

# USE OF DIGITAL CONTROL SYSTEMS IN THE PROCESS INDUSTRIES

Resulting in Improved Standardization and Increased Profits

By Montgomery Phister, Jr

**I**N THE PAST TEN YEARS the digital computer has enjoyed a period of remarkable growth in scientific, engineering, and business application. It has made possible great forward strides in scientific research. It has reduced engineering costs substantially and made feasible engineering calculations which were previously left undone because of the sheer weight of calculations necessary. It has taken over many of the repetitive bookkeeping and accounting operations of business and has given the businessman better data on which to base his decisions. It is evident that the digital computer will find even wider use in these applications in the future and will make further contributions to efficiency. However, I wish to discuss another application of digital computers which promises to become increasingly important in the years ahead—the use of computers in digital control systems.

## Basic Problems in Process Control

I shall begin by describing in somewhat general terms the basic problems which have to be overcome in exercising control over a process. I shall then describe a digital control system and show how it can be used to help solve these problems. Finally, I shall discuss the advantages to be gained from the application of a control system of this kind.

Obtaining the best profit possible from his investment in the plant is, of course, the manufacturer's objective in running a chemical plant or a steel mill or a petroleum refinery. Because a very large number of very complicated strategic and bookkeeping-type problems enter into the determination of what is the best way to make a profit, the operating problem is somewhat simplified at the plant level. Specifically, in connection with some particular operating unit in a plant in the process industries, the various raw materials and products are assigned values, certain costs are allocated to the running of the process, and it is the operator's objective to obtain the maximum return, based on these costs and values. At the same time, he wishes to maintain some minimum level of product quality. Putting it another way, the operator must make a standard product at highest possible profit. Plant operators have available many instruments and much laboratory apparatus and equipment to help them control the process in such a way as to solve the problem. In

order to see precisely how they exercise control and why their problem is difficult, let us examine a typical control system in a little more detail.

The operators are concerned primarily with three different kinds of variables. They must monitor the *product variables*—that is, the variables which determine the character of the product, and in terms of which the product standards are specified. These variables include, for example, the chemical composition or color or weight or other dimensions of a product. Next, there are the *intermediate variables* over which the operators can exercise direct control. For example, an operator can directly control the flow of a liquid in a pipe by opening or closing a valve. Notice that operators control the product variables only indirectly by exercising control over the intermediate variables. There is no knob labeled "color" which an operator can use to adjust the color of his final product, but he may be able to affect the color by making an adjustment in a flow here and a temperature there, for example. Finally, there are the *independent variables* over which the operator has no control. These are the ambient conditions—outside temperature and direction and force of wind, for example—and, in general, the chemical, physical, and other properties of the materials being fed into the process. For example, in a steel mill, the characteristics of the iron ore are independent variables dictated by nature. These characteristics may vary over a fairly narrow range, but nevertheless their variation is an important factor in the operation of the process.

With these three kinds of variables in mind, it is possible to state the operator's and control system's function a little more definitely. The purpose of a control system is maintenance of a standard product quality and operation of the unit at its highest profit, by making adjustments in the intermediate variables (over which the operator can exercise some control) to compensate for variations in the independent variables. Note that if there were no independent variables—that is, if nothing in the process, its environment, or in the materials used in the process ever varied—it would be necessary only to adjust the intermediate variables at some fixed setting which corresponds to best operation of the unit, and thereafter and forevermore the unit would operate without the need for further attention. Unfortunately (or perhaps fortunately for those of us interested in auto-

matic control systems), the plans having a great many important independent variables far outnumber those which can be operated so uniformly.

The operator, working carefully with his instruments and other apparatus, does an excellent job of handling this very difficult control problem. However, in some processes the relationships between control variables are very complicated, and the way they should be manipulated in order to operate the plant in the best possible way is not at all obvious. The result is that a plant may be run in a somewhat erratic way, so that the quality of the product and the profit derived from operating the unit vary considerably from minute to minute and hour to hour. Because many of these processes involve profits of thousands of dollars every day, the elimination of these variations can be a very profitable objective, even if the variations are slight. It is here that the digital control system can be of use.

### **Functions of a Digital Control System**

A digital control system can be thought of as an operator who follows a very complicated set of instructions which direct him to make many arithmetic calculations, to "read" many process instruments, and to adjust many intermediate variables, automatically, continuously, and without error prejudice. A digital control system has facilities which make it possible to connect the temperature, flow, level, composition, and other process measuring instruments directly to a digital computer, so that the computer can determine which adjustments should be made in the process to operate it in the most efficient manner while holding product quality or standards within specified limits. The computer is also connected directly to the equipment which adjusts the intermediate variables, so the computer can take action directly on the process when it has determined that some modification is necessary or desirable. A typewriter input-output system is also provided with a digital control system to enable it to communicate with a human operator.

It is important to note that, in addition to "tuning up" or "trimming" the process in order to keep it at its best possible operation, the computer may have a number of other useful functions. It can be used to interpret instrument readings and to calibrate instruments periodically. It can be used during process startup or shutdown to insure that operations are carried out in a proper (predetermined) sequence. It can be continually and tirelessly on the lookout for instrument or process failures or other troubles, and it can collect and interpret process data for later study by engineering and research staffs.

### **Advantages**

It seems very likely that control systems of this kind will become as widely used in the process industries in the next five years as business data processors have been in the past

five years. If this is so, it will be true for only one reason: such control systems pay for themselves by virtue of the improvements they make possible in process operation. The improvement, in general, will come in one or more of these specific areas: from increased production through better control; from improved quality; or from reduced operating costs. Generally, the improvement will arise as a result of some optimum balance between gains in these three areas. To make it possible to see a little more precisely where these gains may come from, let us examine them in greater detail.

Increased production may arise from a number of different improvements attributable to a digital control system. The continual "tuning up" of the process may mean that the yield of the product from a raw material is higher than before. Better control may make possible reduced maintenance so that an operating unit may be "on stream" for a higher percentage of the time. (For example, the digital control system provides the possibility of eliminating process upsets which would otherwise require that the operating unit, whatever it might be, be closed down for repairs.) Better control may result in fewer periods of off-specification production, when materials are wasted or must be re-run. A digital control system may make possible a quicker startup and shutdown time which will result in increased total production.

Better quality control is a natural benefit obtained from a digital control system, and one which in some instances may be the most important feature of all. Through the better use of current information about the process and the products it makes—information derived from data continually being read from process instruments—a digital control system may make possible a substantial reduction in product variability. Alternatively, or perhaps at the same time, it will be possible to improve the average quality if that is desirable for competitive or other reasons. The continual tightening-up of product standards and specifications leads to an ever-increasing demand by industry for methods which will make possible a better control over product quality, and the digital control system is in its element here.

Finally, the employment of a digital control system makes possible a reduction in operating costs. There will be less waste through the better use of raw materials, catalysts, etc. Better use will be made of the energy supplied to the process, whether it be electrical energy or chemical energy in the form of burning gas, coal, or fuel oil. The trouble-shooting attributes of the digital control system will reduce maintenance costs. Finally, extensive applications of these control systems may make possible a reduction in manpower. It should be noted, however, that manpower is already used very effectively in the process industries, and that such a reduction is not likely to be as important as the applications of computers to business data processing, for example. A process control computer will be employed to make decisions

so complex that they are not made now at all, and we are therefore not contemplating the use of a computer to replace a man or a number of men currently making the same decision. Instead, the present operator or operators will be better able to make use of their time and of their knowledge of the process. They will be freed of the routine and tedious operations they must now perform, and they will be able to devote their time and energy to making still further improvements.

One aspect of the usefulness of digital control systems, which is particularly appropriate and very important, has not yet been mentioned. A computer control system can be extremely flexible, so that simply by changing a set of instructions stored in the computer memory it is possible to change slightly, or even completely, the control actions taken by the computer. This means that it will be possible to improve or to relax product quality in order to meet competition or to handle emergency situations. It will be possible to take into consideration changes in operating costs or in raw material costs or in product prices and make sure that such changes have the proper influence on operating conditions. It will also be possible to modify process operation in order to take into account new technical information about the process and to use this technical information most effectively.

So far, I have discussed only the application of a digital control system to an existing plant, and the economic savings which can be effected by such an application. In addition, there will be important implications in the application of such systems to new processes and to the construction of new plants. Generally speaking, the improved control of

processes through such control systems will permit substantial reductions in plant investment. The reduced investment will come about for several reasons. The prospect of tighter control will mean that some of the sizing safety factors which are put into new plants can be reduced, so that, for given plant output, smaller reactors, furnaces, pipes, heat exchangers, conveyors, etc, may be employed. Furthermore, the very large and expensive storage capacity which must sometimes be provided to help smooth out variations in product quality may be vastly reduced. The most interesting implication of all, however, is the prospect of the use of digital control computers in the control of presently uncontrollable processes. Every day products are made in plants which could not possibly have been operated twenty years ago without modern instrumentation. Twenty years from now there will be processes run by digital control systems which cannot be run today using the conventional methods. In this regard, such systems may have a tremendous impact on process technology.

I hope that the picture I have given of this new and interesting technology has been of interest. Its influence on product quality and standards are fundamental and very important—the essence of any control system is the maintenance of quality. However, it is in the area of increased profit that systems of this kind will stand or fall. Unless they contribute substantially to profits, they will not be adopted. For the reasons I have outlined here I confidently expect that the installation of digital control systems will contribute to greater profits, and that you will be seeing more and more computers applied in process industries in the next five years.

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