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FINAL REPORT

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Beijing, China

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A Microcomputer Closed Loop Control System for MNSR

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20-Aug-1987

The MNSR (Miniature Neutron Source Reactor) was built up in 1984 in Institute of Atomic Energy, Beijing, China. Since March 1985 a PDP 11/34 computer closed loop control system[1] has been used for MNSR and run well. But the PDP 11/34 computer was too expensive and its functions were not better than some microcomputer, so the PDP 11/34 computer should be replaced by a microcomputer. Now a microcomputer closed-loop control system has been developed for MNSR with a compatible computer IBM PC-XT. This system can not only control the reactor, but it is also a perfact data acquisition system and a reactivity monitor for research on reactor. Of course as a closed loop control system, it only may be used for the reactor such as MNSR, in which the power is self-limited and the reactivity is limited to less than 5mk (~0.7$). But as a data acquisition system or a reactivity monitor, it is available for any nuclear reactor. This paper will describe the hardware and software in detail.

HARDWARE

The MNSR is very safe and it has only one control rod in the centre of the core, so the hardware of the control system is very simple. The hardware of the system is shown in Fig.1, and the Fig.2 is a picture of the control system. The centre of the system is a computer IBM PC-XT, of course IBM PC-AT or compatible computer are available too. A additional AD-DA conversion board is necessary, of which the resolution should be 12 bit, the analog input 16 channels and the analog output more then 2 channels and the conversion time less than 100 us. In our system the Type APC-1612 AD-DA converter was used. All the operating data will be collected into computer by means of these ADC channels and the control feedback signal will be send from the DAC channels.

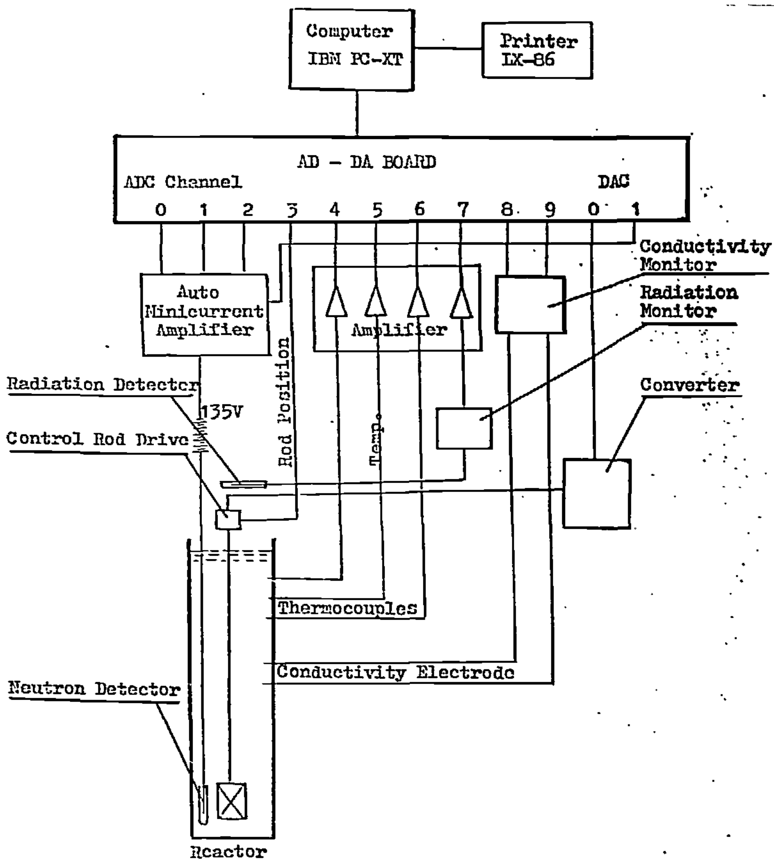

Fig.1 The block diagram of the control system

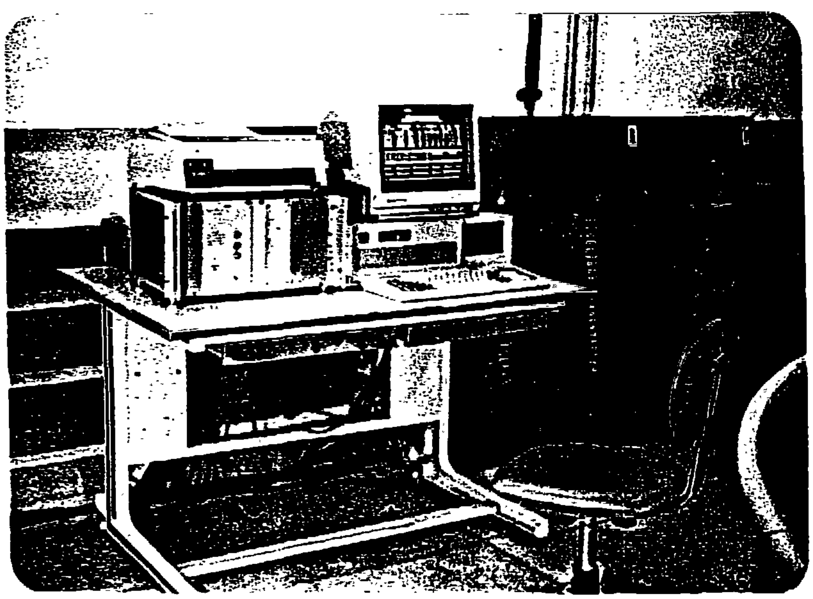

Fig.2 The microcomputer closed loop control system

A small (Φ5X74mm) fission ionization chamber is used as a neutron flux detector, at which a 135V voltage is supplied with the batteries. In the system a auto_microcurrent amplifier has been designed to amplify the neutron fission ionization current, in which the ranges are changed automatically. The analog signal is sent to ADC channel 0 and the 2bit range signals are sent into ADC channel 1 and 2. The amplifier also receive a signal from the DAC channel 1 to trigger the range change, which is synchronized with data collecting period. To change the range to get to a new stable state needs about 50ms, the data collecting period is more than 100ms, so the computer may collect the operating data of neutron flux from 5.0E+07 to 7.0E+12n/s.cm² accurately. The circuit diagram is shown in Fig.3. And the Fig.4 is the picture of the amplifier.

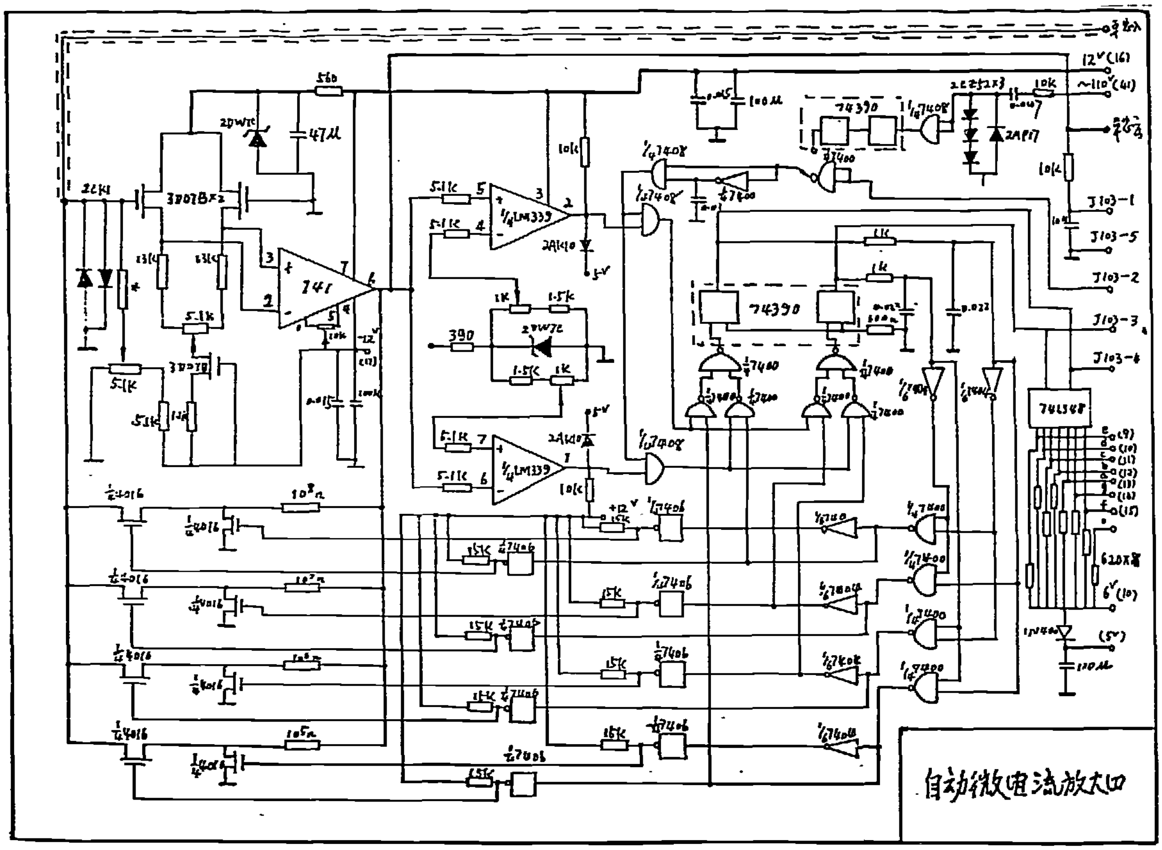

Fig.3 The circuit of the micro_current amplifier

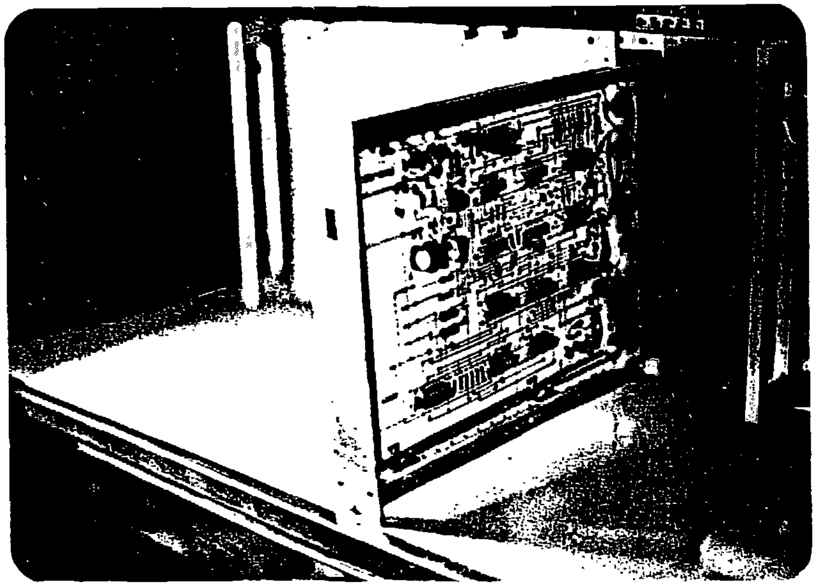

Fig.4 The auto micro_current amplifier

The ADC channel 3 is used to input the control rod position signal, which is given by the potentiometer connected with the control rod driver.

The channel 4, 5 and 6 are used to input the temperature signals, i.e. the inlet, the outlet and the pool water temperature in the reactor. The temperature is measured with thermocouples, and the voltage signals should be amplified 1000 times; then sent into the ADC board.

To prevent the elements from corrosion the water in the reactor must be very pure, the conductivity of the water should be monitored. A water purity monitor has been designed and used in the system. Two conductivity electrodes were used to measure the water in the reactor and in the pool. At the electrodes an alternate ±6V voltage is supplied with the analog switches. The signals will be amplified, sampled and send into ADC channel 7 and 8.

The channel 9 is used to collect the radiation signal. A gamma radiation monitor is fixed on the top of the reactor, by which the gamma radiation will be measured and the signal amplified 100 times will be send into the ADC interface of the computer.

All the operating data of the reactor will be chown on the screen of the monitor of the IBM PC-XT on time clearly, as shown in Fig.5.

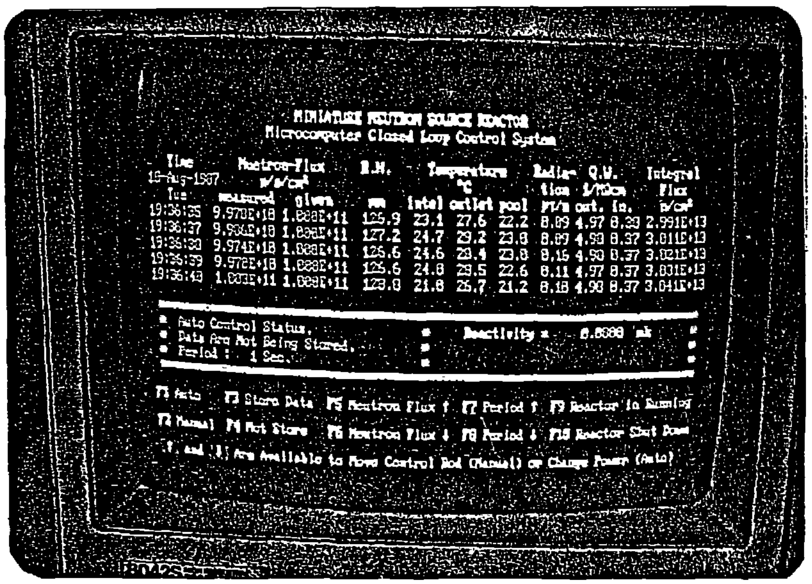

Fig.5 The operating data shown on the screen

The control feedback signal is output from the DAC channel 0 of the AD-DA board. and it is converted into rise (or drop) rod signal to trigger a SCR element turn on. The motor will turn in right (or opposite) direction and the control rod will move up (or down). The conversion circuit is shown in Fig.6. And the Fig.7 is the picture of the control box.

If the control system were out of order, the warning information, including all the operating data, should be printed out from a printer.

After the reactor shuts down, a reactor operating journal will be printed out too at the printer. The reactor operating journal is shown in Fig.8.

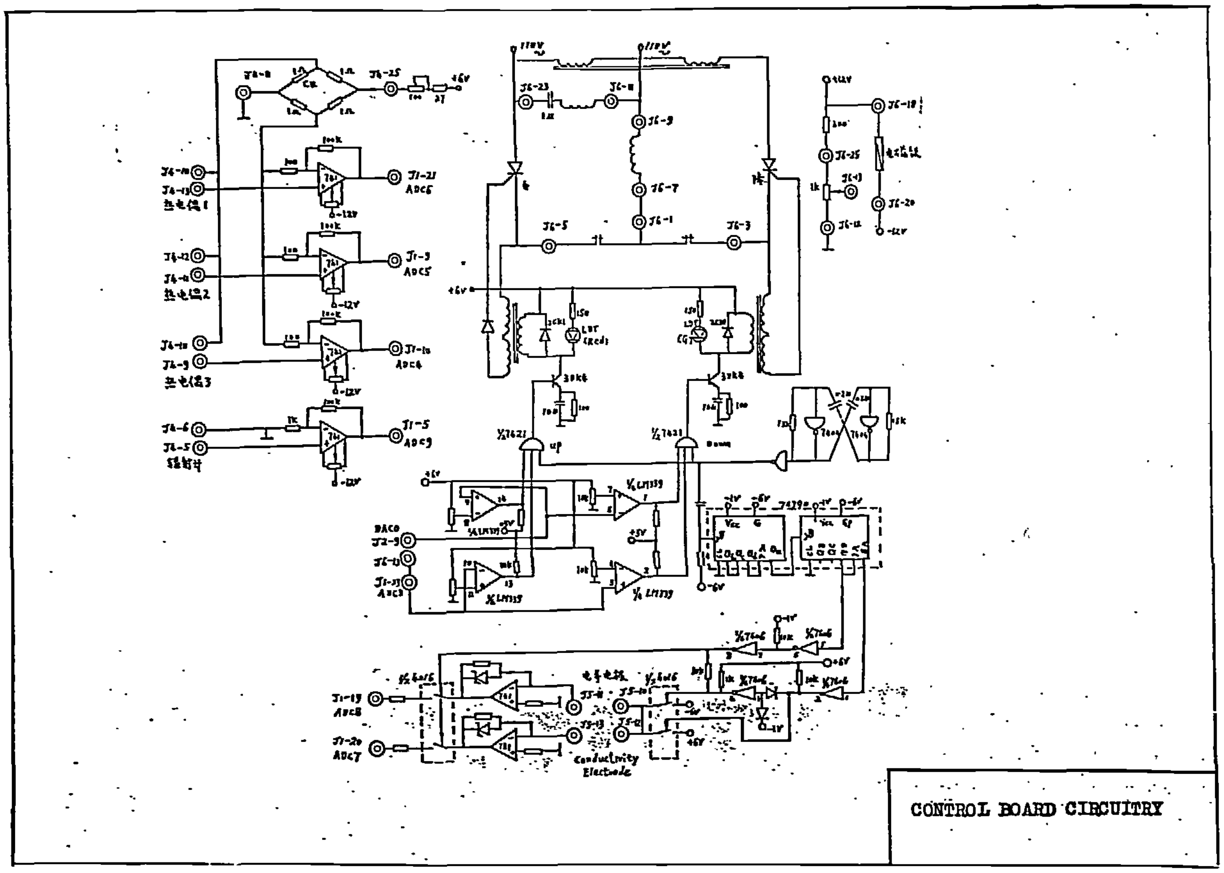

Fig.6 The control circuit

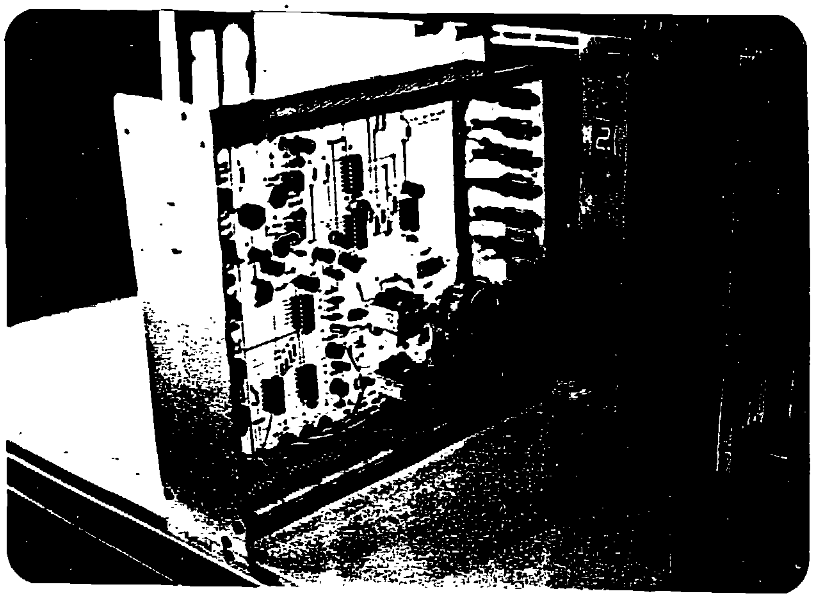

Fig.7 The control box

MNSR OPERATING JOURNAL

Microcomputer Closed Loop Control System

1987-08-22

Time	Nuetron-Flux n/s/cm²		R.H.	Temperature °C			Radia-tion	Q.W. 1/MΩcm		Integral Flux
	measured	given	mm	intel	outlet	pool	μT/s	out.	in.	n/cm²
10:38:18	2.093E+08	1.000E+11	0.3	24.2	24.6	23.0	0.00	3.95	0.32	1.54E+09
10:41:15	1.001E+12	1.000E+12	200.0	23.8	24.3	23.3	0.80	4.45	0.28	1.73E+13
11:08:18	9.967E+11	1.000E+12	163.2	27.8	43.1	23.0	1.23	5.77	0.74	1.64E+15
11:38:18	1.000E+12	1.000E+12	172.3	31.8	46.9	23.4	1.14	5.07	0.79	3.43E+15
12:08:18	9.945E+11	1.000E+12	177.1	33.4	48.3	23.8	1.23	4.78	0.79	5.23E+15
12:38:18	1.003E+12	1.000E+12	179.8	34.6	48.0	23.5	1.31	4.39	0.79	7.02E+15
13:08:18	9.980E+11	1.000E+12	182.1	33.9	50.0	24.1	1.27	4.42	0.88	8.82E+15
13:38:18	9.963E+11	1.000E+12	184.6	34.7	48.1	24.2	1.35	4.50	0.89	1.06E+16
14:08:13	9.977E+10	1.000E+12	0.5	35.2	41.1	24.0	0.35	4.51	1.04	1.23E+16

Operation Time: 3.5000hours Sum Total: 19.4720hours
Burn-up: 1.235E+16n/cm² 8.737E+01kw.h
Sum Total: 4.530E+16n/cm² 3.206E+02kw.h from 1987-08-18 to Today

_No0017____

Fig.8 The reactor oprtating journal

SOFTWARE DESIGN

The software plaies a very important part in entire reactor control system. The control precision, the response speed, the long term stabitity and the safety precautions, all of them depend on the software design. In the system the control software must realize following purposes:

1. Collect and display all the reactor operating data on time.
2. Compare the operating data with the preset value, then decide if need to adjust and count the adjustment amount.
3. Compare the operating data with the preset limited value. If any one of them is beyond the limited value, the warning will be send at once.
4. Check the execution of command. If the control rod position does not change after a command or it moved to contradict the command, a warning will be sent at once, because that means the executive componenet has been out of order.
5. Record the operating parameters and calculate the integral neutron flux and the burn_up of the reactor. after the reactor shuts down, today's operating journal will be printed out.

A rational adjustment period is very important to the computer closed loop control system of the MNSR. If the period wewe too short, the adjustment would be too frequent and harmful the motor. If the period were too long, the respond speed of the control system would be slow and even maybe would lead to the system unstable. Based on the experiments, we choosed the adjustment period of 0.1 to 0.2 seconds.

Because the reactor is designed to have self-limiting power excursion characteristics, and the tatal reactivity is less than 5mk, we need not consider to limit the increasing speed of the reactor power. We only need to keep the neutron flux as a constant to meet the needs of NAA. The on-off type scheme is available in design of the reactor control system, which is very simple and can meet the needs of NAA. The on-off type scheme means we set a operating power level and give a certain band-width near the level. When the real power is just in the band-width, the system do not make any adjustment. If the real power gose out of the band_width, the system will be triggered and lead to the control rod moving to keep the real power into the band_width.

In fact, two kinds of band-widths have been designed in the system. The power level has been devided into 5 parts, as shown in Fig.9.

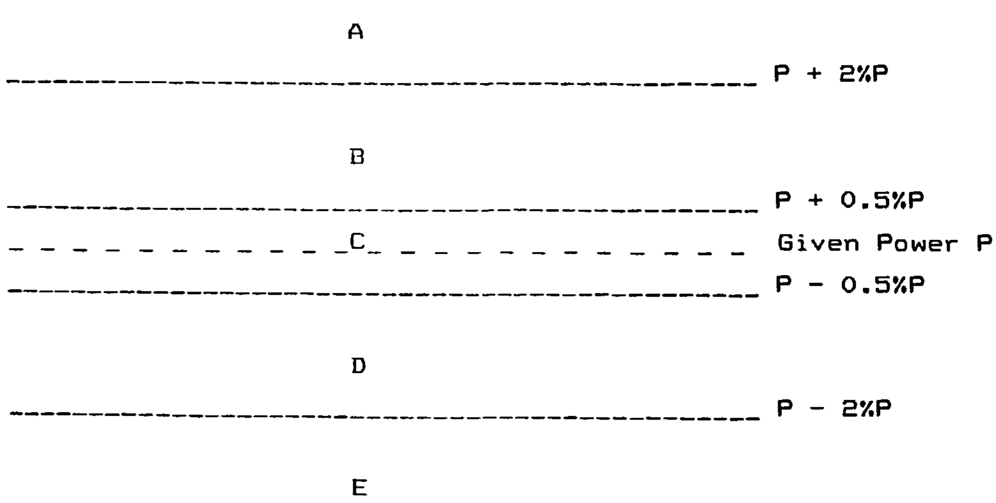

Fig.9 The control Band-width of the reactor power

When the power goes into the area A or E, the rapid adjustment will be performed. That is to say the SCR will be triggered for whole (0.2s) period and the control rod will move abour 3mm in a period. With this way the system can get a fast response characteritic to correct a large deviation of power.

When the power goes into the area B or D, the weak adjustment will be performed. In this case the SCR will be triggered for ~¼ period time and the control rod will only move a very short distance to lead the power into area C. In the area C the system will not do any adjustment, the power will be keep in the given value.

By means of above measures the system has been working stablely and the adjustment is not frequent, which is useful to decrease the mechanical wear and tear and save electricity.

In each period the computer checks the keyboard one time. If there is a function key input on the keyboard, the specific function should be performed. The function keys are designed as following:

F1 --- Set auto control status.

F2 --- Set manual control status.

F3 --- Set data store status.

F4 --- Stop data store.

F5 --- Increase the given value of neutron flux.

F6 --- Decrease the given value of neutron flux.

F7 --- Increase the showing and storing period.

F8 --- Decrease the showing and storing period.

F9 --- Cancel the reactor shut down programme.

F10 --- Entry to reactor shut down programme.

↑ --- Move the control rod up in manual control status.
Increase the given value of neutron flux in auto control status.

↓ --- Move the control rod down in manual control status.
Decrease the given value of neutron flux in auto control status.

Using these function keys the reactor may be operated easily. Besides neutron flux, control rod position, temperature, radiation, conductivity and integral neutron flux, the reactivity of the reactor is also calculated and displaied on the screen on time. To calculate the reactivity from neutron flux the reactor kinetic equation [2,3,4] has been used.

An additional program DSP has been developed to display the operating data stored in disk files. Of course the diagram of curves may be copied on the printer. An example was shown in Fig.10. With the program DSP the operating data also may be printed out on the printer line by line.

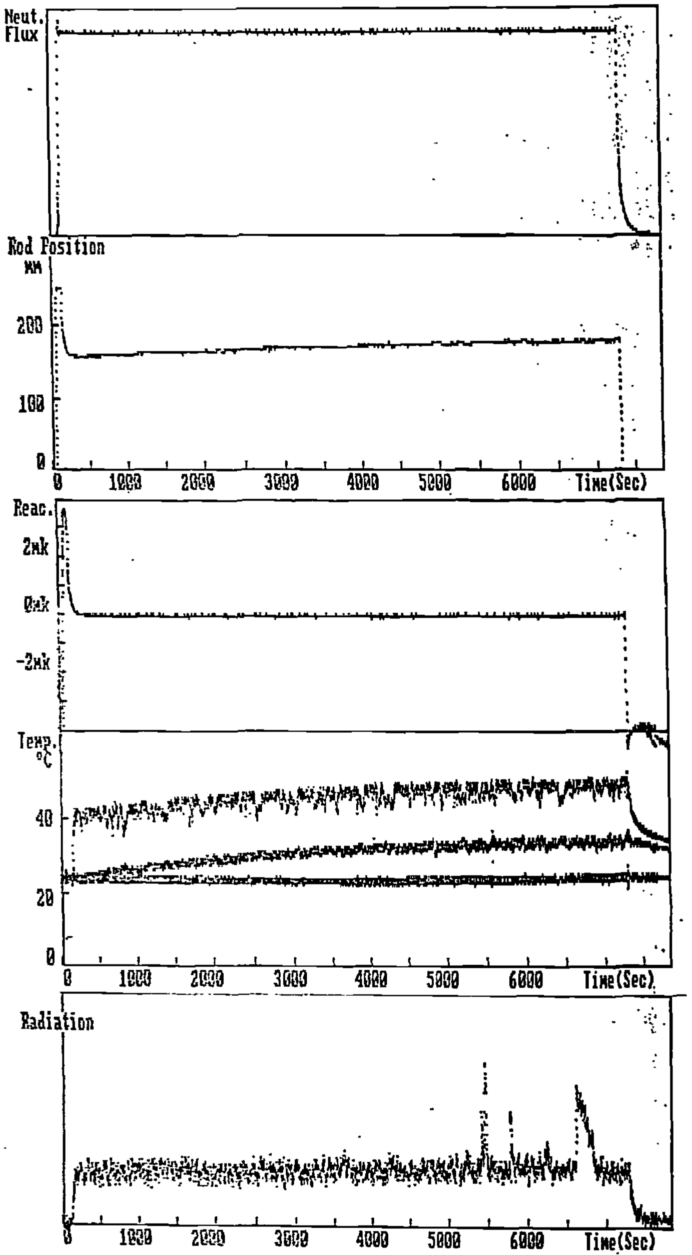

Fig.10 The operating record of the reactor

EXPERIMENTS AND RESULTS

After experiments and improvements the PDP 11/34 computer control system has been going operation since March 1985 in the MNSR. Now the new microcomputer control system has replaced the old one. All the operating results showed the system was successful. And the new one has some more useful functions, so it is more convenient to users. An operating record of the MNSR with the computer control system has been shown in Fig.10. After the reactor was started up, the neutron flux had got to the given value in 5 minutes and keep stable. In two hours the measured value of the variation of the neutron flux (averaged in 5 seconds) was ±0.169%, the minimum of them was 99.84% of the given value and the maximum was 100.29%.

We have carried out following experiments to test the response speed of the control system. A man-made jam was applied to the reactor by means of a piece of Cd metal, which was equivalent of 1mk additional reactivity. When the piece of Cd got into (or got out) the reactor, the system responsed immediatery. As the moving speed of the control rod was limited and the the jam was too large, the power waved 10-13% and got to stable again in 5 seconds. The whole record of the experiment is shown in Fig.11. Of course the reactivity of normal NAA samples is much smaller, so we can not find any power waves during samples got in (or out) just as shown in Fig.10.

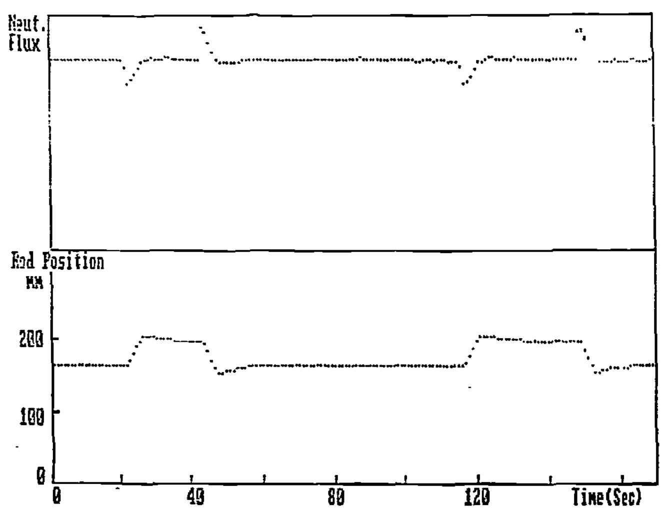

Fig.11 The response characteristic of the control system

CONCLUSION

Since March 1985, the computer control systems have been going into operation and working well. It has been proved that both the two computer closed loop control systems have following advantages.

A. Convenient to NAA. The control system can keep the neutron flux level very stable in the range from 1.0E+8 to 1.2E+12 n/s.cm² and the data of the neutron flux can be used directly for NAA as a important parameter. So the control system is much convenient to NAA.

B. All the operating data of the MNSR are shown on the screen clearly. In case any of the operating data went beyond the limit or the executive body was out of order, the audible alarm would be broadcasted, which made the reactor more reliable, convenient and safe.

C. Because of using the computer control system is very easy, the special operator is unnecessary for the MNSR. Every NAA technician can operate the MNSR by means of the computer control system as simple as using a common equipment. Controlling, data recording, making the operating journal and calculating burn-up and operating time, all of them are performed by the computer automaticly, which can save people much trouble and increase efficience.

D. The system has not only control function, but it is also a perfact data acquisition system and a reactivity monitor. This functions should be very useful to researcher on reactor. Using the system we also may make some experiments for developing some new software to control other reactors.

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