Automation in Vegetable Oil Refineries

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ABSTRACT

Various aspects of automation are reviewed, with particular reference to examples taken from the following processing fields: oil storage, refining, hydrogenation, deodorization, oil compounding, and soapstock treatment. Examples of automation involving centralized control, programmed sequence control, in-plant quality, and process yield measurement as well as on-line computer control are illustrated. Current trends in automation methods and hardware design are also discussed.

INTRODUCTION

Within the context of this review, the term *automation* can be regarded as the function of monitoring and regulating a processing operation nonmanually or remotely to check or maintain the required processing conditions and product quality.

The increasing amount of automation applications within our edible oil refineries during the past two decades has been brought about mainly by the following factors:

1. The need to keep overall production costs per ton of product at a competitive level
2. The need to introduce improved and consistent processing conditions to achieve higher product qualities
3. The need to maximize processing yield and eliminate random losses due to accidental manual errors
4. Safety requirements in processing plants using solvents and hydrogen.

A combination of several of the above objectives has often been achieved in one new process operation. In particular, increased investment in continuous processing plants has created the need for more automation compared with the previous requirements for batch type processing. The central control panel, containing process controlling instruments, chart recorders, alarm annunciators, and plant graphic diagram (Fig. 1) has now become a familiar and essential feature within edible oil refineries.

In the course of this review, several automation examples are described in order to indicate the current trends in process control philosophy and hardware. The objective is to indicate the existing state of the art by current achievements rather than consider which areas of automation application could be considered for future investigation.

"Known art" aspects of refinery automation, such as conventional process control instrumentation for refining, hardening, and deodorizing operations, have not been taken as examples in order to maintain some degree of originality in the subject matter.

In dealing with each of the examples, it will become evident that emphasis has been placed on a general description of the methods involved, and mention of individual equipment manufacturers has been avoided as far as possible, although a discerning eye will be able to detect products from many suppliers in the figures.

The reason for this approach has been threefold. First, citing a particular manufacturer's equipment might seem to imply a preference for that product against possible alternatives. As in any engineering organization, we do have preferences, based upon standardization for maintenance purposes, local servicing facilities, etc., but it could be misleading to translate these preferences to situations outside Unilever. Sometimes, there can be several equal possibilities of equipment for a given automation application; hence, it would be necessary to mention each possible supplier to give a balanced view, and the review would tend to grow into a manufacturer's index. Lastly, the scope of this review is necessarily restricted to a selected number of examples, and thus, by spotlighting certain manufacturers, there is a risk of offending many more equally deserving manufacturers by their chance exclusion.

The gap between what is currently technically feasible and what is actually installed may be regarded by the more purist type of technologist as a yawning chasm which progressively widens with time. It is a fact of life within the edible oil refining industry, as in many other industries, that only a small proportion of the technological advances that become available for industrial exploitation are readily employed for automation purposes. In spite of this, the risk of automation for automation's sake can still be a very real one. Unless the objectives of any automation proposal can be clearly defined and quantified into meaningful advantages, it is possible that the inherent higher investment cost, the sometimes reduced flexibility in processing and increased skills in faultfinding, and maintenance requirements can cancel less tangible reasons in the final analysis.

A well-designed process automation system can be likened in some respects to the human body, which is itself an amalgam of many automatic control systems. Its capabilities should be clearly understood, and, provided it is not abused and is given a regular "checkup" by a qualified "practitioner," it will normally perform happily for a long and fruitful life. One of the biggest enemies of a process automation installation is operational and maintenance neglect coupled with inadequate long-term performance feedback to the system designer.

As well as the paramount importance of correctness in design, the success of an automation system is largely related to its installed reliability. Comparatively small

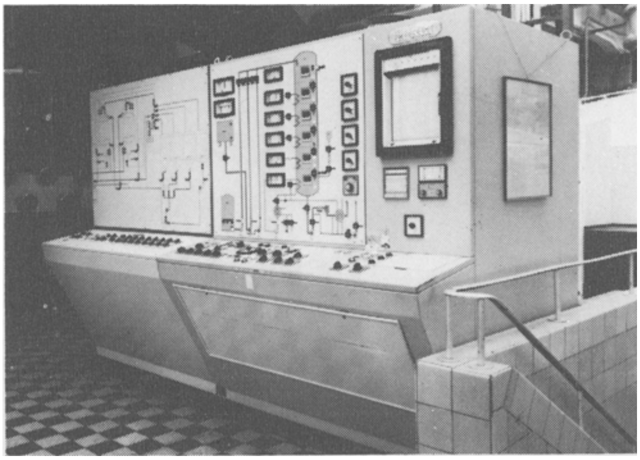

FIG. 1. Typical central control panel (semicontinuous deodorizer).

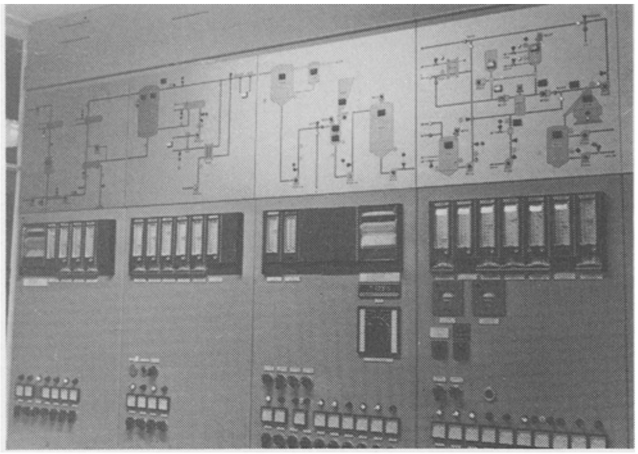

FIG. 2. Centralized control room: pneumatic control instruments.

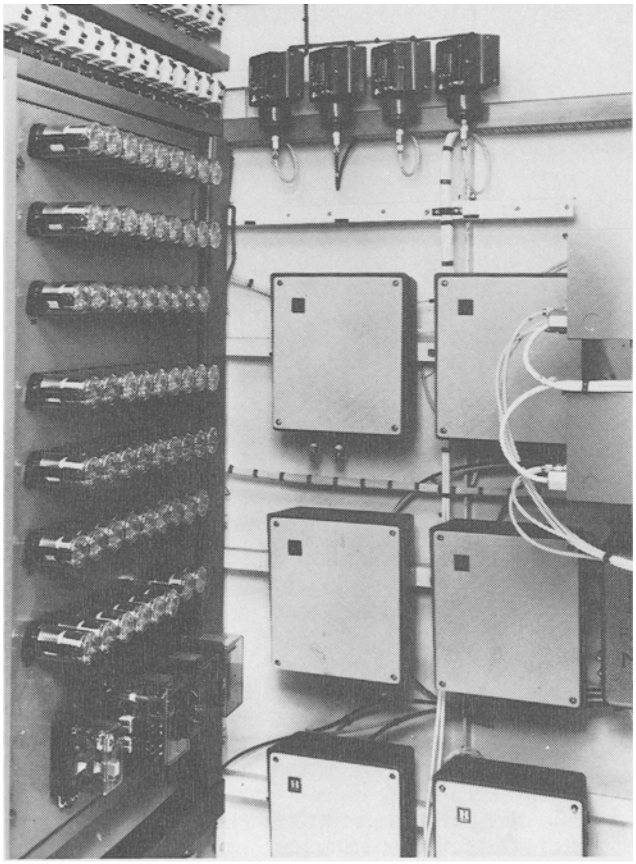

FIG. 3. Electromechanical relay logic rack.

points of detail can spoil the long-term success of an otherwise well-designed system. Once the confidence of the operating personnel is eroded by too many post-commissioning "teething troubles," it can become a difficult and lengthy task to restore the initial enthusiasm so essential to the long-term success of any application.

HARDWARE TRENDS

The rapid advance in the development of low cost, miniaturized electronic circuit building blocks continues to influence the technical approach to automation problems within edible oil refineries as in other sections of industry. Although pneumatic type analogue process controllers continue to be applied for conventional control loop applications (e.g., control of temperature, pressure, level, flow, etc.—see Fig. 2), principally due to lower capital cost and safety (explosion proof) considerations, the shift towards using the electronic counterpart is apparent and inevitable.

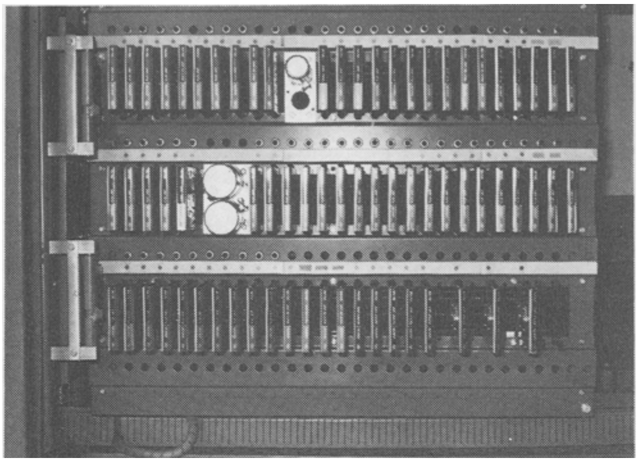

FIG. 4. Fixed function solid state logic rack.

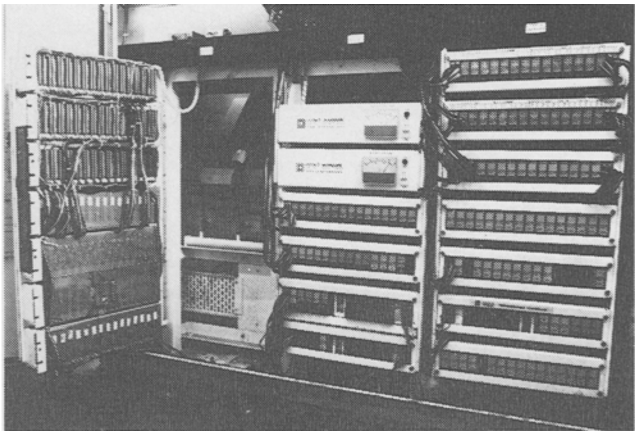

FIG. 5. Programmable integrated circuit logic rack.

The user is largely in the hands of the main instrumentation manufacturers, who in turn have to compromise between retaining a well-proven design of instrument and still remaining competitive with new ranges of hardware introduced by other manufacturers. The user normally prefers infrequent changes in order to limit his spare part stocks and training of maintenance personnel.

In addition to continuously regulating the various process conditions at preset values, an automatic control system often has to deal with the sequential control of events according to prescribed programs or changing process conditions. Checks also have to be made on the state of a process or plant for alarming purposes. It is in this area of switching logic that the greatest changes are being made.

The once familiar rows of electromechanical relays (Fig. 3) have for some time been replaced by solid state switching units (Fig. 4). These fixed function transistorized logic units have been upgraded by the use of integrated circuit elements and programmable read only memory (PROM) units (Figs. 5 and 6). For certain applications, large scale integration is being applied using microprocessor units with addressable memory (RAM) features, and hence the point has been reached where such systems become almost indistinguishable from digital process computer control systems. In the latter form of automation, direct digital computer control of refining processes, combined with a comprehensive management information retrieval system, also has been applied. (See section on direct process control by digital computer.)

The increasing application of such electronic types of

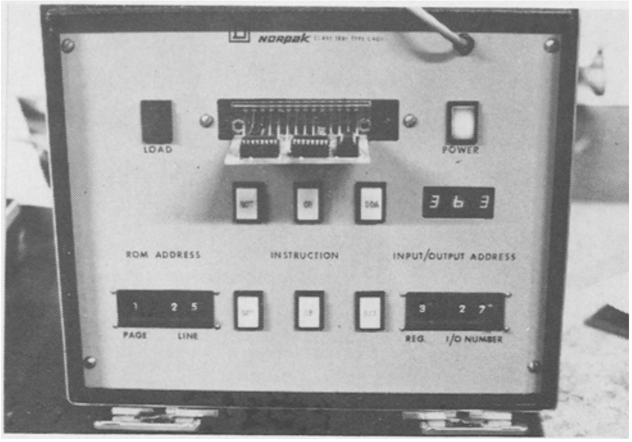

FIG. 6. Field operated logic programming unit.

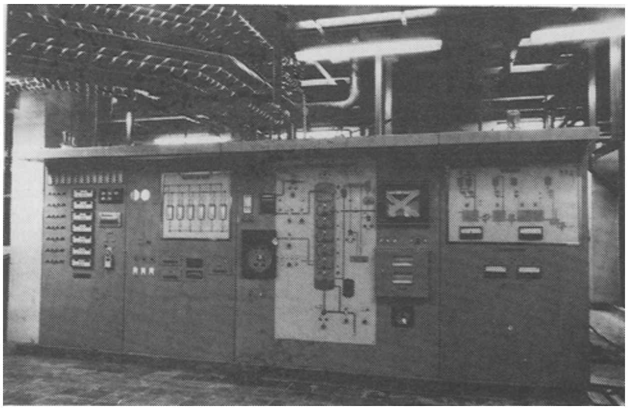

FIG. 7. Integrated group of control panels.

controlling system in edible oil refining is conditioning the user to employ a more integrated approach to his hardware selection in order to have better design flexibility and a reduced range of maintenance skills. In this situation, it is predictable that pneumatics will be eventually displaced from central control panel instrumentation. However, the combination of the familiar pneumatic diaphragm motor with built-on electropneumatic converter is likely to retain its attractiveness as a modulating control valve prime mover for some time to come.

From an on-line installed automation hardware point of view, one can state without fear of contradiction that it is the era of the ball valve. With many manufacturers in the field, the choice is wide and the competition keen. The ball valve has become virtually the number one choice for on/off routing applications in edible oil refining processes. A range of pneumatic types of actuator is available as well as electric motorized forms. Valve position signaling by microswitch or proximity switch is frequently applied.

The development of various forms of in-line sensor based on no moving parts has also enabled automation systems to have a higher degree of reliability. Examples of such sensors are ultrasonic level and interface switches, vortex shedding flowmeters (used for hydrogen consumption measurement for hardening end point control), and gamma ray radiation absorption methods for in-line bulk density measurement on extracted meal.

As new developments continue to add to the armory of automation hardware, there is the need to evaluate the attractive newcomers under appropriate plant operating conditions. A good idea in glossy leaflet form often can become a failure under plant operating conditions. A "self-cleaning" pH electrode system can do just the opposite in your own particular application although it apparently works well elsewhere. There is little substitute for in-plant experience to underline the unexpected differences that can appear between theory and practice.

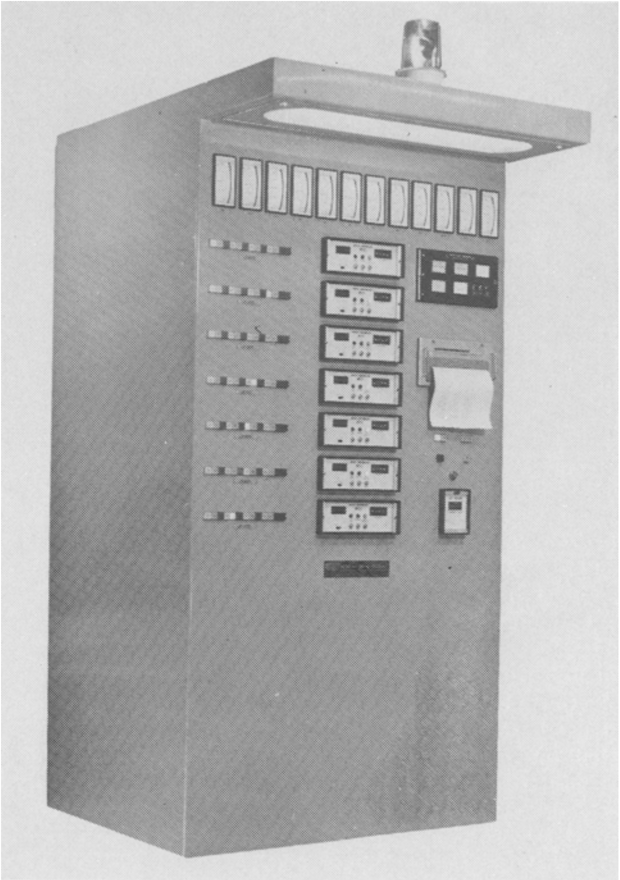

FIG. 8. Batch blending of oils by flowmeter: operator's panel.

CENTRALIZED REFINERY AUTOMATION

Although the concept of grouping together sets of indicating and recording instruments for convenience of display and operation has been practiced for many years, the degree of centralized control applied in edible oil refineries has increased considerably during the last two decades.

This trend has been brought about mainly by installation of continuous plants for neutralization, bleaching, filtration, deodorization, interesterification, and automatic systems for oil routing to and from storage as well as oil compounding and soapsplitting. Plants have also been installed for solvent extraction of residual oil from bleaching earth, and in each instance the concept of a centralized control panel has been adopted.

Where several processes have been introduced at the same time, an integrated approach has been made to the centralized control (Fig. 7).

By centralizing the control facilities in a plant together with a graphic display of the process and alarm indication, it is possible to obtain a quicker operator understanding of the process while at the same time making it possible for more than one process to be controlled from a common control area.

Oil Compounding

Automation has frequently been applied to free the process operator from repetitive manual operations, which by their tedious nature can introduce occasional risk of human error. Such an example is automatic oil compounding. Figure 8 indicates a control panel for a seven-component oil blending system from twelve storage tanks based upon a single flowmeter method. The individual

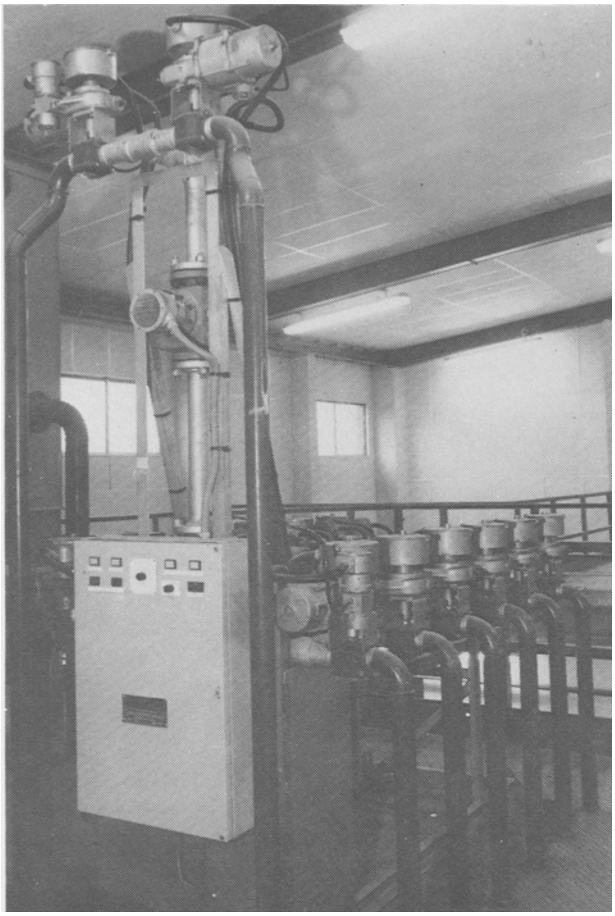

FIG. 9. Batch blending of oils by flowmeter: pipework manifold.

FIG. 10. Batch blending of oils by weight: operating station.

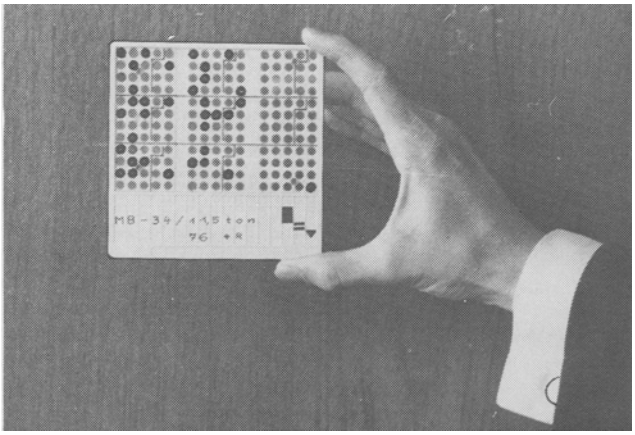

FIG. 11. Batch blending of oils by weight: punched recipe card.

quantities of oil (in temperature compensated liters) are set up in sequence together with the appropriate supply tank numbers. When the "blend start" sequence is initiated, each preset component oil quantity is automatically dispensed in turn, and the individual quantities and supply tank numbers are printed out together with the date and time. Figure 9 shows the pipework configuration for the system, which has been designed specifically to minimize any risk of contamination between oil types.

The pipework manifold is positioned above the top level of the supply tanks, which are separately connected via their supply pumps to the blend manifold via individual ball valves. When a component oil is selected, the appropriate supply pump is started and the associated ball valve opens, together with one of the two outlet routing valves. The oil is then pumped into the flowmeter manifold preceded by the air in the pipework. As soon as oil is detected adjacent to the vortex type flowmeter, the transmitted volume pulses are routed to the appropriate batch counter, and oil metering commences. When the preset quantity of oil has been dispensed, the pump is stopped and the associated manifold valve closed while the oil in the outlet pipework drains into the blend vessel. After a preset time delay, the manifold valve reopens and allows the contents of the flowmeter and manifold to drain back towards the supply vessel. The manifold valve then closes, and dispensing of the next oil component in sequence commences.

The use of a single flowmeter for each blend component in succession has the attraction that any flowmeter calibration percentage error that might occur with time will influence each component proportionately, and hence the blend ratio remains unaffected.

As a further illustration of automation techniques associated with oil compounding, Figures 10 and 11 show an automatic blending system based on a mechanical weigh scale associated with potentiometric transmission and punched card reader. Each of the robust and reusable punched cards contains the necessary data for up to eight component oils to be blended from any of 30 storage tanks. Once again, the blending sequence is carried out automatically, and in this instance the delivery pipework to the weigh scale is emptied into the weigh vessel by air blowing as part of the sequence. The programmed quantities on the punch cards are calculated to allow for the individual delivery pipework quantities to be added to them in order to give the final required component oil quantities. The system also incorporates a combined moving carriage printer and calculator which prints out the date, batch number, tank number, weight of each component oil, and the cumulative weight. Cumulative totals of oils used per day and per week can also be printed out on demand.

Tank Contents Gauging

One of the many differences between the edible oil refining industry and the mineral oil processing field is the approach used to measure quantities of raw material and product in each instance. Within the mineral oil industry, the basic product quantity measurement is founded upon volume, whereas it is the weight of material that is normally of predominant interest to the edible oil refiner.

This difference in basic measurement requirement raises some fundamental points in the approach to oil storage tank automation.

There are a number of reliable tank level transmitting devices based upon the mechanized float principle which can measure the static liquid surface to within ± 1 mm. This form of level measurement, when used in conjunction with the local authority's calibration data for that tank, can give a *volume* measurement with an accuracy of ± 0.1% or better. It is this impressive starting point that can create the attitude in the edible oil field that the best approach for *weight* measurement is to measure the volume very accurately and then multiply the measurement by a density factor. There is nothing fundamentally wrong with this philosophy, except that the "density factor" should be of a similar order of accuracy to that of the volume measurement if the high order of accuracy is to be preserved. The biggest single influence that normally prevents this being possible is oil temperature variation. A change of 10 C will vary the volume of the oil by ca. 0.7% without allowing for any differences between the basic specific gravity of various oils. The problem therefore becomes one of obtaining accurate and representative measurements of temperature throughout the storage tank and combining these to give an average value. If one or two points only are measured, then the resultant calculated weight will be accurate to, say, ± 0.5%.

It is the realization of this overall downgrading of the volume measurement that allows an alternative, more convenient, approach to weight measurement to be made. Except in special circumstances, it is generally impractical to support large storage tanks on weighing devices such as load cells. However, an accurate measurement of the liquid pressure at the base of a vented vessel can form a very convenient and low cost means of measuring the weight of the vessel contents.

By measuring the hydrostatic head in this manner, the effects of basic specific gravity and temperature/density variations are self-compensated, and hence the resultant accuracy of the weight measurement can be well within the previously stated value of ± 0.5%.

The measurement of the liquid pressure is achieved by either the open dip pipe/bubbler tube approach or by use of a diaphragm type 1:1 pressure transmitter. In the latter solution, the liquid pressure on the wetted surface of the diaphragm is balanced by an equal pneumatic pressure applied to the rear of the diaphragm to give a force balance system when in equilibrium. The transfer error of such 1:1 pressure repeaters can be within ± 0.25% over the upper 90% of their working range, and their use eliminates the need to bubble gas through the oil itself. A large number of storage tank farms at present utilize this form of contents measurement, which enables the resultant pneumatic pressure signals to be scanned, converted to equivalent electrical signals, or transmitted direct to remote centralized panels and control rooms.

MEASUREMENT OF REFINING YIELD

It has already been stated that one of the objectives for automation within edible oil refineries is to maximize processing yield and eliminate accidental random losses. To this end, the application of yield (or loss) measuring equipment to continuous refining is of considerable interest. For example, a reduction in oil loss of, say, 0.1% can represent a saving of ca. 50 tons of refined product per line/year. Hence, an investment in yield measuring equipment can show a healthy return on capital invested. As in many automation applications, the magnitude of the economic benefit largely depends upon the process control situation prior to the application. If the production housekeeping is already good, then the gains are necessarily lower. However, it can be argued that the existence of a continuous system for monitoring refining yield can minimize start-up time and reduce operator attention time during processing by use of built-in percentage yield alarm set points. In addition, a continuous recording of percentage yield can provide useful trend information to the operator as well as operational data for management information purposes.

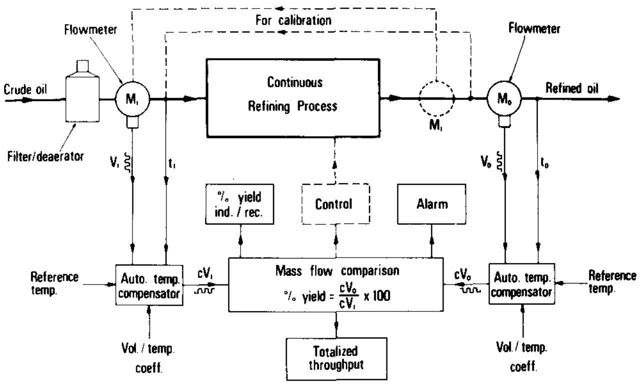

FIG. 12. Continuous refining yield measurement by two-flowmeter method.

Without accurate and rapid data on the running percentage yield, there is more risk that the process operator will "play it safe" and refine with a greater alkali excess than is optimal, with a resultant higher loss of neutral oil to the soapstock.

Of the two basic approaches for continuously monitoring the refining loss, i.e., by analyzing the constituents in the soapstock stream or by making an overall mass balance of crude oil in to refined oil out, the latter method has received more attention from the commercial suppliers of equipment. The inherent problem with such a mass balance approach is the accurate measurement of the small difference between two large quantities. For example, assuming that the oil input and output mass flows can each be measured to within ± 0.1%, then an actual 2.0% refining loss will be indicated anywhere between 2.2% and 1.8%. It can be seen, therefore, that any mass balance form of measurement must be both accurate and reliable to give meaningful percentage loss information.

From an absoluteness of mass measurement point of view, a weighing approach has an attraction over volume flowmetering. However, the weighing approach is normally more expensive, space consuming, can involve additional pumping operations and risk of oxidation, and, in its simpler forms, is less responsive to short-term changes in yield, i.e., time delay for alarming and process control purposes.

On the other hand, liquid flowmetering of edible oils (particularly the crude input stream) can create potential user doubts from both an accuracy and reliability point of view. Experience has shown, however, that two such flowmeter methods for percentage yield measurement can meet the stringent requirements for both accuracy and reliability, provided the choice of flowmeter is carefully made and the overall installation is properly engineered with attention to detail. The inclusion of a filtering and deaerating unit prior to the crude oil meter is necessary, as is also the provision of automatic electronic temperature compensation of the volume signals from each flowmeter to allow for oil temperature/density variations; e.g., a 10 C change in temperature will give a volume change of 0.7%. Mechanical forms of temperature compensation built onto flowmeters are generally less accurate, difficult to check and modify for different volume/temperature

FIG. 13. Continuous yield measuring panel on centrifugal refining line.

coefficients, and subject to long-term changes due to mechanical wear.

Basic components of a typical two-flowmeter continuous yield measuring system are shown in Figure 12. The two positive displacement type flowmeters, Mi and Mo (chosen for maximum accuracy and reliability), are fitted with high frequency pulse transmitting heads with a typical pulse output rate at normal plant throughputs of 10,000 pulses/min. The input and output oil temperatures, t_i and t_o, respectively, are measured normally by means of platinum resistance type probes installed adjacent to each flowmeter. The flowmeter volume pulses and oil temperature signals are fed into the automatic temperature compensator units, which correct the number of pulses received from the flowmeters for variations in temperature according to the preset volume/temperature coefficient (e.g., between 6.5 and 7.3×10^{-4} per C) and the preset reference temperature. This arrangement is a common feature in accurate oil metering systems.

Thus, the output pulse signals, cVi and cVo, respectively, have been continuously compensated to a common base or reference temperature and can therefore form the basis for accurate "mass" flow comparison. Any difference between the specific gravities of the crude input and refined output oils is taken to be negligible within the limits of the required overall measurement accuracy.

Thus, the gross overall percentage yield may be expressed as the ratio (cVo/cVi) x 100, or gross overall percentage loss as [(cVi - cVo)/cVi] x 100%.

The method gives an overall mass balance of the process, and hence the volumetric signals include a certain percentage of free fatty acids (FFA), moisture, dirt, phosphatides, etc., in addition to the actual volumes of oil being metered. (This is also the case with an overall weight measurement method.) Although the refined oil FFA and moisture content after the dryer are normally very consistent and low, the crude oil "impurities" will vary in magnitude and, therefore, can be fed into the mass flow comparator, usually by means of switches or potentiometer settings; hence, a net overall yield value can be calculated and registered as the ratio of oil output:oil input. However, it must be realized that the resultant accuracy of any such net percentage yield or percentage loss registration is directly dependent upon the accuracy of the manual input information, and hence the inherent accuracy of the remainder of the measuring system can be inadvertently downgraded. As an alternative to modifying the gross overall yield or loss display by manually inserted "impurity" information, the gross values can be retained and recorded together with the total impurity information. This latter approach gives a target value against which the process operator can steer the running gross yield or loss value and at the same time provides useful historical information for management control purposes.

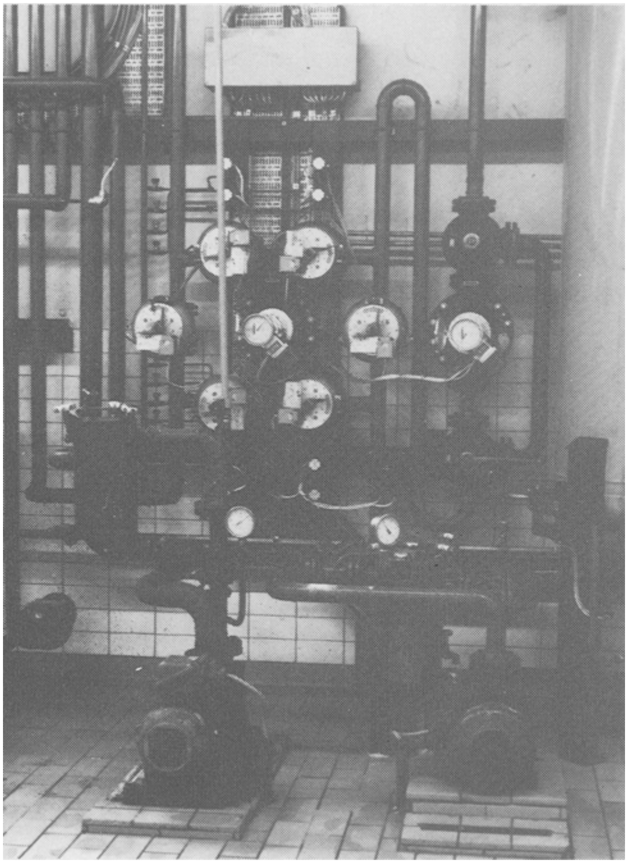

FIG. 14. Continuous refining yield measurement: automatic calibration pipework arrangement.

The resolution of the percentage yield or percentage loss calculations within the comparator can be extremely high due to the high frequency pulse rate from the flowmeters and the digital nature of the calculating techniques used. However, the resolution of the calculating system should not be confused with the accuracy of the resultant percentage yield values, which can only be as accurate as the flowmetering devices themselves.

There are certain aspects concerning the use of the two-flowmeter method which should be appreciated in order that the influence of a stated flowmeter accuracy figure can be kept in perspective.

First, the normally stated accuracy of a flowmeter indicates the largest short-term percentage error that can occur throughout the recommended metering range (usually 10:1 flowrate). It is a meassure of the flowmeter's ability to handle a range of flowrates with minimum change of calibration. In the application for continuous yield measurement, the flowrates are kept relatively constant, i.e., at the plant throughput, and hence it is the repeatability error of the flowmeter which is the more important characteristic. The repeatability error can be a factor of 5-10 better than the overall accuracy figure. It is the ability to give low repeatability errors over long periods of time that most influences the choice of type of flowmeter.

For percentage yield measurement, it is also normal to calibrate the two flowmeters together in series under the

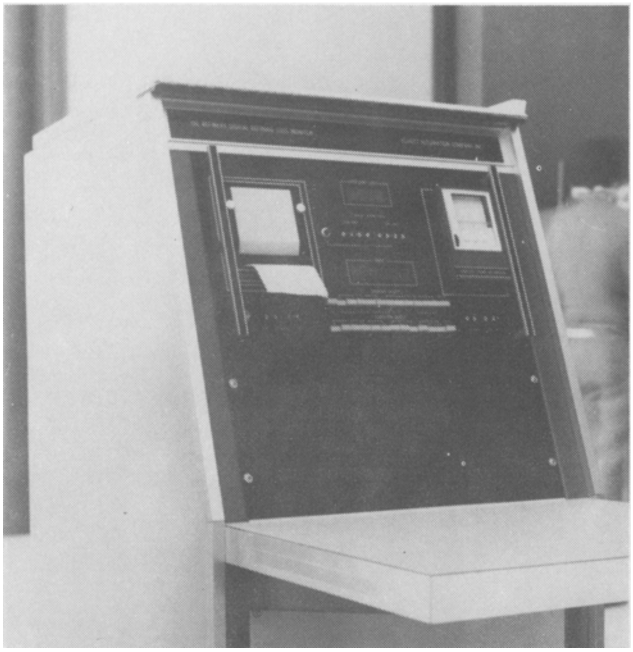

FIG. 15. Continuous refining loss monitoring panel using microprocessor components.

same plant operating conditions, e.g., by use of valves to transfer the input meter Mi (and temperature probe) to the output line (Fig. 12). In such a calibration situation, it is the relative calibration figure that is more important for accurate overall yield, rather than the individual absolute calibration factors for each meter. The time interval between checking the relative flowmeter calibration in this way depends upon the constancy of the flowmeter performance. Continuous yield measuring systems have been installed with fully automatic calibration checking facilities so that the overall system accuracy can be checked within a few minutes at any time by the process operator without processing interruption. Any changes in the relative calibration factor are automatically fed into the percentage yield determining calculations in order to maintain the maximum overall measurement accuracy. Figure 13 shows a continuous yield measurement control panel installed on a centrifuge refining line, and Figure 14 shows the installation of two positive displacement flowmeters with automatic routing valves and pipework to allow automatic calibration checks to be carried out without processing interruption. Figure 15 shows a refinery loss monitoring control panel utilizing a minicomputer for the loss calculation, data storage, and printout purposes.

SOAPSTOCK HANDLING AND TREATMENT

Whether the oil refining operation is carried out by batch or continuous processing, a common factor is the subsequent need to handle and treat the resultant soapstock in order to retain the fatty acid oils and produce an acceptable effluent. Increasing pressures from antipollution legislation in recent years have brought particular emphasis to soapsplitting operations in order to minimize the TFM and sulphate content of effluent streams.

Although investment in new edible oil refining plants is substantially in the form of continuous centrifuge type of equipment, there are still considerable numbers of well-established batch refining plants in operation throughout the world, a large number of which will continue to be operated for many years to come.

Automatic Soapstock Draining of Batch Neutralizing/Bleaching Vessels

To operate batch refining processes as efficiently as possible, a number of automation aspects have been applied: automatic systems for alkali blending and dosing, automatic systems for bleaching earth weighing and dosing, and accurate vessel contents measurement and transmission for yield determining purposes. Yet another aspect of batch neutralizer automation which has received attention in recent years is that of automatic draining of soapstocks with detection and automatic cutoff at the emulsion interface point.

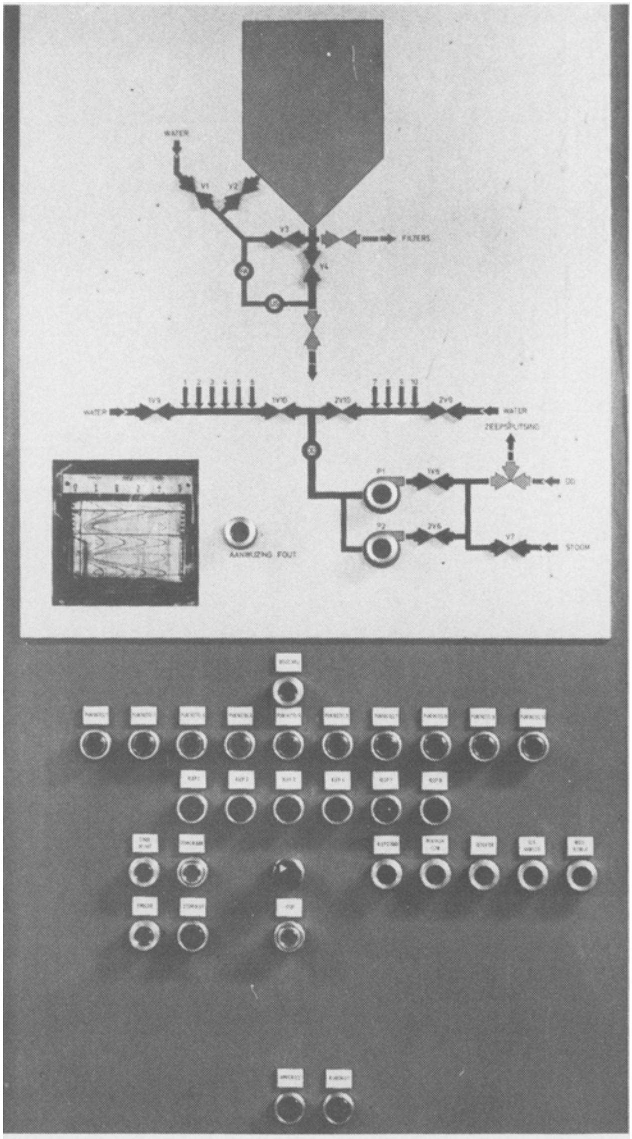

FIG. 16. Central control panel for automatic draining of batch neutralizer soapstocks.

The soapstock draining operation has been traditionally regarded as a skilled manual operation, during which the process operator assesses the onset of the emulsion phase by means of sight glasses, soapstock flow properties, sense of feel, etc. Different oils and different treatments can require small modifications to the operator's detection technique. The effectiveness of the operator's technique in detecting the correct emulsion cutoff point will influence the overall yield of the process.

However, a number of installations are now in operation which enable a complete soapstock draining operation to be carried out automatically and remotely in a consistent and optimal manner. Figure 16 shows a centralized automatic soapstock draining control panel serving 10 batch neutralizing/bleaching vessels. A soapstock draining operation is initiated by a refinery operator on the upper working platform by selecting the appropriate vessel and depressing the start-to-drain button. The necessary interlocking for soapstock pumping and routing is built into the draining pro-

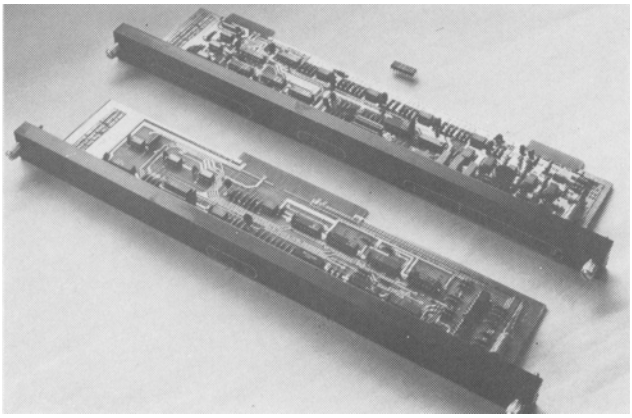

FIG. 17. Integrated circuit (PROM) program sequence modules: automatic soapstock draining.

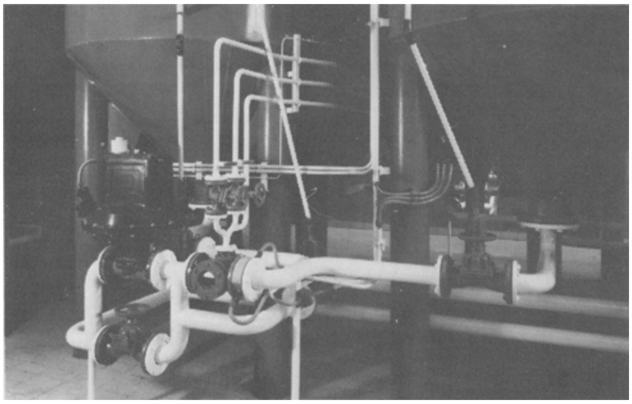

FIG. 18. Automatic detection of acid water/acid oil interface in batch soapsplitting: ultrasonic attenuation method.

gram, as well as self-checking procedures to ensure the ultrasonic detection system per vessel is functioning correctly.

The automatic draining sequence is preprogrammed using integrated circuit (PROM) units (Fig. 17) which control the sequence in which four ball type valves associated with the base of each vessel are operated. The basic automatic draining sequence commences by a short hot water flush of the selected vessel's sampling pipework and detector cell, during which time the detector output signals are automatically checked to ensure that they represent "clear hot water" values. A sampling valve installed part way up the vessel cone base is then opened, and, providing a "normal soapstock" signal is obtained, the main base valve opens and draining commences at full flow. Draining continues until the onset of an emulsion is detected at the upper sample valve, at which instant the main base valve is closed. The remainder of the draining is then carried out at a reduced rate of flow via a smaller secondary base valve and the detector cell. As soon as the onset of emulsion is again detected (this time from the vessel base cone tip), draining is stopped. The system then automatically checks back to ensure that neutral oil is present at the upper sample valve position, and then flushes the pipework system through with hot water in preparation for the next draining.

A number of protective interlocks are built in, such as valve position signaling, sampling flowrate check, and unexpected emulsion/oil checks at certain parts of the sequence. Any of these interlocks automatically puts the system into a fail-safe condition and an appropriate alarm signal is given.

Such automatic soapstock draining systems are being employed in centralized batch neutralizer control configurations, as well as a one system per vessel approach when required. The principal advantages of such draining systems are the ability to control the draining operation in an optimal programmed manner and without risk of detection errors or oil losses. The draining operation can be initiated remotely from the upper operating floor without fear of a control system failure causing a fault condition leading to accidental oil losses. The system can compete with the best possible operator detection ability (at any time of day or night) and can warn production personnel of certain abnormal circumstances within an oil charge during processing, e.g., excessive emulsification and too high TFM in soapstock.

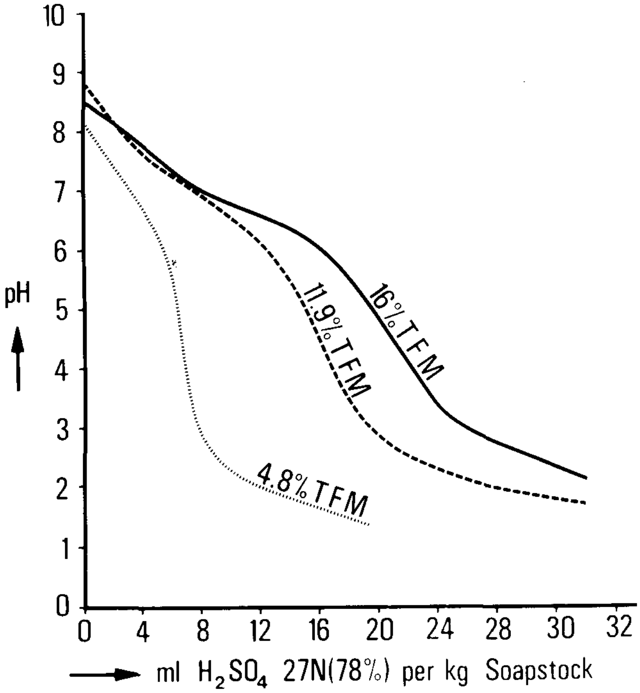

FIG. 19. Soapstock-acid titration curves (temp 90 C).

Continuous Soapstock Splitting

The application of automation methods to soapsplitting can take several forms. In the batch type soapsplitting plants, the accurate addition of splitting acid has been carried out by means of load cell weighing and flowmetering techniques. The control of acid water runoff has also been automated by use of in-line ultrasonic emulsion detection equipment (Fig. 18).

However, the attraction of a continuous form of soapsplitting operation, particularly associated with continuous refining processes, has motivated a number of plant configurations, with their attendant automation requirements.

The basic soapsplitting reaction, using, for example, sulphuric acid, may be expressed as follows:

Soap + sulphuric acid → fatty acid oil + sulphate

The reaction takes place virtually instantaneously, provided an intimate mixture is formed.

Figure 19 illustrates typical soapstock-acid titration curves for different percentage TFM soapstocks, and it is such curves that hold the key to successful soapsplitting on a continuous basis. The steepness of the titration characteristics between, say, 5 and 3 pH indicates that relatively small changes in acid addition in this region result in large changes in pH value. Between 3 and 1.5 pH, however, the titration characteristic becomes much less steep, and hence the pH becomes increasingly less sensitive to acid addition.

It can be seen that to bring the pH down from 3 to 1.5 pH requires approximately double the amount of acid. To obtain good soapsplitting conditions, a pH value in the

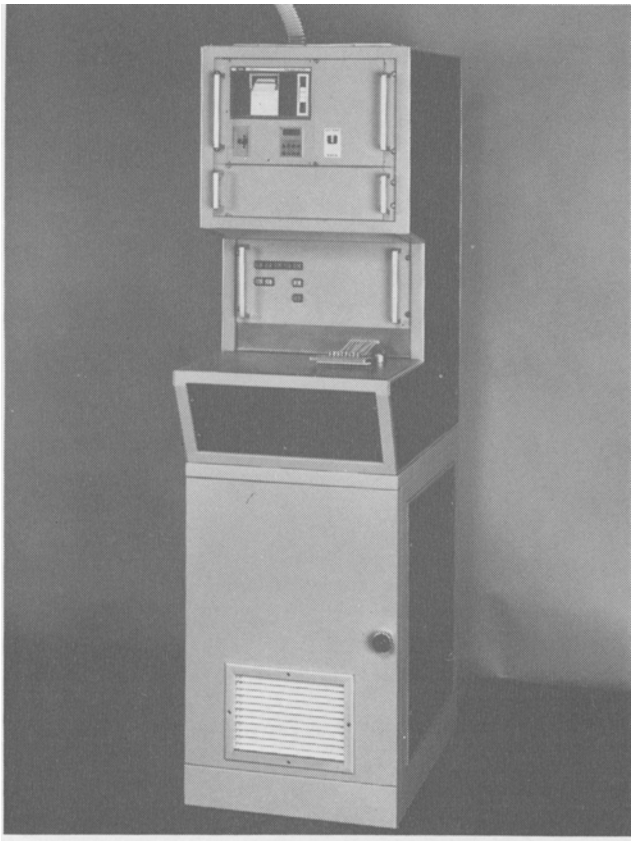

FIG. 20. Automatic slip (melting) point analyzer.

region of 3.0 is desirable, and values significantly less than this will result in excessive overusage of acid (unnecessary cost of acid plus additional neutralization) and increased sulphate load in the acid water effluent.

One of the principal automation tasks in continuous soapsplitting plants is to measure and control the splitting pH in the region of 3.0. Although this is not an unfamiliar chemical engineering/control problem, it is still a task that requires careful design to achieve it simply and reliably. Corrosion problems are also an inherent part of soapsplitting plant design, although the availability of materials such as glass fiber reinforced plastic (GRP) and "Kynar" plastic coatings reduces the problems of former years.

The keys to accurate pH control are:

1. Reliable form of pH measurement
2. Rapid and intimate mixing of acid with soapstock
3. Minimum time delay between acid addition and pH measurement (no distance/velocity lag)
4. Reduced process gain, i.e., less steep titration characteristic, by back mixing
5. Maintenance of consistent splitting conditions, i.e., constant flowrate, temperature, soap consistency, etc.

If the design of a continuous soapsplitting plant is based upon acid injection followed by in-line (static) mixing followed by pH sampling and measurement, then one has built in the fundamental components of an unstable control system. The plug type of flow encourages litttle back mixing, and hence the steepness of the titration characteristic is preserved. In addition, the finite delay (say, 10 sec) between acid injection and pH measurement ensures that the pH controller has little chance of reacting in a sensible manner unless the control system is sufficiently desensitized, e.g., no proportional action.

The solution to the problem lies in the use of a small stirred tank reactor (say, 1 min mean residence time), into which the acid and soapstock are rapidly mixed by maintaining turbulent flow conditions. The turbulent flow conditions also promote good back mixing conditions within the reaction vessel and can reduce the overall dead time, i.e., delay between an acid injection change and an outlet pH reading change, to a few seconds. In this situation, the pH of the reaction can be controlled in the region of 3 pH by means of a conventional two-term process controller.

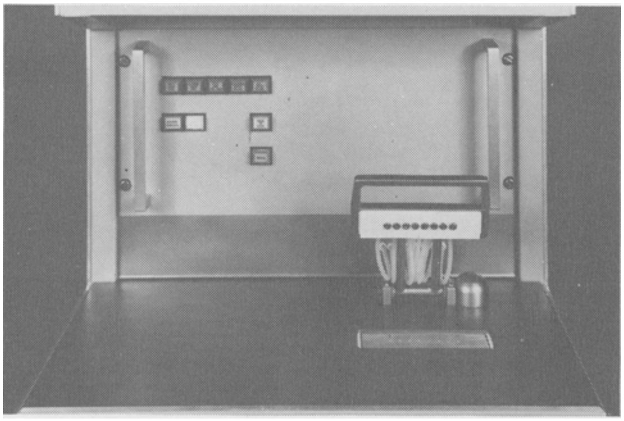

FIG. 21. Automatic slip (melting) point analyzer: capillary block arrangement.

The control of such continuous soapsplitting plants gives a good example of how the best solution to an automation problem is achieved by the combined application of chemical engineering, mechanical design, and instrumentation skills in order to achieve the desired objectives.

AUTOMATION OF QUALITY CONTROL CHECKS

One of the objectives in applying automation within edible oil refineries has already been stated as the need to obtain more constant processing conditions in order to achieve higher product qualities.

The monitoring of an edible oil quality during refining, e.g., FFA, iodine value, melting (slip) point, color, etc., has traditionally been achieved by off-line methods. Often, the more time-consuming absolute laboratory methods are augmented by in-plant "quick methods" for more direct process control purposes. When considering the analytical measurement requirements for in-plant quality control purposes, it is important to recognize the benefits to be obtained from a shorter measuring time, even if the accuracy of the measurement is lower. In the extreme, an absolute method is useless in controlling a process if the time constant of the fluctuations in the required quality is short compared with the time required for analysis. Thus, for certain quality control applications, a "quick and rough" method will give better control than an exact but lengthy method. The mathematical relationship between the measuring accuracy, measuring time, the time constant and degree of process/quality variations, and the resultant limits of controllability are well established and should be considered for each application.

Automation of analysis can minimize the measuring time while maintaining, and sometimes improving, the accuracy of the more manual laboratory method by eliminating subjective errors where they can occur.

As examples of the application of automation to process quality control, the measurement of slip (melting) point and Lovibond color measurement can be illustrated.

Automatic Slip (Melting) Point Analyzer

An automatic slip-point analyzer which is being applied to both laboratory and in-plant quality/process control purposes, e.g., hydrogenation end point control, is shown in Figure 20. The analyzer is completely self-contained and incorporates refrigerated cooling and automatic solvent cleaning for the measuring capillaries (up to 12), which are located in a metal block mounted at the working level (Fig.

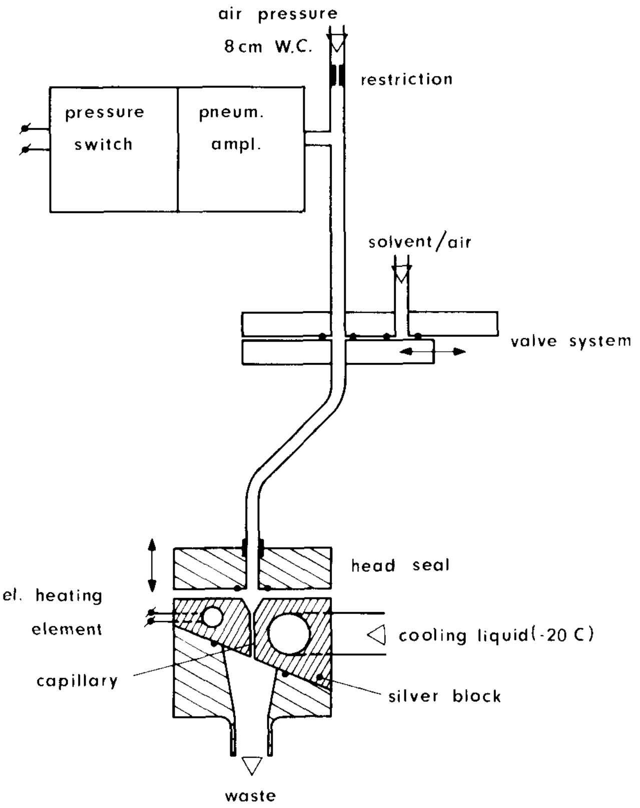

FIG. 22. Automatic slip (melting) point analyzer: measuring principle.

21). Once the operator has inserted a few sample oil droplets into one or more of the measuring capillaries and pressed the start-to-measure button, the analyzer carries out a programmed measuring sequence as follows:

Chilling down to -15 C	120 sec
Heating up to +10 C	30 sec
Heating from +10 C at a rate of 8 C/min	

Thus, for example, a slip (melting) temperature of 34 C is reached in 5.5 min from the start-to-measure signal. When each of the samples has reached its slip-point, the capillary block is heated to 65 C and the capillaries are then automatically cleaned by solvent flushing, and the analyzer then holds itself in readiness for another measuring cycle. A typical overall cycle takes ca. 8 min, although the individual slip-point temperature values can be read from the solid state memory at any time after detection has occurred. An automatic printout can also be used. The individual slip-points are detected pneumatically (Fig. 22) by applying a low air pressure, e.g., 80 mm WC, above each capillary and detecting the pressure drop when each fat sample is pushed from its capillary when the slip-point is reached. The standard deviation of the measurement varies with different types of oil but is normally < 0.1 C.

In addition to hydrogenation control purposes, the equipment is used as a central laboratory analyzer and is capable of making up to 75 determinations/hr, with a total attention time from an unskilled operator of 10 min.

Automatic Colorimeter

As another example of analysis automation for both in-plant and laboratory use, a method has been developed for the quick determination of the Lovibond color of oils without the inherent subjectiveness that the normal manual method entails. The Lovibond color (Y + R) specification is widely used as a product specification for buying and selling as well as internal quality control purposes, and hence there exists a need to monitor color by this particular method during the various edible oil refining stages.

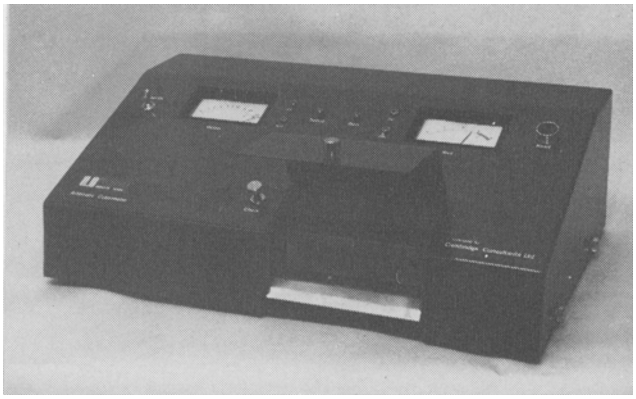

FIG. 23. Automatic colorimeter for edible oils.

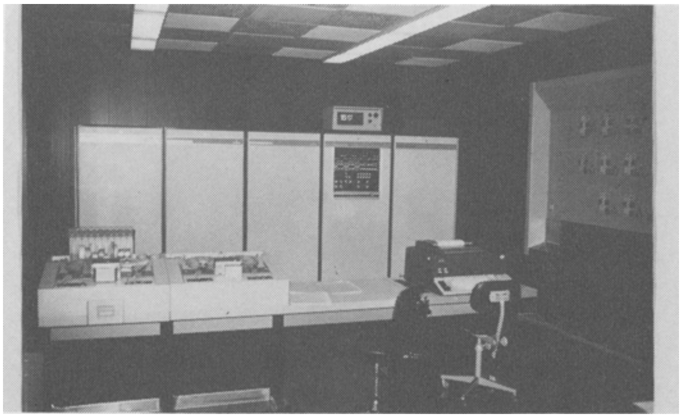

FIG. 24. View of refinery process computer and graphic panel.

The basic operation of the manual Lovibond Tintometer depends upon making a visual comparison between the color of an oil sample in a specified glass cell and the combined color of selected red, yellow, and blue glass filters under prescribed lighting conditions. The method is necessarily subjective and frequently limited to use by laboratory personnel. In addition to the inherent subjectiveness of the method, discrepancies can sometimes occur between the results from similar instruments if their condition is not closely monitored, i.e., age of lamps, cleanliness of the internal reflecting surfaces, etc. However, the instrument is simple, easy to operate, and can be applied to a wide range of materials.

The task of automating such a basic intrument is by no means as simple as it may at first appear, principally due to the very complex nature of the measuring and comparison detector employed, i.e, the human eye. However, a detailed correlation exercise for edible oils has been carried out in order to deduce the optimal choice of transmission filters, i.e., number of filters, nominal wavelengths, transmission "shape," etc., which, when placed successively in series with the oil sample, enables their individual light transmission values to be combined in an algebraic expression which correlates with the particular Lovibond Yellow and Red values of that sample. Figure 23 shows the automatic oil colorimeter thus developed. Normal Lovibond Tintometer type cells are used, and the individual measuring filters are mounted on a rotating disc which enables each measuring filter to be placed in series with the oil sample and light beam, which is continuously focused through the sample cell. The resultant amount of light transmitted by the oil sample and each measuring filter in series is measured by a photocell. The individual electrical output signals from the photocell are combined into the predetermined algebraic expression, and the respective values of Lovibond Yellow and Red are indicated virtually instantaneously on the readout meters.

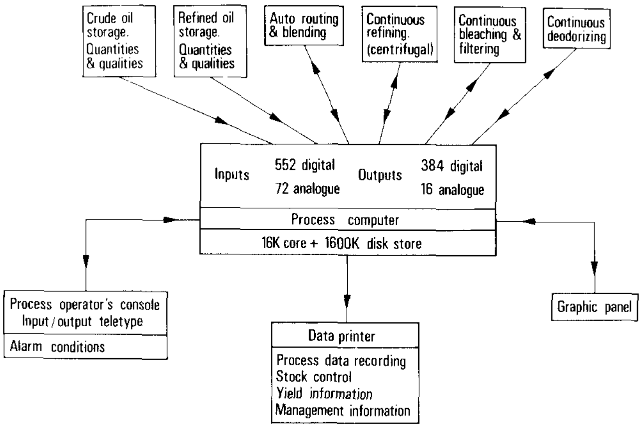

FIG. 25. Computer control of refining processes.

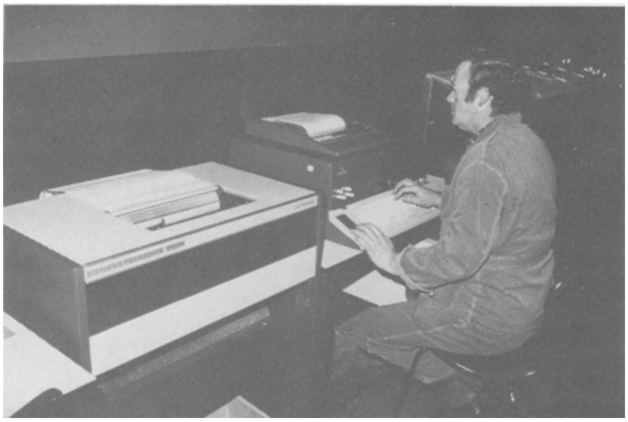

FIG. 26. Refinery process computer: operator's console.

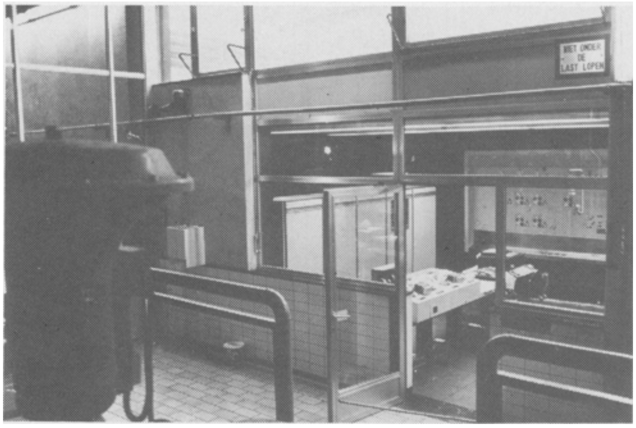

FIG. 27. General view of central control room for refinery process computer.

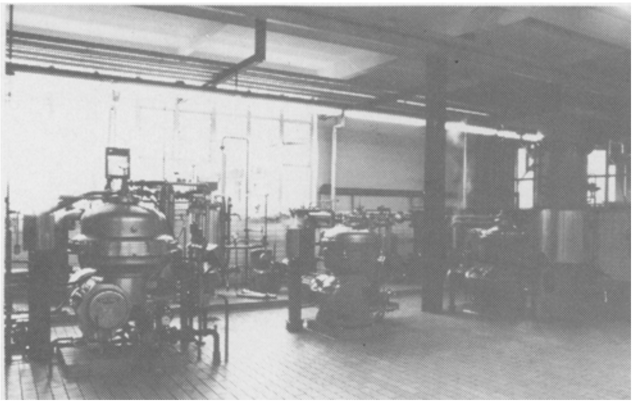

FIG. 28. Centrifugal refining line controlled by process computer.

The possibility of measuring errors due to solid particles within the liquid oil sample or dirty end surfaces on the glass measuring cell, e.g., finger marks, etc., is automatically cancelled by the choice of measuring filters and their interrelationship within the algebraic expression to produce the final readout signal. This automatic compensating feature also provides a certain degree of immunity from any small variations in lamp output and photocell sensitivity.

The automatic colorimeter has built-in check filters which enable the calibration of the instrument to be checked easily; hence, the performance of individual instruments, which may be distributed over a number of users, can be closely monitored to eliminate user/user measuring discrepancies.

As with the automatic slip-point analyzer, the automatic colorimeter can be used for both in-plant and central laboratory applications by unskilled personnel.

DIRECT PROCESS CONTROL BY DIGITAL COMPUTER

The application of digital computers for direct process control purposes, as opposed to off-line data processing, is part of the natural evolution of computer application technology which has been in evidence for many years. For example, some 15 process computers have been applied within Unilever processing plants in general, and the signs are clear that further applications will continue to arise.

Within the edible oil refining field in particular, a process computer (16K + 1600K disk store—see Fig. 24) has been installed as part of a production expansion program for continuous refining, filtration, and deodorizing in our Merksem plant in Belgium.

Principal tasks of the computer, together with the numbers of analogue and digital input/output signals involved and the form of control exercised are shown in Figure 25. In the case of the continuous deodorizer, for example, the total control function is undertaken fully by the computer by converting the analogue control functions into digital form (DDC). Process measurements such as temperatures, pressures, levels, and flowrates are connected direct to the computer, and the resultant controlling output signals are connected back into the plant to operate regulating valves, etc. The normal operator's control panel is replaced by the computer control console and graphic panel in the central control room (Fig. 26). The process operator can change selected operating conditions by inserting instructions with the teletype on the control/printout console. He can also request a printout list of each of the controlled parameters at any instant.

The continuous filters, which are situated beside the computer control room (Fig. 27), are also being operated by direct digital control from the computer, thus enabling the sequence of filtering steps to be carried out according to an optimal program and at the same time logging any manual operations that may at times be necessary. In addition, the computer has been programmed to control automatically the startup and shutdown operations for both the deodorizing and filtration plants.

Control of the principal process operating conditions in the continuous refining line (Fig. 28) is also undertaken by the computer, e.g., oil, water, lye, phosphoric acid flowrates, etc. Conventional field mounted control loops are used for temperatures and levels. During normal production, but before starting to refine a new crude oil parcel, the process operator types in the new oil variety, required throughput rate, percentage FFA, normality and percentage lye and percentage phosphoric cid to the first bowl, and normality and percentage lye and percentage water to subsequent bowls. This information is then interpreted by the computer into individual set-points, e.g., L/hr, etc., for each flow control loop (including acid pump stroke), and these settings are automtically maintained by DDC during subsequent processing.

Each of the processes connected to the central computer has 72 alarm inputs, which are continuously scanned and form part of an integrated alarm logic and annunciator system within the central control room. Each alarm is categorized into either an indication-only function or an automatic plant standby or shutdown sequence. Each alarm condition is printed out with the time it occurs and is also indicated on the graphic panel display.

In addition to the operator's teletype, a second printer is installed within the control room which is used for data logging and management information purposes. As an example, a printout can be obtained for a specified period of time which lists the total quantity of a particular oil which has been deodorized during that period together with the associated plant startup durations, average throughput, and total injection steam consumed.

The experience gained with such computerized process control and information retrieval applications can considerably increase the knowledge required for optimizing edible oil refining processes, while at the same time giving a flexible control system which can be readily updated to give improved processing programs and control philosophies as and when required.

CONCLUDING REMARKS

The changes that have taken place within the edible oil refining field in recent years give ample proof of the advantages that automation methods can bring, some of which have been dealt with in this review.

Each phase of implementation becomes a stepping stone from which the next, often more "progressive," step is considered. An automation approach that could have been viewed as "too sophisticated" some 5 years ago is often considered as commonplace today and will be outdated tomorrow.

The challenges are continually there, in different forms, and, going hand-in-hand with new technological developments, automation applications will continue their inevitable progress throughout our processing areas.

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