THE SPECTROGRAPH AND ITS APPLICATION TO INDUSTRY AND MINING

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The subject of the spectrograph is divisible into three parts which are: (1) what is it?, (2) what does it do?, and (3) what is its commercial value and how can it be used.

(1) *What is it?*

The spectrograph is a measuring and recording machine which will resolve and break up light into its component parts. It measures the light emitted in the volatilization of any substance. Two types are in common use (1) quartz prism and (2) grating spectrograph, both of which resolve light. The latter is most satisfactory. Substances may be volatized by a gas flame, a spark or a carbon arc. The flame is used for solutions and the alkali metals, the spark for gases and easily volatile elements, while the arc is best suited for general work.

The quartz prism instruments do not resolve the light uniformly, e.g. the waves are not evenly spaced from one end of the spectrum to the other, thus making it necessary to resort to higher algebra in measuring every critical line. This mechanical difficulty has inhibited the commercial development of spectrograph and while the instrument is useful to scientists and astronomists who measure time in light years and deal in the abstract, the prism spectrograph is not in general use. Those of us who must find the answers quickly demand a rapid method. Consequently, it was not until the development of a grating spectrograph by Drs. Lindhurst and Hasler at California Institute of Technology, that the instrument began to receive general application. Dr. John Herman (*) installed one in his laboratory in Los Angeles in 1935 and has published a short description of its application. Other instruments are in use throughout the world by assayers, chemists, metallurgists, industrialists and criminologists. Such a grating spectrograph has been installed by Marsman & Company at San Mauricio Mining Company.

The grating is a metal disk three inches in diameter made of a special alloy. One face has a slight inward curvature and upon this face 48,000 lines are ruled one inch long. In a two inch space these lines are cut automatically in a continuous run of six days and nights. If the machine stops before covering the two inches, the work is ruined.

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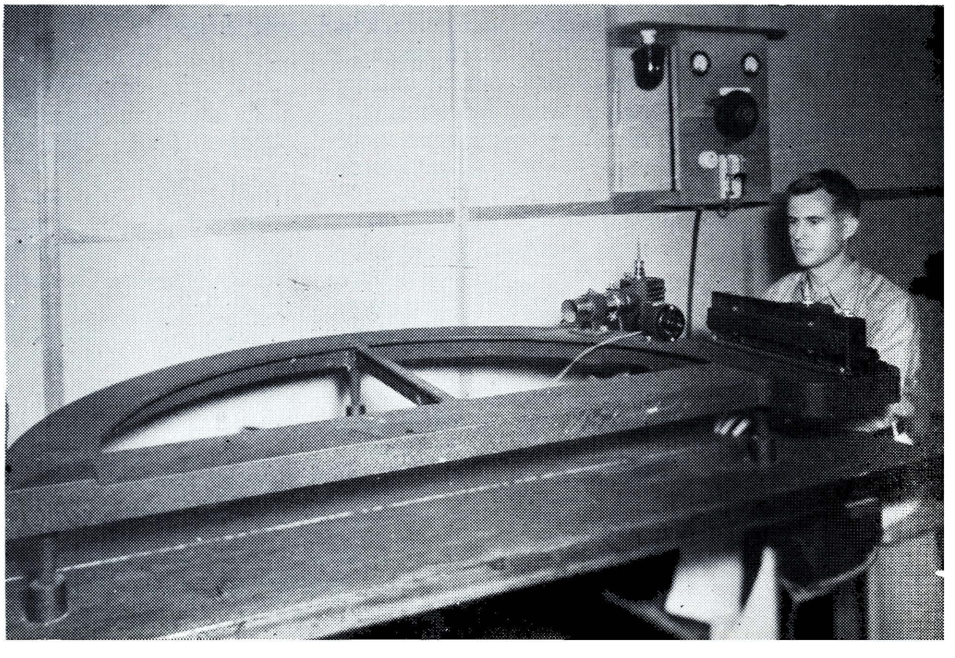
(*) Herman, John—Arc Spectrograph for Mineral Analysis, F. & M. J., Vol. 136, page 632, 1935.



The tube and slit (from left to right) which control the amount of light from the arc house at the far end of the tube. The film is exposed by opening a hinged cover across the front. In the background is a switchboard which controls the direct current supply for the arc. Mr. DeVore is seated at the spectrograph.

The great number of lines gives the grating a higher resolving power than the prism instrument and permits the separation of two spectrum lines 0.1 Angstrom unit apart. Photographic speed is obtained by evaporating aluminum on the surface of the disk giving a high reflecting power.

The camera uses film in place of plates used in prism instruments and which adds greatly to the speed of operation, and unlike most cameras has no lens but simply a long slot which exposes 12-1/2 inches of film at one time. The camera is moved up and down so that four spectrograms can be photographed on one length of film.

Only one lens is used and is placed in front of the arc to keep out harmful fumes and to illuminate the slit evenly. The slit confines the received light to a narrow beam from 0.01 to 0.03 centimeters in width and it can be opened or closed at will.

The samples are volatized by carbon arcs 1/4 inch in diameter. An one-eight inch hole is drilled in the lower rod 1/8 inch deep to hold the powdered sample. In the case of metallic samples rods of the metal may be used for arcing or when only a few milligrams are available they can be placed in the drilled carbon just as any other sample. Direct current of five amperes at 200 volts is passed through the electrodes for one minute which completely melts the sample and volatizes a large part. These volatile fumes give off the light which is reflected and photographed, thereby making a permanent record. The technique is being improved constantly and it is expected that eventually a great deal of chemical work will be done by the spectrograph, for it has only been within the last few years the spectrograph has become a practical instrument. A further improvement has been made in reading and interpolating the results by projecting the film on a screen. Before this innovation it was necessary to use a microscope but it is now possible to read the results as they appear on the screen with none of the eye strain which always results from microscopic work.

(2) *What does it do?*

Nearly all of the known elements which are of economic value are determinable qualitatively and quantitative results are obtainable to the nearest factor of ten. In special cases for a complete study of one or more elements quantitative work, 90 per cent accurate, can be obtained in the determination of minute percentages of many elements. Most of the elements even if present as one part in one hundred thousand are recorded and many of the elements present as one part in a million can be distinguished and the quantity estimated.

The following elements can be determined. The approximate lower limit is given for those elements when this limit is known.

ELEMENTS DETERMINABLE BY THE ARC SPECTROGRAPH

Elements-Lower	*Limit*		*Elements-Lower*	*Limit*		*Elements-Lower*	*Limit*	
Aluminum	.001	%	Holmium			Rubidium		
Antimony	.01	"	Indium			Ruthenium		
Arsenic	.01	"	Iridium			Samarium		
Barium	.001	"	Iron	.001	%	Scandium		
Beryllium			Lanthanum			Silicon	.005	%
Bismuth	.01	%	Lead	.001	%	Silver	.0003	"
Boron	.001	"	Lithium	.005	"	Sodium	.005	"
Cadmium	.005	"	Lutecium			Strontium	.005	"
Cesium			Magnesium	.001	%	Tantalum		
Calcium	.001	%	Manganese	.001	"	Tellurium		
Carbon			Molybdenum	.001	"	Terbium		
Cerium			Mercury	.01	"	Thallium		
Chromium	.001	%	Neodymium			Thorium		
Cobalt	.001	"	Nickel	.001	%	Thulium		
Columbium			Osmium			Tin	.005	%

Copper	.0001 %
Dysprosium	
Erbium	
Europium	
Gadolinium	
Gallium	
Germanium	
Gold	.005 %
Hafnium	
Pelladium	
Phosphorus	.1 %
Platinum	
Potassium	
Praseodymium	
Radium	
Rhenium	
Rhodium	
Titanium	.004 %
Tungsten	.004 %
Uranium	
Vanadium	.004 %
Yttrium	
Ytterbium	
Zinc	.006 %
Zirconium	

(3) *What is its commercial value and how can it be used?*

Economically the spectrograph has been applied to practical use by industry, chiefly chemical manufacturing and metallurgical engineering. It is used in a minor way by criminologists, assayers and geologists. Only within the last few years has the method been available to the geologist and mine operator as a practical way to solve their problems.

It opens up new possibilities for profit to the miner. Most samples are assayed for gold and silver and any base metal which the eye shows to be present. This visual method of assaying was one of necessity since few prospectors have the financial backing to have even one sample completely analized at a cost of nearly ₱400.00. The well organized mining company has not gone to this expense, not that this amount is too high, but that it is customary to take so many samples in evaluating a prospect that such a procedure would make prospecting prohibitive. The spectrograph meets the challenge by completely determining an hour's time all elements found in prospecting and mining.

A consideration of its possibilities leads to the conclusion that spectrographic analysis are especially applicable to such Arts and Sciences as:

(1) Chemical Industry
(2) Metallurgy
(3) Mining and Geology
(4) Chemical research
(5) Criminology

All chemical process must be controlled by the laboratory and any method of saving time in analizing samples will be reflected in greater profits and closer control of supplies and manufactured products.

Some of the many industrial uses are as follows: Determinations of undesirable elements in industrial water or the causes of corrosion to pipes and boilers. In the manufacture of Sulfuric Acid any element harmful to the catalyst can be determined in the source of sulfur even before the latter has been completely volatized. The causes of poor hydraulic properties in cement when due to elements present in minute quantities can only be determined by the spectrograph. The composition of clays suitable for brick and pottery can be determined at small cost. In the mixing of paints any adulterant not suspected or the cause of off color pigments is quickly shown. Sugar factories using considerable bone black, lime, and sulfur for bleaching, must be certain that no impurities are present which cause a low yield or off color product. These impurities are most efficiently determined by spectrographic analysis. The textile industry finds a ready use for the spectrograph in the analysis of dyes, mordants, and metallic fixing agents in order to prevent impurities which may cause fading or poor colors. In the manufacture of explosives rigid control of all supplies must be maintained in order that no unknown may creep in and lower the efficiency or cause premature detonation. Glass production requires close control of traces of certain oxides which cause undesirable colors. The determination of these traces is a long drawn out procedure, however, the spectrograph quickly shows all traces present with a considerable saving of time and money. These are only a few of the many uses but serve to show the wide application and diversity of this method of analysis.

Metallurgically the spectrograph is particularly useful to the metal industries. Small amounts of impurities in metals greatly affects their working qualities and are difficult to determine chemically. Elements requiring a day's time to analize by the usual means are determined by the spectrograph in a few minutes, and furthermore, many elements entirely unsuspected will be revealed. The latter are often the cause of faulty brass and iron castings or the explanation of poor machinability of wrought metal and alloys.

In mining the principal uses are:
(1) Study of ore body zoning
(2) Mineral and rock determinations
(3) Prospecting
(4) Ore testing

1. *Ore Body Zoning*

Ore body zoning is of vital importance to the operator and the geologist and quantitative spectrographic analysis offers a means of easily determining the variables. It serves as an aid to finding ore and prevents much unprofitable exploration. The saving in unprofitable exploration will more than cover the cost of all spectrographic variables.

Ore body zoning is defined as special variation of minerals and elements about and within ore.

Manifestly any change around an ore body which shows consistent variation may serve as a guide to ore and thus it is of vital economic importance to mine operators to determine these variations.

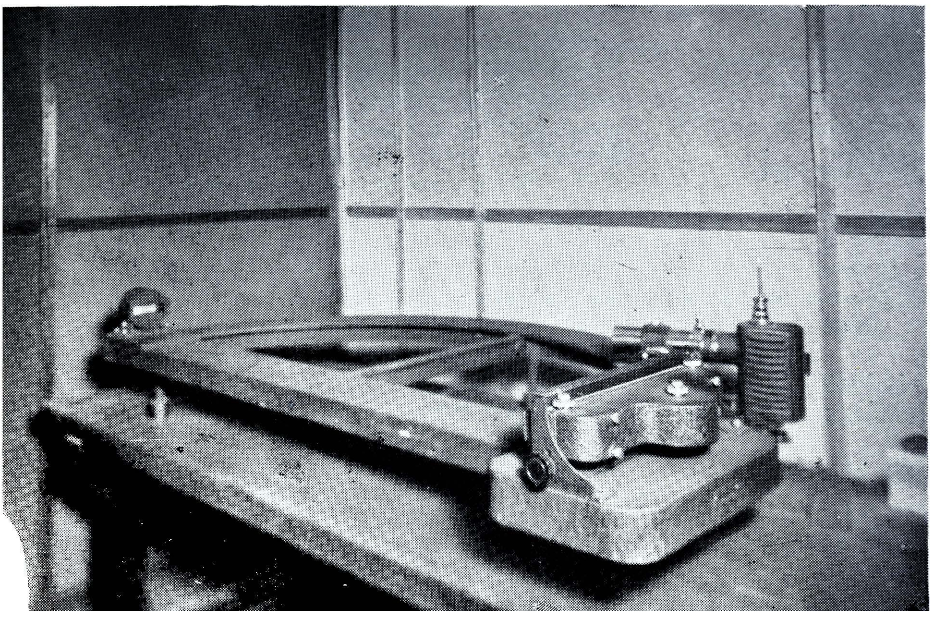
2. *Mineral and Rock Determinations*

Recent work is confirming the known fact that minerals which appear to be homogeneous and of uniform composition carry varying proportions of minor elements, forming imorphous groups which change their physical and optical properties in direct relation to the percentage composition. This is especially true of ore minerals and the spectrograph offers a means to determine these variations quickly on a small amount of material. Impurities and inclusions in ore minerals are commonly of minute size and it is difficult to collect a quantity of known pure mineral sufficient for both a chemical assay and fire assay. Small amounts of pure sample can be collected readily, and by using a microdrill under low magnification pure powder samples can be collected from small patches of pure material on a polished surface. The exact minimum quantity required for a spectrographic analysis depends upon the nature of the mineral, usually 10 milligrams is the minimum for a complete analysis but it is possible to decrease this quantity occasionally.

3. *Prospecting*

In prospecting, river beds and creeks concentrate minerals from hillside and these concentrates are a good indication of what may be found in the surrounding area. Large areas may be covered quickly by interval samples along the strike or at discovery, end and side monuments.

In many area which are thickly covered with bush, road cuts often indicate the presence of hidden ore bodies. Wide samples may be taken because of extreme delicacy of spectrographic work enabling large area to be covered at less expense in addition to revealing the presence of many minerals overlooked in the usual gold and silver assay. Only



This picture shows the grating, at the left, which breaks up the light given off by the arc and reflects on the camera. A side view of the arc house is shown. A door at the right of the house opens in order to place the samples in position for arcing.

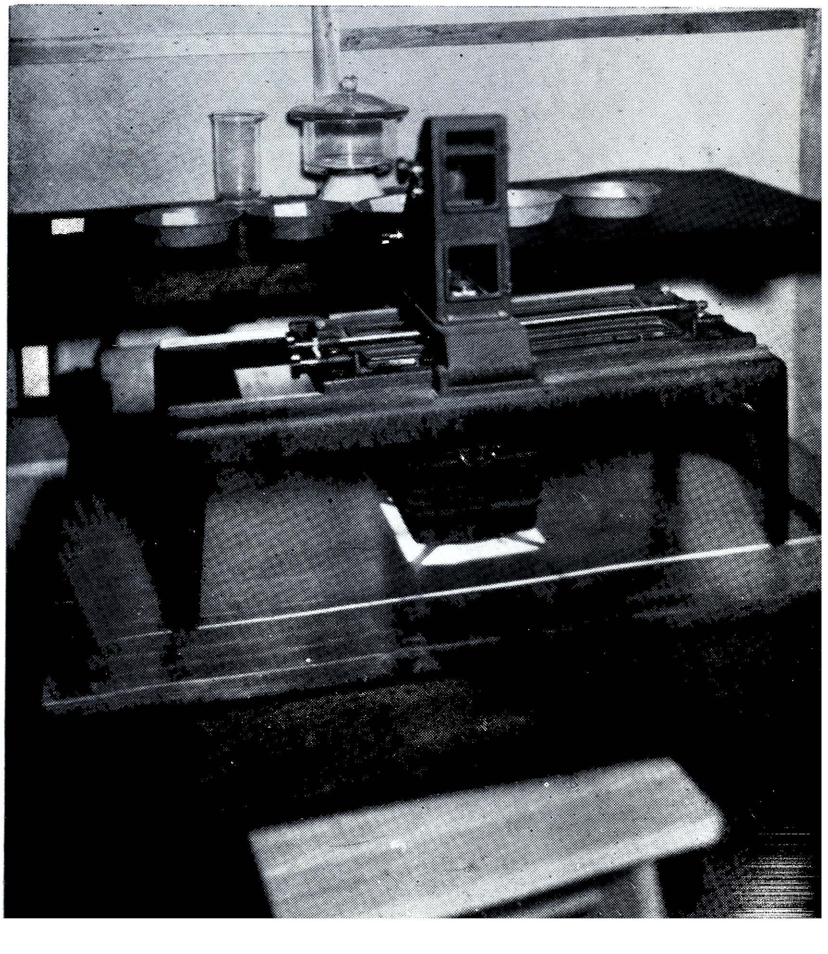
one sample would be necessary to analyze an entire diamond drill core and in case of favorable results the core is divided into sections which will then give the location of important minerals. Even formations favorable to oil and their depth are quickly shown.

The spectrograph is particularly valuable in ore testing by saving considerable time in useless experimenting. In cyanide tests the presence of harmful elements can quickly be determined, while in flotation all the metals which will or can be floated are indicated. In both cases no intelligent approach to ore testing can be made without knowing the composition of the ore to be tested, and these can be determined by the spectrograph in a few minutes and at less cost than determining the principle gangue minerals in an ordinary pulp.

The spectrograph offers a new tool to the research worker. One with which he may cut corners, drive direct and straight to the conclusion of his problem without spending useless time in checking over more possibilities, and days proving or disproving the absence of some minor element. In the ordinary course of laboratory work the spectrograph not only identifies the elements but also detects one thousandth percent in many complex mixtures, even if only a few milligrams of material are present, an impossibility to chemical analysis. Many physicists have attempted to establish certain physical constants, such as melting points, latent heats, expansion co-efficients, electrical resistances, with extreme precision and yet were ignorant of the amount of impurities present which are so quickly determined by the spectrograph.

The spectrograph offers the criminologist a new means of combating crime. He may now positively identify small bits of evidence and in many cases, definitely establish their origin, and not only be prepared to offer photographic evidence free from the personal equation, but to present it in such a way that even a jury will understand.

In conclusion the spectrograph brings to industry and mining a direct, efficient and inexpensive method to determine the causes of defects, poor quality, and failure of materials to react properly. The services of this modern and up to date equipment are offered to all those who wish to avail themselves of its wonderful and marvelous possibilities.



This is the projector. The film, after developing and drying, is placed in the carriage which moves back and forth over the lamp by means of a knob in the rear, and is projected on a screen six feet in front.