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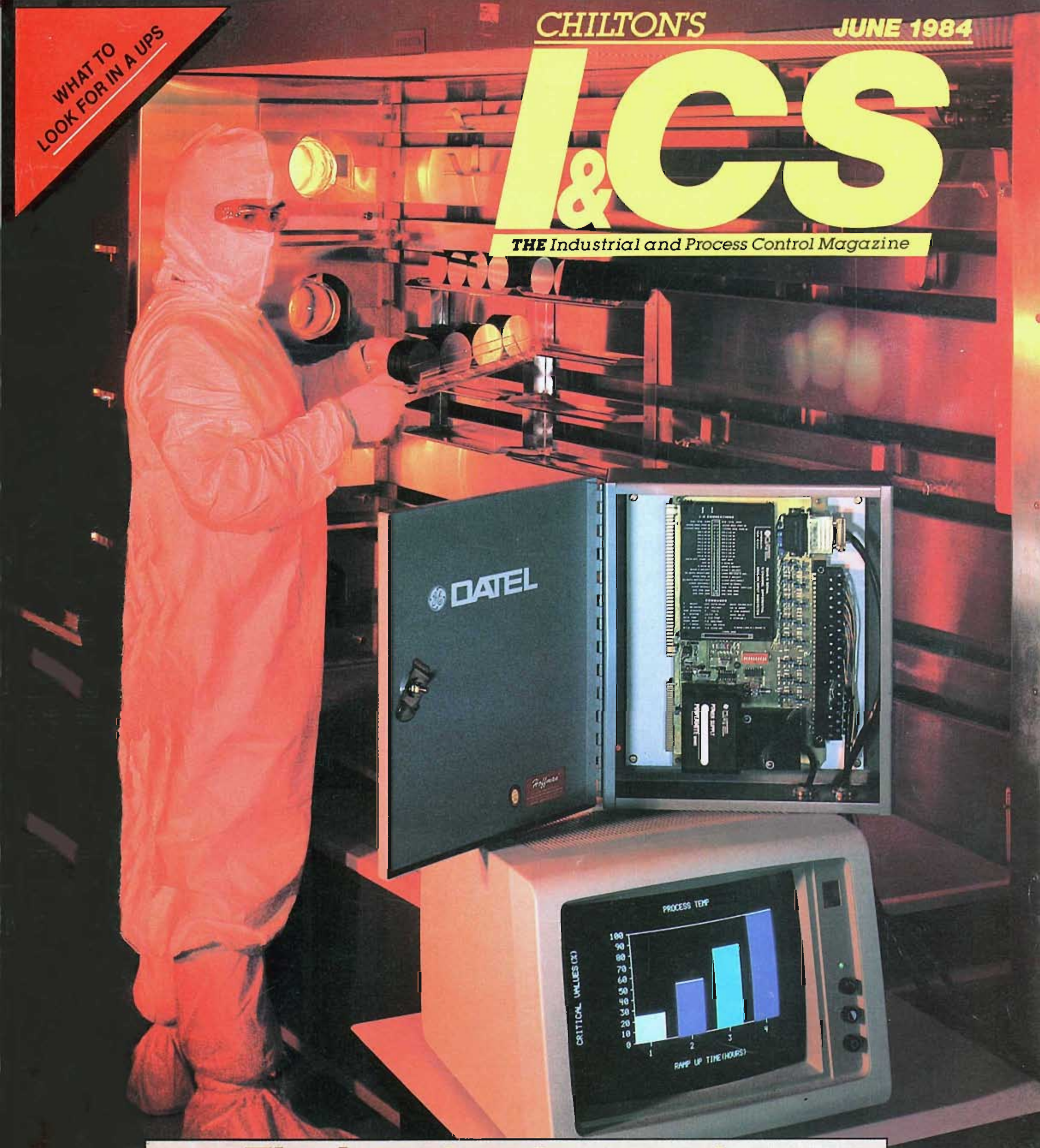


The latest on temperature monitoring and control

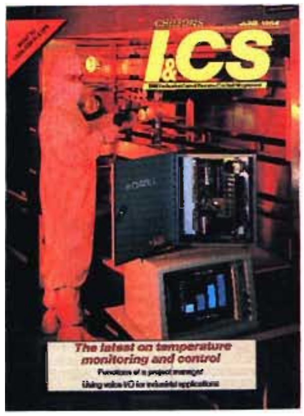
Functions of a project manager

Using voice I/O for industrial applications

CHILTON'S
I&CS
THE Industrial and Process Control Magazine

JUNE 1984
VOLUME 57
NUMBER 6

features



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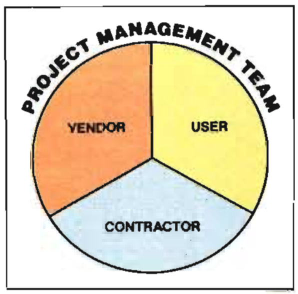

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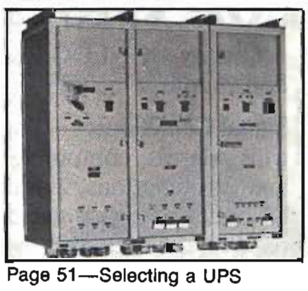
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departments

cover

Temperature measurement and control equipment is getting more accurate, more intelligent, and more capable—all at a lower cost. In the semiconductor manufacturing operation shown, an SDAS-8 "smart" A/D input subsystem is being used to process data on diffusion furnace temperatures. The data is then fed into a personal computer for further analysis. (Photo courtesy Datel, Mansfield, MA). For more on temperature monitoring and control, *turn to page 30.*

Chilton's Instrumentation Group:
I&CS, Instrument & Apparatus News
I&CS (ISSN 0746-2395) published by Chilton Company, Chilton Way, Radnor, PA 19089 (215/964-4000). Chilton Co. is a division of American Broadcasting Companies Inc., New York, NY. Published thirteen times per year. Monthly, with an additional issue in November. Second Class Postage Paid at Wayne, PA 19087 and additional mailing offices.

POSTMASTER: Return Form 3579 WITH COMPLETE ADDRESS LABEL to: I&CS, Box 2025, Radnor, PA 19089-0425.
I&CS is circulated free in the United States and Canada to qualified individuals. Non qualified U.S. subscription rate is $45.00 per year. Rate for Canada and Mexico is $55.00. Foreign rate is $65.00.
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BPA ABP

Supervisory computer control cuts steam use 14 to 30 percent

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Instrument and control engineers have known for some time how to apply advanced control methods to tough processes. The problems often come in implementing such systems—in the installation and adjustment of electronic or pneumatic controllers, computing elements, process and controller signals, supervisory computer, and other equipment needed for the advanced control scheme.

Modern digital process control equipment, however, has eliminated most of these problems. Today, thanks to CRT terminals and high-level languages, it's no longer necessary to physically connect loop elements because all of the connections are internal, performed in software within the control system. Advanced control algorithms are available via simple call-ups from the CRT.

This article explains the steps involved in adding supervisory computer control to an existing regulatory control system. The addition of advanced cascade control, made possible by the computer system, resulted in a steam savings of 14%-30%.

Cyclic variations in flow rates at an Air Products and Chemicals plant had made tight control difficult. The variations, mostly in the separation and purification portions of the process, also increased steam use, wasting energy dollars. Because the plant's control system, a basic Honeywell TDC-2000, could only perform regulatory control, Air Products elected to upgrade it by adding a Honeywell supervisory computer, three supervisory operator stations, and related peripheral devices.

Feed ratio control...the initial computer control step

The purpose of the first advanced control scheme was to save distillation energy by controlling the reactor feed composition. This would improve conversion and reduce the downstream purification load. An incoming feed ratio to reactor make-up flow control cascade was chosen to do the job. Figure 1 shows the basic (regulatory) feed ratio control before computer control; Fig. 2 shows the changes made for computer control.

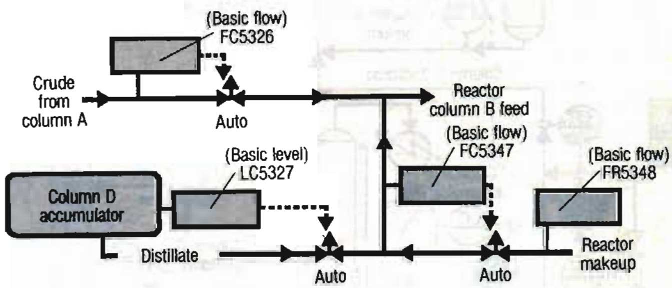
D. B. Leach, will be available to answer any questions you may have about this article. Mr. Leach can be reached at (215) 481-8710 during normal business hours on Tuesday, June 26th and Thursday, June 28th.

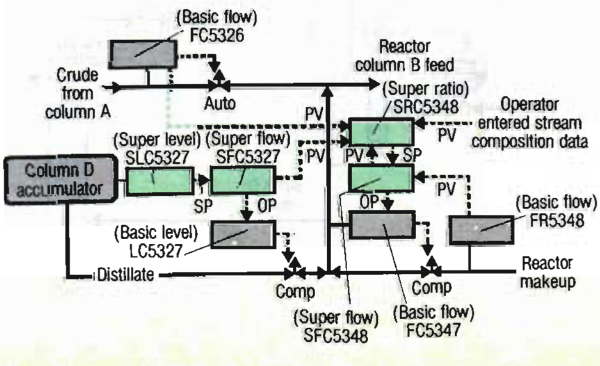
Initial testing of this control scheme showed that the incoming process streams were only conditionally stable, making stable ratio control impossible. The flows varied in a sustained sinusoidal pattern for an unusually long, but repeatable period of 1 to 2 hr (Fig. 3). This existed on the column D distillate, column B reactor makeup, column C bottoms, and the column D steam flows. In each case, the regulatory control scheme consisted of vessel level control only (Fig. 4). A series of supervisory level-to-flow cascade control loops were next implemented to reduce these flow variations (Fig. 5).

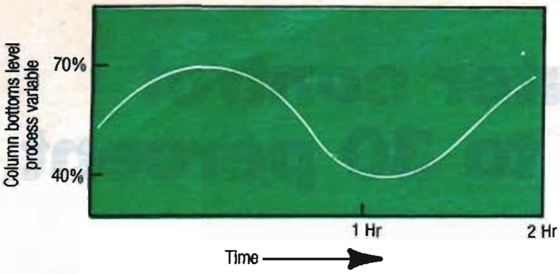
The basis of cascade control is to have a primary controller's output manipulate a secondary controller's setpoint. Thus, disturbances in the secondary control loop can

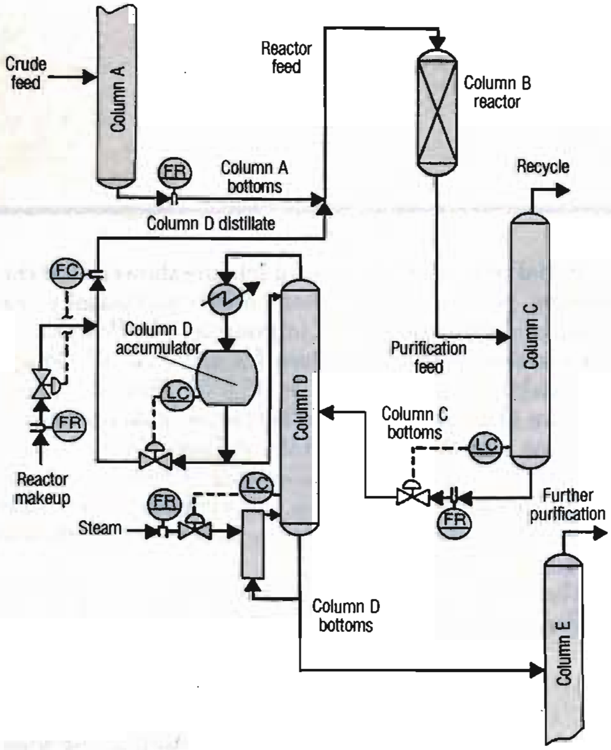
Fig. 1 (below, top): Block diagram of basic flow control loop which had problems with pulsing, composition, and used too much energy. Ratio control was manual.

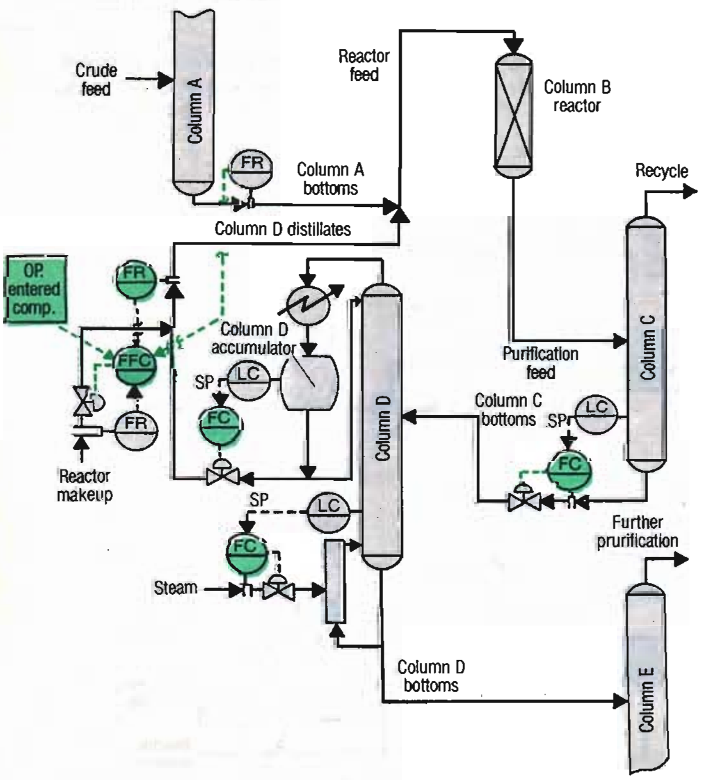
Fig. 2 (below, bottom): Block diagram shows addition of supervisory cascade control to solve the problems. Ratio control is by automatic reset.











(top left to bottom right)

Fig. 3: Controller interaction produced these variations in column bottoms level.

Fig. 4: Basic purification control scheme before the addition of supervisory control.

Fig. 5: Purification process control diagram including supervisory control.

Fig. 6: Addition of supervisory control smoothed out the column bottoms level.

be corrected before they affect the primary loop. Also, process gain variations can be handled better by choosing special algorithms for each loop. Where flow is the secondary control loop and level the primary, cascade control can overcome three problems:

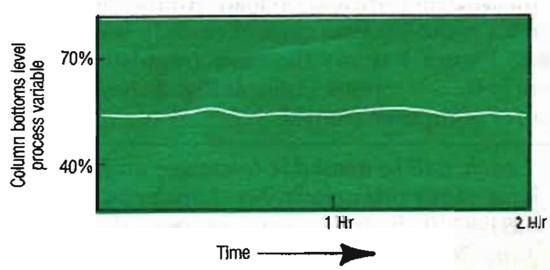
- Rapid changes in pressure drop are handled dynamically by the secondary flow loop before they disturb the level loop.
- Nonlinear valve characteristics, limited valve deadband and/or hysteresis are overcome in the secondary loop before they disturb the primary loop.
- Process gains that are abnormally high, low, or nonlinear, can be compensated for by choosing special algorithms for each loop.

These cascade control schemes provided stable process control on all streams. Flow pulsing was eliminated and the overall energy use was greatly reduced (Fig. 6). Actual results were a 30% steam reduction/lb of product on column D, an 18% reduction on column E, and a 14% reduction on column C.

More energy was saved when the original feed ratio composition computer control scheme was finally put into use. This controlled the reactor makeup to produce maximum product with minimum energy. Calculating the actual ratio of reactor makeup added per unit of key component fed to the reactors, avoided excess makeup and lowered the amount of steam required for distillation. The composition of the feed streams was approximated by entering shift lab data. This was done because reliable online measurements weren't available, and composition changes occurred slowly and were held to a repeatable range.

Digital cascade loop advantages

Several problems with cascade control loops are reduced when a supervisory computer system is used. For example, a common problem is the closing of cascades when computer cascade control is started. With analog three-loop control, each higher control output may need balancing before switching to the cascade mode on the



lower control loop. The master cascade controller setpoint may need adjusting to avoid a bump if the current process variable doesn't match the prior setpoint. With supervisory computer control, cascade closure is greatly simplified. Setpoints of the primary and secondary loops can be initialized so that when closure occurs, they assume current values. Also, back-initialization of all intermediate output values is automatic when the cascade is closed. Once the supervisory cascade control loops are set up and switched to the appropriate control source, an operator starts computer control by switching the basic regulatory control loop to "computer." Thus, bumpless computer control is started by a single command. Also, because it's so simple, operators tend to accept the new system faster.

A second advantage of a digital control system is ease of control algorithm selection. On a distillation column, a bottoms level control scheme can have three problems: high process noise due to column hydraulics, high process gain due to very limited surge volume, and nonlinear level process gain (process gain varies with column level). As a result, PID (proportional plus integral plus derivative) normal linear control often doesn't work. What seems to work the best for this application is a nonlinear control algorithm, such as error squared on integral. This is because the controller integral correction can vary with the square of the absolute error, better matching the dynamics requirements of this integrating process.

Another advantage is the availability of valve rate of travel restrictions, setpoint limitations, and improved input signal filtering. To reduce downstream process disturbances due to level transients, valve rate of travel limiting can be used. Intermediate setpoint clamp limits can limit the bottoms flow to a predicted normal range. Process variable signal noise can be handled with the proper combination of scan time and first order digital filtering. And finally, the results of these algorithm and tuning constant changes can be dynamically observed with computer generated trending. This trending capability considerably speeds up the tuning process.

Vertical trend display

The supervisory system also improved process analysis by providing software generated trend display. Typically, a process variable's field signal, setpoint, and valve output can be trended, with update periods ranging from 5 s to 1 hr. And most important, the process variable's span values can be ranged to display meaningful signal changes. For example, a level indicator spanned in the transmitter at 0-100% can be spanned to any range for display purposes, such as 40-60%. By using a direct screen video copier, trend displays can be recorded to form the equivalent of a strip chart.

Unlike strip charts, however, these trends can be variably ranged at any time to "blow up" selected data. Historical data and real-time data can be retrieved for display and recording. This means several days, or even weeks, of operation can be readily analyzed. Historical data can also be re-ranged to isolate an unforeseen abnormality.

The supervisory vertical trend display was used to analyze these columns and related streams. As a result, the following problem conditions were found and corrected:

- A valve positioner on a column bottoms level valve had an 8% deadband on the downstroke within a certain output range. At times this caused a 40 gpm instantaneous step flow decrease in feed to the next tower. This pulse caused cycling in two towers.
- A column accumulator level control valve was frozen at 50% open. The accumulator would alternately flood and dump despite the attemped corrections by the level controller.
- A bottoms local pneumatic level controller had a 12% deadband, causing the bottoms level to cycle slowly from 0 to 100%.
- Excessive pressure drop sporadically occurred across the reactors' discharge filters, causing erratic reactor makeup flow.

Vertical trend display is also useful for tuning cascade loops. In particular, the graphic trend capability simplifies the step/response method of measuring process dead time and time constants. For example, a step increase in a given independent variable is created and displayed next to the dependent variable on the vertical trend display. This allows the appropriate time constant and deadtime measurement to be read directly in digital form on a CRT display. The response curve can be recorded with the video copier for future reference.

Management reports for long term trending

A computer system makes it possible to easily produce management reports. For example, the system can:

- Provide a listing of current operating conditions.
- Quantify performance indices for production rate, energy, efficiency, and quality.

Operating condition reports covering specific plant areas use four fixed formats: shift, daily, two-day, and monthly. These reduce the time required to gather the process data needed to make engineering and management decisions.

Performance reports provide an analysis of current plant status, such as in the areas of energy use and material balance. For example, performance indices for each distillation column have been computed in terms of lb steam/lb distillate or lb product. This information is used to optimize the performance of each process unit.

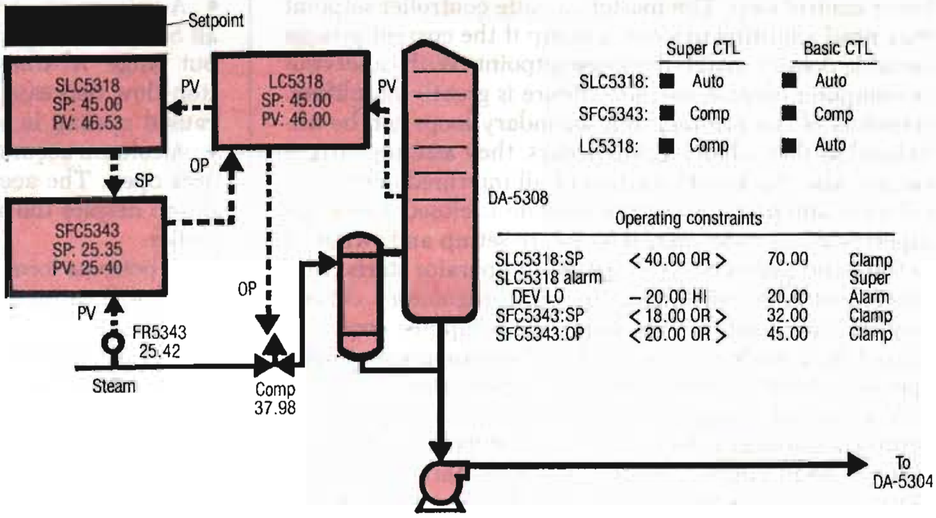
With fixed formatting, report content can be easily changed to suit a dynamic plant operation. Any point in the computer data base can be regularly reported at any time with a "fill in the blanks" programming procedure. Even if a data base point is not reported as part of the routine fixed format reports, an operator can request a summary printout of hourly and daily averages at any time. This historical perspective is a useful tool for analyzing process upsets.

Graphic display

The graphics capabilities of the supervisory system is used in two ways:

- First, selected displays are used to overview current process performance versus the pre-defined optimum condition. These refresh experienced operators rotating to the control room, and help trainees get started.
- Second, process graphics provide a method of increasing

Fig. 7: Typical CRT graphics display of column level control.



the operator's effectiveness both during and after the training period. Control flow diagrams, complete with "live" process data, are developed as new computer control strategies are brought on line (Fig. 7).

Summary

Through the use of a supervisory computer system, Air Products has taken advantage of energy saving cascade control. Trend analysis, reporting, and graphics capabilities have significantly improved decision-making and problem solving. The application of this system has proven important to the cost-effective manufacture of Air Products specialty chemicals. ■

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