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SPECTROSCOPY IN THE ELECTRONICS INDUSTRY

If you trace the history of the industrial revolution now reaching a new climax known as automation, you stumble upon a curious fact. It is the transition from a hole to a slot and now back again to a hole. Without being facetious, what is meant is that production tolerances, first quite close, then for a long period just the reverse, are once more stiffening. In the early days, a one-of-a-kind grandfather clock was built by a craftsman who painstakingly fabricated each of the parts individually before assembly. When constructed, it was, of course, an expensive grandfather clock. Then a long-forgotten individual conceived the notion that a number of blanks could be stacked and worked on collectively to achieve mass-production economies. In this scheme of things, trouble often developed when parts would simply not fit together — until another inventive genius dreamed up the slot — an oversize opening large enough to handle normal production variations yet small enough to permit each clock to tick on time.

In almost every industry, "slop" such as the slot was deliberately employed to increase mass production efficiency. In the electronics industry, it could be found in vacuum tubes, characteristics of which varied considerably from one to the next. Adjustable resistors, capacitors and coils were added to the chassis to compensate for the variations. The man at the end of the assembly line was assigned the crucial adjusting job of coaxing the radio to perform.

The trend in recent years has been to cut down on these variations. A machine shop foreman wants every batch of aluminum rod in a production run to have identical physical properties. Thus assured, his machinists can set their spindles to turn and their tools to feed at the same rate throughout the run. Nowadays the foreman can even predict how long his tool can be used without resharpening. Tight tolerances require equally tight chemical control and probably the greatest need for the spectrograph in industry stems from its great help in producing standardization.

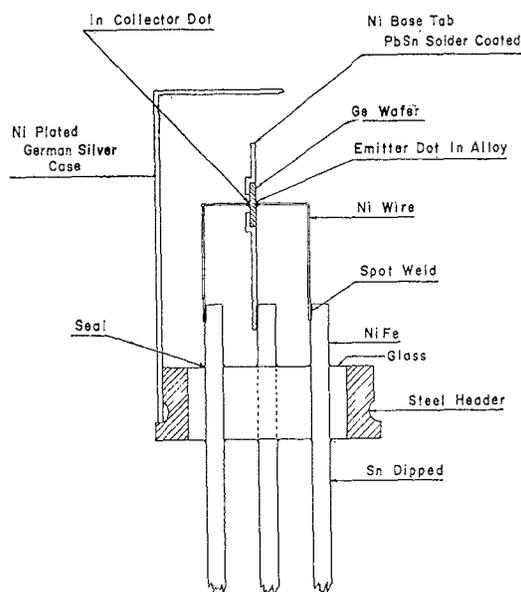
In the electronic industry, the connection between spectroscopy and standardization is just as straightforward. Instead of controlling the composition of a single alloy, however, the spectrographer is called upon to examine almost every material that finds its way into a vacuum tube or other electronic component. Trace elements in Ni cathodes ultimately determine the emission of electrons, thus the behavior of a particular tube. Upon the impurities in Ge or Si depends the very functioning of the transistor of which it is the heart.

Impurities, trace elements, sensitivity of detection—these are the words you hear over and over from spectrographers who are competing in the race between sensitivity and purity. Unfortunately, purity is way out front. That about sums up the big task in the electronics industry today. How well most solid state devices perform depends largely on the presence or absence of minute traces of certain elements. The emission spectrograph, once the mainstay for keeping tabs on the quality of Se for rectifier use now finds itself outdistanced by Ge and Si purity. The case is not hopeless, however, as techniques and instrumentation push to fill the gap.

The gap is somewhere between 10 and 1000 times. In general, the emission spectrograph can detect elements in the ppm range while elements are known to have electronic effects in the ppb range. Si, for example, is sold on the basis of its B content. DuPont has three grades of the transistor grade material in which the B content is guaranteed as less than 7.1, 3.5 and 1.8 ppb respectively. Directly the spectrograph can detect about 100 ppb and so concentration techniques must be employed, one of the best perhaps being that devised by Morrison and Rupp at Sylvania (1). With regard to Si as well as other solid-state materials, the ultimate criterion is their electrical properties and materials are sold with performance rather than chemical specifications. But techniques for the latter are required in order to predict and assure proper performance.

At Sylvania Research Laboratories, Morrison and Rupp have made considerable progress. Taking silicon carbide as their base—it is one of the promising high-temperature semiconductors—they have reported greatly improved sensitivities ranging from 1-5 ppb for Ag and Be to 100-500 ppb for As, Ge, Hg, P, Sb, Sn and Zn (2). Their technique has not been to seek a panacea whereby, with a single gadget or technique, the sensitivity of all of the elements would be miraculously improved. Instead, they have taken step-by-step measures each having small effect but used together the results are cascaded. Carbon electrodes are used rather than graphite; exposure times are matched to the burn-off of the individual elements; an argon atmosphere is used to enhance the sensitivity of certain elements. Present studies are with a high-speed spectrograph with which exposure in the order of one-tenth second can be made for such volatile elements as As and Hg in order to optimize their signal-to-noise ratios.

Such techniques are currently limited to research and there they will remain until the good ones are distilled away from the poor. But trace-element determinations are now commonplace on the production line, especially in connection with the 50 million transistors scheduled for production this year. One way of gaining an insight into the ticklish quality control program facing the industry is to examine the diagram below of a typical Ge transistor enlarged many times. The Ge wafer itself is a slice of a single crystal oriented along the 1, 1, 1 axis. Once sliced, the wafer, about 1/16" on a side and 0.010" thick, is etched to size either chemically or electrochemically. The starting material for the Ge is germanium dioxide almost spectrographically pure which is reduced in a hydrogen furnace, zone refined, doped with a trace of Sb, In, or As and finally grown into a single crystal. To obtain the desired semi-conductor properties, "impurity dots" of In or Pb about 0.008" in diameter are fused to each side of the Ge wafer. Leads are soldered to the dots and also to the solder-dipped Ni base which not only supports the assembly but also acts as a heat sink.



Cross section of a transistor.

To minimize the high rejection or "shrinkage" rate of transistors is the goal of the quality control department. Accordingly, the emission spectrograph, among an assortment of electronic testers and other analytical tools, has become an integral part of the assembly line, its job to predict and pin down brewing trouble. In many plants the quality control program calls for the spectrographic analysis of almost every raw material. Everything including the incoming germanium dioxide, lead wires, impurity dots and solders is scrutinized before being released to the production department.

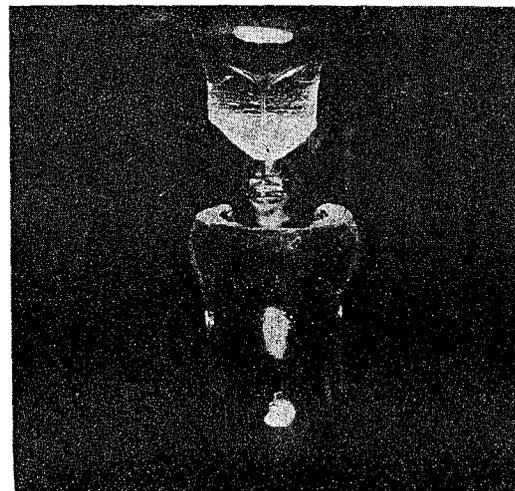
It is interesting to note that alone, a resistance check on a test bar of Ge is not a foolproof test because elements in Group III and V tend to offset one another and certain non-ionizable ones like Si do not affect the resistance. A spectrographic test will often suggest such a situation. But long before the final transistor-grade bar is made, the spectrograph is put on the job. The starting material, germanium dioxide, must show a Si content of less than 10 ppm and all other elements must be undetected. Of course, to the spectrographic tests are added others such as bulk density measurements, the presence of volatiles at 800°C. and a microscopic examination.

Impurity dots are also carefully checked especially in view of the ever-present possibility of mixing up the emitters with the collectors. The former consist of an In alloy generally containing Ga and doped with Ag or Zn while the collector dots are composed of pure In. Solder materials are important in that the wrong material may result in an unacceptably high resistance to ground.

Much research today on transistors is centered around high-temperature applications. Needed especially in military applications are transistors capable of operating at temperatures up to 1000°C. Theoretically, the "three-fives"—compounds of Group III and V elements—should be superior in this respect. One such three-five, gallium arsenide does, indeed, appear promising but good transistors have not, as yet, been made consistently from it. In diodes, however, where purity requirements are not so stringent, gallium arsenide has already found a niche.

One trace-element job of the spectrograph is detecting the undetectable in, say, spectrographically pure Ga. Before purification, the Ga is analyzed and after the first zone refining pass, both ends and the center section are again analyzed. Impurities may either migrate to one end or the other or not move at all during the initial pass. These impurities are detectable spectrographically in the first zone refining pass and an analysis often furnishes clues to the engineer who wants to know how many passes will ultimately be required and whether certain elements migrate altogether. Before the impurities dip below sensitivity levels, spectrographic determinations provide data which is then extrapolated.

In a concerted effort to produce purer gallium arsenide, every operation is being carefully scrutinized. Transistor grade etching acids are further distilled in quartz stills, the purification followed by the rotating disc technique of analysis. One refinement for detecting lower concentrations of impurities is the hollow-cathode in which elements are excited over and over again instead of being lost up the stack. Initial experiments with traces of Fe have been encouraging.



Philco precision process etches tiny depression on surface of germanium blank with tolerance controlled by infrared rays to 1/150 the thickness of a human hair.

There is interest in another Group III element which, presumably, could be coupled with one in Group V. This is B and a recent report by Harvey (3) indicates a general cracking of its sensitivity barriers. For example, he reports detection limits of about 0.5 ppm for Mg, Cu, Cr and Ca using a 1.5-m spectro-

graph which figures, when translated to larger, more modern spectrographs, would probably mean 0.05 ppm. Harvey, like Morrison and Rupp, has chosen to optimize many conditions to obtain higher sensitivity rather than concentrating on but one. Each element and matrix is treated as a separate problem. For some he finds the Stallwood jet useful; for others atmospheres other than air.

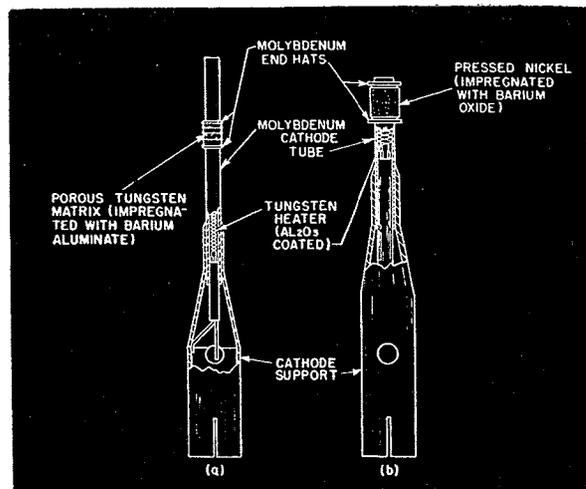
Not all of the work in semiconductor materials is on traces. As mentioned, impurity dots are usually In alloys, the composition of which has to be closely controlled. Hyman (4) reported on the determination of Ga, Zn, Ag and Al in In alloys and has stated that several other elements have recently been added to the porous cup method employed. For the determination of Ga in individual dots, E. Murt of Lansdale Tube Co., Lansdale, Pa., has developed a graphite spark technique soon to be published in *Applied Spectroscopy*. Here a single dot is dissolved and dried on the end of a flat-top graphite electrode where, after drying, it is sparked. Incidentally, trace elements as well as alloying constituents affect the properties of In and methods have been worked out for such determinations. Harry Hyman, at RCA Semiconductor Division, Somerville, N. J., will report in a future issue of *Applied Spectroscopy* on an ac arc method in which In is first dissolved then allowed to dry on a shallow, center-post electrode. This technique permits the preparation of standards from solutions of high-purity In. Few metallic standards are currently available.

Because of the ease in standardization, solutions techniques are becoming increasingly popular despite the necessity for preliminary sample preparation. Old standbys such as the rotating electrode are still used and have a decided advantage when suspended matter is present or suspected (Sn in acid solutions, for example). When complete solution is effected, a number of spectrographers are using the vacuum cup electrode (UCP 6010) originally suggested by T. H. Zink then at Armour Research Foundation in Chicago. With this electrode, the solution is sucked from a Teflon reservoir through a fine hole into the arc column. A similar method, originally proposed by W. M. Henry of Battelle Memorial Institute in Columbus, O., uses a porosified electrode rather than one with a hole drilled into it. The reservoir can be made from almost any plastic material but perhaps the easiest and cheapest source is the 1/2" dia. polyethylene caps used for plastic mixing vials. A hole is simply punched into the center of the cap through which the arc porosified electrode is pushed.* The method has been found to yield almost identical working curves with those from the porous cup technique.

Vacuum Tubes

In the production of vacuum tubes, there is always the possibility that the wrong material will be used or that the material is not up to snuff. The spectrograph is constantly seeking trouble to prevent it from becoming more serious. At Month of the RCA Microwave Div., Harrison, N. J., gave a nice illustration recently. On a magnetron tube was found a glassy deposit containing Mg, Al and Si. It turned out to be identical with the brick inside a furnace in which the tube was baked and a new kind of brick was quickly substituted. Magnetrons, incidentally, are made using OFHC (oxygen-free, high-conductivity) copper and all batches of this material are checked for impurities. A trace of a volatile element would be ruinous to tube operation.

*S. Weisburger of Sylvania has refined the method still further. Upon request, we'll be happy to send you a sample cap and a description of his "wick" technique.



Two typical cathodes used in RCA magnetrons.

In conventional electronic tubes, volatile elements must be carefully avoided, too. Coating the inside of the envelope, an element often makes it conductive and plays havoc with the tube's electronic characteristics. When spotted, a bulb deposit is removed (dabbing with acid-wetted filter paper is one technique) and arced. On one such test recently at RCA, Ag was found and with a little further detective work, it was discovered that a Ni grid wire was wrongly flashed with Ag before being plated with Pd. Ni plating baths are another potential source of volatiles. So frequently are additives used in these baths as brighteners and anti-pitting agents that all new baths are suspect.

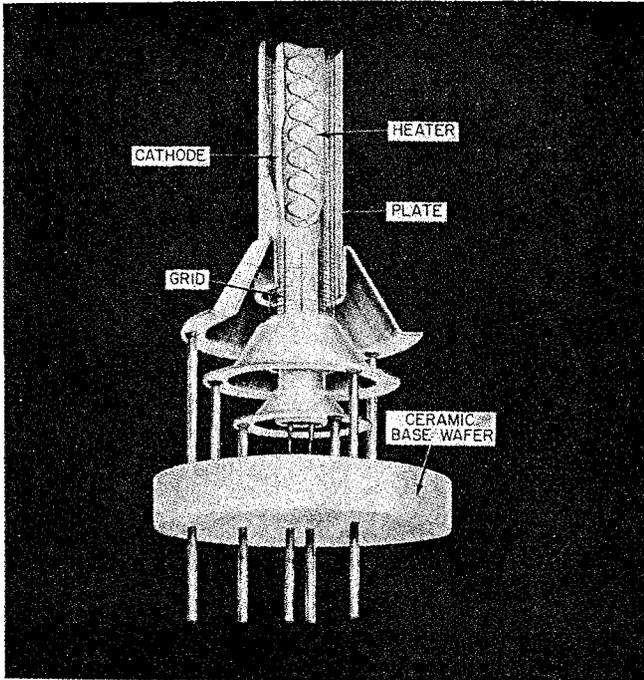
By far the most important part of a vacuum tube is its cathode—the source of electrons. The usual method employed to obtain controlled emissivity is to spray the Ni shell with mixed Ba, Ca and Sr carbonates which are then converted to the oxides by heating as the tube is evacuated. The emissivity as well as the life of the tube depend not only on the composition of the mixed carbonates but also on that of the Ni base. Depending on its purity, Ni varies from active (99.5% pure) to passive (99.99% pure). Elements in the former, such as Si, Mg, Ti and Al, serve as activators for the carbonates. They not only increase the emissivity of the latter but also reduce the time required for activation. The use of passive Ni, on the other hand, results in lower emissivity but, of more interest in military applications, a longer life-time.

Through the work of Committee F-1 of ASTM, great strides have been made in standardization of cathode nickels in the industry. Three standards have been made available (the National Bureau of Standards supplies them) and analytical methods have been thoroughly cross-checked. The early method devised by Jaycox (5) in which Ni is converted to a powder and mixed with graphite is still in widespread use although direct and solution techniques have also been proposed.

A new twist in cathode technology is the introduction of Ni alloys (Co and Mo are two such constituents) to replace the relatively pure Ni. The alloys are sprayed with carbonates and are used where high strength at high temperatures is needed in magnetrons, for example. Magnetrons are made with still another type of cathode called a matrix cathode which consists of a hollow sintered cylinder of W and Ba. The cylinder is slipped over the heater wire which, in turn, is packed with aluminum oxide.

Such techniques are used to pull still greater performance out of tubes for miniaturization, operation at higher tempera-

tures and greater ruggedness are the by-words everywhere. RCA's Nuvistor is a recent development along these lines. It is made completely of metal and ceramic, is a fraction the size of an ordinary receiving tube and has extremely high resistance to mechanical shock and vibration.



Cutaway view of RCA Nuvistor showing cylindrical electrodes and tripod-like supports.

While Ni alloys are being used for greater strength cathode structures, a basic study is now under way on high-purity Ni at Sylvania Research Laboratories. The subject of activators is still more of an art than a science but, with the help of an Air Force contract, Sylvania is attempting to pin down the effects of individual impurity elements on the Ni. Here the emission spectrograph is invaluable in guiding the metallurgists whose job it is to add tiny traces of elements to Ni metal.

As indicated earlier, volatilization inside an operating tube is often its fatal illness and much research has been undertaken to prevent and inhibit the phenomenon. One notable current study is that at RCA's Microwave Division by Joseph Antalec, using the new RCA X-ray spectrograph. Films of various alloys are evaporated and then compared with the base alloy. From these studies it is hoped to predict volatilization rates of the alloys and correlate them with the basic gas laws. As a non-destructive tool, the X-ray spectrograph is also being used for analyzing iron-nickel films which are finding application as tiny magnetic memory devices.

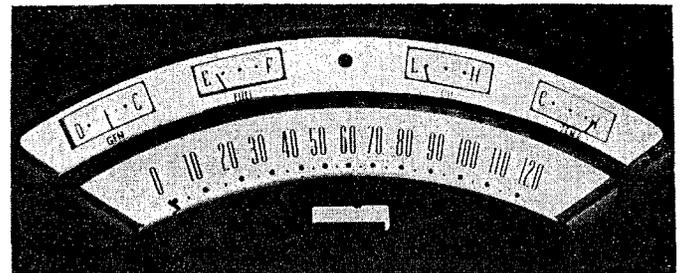
As all of us household appliance repairmen know, an eerily glowing vacuum tube usually means it is time for replacing it. When one glows in inspection it is often more serious because other tubes in the batch may be involved. John A. Grosso of Tung-Sol in Bloomfield, N. J., described several instances where glows were analyzed spectrographically. In one receiving tube, by exciting the gas with a Tesla coil, he recorded the dim light using an exposure of several hours on a 103-F plate. Hydrogen lines were detected indicating the presence of water vapor. In high-power tubes used at microwave frequencies any absorbed water vapor on the surfaces of glass or ceramic insulators may dissociate and release hydrogen to upset the operation of the

tube. Leaks are another source of trouble inside a tube and in a rejected neon indicator lamp Grosso detected nitrogen bands—strong circumstantial evidence of air leaking into the envelope. In a cold cathode tube carbon monoxide bands were detected—pointing an accusing finger at the presence of organic materials, possibly oil from the vacuum pump. In a lamp filled with Kr and N, cyanogen bands were found, once more indicating oil vapor.

Kr may seem exotic to most spectrographers who would probably make some very careful measurements before reporting it. But in the tube business almost any combination of elements is likely to crop up and does. In vacuum tube grid wires one is likely to encounter Fe, Mn, Mo in a Ni base (Hastalloys) or perhaps W-Mo alloy; Cu alloys containing Cr are used in grid supports; Zr, W or both are often alloyed with Ni in cathode alloys for high emissivity; Ba is the metal used in getters which, when flashed, traps residual gases. A really unusual combination of elements was recently reported used to seal lead wires in the ceramic base of RCA's Nuvistor. The base is dipped into a solution of Mo and Li salts and fired in hydrogen to reduce the Mo which adheres nicely inside the holes. The surfaces, also coated, are given a light grinding to remove the Mo.

Phosphors

With the advent of fluorescent lighting, then television and soon electroluminescent lighting, the production of phosphors has mushroomed over the past two decades. Most commercial phosphors are made from zinc sulfide or mixtures of co-precipitated zinc-cadmium sulfide to which small additions of Cu, Ag or Mn act as activators. The efficiency, lifetime, brightness and color are all severely affected by composition and close analytical control is called for with the spectrograph again taking a dominant position. Electroluminescence is fascinating as well as alluring because it offers hopes for panels of flare-free light. Before these panels can be installed in the home, however, efficiency must be raised so it may compete with the more conventional types of lighting. There is no question that research on different materials, activators and technique will someday make such lighting common but, thus far, the only large-scale applications are in automobile dashboard lighting (Sylvania's Panelescent lighting is used in the 1960 Imperial) and household night lights, again by Sylvania.



Panelescent dashboard light, 1960 Imperial.

(photo courtesy Sylvania)

Acknowledgments

Having spoken with and interviewed so many people in connection with this paper, I hesitate to name names for fear of omitting some, and apologize if I have done so. Yet I owe special thanks to the following who have provided much of the material for the article: E. Jaycox of the Bell Telephone Lab-

oratories; R. Kelly and R. Quigley of Wilbur B. Driver Co.; C. Albright and L. Casper of Kawecki Chemical Co.; E. Murt of Lansdale Tube (Philco); S. Adler, J. Antalec, M. Gardels, H. Hyman, A. Liebman, A. Month, H. Whitaker of various divisions of RCA; G. Morrison, R. Rupp and S. Weisberger of Sylvania; J. Grosso of Tung-Sol.

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2. Morrison, G. H.; Rupp, R. L., *Analysis of Impurities in Silicon Carbide*, a chapter in "Silicon Carbide, A High Temperature Semiconductor," edited by O'Connor, J. R.; Smittens, J., Pergamon Press, N. Y., 1959.
3. Harvey, C. E., *Research Investigations of Semiconductor Impurities*, "First Quarterly Report, U. S. Army Signal Engineering Laboratories," Ft. Monmouth, N. J., 1959.
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5. "Methods for Emission Spectrochemical Analysis," ASTM, Philadelphia, 1957, p. 94.

—A. J. Mitteldorf

MASTER PLATES

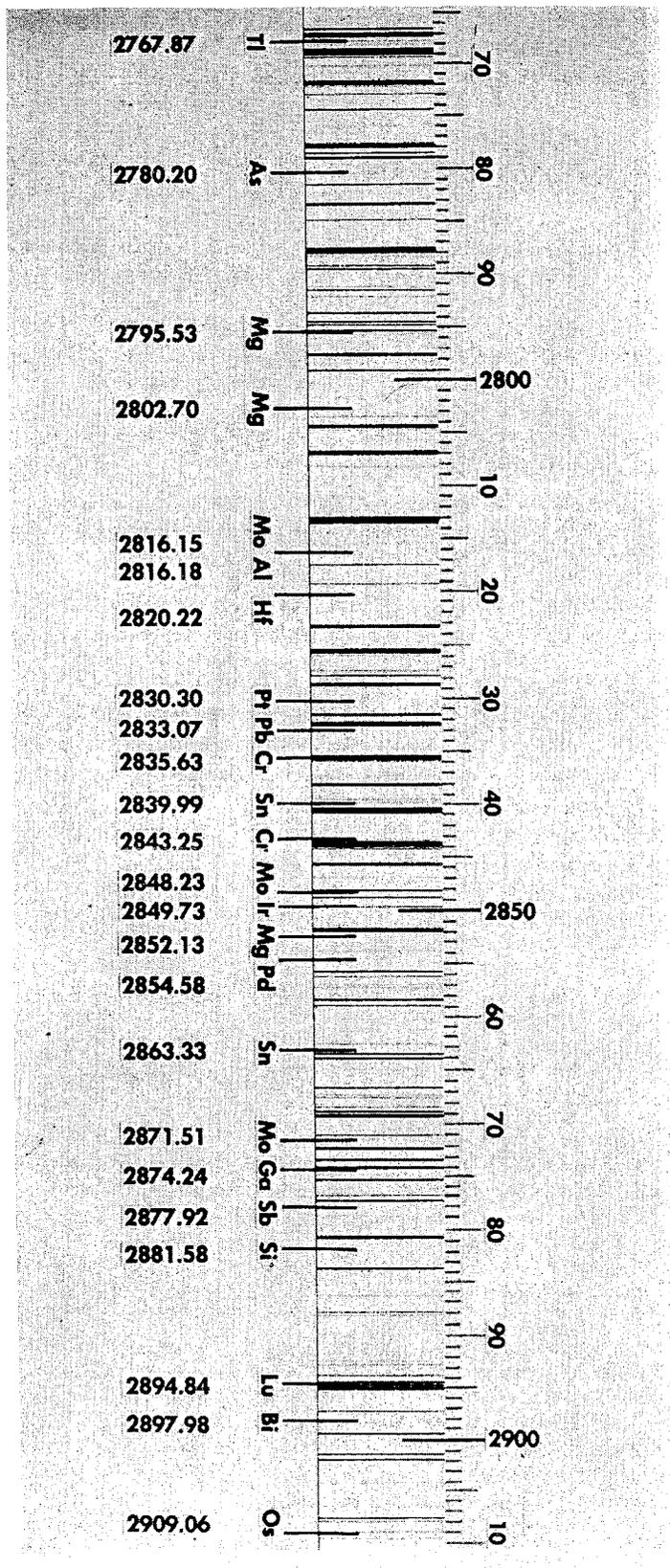
There is need for accurate, convenient-to-use master plates to aid in identifying spectral lines. Many spectrographers simply cannot take the considerable "time out" necessary to prepare such plates.

We think we have the answer: master plates custom-made to match the exact dispersion of your instrument. They have the following features:

1. Two spectra are given in juxtaposition
 - a. An Iron arc spectrum
 - b. Persistent lines of around 70 elements
2. Color coding is used as an identification aid. Persistent arc lines are labeled in green; persistent spark lines in orange; wavelength units are in blue but every 50A is accentuated red. There is a mark for each 1A unit.
3. The master plate is exactly matched to the dispersion of a specific spectrograph and to the wavelength interval chosen.
4. Spectra are overlapped, enabling the spectrographer to readily interpolate the wavelengths of unknown lines.
5. The photographs are on film, sandwiched between two rigid plastic sheets to protect them from abrasion and dust.

At this time, we are offering the master plates only for spectrographs which have approximately linear dispersion, e.g., grating instruments. At a later date, we hope to extend the service to non-linear prism instruments.

1103 **Master Plate**, 4" x 10", as described above. To order send us an iron spectrum covering the region of interest and made under the exact conditions normally used. **Per 10 inches of spectrum** \$85.00



Black and white enlargement of color-coded master plate section.

THE STALLWOOD JET

The principal advantage of the Stallwood jet is in stabilizing an arc. Being jacketed in a sheath of gas, the arc is constrained from wandering and the result is greater reproducibility. The original claims have been substantiated in many other laboratories. For example, we showed (SPEX SPEAKER IV, No. 3, p4) that the average coefficient of variation of the intensities of lines of six randomly chosen elements dropped from 15.8 to 4.6%—a factor of almost 4—when the Stallwood jet was used.

Another well-established claim for the Stallwood jet is its ability to reduce line broadening and reversal by blowing away the self-absorbing metal vapors normally surrounding an arc. This is readily demonstrated by running a Spex G-1 standard both ways at a current of about 7 amperes. With a spectrograph having a plate factor of 5A/mm, the magnesium 2852A line shows strong reversal which disappears entirely when the jet is used. Such reversed lines can be used for quantitative analysis at higher concentrational levels with the Stallwood jet.

Further claims for the Stallwood jet are not so well accepted. One states that it reduces selective volatilization. The mechanism here is the use of a relatively deep crater which maintains most of the sample at a relatively low temperature while the top layer is arced. Although, to our knowledge, no adequate comparisons have been made using a deep crater with and without a jet, our guesstimate is that the jet with a deep crater is probably the best means of reducing selective volatilization, especially when the electrode, as it is consumed, is constantly advanced with respect to the jet.

There is some controversy over the Stallwood jet concerning its effects on sensitivity. First let us once more define terms. By sensitivity we mean the ability of a spectrograph to detect a line above its background. We assume that the sample size is adequate so that signal-to-noise is the criterion of sensitivity not the number of micrograms of an element which can be detected. In modern parlance, we are speaking of trace analysis as opposed to micro analysis. Thus, if the use of the Stallwood jet reduces the *intensity* of a line, it is no indication that the *sensitivity* of that line is worsened. More sample can be burned or light attenuators can be removed in order to increase the overall intensity to a point where background begins to appear behind the line under study.

With these rules and definitions in mind, we ran a series of tests comparing the sensitivity of elements in three sets of our semi-quantitative standards with and without the Stallwood jet. A mixture of 30% oxygen-70% argon was used at a flow rate of 5 lpm. Data given in the table may be summarized as follows:

1) In most instances, the Stallwood jet enhances sensitivity two to ten times.

2) With certain elements, the U1 lines may be little affected one way or the other but frequently the sensitivity of the persistent spark lines is enhanced. This seems to be particularly true for those elements where there is a large difference in the excitation potential between arc and spark lines (e.g., alkaline earths).

3) By reducing the overall level of the cyanogen bands, sensitivity for most lines in these regions is enhanced at least five times.

Data for the following tables were obtained on our 3.4-meter Ebert mount spectrograph. A dc arc discharge of 7 amperes was used, the sample packed in a shallow crater electrode (UCP 105-S) and burned until completion.

COMPARISON OF SENSITIVITY

G STANDARDS

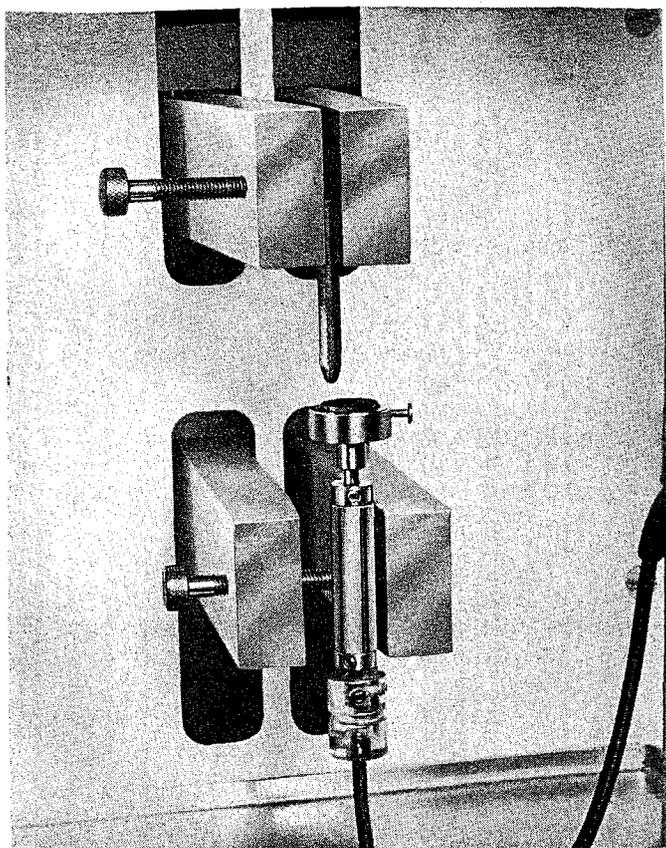
Element	Line, A	Limit of Detection, ppm	
		Open Arc	Stallwood Jet
Ag	3280.7	1	.5
Al	3092.7	10	5
As	2349.8	100	50
B	2497.7	2	2
Ba	4554.0	5	2
Be	2348.6	.1	.5
	3130.4	.5	.02
Bi	3067.7	5	2
Ca	4226.7	1	.2
Nb	3094.2	10	5
Cd	3261.1	20	10
Ce	4186.6	1000	500
Co	3453.5	20	5
Cr	2835.6	10	5
Cs	4555.4	500	500
Cu	3247.5	1	.5
Fe	3020.6	5	2
Ge	2651.2	5	5
Hg	2536.5	500	50
K	4044.1	> 1000	1000
Li	3232.6	500	500
Mg	2795.5	.2	.2
Mn	2576.1	5	1
Na	3302.3	500	500
Ni	3414.8	20	5
P	2535.7	100	50
Pb	2833.0	20	5
Rb	4201.8	> 1000	1000
Sb	2598.0	50	50
Si	2881.6	1	.5
Sn	3175.0	20	5
Sr	4077.7	50	5
Ta	3311.2	—	—
Te	2385.8	500	100
Th	4019.1	500	500
Ti	3349.0	10	1
Tl	3775.7	50	20
U	4241.7	500	500
V	3093.1	20	5
W	4302.1	100	100
Zn	3302.6	50	10
Zr	3496.2	50	10

NOBLE METAL G STANDARDS

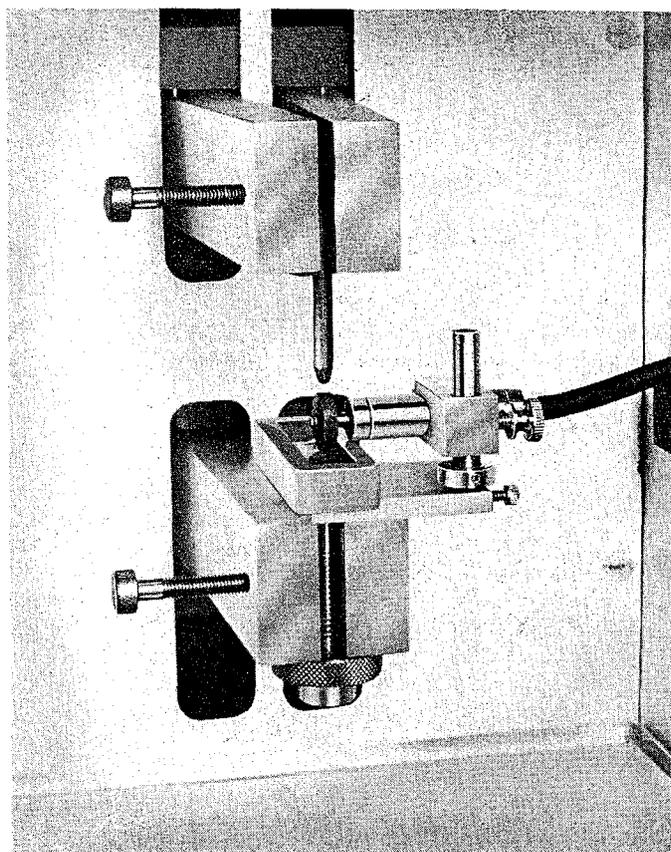
Au	2428.0	<5	<5
Ga	2943.6	5	5
Hf	3194.2	50	10
In	3256.1	10	<5
Ir	3220.8	50	10
Pd	3242.7	10	5
Pt	3064.7	<5	<5
Re	3460.5	50	10
Rh	3434.9	10	<5
Ru	3436.7	100	10

RARE EARTH L STANDARDS

Ce	4186.6	10	5
Dy	4046.0	5	2
Er	3692.6	5	2
Eu	4594.0	5	2
Gd	3422.5	10	2
Ho	3891.0	5	2
La	3949.1	5	2
Lu	2615.4	5	2
Nd	4303.6	20	5
Pr	4225.3	20	5
Sm	4424.3	20	5
Sc	4023.7	1	.5
Tb	3509.2	50	10
Tm	3462.2	5	2
Yb	3289.4	1	.5
Y	3242.3	5	2



Combination Analyzer in position for use with platrodes.



Combination Analyzer in position for use with rotating disc electrode.

COMBINATION ANALYZER

A workhorse in over 100 laboratories for the analysis of liquids, our No. 3400 Combination Analyzer has been extensively redesigned to make it even more useful. On occasion, the stainless steel shaft has proved vulnerable to attack by strong acids and so we are supplying a second shaft of even more corrosion-resistant tantalum. Changing samples has been simplified in the new model by having the rotating section slide in a keyway, thus retaining alignment for the next sample. The original bearings—miniature enclosed needles—have been replaced with a graphite composition sleeve, again removing a potential source of corrosion.

The Combination Analyzer fits almost any arc stand and can turn either vertically or horizontally for the Rotrode or Platrode techniques, respectively. A special flexible cable attaches the rotor through a high-voltage insulator to the motor shaft. The latter is available in almost any speed but 2 rpm is about the best compromise.

- 3400T Tantalum shaft, replacement for Combination Analyzers in useEach \$15.00
- 3400 Combination Analyzer, accessory for use either in Platrode or Rotrode solution analysis techniques, 115 v, 60 cy., complete with both stainless steel and tantalum shafts. Each \$195.00
- 3401 Porcelain boat, spare. One supplied with 3400.
Per doz. \$10.00
- 3402 Table adapter, stainless steel, for 1/4" or 1" dia. discEach \$12.00

- 3403 Aluminum Boat, spare, one furnished with 3400Each \$5.50
- 4032 Graphite mandrel, used to protect tantalum or stainless steel from extremely corrosive substancesPer 100 \$22.00
- 4011 Graphite disc platrode, highest purity, for solution analysis, 1/2" dia. x 1/8" thick. Per 100 \$14.00
- 4012 Graphite platrode electrode, highest purity, for rotating platform technique, 1/2" dia.
Per 100 \$16.00
- 4027 Graphite disc electrode, highest purity, for solution analysis (like 4011 but thicker to permit electrode to run cooler). 1/2" dia. x 0.200" thickPer 100 \$14.00

SPECTRAL TABLES OF RARE EARTH ELEMENTS

Almost 60,000 lines of the rare earth elements plus zirconium, hafnium, thorium, rhenium, and technetium have been compiled at Oak Ridge National Laboratory under the direction of John A. Norris. This 737 page table is available (ORNL-2774) from the Office of Technical Services, Washington, D. C., at a cost of \$7.25. Conforming to the practice of the MIT tables, the lines are listed in decreasing wavelength covering the range 9980 to 1284A. Estimates of line intensity in both an arc and spark are furnished and an additional column lists wave numbers. This publication is an extremely valuable supplement to the MIT tables which were prepared before ion exchange methods were employed for separating the rare earths.

MEETING NOTICES

Fifth Annual Cleveland Conference, May 25, 1960, Western Reserve University, Cleveland, Ohio. Jeanette Grasseli, Sohio Research Center, Cleveland 15, Ohio, chairman.

Eleventh Annual Chicago Symposium on Spectroscopy, June 20-23, 1960, Conrad Hilton Hotel, Chicago, Ill. Harry Wilson, Continental Can Co., Inc., Chicago, Ill., coordinator.

Third Annual Rocky Mountain Spectroscopy Conference, August 8-9, 1960. Submit abstracts by May 1, to A. L. Schalge, Ohio Oil Co., Denver Research Center, Littleton, Colorado.

Seventh Annual Ottawa Symposium, October 3-5, 1960. Submit abstracts by June 15, to C. R. Langdon, Aluminum Co. of Canada, Ltd., Arvida, Quebec.

SPECTROSCOPY COURSE

Annual special two-weeks intensive course in Modern Industrial Spectrography, Boston, Mass. For all information contact Rev. J. J. Devlin, S.J., Dept. of Physics, Boston College, Chestnut Hill 67, Mass.

THANKS!

It was nice seeing so many of you at our Booth during the recent Pittsburgh Conference.

SPEX

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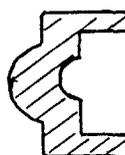
TOWARDS LONGER WAVELENGTHS

DMS subscribers will be interested in knowing that standard 6" x 9" stationery file drawers are ideal for the storage of cards. Cole Steel manufactures single, double and triple drawer units (C369, C3692, C3693), each drawer holding about 1600 cards.

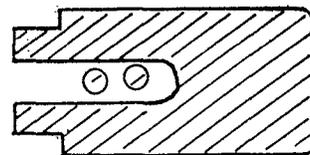
On page 301 of the February, 1960, issue of *Analytical Chemistry*, L. J. Lahr and R. J. Kaier describe a neat technique for preparing micro Nujol mulls. A stainless steel micro capsule containing the sample and Nujol is vibrated in the Wig-L-Bug together with tiny stainless steel balls. We are manufacturing the vial, slightly modified (the bottom is flat so it will stand) and it is listed as follows:

3124 Micro-vial for Wig-L-Bug, Stainless steel, with three 1/8" dia. ball pestlesEach \$7.50

No. 3124



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