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COMPUTER-AIDED DESIGN OF CONTROL LOOP DIAGRAMS

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Abstract: This paper describes the application of CAD/CAM systems to the sales and order entry/engineering stages as well as the design of control systems. Large quantities of drawings are required, and the use of graphic CAD systems can result in considerable savings. Some applications of CAD to system engineering/system generation are described.

1. Introduction

Digital computers, in the form of CAD/CAM systems, are used in the machine shop and factory to ease the designer's job. Machine-shop CAD systems output numerical control (NC) tapes which can be used in computer-aided manufacturing (CAM). Modern process control systems are also implemented using digital computers. So why not supply software, running on such digital computer systems, which allows the control system designer to enter his logic diagrams and control loop diagrams and have the system generate the corresponding control software?

Allowing the user to enter or modify logic diagrams and control loop diagrams and generate updated control software can be regarded as CAD/ CAM in the broadest sense of the term -- because before the advent of digital control systems, such configuration or reconfiguration involved the wiring or rewiring of interconnections between control instruments. The only difference is that the configuration of modern digital systems can be performed in software, without NC equipment or physical rewiring.

2. CAD and Application Engineering

Engineering drawings and diagrams are required in the design, engineering and sales of process control systems. CAD systems can not only make it easy to enter the information required to produce the drawings, they can check design rules, perform necessary computation and simulation, and generate system software as well.

For sales purposes such as cost estimation/quotation, drawings such as suggested system configuration, panel layout, and control loop diagrams are required. Simple, easy-to-read line drawings with intuitive graphics are sufficient for the customer. Ideally, the CAD system should allow explanatory text to be entered, edited and printed along with the diagrams. This should not require any special-purpose software.

For order entry/engineering, the system needs to be able to rapidly draw diagrams containing large numbers of similar elements in predefined formats, and to check design rules.

For design work, simple graphic CAD functions are not sufficient — advanced engineering support functions such as simulators for circuit design are also required.

Table 1 lists some examples of engineering drawings and diagrams which CAD systems can be used to produce. Some of these applications in order entry/engineering are described in more detail below.

Table 1: Examples of drawings that can be produced by graphic CAD systems.

Application	Type of Drawing	Size	Qty	Notes
Estimate/ quotation	Dimensional drawing of field equipment	A4	50	RTD sheaths/orifices
	Control panel dimensional diagram	A3	50	
	Control loop diagram	A3	100	
	Control system configuration diagram	A3	50	
	Control signal diagram for power system	A3	100	
Order entry/ engineering	Panel design drawings	A1	100	Designed for ease of manufacturing
	Gas chromatograph sampling unit	A1	100	Designed for ease of manufacturing
	Internal wiring diagram for power system	A3	100	Using graphic design rules and editing software
	Digital instrument loop diagram	A3	2000	Data added to above drawings, stored on floppy
	Control system installation diagram	A3	200	Data added to above drawings, stored on floppy
Design	Printed circuit			
	Metalwork			NC tape output
	Circuit diagram			Circuit simulation Reliability computation
	Mechanical design			Analysis of limited number of elements

"Qty" (no. of drawings) indicates relative number.

2-1. Internal wiring of electronic control system

This application is for analog systems used to control boilers. Different computational functions are provided as computational modules, and a complex system is implemented by a combination of modules. Safety interlocks can also be implemented using modules and relays. Figure 1 shows the internal system wiring required between modules, relays and input terminal blocks in this example. Between 15 and 30 cards can be installed in each control cubicle.

2-2. Sampling equipment for analyzer system

This analyzer system consists of several different types of analyzers and several different pieces of sampling equipment. The appropriate type of sampling equipment and appropriate analyzer can be selected according to the process. Drawings required for this system include flow diagrams, which show piping and tubing, and assembly diagrams which show the rack mounting of the analyzer and sampling equipment. In this example, several parts of the drawing are identical, and so a graphic CAD system can greatly reduce the time required to produce such a drawing.

2-3. Control panels

Control panels can incorporate large numbers of meters, switches, controllers and panels. To make it easy to supervise the control panel of a large system, the panel must be quite compact, which means a high wiring density. Instrument layout and internal wiring drawings are required — but like the previous example the drawing work is quite repetitive, and it is efficient to do such work on a graphic CAD system.

3. CAD/CAM of Loop Diagrams

Most modern control systems are digital rather than analog. But loop diagrams and logic diagrams are still used. With digital control systems it should be possible for an engineer to enter a diagram of both the control system configuration and the types of control instruments required, and have the system generate the corresponding software to implement it. The automatic generation of control software from diagrams entered by the user can be regarded as a type of CAM. The digital control system in this case is shown in Photo 1. The system consists of control stations which handle I/O signals and control computations, one or more operator stations which monitor the control stations, and a high-speed communications bus which connects operator and control stations. The control loop configuration, entered by an engineer from the keyboard of the operator station, is downloaded via the communications bus to the control stations. Figure 2 shows three ways the control loop configuration can be entered.

DISTRIBUTED SYSTEM

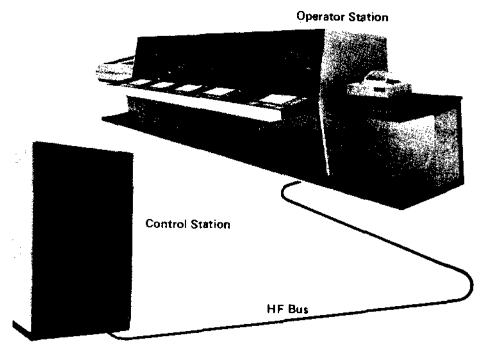

Photo 1. CENTUM control system

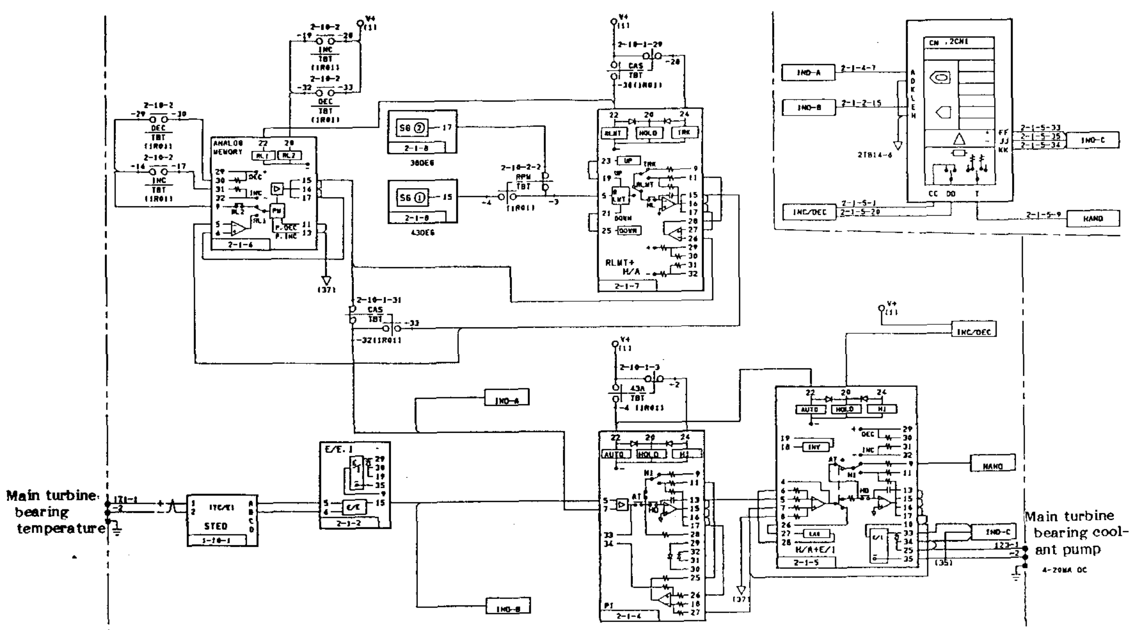

Figure 1. Internal wiring of electronic control system

3-1. Entering worksheet data from operator keyboard

The system configuration information can be first written on special worksheets, then keyed into "fill-in-the-blanks" builder/maintenance panels which resemble the worksheets. First the desired control loop configuration is drawn, then tag numbers, ranges, computational functions, I/O and inter-instrument connections are defined by entering alphanumeric data. Since typing errors are possible when the information is entered this way, the entries (and the worksheets) must be double checked.

3-2. Compiler method

For the above method, entered data can be checked to ensure that it is within bounds. It is more efficient to use a keypunch operator and in-house "host computer" to perform this sort of work. This method is not interactive, but it is fast.

3-3. Using a CAD system to produce drawings

The major difference between the above methods and using a CAD system to produce loop diagrams is that a lot of the engineering information can be entered in graphical format. Figure 3 shows an example of a loop diagram produced by this method. With this method, a system which would normally be defined by 500 to 1000 worksheets can be defined by about 20 diagrams. The control loop diagrams which are automatically produced by this method can be more accurate and provide more information than the ones produced manually with the above two methods. Figure 4 shows a flow chart for this method, and Fig. 5 shows the reduction in engineering time that is possible with such a system. The reduction in engineering design time is very close to that projected when the system was planned.

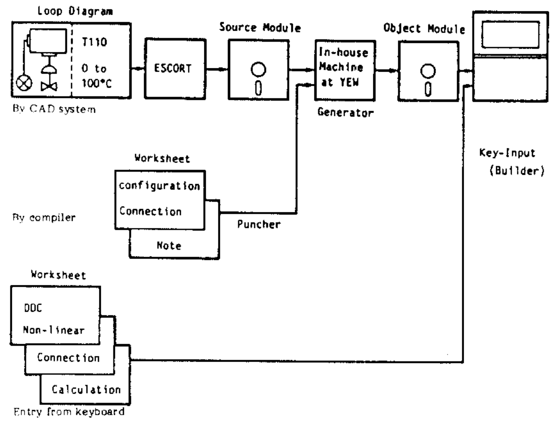

Figure 2. Loop data entry and system generation

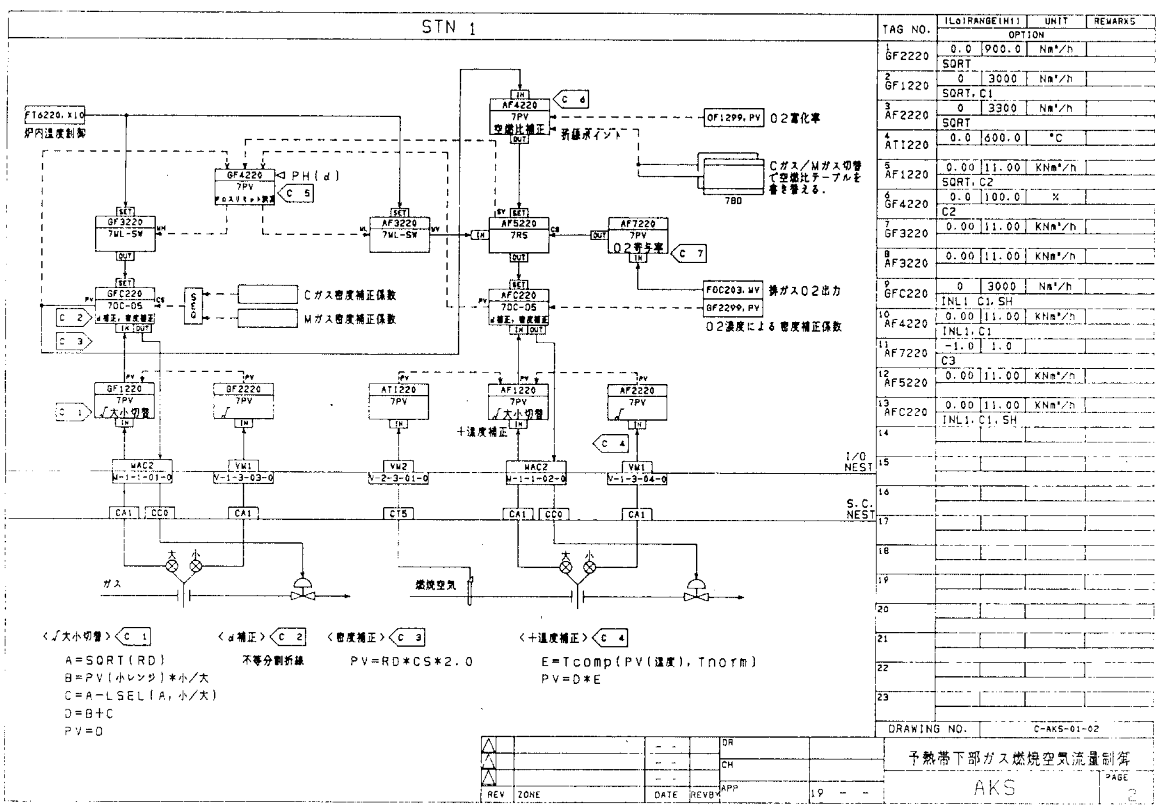

Figure 3. Loop diagram for digital control system

4. Engineering workstation

The configuration of the present CAD system used for producing loop diagrams, as illustrated in Fig. 6, is rather large. We are considering converting to an engineering work station (EWS) which could also be used for other design work. There is no hard and fast definition for what constitutes an EWS, but they usually resemble high-performance personal computers with enhanced graphics. The graphic functions may be used for architectural design, machine design, plant design or printed circuit board design, for example. Block diagrams, with lines connecting the blocks showing signal flow, are the main type of drawing used to describe control systems. Unlike mechanical and architectural drawings, the dimensional accuracy is not important, and a high-resolution color CRT is not absolutely necessary for such signal flow block diagrams. Unlike plant installation drawings, three-dimensional design is not required.

But for complex relay circuits and logic diagrams where logic symbols have special meaning, and for advanced control loop diagrams, there is less routine work — most of the work is application-dependent work, based on the engineer's experience. Ideally, the EWS can provide a library (database) of standard graphics which the user can recall and edit, but most CAD systems don't provide such functions. Graphic software standards such as GKS (Graphic Kernel System) and IGES (Initial Graphic Exchange Specification) will facilitate considerable improvements.

We are using a high-performance personal computer for producing digital control system hardware configuration drawings. Given a system configuration diagram — such as shown in Figure 7 — and a list of inputs and outputs, the system can produce both drawings for customer approval and factory manufacturing specification drawings. The manufacturing specifications include drawings showing which cards are to be installed in which slots of which nests, lists of total number of cards of each type, internal wiring

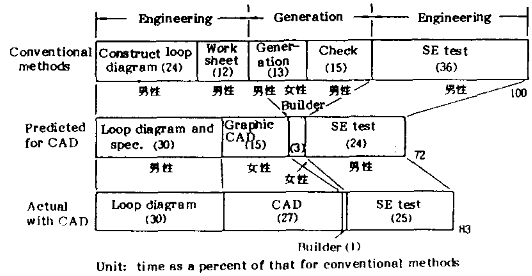

Figure 5. Reduction in engineering time

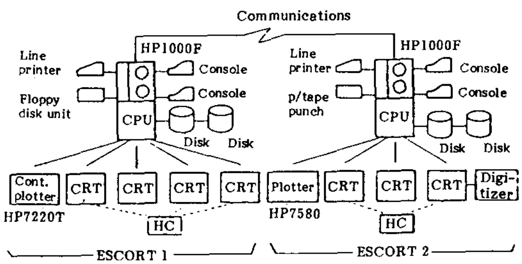

Figure 6. ESCORT system configuration

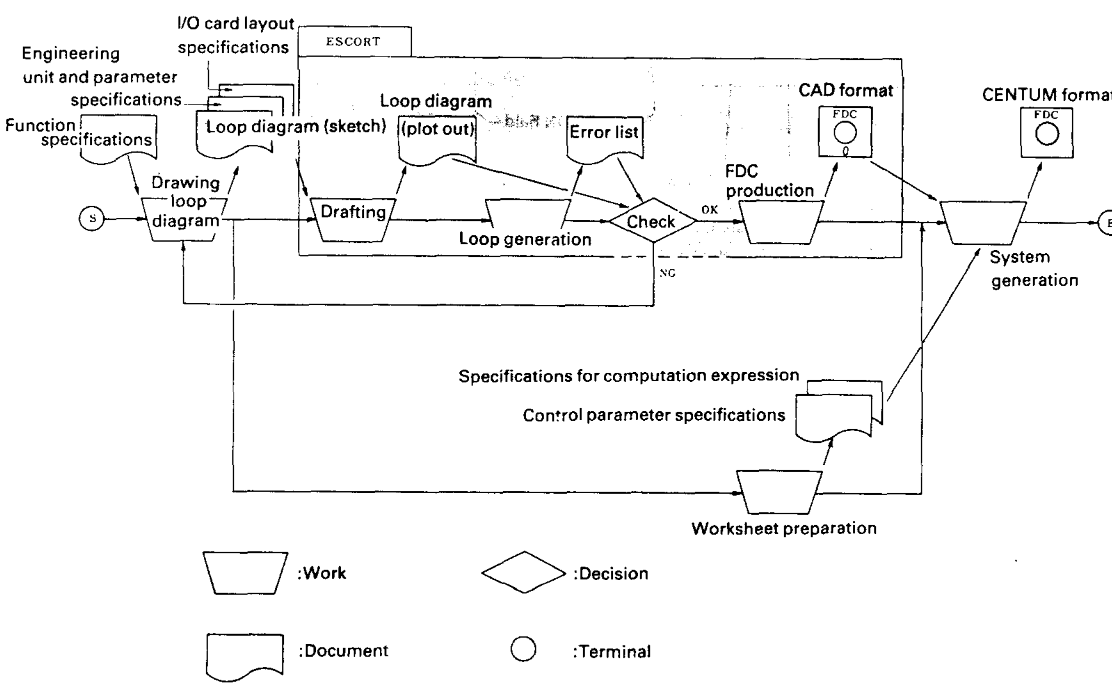

Figure 4. System generation from loop diagram

net lists, and lists showing on-card DIP switch settings for each card. This system took 20 man-months to develop, but costs an order of magnitude less than the previous loop diagram CAD system.

5. Conclusions

Ideally, the EWS concept should be integrated into the digital control system, so that the engineer can interactively configure the system from a terminal. In such a case the system can be used not only for initial system generation but also for system maintenance. However, it is also satisfactory to use an ordinary office EWS, provided that the output from the EWS can be readily transferred to the target system.

We feel that by using either digital control systems or engineering workstations as graphic CAD systems — producing not only loop diagrams but also other engineering drawings — and by expanding the scope of digital control system CAD/CAM, the work efficiency of system engineers can be greatly increased.

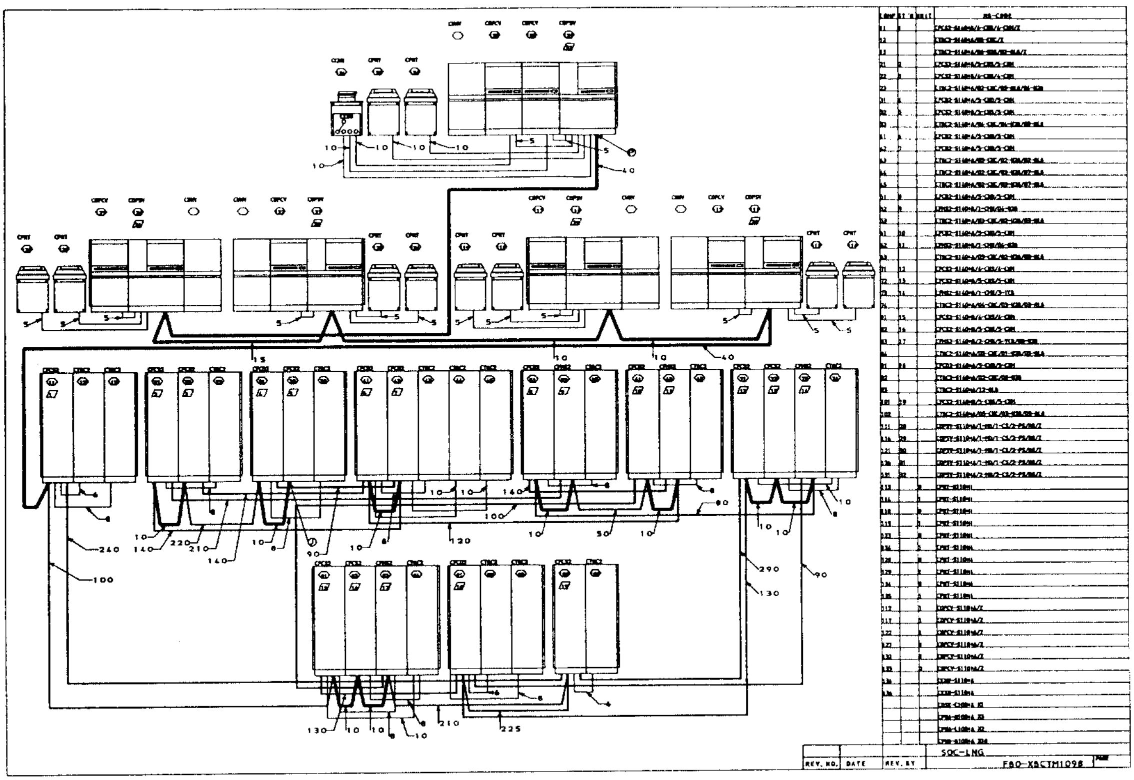

Figure 7. System configuration diagram