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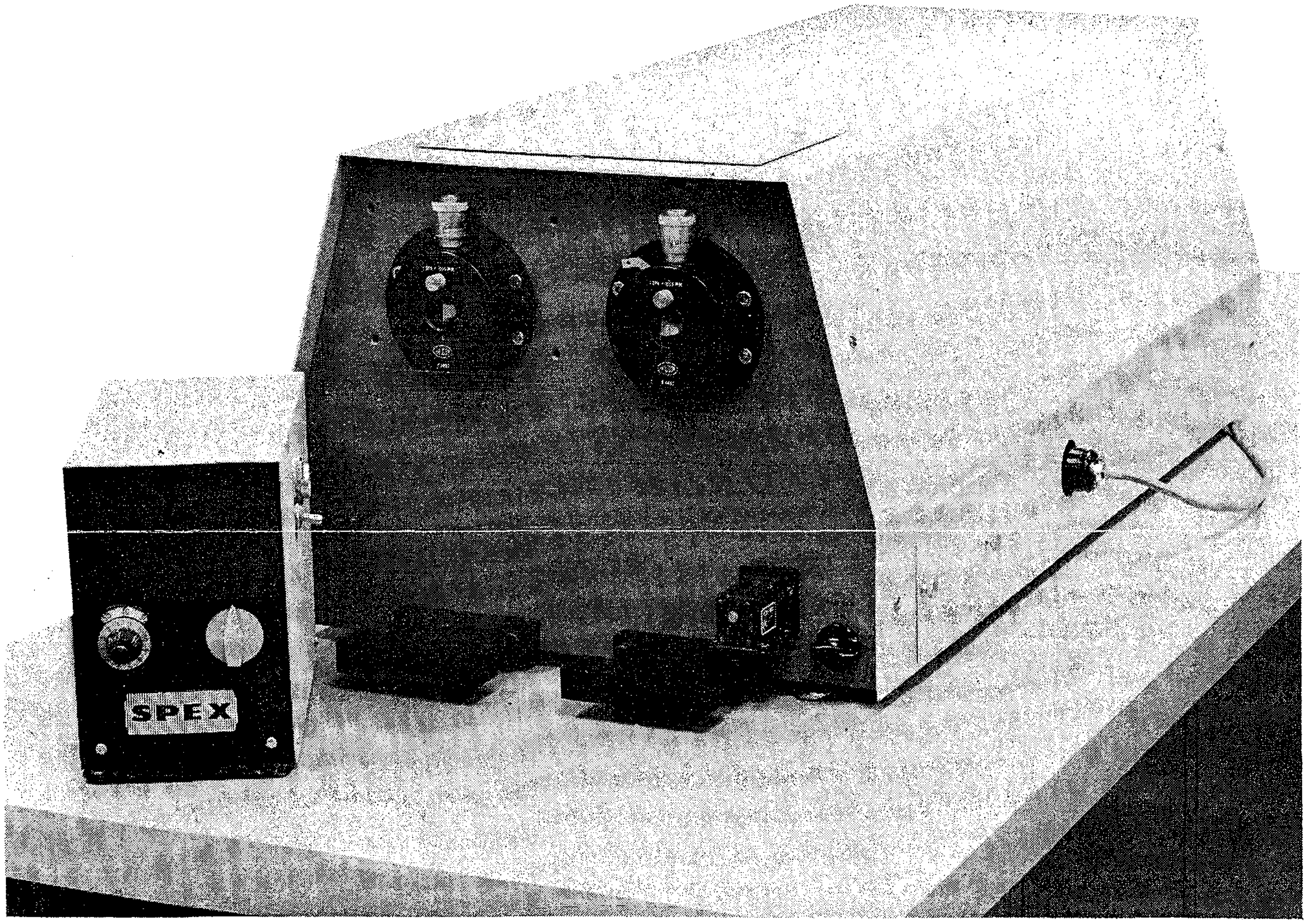
# The SPEX Speaker

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

# NEW CZERNY-TURNER SPECTROMETER-MONOCHROMATORS



AMONG the playthings visitors have noticed rigged together in our laboratory is a 3/4-meter scanning spectrometer. Occasionally, during the past two years, such an instrument has been hand made for a customer who, impressed with its performance, soon passed the good word on. In this fashion about 15 such sales have evolved. Although this is an insufficient quantity to affect favorably the black ink column of our financial ledger, it has provided a more than ample pilot project for systematically exterminating the ubiquitous bugs, engineering several worthy accessories and granting us the rare opportunity of applying hindsight which is so much more prolific than foresight. We are thus taking the privilege of bringing these spectrometers to your attention with the fond hope that some of you may find their specifications and price tags irresistible.

To add a spectrometer-monochromator to the already sizable list on the market may seem trifling. Thumbing through the ads, a reader will quickly spot many, some with prisms, some with gratings, still others using both. Optically fast spectrometers are readily available with poor dispersion, slow ones with high dispersion. Quite a number are locked up permanently in spectrophotometers, colorimeters, fluorimeters, flame photometers, microscope illuminators, and other special purpose analytical tools. A few are designed to be shot up in rockets, there to peer at radiation obstructed from the earth by its own atmosphere.

Conspicuously scarce, however, are building block, module spectrometers—with quick-change gratings; with a host of special purpose accessories; with a sensible compromise between resolution and speed; with a wavelength range extending deep into the vacuum ultraviolet as well as into the infrared. It is this void that our instruments are meant to fill.

A versatile spectrometer can be many things to many scientists. Coupled with an appropriate source, it becomes an analytical tool especially handy where one or two elements are determined routinely. Production control of petroleum products for trace quantities of vanadium using the Plasma Jet would be a typical, economically profitable application. Similarly, the expedient control of phosphorus would please the producers of copper tubing. Augmenting the inexpensive flame photometers now on the market, a high resolution spectrometer could be expected to keep tabs on 70 elements rather than a single handful and offer enticing bonuses of far greater sensitivities and freedom from interferences.

Apart from analytical applications are those of physicists and molecular chemists busily engaged in attempting to explain the workings of the numerous electronic devices—many already developed and those yet to be. What happens in the first few microseconds after a phosphor is excited? Radiation curves of phosphors are well known but do the curves just spring up in one instantaneous leap? Drs. G. E. Peterson and P. M. Bridenbaugh of the Bell Telephone Laboratories, Murray Hill, N. J., through a series of ingeniously instrumented time-resolution spectrometric studies have shown that phosphorescent curves, broad and smooth as they are invariably depicted, actually rise and fall in discreet steps. In the process, one or more atomic transitions take place leaving behind a fleeting trail of sharp-lined spectra. Lasting for but a few microseconds, the line spectra can be detected only with a fast spectrometer hooked up to an appropriately gated and triggered detection system. Interpretation of these spectra helps unlock the mechanism of the phosphorescing reactions.

Also, at the Bell Labs fundamental absorption and emission studies are being conducted on single crystals by Dr. R. E. Dietz. When a wide-gap semiconductor such as zinc telluride is exposed to a high intensity source of radiation from a xenon tube at temperatures in the liquid helium region, both fine-line and broad-band spectra are emitted for a few microseconds. The half-width of lines is finer than 1 wavenumber (0.25A) at 20,000 wavenumbers (5000A). Through Zeeman experiments and those involving strains on the crystal, transition data can be gleaned on the ions giving rise to the properties of a semiconductor. Commercial analytical infrared spectrometers do not have nearly the resolving power needed for such work.

One of the most significant discoveries of the century is the laser and much current research centers about it. To an ordinary spectrometer, laser radiation appears perfectly monochromatic, instantaneously rising and decaying. Again the key to an understanding of the phenomenon is high-resolution, time-resolved spectroscopy where the build-up of the radiation can be followed to determine what atomic transitions are proceeding. At the RCA laboratories in Princeton, Dr. P. Goedertier is working photographic instrumentation and the finest-grained high-resolution plates to their very limits in order to separate the fine lines theoretically predicted. Dr. S. Porto of the Bell Labs is producing and studying Raman lines with a laser source. Here the sharp, single line of the laser shows great promise in revitalizing a type of spectroscopy often shunned because of difficulties encountered with conventional mercury sources.

Much of the work thus far described is being conducted in the visible and infrared regions. At the opposite end, in the vacuum ultraviolet down to 1100A, there is active interest, too. Dr. Martin Pope of NYU's Physics Department is putting a fresh slant on the famous Millikan oil-drop experiment. Our Model 1500 spectrometer is being set up as a monochromator to irradiate charged particles of substances under investigation with known quanta of energy. The dissipation of the charge can then be correlated with the amount of energy impinging on the sample. Dr. R. Buser of Ft. Monmouth's Evans Signal Laboratories is concerned with time-resolution of spectra emitted by plasmas. In his work, a Space Technology Laboratories Image Converter Camera, attached to a Model 1500, serves as the detector. Basically a television camera, it scans the spectra to display a time-resolved band of radiation on its screen. Ultraviolet becomes a visible display which can even be studied at one's leisure by photographing the screen with a Polaroid camera. This quite new, sophisticated approach is capable of remarkable time resolution to 0.05 microseconds.

OVER the years, inventive, imaginative spectroscopists have assembled combinations of gratings and prisms with mirrors and lenses to be rewarded, by having the resulting mount named after them. Modern instruments employ many such mounts for no one is clearly advantageous in all circumstances. It might be well to record the criteria for an ideal grating mount:

1) Linear dispersion
2) Long wavelength coverage
3) A plane reflecting grating
4) Stigmatic with no other optical aberrations
5) Focus unaffected by wavelength changes
6) Wavelength changes mechanically straightforward
7) Simple mathematical relationship between mechanical motion and wavelength readout to optimize readout accuracy
8) No polarization
9) Stationary entrance and exit beams
10) Minimum number of reflecting surfaces
11) Long, flat focal field

Although most of these design targets are self-explanatory, a few may require further elaboration.

The wavelength coverage (criterion 2) of our spectrometers, seen below, is limited by the number of grooves of the grating at the high end, absorption and reflectivity at the low end. The lower wavelength is cut off by air absorption in the 1600 and 1700 instruments and by lithium fluoride (1100A) in the 1500. In all models the grating may be rotated to the direct image position.

| GRATING, *grooves/mm* | DISPERSION *A/mm* | WAVELENGTH COVERAGE *microns* |
|---|---|---|
| 1200 | 10 | 0.2—1.4 |
| 600 | 20 | 0.2—2.8 |
| 300 | 40 | 0.2—5.6 |
| 150 | 80 | 0.2—11.2 |
| 75 | 160 | 0.2—22. |

A plane grating is preferable to a concave one because it can be made better. When a microscopic diamond in a ruling engine plows thousands of times across a surface eventually to create a grating, the ruling engine is taxed to its very limit. The blaze, or wavelength of maximum intensity, is determined by the angle that the diamond makes with the working surface. Constant when the surface is planar, this steadily changes with a spherical surface imposing an extra burden on the engine. Further with a plane grating the distance that the diamond must drop is fixed to minimize the problems of locating it exactly for each groove. This, in turn, minimizes spurious ghosts and "grass."

Yet a concave grating has the advantage of serving two functions, focusing as well as dispersing the radiation. A single reflecting surface can thus replace three surfaces. This becomes important in the region 500-1100A where reflectances of all materials drops markedly and multiple reflecting surfaces compound losses of intensity untenably.

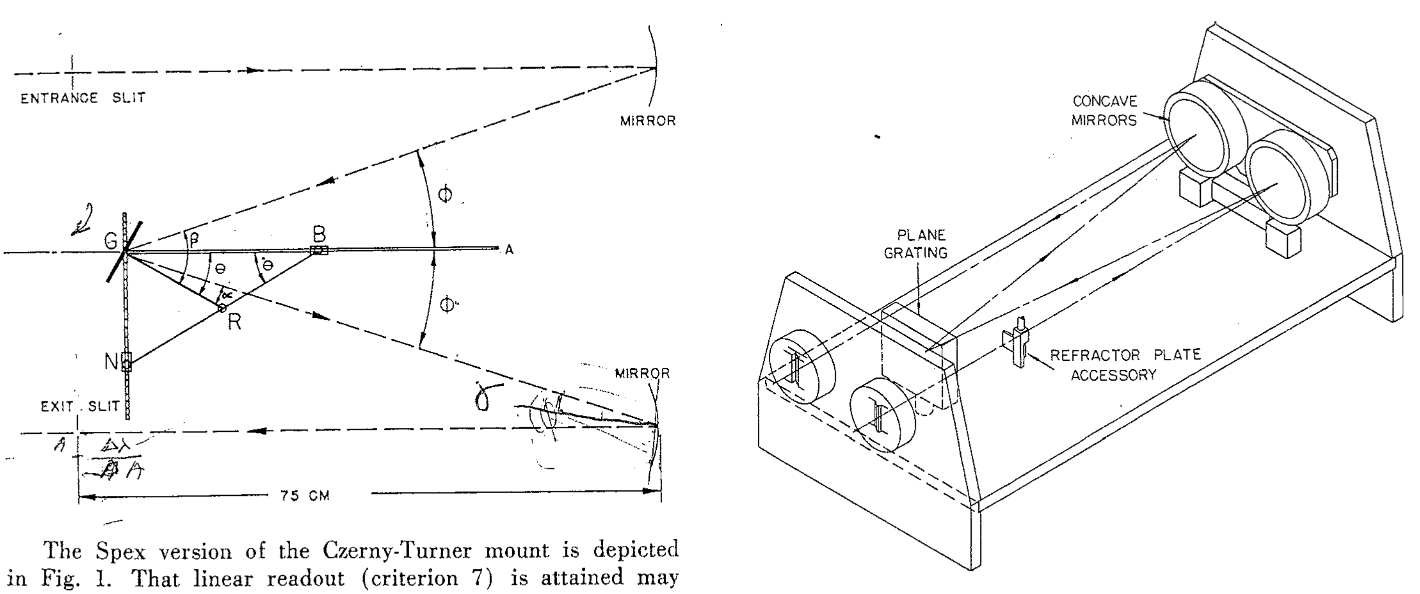


**Fig. 1.** Schematic and isometric diagrams of the spectrometers. The Refractor Plate, an optional accessory, rotates synchronously in the entrance beam repetitively scanning a short wavelength region.

The Spex version of the Czerny-Turner mount is depicted in Fig. 1. That linear readout (criterion 7) is attained may be noted as follows. The grating G is rotated on its axis by arm GR, rigidly attached below the center of the grating face at a position perpendicular to the face. GN represents the precision lead screw along which N, its mating nut, rides while NB pivots around B, R and N. B is a bushing along the centerline of the optical system, GA, while GR turns the grating. Arms GR, NR and RB are identical in length.

The mechanical counter reading wavelength actually counts revolutions of the lead screw GN and therefore measures its effective length. Because NB is a fixed length, GN is proportional to sin $\theta$. It remains to be proved therefore that the general grating equation $n\lambda = d(\sin\alpha + \sin\beta)$ is proportional to sin $\theta$. Since in our Czerny-Turner mount,

$$\begin{aligned} \alpha &= \theta - \phi \text{ and} \\ \beta &= \theta + \phi \\ n\lambda &= d\,[\sin(\beta - \phi) + \sin(\theta + \phi)] \\ &= d\,(\sin\theta\cos\phi - \cos\theta\sin\phi + \\ &\quad \sin\theta\cos\phi + \cos\theta\sin\phi) \\ &= 2d\sin\theta\cos\phi. \end{aligned}$$

Since cos $\phi$ is a constant ($\phi$ is approximately 6° in our design), $\lambda = k \sin\theta$ and is therefore proportional to the length of GN.

By stationary beams (criterion 9) is meant that radiation to and from the grating does not change its path as wavelength is changed. Mounts have been designed in which the radiation at different wavelengths emerges at different angles through the exit slit. If absorption measurements are being conducted all radiation will not pass through the same part of the sample or fall on the same part of the sensitive surface of the detector. Non-uniformities in each will give rise to false readings.

Since our instruments are used primarily with electronic detection, where wavelengths are singled out, a long, flat focal field is not needed. They do, however, permit the substitution of a camera covering around 50 mm of spectra, 500A with a 1200 groove/mm grating.

Thus, the side-by-side Czerny-Turner mount chosen for our spectrometers meets all of the criteria with the exception of the last two. As noted, the use of three reflecting surfaces does not materially affect the intensity of spectra above 1100A where coatings having reflectivities of upwards of 90% are easily obtained. Evaporated aluminum reflects suitably from 2000A through the infrared. An overcoating of magnesium fluoride over the aluminum extends the useful reflectivity down to 1100A.

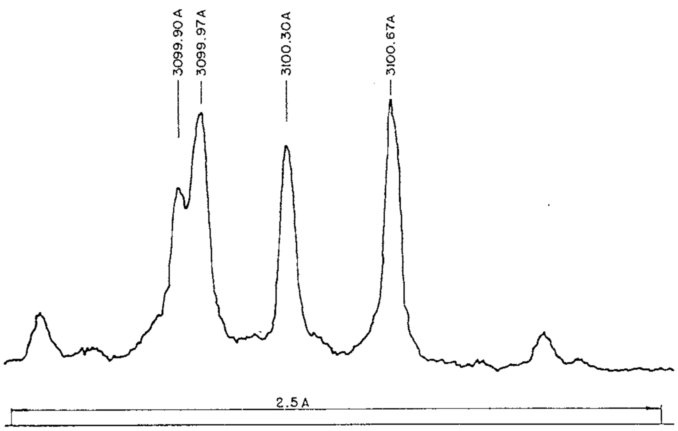


**Fig. 2**

FIG. 2, showing the famous iron triplet with one line split into its two components, is a good illustration of what can be expected from our spectrometers. The source was our 9030 Plasma Jet run at 20 amperes with a 0.1% solution of iron "Nuodex" using argon as the aspirating gas and helium as the tangental gas. The 9033 Spex-Owen Manifold controlled the gas flows. The tracing is of the running jet not of a microphotometer tracing of an integrated photograph and shows the remarkable stability of the Jet. Not only is there no evidence of any "jitter" in the individual spectrometric tracing but repeat tracings were virtually identical. The spectrometer chosen was our 1700 with an optical speed of f/6.8. A 102 x 102 mm, 1200 groove/mm grating was set to the second order where the dispersion is about 5 A/mm. The detector was a 1P28 PM tube with a dynode voltage of 750 and 0.01 microamp full-scale setting on the micromicroammeter. The limiting time constant of the system was around 0.05 seconds; any instabilities in the plasma jet or driving mechanism of the spectrometer of a longer duration would be revealed in the tracing. Yet it is remarkably smooth; there is no evidence of periodic jitter which would reveal vibration somewhere in the spectrometer. Most of the background repeated itself in subsequent spectra, indicating that it is real, composed of weak molecular and atomic lines.

Paradoxically, although there is no practical acceptable definition of resolving power, this is the feature of greatest interest to physicists who find it necessary to wring as much performance from their instrumentation as is possible. In Fig. 2, two lines 0.07A apart are well resolved by all criteria, subjective ("I could drive a Mack truck between the lines.") as well as objective (Raleigh criterion). Further, the half-width of the two single lines is about 0.05A. Under the conditions chosen, we can safely state that the resolving power was at least 0.07A.

The nomograph in Fig. 3 was prepared as an aid in arriving at the theoretical as well as the practical resolving power to be expected from our spectrometers. The function λ/nm (n is the order, m is the total number of grooves in the grating) is plotted against wavelength so that at any wavelength the theoretical resolution may be found on the left side of the chart. Values are for our 1700 and 1500 models where the gratings are 102 mm wide. For our 1600 monochromators, with a 64 mm grating, simply multiply resolution figures by about 64%.

To apply the nomograph:

1) Select wavelength in microns.
2) Read upwards to intersect the diagonal line representing the grating. If the line does not extend to this region, the wavelength is beyond the reach of the grating. One with a coarser ruling constant must be chosen.
3) At the intersection, move to the left to find the theoretical first order resolution in Angstroms.
4) To obtain the slit width corresponding to the resolution, return to the intersection point, move vertically downward to the 1200 l/mm line (solid or dotted), then horizontally to the right.

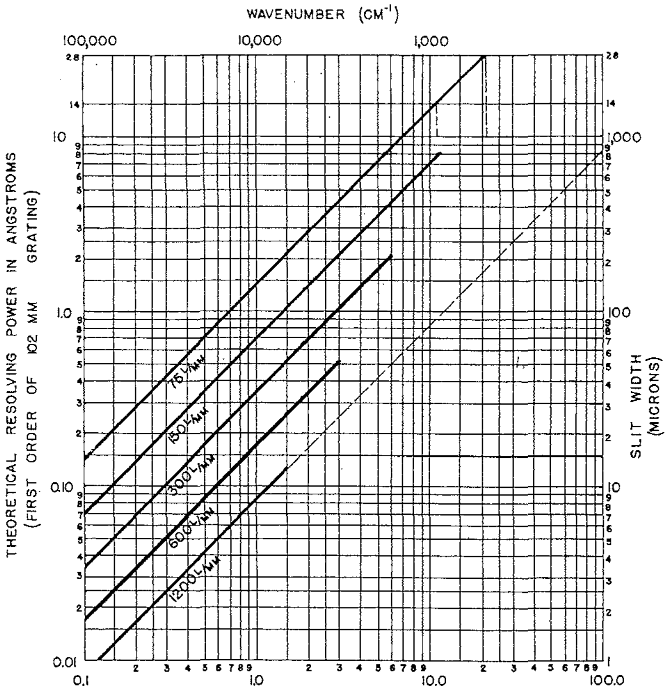


**Fig. 3**

As an example, suppose one wants to determine the best resolution of the spectrometer at 5 microns. Moving upwards at this wavelength, first note that the finest grating usable has 300 l/mm. To obtain a theoretical resolution of around 1.8A, a 42 micron slit must be used. Reducing the slit width, the resolution will not be improved and, of course, speed will suffer.

Of course, no optical device is perfect and the theoretical resolution can only be approached, never equalled. Because of the difficulties entailed in measuring actual resolution of a spectrometer, a conservative figure of 80% can be applied for our instruments. In the example just given, the practical resolution will be around 2A. Thus, the half-width of any line measured at around 5 microns and the separation between two lines at this wavelength can never be less than 2A.

Let us take another example. Suppose one wants to eke out the best resolution at 2500A using a 1200 l/mm grating. The chart tells us that in order I, a resolution of 0.02A can be achieved only if the slit is set to 2 microns, well below the lowest usable slit width. But higher orders can be utilized. The 1200 line extends to around 14,000A, the maximum wavelength with this grating. Dividing this by 2500A, we immediately note that we can set the instrument to a maximum of order V for this wavelength. Since in order V, the dispersion is 5 times that of order I, the slit width at which 0.02A is attained is 10 microns rather than 2 microns. Thus a practical slit width is found to achieve the utmost resolution from the spectrometer.

To facilitate setting up and operation, a number of features have been incorporated. All alignment and focusing controls are accessible from outside the case. After removing a small light-and dust-tight cover plate, each mirror may be independently rocked vertically and/or horizontally on a hardened ball. Adjustments and firm locking are accomplished simultaneously. To focus the instrument, a long lead screw is turned to move the pair of mirrors, as a unit, fore and aft.

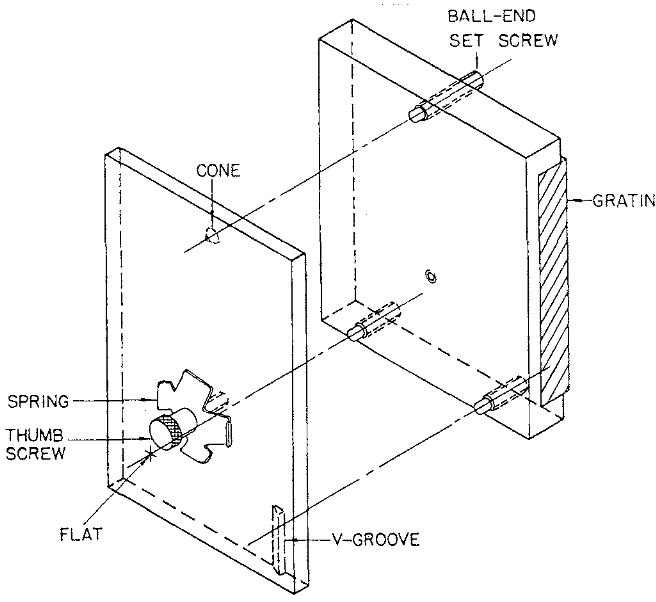


**Fig. 4**

The kinematic grating mount is unique. As shown (Fig. 4), a three-point support permits only one degree of freedom, outwards. When a thumb screw is tightened, this motion, too, is restrained and the grating in its holder is automatically positioned exactly. The three points are actually ball-ended set screws bearing against a flat, a conical hole and a v-groove respectively. Two of the set screws are at the bottom and one is centered at the top of the grating. Once set, the individual grating is thereby permanently aligned and rapid interchangeability assured. Even the set screws are somewhat novel. Protruding outside the threads, a strip of nylon provides enough friction to prevent accidental turning of the screw when the kinematic mount is removed from the spectrometer.

### Slits

The non-evacuable model uses standard Hilger slits which themselves are a product of careful contrivance. The bilaterally opening jaws are typical of the proud workmanship of this oldest of spectrographic manufacturers. They seat on a surface lapped to a tolerance of a few microns and open smoothly and reproducibly to the set values without wedging, or loss of parallelism. They are exceedingly sharp and any nick deeper than 1 micron is cause for rejection. A simple optical shutter is built into the housing of the entrance slit and this may be connected to an electromagnetic actuator. Friction fitted to the slit is a cover containing the fishtail and Hartmann diaphragms. Height of the slit or the number of the Hartmann diaphragm appears in a window.

In the evacuable spectrometer, the slits are of our own manufacture, identical with those on our grazing incidence spectrometers. Adjusted from outside of the vacuum through a tight seal, the slit width is read on a mechanical counter rather than a conventional micrometer head. A unique parallelogram drive not only maintains the slit blades perfectly coplanar and parallel but also minimizes gas leakage by permitting the flow of gas only through the opening between the blades. When gases at relatively high pressure are used either in a source or as a subject for study, the vacuum in the spectrometer proper may be maintained readily through appropriate differential pumping.

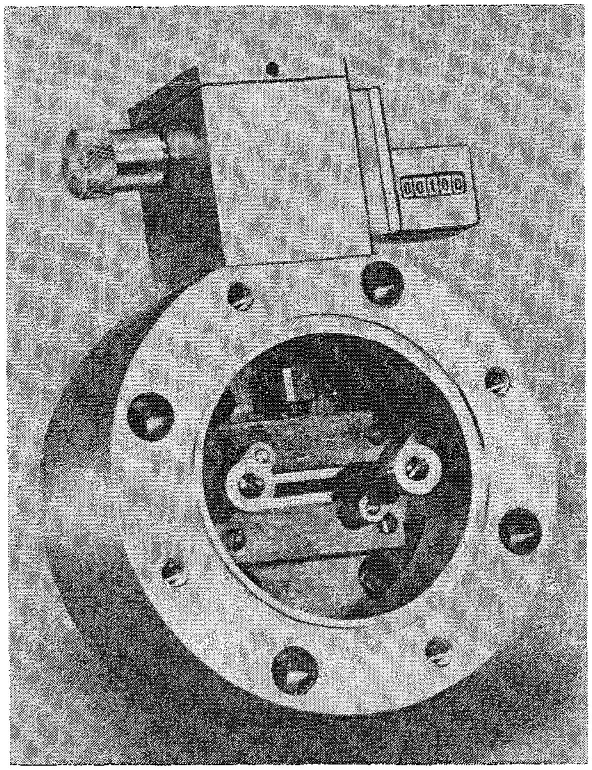


**Fig. 5A.** The slit of the evacuable spectrometer features a mechanical counter for the accurate setting of slit width. So constructed that gas leakage is through the slit jaws only, it is suitable for windowless operation when required.

In 1952, Fastie (J.O.S.A. *42*, 641), discussed the advantages of curved slits over straight ones. Theoretically, as he pointed out, when a long straight slit is used there is a loss of resolution. This can be corrected by employing matched curved entrance and exit slits, the radius of curvature of which equals the distance from the centerline of the optical system (3″ in our instruments). Practically, we have shown that with straight slits to about 8 mm long there is little detectable loss of resolution.

The maximum height of our slits is 20 mm so that above 8 mm it may appear advantageous to employ curved slits. A practical consideration offsets this. To achieve the highest resolution, the two curved slits must be exactly aligned laterally and vertically. If the center of the circle is displaced, the curves no longer match. To align the slits once is no problem yet it can be quite tedious to have to do this every time the exit slit is replaced after setting the instrument up with a camera. Although curved slits are offered we feel they should be purchased only after exhausting the potentialities of straight slits. Worthy dividends result from careful examination of ways to focus and collimate the incoming and outgoing radiation to keep the slit heights below 8 mm.

### Wavelength Marker and Scanning Drive

To convert the instrument to a scanning spectrometer, a continuously variable drive is offered. A servo-controlled dc motor drive, the unit permits scanning speeds over a 200:1 range, (800:1 with change gears provided) is reversible and braked with the throw of a switch. Although speeds are accurately reproduced to better than 0.25%, the determination of wavelength is interpolated with the wavelength marker. At exactly every 5A (first order, 1200 groove/mm grating), a 12-volt dc pulse is generated which can be directed to the event marking pen of a strip-chart recorder. A short, sharp line appears at the edge of the paper (Fig. 2), providing a permanent mark which stretches or shrinks with the paper and so remains faithful to wavelength for extremely accurate determinations. The scanning drive itself is housed in a separate box on a line cord. For many applications, this control box is more conveniently moved to a position near the recorder so repetitive scans can be made, wavelengths read and outputs measured without having the operator move about. To protect the instrument if the scanning drive is left on inadvertently, limit switches at both wavelength extremities interrupt power.

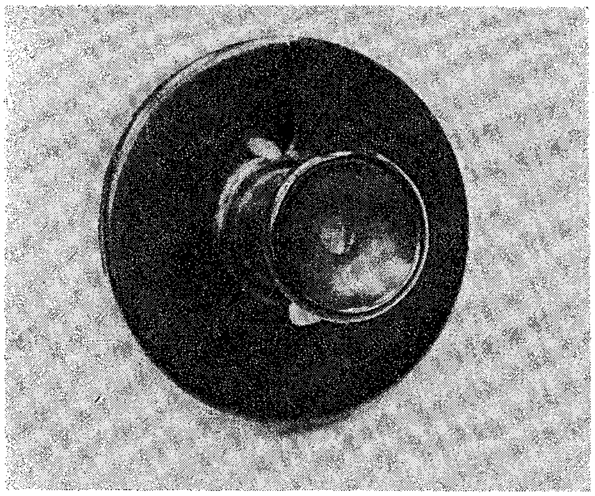


**Fig. 5B.** For alignment, a focusable Ramsden eyepiece replaces the slip-off cover of the standard variable slit of the non-evacuable instrument.

## Detection

By far the most sensitive and least troublesome detectors for use in the region below 8500A are photomultipliers. To our knowledge, however, despite the hundreds of types available, none are specifically tailored to spectrometric applications. The noise of a PM tube is directly proportional to its photocathode surface area. The shape should thus conform to the geometry of the image impinging on it, a rectangle representing the defocused exit slit in the case of an optical spectrometer. The best compromise we have found is a group of EMI PM tubes whose cathode, though not rectangular, is only 1 cm in diameter. Most other PM tubes have cathodes at least 1 inch in diameter.

While the cathode area accounts for the noise, the number of stages of amplification and the total voltage impressed determine the signal. EMI tubes have at least 10 stages and for optimum operation require 1800 vdc at the final dynode. Both the tubes and the stabilized high voltage supply, however, are quite costly.

For many applications, a far less expensive approach is to use mass-produced 1P28 photomultipliers with a 1000 vdc supply and compatible readout system. Such a system is available as a package from us as shown in Fig. 6.

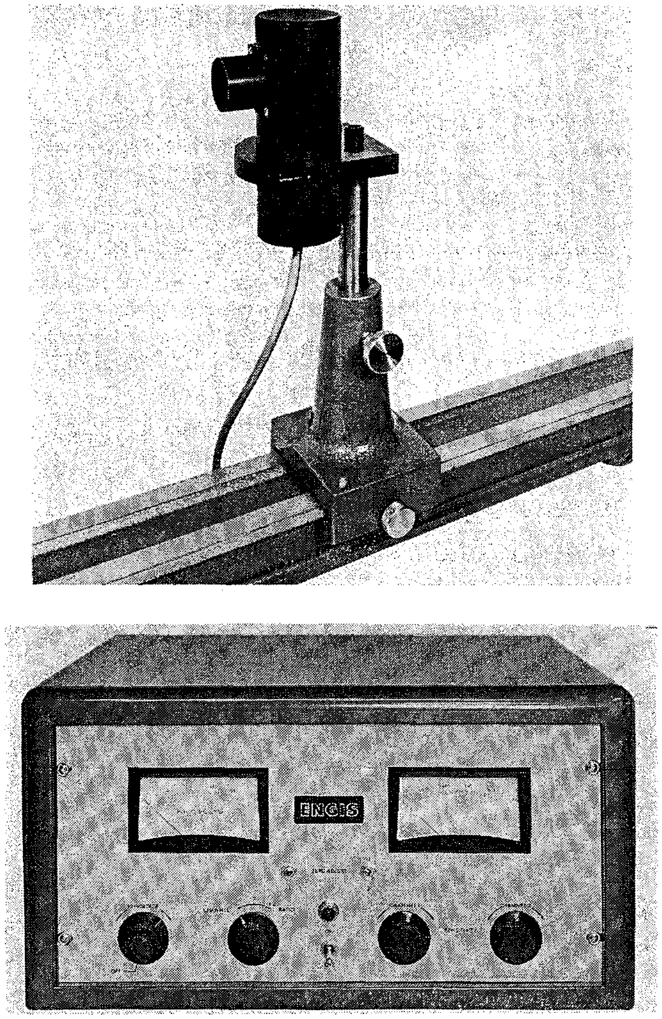


**Fig. 6.** A sidewindow 1P28 photomultiplier mounts in a housing interchangeable with the cover of the exit slit. A relatively inexpensive combined high-voltage supply and micro-microammeter completes the direct reading attachment.

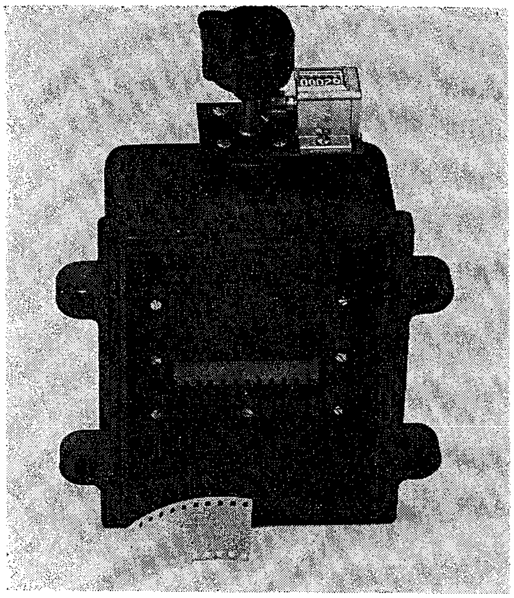
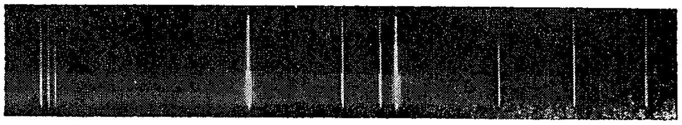


**Fig. 7.** The camera shown takes either 35-mm film strips or plates and racks to expose up to 20 spectrograms. The three spectra below, of a low-pressure mercury arc, were taken with a Polaroid camera using PN film. In a few seconds, development produces a positive print and a negative transparency suitable for densitometric measurements.



## Cameras

Probably the most important accessory for a spectrometer is a spectrograph converter, i.e., a camera. Any time a spectrum is to be recorded because it is too weak or too unstable, there is no substitute for the photographic emulsion. For our instruments we offer two cameras, one employing standard spectroscopic emulsions and capable of being racked, the other a Polaroid back to take 4″ x 5″ film. The latter, with 3000 ASA rated speed film and the new PN film which develops into both a positive opaque print and a negative transparency is certain to prove indispensable in many applications.

To install either camera, the exit slit is removed by unscrewing four external screws. Incidentally, guided by a scribe mark, the operator can replace the slit in a few minutes, assured that the optical performance has not been affected. After the standard camera is loaded in the darkroom with either a 35-mm film strip or plate the turn of a crank brings a darkslide over the emulsion protecting it from exposure during mounting. Slid over its guide rods and locked in place with a pair of thumb nuts, the camera is readied in less than a minute. By setting the entrance slit to an appropriate spectrum height, as many as 20 exposures can be taken in juxtaposition.

While the large size of the Polaroid film back limits racking to two positions, six juxtaposed exposures may, none the less, be taken on each sheet of film by turning the Hartmann diaphragm on the entrance slit to its three successive positions. These are so arranged that they intercept the entrance slit one directly above the next.

### Refractor Plate

When a transparent plate is placed in the path of a beam, the radiation is refracted by an amount depending on the thickness of the plate, its refractive index and the angle at which it intercepts the beam. If the plate is rotated continuously behind the entrance slit, the resulting radiation at the exit slit will be a repetitive wavelength scan covering a short interval. Picked up by a photomultiplier, the signal can be displayed on an oscilloscope as a tracing of wavelength *vs.* intensity.

One application of the refractor plate is to study the shape of a radiation curve from a decaying phosphor. Another, suggested by Dr. Z. H. Heller of Airborne Instruments Laboratories, is as a monitor to measure the transmitted wavelength of interference filters as they are deposited. Presently, the technique is to reflect a beam of incandescent light from the filter through the vacuum chamber. This beam is sent through a reference interference filter to a detector and the deposition halted when the PM tube responds. The system indicates the end-point abruptly, giving little warning to the operator. Substituting the refractor plate and spectrometer for the reference interference filter, the output could be seen on an oscilloscope screen as a tracing of wavelength *vs.* intensity. During deposition, a constantly shifting peak would be seen at the wavelength of maximum intensity and at the exact wavelength bandpass desired deposition could be stopped.

Synchronously driven at 60 rpm (other speeds are available), the refractor plate may also be turned by hand for very accurate wavelength settings, a 360° scale facilitating the operation. The entire assembly replaces the top access cover to the grating and is positioned or removed in but a few seconds.

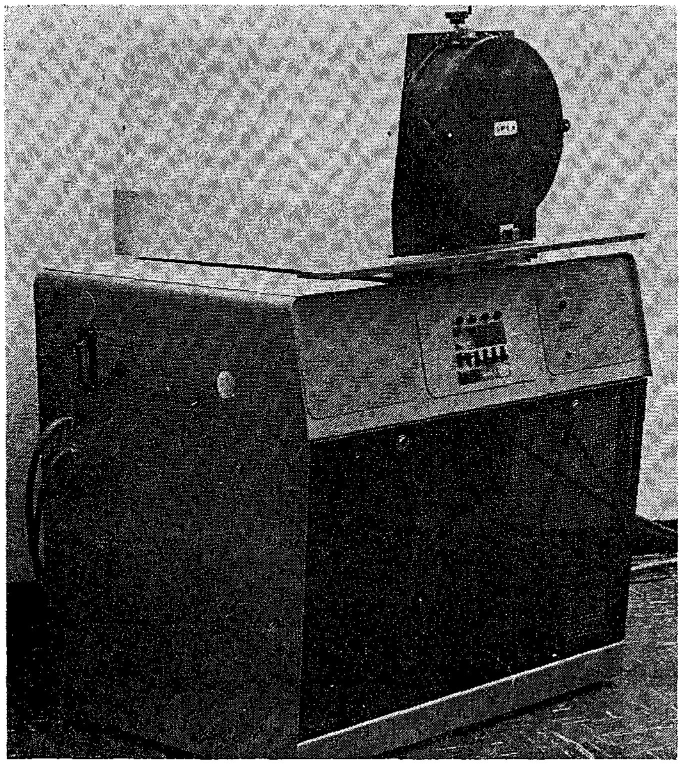


**Fig. 8.** Modified 1500 Evacuable Spectrometer installed at Fort Monmouth's Evans Signal Laboratories. Through the use of 45° mirrors at the slits, a straight-through optical path results to accommodate a large television camera as a detector.

### Vacuum Spectrometer

THE discovery that $MgF_2$, when overcoated on evaporated aluminum, maintains its excellent reflectivity far into the ultraviolet even after years of exposure has extended the range of the Czerny-Turner mount down to 1100A, the cut-off of known window materials (LiF). Accordingly, we have converted the f/6.8 spectrometer to a vacuum instrument extending its application well into the vacuum ultraviolet and also to those regions of the infrared where atmospheric water vapor absorbs. In fact, the resulting Model 1500 spectrometer covers the tremendous range from 1100A to 22 microns. When not needed, the vacuum system is simply not run.

Of particular interest is the pumping unit specifically devised for the instrument. Although standard 4" vacuum consoles will mate with the 1500 and may be coupled to it, generally they have shortcomings. Traces of diffusion pump oil can migrate upwards to coat grating and mirrors and so interfere with their performance. In our design, extreme precautions have been taken to prevent this. An optically dense, antimigration baffle is inserted between the diffusion pump and the spectrometer. By means of a built-in Freon compressor, the baffle is kept at -50°F. There is no path along which a vaporized oil molecule can stray without being cooled to a point where it is condensed and sent scurrying back to the boiler. The Cooke baffle employed is actually a Dewar type bottle in which the walls as well as the intercepting leaves are all cooled while the outside chamber, separated from the cooled section by vacuum, remains at room temperature. Older baffles, made not to ice up on the outside, have warm inside walls along which surreptitious oil molecules can sneak.

To constrain the diffusion pump oil still further, our console incorporates the new NRC cold-cap diffusion pump. In this, cooling water is looped above the jets to reduce so-called backstreaming of vapor. Our choice of pump oil is the latest Dow-Corning silicone, DC 705. It has the lowest known vapor pressure.

The Spex vacuum console is designed to fail safe. A pneumatically actuated gate valve separates the spectrometer proper from the vacuum system. Should the pressure rise in the spectrometer, a controller signals the gate valve which then jams shut. The entire event takes less than 1 second. Water cooling the diffusion pump is monitored; should its temperature rise too high, a relay breaks the heater circuit. Another thermal switch is in series with the gate valve solenoid. Only after the cooled baffle is below the set temperature is it possible to open the gate valve. Another fail-safe precaution blocks the power mains if they should fail and later resume. Once power fails, the operator must reset the vacuum system.

Vibration is still another problem with conventional vacuum consoles. In our design, through jack screws, the forepump is lifted from the console to the floor when in operation. Other jack screws take the console weight off the swivel casters when the unit has been positioned.

HAVING said enough about specifications, we must now confront you with the pricetag. Fully itemized in a listing, yours for the asking, prices of our spectrometers necessarily reflect the type and number of gratings as well as accessories required. A hand-scanning model can be purchased for less than $4,000.00; if your project will benefit from and budget bear more elegant equipment, $13,000. will buy the evacuable model complete with vacuum console. Plagued but undaunted, our production department, having shifted to high gear, is promising deliveries of 4-6 weeks for the non-evacuable models. So far they have kept their promises.

Return Requested

SPEX

INDUSTRIES INC.
3880 Park Avenue
Metuchen, New Jersey

SPECIALISTS IN SPECTROSCOPY

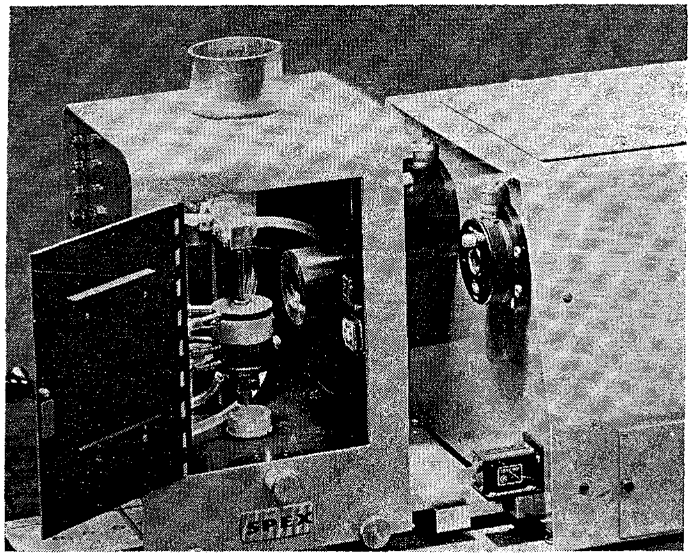


**Fig. 9.** One growing application of the 1700 Spectrometer is in conjunction with the Spex Plasma Jet for the analysis of liquids. Connected to a photomultiplier and appropriate readout system, the instrument is capable of unsurpassed accuracy, reproducibility and speed of analysis. Some 70 elements may be determined at levels ranging from fractional ppm upwards with a negligible interelement effect. A stabilized, high impedance dc arc unit (Spex No. 9040) and a precision manifold (Spex No. 9033) to control the aspirating and tangental gas flows complete the package.

**Editor's Note:**

Too late for incorporation into our article but too good to shelve alongside proofreaders' cuttings is the latest report from our laboratory indicating a maximum of 0.002% stray light measurable in our No. 1700 Spectrometer. This exceedingly gratifying information was obtained by feeding 2537A from a mercury source through a small auxiliary monochromator to the slit of the No. 1700. Scanned through some 10 orders, this miniscule bundle of photons was detected near the low side of the blaze in the eighth order of Hg 2537A. The slit width was 25 microns.