A Look Backward at the "Gestation of a Digital Process Control System" *

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Introduction

The CIBA-GEIGY AG is an international integrated chemical process operating company with plants and offices all over the world. Their main products are pharmaceuticals, dye stuffs, agricultural chemicals, industrial chemicals and photo chemical products.

The experiences described in this paper are those of one of the operating plants of the then-American subsidiary, Geigy Chemical Corporation. Specifically, this is a new herbicide plant built at St. Gabriel, Louisiana. This process was a new one and in the pilot plant stage, as well in similar commercial operations, it was determined that the particular process was heavily dependent upon analytical results for proper operating and end product control.

On these bases, then, it was decided to examine the possible benefits of on-line computer control to the new plant that was then in the planning design stage.

Background

Geigy recognized that any benefits indicated would be dependent upon the availability of technically qualified people to form a project team. Within their own organization such personnel were not available, nor were they to be had from the contractor's side. The decision then was how to get into the modern world of process computer control as quickly and easily as possible, with the ability to build up our own in-house capabilities in this area.

After discussions with their contractor, Geigy was advised to call in a newly established type of company in this area; i. e., a systems engineering contractor. Such an organization existed solely to sell their knowhow in the field of computer technology to users not having an in-house capability. Their rise has been swift and their acceptances universal. References 1, 2, 3 and 4 give some idea of the advantages and disadvantages in going this route.

Be that as it may, Geigy did sign a contract with such an organization with the clearly defined task of producing a feasibility study as to the payout, profits, problems, etc. involved in the application of an on-line computer system to the new plant. Frequent meetings between all parties helped the progress and contributed greatly in maintaining the scope of work to be done in the desired time. In general, the report was based upon pilot plant data runs given to the consultant. From these, he was able to pinpoint those areas showing the greatest variations which would lend themeselves to a smoothed control. Further, the report delineated process area by area the scope, functions and configuration of specifically what the system would be doing.

Based upon the report and the savings it indicated, the decision was made to go ahead with implementing the recommended system configuration contained in the report. The consultant had provided a lot of background work discussing various manufacturer' systems. their performance capabilities, modular expansion possibilities for future applications, prices, etc. Therefore, when the decision was made to proceed, it was an easy matter to draw up a tabulation and make a justifiable choice.

Definition of Scope

As stated above, the particular process was heavily dependent upon both laboratory and on-line analysis. One of the payouts was the availability of fast, accurate and reproducible analysis results from both areas. Therefore, any machine chosen would have to be capable of handling this task. The final configuration was a dual system; an IBM 1800 for general plant applications and an on-line IBM 1130 specifically for the data processing of chromatographic analyzer results. The 1130 was conceived as an off-line engineering computer system. However, the consultant also offered the expertise in the hardware area of having built a multiplexer front end for this computer, thereby turning it into "junior" 1800. This was a decided advantage in developing a communication software link between the two machines for the transferring of analysis data from the 1130 to the 1800 for the latter's use in its normal foreseen functioning. Figure 1 shows the general configuration of the dual system.

There are three different laboratory locations with a total of 27 lab GLC's sending data to the 1130. In each of these locations is a teletyper for communicating with the 1130. The lab technician enters all of the essential data concerning any analysis, waits for an OK from the computer that it can handle the analysis and then he injects the sample, at the same time pressing a GO switch that activates the computer scanning. At the end of the analysis, the 1130 sends back to that same

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* With apologies to CHARLES H. MARKS, Manager, Project Management, Digital Systems, The Foxboro Company. – This article was developed from a paper presented on June 3, 1970, before the Société Vaudoise des Sciences Naturelles at the Institut de Chimie Physique of the Ecole Polytechnique Fédérale in Lausanne.

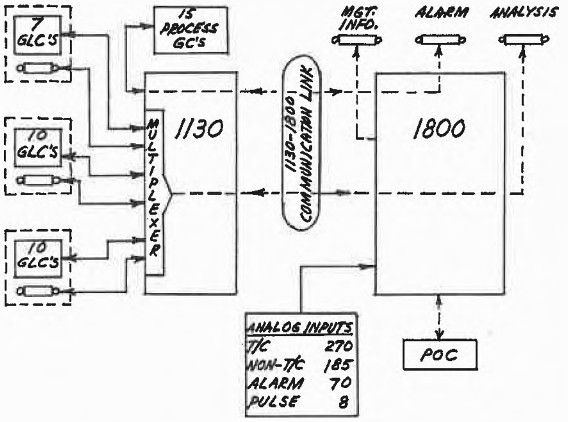


Figure 1. 1130–1800 Dual Computer System Configuration

teletyper a formatted report giving the date, time, technician's number and the analysis data. Each sample has a method in which one parameter tells the 1130 whether or not to transmit the results to the 1800.

As shown, there are also 15 process gas chromatographs involved with the 1130. Here, one big savings area indicated in the feasibility report was the savings to be realized through the elimination of the conventional black boxes usually found in process GC systems. Accordingly, all analyzer valve functions are taken over by the computer which actuates these valves baded upon programming. Further, the computer integrates areas under the peaks, tracks baseline shifts and resolves shoulder peaks. It reports only by exception. That is, if an analysis is within the tolerance limits set, no report is printed. If an analysis shows a component with either peak amplitude or elution time being out of limits, then a report is printed on the alarm typer in the control room with the remark that this analysis is wrong. In this case the computer does not store these results. Rather, it uses the last good analysis in memory for whatever use it has of such data. However, an operator can always demand an analysis *via* the process operator's console.

To prevent the total loss of on-line process GC's should the computer fail, a *Man/Chromatograph* interface is supplied that allows the control room operator to individually run manual samples for each process GC.

Part of the feasibility study detailed specifically what the 1800 computer should do for each definable process area. There were certain computer functions that were common to all areas, e. g.

- Scan all analog inputs and convert to engineering units
- Alarm all out-of-limit variables
- Display current value, maximum limit and minimum limit on process operator's console
- Print on-demand engineering values of selected process variable
- Print hourly operator's log
- Print management information daily log

Further, for each specific process area there were functions that were particular to that section.

As mentioned, one of the goals of the feasibility report was a financial analysis of the various benefits inherent in the computer system. These were divided between the 1800 and the 1130. In each case, there were both direct and indirect benefits. The 1800, or process computer's functions were recognized as being plant monitoring, data logging, supervisory control, management information reporting and statistical data handling of chosen lab analysis data. Some of the direct benefits were:

- Monitoring of the steam plant boiler performance
- Monitoring of the refrigeration system
- Calculation of the optimum reactor catalyst replacement schedule
- Control of reaction system
- Savings on manual data gathering and engineering calculation time

Some of the indirect, or intangible, benefits calculated were:

- More complete and accurate operating data
- Improved control
- Data analysis and complex calculations
- Improved plant safety

The 1130 was chromatograph computer and the direct benefits accuring to it were:

- Elimination of three "black box" components for each of the 15 process GC systems—programmer or timer, peak picker and recorder
- Reduction in staff of between two and three men per shift for monitoring and reducing the data from the lab GLC's
- Reduced maintenance on process chromatographs

The indirect, or intangible, benefits for this computer were:

- Reduction in control room costs through the elimination of many board-mounted components that also contribute to the down time of such key sensing devices
- "Accurizing" of such data making it more useful as a basis of closer control through the speed and calculating ability of the computer in peak area integration, summing, normalizing, totalizing, etc.
- Formatting each analysis in engineering units for use by process personnel in running the plant, rather than analog peak height presentation that requires interpretation

Project Control

The first thing Geigy did was to hire two experienced computer project people as part of their own staff. These people were assigned to Geigy's project team and worked closely with the other members, as well as with

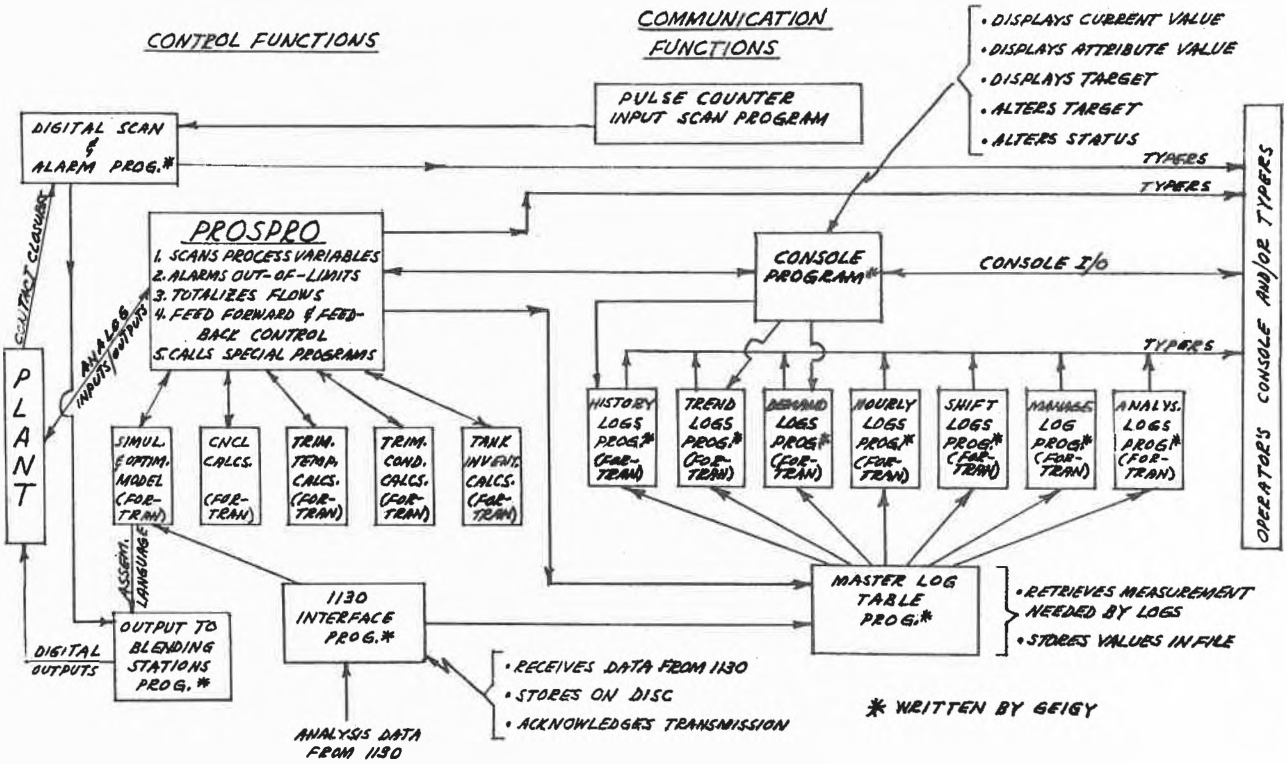
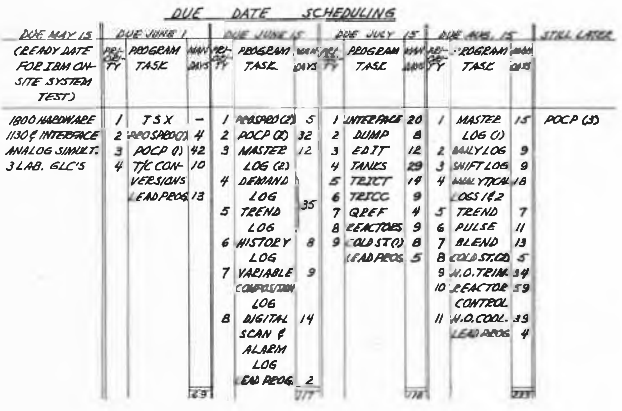


Figure 2. Software Programming Interconnecting Diagram

the engineering contractor and the systems consultant who was kept on to provide a turn-key project for the 1130 chromatograph computer system. The two men hired were a project manager and a process analyst. Together with an analytical instrument technician, they formed the initial computer group. It was quickly recognized that this process was so dependent on chromatographs and that these would be key analog inputs. Therefore, it would be best to have the supervision of these within the computer group who had to work so closely with this type of sensing device.

The next step was the painful awareness that most of the other project team groups had not been through the disciplining exercise of laying out all of their work in great detail so that it could be scheduled to reflect the manpower requirements and availability. Therefore, a computerized CPM (Critical Path Method) program was initiated that forced the various groupe to define their project tasks and carefully schedule them. This was programmed for a computer that was available from the firm from whom this program was purchased. Weekly and then monthly printouts reported the updatings given by the groups. At first, this updating exercise was a traumatic experience for the people involved, but it soon became a routine matter and proved to be an invaluable benefit in the allocation of available manpower for the tasks in their order of priority assigned.

Because of the timing of the plant start-up and the desire to have the computer on site and ready, it was clear that extra tight precautions had to be taken to insure that the scheduling of all assignment completions were reasonable and attainable. Once this had been done, it then became very obvious that with so many different parties involved in the data exchange a tight control of all time was necessary. The various groups with whom the computer team had to work were their own Geigy project team, the engineering contractor, the systems consultant, various suppliers and the analytical control group. Of particular concern was the ability to monitor the progress of the consultant for the software he was supplying. Figure 2 shows a software interconnecting diagram that became the basis for all program identification and detailing.



DUE DATE SCHEDULING

DUE MAY 15	DUE JUNE 1			DUE JUNE 15			DUE JULY 15			DUE AUG. 15			STILL LATER
(READY DATE FOR IBM ON-SITE SYSTEM TEST)	PRI-ORI-TY	PROGRAM TASK	MAN DAYS	PRI-ORI-TY	PROGRAM TASK	MAN DAYS	PRI-ORI-TY	PROGRAM TASK	MAN DAYS	PRI-ORI-TY	PROGRAM TASK	MAN DAYS	
1800 HARDWARE	1	TSX	–	1	PROSPRO (2)	5	1	INTERFACE	20	1	MASTER LOG (1)	15	POCP (3)
1130 & INTERFACE	2	PROSPRO (1)	4	2	POCP (2)	32	2	DUMP	8	2	DAILY LOG	9	
ANALOG SIMULT.	3	POCP (1)	42	3	MASTER LOG (2)	12	3	EDIT	12	3	SHIFT LOG	9	
3 LAB. GLC'S	4	T/C CONVERSIONS	10	4	DEMAND LOG	35	4	TANKS	29	4	ANALYTICAL LOGS 1 & 2	18	
		LEAD PROG	13	5	TREND LOG		5	TRICT	14	5	TREND	7	
				6	HISTORY LOG	8	6	TRICC	9	6	PULSE	11	
				7	VARIABLE COMPOSITION LOG	9	7	QREF	4	7	BLEND	13	
				8	DIGITAL SCAN & ALARM LOG	14	8	REACTORS	9	8	COLD ST. (2)	5	
					LEAD PROG.	2	9	COLD ST (1)	8	9	H.O. TRIM.	34	
								LEAD PROG.	5	10	REACTOR CONTROL	59	
										11	H.O. COOL.	39	
											LEAD PROG.	4	
			69			117			118			223	

Figure 3. 1800 Computer Programming Completion Estimates

PROGRM. TASKS	MARCH (20)	APRIL (25)	MAY (20)	JUNE (20)	JULY (25)	AUGUST (20)	LATER	T. ECCLES
TSX, ETC.	4	5	4	4	5	4		NON-CONTROL
T/C CONVERSIONS	6	4						
COLD START 1					1			
COLD START 2					3	2		
INTFC	2	7	5		6			
DUMP	1	2	2		3			
BLEND & PULSE	7	7				6+4		
TREND			5			2		
SUB-TOTAL	20	25	16	4	18	18		CONTROL
REACTOR CONTROL	→(CODING & ASSEM)			14	2	5	6	
HOT OIL COOLER				4	5			
HOT OIL TRIMMER			5			2	4	
TOTAL-MANDAYS	20	25	21	18	25	25	10	

Figure 4. 1800 Computer Programming Completion Estimates

PROGRM. TASKS	MARCH (20)	APRIL (25)	MAY (20)	JUNE (20)	JULY (25)	AUGUST (20)	DAI N.Y. GROUP
DIGITAL SCAN & ALARM	8		3	3			
MASTER LOG (2)	6			3			
TREND & DEMAND	10	10	8	7			
HISTORY LOG	4			3			
VARIABLE COMP	4			3			
EDIT	6				4		
ANALYSIS LOG		9				9	
MASTER LOG (1)		6				7	
DAILY LOG			4			4	
SHIFT LOG			4			4	
TOTAL-MANDAYS	38	25	19	19	4	24	

Figure 5. 1800 Computer Programming Detailed Steps

PROGRAM	SPECS.	FLOW-CHART	COD-ING	PUNCH &/OR COMP. ASSEM.	UNIT TEST	SYST. TEST	DOCU-MENT
BLEND	DONE	DONE	3	1	3	5	1
PULSE	DONE	DONE	3	1	3	3	1
DIGITAL SCAN & ALARM	DONE	DONE	4	1	3	5	1
INTFC: DUMP.	DONE	2+1	5+2	2	5+2	5+2	1+1
EDIT	DONE	DONE	2	2	4	3	1
TREND	DONE	DONE	3	1	1	1	1
ANALYSIS LOGS	DONE	N.R.	7	2	N.R.	7	2
MASTER LOG 1	1	1	5	1	N.R.	5	2
MASTER LOG 2	1	2	4	2	N.R.	2	1
DAILY LOG	DONE	1	3	1	2	1	1
SHIFT LOG	DONE	DONE	3	1	2	1	1
TREND LOG	N.R.	N.R.	20	→	N.R.	13	2
DEMAND LOG	N.R.	N.R.	X	X	X	X	X
VARIABLE LOG COMP.	1	1	3	1	N.R.	2	1
HISTORY LOG	1	1	3	1	N.R.	2	1
TIME IS IN DAYS	4	9	70	17	25	57	18

Figure 6. 1800 Computer Programming Detailed Steps

A method was developed whereby each person was asked to provide a reasonable estimate of how long each defined task would take. Then, this was plotted on a chronological basis and as each reporting period came up, the number of hours spent on any task was entered. In this way it was possible to check on the time spent and compare it with the time estimated. The result was a percentage completion figure that told how efficiently each person was working. Figure Nos. 3 and 4 show a chronological estimate for completion by group and person. Figure Nos. 5 and 6 show the then current status, along with an estimate of manpower to complete the various stages involved for each program.

Pre-delivery Implementation

As time went on, it was an easy matter to see where certain activities needed additional support. One was in the area of process analysis and, consequently, another experienced man was hired. Another area was in the training of the operating personnel so that they would understand specifically what the computer systems were there for and what they could offer to improve the performance of the operators. For this, the computer team developed a series of lectures that were given weekly. For some of these, as applicable, the various suppliers were used. The main idea behind all of training was to make the engineering and operating personnel unafraid of the computers. Our theme was that the hardware represented just another instrumentation box that was under their control and under their command to provide a communication with the process and give results as requested by them. It was a complicated, but not complex, box. However, we did want them to be able to step up to the console and understand the potential this represented.

The computer arrived before its home at the site was ready. A temporary location was found. It was in a research institute and the Figure 7 shows the various pieces of equipment. This location was the best thing that happened to us. It was a large area that allowed us to try different configurations of the equipment. It was

PROGRAM	SPECS.	FLOW-CHART	COD-ING	PUNCH &/OR COMP. ASSEM.	UNIT TEST	SYST. TEST	DOCU-MENT.
CONV., PISW & ECO CODES	2	N.R.	N.R.	–	1	2	1
DISPLAY DBD	2	1	1	–	1	1	1
INTFC/PROC. LOGS	1	2	2	–	2	4	2
INTFC/ANALY. LOGS	1	1	1	–	1	1	1
INTFC/NON-CONTROL & PROSPRO	2	2	2	–	1	2	1
ADD AVRG. TO POC & ADD ATT.	→			2	→		2
COMPLETE CONV. OF ON/OFF & IN/OUT ON MAD -10	→			1	→		1
FREEZE OUTPUTS	→			2	→		2
DISPLAY & CHANGE TIME	→			1	→		1
PRINT VALUE	→			2	→		2
CHANGE TYPERS	→			2	→		2
UPDATED DISPLAYED POINT	→			2	→		2
TIME IS IN DAYS	8	6	6	12	6	10	18

Figure 7. Computer Systems' Installation at Institute

large enough to allow us to install the actual plant devices that would be inputting and outputting to and from the computers. It allowed us to have an operating, simulated and debugged system available for many months. This afforded us ample opportunity for training on both an informal and formal basis. Very often operators and engineers would drop in on their way home from the plant to talk about a problem they had and they would ask whether the computer could help out. It became the major impetus in planning future areas for the system expansion. We encouraged them to work through their problems; to write out the equations they would use to, say, calculate a yield by hand. Then, it was an easy matter to review this and plan to programm it as it best could be scheduled. In this way, along with our own foreseen expansions, the next few years for the computer were planned and the team knew that it was concerned with a dynamic system concept, rather than one that would become a boring routine day-to-day task of watching a computer doing its job.

In retrospect, we can say that the earlier a computer project team enters the process project work, the easier it will be to coordinate the efforts of all concerned to avoid errors, corrections and duplications. This is especially true when a engineering contractor is involved. Contrary to their usual claims, maybe only one or two ever have had any direct involvement in working in detail on a process computer project. Constant communication at the lowest working levels is required to make certain that the detailed engineering reflects the computer system requirements.

The main difficulty working with the systems consultant was primarily in the beginning when his project management was in one location and the people doing the actual work were in another 1500 miles away. In addition, the turnover of personnel in the consulting company was an undesirable feature. One of the strongest requirements for successful implementation is continuity of personnel. Having to meet new faces each time there was a corporate upheaval or change meant that we had to teach and train a continuous stream of strange people. In the programming area this is a particular hardship because of the time it takes one programmer to understand what his predecessor had done and then build on it.

It must be understood that such a consultant's main product is his time. In our case he also offered hardware and standard lab chromatograph software package. Therefore, the unconscious tendency is to drag out the time on a contract that is paid by the hour. Of course, on the chromatograph computer system this was a lump-sum type and it was not a matter here of milking the budget. Rather, it was the completion on time to provide that facility to the analytical laboratory chemists.

Also in retrospect, we can say that the computer team must have a very early contact with the instrumentation engineers. An experienced computer hardware man will provide an extremely valuable liaison in making certain that the choice of sensors, their installation, noise, signal level and characteristic, cabling, and all of the problems involved in the physical installation are recognized early enough where the answers are available at a point in project time that errors are avoided. This leads into working with the applicable equipment suppliers and we found ourselves on that firing line early and often. We had to visit factories, inspect performances and work very closely with these vendors so that the normal course with the contractor's and Geigy's own engineers, also interfacing with the suppliers, was worthwhile and yielded the necessary answers.

To most fully utilize the complete facilities we had at the research institute, we planned to run some of the contractual acceptance tests there. Because of the plant delays, instrumentation was not available. We had the space and the equipment, so we negotiated to demonstrate the initial acceptance phase there. We point out that this aspect is one of the most important in insuring a successful system in time. This has been recognized also by the Instrument Society of America and they have a current project in subcommittee working on a recommende practice covering computer system factory tests. In addition, we would recommend that equal emphasis be given in the pre-contract time to formulating a mutually fair and reasonable on-site test, also. Do not try to achieve this after the contract has been signed and it was omitted. There is nothing quite as strong as an unsigned contract for bargaining purposes. To paraphrase, the roadway to unsuccessful and unhappy computer projects is paved with good intentions that never were brought up for discussion!

Implementation at Delivery

As mentioned, the research institute concept was to enable us to profitably use the time in getting as much done as possible before the plant site was ready. This entailed programming, debugging, development, checking process chromatographs and setting into operation lab GLC's. Having the time ... and luck ... to accomplish this also meant that we had a natural training site for all plant personnel working with the computer. To provide a dynamic environmental situation where, for example, inputs and outputs could be changed throughout their expected ranges, we specified and purchased signal simulators for analog inputs, digital inputs, digital outputs and pulse inputs. This enabled us to check programming ramifications for undesirable interactions. Troubleshooting and correcting in this fashion and to this degree of completeness meant that we identified many of the possible problem sources. The, when we moved to site, we had a handle on these and could readily track down new, other and/or different symptoms causing computer system failures.

The heavy dependence upon lab analyzers dictated that we obtain some "hands on" experience with the GLC's actually purchased. We received some of these at an early enough date to have them set up at the institute and gain some operating experience with them. The analytical chemists also profitably used this facility and time to develop, debug and refine their methods associated with analyzers working with the computer. Figure 8 shows these hooked up to the computer.

With the process chromatographs, we received all 15 of them at the temporary computer center and were able to check and test them, also. Many errors were found, in addition to damages suffered in transportation. Our findings were given to the engineering contractor for him to handle these with the vendor. During this time the plant maintenance group assigned their instrument technicians to work with our man and learn together about the devices and how they interfaced with the computers. Figure 9 shows a process chromatograph being checked out.

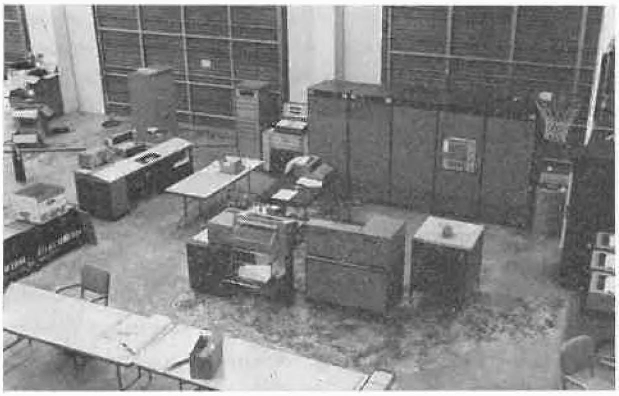


Figure 8. Lab GLC's Installed and Connected

Figure 9. Process Chromatograph Being Tested

Figure 10. Analog Input Signal Simulator

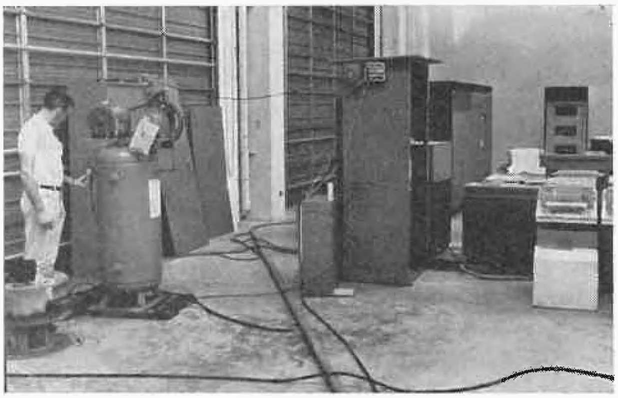


Figure 11. Digital Input/Output Simulator

To compensate for the fact no plant instruments were available as input devices, we specified and purchased signal simulators to provide the facility of having such signals and being able to change their ranges. Figures 10 and 11 show respectively the analog input simulator and the digital input/output simulator. With this array, we could introduce (and change) an input signal, check the computer software handling of this, change parameters, monitor alarms, check computer control action, etc.

As stated, the initial phase of the on-site acceptance tests was done at the institute. In scope, this was to demonstrate that the basic chromatograph software package and the applicable hardware interface units worked together in a trouble-free manner. This was critical from a scheduling aspect because of the parallel work that had to be done by the analytical chemists. Their help and cooperation went a long way in defining problems and resolving these. The next phase of this acceptance test was to demonstrate the remaining features of the software package that, from a scheduling standpoint, had not been available during the previous first phase. This second phase was also to be conducted at the institute. However, because of the aforementioned changes in the consultant's personnel we lost the continuity of effort and had to wait until another person joined us. This resulted in a delay, thereby causing a postponement in the second phase testing. It finally was done after the systems had been moved to the computer room at the plant site.

Installation on Site

The computer team had been pressing all along that the systems not be moved until all of physical work on site and in the computer room had been finished. This meant that all of the plant cable runs were to have been pulled to the junction boxes, then in trenches under the control room floor, then under the false floor in the computer room. Here, they would be dressed and prepared for tagging each individual lead, so that when the time came to connect them to the computer terminals, it would be a relatively easy matter for the electrical technician to refer to his wire lists, find the corresponding lead and make the connection. We found here that all of the many hours of thought and preparation of comprehensive documentation paid for itself over and over. The physical hooking up at this stage went quickly, smoothly and correctly.

Because of the time and space we had at the institute for working with the machines, our final choice as to configuration was the optimum and the installation in the computer room went in with no trouble at all.

The reloading of the programs, retesting of same and using the simulators to reestablish the same levels of operation and confidence we had at the institute all took up the next immediate period after the move to the plant site. Figure 12 shows what an earlier estimate schedule looked like for this period in question. Actually, considering the number of signals, the other plant start-up problems and the labor problems encountered, this plan was realized reasonably within the timing foreseen.

The previous debugging and testing did, indeed, accomplish their goals of identifying both hardware and software problems so that when we got to site new problems could be identified quickly and easily. This was accomplished and the new problems were all the more clearly recognized. Specifically, the biggest one was with the consultant's software package for the process gas chromatographs. In part, this in turn came as a result of their key programmer in this area leaving the company and the need for a new man to take over and carry on. Another was with changes in hardware that were not documented promptly and correctly. This whole area of documentation is worth a separate talk. In brief, however, the only permanent guideposts for any project are the documents generated. It must be the complete responsibility of the project manager to encourage, cajole and stimulate the involved people to write down what they do. Then, he must take a sledge hammer approach and strictly enfore the rule that all changes be documented as part of the job files. Without saying, this applies for software as well as hardware. From the first day the computer is turned on, a permanent log book is chained to some convenient surface and, practically but exaggeratedly speaking, under pain of some fate worse than death every one who makes any change whatsoever must note this in the log book. It can reduce strong men to simpering fools to try and track down some computer malfunction caused by something that someone *did*, but that they *did not* document. The computer project documentation is the guideposts to going ahead into the future with planned expansions. It is the compass without which you cannot get to where you want to go because you do not know where you were.

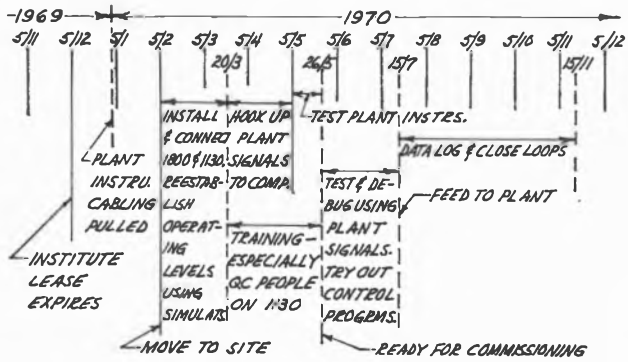


Figure 12. On-site Installation Completion Schedule

After the move to site, in addition to the mentioned software problems that cropped up, we also met some unexpected hardware and instrumentation problems that the checking of the computer revealed. For example, it was found that when we tried to close the first loop the associated analog controller on the board had been furnished and installed with no stepping motor that was to be driven by a controlled output signal from the computer. Another installation problem was uncovered when the computer was called upon to scan some reactor temperature profiles. The computer-logged values were quite different from those recorded on strip chart recorders. Subsequent checking showed the thermocouple sensore going to the computer had not been installed properly and had to be changed.

Conclusions

The conclusions to be drawn have been mentioned already as part of the foregoing text. To summarize, we concluded that:

- A strong computer project team is a must. Their quality is essential and it is better, for any task, to have—for example—one $ 20000 per year man than it is to have two $ 10000 men.
- The team must be an integral part of the discussion groups right from the very beginning of the project so that later costly errors and duplications can be avoided.
- The team must have on it the various skills represented by the scope and goal of the particular project. In our case, we had a process that was very heavily dependent upon analysis instrumentation. Therefore, an integral team member was a person having this background and experience.
- Project goals must be defined at the very beginning to serve as a yardstick by which project and individual performances can be measured.
- Tasks must be broken down to their smallest unit and must be kept simple so that management of them is a routine and easy job.

- The conclusion of the project is represented by the documentation and the success of the latter stages squarely reflects the thought and effort put into this all-important aspect.
- The overall control of such an endeavor must be central with the one man who serves as the focal liaison for the computer project team and who has the responsibility to steer the project through the often rough waters of the job duration. This is the project manager. His art is seen in his ability to work together with all parties concerned, delegate responsibilities and then enforce their reasonable attainment. He must be a negotiator (horse trader) par excellence with the intuitive ability to know when to give and when to press for an advantage.
- Each company must develop that degree of dispassionate objectivity to be able to evaluate their own in-house capabilities and, thereby, know when they must call in outside help.

In a lighter vein, we recommend that the team

- *start out with established goals*
- *keep it defineably simple*
- *keep it discrete*
- *use past experiences as a guide not as a rule*
- *commit to continuing education*
- *keep the project dynamic*

and, *good luck!*

References

1. Computer Systems Houses Continue to Thrive, Multiply, *Control Eng. 1970* (January) 65–70.
2. Computer Control Systems—Make or Buy? by Dr. R.S. Davis and D.J. Fraade, *Instrument Practice 1968* (April) 323–7.
3. *The Systems Contractors Valuable Professional or Unnecessary Middleman?* by D.J. Fraade, M.T. Tayyabkahn and C. E. Watson, paper presented at the Fourth Annual Conference on the Use of Digital Computers in Process Control held at Louisiana State University, Baton Rouge (Louisiana), February, 1969.
4. Should You Use a Consultant? by D.J. Fraade, *Research/Development 1970* (April) 38–40.
5. *Gestation of a Digital Process Control System,* by Charles H. Marks, The Foxboro Company, Foxboro (Massachusetts).
6. What Went Wrong? by T.M. Nourse, *Instruments & Control Systems 33*, p. 75, 76.
7. New Trends in Handling Computer-Control Projects, by P. A. Ast, John C. Cugini and Dr. R. S. Davis, *Chem. Eng. 1969* (July) 129–32.
8. Spotlight on 'System' ... What It Realy Is, *Package Eng. 1968* (November) 69–75.
9. 10 Years After—A Word to the Wise, by D.J. Fraade, *Instrument Practice 1969* (July) 504–7.
10. Computer Control—Why, How, Where, a special report on digital computers in industry, *Control Eng. 13* (September, 1966) 9, 84–142.
11. Curing Hardware and Software Headaches—A Process Computer Goes On Line, by A. Haalman, *Instrumentation Technol. 1969* (August) 55–61.