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THE SPECTROGRAPH'S BEEN WORKING ON THE RAILROAD

Introduction

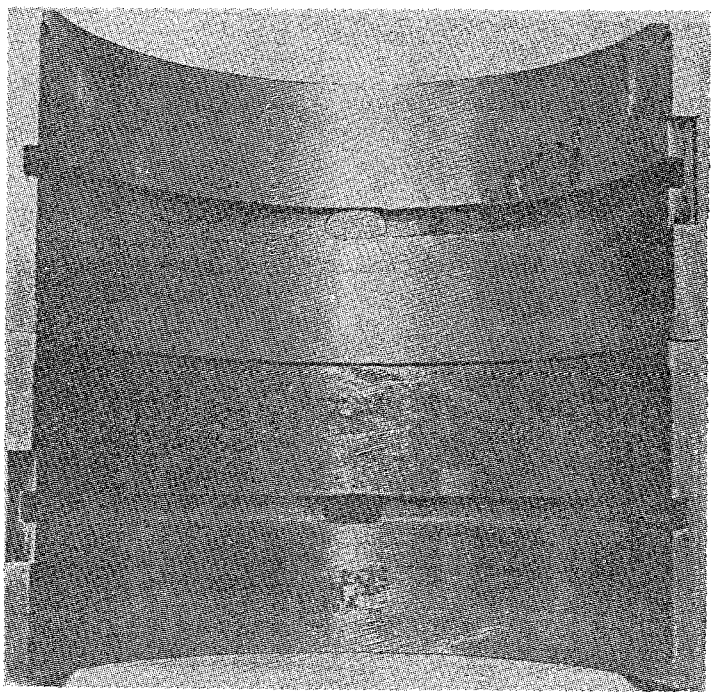
Over 90% of all locomotives in the United States are now Diesels. Sleek, fast and clean, they have just about relegated the roaring, smoke-belching steam engine to the toy manufacturers. The old iron horse, mighty and awesome, was, by modern standards, a lumbering giant. Its slow-moving parts were cautiously over-designed and, consequently, were overweight and oversize. Machining tolerances were loose and the number of alloys used could be counted on your fingers. By contrast, a modern Diesel locomotive is like a delicate watch, its precision parts meshing smoothly, and intricately. Hundreds of components are machined to tight tolerances from alloys carefully specified on the basis of chemical and physical properties.

With this revolution in railroading, came a huge maintenance problem. Heavier loads and faster moving parts could —and did—result in greater wear and tear. When first introduced, Diesels had an embarassing habit of giving up in the middle of nowhere when a main bearing seized. Worn gaskets would frequently let the cooling water seep into the crankcase to upset the lubricating system. Air filters would go bad, damaging the cylinders with abrasive road-bed dust. Worn rings would permit fuel blow-by into the crankcase to destroy the efficiency of the lube oil.

It was soon discovered that the lubricating oil itself could be used to diagnose impending trouble. Ray McBrian, of the Denver and Rio Grande Western Railroad Company, in the early forties, was the lone pioneer. He reasoned: foreign material did not belong in the crankcase. If found in small concentrations, it would serve as a warning of problems ahead. He convinced his management of the potentialities of the spectrograph and soon bought one. Today, the emission spectrograph is a valued tool on many railroads throughout the world. Routinely, a sample of crankcase oil is taken from each engine and brought in for a check-up. Spectrographically, its lead, chromium, silicon, iron, and often silver, copper, tin, aluminum and boron values are obtained and charted. Concurrent with spectrographic tests, other tests are run, all aimed at keeping trains on schedule.

Through the years, test engineers have told many stories about the spectrograph as a sleuth. L. S. Crane, of the Southern Railway, relates an early experience where his spectrographer reported about 300 ppm of lead and 500 ppm of copper in an oil sample. These figures would be instantly recognized today as a sure sign of real trouble. At that time, understandably, Crane was not so sure. Very gingerly, he suggested that the engine be torn down. Part after part was examined and part after part was found in perfect condition. The lab was in a ticklish spot for awhile. In the end, however, the lab's conclusions were verified. Not in the main bearing section, but at the accessory drive end a chewed-up bearing was found. Operated a little longer, the shaft itself would certainly have been torn apart.

The engineer of tests of another major railroad tells of finding high lead in the oil of a Diesel. Maintenance was quick to chide: that particular engine had *aluminum* bearings. But here, too, the lab had the last laugh. Upon examination, the main bearings were found to have a copper flash and a lead overlay, both of which were badly scored.



A badly scored bearing from a Diesel engine. The lead from the bearing was detected in the crankcase oil spectrographically and the engine was pulled out of service. Operated much longer, the engine would surely have had a costly breakdown.

The Spectrographic Laboratory

To get an idea of the magnitude of operations of a typical railroad spectrographic laboratory, first consider that up to 300 oil samples per day are analyzed—samples from engines which are hundreds of miles away. Depending on the railroad, the use to which the engine is being put and the make of the engine, oils are analyzed semi- to bi-monthly. This represents a mileage of 3000 to as many as 24,000 miles between analyses.

Most spectrographic methods involve ashing the sample. In a porcelain crucible, the oil is first ignited and then ashed at around 500°C. The ash is mixed and ground with a known weight of a buffer material. Lithium carbonate and/or graphite seems to be the most widespread buffer material. Standards like the Spex L Semi-quantitative standards are employed as references. The sample is excited in a dc or ac arc.

Since the ashing procedure is lengthy, many spectrographers have proposed direct burn techniques. An early one involved plunging two red-hot graphite electrodes into the oil. After drying, they were arced. This method has fallen into disuse, however, principally because its accuracy suffers when oils differ in composition.

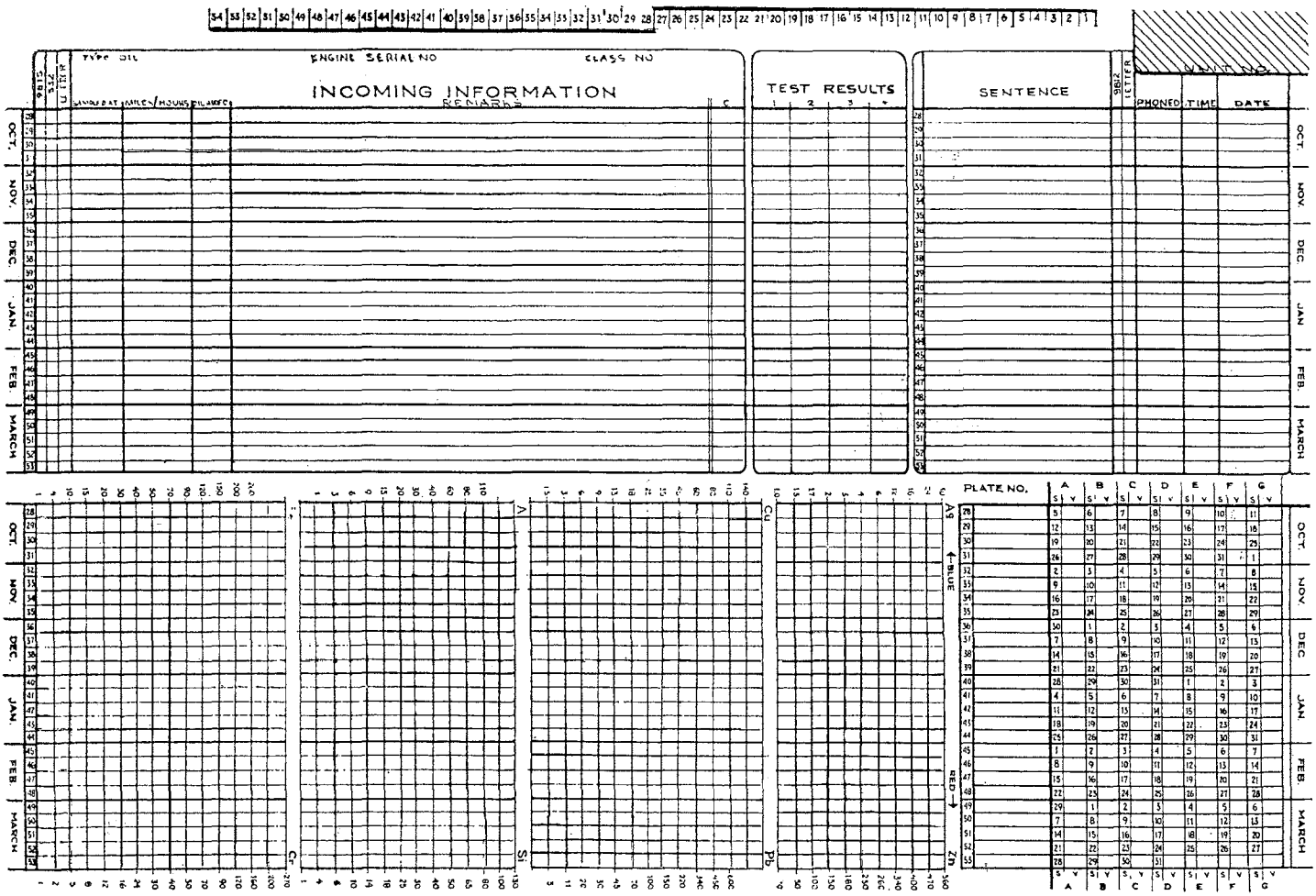
In another method, the oil is placed in a deep porous cup electrode and a spark directed to the floor of the electrode. This method, too, did not work satisfactorily for used oils. The sediment was filtered out by the graphite so that a representative sampling was not achieved.

The direct burn method that does work uses a rotating electrode. Here, a graphite disc dips into the oil using an accessory like the Combination Analyzer. A spark is directed to the top edge of the disc. The natural question is, of course, why don't all railroad laboratories use the direct burn technique? The answer is not clear. Among other reasons, it appears to be related to the instrumentation. Some laboratories, for example, have only dc arc sources which cannot be used in the rotating electrode technique. Other labs report that their spark sources are not hot enough for the required sensitivity. Still another reason pertains to the lube oils used. Some railroads have excellent control over the kinds and grades of oils used in their engines. Others, making it a practice to buy materials locally, have large variations in the additives used in the oils which adversely affect the accuracy of rotating electrode techniques. Using the ashing technique, on the other hand, differences in oils composition are compensated by the dilution of the oil with large amounts of buffer.

A compromise method was worked out by J. T. Rozsa, of National Spectrographic Laboratories. He devised a graphite platform electrode, a disc 1/2" in diameter with an annular groove in the surface. In this groove is dropped a sample of the oil to which is added an internal standard and buffer consisting of lithium and cobalt naphthenates. The disc is heated so that the oil is converted to a tar. This may be rotated horizontally in the Combination Analyzer while a spark is directed to the groove.

Other methods have been proposed although probably not so widely used. In principle, they involve coking the sample rather than completely ashing it, to save a good deal of time.

Record keeping in a spectrographic lab is, in itself, a for-



Data card used by Canadian National Railways for control of individual engines. The numbers on top of the card are punched at every check-up. This permits the lab technician to pick out an engine not checked during a certain period. Values for eight elements are plotted on the card. Any sharp change in the contour of an element may mean engine trouble.

midable task. D. R. Jackson, of the Canadian National Railways, uses a card about 10" x 15" for each Diesel engine on the line. The top edge of the card is slotted in a specific spot each month. In this way, a locomotive which has not been checked that month may be instantly spotted just by looking at the top of the deck of cards. On the face of each card are plotted values for lead, copper, chromium, etc. Any abnormal rise can be readily detected from a change in the slope of the line.

The Canadian National Railways have been able to reduce the time needed to record each oil analysis to 1.85 man-minutes, through the use of several interesting aids. Twelve data cards are placed alongside each other in a home-made calculator. With it, readings from the microphotometer are converted directly to percent concentration, and the actual value is recorded right on the card, which is slotted to take the point of a ballpoint pen.

Data other than spectrographic are often recorded on the card as well so that a complete picture of the "health" of any engine is immediately available. These other data are, by no means, less important than the spectrographic ones. In fact, too often do people tend to think of a spectrograph as a tool capable of diagnosing all impending trouble inside a Diesel engine. Nothing could be further from the truth. Used properly, the spectrograph works hand in hand with other tools. Results of many tests must be properly interpreted in any well conducted maintenance program.

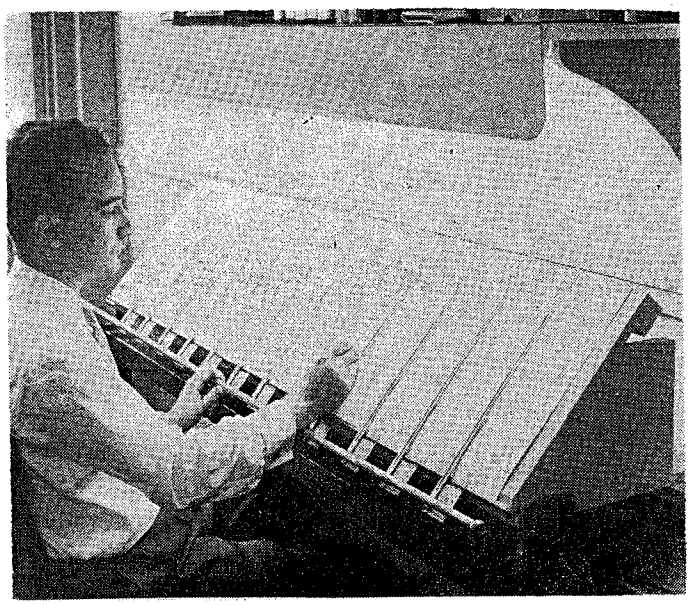
For example, there are physical tests, many of which are conducted on the engine itself. One is a blow-by test used to check the tightness of the cylinders. Air is blown into the engine and the pressure drop noted after a fixed time. Another important test involves a load-box to check the horsepower output of an engine. It must not be forgotten that a man with a dip-stick performs probably the most important maintenance check of all as he checks the level and the appearance of the oil every 1000 miles or so.

At the lab, meanwhile, a series of chemical tests is conducted to supplement the spectrographic analyses. Of these, perhaps viscosity is most important. A decrease in viscosity indicates a fuel leak, serious because of its effects on the lubricant. The shops generally conduct viscosity tests, too, since a simple viscosimeter is as inexpensive as it is important. Another test is used to determine the condition of the oil. In this, the used oil is extracted with pentane and the residue saved. It consists mainly of oxidized oil products and carbon. The amount of oxidized oil is determined by dissolving it in benzene. Oil containing above 1/2% of oxidation products is cause for drainage of the entire crankcase. The carbon is the result of blow-by and, in time, will require replacement of piston rings.

Interpretation

The engineer of tests must evaluate results from all of the tests at his disposal. Let's take a hypothetical example. A sample is received from one of the shops. There, the maintenance crew tossed a few drops of the oil on a hot plate—a check on the water content. Sizzling and spattering of the oil indicated the presence of water which can do harm to an engine. In the lab, the total amount of water is ascertained to appraise the seriousness of the leak. Of course, in this instance, the spectrograph would be too late. Its value would have been much earlier in detecting the leak through a rise in the chromium content. Small water leaks in an engine gasket are hard to detect directly because, at the operating temperature of an engine, the water evaporates. Remaining behind, however, is a deposit of chromium from the chromates

(*continued on page 6*)



Calculator used by Canadian National. With this home-made instrument, raw spectographic data are converted to percent concentration and values are recorded directly on the data card. Behind the twelve vertical scales are twelve data cards representing as many engines. The scales are slotted to accommodate the tip of a ball point pen. The use of two colors permits each chart on the card to be used for two elements.

DOCUMENTATION OF MOLECULAR SPECTROSCOPY (DMS)

Literature References

The DMS system of cataloguing infrared spectrograms and literature references has added still another service. At six-week intervals, a current literature list will be sent to all subscribers. The first list consists of about 150 references taken from journals of many countries. Key letters are used to tell the reader, at a glance, whether spectral diagrams are given, whether analytical applications are discussed, etc. The most important references will, of course, later be abstracted for the DMS Literature Cards.

Alphabetical Index

Several subscribers have stressed the need for a supplementary alphabetical index to the catalogued compounds. Although the exact form of the index has not, as yet, been established, it will be available shortly. Present subscribers are being polled to determine the best means of presenting such an alphabetical index.

Cards Currently Available

May we try to straighten out the confusion regarding the cards thus far issued. Consisting of 2000 cards, the first issue is designated 1956 but actually was distributed during 1957. During the first six months of 1958, the second (or 1957) issue is being sent to all subscribers.

Blank Cards

In order that subscribers may include compounds of their own choosing together with the regular DMS cards, blanks may be obtained. Sold only to subscribers, these are priced at $6.50 per hundred or $23.50 per 500.

SPEX MIXER/MILL

Price List

★ ★ ★

8000 Mixer/Mill, Grinder and mixer. 1/4 HP Motor, 115 vac,* 1-hour timer. Complete including shock-mounted housing attractively finished in gold hammertone, safety switch, continuously variable clamp jaws, but without vials. (Net weight 64 lbs., crated 85 lbs.)

Each $270.00

6135 Mixing Vial, polystyrene with polyethylene caps, 1-1/4" dia. x 3" long, 60 ml capacity.

Per 100 ..... $ 12.00
Per 1000 ..... $ 90.00

3112 Ball Pestles, clear Plexiglas, 3/8" dia.

Per 100 ..... $ 1.80
Per 1000 ..... $ 12.00

8001 Grinding Vial, Case hardened steel body with removable end plugs of hardened tool steel, 1-15/16" d. x 2" long, grinding capacity about 25 ml. With four 1/4" d. and two 1/2" d. hardened steel balls; total capacity about 70 ml.

Each ..... $ 32.00

8002 Mixing Jar, polystyrene with screw-on plastic cap, 2-1/8" dia. x 2-1/2" long, 130 ml capacity.

Per 100 ..... $ 20.00

8003 Ceramic Vial, made of 96% alumina-ceramic with a 1/2" diameter ball of the same material. Grinding capacity about 15 ml; total capacity about 40 ml.

Each ..... $ 32.00

8003A Ceramic Ball, made of 96% alumina-ceramic, 1/2" diameter, Spare (one furnished with 8003).

Each ..... $ 2.90

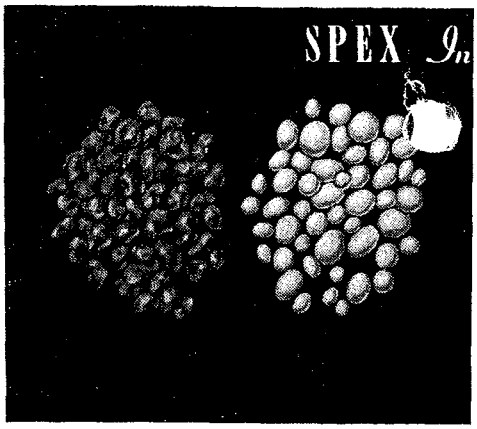
8004 Tungsten Carbide grinding vial with two WC ball-pestles, grinding capacity about 10 ml.

Each $125.00

8004A Tungsten Carbide ball-pestles, 7/16" dia.

Each ..... $ .85

* Available on special order for other suply voltages.



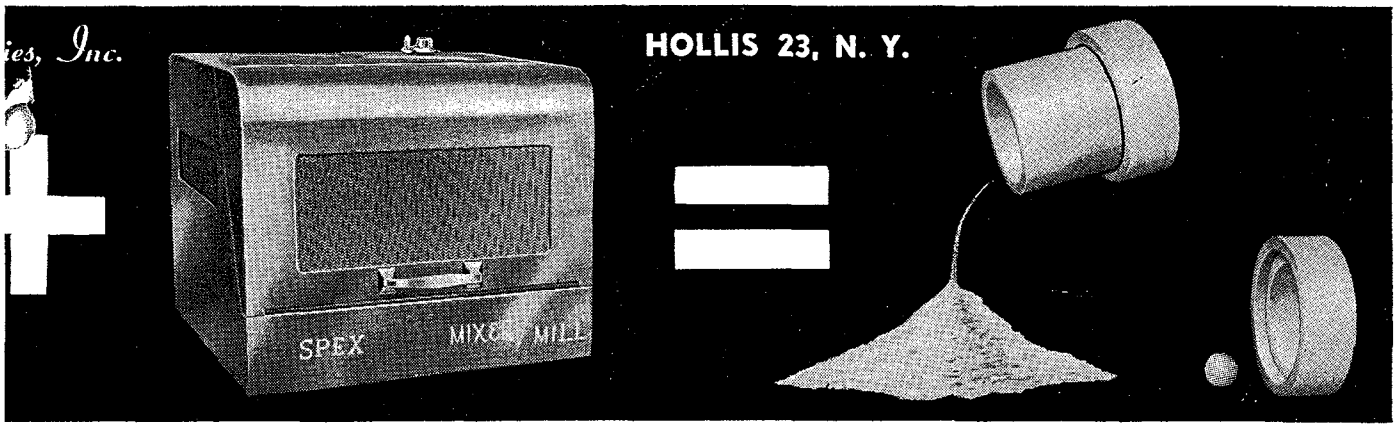
You will be interested in a few of i
grinding catalysts. Consisting of tiny bal
only because of the time required but beca
The Mixer/Mill makes short work of gri
the high-alumina ceramic vial.

As expected, unexpected grinding a
dust-free method of grinding carbonaceou
carbon in 1/4" chunks. Ten grams were
grinding of coal samples.

For x-ray spectrochemical analysis,
manganese, ferro molybdenum, etc. Anot
most techniques.

Try this new technique! Wet grin
leakage. Extraordinary improvement in s

Please send us your samples for g
promptly.



A couple of years ago, when we helped introduce the Wig-L-Bug as a spectrographic appliance, you told us that a larger strument would have many other applications. Our answer, the Mixer/Mill, was demonstrated for the first time at the Annual eeting of the Society for Applied Spectroscopy last November. Since then, over seventy instruments have been delivered.

ications. In petroleum laboratories, the instrument has been found excellent for ods, these materials are brittle but quite hard. Hand grinding is frustrating not frivolous beads skoot right out of the mortar when approached by the pestle. catalysts either in the tool steel vial or, in order to avoid iron contamination, in

Grinding ores, rocks and slags are applications in metal and geological labs. For this purpose, a newly introduced tungen carbide grinding vial promises even better results. Harder than most materials, tungsten carbide has the additional advange of introducing only tungsten and cobalt as impurity metals. These are not ordinarily objectionable as contaminants.

ions have cropped up. The Mixer/Mill has, for instance, been found to offer a rials. Before ordering an instrument, one company sent us a sample of activated to -300 mesh in about 5 minutes. Others are using the instrument for routine

uses the Mixer/Mill to prepare samples of ferro alloys such as high carbon ferro covered an excellent method for grinding mica which is extremely difficult by

Thus far we have spoken only of the Mixer/Mill as a grinder. It is equally successful as a mixer. Many labs find it e most convenient method of preparing large quantities of powder standards. The use of plastic jars and ball-pestles eliminates e danger of metallic contamination. Checks employing materials of different colors indicate that 100 ml of most substances ay be mixed intimately in less than 5 minutes.

now possible with the Mixer/Mill. Neoprene gaskets are provided to prevent f grinding and particle size reduction result.

or mixing. Kept in confidence, reports as well as samples will be returned

used to condition the water. This is what the spectrographer hunts for.

But the engineer of tests cannot take a high chromium value as a positive indication of a water leak. Used in alloy steels and as a plating on piston rings, chromium can occur from wear as well. The engineer looks for more clues. If, for example, there is a rise in iron as well as chormium, the ratio of the two would point to a particular type of steel. A new test is being worked out to differentiate chromates from chromium metal. It is based on the fact that chromates will color a lead nitrate coated paper strip.

Now we see the value of the spectrograph for determining both lead and chromium. The third tell-tale element is silicon. The principal constituent of road-bed dust, high silicon is an indication of an air filter not doing its job. Dirt is a bad actor in any engine. Alco, one of the major manufacturers of Diesel locomotives, reported results of some tests they ran on a crankcase oil before and after the injection of 1/2 pound of standardized dirt to an engine. After just 10 hours of operation, signs of wear began to appear spectrographically. Silicon values rose by a factor of 5 and lead began to soar. In practice, the engineer would interpret this as disastrous wear of the piston rings and liners as the result of a defective air filter. Such an event would be cause for pulling the locomotive off the road, at which time the piston liners would be checked and air filter replaced. If possible, the locomotive engineer, himself, would be warned of the danger by radio telephone.

Zinc is another element of concern, especially in Electromotive (General Motors) Diesels. Apparently, zinc above 20 ppm is corrosive to silver bearings used in the EMD engines. A few years ago, a zinc metallo-organic was used in some heavy-duty lube oils. When used oils from an EMD engine are checked spectrographically, zinc is thus sought.

Bonuses

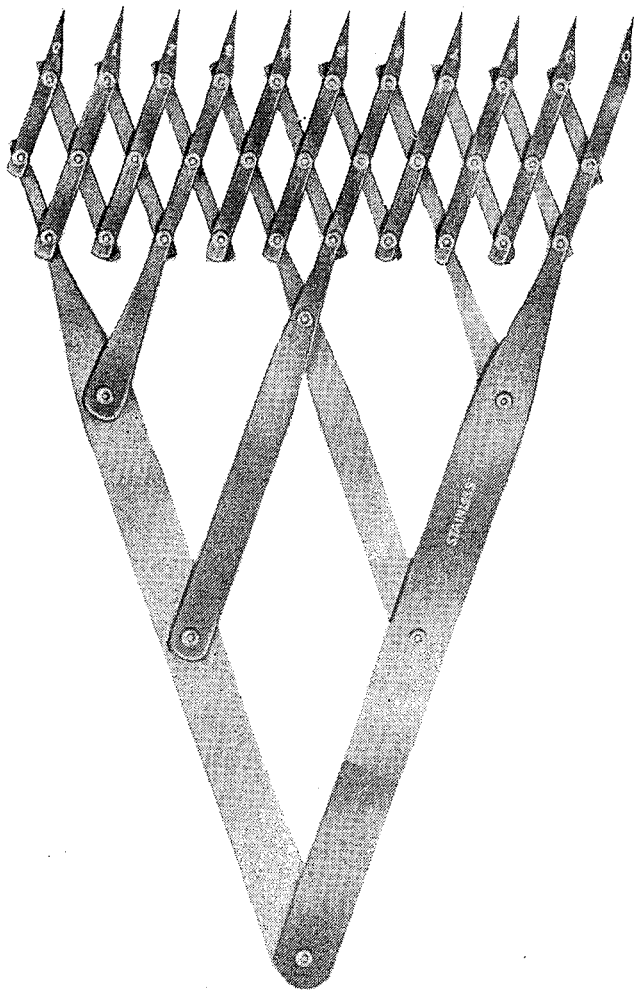
Every railroad which has purchased a spectrogaph has been rewarded with bonuses. Problems were solved which could not be handled by other means. For example, Miss M. E. Zietlow, spectroscopist, reported an application on the Rio Grande Railroad. A reconditioned generator shorted out soon after it was placed back in service. Its carbon brushes were found to have a metallic deposit. Examined spectrographically, solder components and copper were detected as exepcted. But silicon, too, appeared. Weighing the evidence, the engineer assigned to the job concluded that, after the generator parts were stoned, they had not been properly cleaned. The outcome was a factory replacement of the generator.

L. L. Kathan, of Alco Products, told us how his laboratory was able to save a great deal of time in the analysis of a batch of 200-300 samples of Monel tubing. First, all the samples were subjected to spectrographic analysis. On the basis of the tramp elements found, the samples could be separated into seven heats. It was then necessary to run but seven complete chemical analyses instead of several hundred. Spectrographically, the improper parts were easily found and discarded.

Another place where the spectrograph is turning out to be valuable is in the analysis of Diesel fuels. Often, unrefined residual or bunker fuels are used. In these, traces of vanadium or nickel may be present and are bad actors. They are corrosive and gum up the fuel system. Tank cars of such fuels are first approved spectrographically before use.

Money in the Bank

Such bonuses are one reason why it is difficult to equate the spectrograph to money saved for the railroad. Nevertheless, appraisals have been made. To make the appraisal, the railroad thinks in terms of the entire company and the entire



Spacing Divider No. 3506

preventive maintenance operation. That is, the spectrographer, with perhaps a $40,000 laboratory and the oiler with his dipstick must be lumped together. Because of the indirect, as well as the direct savings effected, estimates of money saved vary quite a bit. Thus, J. J. Wright, Director of Technical Research, estimates that the New York Central System's annual savings amount to $16,000,000. In addition to the prevention of costly breakdowns, Wright cites the extension of Diesel overhaul periods, which, in turn, has led to the need for fewer maintenance shops and less personnel. Some indirect benefits are in the form of invaluable good-will. Breakdowns mean delays. Perishables spoil; production schedules are bottle-necked; tempers of passengers are strained.

The New York Central estimate of its annual savings comes to about $7,000. per unit. Because of the intangible factors mentioned, two other railroads estimate that their savings amount to, respectively, $2,000. and $800. per unit per year. On the larger railroads, employing as many as 2500 units, these figures add up to annual savings of millions of dollars.

Acknowledgments

I owe many thanks to the wonderful cooperation of the following people who so generously supplied information, permitted me to interview them, and weeded out errors in the manuscript. These are: L. L. Kathan and J. A. McGowan, of Alco Products, Inc., D. R. Jackson, of the Canadian National Railways, Martha E. Zietlow, of the Denver and Rio Grande Western Railroad Company, J. J. Wright, of the New York Central System, and D. E. Parker, of the New York, New Haven and Hartford Railroad Company.

—A. J. MITTELDORF.

tricks of the trade

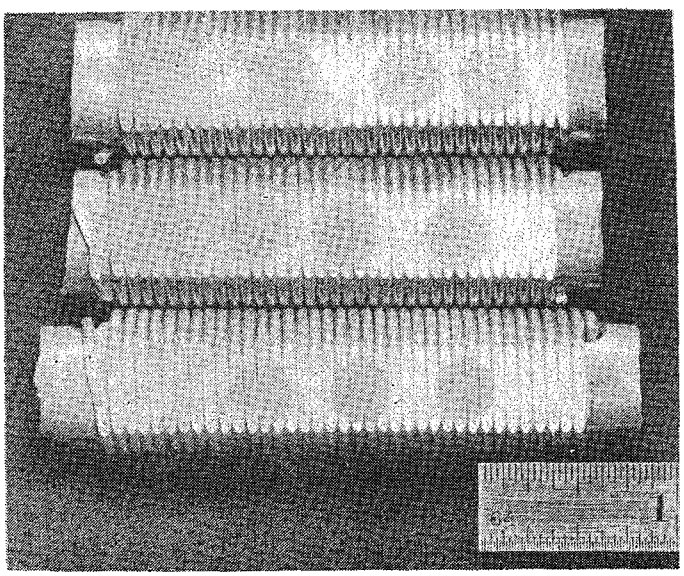
SPACING DIVIDER

Found in every emission laboratory is a well-worn copy of the MIT Wavelength Tables, evidence of how much time is spent by the spectrographer in measuring wavelengths of spectral lines. On prism spectrographs, such measurements are particularly troublesome because of the non-linearity of dispersion. But even on many grating instruments measurements are hampered by varying dispersion, especially when the wavelength region is shifted.

Here the SPACING DIVIDER is a valuable time-and-effort saver. With it, measurements are made by interpolation or extrapolation using the distance between two known lines as reference. An accurately constructed pantograph-like drafting tool, the instrument has eleven teeth so arranged that they always divide the extreme setting into ten equal parts. As pictured, each tooth is numbered, left to right on one side, right to left on the other. Suppose you want to measure the wavelength of a line in the 2500A region. Right on the microphotometer screen, the instrument is set on the silicon 2506.9 and 2516.1A lines, 9.2A apart. Then you simply read off the distance directly in angstroms from a known line to the unknown. Estimates to better than 0.2A are generally possible.

There are two models of the SPACING DIVIDER, both precision tools constructed of stainless steel. The 6″ instrument has a maximum spread of 23 mm. and a minimum distance between teeth of 3 mm. The minimum distance between teeth on the 12″ model is 6 mm., maximum, 47 mm. The smaller instrument is recommended for most spectrographic measurements.

3506 Spacing Divider, 6″ model $35.00
3512 Spacing Divider, 12″ model $40.00



Sparking to a wire which has been wound around a metal tube and then sanded flat. The tube conducts away the heat so that the spectrograms match those obtained with flat samples.

Dr. E. S. Hodge, of Mellon Institute, in an address before the Spectroscopy Society of Pittsburgh, presented a host of innovations developed in his laboratory. Of special interest are:

SECOND ORDER FILTER

A Wratten K-2 filter used by amateur photographers is ideal for cutting out the second order on a grating spectrograph. Standard ring holders are available to snap on the lens stand of a spectrograph.

CALCULATORS

Disk calculators have been described in the literature. They are especially useful in non-routine laboratories where the work necessary to set up a calculating board is often not warranted. To make one, the scale of a circular slide rule is photographed and enlarged to 10-inch diameter. This is then fastened to a disc of 1/16″ aluminum. A smaller disc 8-1/2″ indiameter is covered with a sheet of white paper and %T values are put on a circular scale in the same way a linear scale is made. According to Ed, this is one of the greatest time savers in his lab.

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MOUNTING SAMPLES

1) Mrs. Daisy Terwilliger and Mr. Raymond Scott of Sikorsky Aircraft have found a neat way of mounting rods and wire on the Petrey Stand for sparking. Rod standards, like those supplied by the British Bureau of Analyzed Samples and the National Bureau of Standards, are force-fitted into a steel cylinder drilled through to accommodate the rods. Positions of the rods are inscribed on the outside of the cylinder for ready reference. To resurface all of the rods simultaneously, the entire cylinder is sanded or faced off in a lathe.

2) To mount wire, the sample is wound on a cylinder of aluminum or copper (to conduct away the heat). The wires are then flattened on a belt sander and this surface sparked. Mrs. Terwilliger reports that samples so prepared burn quite similarly to disc standards and working curves are used without correction factors.

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CARBON ELECTRODES

Louis E. Owen, of Goodyear Atomic Corporation, pointed out that, in our article last year on spectrographic electrodes, we skimmed over carbon (as distinct from graphite) electrodes. According to Owen, these are quite useful, especially for the analysis of refractories. Although somewhat hard to grind in the laboratory, both National Carbon and United Carbon Products, will, on special order, machine preforms from this material. A recent article in *Applied Spectroscopy*, by J. W. Mellichamp and J. J. Finnegan, describes the advantages of carbon as a means of enhancing the sensitivity of many elements.

May we quote you on special carbon as well as graphite preforms? Send for our chart showing the many kinds of preforms and rods which we stock for immediate delivery.

ILFORD SPECTROSCOPIC Q PLATES

The Ilford Q emulsions, unsensitized and containing little gelatin, have a spectral range that extends from the x-ray region to about 5000A. Although they are widely used for vacuum spectroscopy, they are also valuable to the spectrographer in the region 2000 to 2400A. Here the gelatin in other emulsions absorbs most of the radiation and spectral lines that do appear tend to be "washed out" in appearance. By contrast, lines on a Q plate are crisp, black and well suited for densitometric measurements. If you are interested in determining elements such as the following in trace concentrations you will want to try Q plates:

Arsenic	2288A	Phosphorus	2149A
Antimony	2311	Selenium	2068
Cadmium	2288	Zinc	2138

They are available in three types, the highest speed emulsion having least resolution and contrast. We shall attempt to maintain stock in the 4" x 10" size.

Q1 **Ilford Photographic Plates, 4" x 10",** lowest speed

Q2 **Ilford Photographic Plates, 4" x 10",** medium speed

Q3 **Ilford Photographic Plates, 4" x 10",** highest speed

Per dozen ..... ~~$9.13~~ 8.50

MEETING NOTICES

Cleveland Society of Spectroscopy, Third Annual Conference to be held at Tomlinson Hall of Case Institute of Technology, Cleveland, Ohio, May 21, 1958. Chairman, R. W. Loofbourow; W. F. Meggers will speak.

American Association of Spectrographers, Ninth Annual Symposium on Spectroscopy to be held at Pick-Congress Hotel, Chicago, Ill., June 9-11, 1958. For information contact Grace Marsh, Standard Oil Company of Indiana, Whiting, Indiana.

Rocky Mountain Spectroscopy Society, First Annual Conference, Denver, Colo. Aug. 11-12, 1958. For information contact A. T. Meyers, U. S. Geological Survey, Denver, Colo.

Denver Research Institute, Seventh Annual X-Ray Conference, to follow on Aug. 13-15, 1958.

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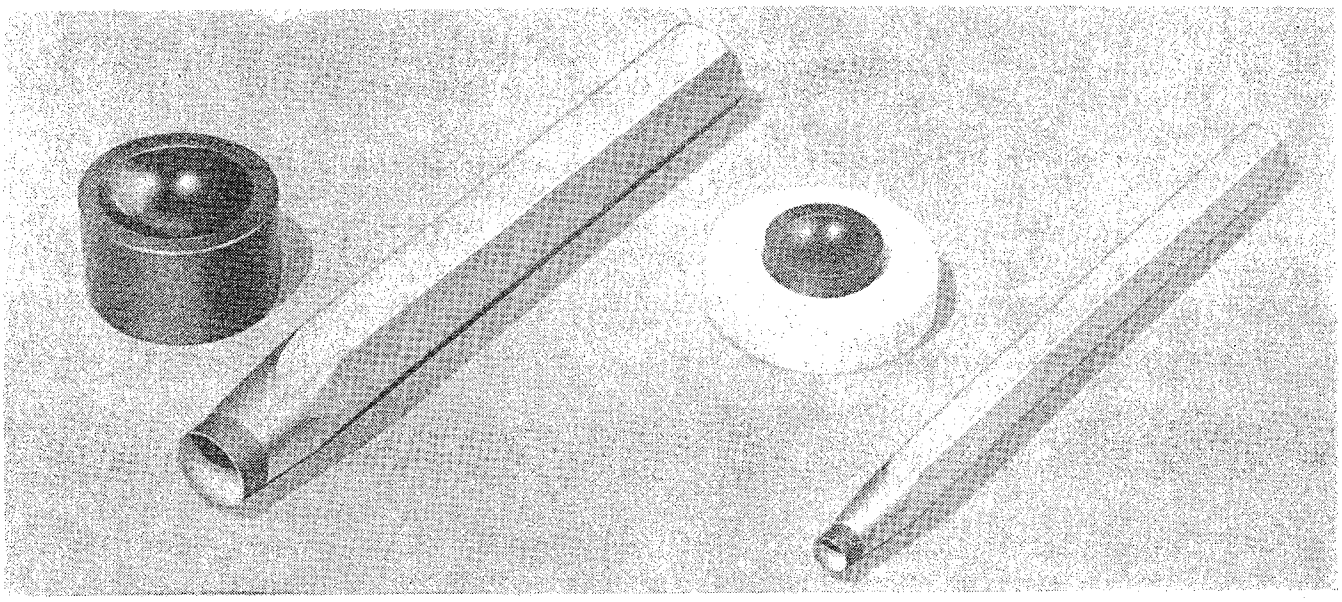
NEW WIG-L-BUG VIALS

Under cat. no. 3111, we supply plastic vials 1/2" d. x 1" long for mixing samples in the Wig-L-Bug. Inexpensive enough to be disposable, they are ordinarily used to mix and store a single sample. Recently, we modified the design of these vials to improve mixing and facilitate removal of the sample. Instead of a square corner on the inside, bottoms of the new vials are rounded. Packing in the sharp corners, which sometimes occurred in the older vials, is thereby eliminated. At the same time, the bottom has been thickened to increase impact strength considerably.



BORON CARBIDE MORTARS AND PESTLES

Boron carbide is one of the best materials for hand grinding. Possessing a hardness close to diamond, it is also extremely inert, resisting attack by most acids and alkalies. In addition, boron carbide is unbonded so that the only possible metallic contaminating element is boron itself. Here it differs from, say, tungsten carbide which is usually bonded with cobalt. The material from which the mortars are produced is made by the Norton Company. Compressed under great pressure, its density approaches the theoretical value.

As pictured, the smaller mortar is mounted in a removable plastic base for ease in handling. Pestles are attached to an aluminum handle.

We can supply mortar and pestle combinations with cavities ranging from 1/2" to 3" in diameter. Also available are double cavity mortars—a crater on both ends of a cylinder. Please write us for price and delivery information on these special sets.

3201 **Mortar and pestle, boron carbide.** Mortar cavity 1/2" d. by 5/32" deep, highly polished. Pestle 1/4" d. attached to aluminum handle **per set** **$35.00**

3202 **Mortar and pestle, boron carbide.** Mortar cavity 1" d. by 1/4" deep, highly polished. Pestle 9/16" d. attached to aluminum handle **per set** **$77.00**