Vol. IX—No. 3 October, 1964

The SPEX Speaker

SPEX INDUSTRIES, INC. · 3880 PARK AVENUE · METUCHEN, N.J. · ☎ 201-549-7144

WHAT'S NEW IN CZERNY-TURNER SPECTROMETERS?

JUST under a year ago we introduced a series of versatile Czerny-Turner mount spectrometers which, in this short interim have already found welcome homes in this country, Canada, England, France, Germany and Israel. Despite the fair number delivered, their design has been far from static. We have continually incorporated modifications to make life a little easier for the stouthearted investigators who tread among lasers, semiconductors, electro-magnetic-optical effects, plasmas and the unknowns of the upper atmosphere. This issue will review the original concept, survey subsequent developments and put current specifications unequivocally into print. Although such efforts will in no way alter the course or the pace of activities in our development lab it may assuage our frenzied production and sales people who keep the suggestion box stuffed with requests for a design freeze.

The side-by-side Czerny-Turner mount combines several unique advantages. A plane grating permits wavelength to be scanned simply by turning the grating on its own axis. Attach a well engineered and executed sine bar and the readout becomes direct in angstroms, give or take a few. High quality plane gratings are easier to produce than their concave counterparts. Blaze angle can be controlled to put the energy where it is wanted. Large replicas can be produced relatively inexpensively. While subject to individual variations, their resolution is generally excellent. Imperfections such as ghosts and satellites are kept below bothersome levels.

One of the biggest advantages of the mount is its wavelength expanse. The lower limit is imposed by the reflectivity of the surfaces. When overcoated with MgF_2, aluminum reflects 80% above 1100A and well over 90% of the radiation from 1500A to at least 22 microns. The upper extreme is determined by the angle to which the grating can be turned and the coarseness of ruling. At 65° and 75 grooves/mm, respectively, our Czerny-Turners reach 22 microns.

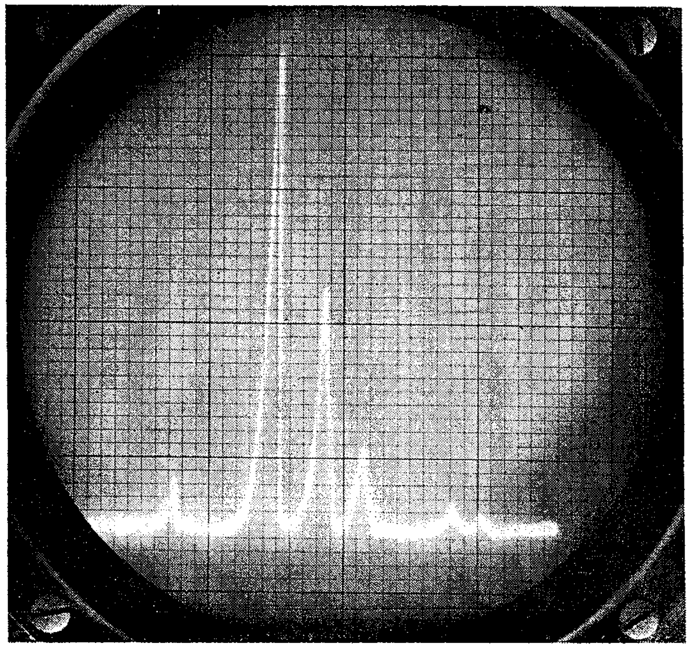
Other advantages of the mount are:

1) Stigmatic image—sources can be studied for any geometric inhomogeneities.

2) Stationary entrance and exit beams—absorption through a substance can be conducted at different wavelengths with the beam path invariant.

~~3) Polarization is essentially absent. In some mounts, the intensity of light emerging in a direction parallel to the grating rulings is different from that emerging at right angles.~~

To this basic system, first described in the '30s, we have now added an optical twist. For the rapid interchange of photographic and photoelectric detectors, an internal mirror has been placed before the exit slit. It is indented to 45° for camera use, flipped out of the way for photoelectric work. In our earlier models mounting the camera required removal of



Oscilloscope trace of Fe Hollow cathode source scanned by Refractor Plate. About 40 pulses of Fe 3737, 3735 and 3733 were recorded (L-R) in the 4 sec. exposure. The 1.5mm quartz plate provides a scan of about 20A in the first order of a 1200 L/mm grating.

the exit slit. Dr. S. P. S. Porto, of the Bell Telephone Laboratories, who first suggested the beam deflector, is studying the Raman effect with a continuous laser source. The new camera arrangement lets him locate the exceedingly weak Raman lines photographically before centering on them with the most sensitive photomultipliers.

Speed: Photographic vs. Photoelectric

The 1500 and 1700 spectrometers have a photographic speed of f/6.8 which is simply calculated on the basis of a circle of cross-sectional area equal to that of the 102 x 102 mm grating. This must be corrected for the angle of incidence made by the incoming beam on the grating which, in all of our Czerny-Turners is 6°. The formula then becomes f/d' where

$$d' = 2[(hw \cos i)/\pi]^{1/2}$$

where

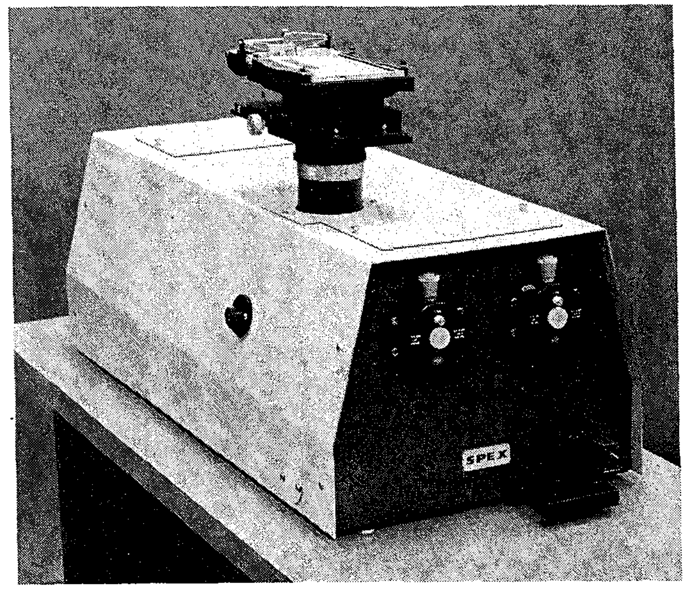
f = the focal length (750mm)
d' = the effective diameter
h = the height of the grating (102mm)
w = the length of the grating (102mm)
i = the angle of incidence (6°)

In a photographic instrument, the flux transmitted per unit area is the overriding parameter in determining its speed. One is interested in a line of light not the radiation impinging over the entire surface of the plate.

By contrast, a photoelectric device responds to the *total* flux received on its sensitive surface. Let us assume an extended source, one at least 50 mm long (such as a Globar widely used in infrared or a pinched plasma). With this, a long entrance slit can be used to admit as much flux as possible. If the detector is somewhat shorter than the slit length, a condensing lens can be inserted after the exit slit to squeeze the beam appropriately so it conforms to the detector surface.

In an article by Jarrell in Clark's "Encyclopedia of Spectroscopy," a photoelectric figure of merit of several instruments is presented. Here, an arbitrary spectral purity of 0.2A is chosen to normalize all of the instruments. Spectral purity is defined as the half-width of a line. In many instruments, including the Czerny-Turner and Ebert mounts, increasing the length of a straight entrance slit results in poorer spectral purity or resolution. If, however, both the entrance and exit slits are curved as originally suggested by Fastie (*J.O.S.A.*, *42*, 648, 1952) then the slit length is no longer so limited.

With this background, the following table was prepared after that in the Encyclopedia to which we have already referred. The figure of merit is given in the last column and our 1500 or 1700 instruments are referred to in rows three and four. Note that with 18 mm straight slits the spectral purity of 0.2A is maintained and the figure of merit is 146. With 50 mm curved slits, the figure is boosted to 375, exceeded only by a competitive 1.8 meter instrument using a very large grating.



1700-II Spectrometer showing the 1710 Tower and 1628 Camera for 4" x 5" Polaroid film. Note the external lever on the left side for the swing-away mirror.

FLUX TRANSMITTING POWERS AND f/NUMBERS OF SOME COMMERCIAL SPECTROMETERS*

$$F = T\ L/f\ A\ d\theta/\lambda$$

Instrument	T	h	Wcos i	$d\theta/d\lambda$	L/f	Effective f/number	Fx10^4
f/4.5 Quartz prism, doublepass	.59	70	40	1.48×10^{-4}	1/270	4.5	9.0
Ebert f/8, 0.5 meter 1200 L/mm, curved slits	.52	52	50	1.18×10^{-4}	20/500	8.8	64
SPEX 1700-II Czerny-Turner f/6.8, 0.75 meter 1200 L/mm, straight slits	.52	102	96	1.18×10^{-4}	18/750	6.8	146
SPEX 1700-II Czerny-Turner f/6.8, 0.75 meter 1200 L/mm, curved slits	.52	102	96	1.18×10^{-4}	50/750	6.8	375
Ebert 1.8 meter 1200 L/mm, curved slits	.52	125	135	1.18×10^{-4}	100/1800	12.3	558

F = Flux Transmitting Power
T = Optical efficiency
A = h Wcosi = effective area of dispersive element
$d\theta/d\lambda$ = angular dispersive power
L/f = slit height/focal length for a resolution of 0.2A

*From Clark, "Encyclopedia of Spectroscopy," pp. 248, 249, 250 Reinhold Publishing Co., N. Y. 1960.

Cameras

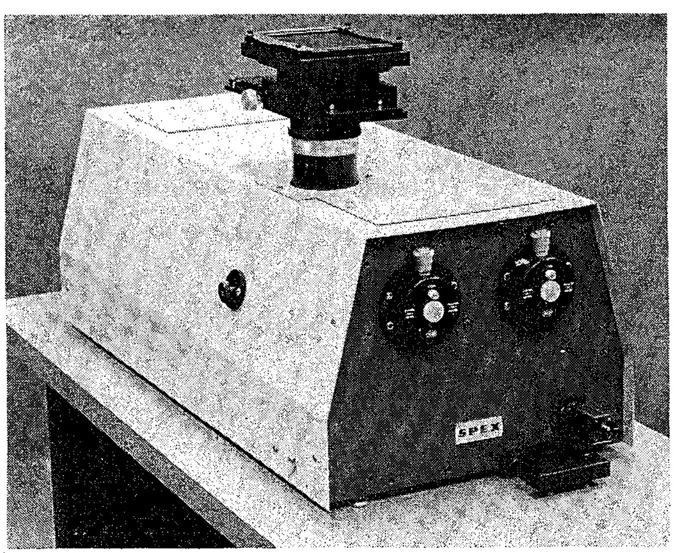
OUR standard and Polaroid cameras are a result of a good deal of thought and experimental development. Polaroid films have made a marked impact on spectroscopic research. To obtain a hurried photograph when there is no need for quantitative interpretation of spectral intensity, the various emulsions now offered are wonderful time savers. Type 57 and 47 with ASA speeds of 3000 will pick up the most fleeting line in the region from 2300A to about 6500A. The infrared emulsion, Type 413 now available commercially only in roll films, extends the sensitivity to 9200A. From a practical standpoint, the best kind of spectroscopic Polaroid film is that packed and processed individually, the 4″ x 5″ sheet film. Instead of an entire roll, only one sheet is loaded in the camera. Polaroid, however, makes it a practice to utilize roll-film for their experimental and new emulsions and, for this reason, we offer both cameras. At present only two 4″ x 5″ sheet film emulsions are of spectroscopic interest: the 3000 speed, type 57, and the P/N type 55. The latter develops into a positive print and a negative transparency which can be microphotometered.

Our third camera takes ordinary 4″ x 5″ plates. Although spectroscopic plates can be obtained in many different sizes, the most popular is 4″ x 10″. These are stocked not only by the manufacturers but by many dealers. It is a simple matter to score and break a 4″ x 10″ plate into two. (We will send you an Eastman Kodak leaflet on request.)

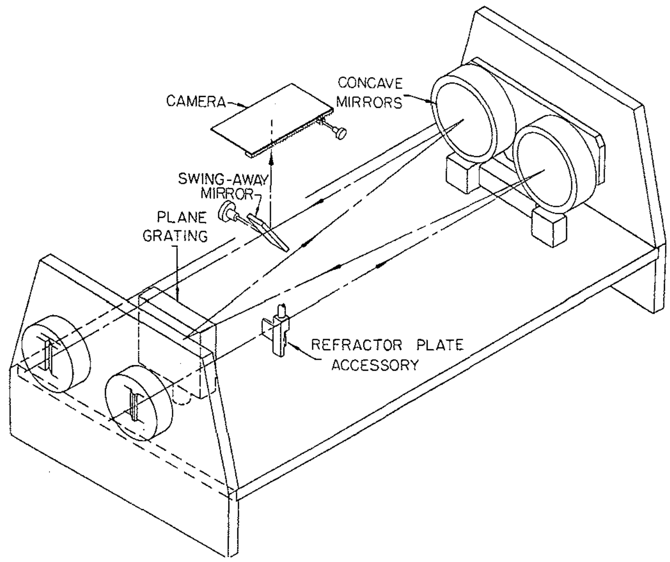
All three cameras are fully rackable when used on the 1710 Tower. By setting the height of the entrance slit to 1 mm, as many as 50 exposures can be taken on a film or plate. The Hartmann diaphragm on the entrance slit can be used for error-free wavelength interpolations against an iron reference spectrum.

Scanning

The customary motorized spectrometer drive is, as in the earliest autos, a transmission and gear shift allowing several pre-selected speeds. As in an auto, too, the motor operates at full speed at all times while the reducing gears drone away, each contributing to the overall vibration level. Our approach was to abandon the mechanical gear drive in favor of an elec-



1700-II Spectrometer with the 1631 Camera for standard emulsion 4″ x 5″ plates mounted on the 1710 Tower.



trical servo. This both eliminates most of the gear train and permits the incorporation of a low-speed motor with high, constant, vibration-free torque. One deficiency in our first effort was the inconvenience in reproducing a fixed speed. To scan at exactly 2 A/min, one had to prepare a calibration chart of potentiometer position *vs.* speed. In the present design, a resistor providing a fixed speed may be plugged in to override the variable pot.

Refractor Plate

The refractor plate has proved to be a unique research tool for scanning a short wavelength interval repetitively. Intensity changes and wavelength shifts can be studied while they occur simply by viewing the screen of an oscilloscope. Interposed between the entrance slit and the first mirror is a thin piece of quartz or other transparent material. As it rotates, it deflects the spectrum to an extent depending on its thickness and refractive index.

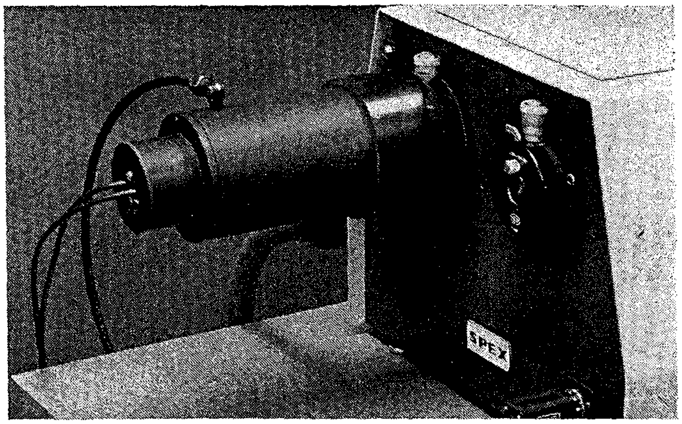
Suppose it is desired to optimize the signal: noise of a particular source by adjusting its various electrical and mechanical parameters. To do this either photographically or photoelectrically is a burdensome chore entailing measurements of both the line and background intensity. With a refractor plate plugged into an oscilloscope through an intervening photomultiplier, the task is facilitated. A stationary tracing appears on the oscilloscope; changes in line and background intensity and shape can be seen simultaneously as the parameters are varied. Dr. Gunther Fenner of the General Electric Research Laboratory in Schenectady, N. Y., is using our refractor plate for such an application. He is studying the wavelength shifts in the emission of injection lasers subjected to pressure and temperature changes.

Despite the fact that a synchronous motor was chosen to drive the refractor plate, small speed fluctuations did occur in the original models and it was difficult to match the oscilloscope sweep with the repetition rate of the refractor plate. In the present design, an opposite approach is taken. Rather than attempt to hold the speed of the rotating plate constant, it is deliberately made variable. Plugged into the same servo box used to control the scanning rate, the rotation speed of the refractor plate may be varied from about 10 to 3600 rpm. A compact photoelectric pickup triggers the x-axis sweep of the oscilloscope. Once per revolution of the refractor plate, a tiny mirror on its shaft reflects the light from a small lamp to a solar cell. Transistor amplified, the signal from the cell is fed to the oscilloscope. The result is a perfectly stationary scan regardless of the speed of the refractor plate.

Photomultiplier Cryogenic Housing

The factor limiting the response of all photomultipliers, but especially those sensitive in the infrared, is Johnson noise—the erratic movement of electrons in response to heat.

Substantial improvement in signal:noise can thus be attained by reducing the temperature of the PM tube and its voltage-stepping resistor network. A problem with all cryostats is atmospheric moisture which, unless adequate precautions are taken, will condense on the window of the tube attenuating the light intensity.

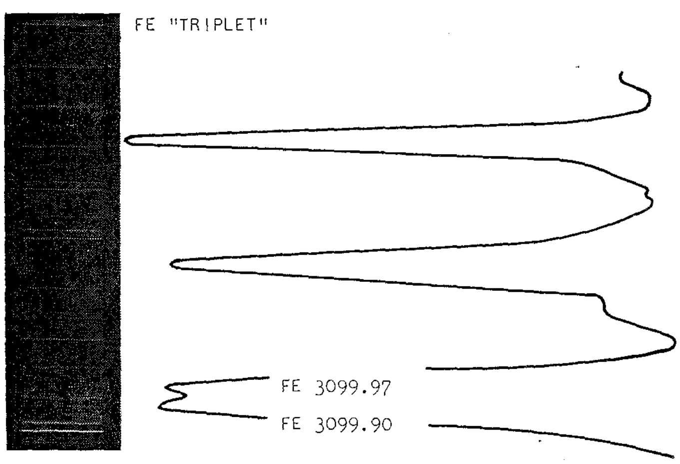


Cryostat Assembly mounted on the exit slit.

In our design liquid nitrogen boiling out of its Dewar enters the housing, swirls so it touches the entire tube and the potted resistors, then blows out. An evacuated quartz cell in front of the PM window insulates the space between the tube and exit slit to prevent condensation effectively.

SPECIFICATIONS — 1500 (EVACUABLE), 1600 and 1700-II ¾ METER SCANNING SPECTROMETERS

High resolution, high aperture scanning spectrometer/monochromators, these instruments use readily interchangeable B&L replica gratings. The principal difference between the 1600 and 1500 or 1700 is optical speed; f/9.8 for the former, f/6.8 for the latter two. Incoming radiation is directed through the entrance slit to a spherical mirror which collimates it to a plane, reflectance grating, from where it is reflected to a second spherical mirror and finally focused at the exit slit. Wavelength is adjusted by rotating the grating on its vertical axis, thus maintaining both slits in fixed positions. Essential for asbolute as well as comparison measurements, entrance and exit beams remain stationary as wavelength is changed. Aluminized mirrors are overcoated with MgF_2 to protect them from deterioration and facilitate cleaning.



In the microphotometer trace of the Fe triplet note the Rayleigh resolved 3099.90—.97 "line." The resolution limiting factor here is the Polaroid film. A high resolution plate would have been preferable for this third order photo.

The normal side-by-side Czerny-Turner system can be modified in the **1700 model only** through the use of an optional accessory containing a mirror that is turned externally through 45°, thus directing the exiting light upward to a camera. This avoids the necessity of removing the exit slit for photographic work.

A hose connection permits purging the instrument with dry nitrogen to extend the wavelength coverage down to 1850A and eliminates waterband regions in the infrared.

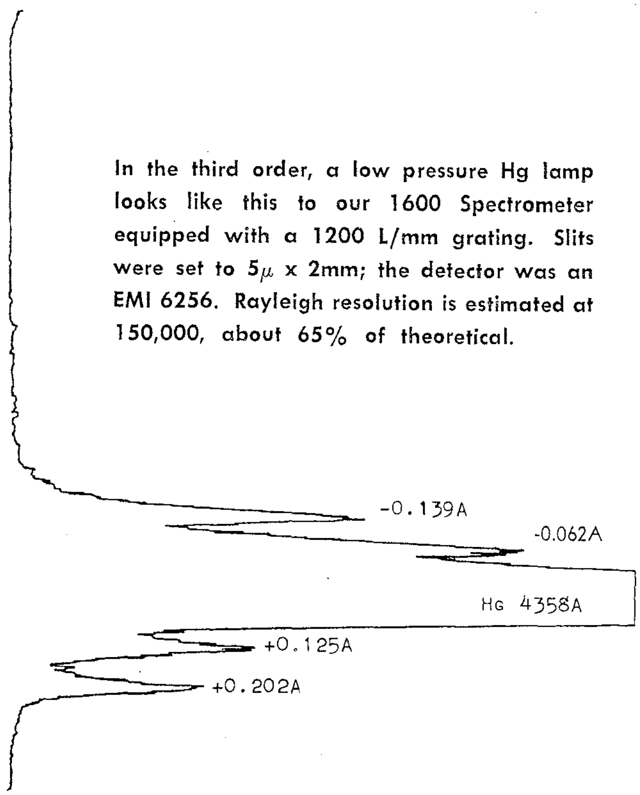
The 1500 may be evacuated for use below 2000A and is so constructed that vacuum-tight sources and detectors may readily be coupled to it. Standard o-ring gland connections are provided for vacuum gauges.

To simplify the presentation, all optical specifications that follow pertain to a 1200 L/mm grating in Order I.

Photographic Speed: f/9.8 in model 1600; f/6.8 in models 1700 and 1500.

Dispersion: linear at any setting, the reciprocal dispersion varies from 10.6A/mm at 2500A to 6.5A/mm at 14000A.

Resolution, Photoelectric: 0.12-0.20A. An ambiguous term depending on the measuring means, resolution is defined herein very conservatively by half-width measurements of the 3131A doublet produced by a low pressure mercury discharge lamp. If the more liberal Rayleigh criterion is substituted, our resolution figures can be 50% better. The limiting factor is the particular grating.



In the third order, a low pressure Hg lamp looks like this to our 1600 Spectrometer equipped with a 1200 L/mm grating. Slits were set to 5μ x 2mm; the detector was an EMI 6256. Rayleigh resolution is estimated at 150,000, about 65% of theoretical.

Optical Bar, 1522 B&L ways, 30″ long.

Gratings, 1501, 1502 and 1601, 1602: a wide range of B&L CP replica gratings is available; prealigned, kinematic mounts permit rapid interchange; when reset, the wavelength calibration is identical within ± 1A; MgF_2 overcoating optional to enhance reflectivity below 2000A.

Bausch & Lomb Replica Gratings Available

64 x 64 mm for 1600 Spectrometer; 102 x 102 mm for 1500 and 1700

GROOVES/MM

Blaze Wavelength	1200	600	300	150	75
1500A	X	X			
2000A	X	X			
3000A	X	X			
5000A	X	X			
7500A	X	X			
1μ	X	X	X		
2μ			X	X	
3μ			X		
4μ				X	
6μ				X	
8μ				X	X
12μ					X

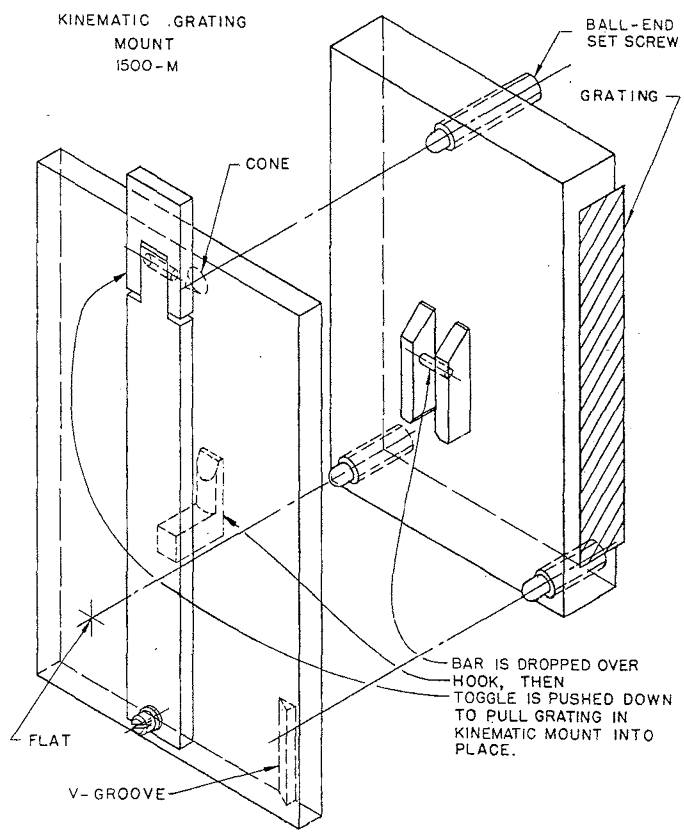
Scattered Light: less than 0.002%. Measured with monochromatic Hg source at 2537A, 0.5A bandpass at or more than 25A from line.

Wavelength Precision: readable and settable to ±0.3A with vernier and mechanical counter.

Wavelength Accuracy: mechanical counter readout direct in angstroms and correct to ± 2A over any 5000A interval.

Mirrors: Pair matched in fl to 0.5 mm; 127 mm dia.; figured to 1/20th wave; aluminized; MgF_2 overcoated.

Scanning Attachment, 1513: continuously variable from 0.25 to 500A/min; constancy of speed maintained by servo drive to ± 0.5% at 2A/min to ± 0.05% at 25A/min and faster; plug-in jack with adjustable potentiometer permits exact setting of any speed up to 100A/min; pulse every 5A can be fed to 6vdc event marker of a strip chart recorder for accurate wl interpolation; limit switches at both lower and upper wl extremities; 115 vac.



FOR 1600 and 1700-II (NON-EVACUABLE)

Coverage: 1850A (N_2 flushing) to 1.4μ (to 22μ with 75 L/mm grating)

Mechanical Construction: non-magnetic with the exception of small items of hardware such as bearings and optional optical bar; optics mounted on jig plate aluminum bed; all alignment adjustments are external; leveling legs.

Dimensions: 34″ x 16″ x 13″ high.
Weight: net 130 lbs.; gross 200 lbs.

Slits, Adjustable, 1611: bilaterally opening 5μ/div.; maximum height 18mm adjusted with fishtail; Hartmann diaphragm, 3 position; mechanical shutter; slit width 5μ to 1.5mm; lens or filter mount on removable cover.

1711: like 1611 but opens at two rates Closed to 100μ = 1μ/div.; above 100μ = 5μ/div.

Slits, Fixed, 1610S: straight jaws 50mm high; 10, 25, 50, 100μ wide; in prealigned interchangeable mount.

1610C: curved jaw version of above.

NOTE: For extreme light gathering power long slits (1610S) may be advantageous. In addition, resolution is improved with the use of curved slits (1610C) when heights of 8 mm or more are required. With a condensing lens placed after the exit slit either the 1610S or 1610C, 50mm long, utilizes the full light gathering power of the spectrometer.

Camera Adapter 1632: replaces the exit slit assembly in order to convert the 1600 or 1700 to a spectrograph covering approximately 500A/exposure.

Camera Tower 1710: for 1700 only. Eliminates the need for removing exit slit, when converting to a spectrograph, by directing the light upward by means of an externally controlled 45° mirror mounted behind the exit slit. Includes focusing ring and means for mounting cameras 1628, 1631, 1731.

Cameras:

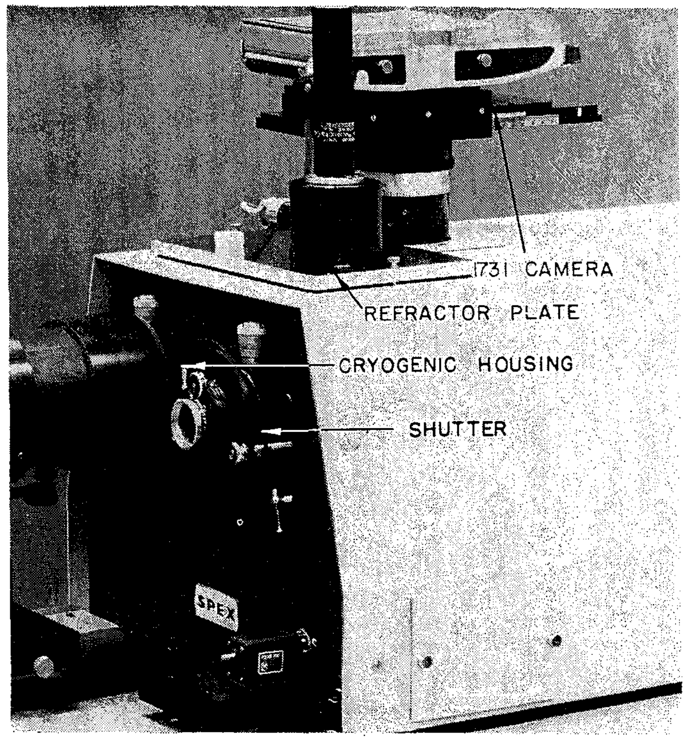
1623 replaces exit slit assembly and provides as many as 20 exposures on one plate or 35mm film strip with 500A coverage; daylight loading.

1628 can replace exit slit or be mounted on 1710 Tower and holds 4″ x 5″ Polaroid film. Six exposures are provided in the exit slit position; fully rackable on the Tower, up to 50 exposures may be taken from that mount.

1631 can replace exit slit or be mounted on 1710 Tower and holds 4″ x 5″ standard emulsion plates. Six exposures are provided in the exit slit position; fully rackable on the Tower, up to 50 exposures may be taken from that mount.

1731 can be used only on the 1710 Tower with 3-1/4″ x 4-1/4″ Polaroid roll film; fully rackable.

Photomultiplier Housing 1624: fits on studs directly over exit slit; may be used with side window or end-on tubes up to 3″ dia.



1700-II Fully loaded as indicated.

Shutter 1625-II: mounting over either the 1611 or 1711 entrance slit, this mechanical shutter permits ordinary photographic exposures including bulb and speeds from 1/125 to 1 sec. It is synchronized X for electronic flash guns.

Refractor Plate 1626-II: for fine scanning and time sampling of a short wavelength interval, a thin quartz (other material may be readily substituted) plate rotates between the entrance slit and the collimating mirror. Speed may be continuously varied with the same servo control used with the No. 1513 Scanning attachment. Once per revolution a photoelectric pickup generates a signal which may be sent to synchronize the x-sweep of an oscilloscope to furnish a repetitive display on its screen. Alternatively, the refractor plate may be turned by hand, referencing against a 100-division dial. The entire unit replaces the cover plate above the grating. Supplied with a 24-volt battery pack for the photoelectric pickup and lamp.

Straight-through Optics 1627: 45° mirrors mount outside entrance and/or exit slits to achieve in-line optics; indents position mirrors exactly; may also be used to compare two sources or detectors, one of which is held at right angles to the normal path.

Alignment Eyepiece F.1515: focusable, replaces cover on exit slit, 1611 and 1711.

Photomultiplier Cryostat Assembly 1630: cooled by passing dry N_2 from liquid N_2 into the PM housing, achieves highest S/N. Designed for end-on tubes up to 2″ dia., the cooling is of the entire tube and potted resistor network. To prevent condensation, an evacuated quartz cell protects the window.

FOR 1500 EVACUABLE MODEL ONLY

Mechanical Construction: non-magnetic with the exception of small items of hardware such as bearings; vacuum tank flanged at bottom to mate with standard 4" vacuum systems.

Dimensions: 34" x 17" x 18" high.
Weight: net 150 lbs.; gross 245 lbs.

Coverage: 1100A to 1.4 microns (to 22 microns with 75 groove/mm grating).

Slits, Adjustable 1511: Bilaterally opening; maximum height 20mm adjusted with masks; slit width 5 microns to 1.5mm readout on a mechanical counter accurate to ± 2 microns; curved slit jaws optional.

Camera Adapter 1632: Non-evacuable, replaces exit slit for use with 1628 and 1631.

Polaroid Film Back 1628: Takes 4"x5" P/N type Polaroid film packs, positive print, negative transparency. Requires 1632.

Plate Holder 1631: Takes 4"x5" plates with standard spectroscopic emulsions. Requires 1632.

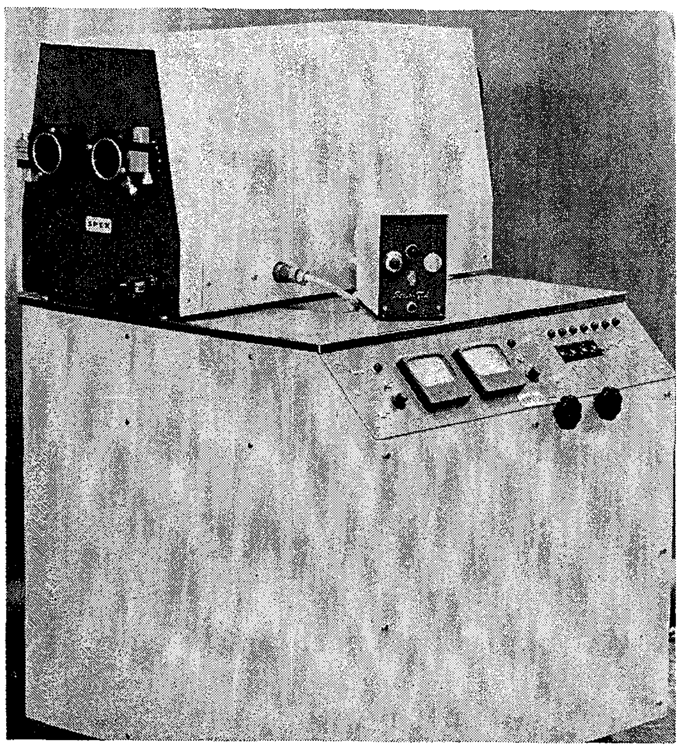
Camera 1523: Replaces exit slit assembly; as many as 20 exposures on one plate or 35-mm film strip; 500A coverage; daylight loading; evacuable for use down to 1100A.

Photomultiplier Housing 1524: Fits on o-ring seat of exit slit; may be used with side window or end-on tubes up to 3" dia.

Alignment Eyepiece 1529: Focusable; fits on exit slit; not meant for use while instrument is evacuated.

Straight-through Optics: Where space considerations dictate, the instrument may be modified through the addition of two external 45° mirrors, to achieve an in-line optical path. (Further information on request.)

Detection and Readout: The simplest high sensitivity devices for photomultipliers are attendant power supplies and microammeters. If the instrument is to be used in the region below 2000A, the PM tube can be coated with a fluorescent material, sodium salicylate, for adequate response. For such work, many commercial components may be used.



1500 Evacuable Spectrometer with 1513 Scanning Attachment and 1530 Vacuum Console.

For absolute intensity measurements, vacuum thermopiles can be provided. Because of the wide number of permutations and combinations offered, we invite your inquiries so we can supply up-to-date information.

Vacuum Console 1530: When used below 2000A, the spectrometer is evacuated through a 4" dia. flange connection on its underside. Meeting ASA 150-lb. specifications, this flange mates with all American 4" commercial vacuum systems. Utilizing carefully selected commercial components, the Spex No. 1530 console is a self-contained vacuum system designed to meet the special requirements of the No. 1500 Spectrometer. Pumpdown times are short; extensive precautions are taken to prevent any diffusion pump oil vapor from ever reaching the optics; vibration is minimized to prevent interference with optics. The mechanical pump can be loaded against the floor by jack screws. The entire console can be steadied and adjusted over a limited height range by another set of jack screws. In cycling, a vacuum in the 10^{-6} torr range is reached in 20 minutes. A self-contained Freon compressor cools the baffle. All components as well as the entire system are designed to fail-safe.

Dimensions	33" w. x 34" d. x 36" h; on swivel casters; sloping panel
Weight	about 300 lbs.
Utilities required:	
Compressed air:	70-100 psi
Electrical:	115 vac or 230 vac (specify); about 3 kva
Water:	20 gal/hr at 25°C max.
Diffusion Pump	750 L/sec; anti-backstreaming cold cap; quick-cooling; DC—705 Silicone oil; thermoswitch turns heater off if cooling water temperature rises too high (NRC HS-750)
Forepump	5 cfm (Welch 1402)
Baffle and Cold Trap	Water cooled baffle and anti-migration, Dewar construction optically dense cold trap, stainless steel (Cooke D-100S)
Compressor	Sealed type circulates Freon at —50°C or lower through baffle; settable, calibrated thermoswitch closes gate valve should temperature rise.
Gauging and Control	Combination 4-thermocouple, ion gauge controller; TC section reads 1-1000μ ion section 10^{-9} — 10^{-3} torr; if pressure rises, above full scale setting at any of six ranges, ion gauge filament shuts off and pneumatic gate valve closes.
Pneumatic Gate Valve	At the very top of the No. 1530 console is a gate valve held or closed by compressed air. It jams shut in less than one second.

Fail-Safe Provisions

Practically speaking, the worst potential source of trouble in a vacuum system is overheating of the diffusion pump oil. To prevent this, a thermal switch is connected on the outlet side to interrupt the heating coil should the temperature of the water to the diffusion pump rise. The pneumatically-controlled gate valve closes to isolate the vacuum system from the spectrometer should 1) the power fail; 2) the pressure rise above a preset value. If the power fails, the main switch must be manually reset for re-operation.

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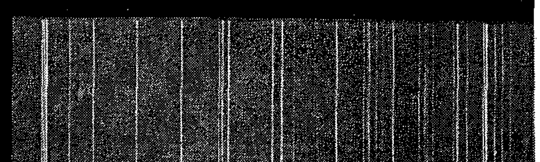
SPECIALISTS IN SPECTROSCOPY

SPEX OPTICAL SCANNING SPECTROMETER!

- wl range: 1100A to 22 microns
- speed: f/6.8
- gratings: easily changed, kinematic mount
- two models: air path and evacuable



A typical 2nd order spectrum of 1 sec. exp. with 10 micron slit indicates:

- Lack of astigmatism
- Freedom from Coma
- Excellent uniformity
- High S/N

If you have the fortitude to locate **Booth 81** within the labyrinth at the **NYC Physics Show Jan. 27-30, 1965** you will find us unabashedly displaying all our best features.