CONVERSION OF PHOSPHORIC ACID PLANT CONTROLS TO A DISTRIBUTED CONTROL SYSTEM

by

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ABSTRACT

In a ten-month period starting April 1988, Agrico Chemical Company retrofitted existing pneumatic controls of the rock grinding, attack and filtration, evaporation, and storage areas of their Uncle Sam, Louisiana phosphoric acid plant with a state-of-the-art Distributed Control System, (DCS). This paper covers the preparation leading up to the conversion, including justification, vendor selection, in-house system configuration and planning of individual control ldop hook-ups, strategies used to convert to DCS in stages while minimizing extra downtime, and plans for use of the system in process control over the coming years. Additional topics covered are training given to operators and E&I personnel, and the level of acceptance of the new system by plant personnel, engineering staff, and management.

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INTRODUCTION

Our plant had one control room for rock grinding, one for attack and filtration, and one for shipping and storage, separated by a total of 1,000 feet. Pneumatic control loops of 1968 vintage were slow acting and in some cases were run in manual because they were not reliable in automatic. Control improvements with pneumatics were cumbersome tasks, requiring purchase and installation of additional equipment. All data was hand logged, averaged, and entered into our DEC computer for management information services (MIS) reporting.

We decided to solve this problem by installation of a state-of-the-art distributed control system (DCS) to replace our existing controls, expecting to achieve cost savings through productivity and recovery improvements. Our plan included combination of the rock grinding control room with attack and filtration, and giving the main control room the capability of monitoring and controlling the shipping and storage area. We also planned for the new system to automatically dump data into the DEC system for generation of MIS reports.

This paper is essentially a narrative of our experience, and we hope it will be of some help in the planning of DCS installations at other locations.
It is assumed the reader is familiar with phosphoric acid production, and this paper is written from the perspective of a chemical engineer who configured part of the Uncle Sam plant's DCS.

PLANT BACKGROUND

Agrico's Uncle Sam, LA plant came on stream in 1968, and has a capacity of 800,000 TPY P_2O_5 as 54% phosphoric acid. We receive molten sulfur and phosphate rock as raw materials. Sulphuric acid is produced in three single absorption and one double absorption acid trains, with two turbogenerators for power production. We have two ball mills for rock grinding, with two Prayon attack tanks and 30C filters for 30% P205 production. Our uranium recovery plant processes the 30% acid, then we concentrate the acid in 4 stages using 8 evaporators. We have a small tank farm for shipping, storage, and special product production.

JUSTIFICATION

Justification was done on two bases: process improvement and more efficient use of personnel. We chose to justify process improvement using historical data, as better control should shift key process variable distributions into more favorable economic ranges*. Two other common methods for calculating economic benefits of a DCS were difficult to apply to our situation. One method using other plants' experience as justification was rejected because of the two phosacid producers that had a DCS, neither plant's situation matched our own. One plant's system was an original installation during construction. The other plant was a retrofit, but additional significant process improvements were made at the time they installed their DCS. Another common method of justification involves comparing results between the best and average shifts. This was rejected because the slow process response of a phosacid plant carries the efforts of one shift's actions into the next shift, obscuring any differences in operating capability.

Water soluble losses and final product sulfate concentration are two variable but controllable sources of operating expense. We estimated that application of digital controls would shift the distribution of these variables to the upper 15% of the current distribution. In other words, we assumed that our average operation after the installation of digital controls would improve to the best 1/6 of our current operation. The estimated improvement of water soluble losses and final product sulfate amounted to 77% of the economic justification of our project. (Figure 1)

Economic benefits stemming from personnel changes were partly due to the greater efficiency of combining control rooms, allowing us to eliminate the rock grinding supervisors through attrition, and reassign one operator per shift to other duties. This accounted for 20% of the justification. The remaining 3% was due to decreased E & I manhours spent maintaining control room instrumentation and pneumatic transmitters in the field.

There were other indirect benefits, some of which have been mentioned already:

- A first step in gradual overall plant automation
- Flexibility in altering control systems
- Introduction of advanced control techniques
- An extensive database of process data
- Real-time monitoring on our DEC system
- Automatic logging capability
- Uniform basis for control among shifts
- Improved system reliability

*Bozenhardt, Herman, and Dybeck, Martin. "Estimating Savings from Upgrading Process Control." Chemical Engineering, February 1986, pp. 99-102.

VENDOR SELECTION

With goals set out, but no experience in distributed control systems, we called in a consultant to help develop a bid package, and then to evaluate those bids submitted. Proposals from ten distributed control system manufacturers were narrowed down to three proposals that met our overall criteria. The vendors who were cut did not meet various aspects of our specification for a true distributed control system. Common exceptions were providing redundant centralized control (as opposed to being distributed), no common data highway (units were linked by individual data paths), or no provision for linking our DEC computer for data transfer.

The final three vendors were close in price, allowing our decision to be based solely on technical merit. Our judgement was based on whether the systems were:

- At the leading edge of technology
- Upwardly compatible
- Easy to maintain and repair
- Suited to a harsh control room environment
- User friendly
- Supported by a local staff
- Established with a proven track record

We chose Bailey Control's Network 90™ System. Six Process Control Units (PCU's) would control sections of our process, each with redundant hardware. Operator interaction would be through redundant Management Command Systems (MCS's), with five CRT's and two keyboards in the main control room, and one CRT and keyboard in the shipping & storage control room (we later added another keyboard in the main control room). Peer-to-peer communication was provided on two plant loops for redundancy, which linked the six PCU's, two MCS's, an engineering work station, and the interface for the DEC computer.

FINAL COST

Breakdowns of the cost of the project are shown in Figure 2. The DCS equipment iself amounted to 38% of the cost of the project. Instrumentation was 22% of the cost, and includes revising control loops with new conduit and transmitters. Sixteen percent (16%) of the cost went to installing the DCS equipment, and includes modifications to our motor control centers. The 10% for engineering and drafting does not include in-house engineering, which is on the order of 12 man-months. This is why the proportions of our costs do not match a typical DCS installation project. The remainder of the costs are for power and control room modification.

SYSTEM CONFIGURATION

We decided to configure the system in-house, using our process engineering staff and the two engineering work stations (EWS) that we had purchased. This gave us several advantages:

- It spared the expense of vendor configuration
- Gave the engineers experience to later troubleshoot the system
- Intimate knowledge of the system improves the introduction to the operators.
- Gave the engineers insight into the capabilities of the system for control improvements

Three weeks of configuration training were given to three process engineers, two of these weeks at our plant site. Configuration of individual control loops was begun on the EWS's months before the delivery of the rest of the equipment.

Another important decision was to essentially duplicate our old control strategy during installation of the DCS. While this might cost us some benefits initially, we feel that keeping control changes to a minimum made the transition relatively painless. Now that our operators are familiar with the system and our process engineers are experienced in programming, implementation of process improvements should go smoothly.

On the whole, programming was straightforward but repetitive, with 90 control loops and over 900 tagged items to be configured. Even so, close contact with vendor engineering was essential to catch oversights and clear up some of the more unusual problems. The vendor's EWS software employed CAD for loop configuration. The engineers programming the system all had chemical engineering backgrounds, with little or no experience in instrumentation, and a basic knowledge of controls. The CAD software not only made the configurations easier to understand, but also produced schematics, reducing the drafting load. CAD software was also used to generate the graphic displays. The amount of line-by-line programming we did was practically zero, contributing greatly to our success in bringing the system on-line.

Graphics for operator use can greatly influence the success or failure of a DCS. Going from roughly 350 sq. ft. of pneumatic control panels down to 6.4 sq. ft. of CRT's is a shock no matter how well-planned the transition. Our CAD system for graphics design put few restrictions on our creativity, but meant that we had a terrific challenge to develop the most efficient graphics. We involved our operators early in the project by presenting to them several examples of possible graphics for different systems. Once they had an understanding of the design capabilities, they provided valuable and sometimes surprising input. For example, we assumed that flow diagrams and process schematics would be the best way to view attack and filtration controls (Figure 3). The final graphic was more of a table, and we designed numerous revisions before all were satisfied (Figure 4). Controls are accessed via "pop-up" faceplates such as in the lower right hand corner of Figure 4. Similarly, an evaporator summary screen (Figure 5) was preferred to schematics of individual evaporators (Figure 6). On the other hand, a process schematic was superior for displaying the controls of the conveyor and silo system feeding the rock grinding area (Figure 7). Besides improving our graphics, early involvement of the operators helped sell them on the new system, and their input gave them a sense of ownership of the project.

The rest of the off-line configuration involved assembling a database of control loop data. The vendor's EWS used a popular database software package to store data in a specified format. Again, this phase was relatively simple, but quite repetitive. There are some 12,000 items in our database that must match both the loop configuration and the graphics for the system to work properly. A continuing problem is keeping discrepancies from entering the program due to mistakes and typographical errors, and we must periodically cross-reference the database with the loop configuration and the graphics. This takes 1 to 2 days to complete, and is generally required after 3 or 4 man-months of programming.

DESIGN AND PLANNING

Revisions to our instrumentation, electrical system, and control room were designed in-house with the assistance of a consultant. Coordination of the control loop design, DCS configuration, and field work was a full-time job, as the control loop designer and the programmer have to understand each other perfectly, and the installation has to match their configuration. Misunderstandings were common at first. For example, a "normally open contact" means one thing to a process engineer who knows how an interlock should work and something different to an electrical engineer who must wire the relay. In some cases we had to re-learn or even re-design control loops so that both the designer and programmer were satisfied.

Another decision we made frequently was whether to hardwire or softwire certain features of control, mainly interlocks for safety or prevention of equipment damage. In these cases we tried to consider the reliability and simplicity of the final design. Some loops were a combination of hardwired and softwired features. For example, our evaporators have two interlocks for equipment protection. One interlock which trips steam flow with loss of the circulating pump remained hardwired. But to trip the steam on high temperature we configured our DCS to generate a signal at 200 deg F, which passed through an interposing relay, and dropped out another relay in the steam valve circuit. Because the flexibility is available to handle such functions a number of ways, early decisions and thorough planning can avoid much unforseen work.

TRAINING

Formal training for operators and E & I mechanics was minimal. This does not mean that we did not have to do a lot of education, but a classroom environment was not suited to helping our people make a transition.

The really important questions are never asked in a meeting, and having our plant engineers intimately involved with the DCS installation paid off in fielding these questions and getting our people ready for the transition. When they asked about the effects of our plant being "controlled by a computer", we had to inform people specifically and one-on-one about the effects on personnel and plant control, and it required a patient repetition of good, frank answers to get the point across. We've seen some attitudes change from totally negative to generally supportive as involvement and understanding increased, and found that the level of comfort with DCS is a function of exposure to it.

Operators were given half a day's training on a vendor's demo unit on which we had loaded some of our graphics and simulated some control loops. Further training was given on the job as control was gradually shifted to DCS.

E & I training was completely hands-on as they transferred control to DCS. We originally tried to rotate pairs of mechanics to spread experience around, but we needed more continuity to get things done. We settled on two mechanics to do most of the work, involved our shift E & I mechanics, and gradually brought in others as needed. We are continuing E & I training by having weekly sessions on a specific topic of the DCS.

CONVERSION

Our goal for conversion was to do so without creating any extra downtime, and we very nearly achieved this. We literally started in the area where mistakes could cause the least damage, our shipping and storage area. We kept our operators informed of the progress by covering defunct instruments with "On DCS" tags. Upon successful completion of this area, we moved into our attack, filtration, and evaporation areas. Critical loops were converted on scheduled turnarounds; others were hooked up on a daily basis. The rock grinding area was completed last. Significant dates are shown in Table 1.

We had a very awkward period with partial control on DCS, and the rest on the old panels. When operators returned to work they would have to learn what loops had been converted to DCS since they had left, and where they could access the loops. Our new equipment was exposed to a dust-laden environment as control room modifications were carried out. Even though this was our period of greatest exposure to problems, we had no major incidents. See Figures 8 and 9 for control room modifications.

LEVEL OF ACCEPTANCE

There is a considerable amount of public relations involved in thrusting an abrupt change into a work environment. Successful completion of this project required salesmanship not only with operators and E & I mechanics, but also with production supervision and plant management.

Operators' and mechanics' attitudes were predictably skeptical at first, but usually turned around as the conversion progressed and their involvement increased. Because we involved these people early, we benefitted from many useful suggestions during the project, and we tried to implement as many as we could. Our operators and mechanics seem to enjoy the DCS, and take pride in working in a new environment with state-of-the-art equipment.

An unofficial duty of the engineers installing the DCS was to educate production supervision and plant management about the characteristics of the system. A retrofit of pneumatic controls with digital equipment is bound to have some "birth pangs". Even simple problems can have wide-ranging effects and appear quite mysterious upon first encounter. Dissimilar problems can show the same characteristics. When we ran into a snag our management needed to know:

- Whether the problem was with hardware, vendor's software, our software, "firmware", field wiring, field hardware, etc.
- If the problem was easily correctable or required some time
- If the solution was temporary or permanent

This point is brought out because it was quite easy to assume the rest of the engineering and management staff understood the nature of the startup problems, and we could have benefitted by anticipating this communication gap and formalizing our problem reporting.

FUTURE CONTROL IMPROVEMENTS

The first phase of our project, the duplication of existing control strategy on a DCS, is essentially complete. Advanced control schemes are being proposed, some requiring only programming changes, others requiring some new instrumentation. Some areas are:

- Provide stable sulfate control
- Smooth out the gypsum filter operation
- Automate startup/shutdown of the rock grinding area
- Improve quality of evaporator product
- Simplify rate changes to adjustment of one flow, such as rock feed rate or steam load
- Implement automatic reporting to DEC computer

Each of these categories is in various stages of development, but we are confident that all are achievable.

SUMMARY

Before we began this project, we surveyed local DCS users to find out how their systems were performing. An interesting discovery was that most could not distiguish the actual economic benefits of their DCS due to raw material changes, equipment improvements, and other changes to their operation. We now have the same problem, as our filter wash water quality and our sulfate control goal have changed since the justification of this project, and we cannot calculate the improvement of water soluble losses and product sulfate concentration because the old body of data is not applicable to our current operation. We have also tripled our attack tank recirculation, further changing our system's behavior. However, we do know that our control is tighter than before, because the DCS enables us to see detail and process swings that we could not previously detect. We are able to tune our control valves tighter than before. The implementation of advanced control schemes should further boost the economic benefits of the system.

We would not have changed much in our general installation plan, but we did learn a few lessons:

- Accurate input/output counts are very important in planning, and the addition of 40 loops with the unforseen separation of critical loops required more I/O hardware than we originally planned.
- Unoccupied rooms that housed DCS equipment required temperature sensors to detect air conditioning malfunctions.
- Individual control loop hookups could have been done more efficiently by contractors, to provide continuity of personnel.
- Revision drafting has been a larger job than anticipated.
- None of our engineers are control specialists and training in advanced control concepts and design could hasten the development of control strategy.
- Our chosen method of alarm management has proven to be controversial. Currently alarm recognition and acknowledgement is done through CRT graphics, as opposed to a separate, dedicated unit. Though we are not changing our original plan, the designers of a new system should carefully consider other options before relying solely on CRT's for alarm management.
- A related problem was our compensation for the limited viewing capacity of the CRT's by providing additional process alarms. We felt that high, low, and setpoint deviation alarms would keep an operator informed. This turned out to be a mistake. The quantity of alarms quickly became unmanageable, and in most cases the new alarms were not crucial information. We deleted most of the new alarms we had configured.

On the whole, we consider the project a success. We already tend to take our new equipment for granted, and it is hard to remember just how far we have come from leaving our old pneumatic controls in manual and "rapping the controller" to urge a reluctant chart pen to move. Upper management's acceptance of this project is evident in the inclusion of distributed control systems in new capital spending proposals. The days are gone when the control of our plant was just a little bit mysterious.

ACKNOWLEDGEMENTS

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Ms. S. K. "Kay" Bourque, Assistant Superintendent of Maintenance, Agrico Chemical Co., Uncle Sam, LA.

Mr. W. S. "Bill" Ellis, Process Engineer, Agrico Chemical Co., Uncle Sam, LA.

Mr. R. J. "Ray" Kliebert, Engineering Aide, Agrico Chemical Co., Uncle Sam, LA.

Mr. J. M. "Johnny" Prewitt, Technical Services Manager, Agrico Chemical Co., Uncle Sam, LA.

TABLE 1: KEY INSTALLATION EVENTS

July, 1987	Issued purchase order to the vendor, commenced system design and drafting
August, 1987	Started configuration training
November, 1987	Configuration, database, and checkout graphics sent to the vendor for system checkout.
December, 1987	Interim control room modifications and electrical construction begun
January, 1988	Completion of DCS equipment checkout at vendor's site
February, 1988	DCS equipment delivered and installed in interim configuration
March, 1988	Startup and checkout of DCS equipment
April, 1988	Start conversion of shipping and storage controls
May, 1988	Shipping and storage conversion essentially complete, start conversion of attack and filtration, evaporation
August, 1988	Electrical construction completed
October, 1988	Attack and filtration, evaporation conversions essentially complete
November, 1988	Removed old control room panels, began final phase of control room modification, start conversion of rock grinding
December, 1988	Final control room modification complete
January, 1989	Rock grinding conversion essentially complete, begin punchlist work

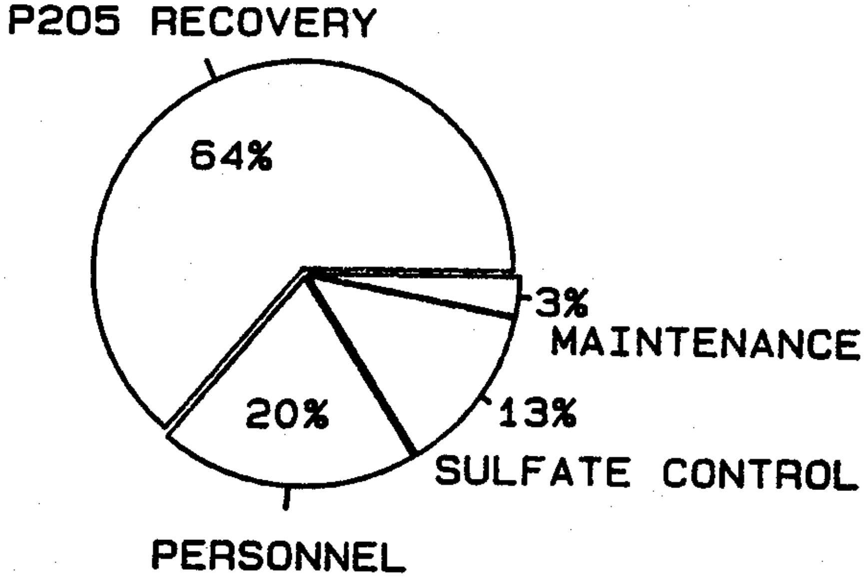


FIGURE 1: DCS JUSTIFICATION

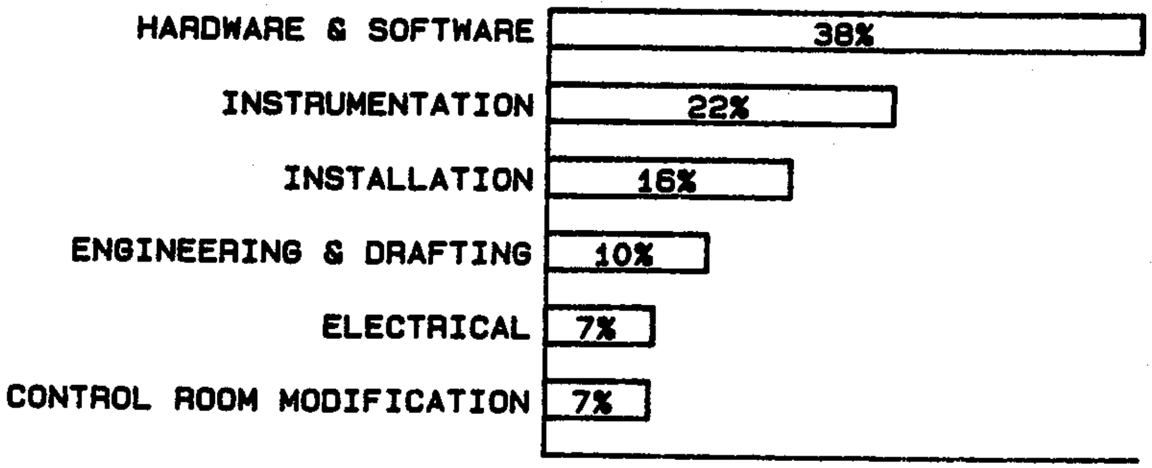
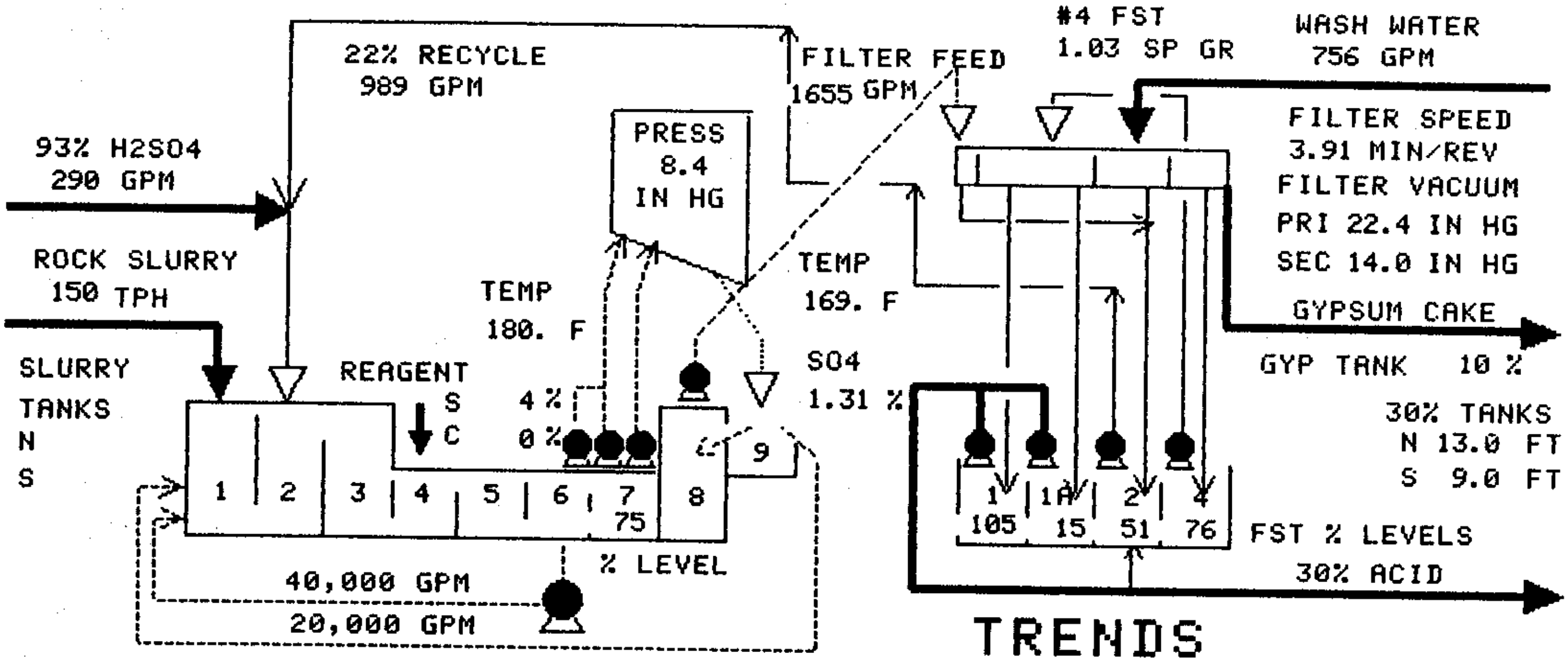


FIGURE 2: DCS COST (IN-HOUSE ENGINEERING EXCLUDED)

07:25:40 26-APR-89 WEDNESDAY SOUTH A&F FLOW DIAGRAM 2345S



FACEPLATES

L FILTER & 1/1A
M ATTACK AGITATORS
N FILT AGIT/PUMPS
O STATIONS I
P STATIONS II
Q ROCK SLURRY
R FC & FF PUMPS

S VAC PUMPS/FANS
T GYPSUM
U REAGENT
V 30% TANKS
W B/O TANK & POND
X 03 UTILITIES
Y SOUTH A/F
Z 03

TRENDS

1 TPH ROCK,GPM 93% ACID,
GPM DILUTION WATER & %FREE SO4

2 GPM FILTER WASH,FILTER FEED & RECYCLE
#7 ATTACK %LEVEL,# 2 FST %LEVEL

3 PRI VACUUM,#2 FST SPGR,#4 FST SPGR

4 INHG F/C PRESS,DEG F #2,4,7,9 ATTACK

5 PPM P205 E&W TRENCH,PPM F EAST TRENCH

6 UMHOS E&W TRENCHES

7 GPM SLURRY,%SOLIDS,GPM TOTAL POND,
GPM 93% SPLIT,GPM 22% SPLIT

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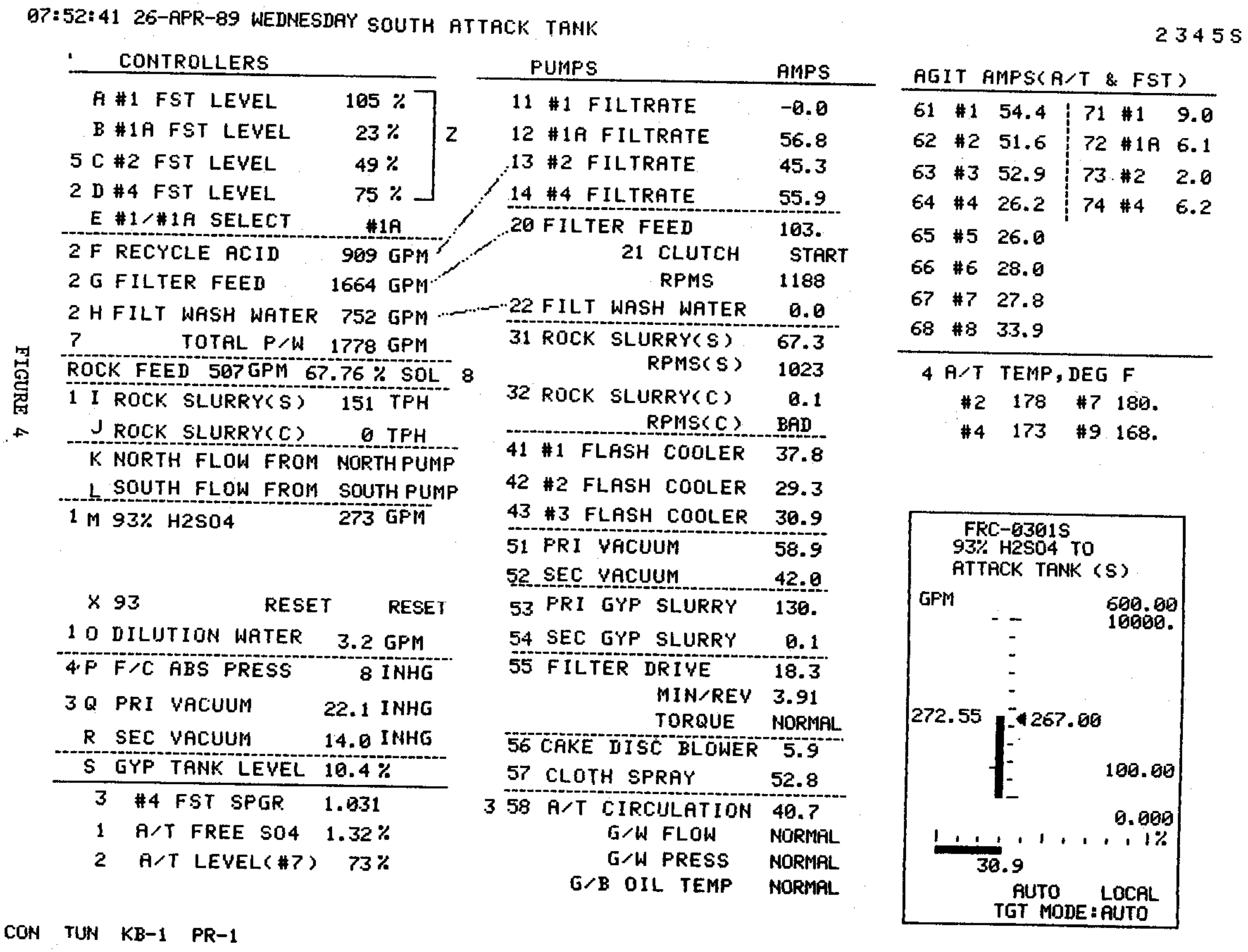
FIGURE 3



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07:52:41 26-APR-89 WEDNESDAY SOUTH ATTACK TANK                                            2345S
'   CONTROLLERS                      PUMPS                       AMPS      AGIT AMPS(A/T & FST)
   A #1 FST LEVEL        105 % ┐      11 #1 FILTRATE             -0.0      61 #1 54.4 ┆ 71 #1  9.0
   B #1A FST LEVEL        23 % │ Z    12 #1A FILTRATE            56.8      62 #2 51.6 ┆ 72 #1A 6.1
 5 C #2 FST LEVEL         49 % │      13 #2 FILTRATE             45.3      63 #3 52.9 ┆ 73 #2  2.0
 2 D #4 FST LEVEL         75 % ┘      14 #4 FILTRATE             55.9      64 #4 26.2 ┆ 74 #4  6.2
   E #1/#1A SELECT         #1A        20 FILTER FEED             103.      65 #5 26.0
 2 F RECYCLE ACID      909 GPM               21 CLUTCH           START     66 #6 28.0
 2 G FILTER FEED      1664 GPM                  RPMS             1188      67 #7 27.8
 2 H FILT WASH WATER   752 GPM        22 FILT WASH WATER          0.0      68 #8 33.9
 7        TOTAL P/W   1778 GPM        31 ROCK SLURRY(S)          67.3
 ROCK FEED 507GPM 67.76 % SOL  8                RPMS(S)          1023       4 A/T TEMP,DEG F
 1 I ROCK SLURRY(S)    151 TPH        32 ROCK SLURRY(C)           0.1          #2 178  #7 180.
   J ROCK SLURRY(C)      0 TPH                  RPMS(C)           BAD          #4 173  #9 168.
   K NORTH FLOW FROM  NORTH PUMP      41 #1 FLASH COOLER         37.8
   L SOUTH FLOW FROM  SOUTH PUMP      42 #2 FLASH COOLER         29.3
 1 M 93% H2SO4         273 GPM        43 #3 FLASH COOLER         30.9       FRC-0301S
                                      51 PRI VACUUM              58.9       93% H2SO4 TO
                                      52 SEC VACUUM              42.0       ATTACK TANK (S)
   X 93          RESET      RESET     53 PRI GYP SLURRY          130.      GPM          600.00
 1 O DILUTION WATER    3.2 GPM        54 SEC GYP SLURRY           0.1                   10000.
 4 P F/C ABS PRESS       8 INHG       55 FILTER DRIVE            18.3
 3 Q PRI VACUUM       22.1 INHG                 MIN/REV          3.91
   R SEC VACUUM       14.0 INHG                 TORQUE           NORMAL    272.55  ◄267.00
   S GYP TANK LEVEL   10.4 %          56 CAKE DISC BLOWER         5.9
   3   #4 FST SPGR    1.031           57 CLOTH SPRAY             52.8                     100.00
   1   A/T FREE SO4   1.32 %        3 58 A/T CIRCULATION         40.7                      0.000
   2   A/T LEVEL(#7)    73 %                 G/W FLOW            NORMAL                       1%
                                             G/W PRESS           NORMAL         30.9
                                          G/B OIL TEMP           NORMAL           AUTO    LOCAL
                                                                                  TGT MODE:AUTO
CON  TUN  KB-1  PR-1
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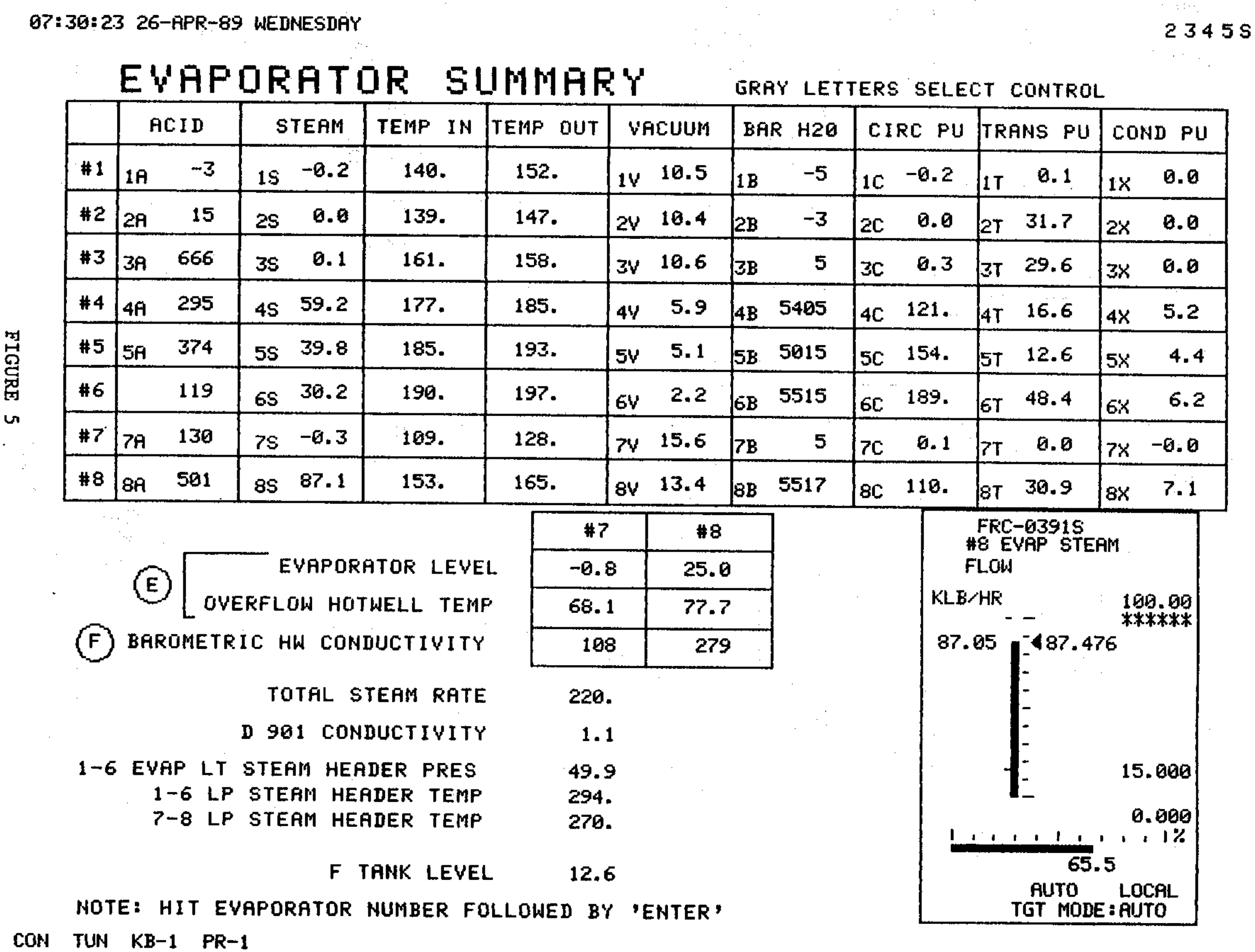
FIGURE 4



07:30:23 26-APR-89 WEDNESDAY

2 3 4 5 S

EVAPORATOR SUMMARY GRAY LETTERS SELECT CONTROL

	ACID	STEAM	TEMP IN	TEMP OUT	VACUUM	BAR H20	CIRC PU	TRANS PU	COND PU
#1	1A -3	1S -0.2	140.	152.	1V 10.5	1B -5	1C -0.2	1T 0.1	1X 0.0
#2	2A 15	2S 0.0	139.	147.	2V 10.4	2B -3	2C 0.0	2T 31.7	2X 0.0
#3	3A 666	3S 0.1	161.	158.	3V 10.6	3B 5	3C 0.3	3T 29.6	3X 0.0
#4	4A 295	4S 59.2	177.	185.	4V 5.9	4B 5405	4C 121.	4T 16.6	4X 5.2
#5	5A 374	5S 39.8	185.	193.	5V 5.1	5B 5015	5C 154.	5T 12.6	5X 4.4
#6	119	6S 30.2	190.	197.	6V 2.2	6B 5515	6C 189.	6T 48.4	6X 6.2
#7	7A 130	7S -0.3	109.	128.	7V 15.6	7B 5	7C 0.1	7T 0.0	7X -0.0
#8	8A 501	8S 87.1	153.	165.	8V 13.4	8B 5517	8C 110.	8T 30.9	8X 7.1

	#7	#8
(E) EVAPORATOR LEVEL	-0.8	25.0
(E) OVERFLOW HOTWELL TEMP	68.1	77.7
(F) BAROMETRIC HW CONDUCTIVITY	108	279

TOTAL STEAM RATE	220.
D 901 CONDUCTIVITY	1.1
1-6 EVAP LT STEAM HEADER PRES	49.9
1-6 LP STEAM HEADER TEMP	294.
7-8 LP STEAM HEADER TEMP	270.
F TANK LEVEL	12.6

NOTE: HIT EVAPORATOR NUMBER FOLLOWED BY 'ENTER'

CON TUN KB-1 PR-1

FRC-0391S
#8 EVAP STEAM
FLOW
KLB/HR 100.00
******
87.05 87.476
15.000
0.000
%
65.5
AUTO LOCAL
TGT MODE:AUTO

FIGURE 5

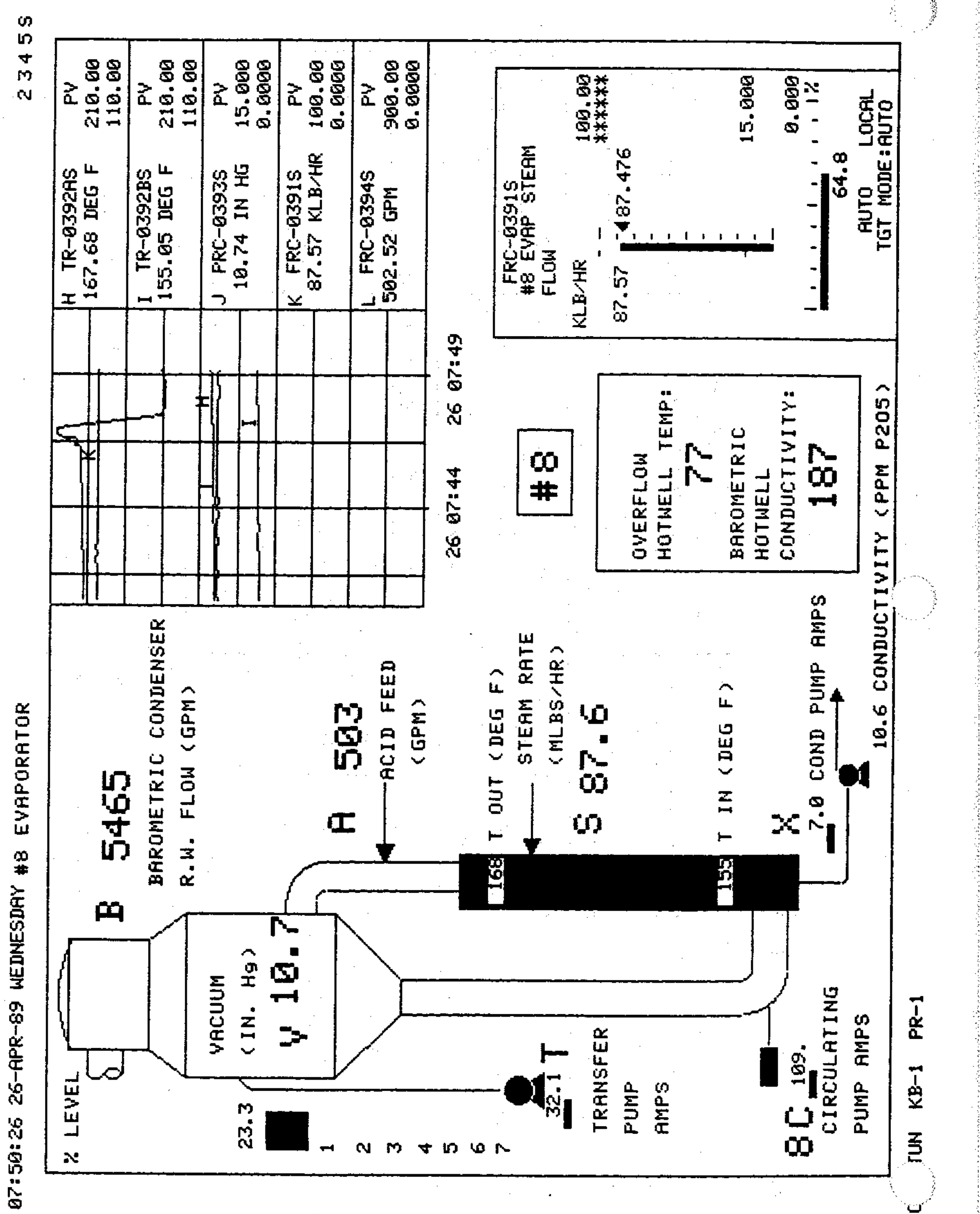
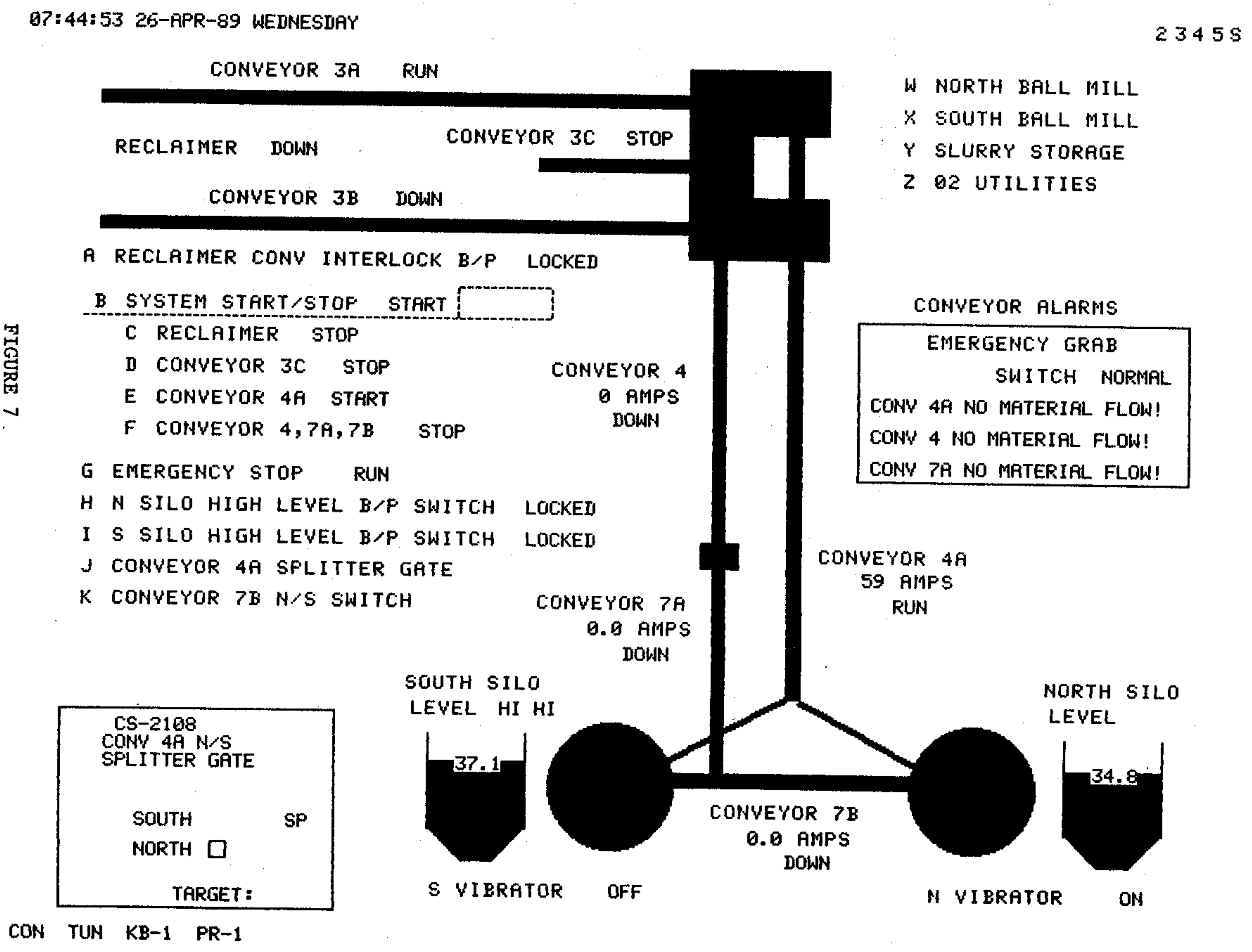

07:50:26 26-APR-89 WEDNESDAY #8 EVAPORATOR
2 3 4 5 S
% LEVEL
23.3
1 2 3 4 5 6 7
B 5465
BAROMETRIC CONDENSER
R.W. FLOW (GPM)
VACUUM
(IN. Hg)
V 10.7
A 503
ACID FEED
(GPM)
T OUT (DEG F)
STEAM RATE
(MLBS/HR)
S 87.6
168
155
T IN (DEG F)
X
7.0 COND PUMP AMPS
10.6 CONDUCTIVITY
32.1 T
TRANSFER
PUMP
AMPS
8C 109.
CIRCULATING
PUMP AMPS
H TR-0392AS PV
167.68 DEG F 210.00
110.00
I TR-0392BS PV
155.05 DEG F 210.00
110.00
J PRC-0393S PV
10.74 IN HG 15.000
0.0000
K FRC-0391S PV
87.57 KLB/HR 100.00
0.0000
L FRC-0394S PV
502.52 GPM 900.00
0.0000
26 07:44
26 07:49
#8
OVERFLOW
HOTWELL TEMP:
77
BAROMETRIC
HOTWELL
CONDUCTIVITY:
187
CONDUCTIVITY (PPM P2O5)
FRC-0391S
#8 EVAP STEAM
FLOW
KLB/HR
87.57
87.476
100.00
*****
15.000
0.000
64.8
1%
AUTO
LOCAL
TGT MODE:AUTO
CC TUN KB-1 PR-1

FIGURE 6



07:44:53 26-APR-89 WEDNESDAY

2 3 4 5 S

CONVEYOR 3A RUN

RECLAIMER DOWN

CONVEYOR 3C STOP

CONVEYOR 3B DOWN

W NORTH BALL MILL
X SOUTH BALL MILL
Y SLURRY STORAGE
Z 02 UTILITIES

A RECLAIMER CONV INTERLOCK B/P LOCKED
B SYSTEM START/STOP START
C RECLAIMER STOP
D CONVEYOR 3C STOP
E CONVEYOR 4A START
F CONVEYOR 4,7A,7B STOP
G EMERGENCY STOP RUN
H N SILO HIGH LEVEL B/P SWITCH LOCKED
I S SILO HIGH LEVEL B/P SWITCH LOCKED
J CONVEYOR 4A SPLITTER GATE
K CONVEYOR 7B N/S SWITCH

CONVEYOR 4
0 AMPS
DOWN

CONVEYOR ALARMS

EMERGENCY GRAB
SWITCH NORMAL
CONV 4A NO MATERIAL FLOW!
CONV 4 NO MATERIAL FLOW!
CONV 7A NO MATERIAL FLOW!

CONVEYOR 4A
59 AMPS
RUN

CONVEYOR 7A
0.0 AMPS
DOWN

SOUTH SILO
LEVEL HI HI
37.1

NORTH SILO
LEVEL
34.8

CONVEYOR 7B
0.0 AMPS
DOWN

S VIBRATOR OFF

N VIBRATOR ON

CS-2108
CONV 4A N/S
SPLITTER GATE

SOUTH SP
NORTH ☐

TARGET:

CON TUN KB-1 PR-1

FIGURE 7

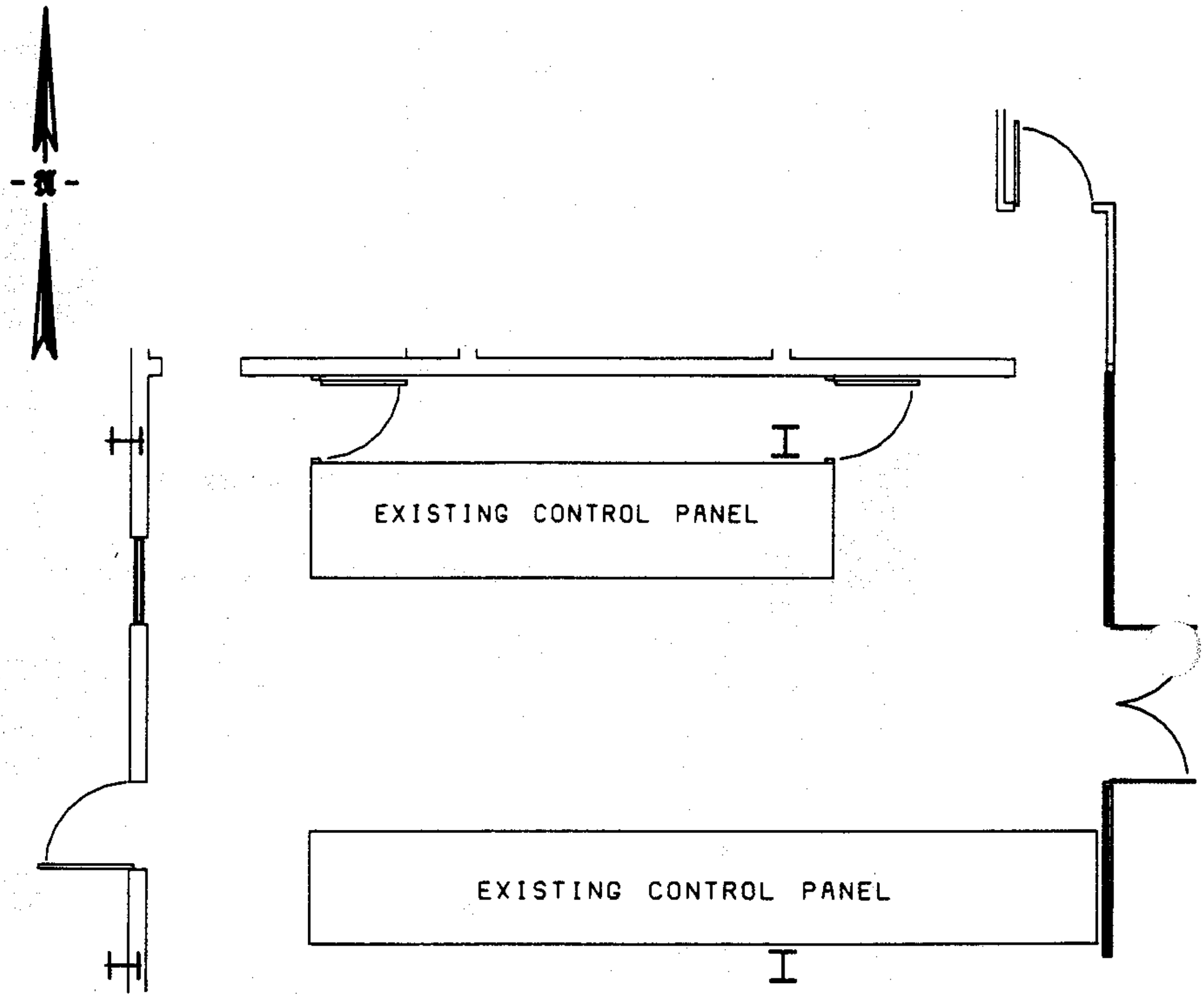


FIGURE 8: ORIGINAL CONTROL ROOM LAYOUT

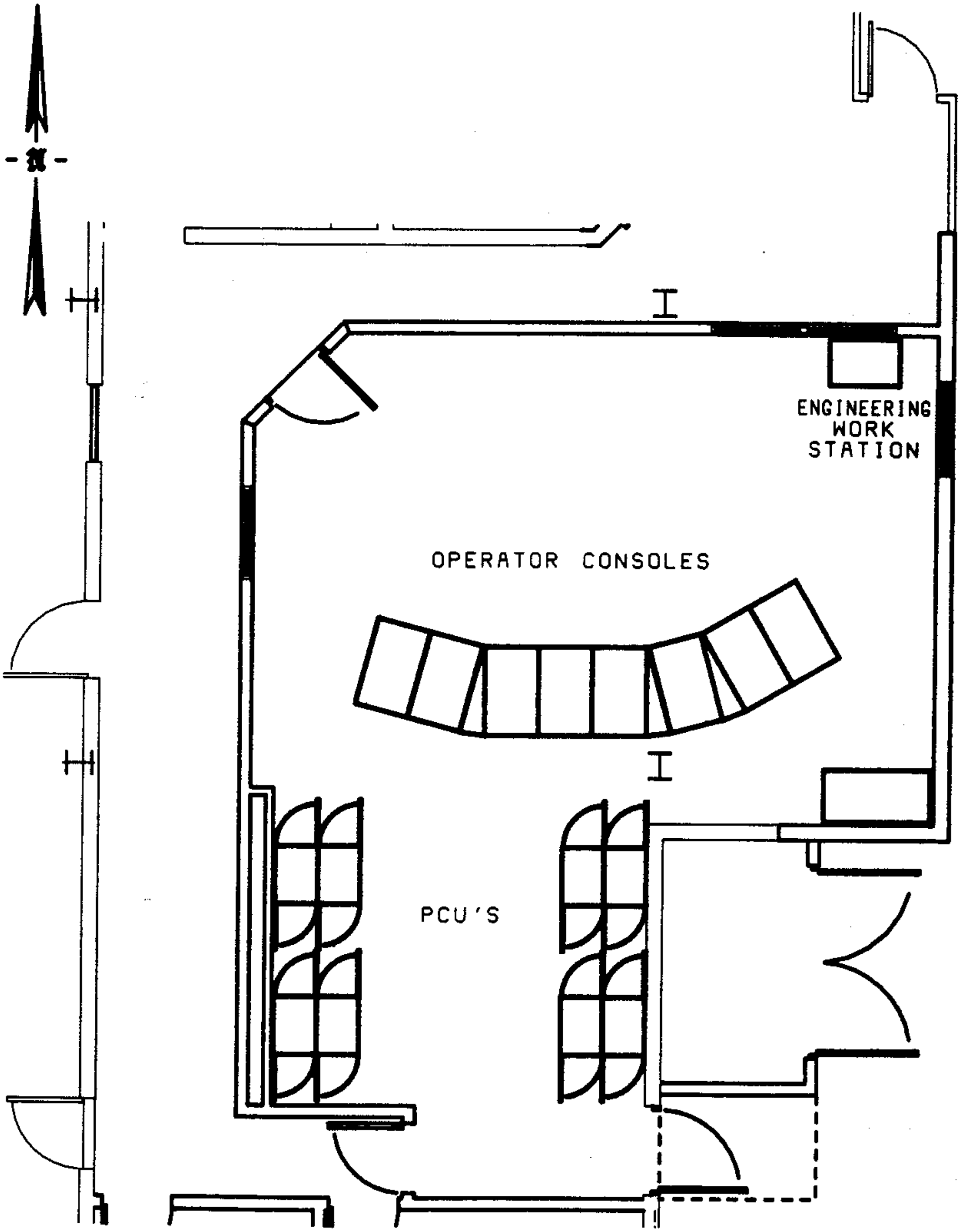


FIGURE 9: FINAL CONTROL ROOM LAYOUT