A Spectrograph for the Far-Ultraviolet[1]

R. D. PAYNE[2] and F. C. TODD

Oklahoma State University

For a thorough investigation of the physical state of shock-compressed metals that result from a hypervelocity impact, a spectrograph has been constructed for the far and intermediate ultraviolet. Since the performance characteristics of a spectrograph may be considerably modified by

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[2]1st Lt. Payne is now in training at Ft. Belvoir, Va.

the design variables, these are selected to most efficiently achieve a selected objective. For the optimum applicability of the device for clarification of impact phenomena, the maximum intensity is desired at the shortest wavelengths that appear in the far ultraviolet, even when these lines are very weak. To obtain the maximum intensity, grazing incidence on the grating must be employed. In addition, the lines in this region are to be spread with considerable dispersion in order to accommodate a photosensitive device at some future time. The spectrograph has been constructed to have two ranges. One range is in the far ultraviolet and extends from 100 to 1400 A. A second range, with much less sensitivity, covers the intermediate range from 1000 to 3300 A.

GENERAL DESIGN FEATURES

For both the far and the intermediate ranges in the ultraviolet, the spectrograph must be of the vacuum type without lens. For the designated spectral ranges, the grating is ruled on a concave mirror in order to simultaneously obtain diffraction and focusing of the diffracted lines. A Rowland mounting was selected for the spectrograph. The entrance slit, the center of the grating and the film are on the circumference of a circle with a diameter that is equal to the radius of curvature of the concave mirror on which the grating is ruled. Rowland employed approximately normal incidence on the grating for maximum resolution of the lines in the spectrum. For wavelengths in the range for this spectrograph, grazing incidence is employed to obtain more intensity of the diffracted light, and more dispersion, but less resolution. To illustrate the need for grazing incidence, the reflectivity at normal incidence decreases from 90% at 2000 A to 3% at 800 A. At grazing incidence, the reflected intensity decreases as the angle of diffraction increases. The use of gratings at grazing incidence was pioneered by Compton (1936).

The basic theory for the Rowland mounting is valid whether the light is incident near normal, or near grazing incidence on the grating. A typical arrangement for near grazing incidence is illustrated in Fig. 1. Light enters the slit at the lower left, traverses the path S, and is incident on the grating. The diffracted light for a line of wavelength λ traverses the path R' and is incident on the film which is wrapped around the circumference of the Rowland circle. $R/2$ is a line from the center of the grating as indicated in the figure. From the diagram, the distance from the slit to the center of the grating is

$$S = R/2 \cos A$$

The triangle with the sides S and R has a right angle at the slit for it is a triangle that is inscribed in a semicircle. The length of the path R' is

$$R' = R/2 \cos B$$

for the angle at the film is a right angle for the same reason as above. In a standard reference article on the theory of concave gratings (Beutler, 1945), it is shown that the diffracted lines are in focus at the film position. It is also shown that the distance along the film L and the wavelength λ are related by the expression

$$bL/d\lambda = B/e \cos B$$

where e is the distance between the grooves of the grating. This expression may be integrated to give

$$\lambda = e(\sin A - \sin B)$$

where $L = R(A\text{-}B)$. These are very convenient equations for designing and aligning the spectrograph.

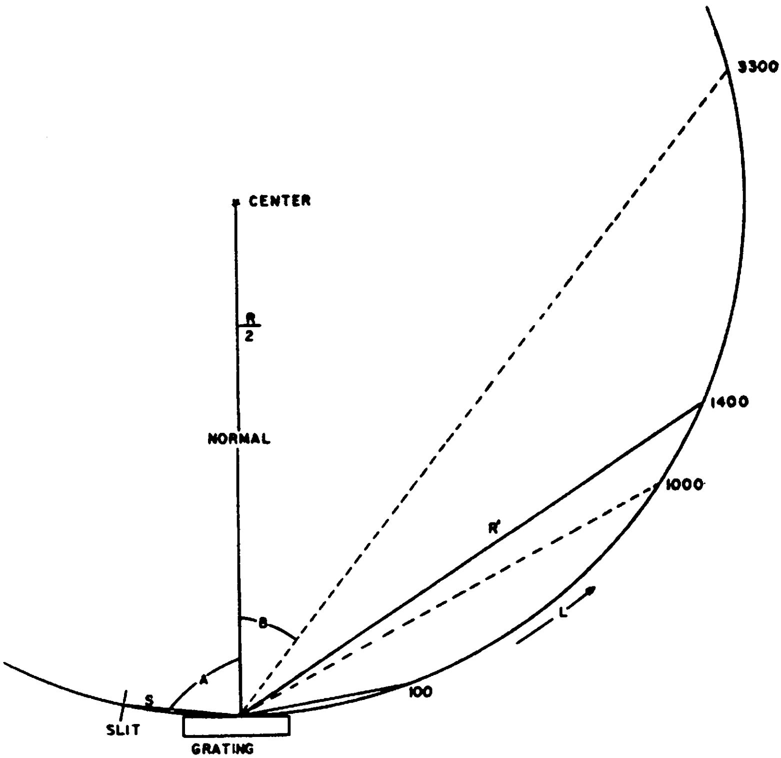

Fig. 1 Rowland Circle and Relative Scale of Position of Spectrum

CONSTRUCTION FEATURES

For this spectrograph, the angle of incidence of light on the grating is made to be 86 degrees. With this angle, this spectrograph is constructed to have two spectral ranges as shown in Fig. 1. The ranges for the far ultraviolet, 100 to 1400 A, and the intermediate ultraviolet, 1000 to 3300 A, are indicated roughly to a relative scale for a grating with 30,000 lines per inch. The grating for this spectrograph has the lines engraved on a concave glass surface with a radius of curvature of 150.2 cm which is then coated with a thin layer of aluminum. To obtain the greatest intensity in the spectral range from 100 to 500 A with a practical ruling, thin lines are ruled on glass without any blaze. Most gratings have the rulings shaped, or blazed, so the angle of incidence is roughly equal to the angle of reflection at the center of the selected spectral range which is of particular interest. The grating for this spectrograph was ruled under the general direction of Dr. John Strong in the Optical Shop at Johns Hopkins University.

With grazing incidence, the width and height of the ruled portion of the grating that may be illuminated without aberrations that broaden the lines at the film is strictly limited. This has been studied and reported by Mack, Stehn and Edlen (1932). The subject was later reviewed by

Beutler (1945) and their recommendations are followed. In order to limit the height and width of the illuminated portion of the rulings, the entrance slit and an additional defining slit are arranged as shown on the reproduction of the shop drawing for the entrance portion of the spectrograph. The drawing is included as Fig. 2. The light enters at the right and passes through the open Alpert valve; the beam size is determined by the defining slit on the left. The grating case is mounted to be as close as possible to this defining slit: i.e., the grating case is ⅛ inch from the slit. The illuminated region on the grating is limited to 1 cm height by 1½ cm width with some haziness around the edges. The Alpert valve also serves as a vacuum-tight seal between the spectrometer case and any vessel with the light source. The valve may be closed to permit changing the film without admitting air to the source region.

The length of the film is the same for both ranges of the spectrum, so the same film support may be used for each. The range in the far ultraviolet, 100 to 1400 A, is very close to the grating. The intermediate ultraviolet must be farther from the grating and requires a larger case. The relative size of the vacuum chambers which have been constructed for the two ranges are shown by the two outlines in Fig 4. The position of the grating is indicated in both sketches. Parts labeled one, two and three are the complicated components at the front end of the spectrometer and include the grating. These parts are common to the two assemblies, as well as to the mounting which supports the spectrograph. The part eight is inserted to decrease the volume to be evacuated.

The auxiliary equipment includes a laminated plastic film holder. The film is loaded into the holder while in the dark room. The holder is then brought to the spectrograph and bolted onto the back in order to insert and remove the film, which is a little over 5 ft in length. The case

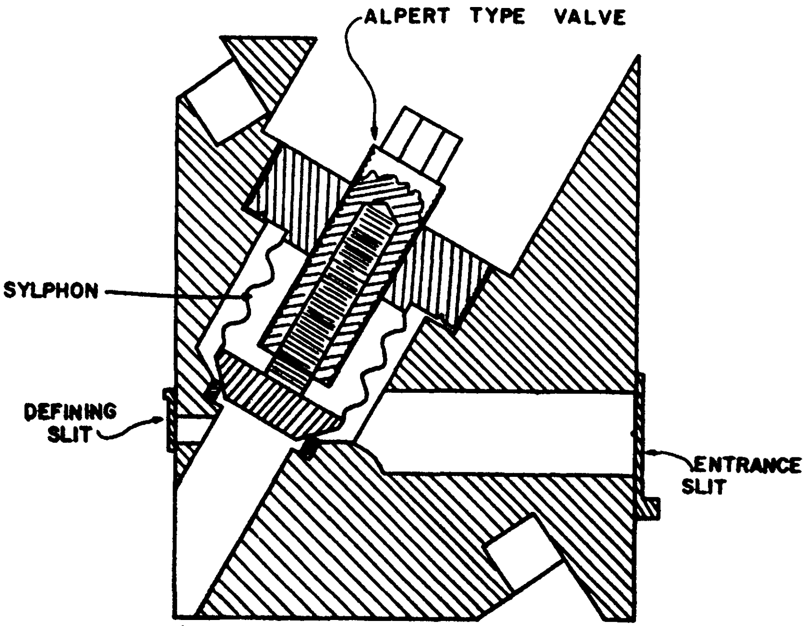

Fig. 2 Detail of Entrance and Defining Slits and Alpert Valve

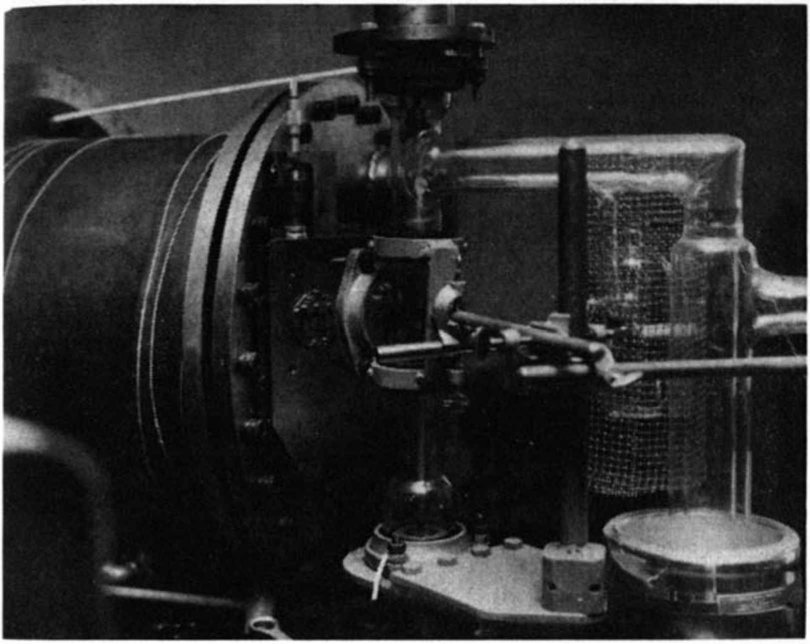

Fig. 3 Front End of Spectrograph with Entrance Slit to Left of Center and Spark Source in Tube at Center.

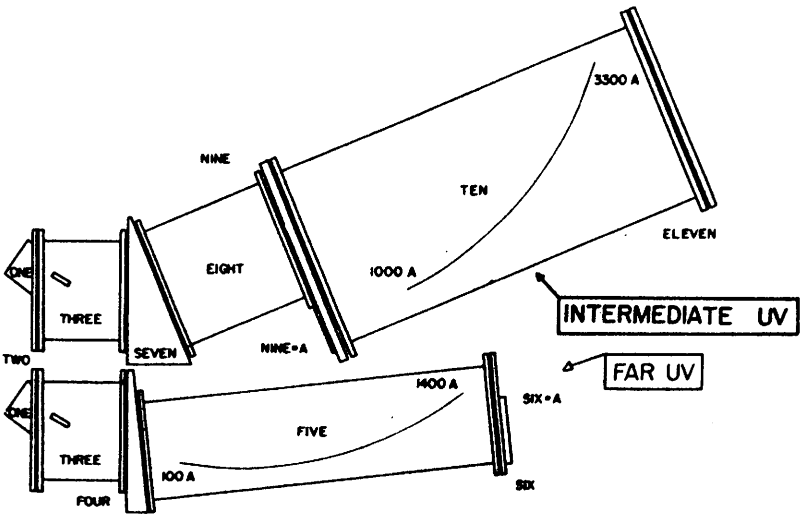

Fig. 4 Relative Sizes of Spectrograph Housings

for the film changer is shown in Fig. 5. Unfortunately, foreshortening is rather bad in this photograph. The distance from the back of the spectrograph to the near end of the film changer is about 6 ft. There is a revolving shutter in the large, laminated plastic disc on the spectrograph end of the film holder and a matching, revolving, metal shutter is just inside the large end of the spectrograph. There has been no trouble from light leakage by either of these two shutters.

The spectrograph is of moderate size. The general appearance is indicated by the view that is shown in Fig. 6. The grating is in the section on the left end to which the diffusion pump is attached. The film is wrapped around a section of a cylinder with the radius of the Rowland circle. This part is in the large tube on the right.

ACKNOWLEDGMENTS

Mr. H. W. Gurney designed and built the film changer, and assembled the entire unit for operation. Mr. Larry Peery is making the final adjustments and has obtained the first photographs.

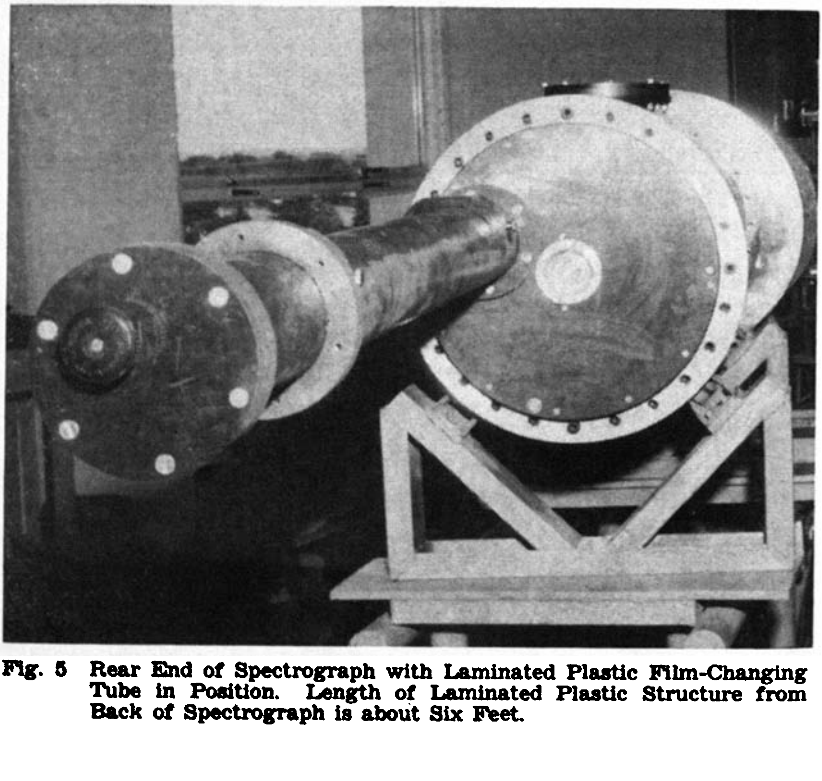

Fig. 5 Rear End of Spectrograph with Laminated Plastic Film-Changing Tube in Position. Length of Laminated Plastic Structure from Back of Spectrograph is about Six Feet.

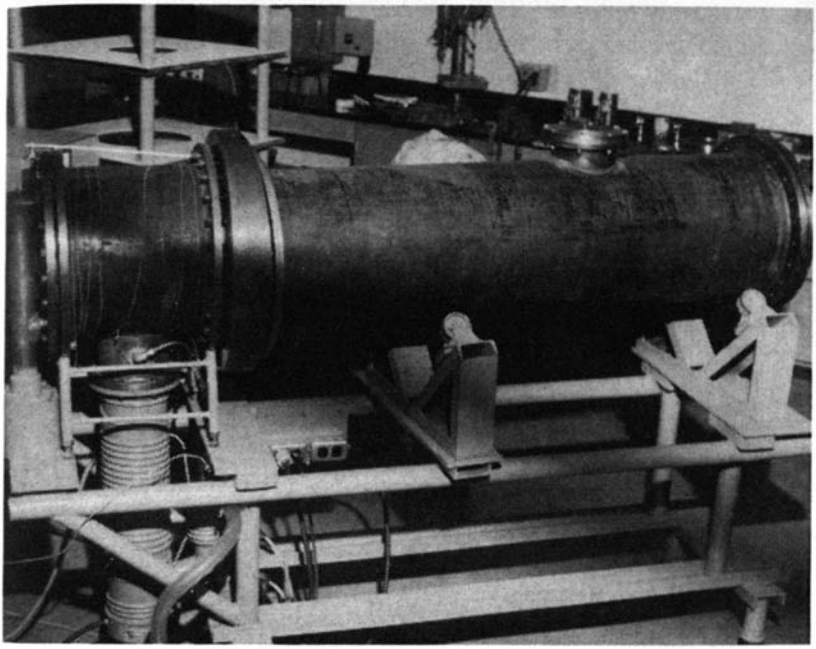

Fig. 6 Side View of Spectrograph with its Support. Diffusion Pump at Left is Under the Grating.

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