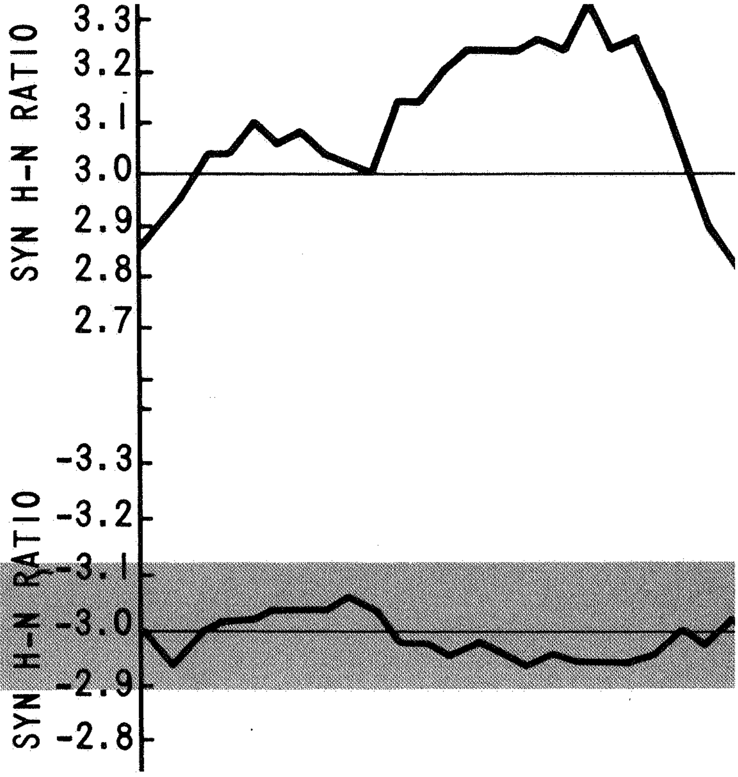

AMMONIA PLANT OPERATIONS:

Computer Control of Ammonia Plants

Five commercial plants have proven successful following installation of digital computers, and a sixth unit is now going into full operation. Payouts of a year or less are being achieved.

L. C. Daigre, III, and **G. R. Nieman,** Fisher Controls Co., Marshalltown, Iowa

Synthetic ammonia plants can operate more smoothly and safer with digital computer control. Furthermore, management is aided in making crucial operating decisions because data on significant process variables are displayed at the control center on an instantaneous basis.

The resultant improvement in efficiency—2-3% better when computers are installed in existing plants—means payouts on the computer investment of as quickly as one year or better.

Up to now, five ammonia plants have had successful implementation of computer control. They include: in 1959, a Chemico unit for Monsanto at Luling, La.; in 1962, a Chemico unit for Monsanto at El Dorado, Ark.; in 1967, a Kellogg unit for Monsanto at Luling; in 1967, a Chemico unit for Borden at Geismar, La.; and in 1973, a Kellogg unit for Terra Chemical at Sargent Bluff, Iowa.

The tasks performed by these computers can be put into four broad areas: 1) closed loop computer control of key "loops" in the plant; 2) monitoring process variables for potential and existing alarm conditions; 3) calculating critical parameters which don't lend themselves to easy, direct measurement, steam-gas ratio for example; and 4) preparation of logs and management reports.

In the first category, closed loop computer control has been achieved in the following areas:

- Primary reformer control, including feed flow determination, catalyst tube temperature control, methane leakage control, flue gas temperature control, and steam-gas ratio control.
- Synthesis H-N ratio (hydrogen-nitrogen).
- Purge flow.
- Synthesis reactor control.
- Optimal loading of the reciprocating compressors (older style plants).
- Compressor tripout response (older style only).

Advantages of computer control

There are several advantages to placing certain key control loops or functions under the control of the computer: consistency in operation, smoother operation, response to unusual conditions, and overcoming problems due to the human factor.

Consistent operation. The computer will carry out, without variation, a predetermined control strategy stored in its memory. This will eliminate the shift-to-shift variations that are always found in plant operation. In fact, the computer can be made to implement a "best operator philosophy." Using this approach, the control strategies of the most skilled operators can be programmed and stored in the computer's memory and be implemented consistently and continuously 24 hours per day, seven days per week.

Smoother operation. The computer will make small, precisely determined, relatively frequent changes. These changes are typically small fractions of a percent of a valve movement or set point, but made on intervals of one second to five minutes, depending on how critical the loop is. Because less frequent changes must represent larger changes to achieve the same result and are rarely "precisely determined," computer control results in significantly smoother operation. This will obviously place less dynamic strain on operating equipment, which increases overall operating time and lessens chances of emergency tripout and shutdowns.

Response to unusual conditions. As an example, consider the tripout or even the deliberate shutdown of a reciprocating compressor. This will represent an "instan-

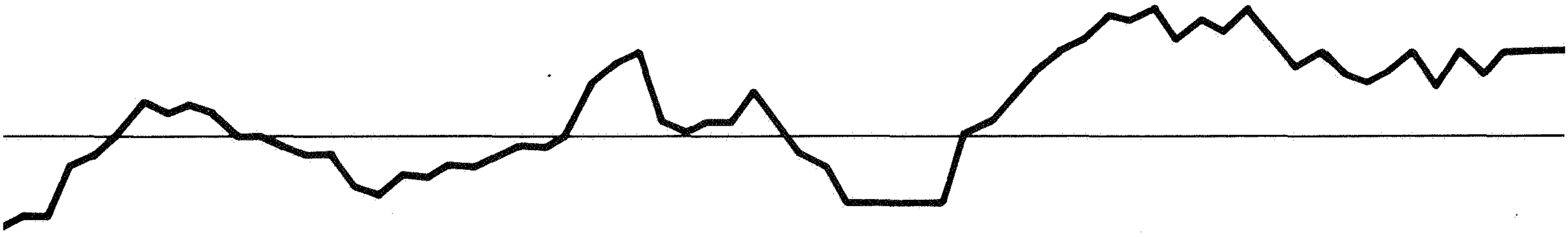

FIGURE 1A. NON COMPUTER OPERATION

Figure 1. Upper curve shows variations in hydrogen-nitrogen ration in a synthetic ammonia unit over a 24 hour period without computer control of operations, and the lower curve shows variations with computer control.

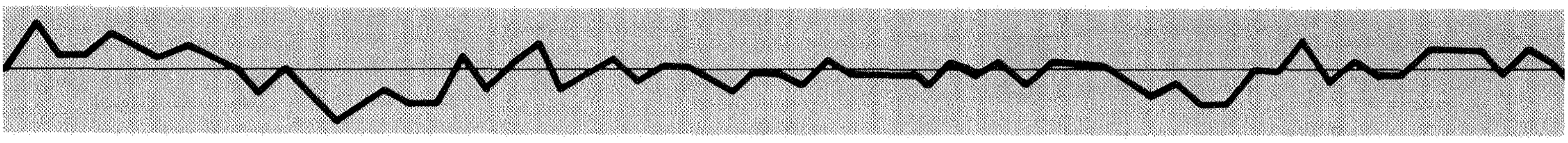

FIGURE 1B. COMPUTER OPERATION

taneous" loss of 12-15% of the process compression capability. This event is automatically monitored by the computer. When this situation occurs, the computer instantly trims all plant inputs maintaining proper flow ratios to prevent overload, lifting of relief valves, and upsets in controlled variables. A computer in this instance has made a routine occurrence of what was usually a mini-crisis.

Human factors. Most operators tend to over-react, or over-correct, and often further upset the process when trying to correct an "out-of-control" condition. As human beings, they often get impatient when trying to control loops with deadtimes or long time constants. Controlling H-N ratio is typical of loops with deadtime and rather large time constants. The computer, not prone to human problems, can better cope with such situations.

The computer can also control critical areas of the plant during upset while the operator is busy correcting the problem causing the original disturbance.

An example of the differences between computer control and non-computer control is shown in Figure 1. This is a comparison of H-N ratio in an existing Kellogg ammonia plant with and without computer control. Figure 1A shows a 24-hour period of non-computer control ratio readings. Figure 1B is a similar graph, but with the computer controlling the H-N ratio. The *difference* (standard deviation) in control between the two modes of operation was approximately ±0.1 ratio units. This difference affected production by nearly 1%.

Precise manual control of H-N ratio is difficult, even when an on-line gas chromatograph is available. The difficulty is due to the great sensitivity of the H-N ratio inlet synthesis converter to changes in the reform or "front end" H-N ratio as measured at the exit of the methanator. A one-ratio-unit change in the reform H-N ratio is magnified about 13 times in the synthesis loop of a typical Kellogg plant.

A computer-controlled H-N ratio system will achieve precise control of the ratio inlet to synthesis converter. The standard deviation, based upon actual case history, is 0.04 ratio units. Because this control is virtually absolute, this system has been used experimentally to determine the best ratio for the operating level of a particular process.

Alarm monitoring is improved

The second major task performed by the computer, stated earlier, is the monitoring of process parameters for potential and existing alarm conditions. This can be done better by computer for the following reasons.

1. Each alarm condition can be logged in permanent written form and can give more meaningful information than that obtained from a typical annunciator panel. The information that can be included in an alarm message would be the exact time of the alarm condition, the value of the alarm parameter in engineering units, and the exact sequence of occurrence if multiple alarms occur "simultaneously." This exact sequence is extremely valuable in determining what event triggered the upset. Suggested corrective action can also be printed by the computer, along with the time of acknowledgment of the alarm by the operator.

2. To assist operators in determining the exact cause of the alarm, the computer can print out all important process variable values at the exact instant of the upset or alarm condition. In some installations, a "rolling log" of key process parameters is retained in the computer's memory at all times. This rolling log is a record of previously stored process parameters recorded at frequent intervals prior to the present time. For example, the computer could retain the value of all process variables at one-minute intervals for the previous half hour, or a reading of their values every five minutes for the previous eight hours. With this "rolling log" approach, the plant conditions prior to the upset or alarm can be printed to help pinpoint the cause. The advantage to this is that the information is delivered only on demand. That eliminates a frequent problem where the operators hear and see a constant stream of print-outs, horns and flashing lights, which they eventually tend to ignore.

3. The computer can implement more sophisticated

alarm techniques than are normally available with conventional alarm schemes. One example would be the monitoring of the rate of change of a given variable so as to predict when a given parameter will go into an alarm condition, rather than waiting until that alarm actually occurs. Another example is the correlation of two or three variables where certain combinations of these variables would indicate potential trouble. The primary purpose here is to predict an alarm condition *before* it occurs, rather than forcing the operator to react to an alarm condition *after* it has occurred.

Value shown in logs and management reports

The third major task performed by the computer, preparation of logs and management reports, can prove quite valuable to both operating personnel and plant management. Typically, this information includes the following:

Process log. This log could present, on a scheduled basis (hourly, shift, and daily) any or all process variables and also calculated parameters, such as ratios. All variables can be displayed in engineering units and pressure/temperature compensation applied as required.

Snap-shot or trend logs. The snap-shot log presents one or more preselected groups of data about major pieces of equipment on a demand basis. The trend log is similar to the snap-shot log; however, it is automatically repeated at a frequency selected by the operator. These are quite valuable during start-ups, shutdowns, and during process upsets, especially when many "correlations" and calculations are involved. Instant access to vital data is known to have prevented unnecessary shutdowns and has decreased startup time by several hours. Prevention of shutdowns and faster start-ups mean dollars saved in terms of raw materials, labor, and stress or strain on plant equipment.

Management reports—These typically include shift or daily production/efficiency summaries. Data which can be presented include: production, process gas, fuel and steam consumption, primary and auxiliary boiler fuel consumption, total B.t.u. consumption, compressor steam consumption, and total purge.

Normally, all process parameters monitored by the computer can be displayed to the operating personnel through a simple request. Calculated parameters such as ratios and pressure/temperature compensated flows can be displayed, together with totalized flows and production. Therefore, the operator has, at his finger tips, more accurate and timely information than normally obtainable. This information typically can either be recorded in hard copy form using a teletype or displayed on a cathode-ray tube display. Devices such as these can be placed in offices, remote from the control room, so that plant technical and management personnel can have access to the operating data as easily as if they were in the control room. This really helps in making a critical "4 a.m. go down/stay up" decision where time is of the essence.

Operator's reluctance

Many operating personnel fear the computer will complicate their daily tasks when, in fact, it will greatly assist them in carrying out their duties. The operator usually need not concern himself with the control of those loops that are under supervision of the computer. Thus, he is free to do other tasks. He can maintain a closer watch on other areas of the plant. This is especially important during upsets when manpower is in short supply and many things need to be done quickly.

The sophisticated alarm capabilities mentioned earlier can alert the operator to potential problems which are more easily averted before they reach the critical state. Documenting of the alarm condition and plant status during this time can assist operations, maintenance, and the safety departments in the prevention of future disturbances. In fact, the computer's program can contribute significantly to insure that the plant will run smoothly and be subject to a minimum of human errors.

Specifically, a typical computer program would take the following four steps:

1. Continually check process data against high and low process limits and against high and low instrument range limits. For example, if the process temperature normally has a range of 500°F. to 600°F. and the temperature transmitter normally has a range of 400°F. to 700°F., the program checks the temperature and should it exceed the 500°F. to 600°F. range, will inform the operator that the process is out of its normal range. If, on the other hand, the temperature signal indicates a value outside the 400°F. to 700°F. range, it informs the operator that it is not only out of range, but that there appears to be an instrument problem. Process variables can also be checked with respect to their rate of change to pinpoint an abnormal situation that would normally go unnoticed.

2. All of the set points entered by the operators (with management approval of course) are checked against high and low set point limits to prevent the inadvertent entering of a set point that might cause operating problems. In addition, the set point is limited to certain "maximum change" values. For example, if management does not want the operator to have the ability to change the H-N ratio from 3.0 abruptly to 2.5, the program can limit this change to a maximum of 0.1, or a ratio unit at any single time. This limit is entirely flexible and may be changed by management at any time. Thus, the computer has a safeguard over and above that of changing set points using the conventional analog controllers.

3. When on control, the computer program can check to see that all control devices—for example DDC stations, computer set stations, etc.—are in the computer mode of operation before it will allow the program to operate. In other words, the electronic interface controls must be capable of receiving their set points from the computer before the computer will permit itself to assume control of the set points. An example of this might be in the area of furnace control. Should one of the burner DDC stations be connected in the manual mode, the computer would obviously not be able to change the output from this particular station. This would result in a degrading of the performance of the computer program. In this case the computer would turn the control back to the operator and provide him with a printout or instruction to this effect.

4. The computer also will check an output control signal before it actually permits it to be output, thus preventing extremely large signal changes to be transmitted, which would cause bumps in the process. In addition, maximum and minimum valve position limits are usually established. These would also be checked before any output is made. An example of this might be in the fuel flow to the furnace. It is of course essential to not completely close a fuel flow valve, and the computer could be programmed to keep that valve in some predetermined minimum condition, no matter what the other considerations might be.

An important point about day-to-day operation is that the addition of a computer system can be easily made in such a way so that a failure of the computer will in no way affect the operation of the plant. By adding to the existing instrumentation and control equipment rather than replacing it, the operator can always go back to the "old way" of controlling the plant. In fact, a computer system can be easily designed in such a way that a computer failure, a program failure, or an electrical power failure can be detected and transfer made to the backup mode of operation. Monsanto's two ammonia plants at Luling, La., have operated for over seven years with a system of this type and have never experienced a shutdown due to a computer or program malfunction.

How to use computer control effectively

Implementation of computer control can be easy if the following guidelines, learned and refined through years of experience, are used. Easy is defined as meaning that the plant manpower required to implement it can be on the order of one to six man-months, and that the time required to implement one or more of the applications discussed would be measured in weeks rather than in months or years. To do this, it is suggested that the following guidelines be used:

1. Confine the job scope to something reasonable. Do not try to place the entire operation of the plant under the control of the computer. Experience has proven that just a handful of control loops, typically 15 to 20, are the most critical with respect to efficiency, production and safety. Allow the computer to control these and let the other loops in the plant operate as they were.

2. Implement the project in easily handled, incremental steps. This has several advantages. Peak load manpower requirements are reduced. Results of each individual application can be more easily measured, and if any problems are encountered in the individual application, that particular portion can be deactivated and corrected while the other applications continue to function.

3. Utilize the existing technology wherever possible. With several plants under computer control, a great deal of technology and information is available. Re-inventing the wheel, although satisfying to the ego, is expensive and prone to unforeseen, but avoidable problems.

4. Plan to perform plant modifications, if any are required, during a turnaround. Typically, these plant modifications are relatively minor, and usually include:

- Replacing a handful of existing manual loaders and controllers on the panel board with similar but computer-compatible instruments.
- Adding a few transmitters in the plant and running the signals to the computer.
- Adding a few transducers behind the panel board to convert certain existing signals. For example, converting pneumatic signals to electronic, converting thermocouples and analyzer signals from low level (millivolt) signals to high level (1–5 volt) signals.

Using this approach, the computer and the computer programs can be implemented at any time during plant operation without interfering significantly with the day-to-day operations and—most importantly—without requiring a special plant shutdown.

Economics are favorable

No discussion of this type would be complete without at least mentioning the economics of computer control. Utilizing present computer technology, total installed cost for today's large scale plants (600- to 1,500 ton/day) is in the $75,000 to $150,000 range. This cost includes all the computer equipment, interfacing equipment, computer programs, and plant installation manpower. The hardware can be installed in one week or less, and the rest of the system brought on stream in one to four weeks, depending upon how many applications are implemented.

Savings of over $125,000/yr. have been measured in 600 ton/day plants. If we can assume a linear interpolation, that would mean savings of approximately $200,000 for 1,000 ton/day and larger plants. These savings were calculated on a net back of $20/ton, which may be quite conservative in today's market.

Summary

The use of a digital computer can result in smoother operation of a plant and contribute significantly to safe plant operation. It can be used to implement a "best operator philosophy" and result in a more consistent operation through the elimination of shift-to-shift variations in operating philosophy. By continuous monitoring and controlling of key process variables, the plant will run more smoothly and will be able to react more quickly to process disturbances. The ability to instantly display key process data can assist management personnel in making crucial "go down/stay up" decisions. More sophisticated alarming techniques can make operating personnel aware of potential alarm conditions before they occur. This will give them a head start so they may prevent unsafe conditions.

Computer control is not new technology. Thus it can be implemented without the problems and headaches encountered when "inventing the wheel." The improved reliability of digital computers available today, together with "off-the-shelf" proven technology, mean that this type of control can be implemented quickly and easily without straining the plant's resources. The increased efficiencies of 2–3% that have been achieved by existing installations mean that payout periods of one year or less can be achieved. This means that now the computer can take its place as an easily usable tool to help plant operating and management personnel run their plants in a safer and more efficient manner. #

L.C. Daigre is currently an electronic sales engineer with the J.H. Carter Co., an agency of Fisher Controls Co. Until recently, he was a research engineer for Fischer Control where his major responsibilities involved process control computer applications design and programming with emphasis on computer control of ammonia plants. Daigre earned his B.S.Ch.E. from Tulane University. He was previously employed by Monsanto Co. where he was responsible for computer control projects involving two ammonia plants.

G.R. Nieman is assistant sales manager of Fisher Controls Co. He has nine years experience in the computer industry, six of them in the digital process control area. Nieman earned a B.S. in mathematics from Washington University. He has also done post-graduate work in electronic engineering and computer sciences at the University of Missouri.

DISCUSSION

JOHN CROMEANS, Catalyst Consulting Services: In describing the differences in controlled computer loop and non-computer loop control, you explained the advantage of the computer on H_2/N_2 ratio control would be about one per cent more production.

Question Number one, Is the onstream chromatograph providing the only signal you're using in this example? In other words, are you also using other signals to back up the chromatograph? Question two, what are you actually controlling to maintain the ratio? Question three, how did you establish the value of one per cent more production?

NIEMAN: There was a chromatograph in the converter loop. This is necessary to measure hydrogen and nitrogen. We'd also like to measure all five components. There was also a continuous analysis of hydrogen and methane exiting the methanator. The objective here was to do cascade control because there is quite a bit of sensitivity in the syn loop with regard to fluctuations in the front end of the plant. This sensitivity was about 13 to 1 as a matter of fact as measured at the Monsanto plant at Luling, La.

We also measured process gas and air and did pressure/temperature compensation. So you had the gas flow, gas pressure, gas temperature, air flow, air pressure, and temperature also as inputs. So I believe those were all the signals.

CROMEANS: In proving the difference, your one per cent, how did you come up with this value?

NIEMAN: This was done by having a turbine meter at the end of the ammonia plant measuring ammonia in 200-gallon increments. It was temperature compensated, so we had a mass flow calculation, and we also put it into a cryogenic tank for at least several days, and measured the production, the tank level that way. The plant people felt they were pretty accurate with regard to production. In fact, the plant accounting people now use those production figures as the Bible. I guess that was a milestone as far as operating personnel were concerned. When the accountants stopped questioning the turbine meter readings, the operators felt they had achieved something.

CROMEANS: Where did you have your control?

NIEMAN: We were manipulating the air to the secondary.

* * *