2. SYSTEM MODIFICATIONS

2.1 Shielding

In keeping with the aim of minimizing radiation exposures as defined in Reference 2.1 the shielding of the reactor has been augmented. The goal of this shielding modification is to achieve radiation levels at 500 KW equal to or less than the levels experienced during prior operation at 100 KW. The analytic basis for the shield modifications is given in Chapter 5.

When the reactor power was increased from 10 KW to 100 KW the following shielding additions were made:

1. Lead shielding was installed between the graphite reflector and the concrete shield.
2. Concrete blocks (4 inches x 8 inches x 12 inches) were stacked outside the existing shield structure.

To allow for reactor operation at 500 KW, most of the stacked concrete blocks were replaced with sixteen new large concrete shield blocks. These blocks were located around the sides of the permanent shield as shown in Fig. 1.1. In addition new concrete shield blocks were fabricated for the top of the reactor as shown in Fig. 2.1.

The reduction in radiation levels achieved with the added shielding are discussed in Chapter 5. From these results it can be seen that the radiation levels are decreased substantially. Thus operation at 500 KW with the modified shielding should result in less radiation exposure than was experienced at 100 KW with the original shield structure.

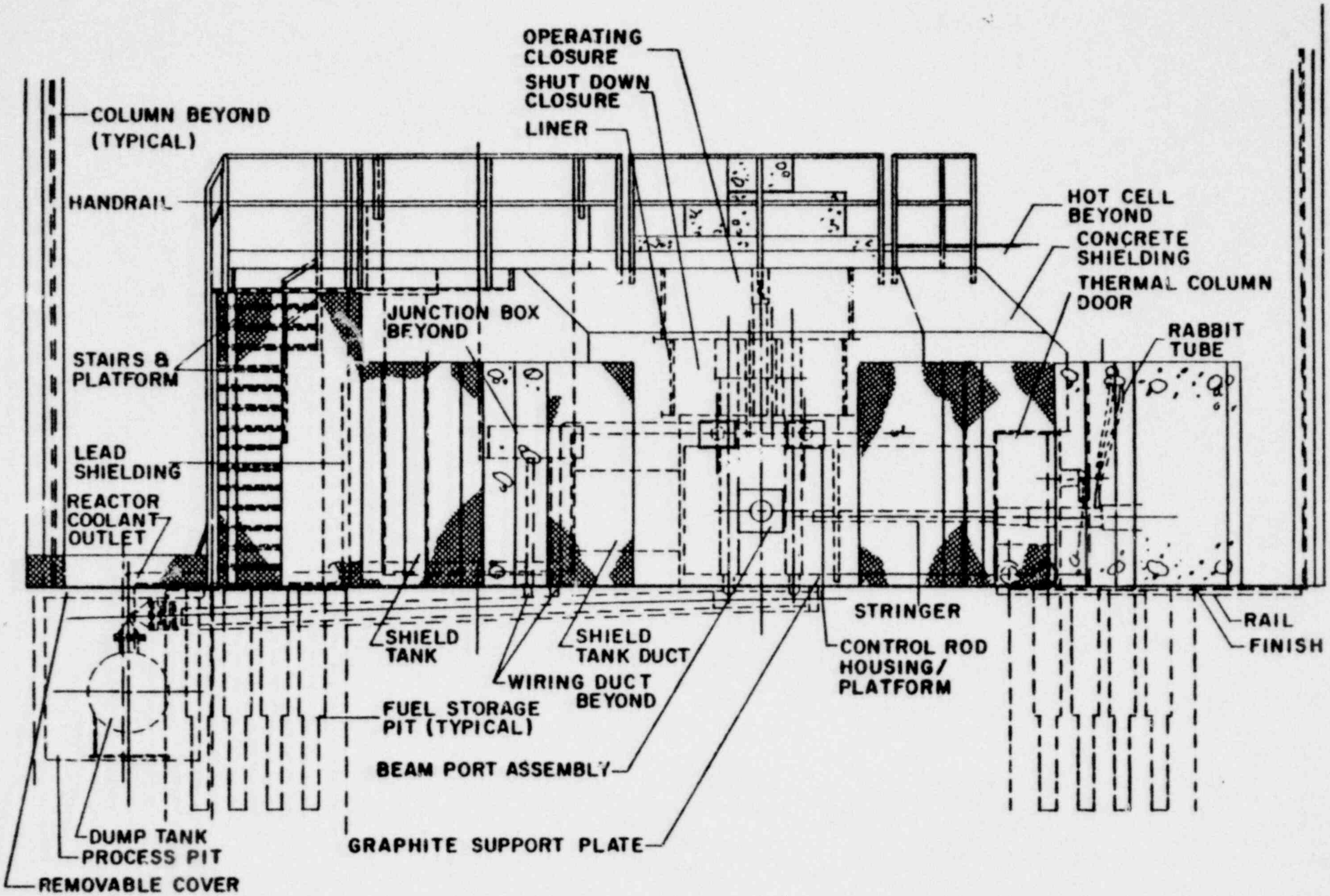

OPERATING
CLOSURE
SHUT DOWN
CLOSURE
LINER
COLUMN BEYOND
(TYPICAL)
HANDRAIL
HOT CELL
BEYOND
CONCRETE
SHIELDING
THERMAL COLUMN
DOOR
JUNCTION BOX
BEYOND
RABBIT
TUBE
STAIRS &
PLATFORM
LEAD
SHIELDING
REACTOR
COOLANT
OUTLET
STRINGER
RAIL
FINISH
SHIELD
TANK
SHIELD
TANK DUCT
CONTROL ROD
HOUSING/
PLATFORM
WIRING DUCT
BEYOND
FUEL STORAGE
PIT (TYPICAL)
BEAM PORT ASSEMBLY
DUMP TANK
PROCESS PIT
GRAPHITE SUPPORT PLATE
REMOVABLE COVER

Fig. 2.1

2.2 Primary Cooling System

A schematic diagram of the existing primary and secondary cooling system is shown in Figure 2.2. In order to upgrade the maximum operating power to 500 KW, we have made preliminary analyses of the required flow rates through the core. (See Chapter 3) The alterations that we propose to make are described below and schematic diagrams of the new primary and secondary system are shown in Figure 2.3.

2.2.1 Primary Cooling Pump

The specifications for the new primary cooling pump are summarized in Table 2.2

Table 2.2

Specifications for Primary Cooling Pump

Manufacturer	Crane Co., Chempump Division
Model No.	GC-1 ½K-152H-LS
Flow Rate	100 GPM with 40 ft. head
Impeller Diameter	4 1/8"
Volts	230/450, 3 phase A.C. 60HZ, 3450 RPM
Amps.	7.7/3.8
Full Load kw	2.5

2.2.2 Primary Cooling Piping

In order to accomodate the increased flow rate, certain portions of the existing piping must be replaced with larger size piping. Specifications for the new piping are: aluminum pipe, Type 6061-T6, Schedule 80; 2.875 in. O.D., 2.323 in. I.D.

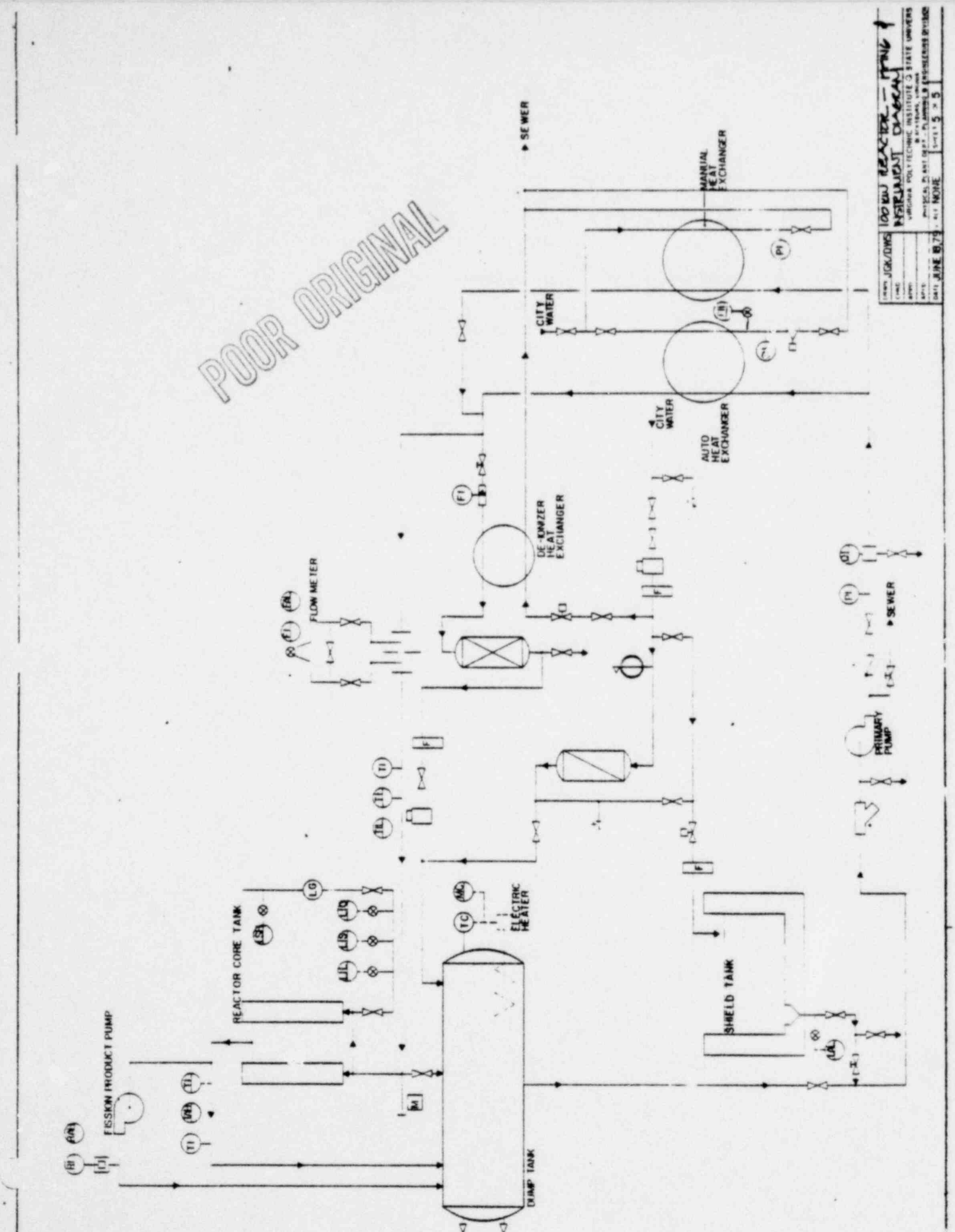
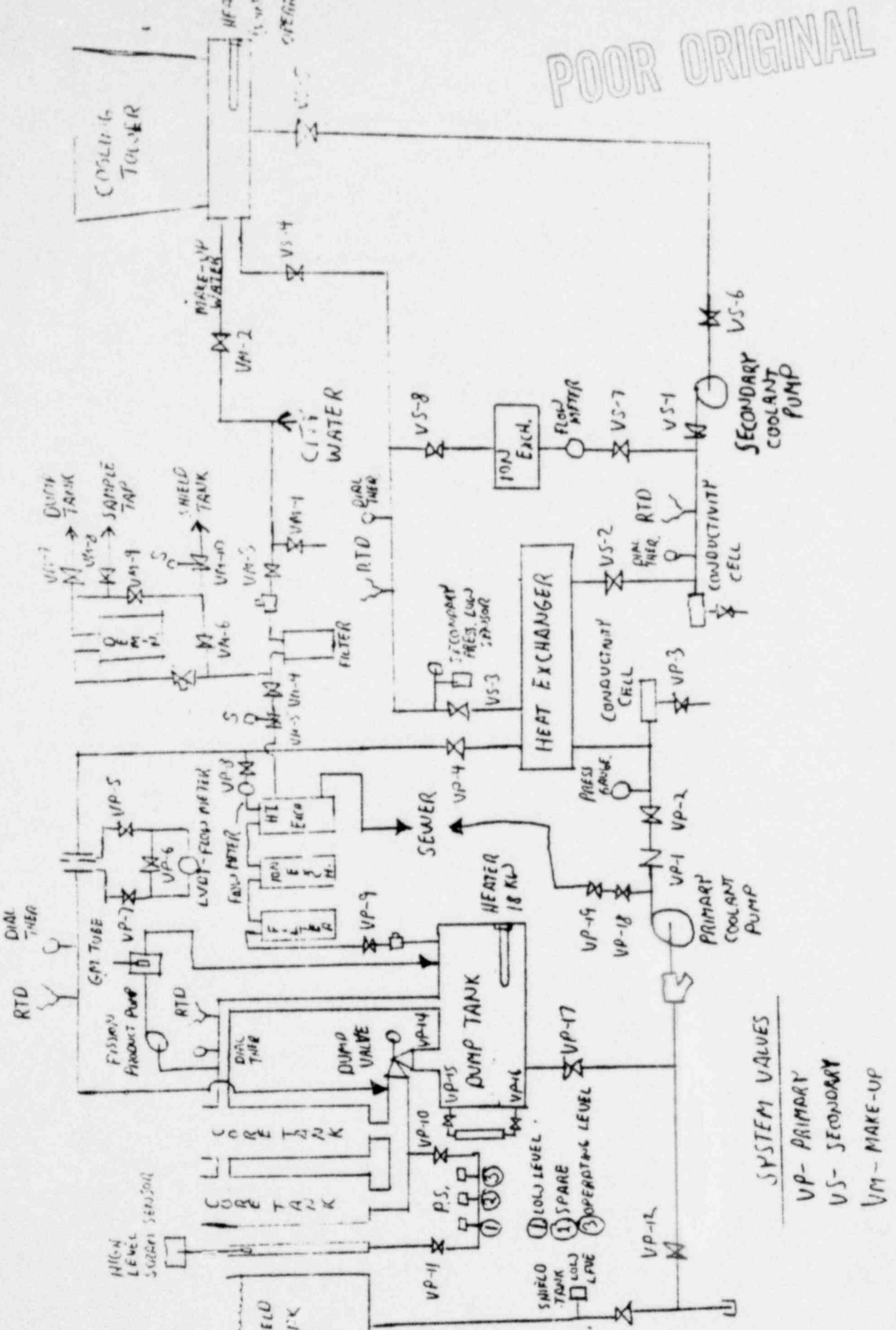


Fig. 2.2 Existing Primary and Secondary Cooling System



PROPOSED COOLANT SYSTEM

Fig. 2.3

2.2.3 Heat Exchanger

The two existing heat exchangers will be removed and a new heat exchanger will be installed in the NE corner of the reactor cell. The location of the new heat exchanger is shown in Figure 1.1. The specifications for the new unit are given in Table 2.3, and a drawing of the unit is shown in Fig. 2.4.

Table 2.3

Specifications for New Heat Exchanger

Manufacturer: Richmond Engr. Co. Inc.

D.P. : 30 PSI

HD. THK. 1 5/8"

SH. THK. 1/4"

DIA. 20 1/2"

LG. 214 5/8"

Temp. 150° F

HD. Rad. Flat

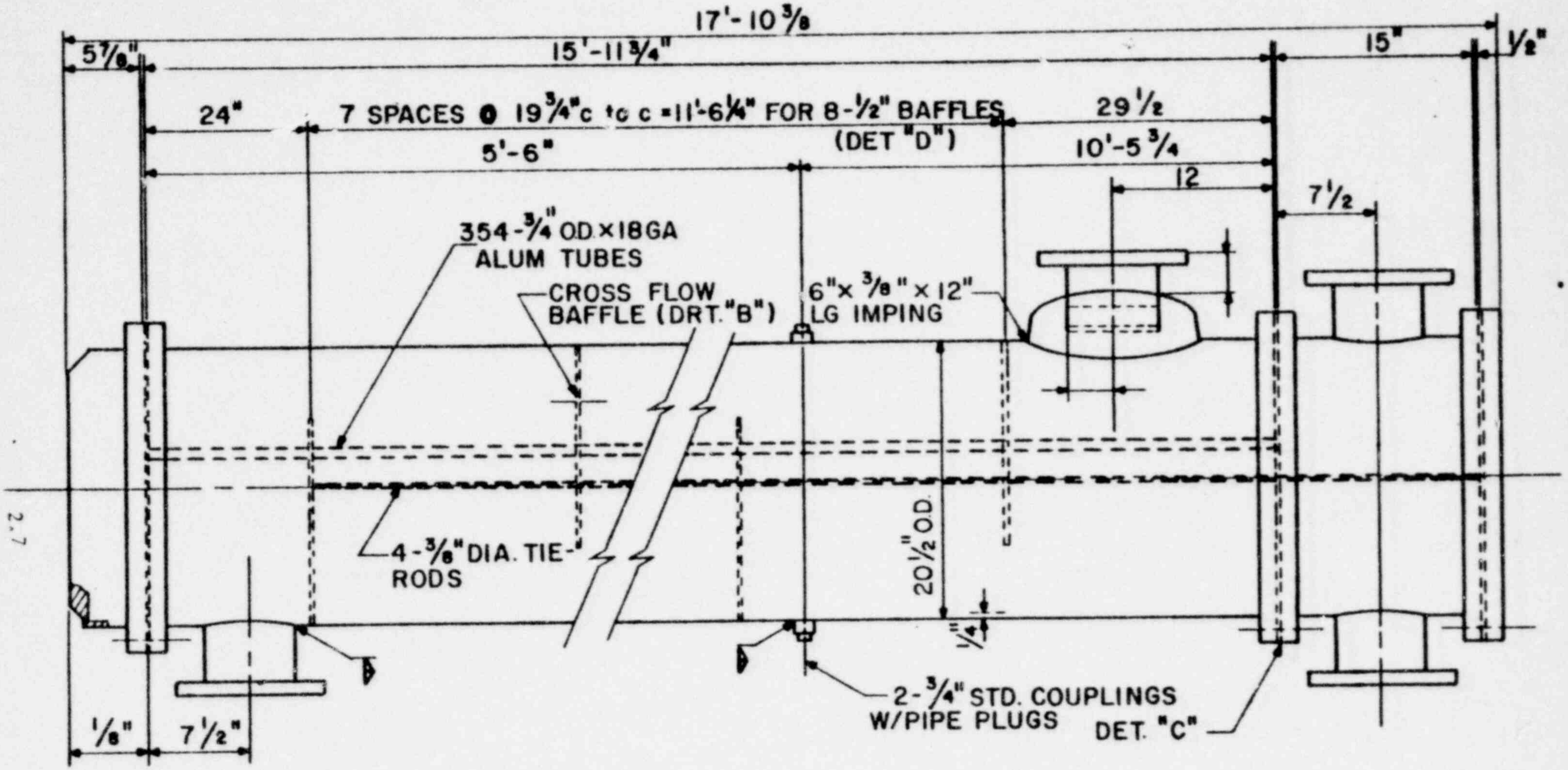

17'-10 3/8
5 7/8"
15'-11 3/4"
15"
1/2"
24"
7 SPACES @ 19 3/4"c to c = 11'-6 1/4" FOR 8-1/2" BAFFLES
(DET "D")
29 1/2
5'-6"
10'-5 3/4
12
7 1/2
354-3/4" O.D. x 18GA
ALUM TUBES
CROSS FLOW
BAFFLE (DRT. "B")
6" x 3/8" x 12"
LG IMPING
4-3/8" DIA. TIE-
RODS
20 1/2" O.D.
1/4"
2-3/4" STD. COUPLINGS
W/PIPE PLUGS
DET. "C"
1/8"
7 1/2"

Fig. 2.4

2.3 Secondary Cooling System

The existing heat exchangers use the building water supply on the secondary side. With the modified system, a closed secondary loop with a cooling tower will be installed. (See Fig. 2.3)

2.3.1 Cooling Tower

The specifications for the cooling tower are shown in Table 2.4.

Table 2.4

Specifications for the Cooling Tower

Manufacturer: (to be bid)	Fluid Circulation: (pH 6.0) Potable Water
Model No. : (to be bid)	Gravity : 1.0
Flow Rate : 375,000 lb/hr.	Specific heat : 1.0 Btu/lbm
T-in°F : 100°F	Plenum reserve (min.gal.) 1600
T-out °F : 95°F	Heat exchanged : 1,875,000 Btu/hr.
	Operating pressure: Atmospheric

The cooling tower will be located in the roof of Robeson Hall as shown in Figures 2.5, 2.6, and 2.7.

2.3.2 Secondary Cooling Pump

The specifications for the secondary cooling pump are given in Table 2.6.

Table 2.5

Specifications for Secondary Cooling Pump

Manufacturer: (to be bid)

Model No. :

Flow Rate :

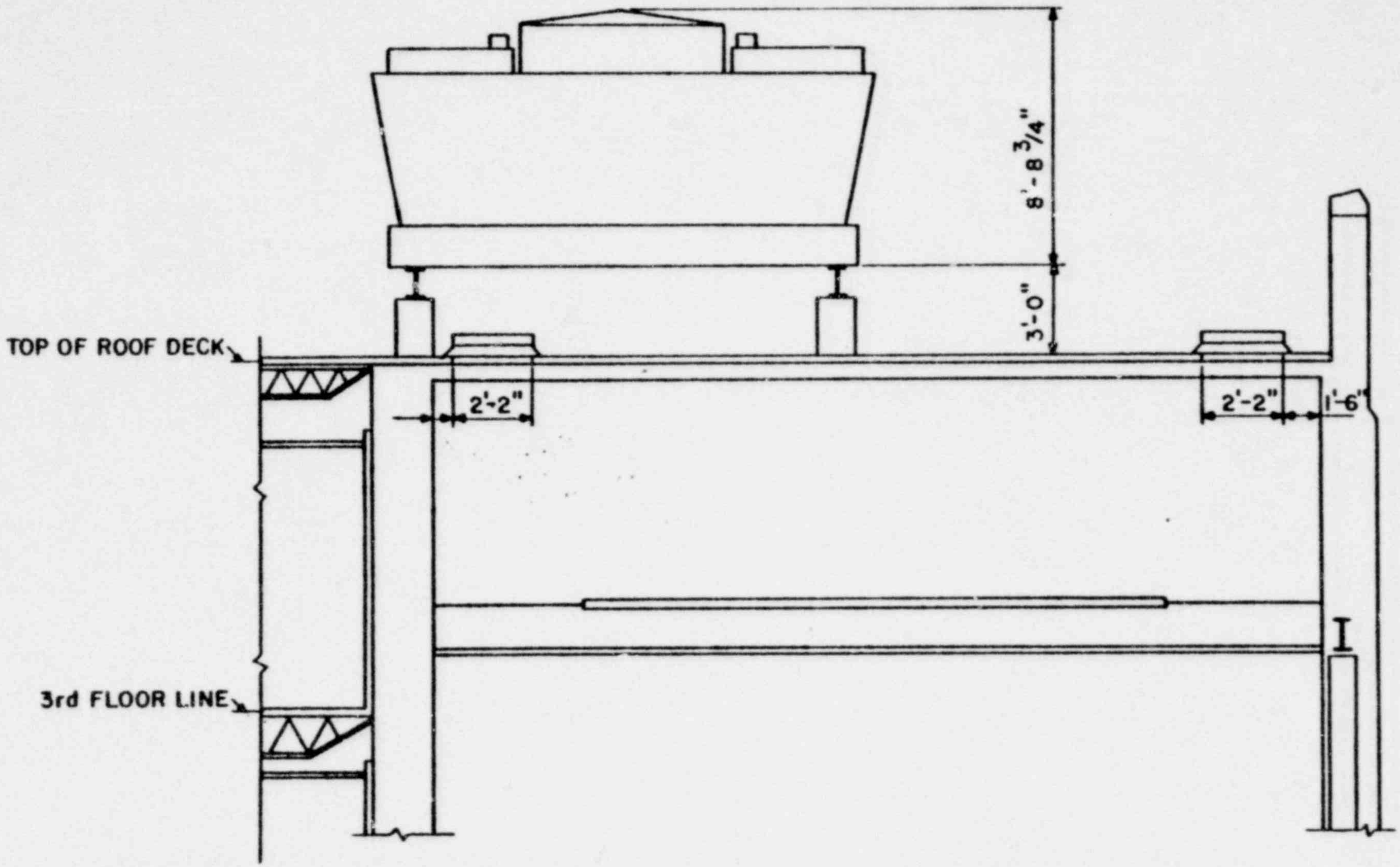


Fig. 2.5 Cooling Tower (Elevation)

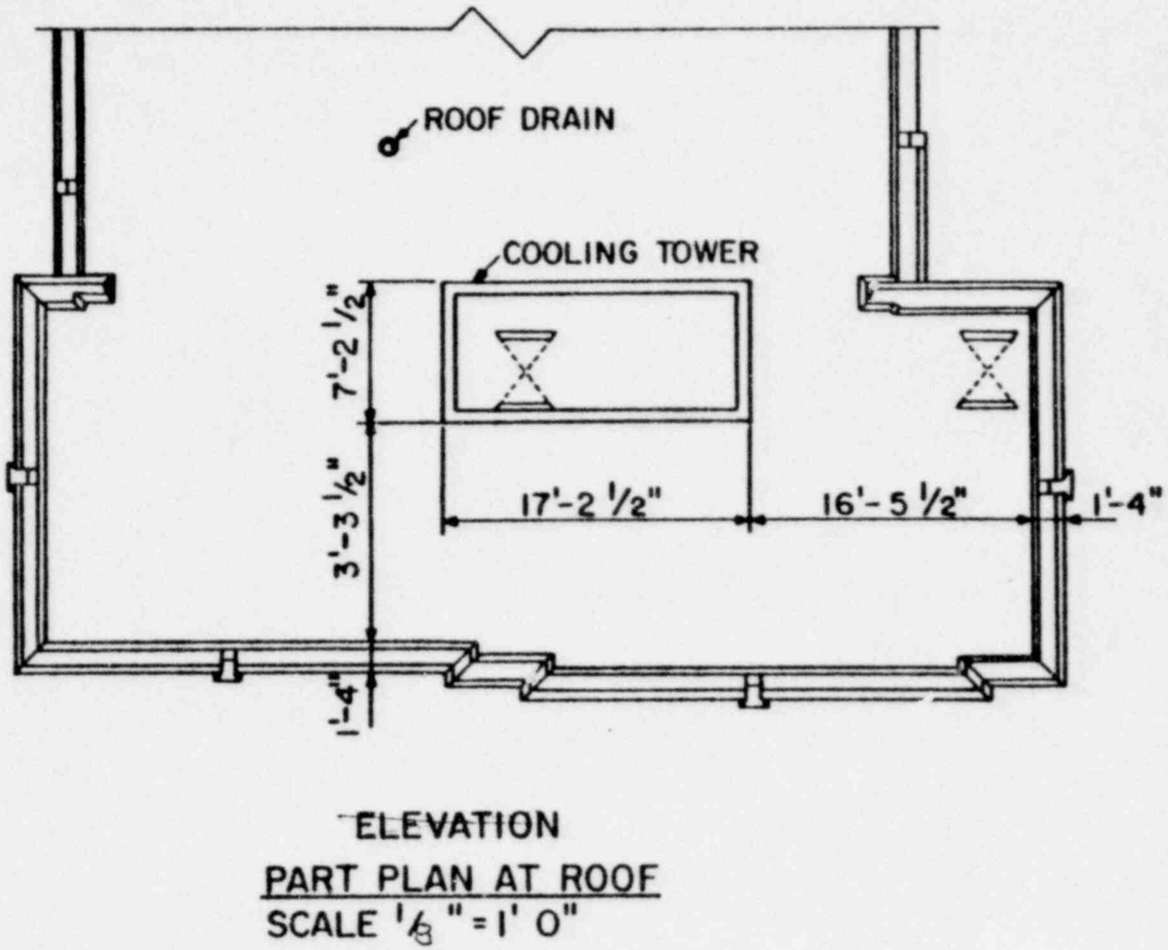


Fig. 2.6 Cooling Tower Location (Plan)

Fig. 2.6 Cooling Tower Location (Plan)

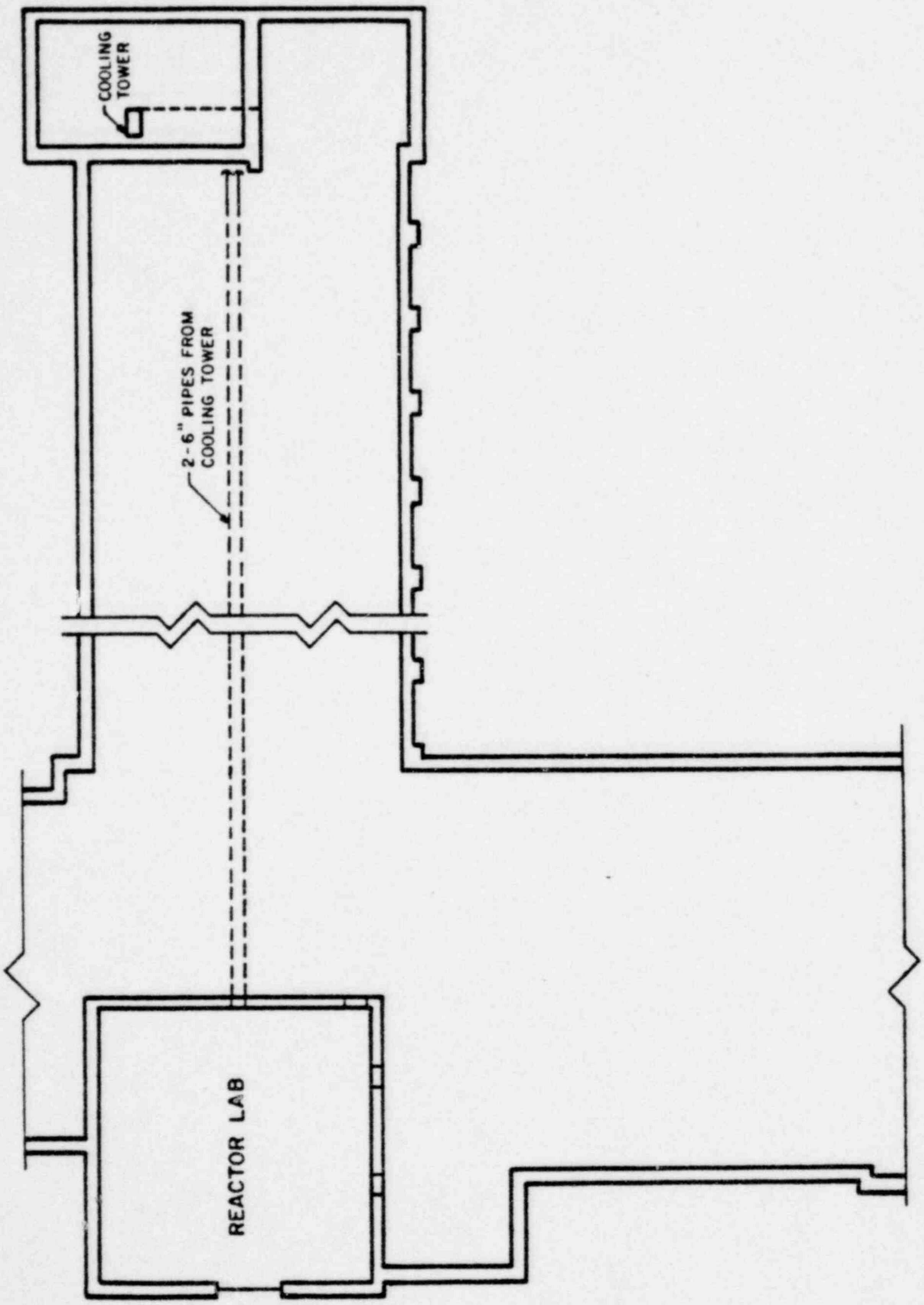


Fig. 2.7 Cooling Tower and Piping Run

Fig. 2.7 Cooling Tower and Piping Run

2.4 Fuel Element Configuration

The fuel elements used for 100 KW operation comprise an assembly of 12 fuel plates as shown in Fig. 2.8. The same configuration will be used at 500 KW operation.

2.5 Instrumentation

2.5.1 Air Particulate Fissi Product Monitor (APFPM)

In the original reactor instrumentation, no provision was made for measuring any unp. ..d release of airborne fission products. Currently, such instrumentation is needed to comply with both federal [2.2] and state [2.3] requirements. Accordingly a new monitor system was installed. A block diagram of the system is shown in Figure 2.9.

An air sample is drawn from the reactor exhaust stack and passed through a moving filter tape. The activity on the filter tape is measured with a NaI (Tl) scintillation crystal. Under normal operating conditions two short-lived fission products are detected: Ba-139 and Y-91m with gamma energies of 166 and 556 keV, respectively. These fission products are produced from traces of U-235 which are present as a contaminant on the reactor fuel plates. A plot of the gamma spectrum from the air particulates is shown in Fig. 2.10; these data were obtained with the NaI (Tl) detector while the reactor operated at 100 KW. Pulses from the scintillation detector are amplified and then routed to a single-channel analyzer (SCA), ratemeter, strip chart recorder and alarm circuit. The SCA window is calibrated to accept those pulses associated with the photopeak of Ba-139. In the event of an abnormal release of fission products, the system output records the magnitude of the release.

Periodic calibration of the system with standard gamma sources allows an evaluation of any release of fission products from the exhaust stack.

After the gamma sensitivity of the detector is calibrated, the operation of the entire system will be tested by irradiating a small sample of barium in a known flux for a pre-determined time. The irradiated sample will then be placed on the moving tape and the response of the APFPM system will be measured.

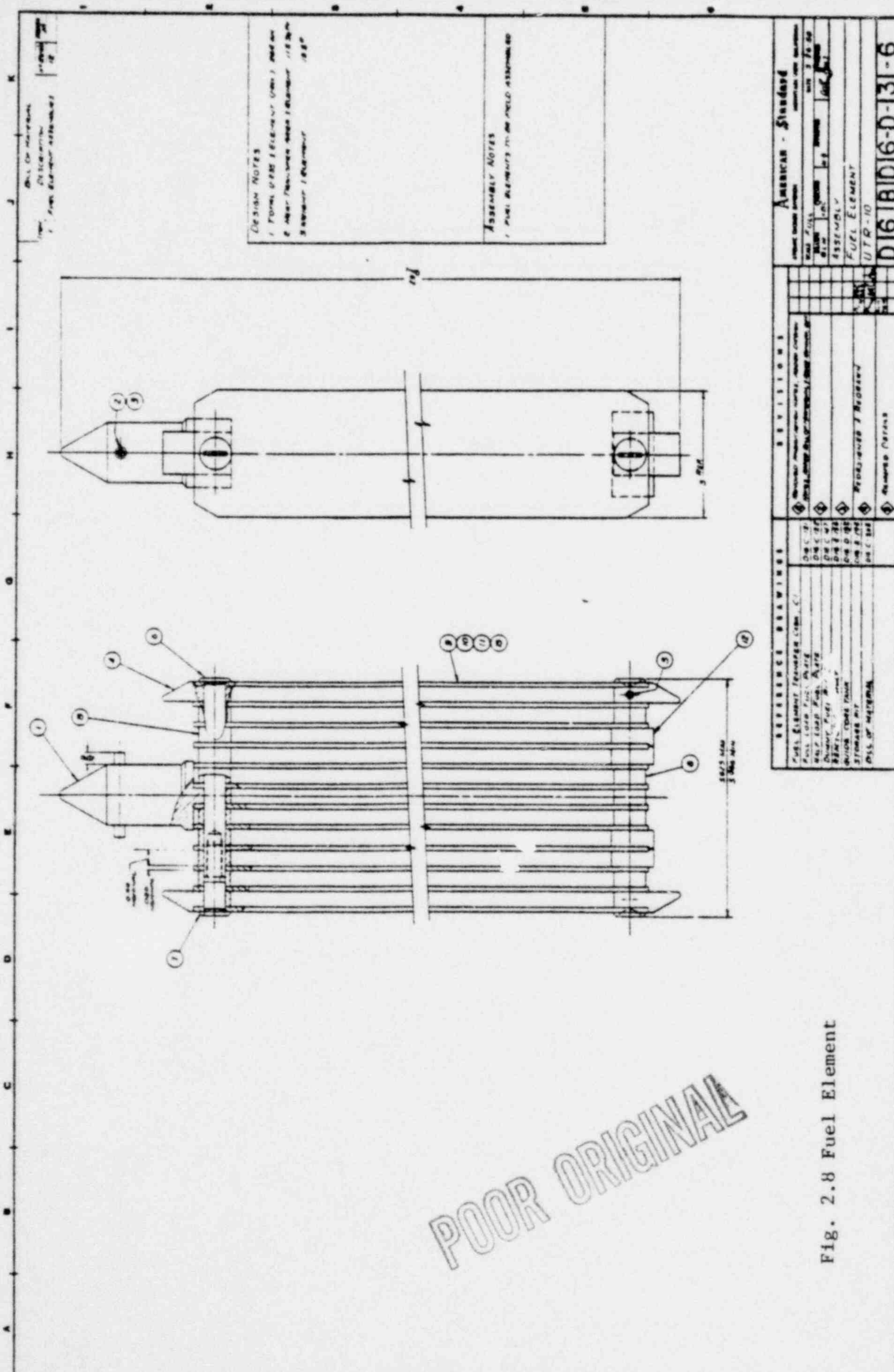
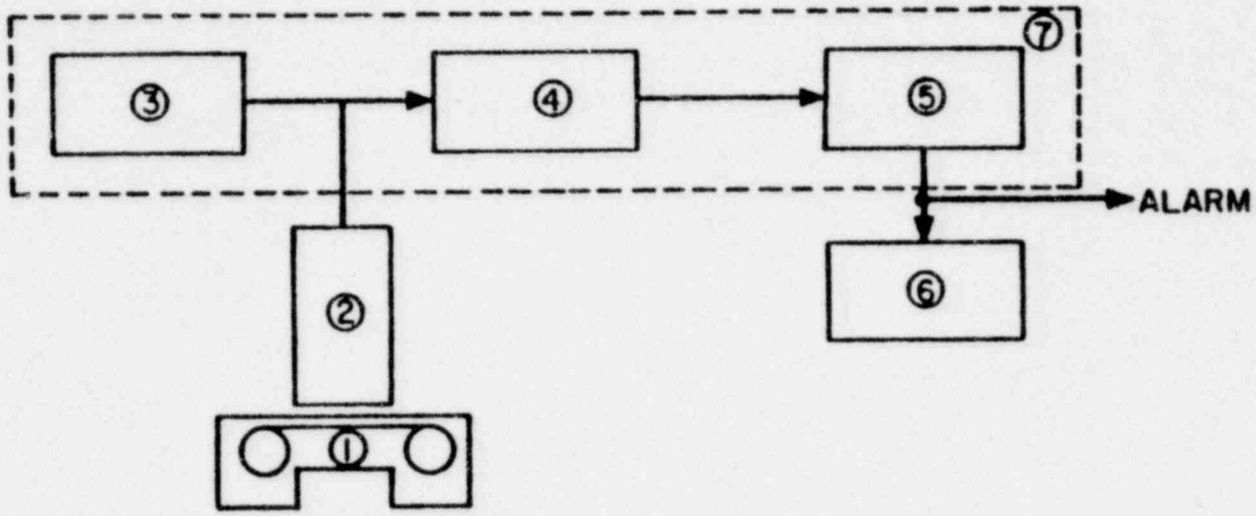


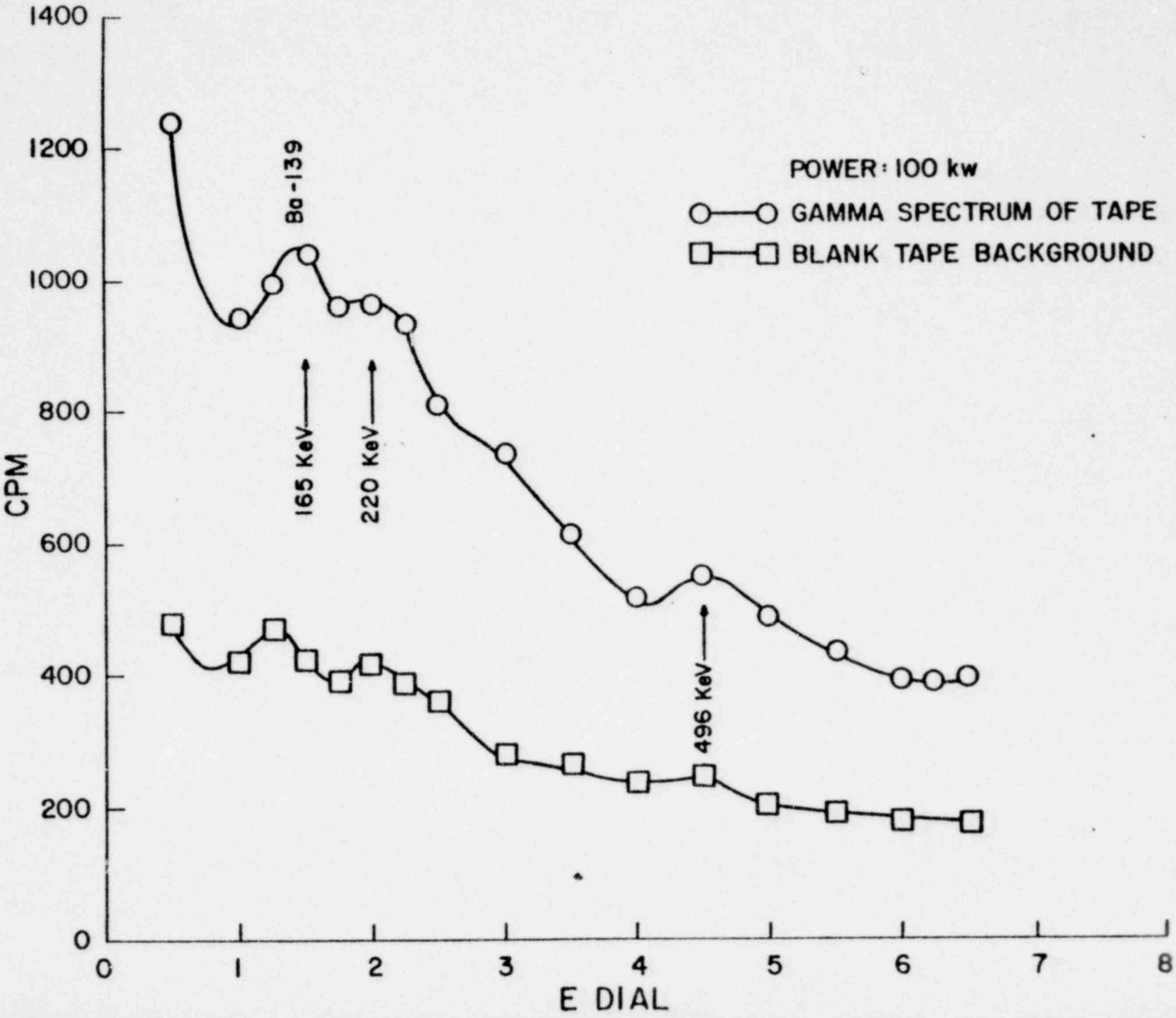
Fig. 2.8 Fuel Element



1. FILTER PAPER DRIVE
2. NaI (Tl) SCINTILLATOR, PHOTOMULTIPLIER AND PREAMPLIFIER (Harshaw Model 858 Tennelec Model TC155A)
3. HIGH VOLTAGE SUPPLY (Tennelec Model TC 951)
4. LINEAR AMPLIFIER AND SINGLE CHANNEL ANALYZER (Tennelec Model TC216)
5. RATEMETER, AUTORANGING (Tennelec Model TC595)
6. STRIP CHART RECORDER (Rustrak Model 288)
7. NIM BIN AND POWER SUPPLY (Tennelec Model TB-3/TC911)

Fig. 2.9 Schematic of the APFP Monitor

Fig. 2.15 APFP Monitor Gamma Spectrum



2.5.2 Neutron Detector Location

The flux monitoring system was originally designed to have the detectors placed directly on top of the graphite blocks which surround the core tanks. Experience with the problems which have been encountered in the instrumentation system following the increase in reactor power from 10 KW to 100 KW led to a program of shifting the flux detectors to positions farther removed from the fueled regions of the reactor. At the present time the compensated ion chamber which supplies the signal for the intermediate range instrumentation is located in the shield tank while an uncompensated ion chamber and fission chamber are located in the thermal column.

The principal concern which led to the shifts in detector locations was the relatively large gamma doses which were received by reactor personnel who replaced radiation-embrittled cables and cable connectors. An additional reason is the ease of accessibility in the new locations. To obtain access to the detectors when they were located on top of the reactor core required complete removal of the fuel which typically requires a week of downtime. In the new detector locations, access requires only a few minutes.

The new detector locations are vertical tubes inserted on the core side of the shield tank and experimental ports in the thermal column; these locations lend themselves well to the proposed increase in reactor power. Since the neutron flux at any point in the reactor is directly proportional to reactor power, the detectors were shifted in their positions to allow them to "see" the same flux at 500 KW as they do now at 100 KW while providing the same degree of accuracy. Also, since the flux levels detected by any given monitor will be the same at 500 KW as they are now, the power instrumentation need not be altered for the power increase.

2.5.3 Core Flow Rate Monitor

The existing monitor consists of a flow orifice that transmits a pneumatic differential pressure to a diaphram connected to a linear variable differential transmitter (LVDT) which converts the differential pressure to an electrical signal. The output of the LVDT is sent to a Swartwout Autronic flow monitor mounted on the reactor console. It will be replaced with a monitor with a range of 0-125 gpm.

2.5.4 Reactimeter

Measurements of reactivity, ρ, are frequently made during reactor operations, e.g. in calibrating control rods. The conventional method of determining ρ is to measure a positive asymptotic period, τ, and then to utilize the in-hour equation:

$$\rho = \frac{\ell^*}{\tau k_e} + \sum_{i=1}^{6} \frac{\beta i}{1 + \lambda_i \tau} \qquad (2.1)$$

where: ℓ^* is the effective neutron lifetime

k_e is the effective multiplication constant

β_i is the fractional abundance of the i^{th} delayed neutron group

and λ_i is the decay constant of the i^{th} delayed neutron group

A micro-processor based reactimeter has been designed, built and tested for performing reactivity measurements [2.5], and the instrument is now on-line. Input to the reactimeter is taken from the same compensated ion chamber that drives the Keithley picoammeter. The accuracy of the unit is approximately $\pm$ 1 pcm or $\pm 1 \times 10^{-5}$ $\Delta K/K$. A block diagram of the reactimeter is shown in Fig. 2.11.

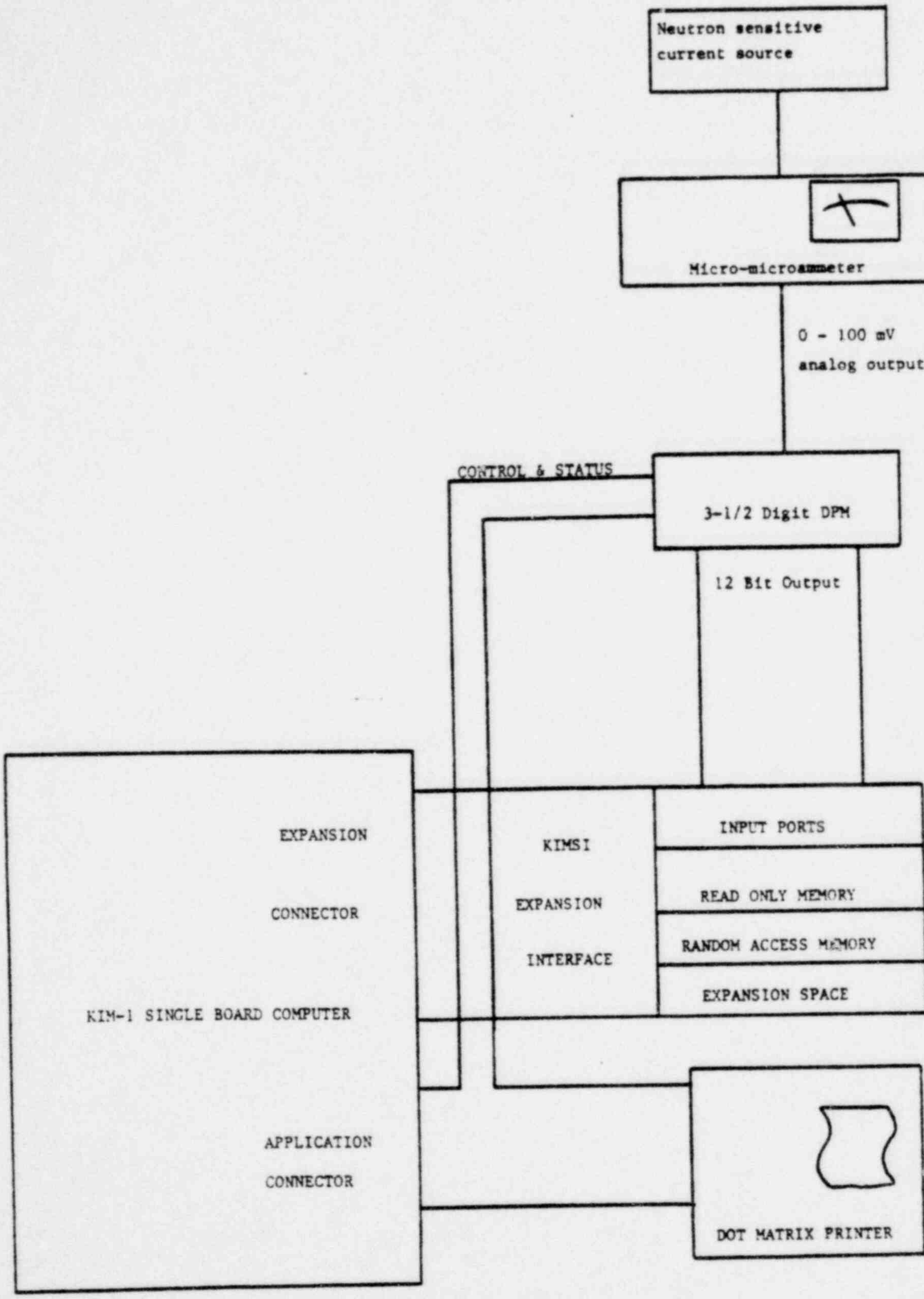


Fig. 2.11 REACTIMETER BLOCK DIAGRAM

2.6 Argon-41 Control System

During operation at 100 KW, argon-41 is produced in the air-filled spaces around the core. The argon-41 is then released to the atmosphere via the stack; the release rate at 100 KW is 0.14 Ci/hr with a stack flow rate of 2100 ft^3/min. A summary of argon-41 emissions during CY 1978 is given in Table 2.6.

Table 2.6

Argon-41 Emmission (1978)

Quarter	Emission (Ci)	% MPC
1	39.6	50.3
2	37.0	46.99
3	22.9	29.14
4	45.0	57.19
Total	144.5	-

Prior studies [2.4] have shown that the emission of argon-41 from the stack could be substantially reduced by replacing the air in the core with nitrogen gas. Using this system the release of argon-41 at a power of 500 KW will be approximately 60 percent of the maximum permissible concentration.

2.8 References

2.1 AEC Regulatory Guide 8.8. "Information Relevant to Maintaining Occupational Radiation Exposure as Low as Practicable (Nuclear Reactors)", July 1973 (See also 10 CFR 20.1 (c).)

2.2 NRC Regulatory Guide 2.6. "Emergency Planning for Research Reactors".

2.3 Radiological Emergency Plan, Commonwealth of Virginia (draft)

2.4 Holland, Thomas E., "A Study of Argon-41 Production by the VPI & SU Research Reactor under Various Nitrogen-Blanketed Conditions", M.S. Thesis, VPI & SU, June 1972

2.5 Stone, R. T., "A Microprocessor-Based Reactimeter", Proc. IEEE Southeastern 79 Conference, 1979