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AUTOMATED ON-LINE ANALYSIS FOR CONTROLLING INDUSTRIAL PROCESSES

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Abstract - Production economics and the need for continuous survey of the production process dictate the need for rapid on-line assays. It is essential to consider all aspects of on-line analysis and automation, especially in the area of primary and subsequent sampling. More than 50 on-line analytical systems are now in use in a number of industries where processes can be automatically controlled. Many are operating under closed loop control. Dry powder processes such as cement, coal, iron ore, dried slurry, glass kiln feed, etc. can be controlled by automatically grinding, briquetting and presenting the sample to a Quantometer and by utilizing the 20 element assay obtained in 30 seconds as the input to digital controllers. In the cement industry the analysis is used to control weigh feeder belts and so eliminate the need for blending silos. It can be shown that the energy savings alone are more than sufficient to amortize the system in a year. In the mining industry all elements from Si to U are assayed in slurries. As many as 20 streams are assayed in 10 minutes. All assays are supplied by computer in dry weight percent including all corrections for pulp density and other elements. Many solutions can be readily analyzed for elemental concentrations down to 0.25ppm in an on-line mode. Oils can be analyzed for S and blended to ensure that the percent S in the final blend is correct prior to shipment. Oil blending systems can drastically reduce the blending and loading time of containers. Rapid amortization is obtained by reduced time and turn-around of vessels. Savings are obtained from on-line mining systems by increased throughput, increased recovery, reduced reagents, reduced maintenance and total reduced costs.

INTRODUCTION

The analytical chemist was largely responsible for promoting the use of x-ray analysis in the production control laboratories of practically all of the industrial processes in operation today. The need for higher recoveries and more production from inferior orebodies placed a heavy load on the laboratories. The need for better quality and higher purity, both of the product and the wastes increased the workload still further. This increased workload, combined with the shortage of analysts, created the need for more and more automated production analysis and on-line analysis.

To date the number of laboratory x-ray analyzers is in the many hundreds. In the cement industry the x-ray analyzer is regarded as, and can be certified as, equal to the analyst in accuracy and performance. Cement producer's groups have been very instrumental over the past years in performing comparisons of the various means of analyzing cement products and in the testing of many involved methods of handling and processing the samples of their industry. Of course, this is also true of the analysts in the metals industries and in mining. The x-ray fluorescence analyzer has been well tried and tested on practically all elements of interest and the techniques developed for analyzing various products have proved to be very stable and accurate.

In all industries a common problem existed, and that is, is the sample to be assayed representative of the product? Many varied means of extracting what was hoped to be the "correct" sample, were developed. Even when the correct samples were determined to have been extracted, by the time the analytical results were obtained and verified, the information was only of historical value.

Many automatic samplers were constructed and operated. These devices efficiently extracted large volumes of sample, but only a small portion could be usefully analyzed at any one time due to a lack of analysts to prepare and assay the samples. The next obvious step was to automate the entire procedure from the sample extraction to the information output.

In order to prevent the information from becoming history, it was necessary for the overall time to be short. With the high speed throughputs of modern plants an analysis should not exceed five minutes in time.

Basically the industries separate into two types of analysis, wet and dry. The wet systems are primarily in the mining concentrators and analyze flowing slurry. Other wet applications are solution extraction processes and blending of oils etc. Dry systems are mainly cement, phosphates, bauxite, and coal etc. Increasing in interest is iron ore, sinter plants and high volume laboratory samples. Each application of automated analysis has its own problems and methods of handling samples.

In order to obtain relevant and accurate data, the x-ray techniques developed for use in the laboratory were adopted. This permitted the systems to be calibrated and tested against standard analytical techniques developed and used by the analyst. In all systems except oil blending, more than one element was needed to be analyzed and density variations were always present as wet and dry specific gravity variations in wet systems and dry specific gravity variations in the dry samples. The assay of some products necessitates as many as 15 elements to be analyzed to obtain the correct data. As many as 25 streams of flowing slurry and 6 to 7 dry products are handled by the systems in use today. Although the systems are composed of standard components a certain amount of customization is necessary, as all product plants are different. This is true not only of the hardware, but it is also applicable to the software that is used in the computer programs.

Generally a small dedicated computer is preferred for such systems. Now with the advent of microprocessors, practically any computer or system can be interfaced with relative ease. In order to obtain and maintain maximum efficiency and "uptime" of the systems, diagnostic routines are used in many systems. Some are sophisticated enough to notify anyone of a possible or actual fault and its location, and also to issue instructions as to the method or procedure for correction of the fault. Increased product safety regulations have also required that methods of insuring safety are also built into the system and protected by software. The programs relating to the general operation of the plant, the analysis of the process control loops are all readily available for rapid change by the operator without the need for any special programming knowledge.

Now that there are a number of closed loop control systems based on analysis in use in many parts of the world, it appears that the reasons for their existence and their subsequent justification are many and widely varied. In general the justifications vary as to geographical location, the type of product and the available labor force.

DRY SYSTEMS

Laboratory x-ray fluorescence analyzers have now been in use for over 20 years. The major use has been in production control in all types of industries. Ever increasing use, advances in technology, new methods of sample handling and preparation techniques have now produced reliable analyzers capable of analyzing up to 23 elements simultaneously and of handling hundreds of samples a shift. (Figure 1) Sample collection and preparation is costly and time consuming. In an attempt to alleviate this problem the analyzers have been equipped with many various types of automatic sample handlers, allowing the analyst and operator more time for sample preparation.

As demands for more data and process control advanced, a number of automatic sample systems were developed. These consisted of a primary sampler delivering the sample to either a moving belt, a slow rotating wheel or filling metal cups etc. All these systems demonstrated that more work needed to be carried out in this area. As none of these systems prepared the sample in a like manner to the standard laboratory techniques, correlation of data was difficult.

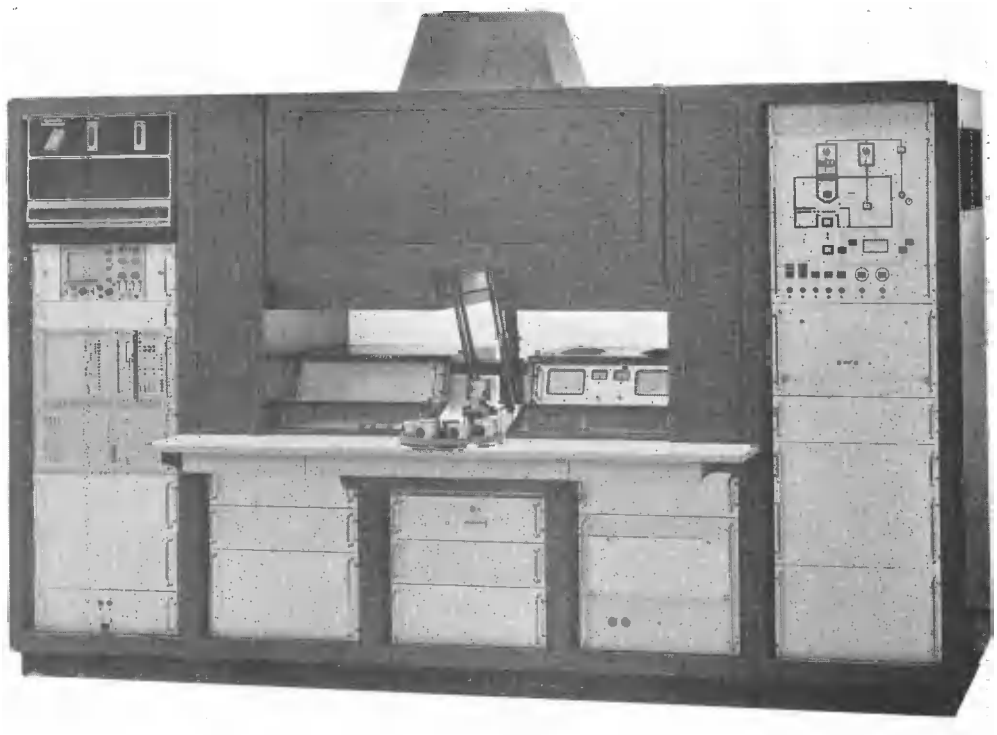

Fig. 1 Laboratory x-ray analyzer with automatic sample loader

Analysis of cement products

By 1964 devices were produced which approximated standard laboratory methods. Major producers were General Electric, Philips and Applied Research Laboratories. In a recently developed system which approximates very closely the standard laboratory procedures, the sample is extracted in a continuous manner from the main product and it is then processed through an autogenous grinder using compressed air as the grinding power. Sample enters the mill at ~80%-200 mesh at a rate of 8.25 kilograms/hour and exits with a particle size of 90%-11 microns and 50%-5 microns. This method of grinding is the most significant advance yet in this field. The grinding is performed dry and at a temperature high enough to remove any residual moisture. The fineness is such that matrix effects are almost eliminated or at least very significantly reduced. (Figure 2)

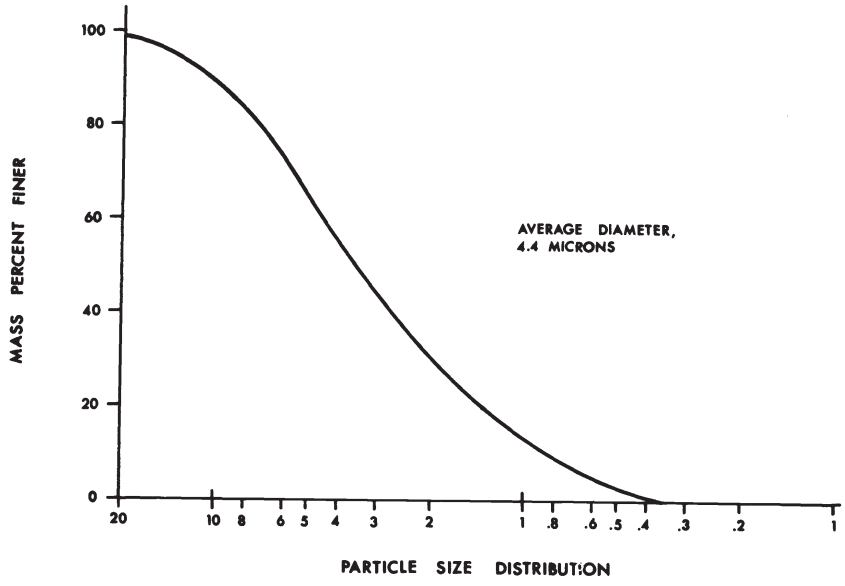

Fig. 2 Particle size distribution of air ground sample

The ground sample is automatically collected and briquetted. The briquetting pressure can be varied up to 27 metric tons. This Powder Briquetting System is shown in Figure 3. The entire process is controlled by an automatic self checking logic control system. Provision is made for computer monitoring and diagnostic maintenance. Samples are ground, prepacked, briquetted and delivered on a 4.5 minute cycle. The system is self cleaning and a completely different sample can be entered into the grinder, manufactured and delivered in 6.5 minutes without significant cross contamination from other widely different samples.

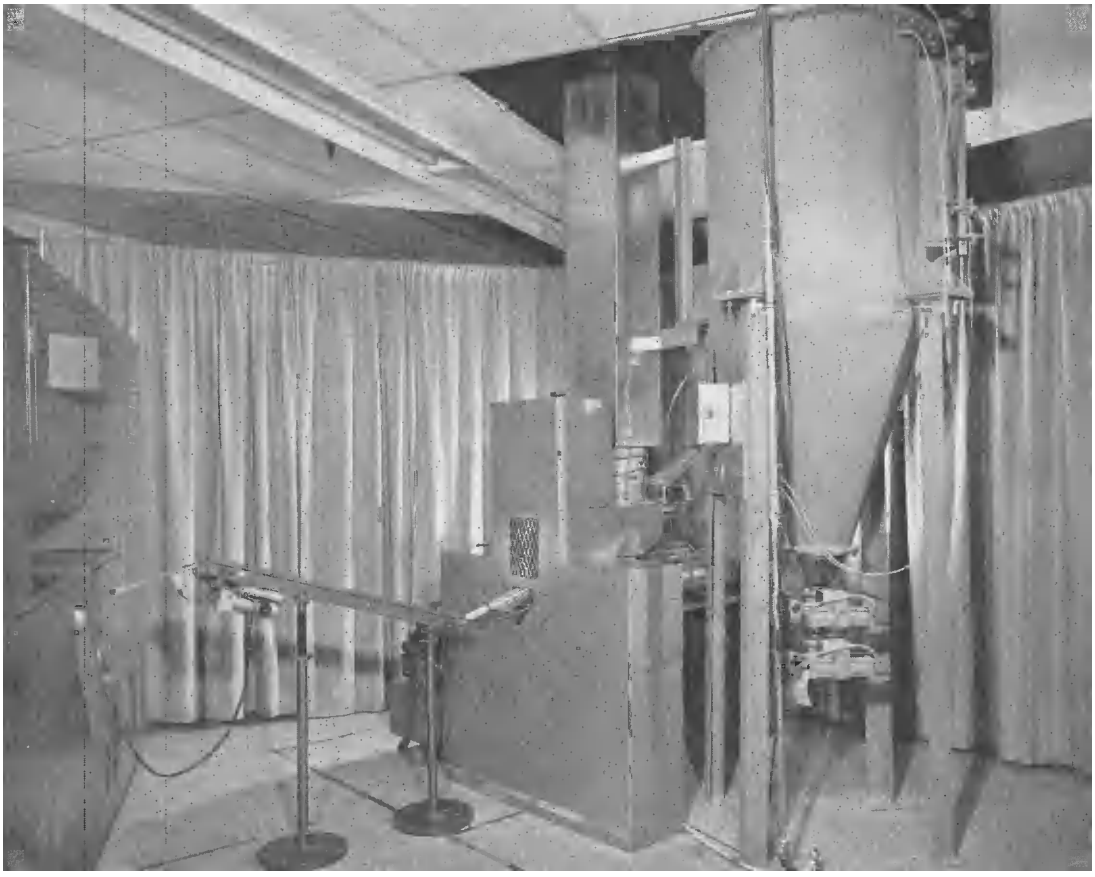

Fig. 3 Powder briquetting system

As each briquette is completed it is transferred to the x-ray analyzer and the briquetter will then continue to continuously manufacture briquettes. The briquette is analyzed in a simultaneous mode for all necessary elements, generally up to 15 in a cement assay in a total time of 30 seconds. This short time of assay then leaves some 4 to 4-1/4 minutes where the analyzer is not being used. To enable the full use to be made of this available analytical capability, the system is provided with another automatic loop that inspects every motion of the briquette maker and checks the elapsed time of the briquette in manufacture.

Meanwhile laboratory technicians could manually manufacture briquettes of other production samples such as limestone, sand, shale, hi rock etc. By using a pushbutton on the control panel indicating that the technician wishes to use the analyzer, the computer will signal yes or no depending on the time status of the on-line briquetting system. The computer will switch to the correct calibration curve and accept the sample if possible. As the auto sample being manufactured approaches the analyzer, the computer will block the next manual sample, switch back to the on-line assay curve, perform the analysis of the sample on-line, compute the correction formula, issue instruction to the control loops, and return to the manual samples again.

Closed loop control

Assuming that the application is an automatic raw mix control system for cement manufacture,

then the on-line sample would be the raw mix blended prior to the kiln. The manual samples would be the ingredients of the raw mix, limestone, sand, shale and coal etc. These data from the manual samples will be obtained on a frequent basis and the results fed into the computer memory. Each time the analysis of the on-line sample is obtained the computer will obtain the assay data from this analysis and compare it to the target set points in its memory. If it is incorrect, either high or low, the computer then decides on which of the raw mix ingredients to vary according to their individual concentration of each element in those materials. The analysis of the coal is used to trim the set points as the ash of the coal after firing can also affect the analysis of the final product (Ref. 1, 2, 3, & 4).

By maintaining or adopting standard lab techniques and methods for the on-line system, then standard lab accuracies can also be sustained. Typical results are shown below in Table 1 (Ref. 1).

TABLE 1. Accuracy of the powder briquetting system

	Static	Dynamic		Static	Dynamic
SiO_2	.017	.22	SO_3	.013	.07
Al_2O_3	.008	.09	Na_2O	.033	.09
Fe_2O_3	.039	.07	K_2O_3	.002	.01
CaO	.025	.33	F		.05
MgO	.016	.06	TiO_2	.004	.006

Static = 1 sample 5 times analyzed
Dynamic = 21 different samples from 1 batch

All samples are taken from the same batch of raw mix sample. In Table 2 the comparison between the two most common methods of sample preparation are shown. Fusion is used by many labs as a means of obtaining results free from effects of particle size etc. Briquetting is generally used as a much faster method and for its repeatability. Due to the exceptionally fine size of the particles it is seen that the results of the briquetting system are equal to the best fusion methods. Both methods are the averages of 11 and 21 different dynamically manufactured and analyzed samples from similar batches of raw mix.

TABLE 2. Dynamic analysis of 10 fusion tablets and 21 pressed briquettes

	Fusion		PBS Briquettes	
	% Conc	σ	% Conc	σ
SiO_2	22.5	±0.04	13.29	±0.028
Al_2O_3	4.45	±0.03	6.87	±0.023
Fe_2O_3	1.51	±0.04	1.56	±0.039
CaO	67.30	±0.15	36.35	±0.12
MgO	0.82	±0.02	4.49	±0.013
SO_3	2.01	±0.04	0.2	±0.001
Na_2O	N.D.		0.30	±0.008
K_2O_3	0.46	±0.005	0.69	±0.009
TiO_2	0.24	±0.005	0.30	±0.003

In addition to demonstrating the similarity in techniques, these data in Table 3 also show that the automatic system prepares samples more consistently than do manual methods. The briquetting system is also approximately 10 times faster than fusion methods and approximately 9 times faster than manual briquetting.

TABLE 3. Dynamic precision raw meal cement

	Concentration	21 Manually Made Briquettes		21 Automatically Made Briquettes	
	%	σ	R.S.D.	σ	R.S.D.
Si_0^2	13.29	0.032	0.24	0.028	0.21
Al_2O_3	6.87	0.065	0.94	0.023	0.33
Fe_2O_3	1.56	0.033	2.1	0.039	2.5
CaO	36.35	0.15	0.41	0.12	0.33
MgO	4.49	0.26	0.57	0.013	0.28
SO_3	0.2	0.006	3.0	0.001	0.5
Na_2O	0.30	0.0068	2.3	0.008	2.8
K_2O_3	0.69	0.003	0.43	0.009	1.3
TiO_2	0.30	0.0049	1.65	0.003	1.15

Justification of control of dry powders

However speed is not the major point of justification for such a system. Consistency and being able to relate directly to ASTM methods are more important. Real justification comes from the now proven fact that a raw mix closed loop control system using x-ray fluorescence and a Powder Briquetting System can produce a more consistent product than a manually operated or a direct digital control system. Blending control enables new plants to require only one small blending tank, of ~15 minutes supply.

The savings on eliminating the need for two or three large blending silos are enormous. Energy used to operate the blending silos is many hundreds of kilowatts per hour and could almost be justification alone for such a system. The capability of more products at a much tighter specification being consistently produced is a tremendous advantage in present day markets.

In addition to cement applications the iron ore pellet manufacture can be controlled in a similar manner by analyzing the bentonite, limestone and iron ore and controlling the balling mix. This analysis of both on-line and off-line ingredients enables the most economical mix of bentonite to be used, as this is an expensive ingredient. The end result is a more consistent product at less expense.

The analysis of coal before leaving the pit head or prior to its use in power plants is also of great advantage. By analyzing for many elements, the data can be processed by computer and the final output can be a figure of total ash in the coal prior to firing and an additional assay of individual elements that would be left in the ash after firing.

There is evidence that in the large volume dry product plants that production control is moving from the standard assay laboratory towards more a mix of process control as a prime factor and the batch use of the analyzer as a check unit. This double duty of the x-ray analyzer enables the unit to be used on a total 24 hour basis. In addition to the 12 automatic on-line samples per hour, some 90 samples per hour can be manually loaded and assayed without interfering with the closed loop on-line control system.

WET SYSTEMS

Laboratory techniques were as well established for the analysis of slurry as they were for the analysis of dry powders. Slurry samples were collected, weighed, filtered, dried, homogenized and a portion assayed. This technique was too time and function consuming to be copied or adapted. The x-ray fluorescence units were modified to permit flowing streams of slurry to pass through the x-ray optic analytical plane. It was a logical decision to use the same type of basic analyzer as used in the laboratory. This resulted in analytical techniques such as interelement corrections and scattered radiation* corrections for density being readily adaptable.

*Patent No. 2,897,367, July 26, 1959

Analysis of slurry

The first on-line slurry units were commissioned early in 1962, Philips in New Jersey USA, Anglo American in Zambia and ARL in Montana USA were among the innovators. Since then some 55-60 units from all manufacturers have been placed into operation worldwide. The same basic principles apply to all systems, that is the analysis is by x-ray fluorescence, the majority using x-ray tubes as sources of excitation and approximately 8-9 are using radioactive sources. The x-ray tube units are generally used in single and multistream systems where more than two elements are assayed in each stream. The x-ray tube units also provide much better precision and accuracy data at the important lower levels of concentration. Radioisotopes are used for analyzers of one stream for one element and for units that are immersed in launders and flotation cells etc. In these units the number of elements analyzed is generally restricted to two and density variations must be obtained by another unit installed near the elemental unit. The major problem with insertion units is the density measurement where entrained air creates errors of up to 40%. Slowing the flow to reduce the air allows the analysis window area to become contaminated (Ref. 5). These errors in addition to the lack of sensitivity of radioisotope units at the important low levels of concentration and the difficulty of correlating the probe data, without interelement corrections, to the actual shift composite sample tend to make these units more of a trend analyzer.

The precision and accuracy of the on-stream analyzer should be as close as possible to that obtained with normal lab standards. This applies especially to slurry analyzers as variations in density, matrix and particle size are factors that can be continually changing in the process stream and impose a great burden on the analyzer. The use of the x-ray tube and the simultaneous analysis of up to eight elements and the measurement of scattered radiation enables each data point to be corrected for interelement effects and compensated for density and partical size effects. In order to obtain accuracy equivalent to a normal assay, the methods used to perform the computations are of importance. For example, the density curve of each stream will differ according to its matrix. In a tailing stream each element is first corrected for density and some degree of particle size variation by using the scattered radiation technique. Then each corrected element is used in the interelement correction equation. It is also important to consider and determine the order in which the elemental coefficients are used in the equation--incorrect placement will mean incorrect results. A different density curve would be used for a feed or a concentrate stream and those correction equations would also differ from each other. The maximum intensity permitted by the use of x-ray tubes is an advantage when some slurry streams may be as low as 5 to 10% solids of low elemental concentrations, as this is of course only 5 or 10% of the signal that would be obtained in a dry assay.

Sampling systems

One common problem that exists for all on-stream analyzers is where should the stream be assayed, how to extract the sample and how to maintain homogeneity once it is collected, then how to maintain it in motion. Over the past 14-15 years many different types of samplers have evolved. They fall into two categories, moving samplers and fixed samplers. Moving samplers have a great number of problem areas in their construction and operation. The cost is high, maintenance is a major problem, as the ore is naturally abrasive, the sample cutter blades wear rapidly, changing the character of the sample for particle size and density. On a moving sampler the speed of the cutter through the product stream is very critical. As wear progresses the cutting speed varies and the sampler is able to falter, resulting again in sample inaccuracies.

Extensive tests on sampler accuracies which were conducted in Zambia at the time of the installation of the first multiple on-stream slurry analyzer confirm these problems with moving samplers.

Static samplers placed directly in a predetermined position in the stream are subject to attrition and change to a greater degree than the moving samplers. However they are relatively inexpensive and can be changed frequently in a few minutes. As there are no moving parts the maintenance is reduced considerably and variable factors such as speed of cutting, blade shape, sample impingement etc. are eliminated. Thief type samplers inserted into the throat of a pump are very effective and can also be used to eliminate the need for an additional pump and sump. Each on-stream system will have its own customized sampling plan, depending on the plant and its needs. It is clear, from extensive tests covering several years, that the sampling accuracy of the static samplers when compared to moving samplers installed on the same process lines is equal to or more consistent than the optimum moving sampler (Ref. 5).

Homogeneity of sample is a matter of selecting the optimum site and then ensuring that the sample is kept in a state of continuous motion. Flow rates should generally be a minimum of 75 liters per minute, less than this results in excessive pumping pressure, small lines and excessive sanding. It is preferred to use plastic or rubber pipes in order to obtain long slow bends, avoiding all sharp bends and horizontal runs for the sample transport lines. Many installations are equipped with tertiary samplers which extract a sample for the

chemist's composite shift sample. This is timed by the computer to cut the sample from the stream as it is flowing through the analytical cell.

Providing that the sample in the cell is a true sample then the x-ray system will produce an analysis directly comparable to laboratory techniques.

Closed loop control

With the advent of computers and microprocessors many features that were desired in 1961 and 1962 are now standard items. The present day version of a multistream x-ray analyzer is shown in Figure 4. In this unit a microprocessor is used to automatically control all the analysis, sample stream controls, in addition all the diagnostics and safety circuits are monitored once every second. Should a fault occur, the area of trouble is located and necessary instructions for its correction are typed out on the printer and shown on the TV screen in color. The microprocessor talks directly to and obeys the computer, unless the computer malfunctions, in which case the microprocessor will continue on its own and store all the data for the computer until it returns to operation.

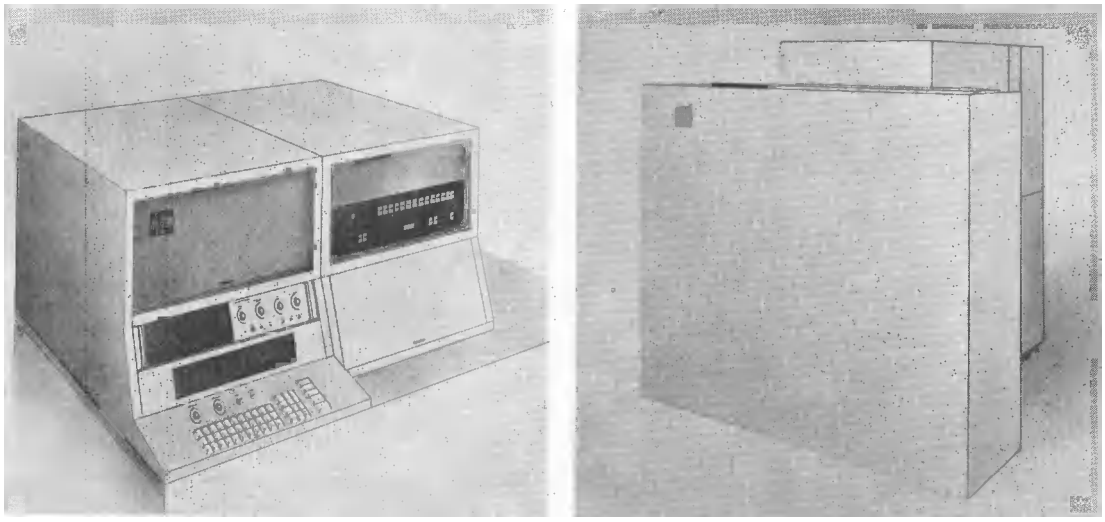

Fig. 4 Multistream slurry analyzer

In addition the advent of on-stream particle size analysis (Ref. 6) permits the x-ray computer system to collect the particle size measurement data, pH data and pH control function, weightometer feed rates and flow information of the tails to the tailing dam and massage all this together. Particle size measurement permits the grinding circuit to be placed under control for either maximum liberation of the elements, particle size distribution and density control. The pH control can be used for the addition of lime in the correct circuits. Weightometer feed rates can be adjusted for maximum ball mill loading and control. Assay data is then used to vary the rate of the reagent pumps according to the flotation feed assay. The end result is reagent control for the process streams. Particle size distribution pH control points, mass flow data, are all printed out and recovery calculations in tons of metal per day are tabulated. Then a price for the metal can also be inserted to produce dollars per day.

In addition, continuous inventory can be carried out and totals of pounds of reagent per day, pounds of reagent per ton, kilowatt hours of the ball mill, time for ball mill bearing lubrication and other equipment maintenance in hours to go before shutdown etc. can all be memorized, summed and printed out weekly or monthly.

Approximately 1/3 of the total installations are now operating under full closed loop control. In other words a centralized control is now readily available where all data is used to produce maximum recovery from the ore irrespective of feed rate or grade.

Justification of controlling slurry processes

Costs of these systems range anywhere from $70,000 to $500,000. Even the largest system yet installed has recovered its cost in less than six months. The results are not easy to quantify in terms of the system alone due to the fact that as soon as good data become available, then operators tend to use it to improve the metallurgy as well as improving the circuit efficiency to produce even better recovery (Ref. 6, 8, 9, 10, 11, 12, 13, 14, 15 & 16).

From a survey recently taken of almost half of the current installation, it is shown that recovery of the products increases by 1%-1 1/2% more than before installation, in some cases the feed grade had fallen off or remained the same. Reagent control resulted in still more savings. It varies according to the size of the concentrator and it ranges from $10,000 to $50,000 per year (Ref. 6, 8, 9, 10, 11, 12, 13, 14, 15 & 16). Personnel are becoming harder to find and training costs to run a concentrator are increasing. These systems are capable of assisting in those areas where manpower is difficult to obtain and retain. The main benefit is derived from the consistency of operation of the control loops irrespective of the human variables. It is a well known fact that many operators and shift supervisors have their own pet way of "training" a plant until it conforms to their version of maximum output. These variations can now be smoothed out with the result being greater recovery output for less manual effort and a stable concentrator.

Justification for any concentrator is not easy to put on paper. The lack of trained manpower is common, but their value varies from place to place. In addition the cost of reagent also varies depending on the ore and extraction method. Table 4 shows the overall effect of a PCXQ in percent recovery increases in various concentrators and the total approximate savings allocated to increased recovery, reduced comsumption of reagent and manpower savings.

TABLE 4. Increased recovery of major products using process control in concentrators

	% Concentration			Value *
	Before	After	Diff. %	$
Nickel	8.14	9.67	1.53	--
	8.21	8.67	.45	--
Copper	24.0	24.8	.8	433,000
	20.0	24.0	4.0	--
	24.0	25.1	1.1	588,000
	19.9	20.9	1.0	106,500
Zinc	52.0	52.9	0.9	710,000
	52.7	53.1	0.4	--
	52.2	53.5	1.3	48,000

*Value varies according to tonnage output

As the controls become more simplified and unified, the ratio of analytical and control instruments to the total plant cost will increase at a fairly constant rate. The rising cost of instrumentation will be offset by the ongoing reduction in personnel and plant size. All plant operating changes or modifications to the process will be via the keyboard or a switch which automatically operates the keyboard. The changes will be faster, simpler and much more predictable due to the increase of measuring points and data.

Controlling the process by computers and automation now permits the smelter to demand that the concentrators remove unwanted contaminants before smelting the ores. In some instances calcium, silica and magnesia or other troublesome elements can be readily analyzed and subsequently removed in the flotation process. Removing unwanted elements enables the smelter to extend the life of the reverberatory furnaces and assist in the control of

pollution. Controlling a process can have far reaching end results making them even more difficult to justify, even though they are known to be cost saving.

Oil analysis

Another ever increasing requirement is related to the energy supplies of the world. Oil should now be as sulphur free as possible. An arbitrary limit of 0.5% sulphur is now in operation. Due to the wide range of sulphur in various oils from very low to very high, it is necessary to blend the oils to derive maximum benefit from the very low sulphur content of some fuel oils.

Generally the assay of oil has been a straightforward, pure chemical analytical job. Laboratory x-ray was introduced into this field some 5-6 years ago. In this method a small sample of oil or any refinery product was placed in a specially designed cell. To obtain maximum accuracy the cell was agitated to suspend the solids and it was equipped with pressure compensation (Ref. 17). While excellent results are obtained from these units, the real requirement is in rapid blending of oils during the loading of tankers. Grab samples taken during this type of loading left many doubts as to the analysis of the whole shipment. Blending errors are costly when the tankers full of bunker fuel are rejected at their destination. The end result is either heavy penalties or return of the product to its origin or storage to be reblended.

A large number of on-line analyzers using x-ray absorption techniques were installed, but the results of the S analysis were subject to influence by the variable density and other absorbing elements. Latest techniques for on-line oil analysis (Figure 5) uses x-ray fluorescence to assay the flowing oil. The cell is designed to minimize density effects and the analysis is unaffected by other interfering elements. An x-ray tube is used in preference to a radioisotope because of the explosive nature of the installation. Generally refineries refuse to permit radioisotopes on the plant for that reason. X-ray tubes can be turned off. The entire system is flame proof and designed to operate in the refinery itself. Excellent stability and accuracy of 0.02% at 0.5% is readily achieved.

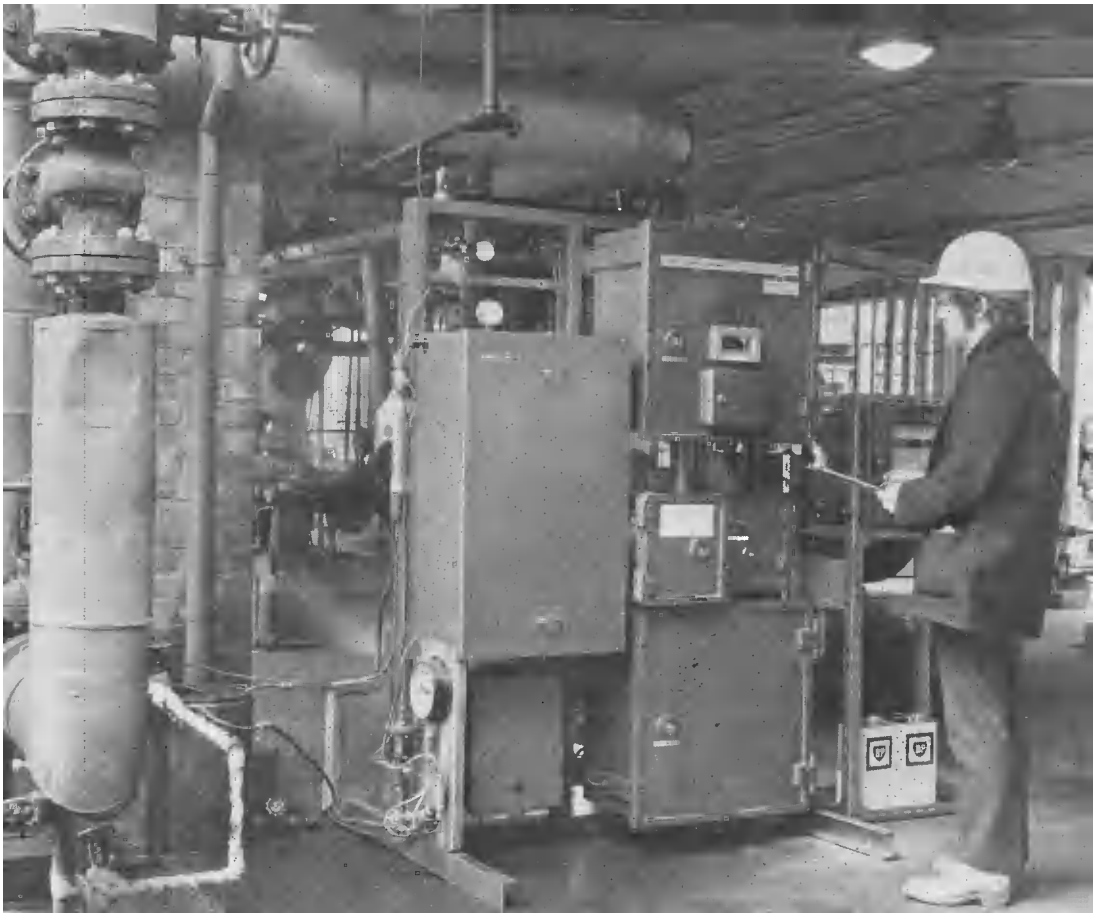

Fig. 5 On-line oil analyzer

Oil sample system

The major problem as in other on-line systems is the sample. In this case it is a very heavy thick oil, almost a tar. The oil is normally heated by steam tracing to make it flow and pump readily. A sample of ~23 liters/hour is extracted from the main process by valving and supplied to the analyzer. The temperature and pressure of the sample through the flow cell are regulated at 80°C ±5°C and 0.70 Kg/cm^2. The entire sample conditioning system of the analyzer is also steam traced. At this temperature the analysis could vary significantly and the barometric pressure variations become more significant. Automatic compensation factors for these two major variables are built into the circuits in addition to the numerous diagnostic and safety routine features. An automatic system ensures that the system cannot be started or switched on until the units have been air purged and it is safe.

An analysis can be obtained every 100 to 300 seconds as desired (Figure 6) (Note a). The result is used to control the blend of two or more oils to ensure that the total amount of % S is just less than the maximum stipulated by law or contract. Standardization of the system against NBS oils or similar oil standards can be carried out by operating two built-in switches. By standardizing before and after a loading and assaying one or two chemists check samples, ensures correct blending and maximum savings.

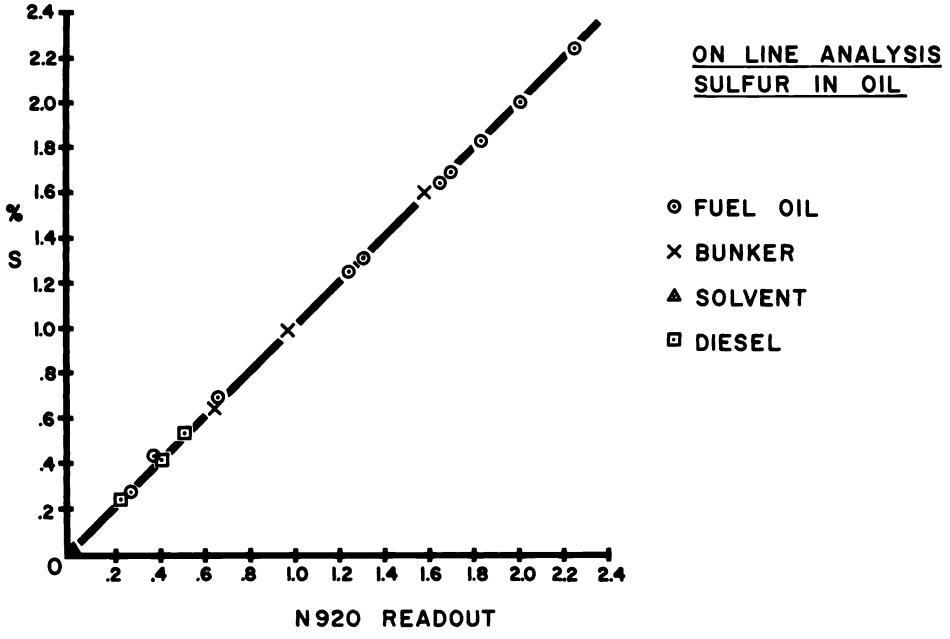

Fig. 6 Graph of S in oil (bunker, diesel, fuel, etc.)

Justification for oil blending control

The potential savings on a super tanker could be as high as $300,000. Unloading an incorrect mix could involve 20 to 30 hours at a delay cost of $300 an hour plus the extra losses in shipment (Ref. 18).

In a desulphurization plant the cost of reducing the sulphur level is approximately $0.50 to $0.75 a barrel per 1% sulphur (Ref. 19 & 20). In plants of 50,000 barrels a day this represents a significant savings. Assuming the level is 0.1% sulphur over specification this is $2,500 to $3,750 a day. At high throughputs the job of the chemist is almost impossible, but an on-line analyzer can supply accurate data every two minutes without problems. The chemist would still be required for check samples and for testing the homogeneity of the standardization samples.

Note a: With acknowledgements to British Petroleum Co. Ltd.

The major savings or justification in oil analysis is not personnel, but accuracy in delivery to a specification, time in loading a ship and saving of dock fees.

Computer control of the blending system is a relatively simple step. Viscometers, flow meters and temperature and pressure indicators would be computer inputs together with the percent concentration of S. Mass flow and a continuous analysis of the blend every two minutes would provide a good specification record of the loading.

A programmable calculator or a microprocessor would be adequate in both capacity and cost for such an application. As the system is a slow batch control, the program could be easily changed to accommodate various size ships, different grades and types of oil etc. without the need for an experienced programmer.

SUMMARY

Automation and process control are slowly but surely increasing in the number, size and complexities of installations. The supplying industries are maintaining an equal pace with the new equipment and more importantly, improved techniques in both analysis and methods provide a means of achieving these complex controls while maintaining simplicity.

A decade ago the reasons for process control were few, mainly better recovery and reduced costs. At present the list of reasons now includes large personnel turnover, loss of operating skills, energy savings, pollution control, reduction of environmental impact, more consistent bookkeeping, more complex ores to deal with, lower grade orebodies, scarcity of analysts, integration of mass flow controls to provide a better overall picture of the process. Undoubtedly, more reasons will be added but at present automated analysis for controlling the process is certainly becoming the analysts number one helper.

Such systems do not just happen, they are the result of some 20 or more years of experience in various fields and in order for present day systems to be successful it is considered essential that the expertise available should be used or at least consulted. The benefits can be huge, and if all factors are correctly considered in the beginning, then the end result can be very rewarding in both financial and operational aspects.

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