MIRROR
M₂ – FLAT TURNING
     MIRROR
S – SLIT OF HIGH SPEED
    SPECTROGRAPH
O.A.–OPTICAL AXIS OF
     SPECTROGRAPH
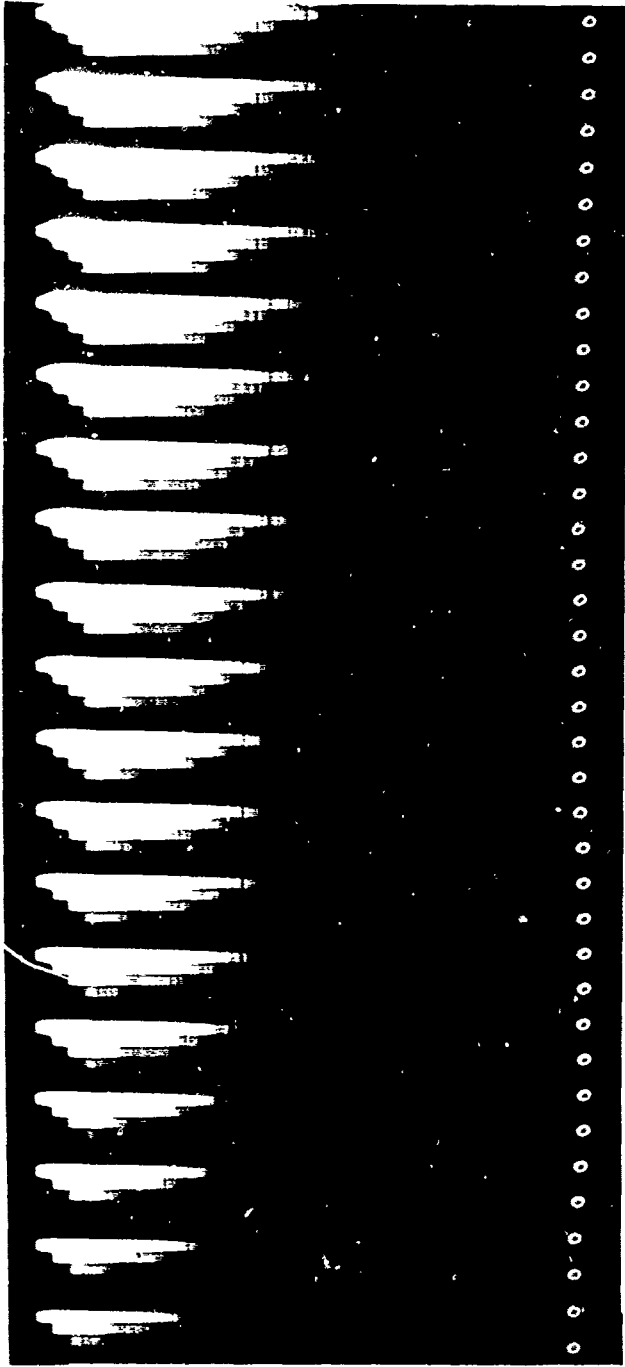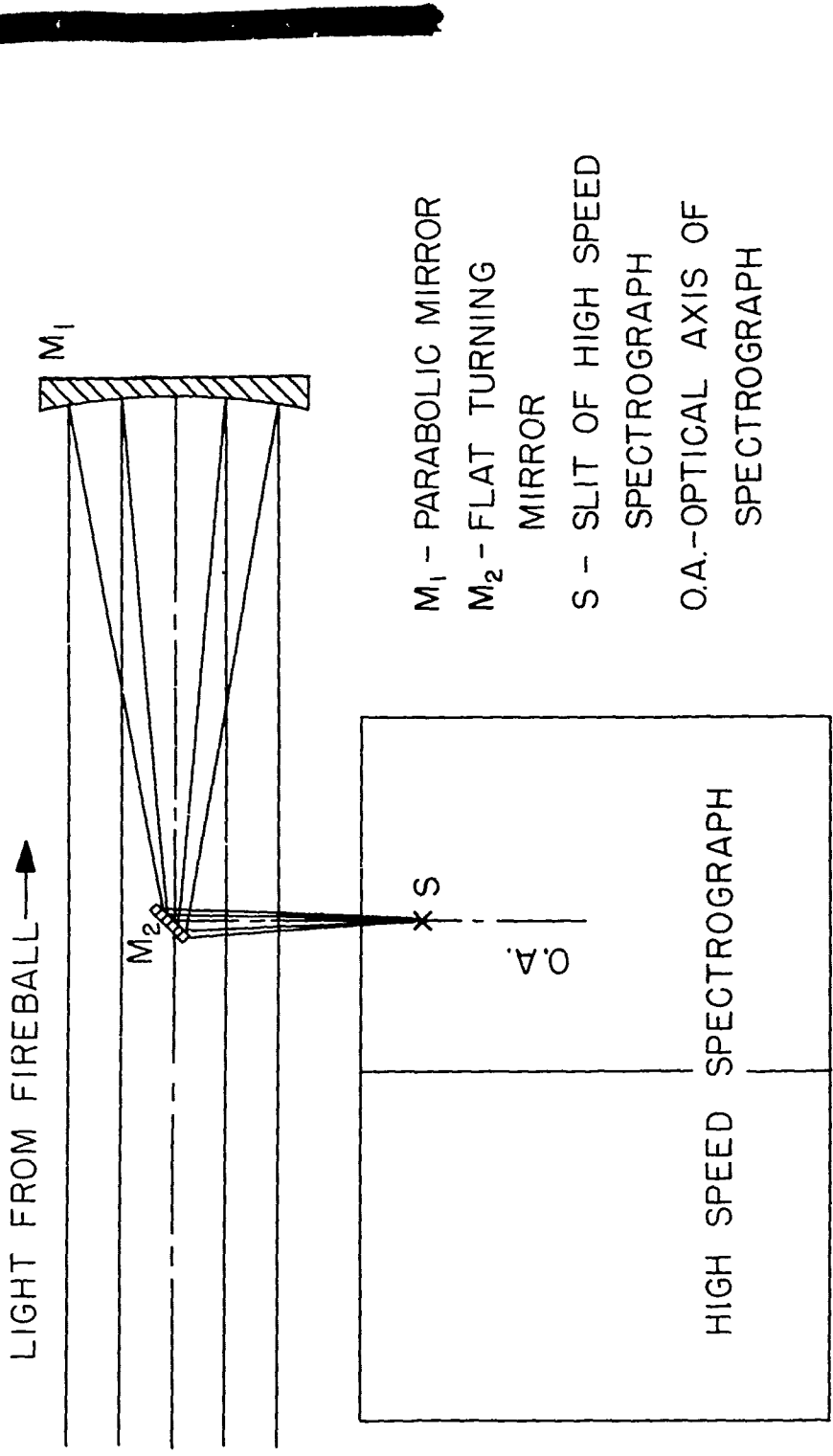
(NOTE: NOT TO SCALE)

Fig. 3 – Sketch of the Newtonian system used to illuminate the spectrograph

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M₁ ← LIGHT FROM FIREBALL

O.A.

P

M₂

M₁ - PARABOLIC MIRROR
M₂ - FRONT SURFACE FLAT
M₃ - FRONT SURFACE FLAT
P   - SUPPORTING PLATFORM
O.A.- OPTICAL AXIS

O.A.

(NOT TO SCALE)

200 FT.

TRAP DOOR

TO SPECTROGRAPH
O. A.   M₃

GROUND LEVEL
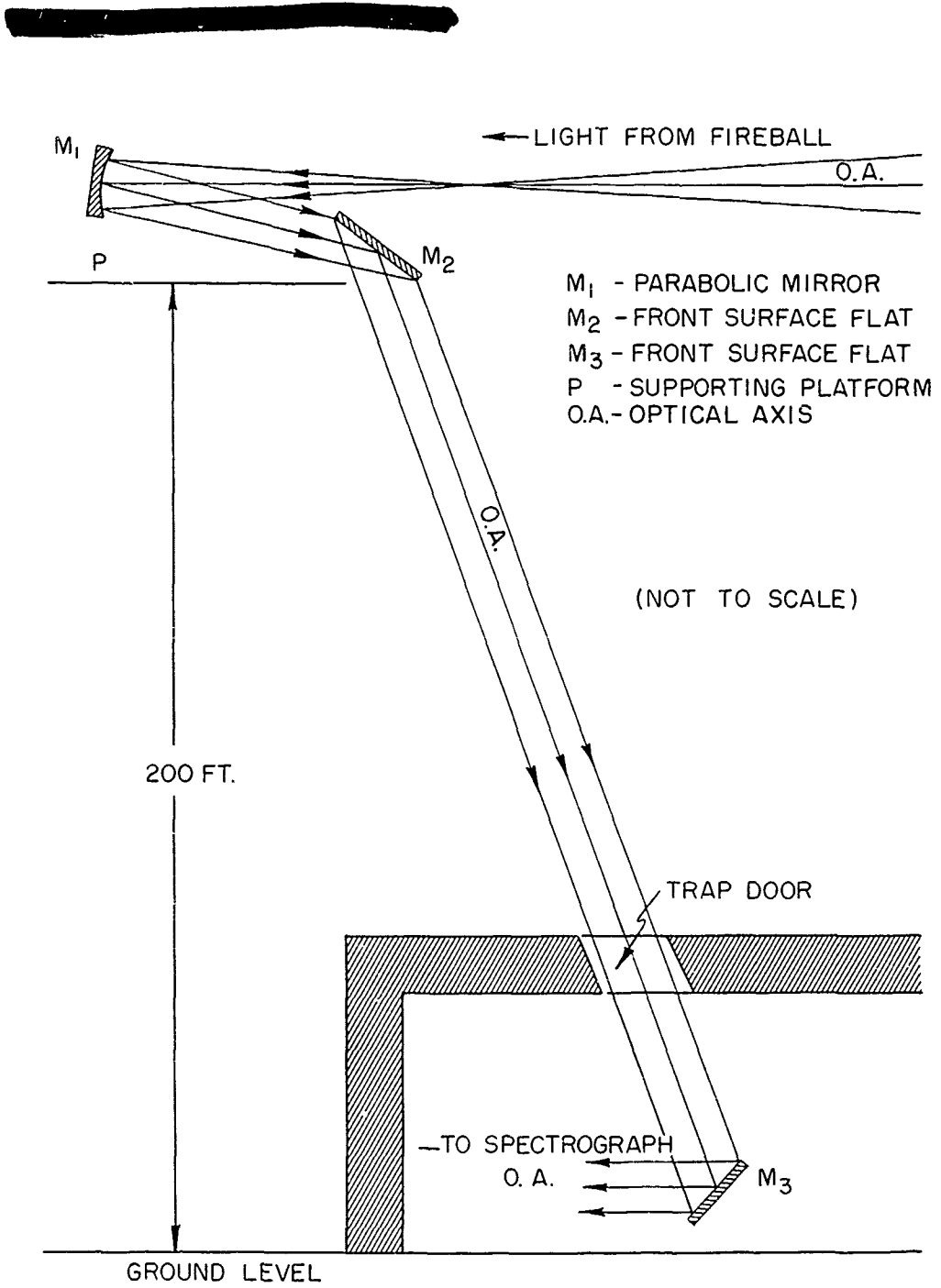
Fig. 4 - Sketch of the optical system used at Bikini

NOTE: THIS DRAWING IS NOT TO SCALE

TO SPECTROGRAPH

O.A.

STATION GA

VICOR GLASS-COVERED APERATURE

LIGHT FROM FIREBALL

O.A.

M₁
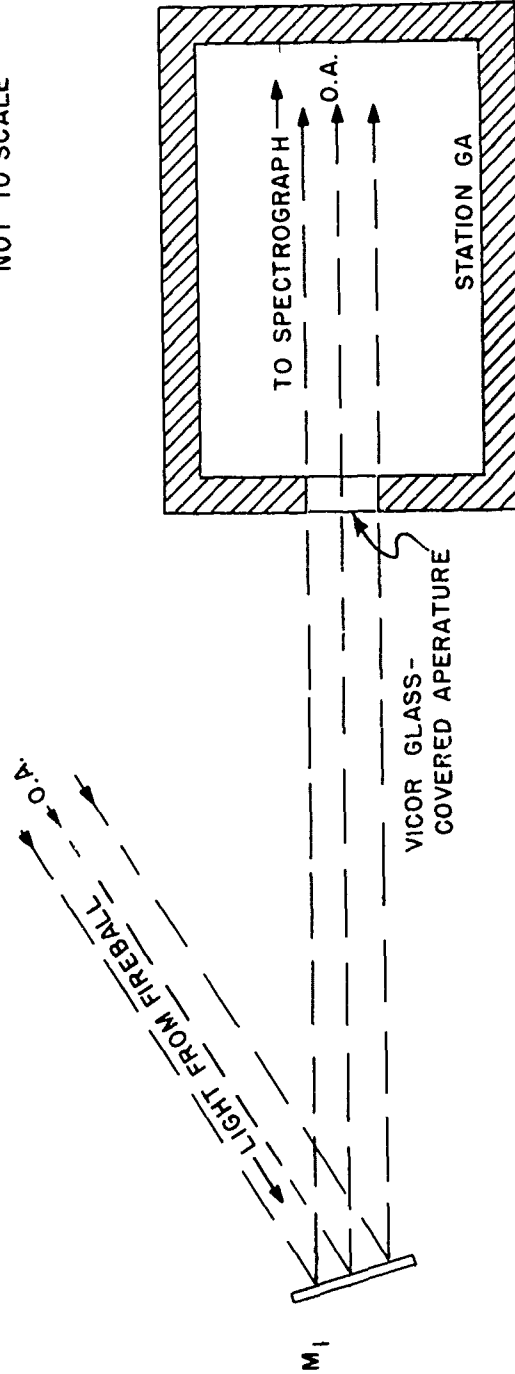
O.A.-OPTICAL AXIS

M₁-FRONT SURFACE FLAT MIRROR
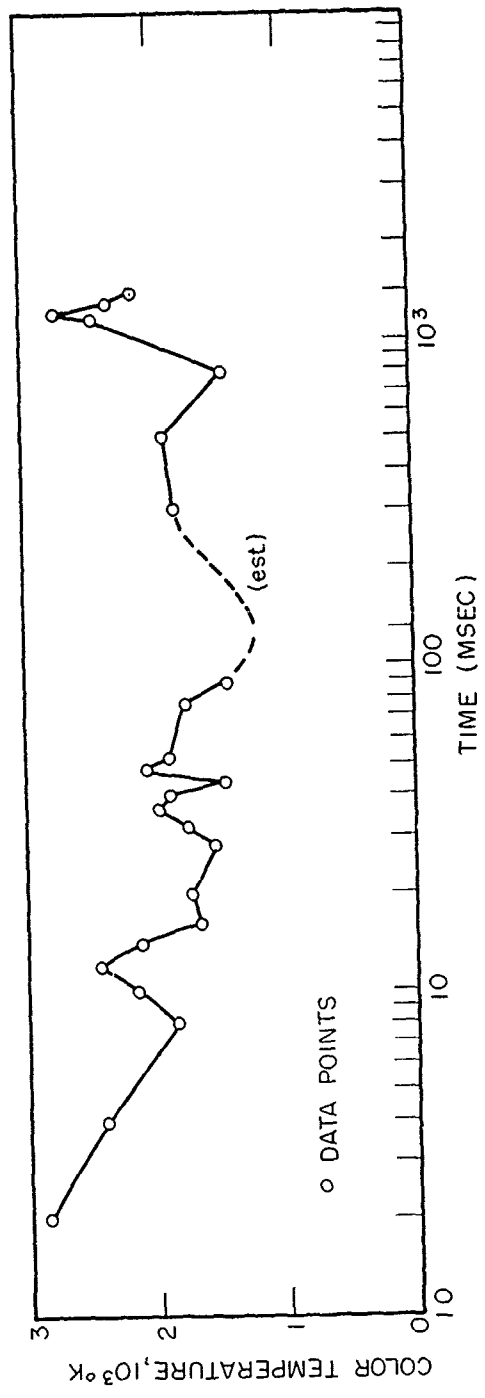
Fig. 5 – Sketch of the optical system used at Engebi, Eniwetok

Fig. 6 - Color temperature vs. time for CASTLE-Nectar