BOILING AND CENTRIFUGING OF WHITE SUGAR USING A DISTRIBUTED CONTROL SYSTEM

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INTRODUCTION

Four years ago American Crystal Sugar installed a Distributed Control System (DCS) at the Moorhead factory to control the white centrifugal battery and the lime slaker. Two years ago the decision was made to add control of the white pans at Moorhead to the DCS. The results of both projects has exceeded the expectations factory management had hoped to achieve.

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REASONS FOR DISTRIBUTED CONTROL

American Crystal began the move toward distributed control in 1986 when the decision was made to place the control of the white centrifugals at the Moorhead, Minnesota, factory on a distributed control system versus the more traditional idea of using programmable logic controller (PLC) for the control of the station. The following are the reasons a distributed control system (DCS) was chosen:

1. The ease of changing control strategies without the need to change hard wiring.
2. The ability for American Crystal employees to do the system configuration.
3. The ability to expand the control system throughout the factory as the opportunities present themselves.
4. To prove the ability of a DCS to effectively control discrete functions that were historically done by PLC's.
5. The option to control a process from different locations within the factory when needed.
6. The option to control from a process graphic and also to modify the process graphic when changes in the process are made.
7. The ability to use diagnostics in the form of graphics to aid in the trouble shooting of equipment problems to reduce machine downtime.

CENTRIFUGAL CONFIGURATION

After the DCS was chosen there were numerous meetings held with the factory operations personnel (productions shift supervisors, sugar end foreman) to ascertain their feelings as to the proper operation of the white centrifugal station. At this time a matrix was initiated to show the reason for the centrifugal to advance from its current state to the next state in the cycle, and what would happen as a result of the change of state (see figure 1). After several modifications of the matrix the initial configuration of the system was done. The factory operations personnel also decided to have only one set of timers for the entire centrifugal battery. This was done to force the operator to have any mechanical problems, no matter how minor, fixed. Historically, the timers of a machine with a minor mechanical problem were just adjusted to compensate for the problem, and when the problem could no longer be compensated for the resultant downtime of that machine was fairly lengthy. Completion of the configuration for the centrifugals took ten work weeks.

The system hardware layout was also done in such a way so the failure of a controller card would cause the loss of only one white centrifugal machine (see figure 2).

CENTRIFUGAL OPERATION/RESULTS

During the campaign start up it was discovered that if there were mechanical problems with the white centrifugal machines the control system would not allow the machine with the problem to continue in operation. After the problem was rectified the machine could then be placed back in operation. Prior to the installation of this system it was possible to run a machine that had a mechanical problem which would eventually slow down the operation of the entire centrifugal battery. It was discovered that by keeping the machines in tip top shape mechanically we were able to add 35 to 45 seconds to the amount of "spin/drying" time to each machine cycle without reducing station capacity. Through the use of machine diagnostics in the form of video graphics the centrifugal station operator can now discover the reason for having an operational problem with a machine, and then the operator can contact the appropriate maintenance personnel. Prior to installation of the DCS on the white centrifugals it took factory maintenance personnel approximately 40 hours per week to keep the white centrifugal station operational. It now takes only 1 or 2 hours per week to keep the station operational. The same DCS was installed at the Drayton, North Dakota, factory prior to the 1990-1991 campaign for control of the white centrifugal battery. The results from both systems have proven to be very similar.

WHITE PAN CONTROLS; DISTRIBUTED VERSUS DEDICATED

As part of the Moorhead factory 1989 capital plan was a project to upgrade the existing controls installed on the white pans. The original concept for improved control of white pan boiling was to replace the 1970's vintage analog control system with a dedicated, one system/one pan, microprocessor based system. It was suggested, during initial planning, to expand the DCS installed to control the white centrifugals, to control the white pans. A team was formed to evaluate the system options, distributed vs. dedicated, and then to make a recommendation to the Moorhead factory management. After listing and discussing the relative advantages and disadvantages of each type system the team recommended and received approval for expansion of the DCS to control the white pan boiling.

WHITE PAN CONFIGURATION

The team was then given the task to develop the process control sequence/matrix. First, a flow chart was developed of the system each of the sugar boilers used from which the team was able to establish a baseline program that reflected the best of all four systems. Two recommendations, the first from Michigan Sugar Co.; Saginaw, Michigan, and the second from Southern Minnesota Co-op; Renville, Minnesota, were also incorporated in our configuration. Michigan Sugar suggested we use a nuclear density gauge as the primary measurement for pan boiling since it is not affected by impurities in the juice. Southern Minnesota Co-op had used 80 lb. steam pressure to break vacuum which had helped to reduce the time it took to drop and steam out a pan. Along with these ideas all the valves and controls used to charge, boil, drop, and steam out the pans were automated. An operator acknowledge button and two indicator lights were provided at each pan for field interface but all operations can be handled from the CRT in the control room. After completion of the configuration, which took three work weeks, the sugar boiler needs only to push a button to start a pan, fill the seed pot, and push button to start the final brixing of the pan, all other sequences are handled automatically.

PAN OPERATION

The white pan boiling system operates by taking the pan through various "states", or steps, which are then changed when certain operating conditions are met. The sugar boiler is able to set values for different variables such as pan target size, density for seeding, final brix amps, etc., from a CRT. Manual control of any valve or motor starter is possible from the CRT at any time during the sequence. The sugar boiler has several options for control of the pans. The first is to use the group displays on the CRT which are a representation of eight controller faceplates. There are seven group displays set up for control of the two white pans. The second option is to use process graphics for control of the pans. For this application there were three process graphics developed to assist the sugar boiler. There is an overview graphic and a graphic for each white pan. From these graphics, the sugar boiler is able to perform the same operations that are available on the group displays with a minimal amount of button pushing.

ACCEPTANCE

The sugar boiler acceptance of the system has been extremely good. This is due in large part to the key role the sugar boilers had in the specification of the system and the contribution to the concepts used for the pan sequence configuration. The sugar boilers also attended a operator training course at the facilities of the DCS supplier. This course introduced them to hands on use of the system making implementation of white pan control much easier.

PERFORMANCE

System performance as evaluated versus baseline data has shown a significant reduction or tightening of the control ranges in the Mean Aperture (MA), and Coefficient of Variation (CV), of the sugar produced. The MA was reduced from an average of 15.69 to 13.8 and its control range went from 7.3 to 2.7, a reduction of 63 percent (figure 3 and 4). The CV went from a mean of 29.18 to 27.1 with a control range going from 22.35 to 3.8 for a reduction of 83 percent (figures 5 and 6). This reduction in control range indicates much better control over pan operations. Another area where large gains were realized was in the time taken to drop a pan. By automating all the discrete valves plus the addition of 80 lbs. steam to break vacuum, the time to drop a pan, steam out, and be ready to start the next pan has been reduced from approximately 13.5 minutes to 4.5 minutes. For Moorhead, this translated to an additional 36,000 minutes or 25 days available for white sugar boiling.

CONCLUSION

American Crystal Sugar feels the distributed control system approach has more than met the requirements for process control in our factories. The white pan boiling system was implemented at our East Grand Forks, Minnesota, factory prior to this campaign. The results at East Grand Forks are comparable to those achieved at Moorhead. The distributed control system is also being used to control carbonation, sugar production scale, and intermediate centrifugals. Future areas of expansion include sugar storage and retrieval, first carbonation membrane presses, and a standard liquor concentrator. The final point we would like to mention is how important the training of operational and maintenance personnel involved in the day to day operation of the system was to the success of both control projects described in this paper.

* M1 (AGITATOR MOTOR) HAS ADDITIONAL LOGIC IN THE DISCRETE MOTOR CONTROLLER TO PRECLUDE AUTO OPERATION WITH TANK LEVEL LESS THAN 1 FOOT

1 = ENERGIZED

		STATE NUMBER			HOLD TIMER	M1	RAMP SP DOWN V4	RAMP SP UP V4	V3	V2	V1
CAUSE TO LEAVE STATE	COMMON NAME	#		h	g	f	e	d	c	b	a
OPERATOR ENTRY	SAFE	1	a				1				
RAW 1 = TARGET	FILL1	2	b								1
RAW 2 = TARGET	FILL2	3	c			1*		1		1	
HOLD TIMER DONE	HOLD	4	d		1	1*		1			
LEVEL < = 0 FT	DRAIN	5	e			1*		1	1		

Figure 1

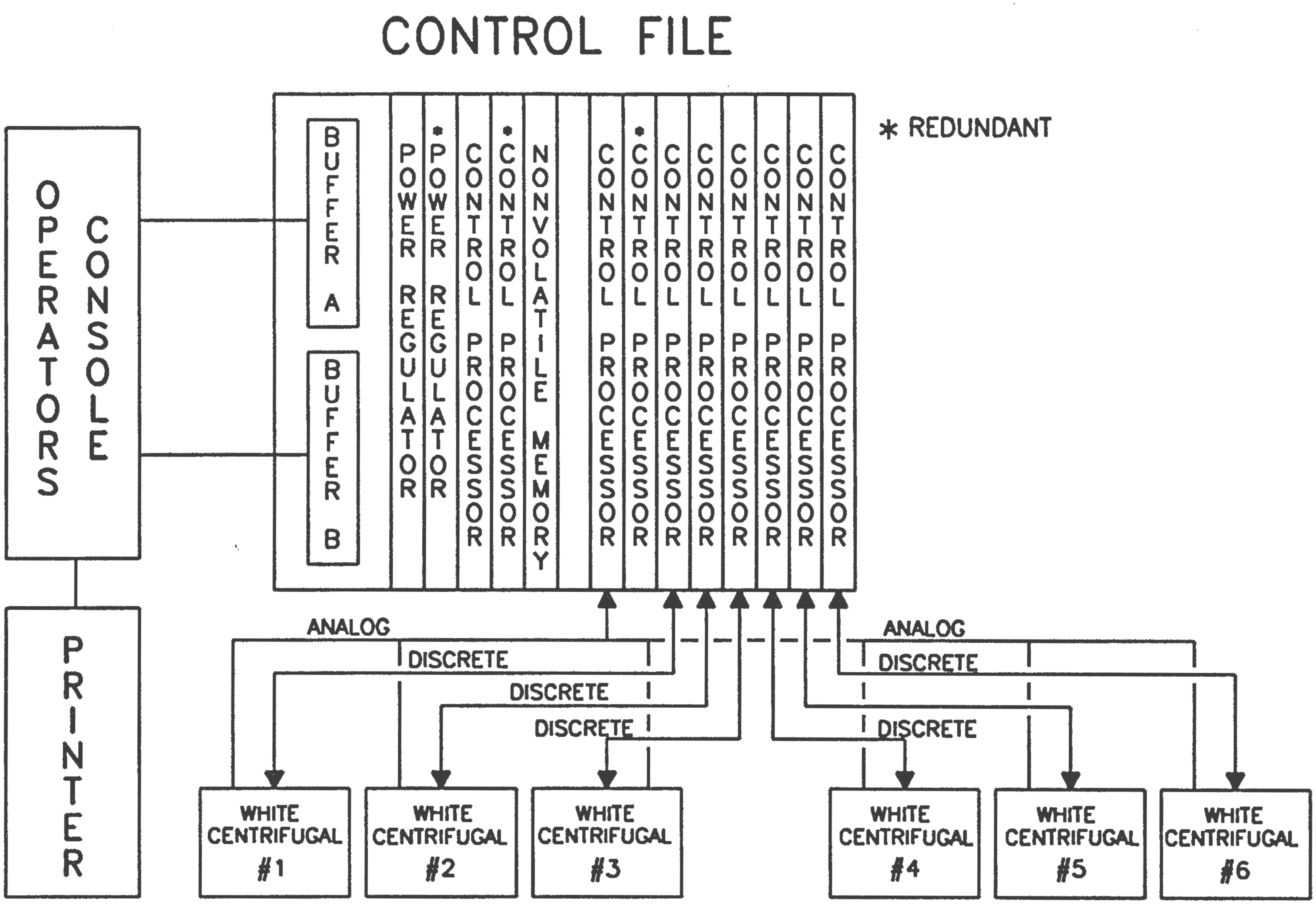
CONTROL FILE
* REDUNDANT
OPERATORS CONSOLE
PRINTER
BUFFER A
BUFFER B
POWER REGULATOR
*POWER REGULATOR
CONTROL PROCESSOR
*CONTROL PROCESSOR
NONVOLATILE MEMORY
CONTROL PROCESSOR
*CONTROL PROCESSOR
CONTROL PROCESSOR
CONTROL PROCESSOR
CONTROL PROCESSOR
CONTROL PROCESSOR
CONTROL PROCESSOR
CONTROL PROCESSOR
ANALOG
DISCRETE
DISCRETE
DISCRETE
ANALOG
DISCRETE
DISCRETE
WHITE CENTRIFUGAL #1
WHITE CENTRIFUGAL #2
WHITE CENTRIFUGAL #3
WHITE CENTRIFUGAL #4
WHITE CENTRIFUGAL #5
WHITE CENTRIFUGAL #6

Figure 2

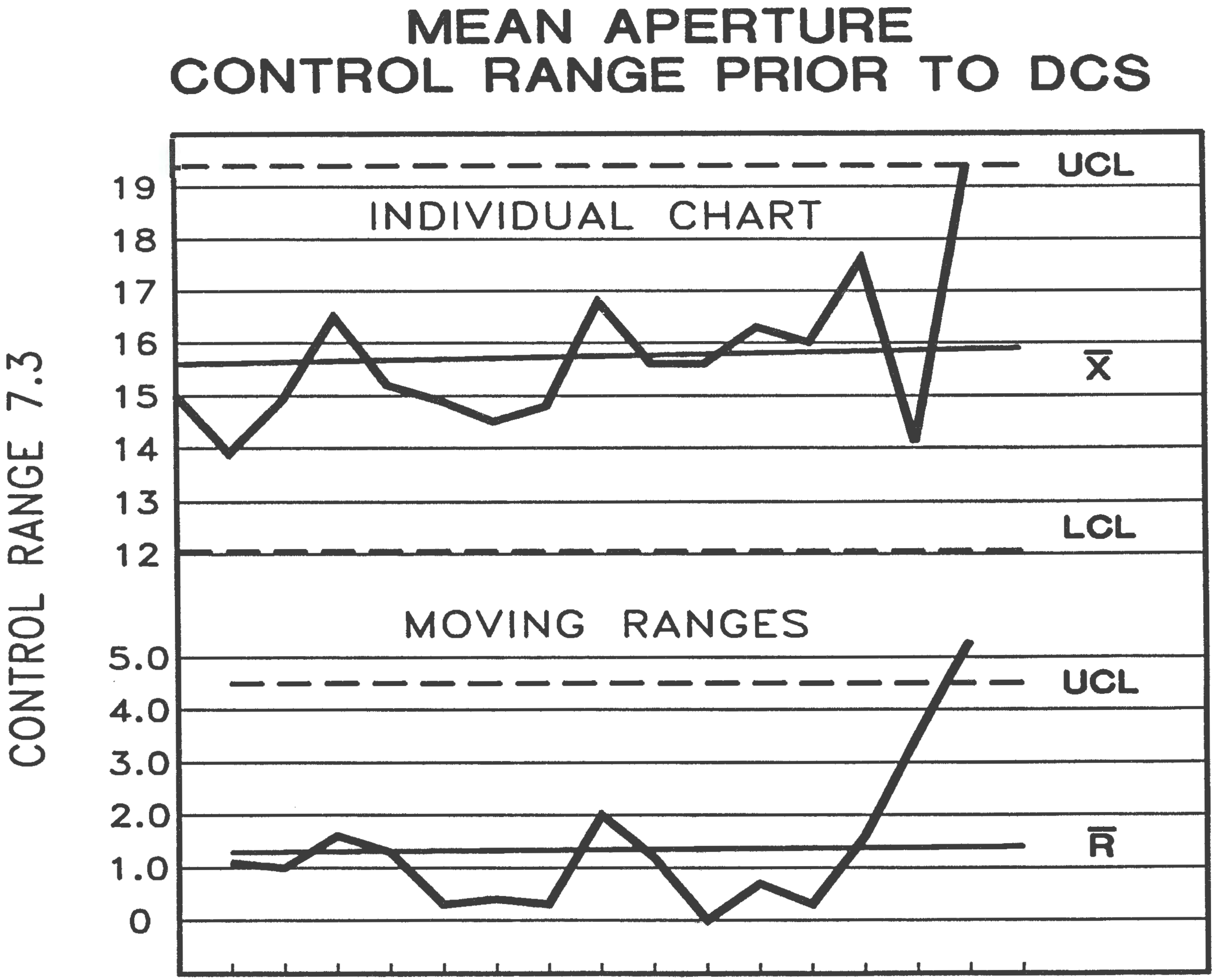
MEAN APERTURE
CONTROL RANGE PRIOR TO DCS
CONTROL RANGE 7.3
INDIVIDUAL CHART
UCL
$\bar{X}$
LCL
19
18
17
16
15
14
13
12
MOVING RANGES
UCL
$\bar{R}$
5.0
4.0
3.0
2.0
1.0
0

FIGURE 3

MEAN APERTURE
CONTROL RANGE AFTER DCS

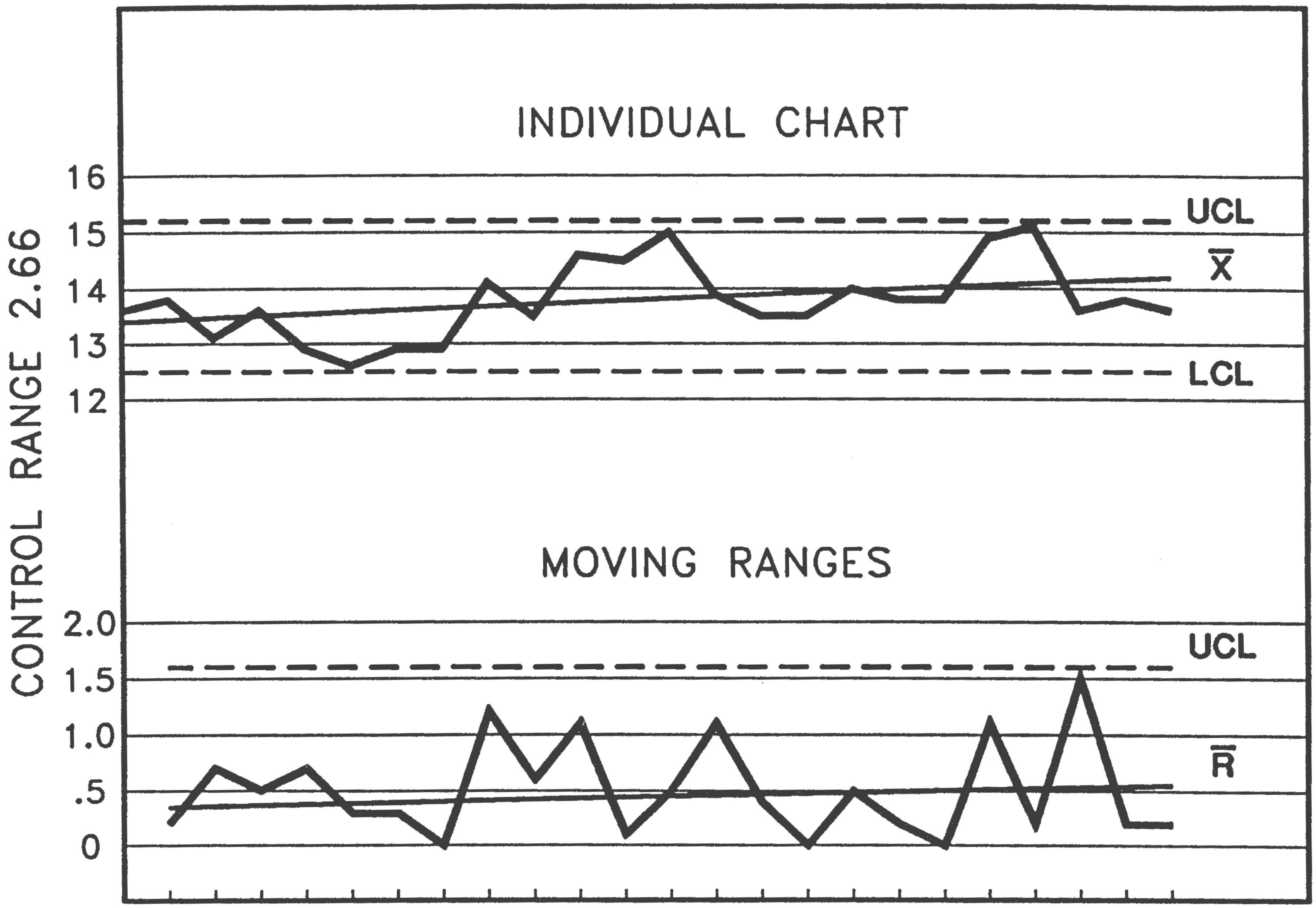

FIGURE 4

COEFFICIENT OF VARIATIONS CONTROL RANGE PRIOR TO DCS

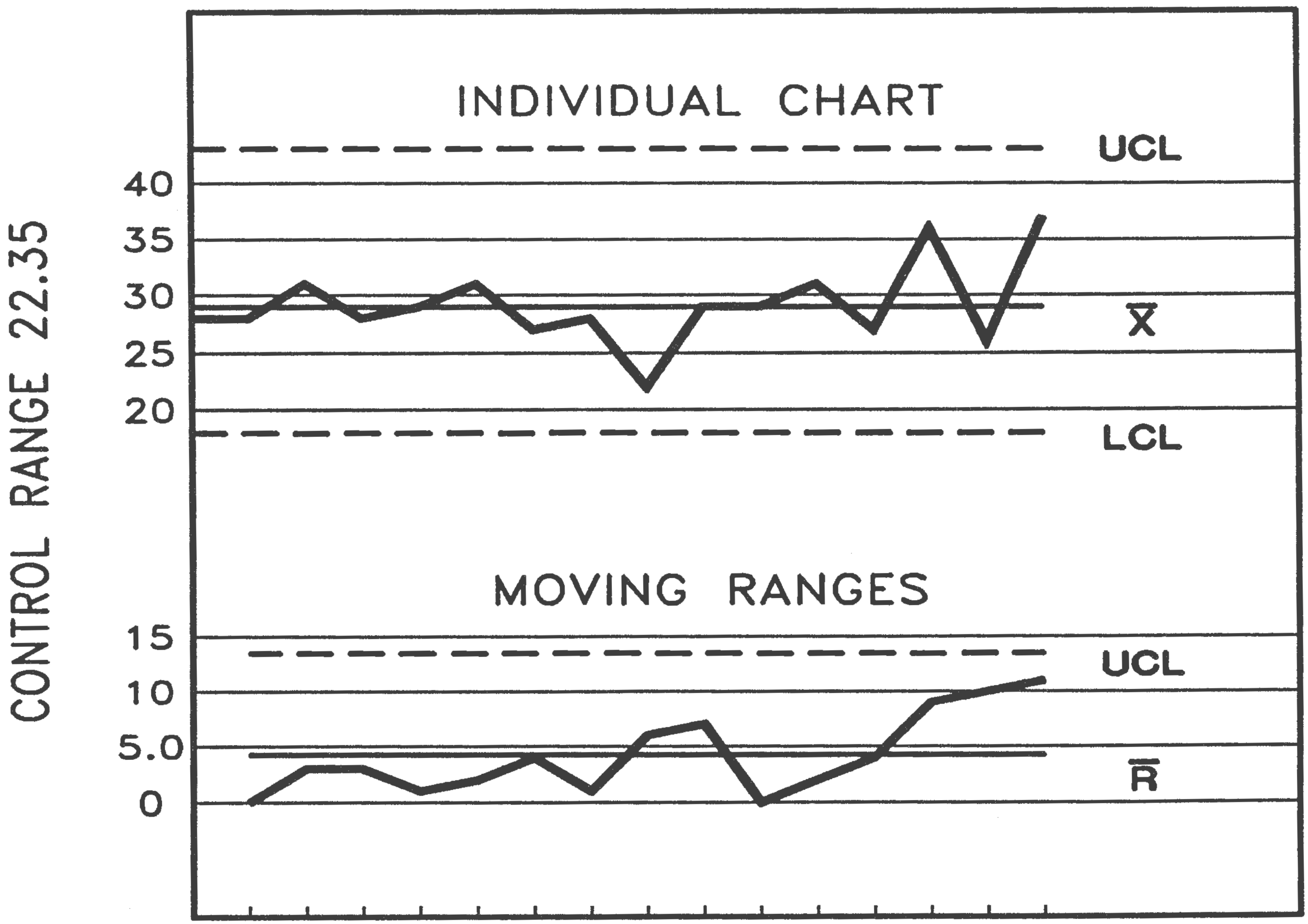

FIGURE 5

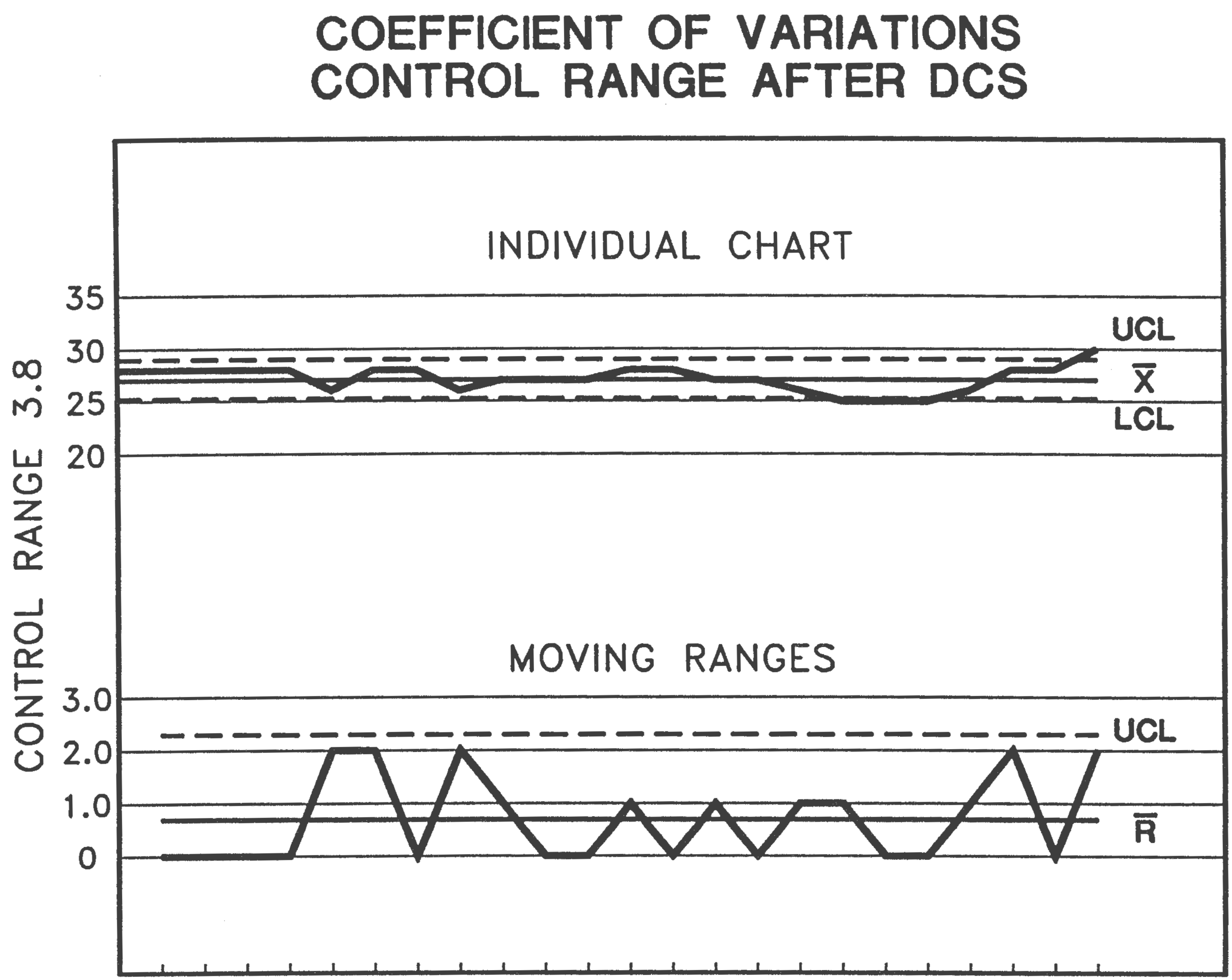
COEFFICIENT OF VARIATIONS
CONTROL RANGE AFTER DCS
INDIVIDUAL CHART
35
30
25
20
UCL
X̄
LCL
MOVING RANGES
3.0
2.0
1.0
0
UCL
R̄
CONTROL RANGE 3.8

FIGURE 6