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EXPERIMENTAL BREEDER REACTOR-II AUTOMATIC CONTROL-ROD-DRIVE SYSTEM*

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by

L. J. Christensen

Argonne National Laboratory
Idaho Falls, Idaho 83401

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EXPERIMENTAL BREEDER REACTOR-II
AUTOMATIC CONTROL ROD DRIVE SYSTEM

L. J. Christensen

A computer-controlled automatic control rod drive system (ACRDS) was designed and operated in EBR-II during reactor runs 121 and 122. The ACRDS was operated in a "checkout" mode during run 121 using a low worth control rod. During run 122 a high worth control rod was used to perform overpower transient tests as part of the LMFBR oxide fuels transient testing program.[1] The testing program required an increase in power of 4 MW/s, a hold time of 12 minutes and a power decrease of 4 MW/s. During run 122, 13 power transients were performed.

The ACRDS design featured two operating modes: (1) a manual mode where the reactor operator controlled the rod movement using the existing raise-lower switches, and (2) an automatic mode where a computer generated the error signal to the controller that operated the dc rod drive motor. The control system is shown in Fig. 1. The ACRDS was used on only one of the eight control rods with the other seven operated in manual mode. The ACRDS replaced the existing single speed drive motor with a servo-controlled dc motor.

Manual mode was the preferred operating mode from a safety standpoint due to its slower speed. Abnormal conditions sensed in automatic mode would trip the system back to manual mode. Even in manual mode, interlocks prevented rod insertion unless the reactor power was less than 16% or the rod had previously been inserted to 8 inches. The ACRDS could be removed in manual mode at anytime since this was the less reactive condition.

In manual mode the control rod speed was the same as the other control rods. The manual controller output voltage was limited and clamped so rod speed could not exceed the normal 0.083 in./s.

Automatic mode was severely restricted both by procedure and by hardware and software interlocks. Nine conditions were required to be fulfilled before the automatic permissive circuit was active. Two interlocks were associated with the computer; (1) one was a software check that verified all parameters were within expected limits, and (2) a circuit that checked that the software was cycling through the main program. One interlock was activated by power level and one by the position of the ACRDS control rod. The others were associated with rod operation.

In automatic mode, the velocity demand signal was generated by comparing the power feedback signal with the power demand trace stored by the computer. The computer algorithm calculated the velocity error signal required. The motor was operated in automatic mode from stop to nearly maximum control speed and would move the 0.83$ control rod at rates up to ±1.2 in./s. This provided sufficient reactivity insertion rate to quickly achieve and maintain the 4 MW/s change in power. The fast acceleration and deceleration times, < 200 ms, and ample velocity provided a system that could change power rapidly. Very little power overshoot or undershoot existed by the design as shown in Fig. 2.

A 16 bit microcomputer with 128 K RAM, 8 D/A channels, 8 A/D channels, and hardware multiply-divide was used. The subroutines occupied less than 64 K of the memory. The computer system had a printer and CRT terminal. The printer was used to print, for verification, the control parameters for the transient to be run. The CRT terminal was used to input and output information to the operator prior to and after the transient. The computer I/O handler required too much time to run in real time during a transient and could not graph the progress of the transient.

The use of a dc motor in a servo feedback system created safety problems since the dc motor is not inherently speed limited. Both controllers were modified internally so the voltage to the motor, and therefore the speed, was limited to values supported by safety analysis. The dc servo controller-motor system had the feature of constant torque and therefore constant acceleration. The 460 oz in. motor accelerated the control rod to control velocity in 200 ms.

Software development consisted of several stages.[2] In a mockup ACRDS test assembly, the transfer function of the ACRDS rod, drive motor, and gearing was measured using a white noise source. EBR-II dynamic parameters and control rod worths permitted a preliminary controller algorithm design. Final controller design and simulated tests were conducted on a hybrid computer. Parallel to this effort, an EBR-II dynamics and rod worth simulator (portable analog device) was fabricated allowing preliminary algorithm testing on the ACRDS control computer with a mockup control rod. Final transient simulations were performed with the control rod installed in the reactor.

Operational and safety interlocks and trips were provided to assure operation within the approved safety envelope. The safety criteria required that (1) a single failure would not insert reactivity faster than 12 ¢/s and (2) that sodium boiling temperatures could not be reached. The first criterion was achieved by limiting the voltage output of the contoller and velocity check by the computer. The second was met by software and hardware interlocks on rod position that would cause the ACRDS to trip to the slow manual mode. Additional interlocks were provided to prevent unauthorized use of the ACRDS in automatic mode and to limit rod movement.

During reactor startup the ACRDS rod was fully inserted using manual mode. Prior to performing a transient, the ACRDS was lowered to its starting position and the system placed in automatic mode.

To get into automatic mode required all interlocks to be satisfied, a transient permissive key was issued by the shift supervisor and the transient software was loaded into the computer. The transient software was considered a controlled document and was issued by approved procedure.

The power was then held constant by the computer controlled system until the "transient start" pushbutton was depressed that started the transient sequence. A typical transient is shown in Fig. 2 with the rod movement shown in Fig. 3. During the 12 minute hold time a second rod was lowered in order to insert the ACRDS rod in preparation for the down ramp. The down ramp was achieved by dropping a rod worth 0.20 $ and simultaneously running the ACRDS rod out. The ACRDS rod then reinserted to level power at the original level.

The ACRDS was only installed for runs 121 and 122 and then removed. The installation was covered by a test procedure. The design of a permanently installed ACRDS is in progress. When installed in early 1984, EBR-II will have the capability to operate in the automatic mode during normal plant operation and with simple changes perform high ramp rate transient tests.

REFERENCES

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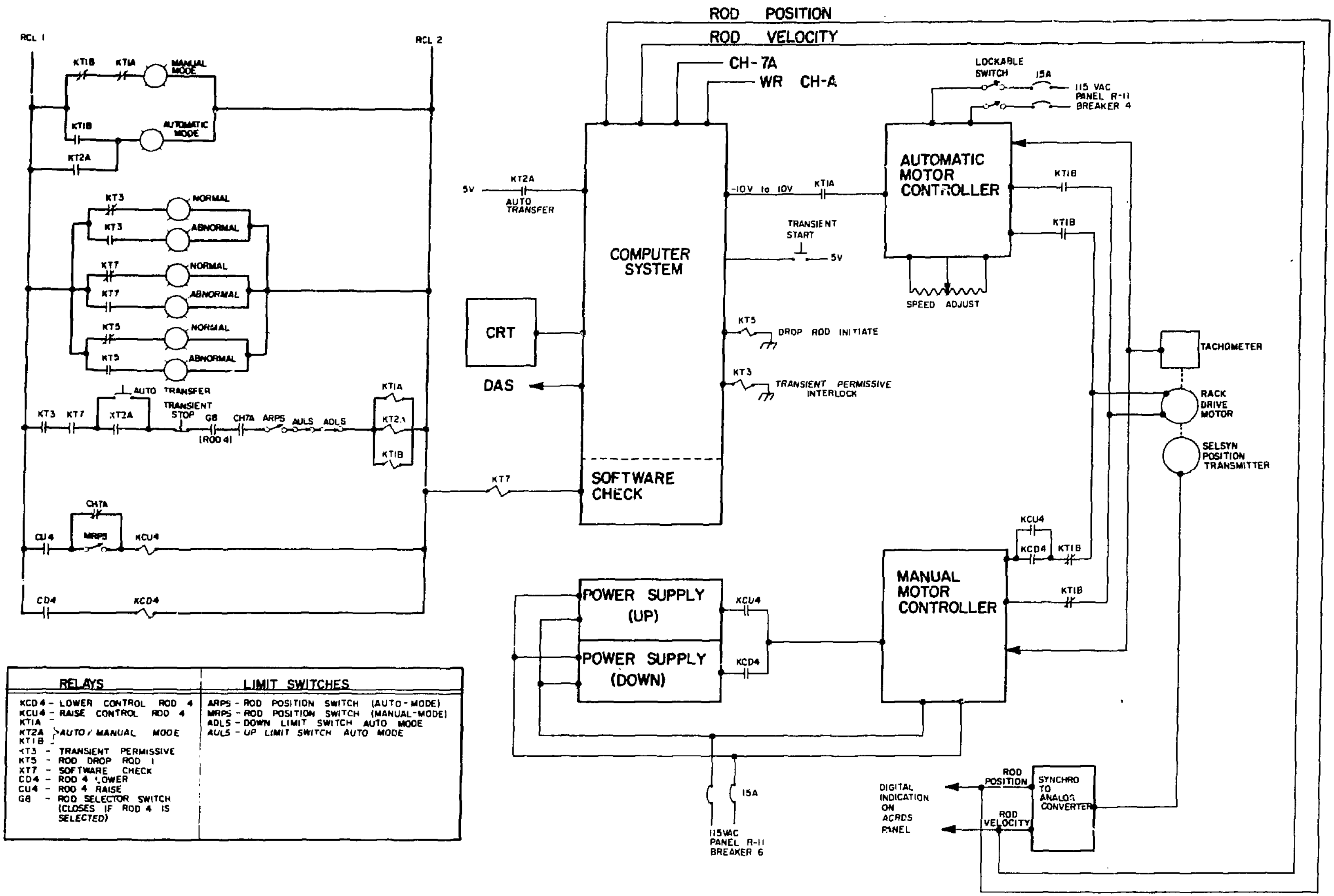
2. Personal Communication, J. Sielensky and D. Chick, EG&G Corp. (1982).



RELAYS	LIMIT SWITCHES
KCD4 - LOWER CONTROL ROD 4	ARPS - ROD POSITION SWITCH (AUTO-MODE)
KCU4 - RAISE CONTROL ROD 4	MRPS - ROD POSITION SWITCH (MANUAL-MODE)
KT1A, KT2A, KT1B - AUTO / MANUAL MODE	ADLS - DOWN LIMIT SWITCH AUTO MODE
KT3 - TRANSIENT PERMISSIVE	AULS - UP LIMIT SWITCH AUTO MODE
KT5 - ROD DROP ROD 1	
XT7 - SOFTWARE CHECK	
CD4 - ROD 4 LOWER	
CU4 - ROD 4 RAISE	
G8 - ROD SELECTOR SWITCH (CLOSES IF ROD 4 IS SELECTED)	

Fig. 1 **AUTOMATIC CONTROL ROD DRIVE SYSTEM** (Simplified Schematic) T/P R-20151-C

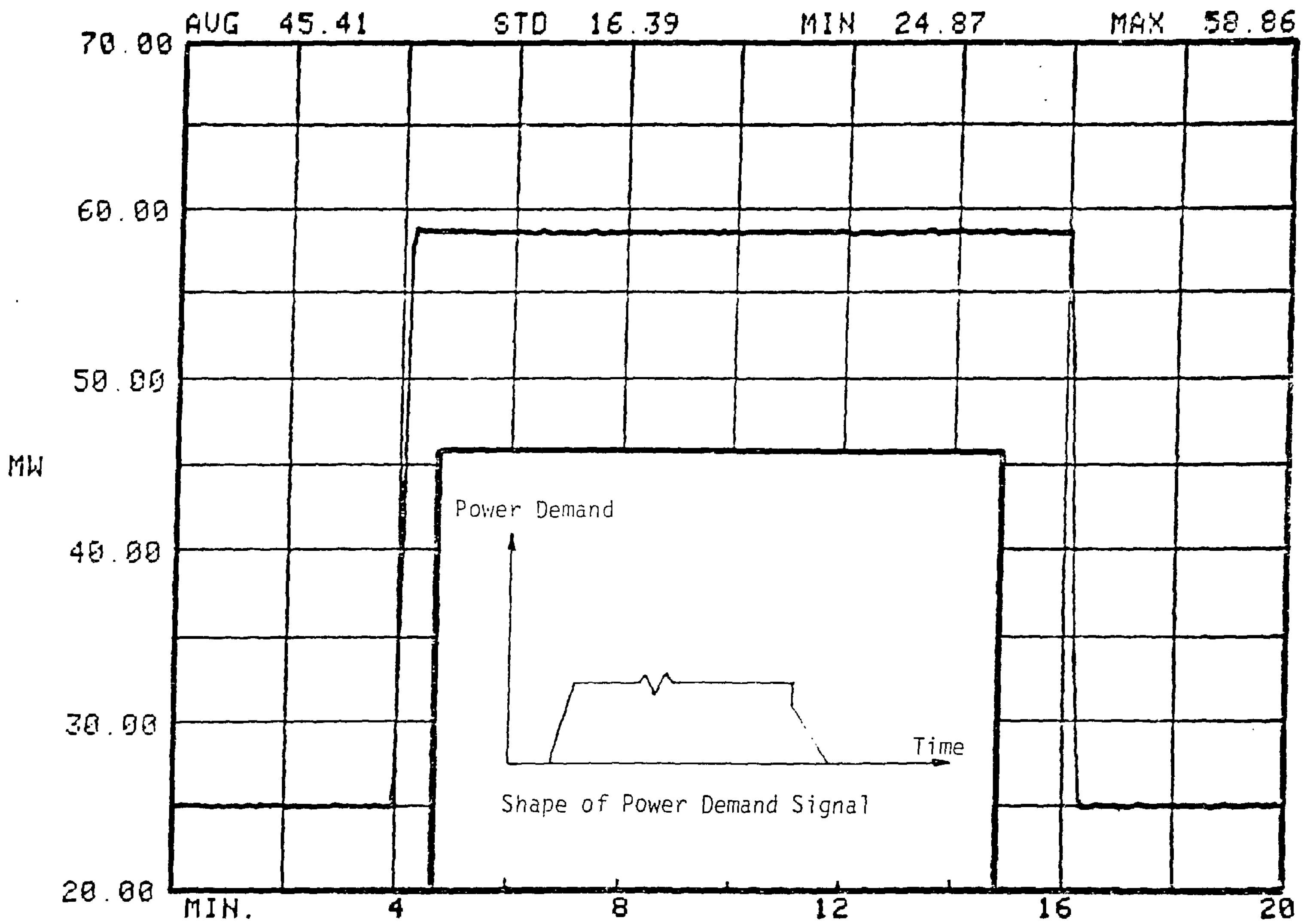


FIG. 2 POWER RESPONSE AND DEMAND SIGNAL SHAPE FOR ACRDS TRANSIENT.

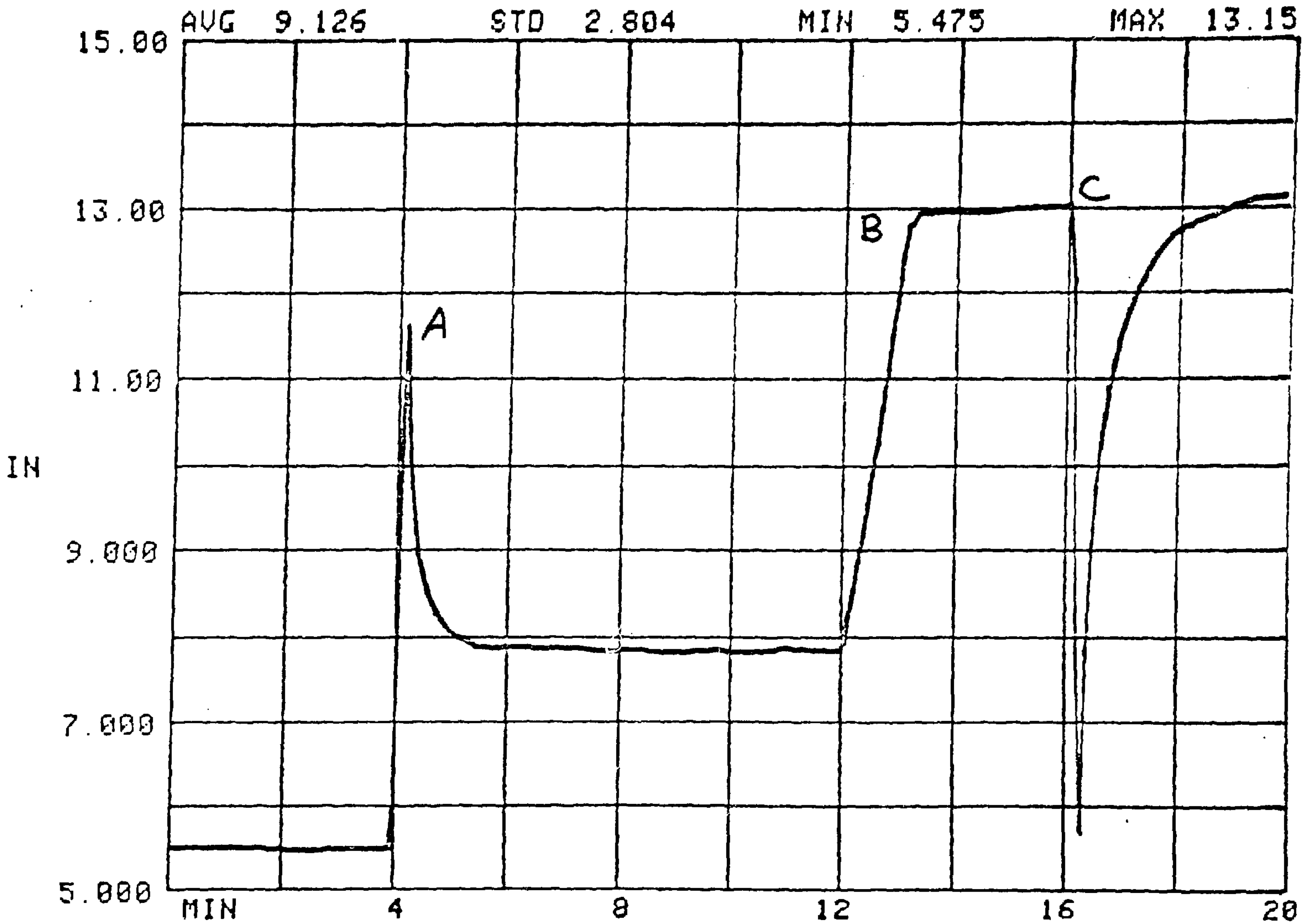


FIG.3 ROD POSITION FOR ACRDS TRANSIENT.