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AEC Research and
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UC-81, Reactors - Power
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EVALUATION OF WIRE SCANNER FOR SM-1

ALCO

ALCO PRODUCTS, INC.
NUCLEAR POWER ENGINEERING DEPARTMENT
P. O. BOX 414, SCHENECTADY 1, N. Y.

APAE Memo-296
AEC Research and
Development Report
UC-81, Reactors, Power
(Special Distribution)

EVALUATION OF WIRE SCANNER FOR SM-1

By:
S. N. Kemp

Approved By:
M H. Dixon, Project Engineer

Issued: November 22, 1961

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with U.S. Atomic Energy Commission,
New York Operations Office

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ABSTRACT

This report presents and evaluates preliminary design concepts of a wire scanner for experimentally evaluating spatial variations of neutron flux in the SM-1 reactor core. Results of a literature search and determination of optimum criteria for flux mapping the core in minimum time dictated requirements for design concepts and specifications.

The report analyzes the utility of both manually instrumented and automatically instrumented wire scanners with respect to rapidity of measurement, selectivity of detector location, cost, value of data, plant downtime and additional factors.

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SUMMARY

This report presents and evaluates preliminary design concepts of a wire scanner for measuring spatial variations of neutron flux in the SM-1 core. Work on this report was performed in FY'61 under Task 2.7 of the Program for Engineering Support and Development of Army Pressurized Water Reactor Power Plants, Contract No. AT(30-1)-2639, with the New York Operations Office of the AEC.

On the basis of the work performed under Task 2.7, certain conclusions were drawn. Utilization of a wire scanner with manual instrumentation methods allows flux and spectrum analysis only at room temperature, with no coolant flow or pressure, and in regions of low flux. This method can only be used during extended periods of shutdown, because a minimal mapping of one quadrant of the core would require 14 working days.

On the other hand, utilization of an automatic wire scanner and automatic instrumenting techniques permits rapid measurements of flux and spectrum in preselected elements without a significant effect on reactor operation. However, this method would also entail a major design and fabrication effort.

It is felt that the neutron flux measurements achievable by the automatic method are of significant value in furthering the state of the art of reactor core design. Accordingly, it is recommended that:

1. Consideration be given only to the automatic scanner and automatic instrumenting system for installation at SM-1.
2. An integrated automatic instrumenting system and automatic scanner be let for bids to determine costs more realistically.
3. A new SM-1 Core support structure be designed and fabricated to accommodate the automatic system.

1.0 INTRODUCTION

One of the major problems in power reactor core design is an accurate definition of power and flux distributions at varying core conditions. It is desirable to know the power distribution as a function of core life, xenon concentration, temperature and pressure both to provide a basis for evaluating core performance and to evaluate such modes of operation as rod programming and fuel management. These measurements provide bases for design and operation of replacement cores having longer lives, more uniform power distribution, reduced fuel cost and increased operating efficiency. In view of this, it is evident that consideration of various experimental methods for the measurement of flux and power distributions is justified.

Foil and wire activation techniques and gamma scanning are among the methods of measuring neutron flux and power distribution. Each has advantages as well as limitations and restrictions. Foil activation methods render valid determinations of neutron flux and power distributions in unpressurized systems at room temperature. However, due to accessibility problems and uncertainty of foil locations, this method proves inadequate for measuring power distribution as a function of core burnout in operating reactors. In addition, a great number of foils is required to obtain a flux distribution, and the method requires special instrumentation techniques. The problem grows more complex when measurements are desired at temperature and pressure. The same holds for the wire activation technique, except that fewer detectors are needed to achieve the same results and the wires allows both more rapid measurement and measurement of continuous, rather than discrete, distributions.

The gamma scanning technique(1) offers a method for determination of relative power distribution for a fuel element integrated over the latter portion of core operating history. However, this method gives an integrated result, independent of specific temperature, pressure and xenon concentrations. One of the prime drawbacks to this method is its operational sequence; the reactor is shut down, opened up, and each element to be scanned is either withdrawn, transferred to the scanning mechanism, scanned, and returned to the core, or a miniatue ionization chamber is inserted between the plates and scanning carried out in this manner. This is quite time-consuming; however, it is no more time-consuming than inserting either foils or wires in the core, using manual instrumenting techniques.

The wire scanning technique, which offers both rapid data collection at a variety of core conditions and continuous flux maps, prompted this investigation and conceptual design consideration. The study approach presented here was to review the literature (summary in Appendix A) and reactor environmental requirements, then to divide the study into two areas: the methods for instrumenting the fuel elements with the wire detectors (Section 2.2), and the methods for scanning the exposed wire detectors (Section 2.3). This plus the development of conceptual designs and specifications for the components of a wire scanning system in an integrated system, either with or without automated provisions, constituted the evaluation.

The work covered in this report was accomplished under item 2.7 of AP Note 286, Addendum 1, Revision 1.*

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* AP Note 286 Addendum 1 Revision 1, "Program Plan for Engineering Support and Development of Army PWR Power Plants," Alco Products, Inc., May 1, 1961.

2.0 INSTRUMENTING METHODS AND SCANNER REQUIREMENTS

2.1 REACTOR ENVIRONMENT

The SM-1 core is a 7 x 7 array of fixed and control rod fuel elements with the four corner elements missing. There are 38 fixed fuel elements and 7 control rod assemblies. Fig. 2.1.1 shows the core with two of the top grid doors open and control rod assembly B removed. Only the 11 central water channels are visible through the opening in the end boxes in the fixed elements and no control rod fuel element channels are directly accessible without removing control rod caps.

The stationary fuel elements contain 18 fixed fuel plates as illustrated in Fig. 2.1.2 and dimensioned in Fig. 2.1.3. The control rods (Fig. 2.1.4) consist of a fuel element and absorber section inserted in a tube; insertion of the absorber section displaces the fuel element. The control rod fuel element contains 16 fuel plates, the dimensions of which are given in Fig. 2.1.3. The absorber section is shown in Fig. 2.1.5. The width of the water gap between fuel plates in approximately 133 mils for both stationary and control rod fuel elements.

The reactor vessel (Fig. 2.1.6), which contains the active core, the support structure, and thermal shielding, is a cylindrical vessel of 47-1/2 inch ID, approximately 5-1/2 ft long, with a 22 in. ID extension approximately 4 ft long on the bottom to house control rod racks and associated equipment. Wall thicknesses are 2-3/4 and 1-1/2 in. respectively.

During full power operation, the average water temperature in the SM-1 core is 440°F, at a pressure of 1200 psia.

Normal operational routine of the SM-1 plant includes training, research and development, which limits the time available for measurement of power distributions. Without a major design and modification program, distributions can only be measured during shutdown, when removal and replacement of the reactor vessel cover is possible. Removal of the vessel cover for experimental purposes would be limited to probably no more than once a year, thus making the core accessible only 2 or 3 times during core lifetime.

2.2 METHODS FOR INSTRUMENTING FUEL ELEMENTS

The power distribution in the SM-1 is characterized by peaks at the edge of the fuel region of the plate due to absence of fuel in the side plate region. Figure 2.2.1 shows a measured radial distribution in the SM-1 Core II obtained at Alco's Critical Facility. Also shown on Fig. 2.2.1 is the region accessible through the hole in the end box. It is clearly not feasible to locate wire detectors in regions

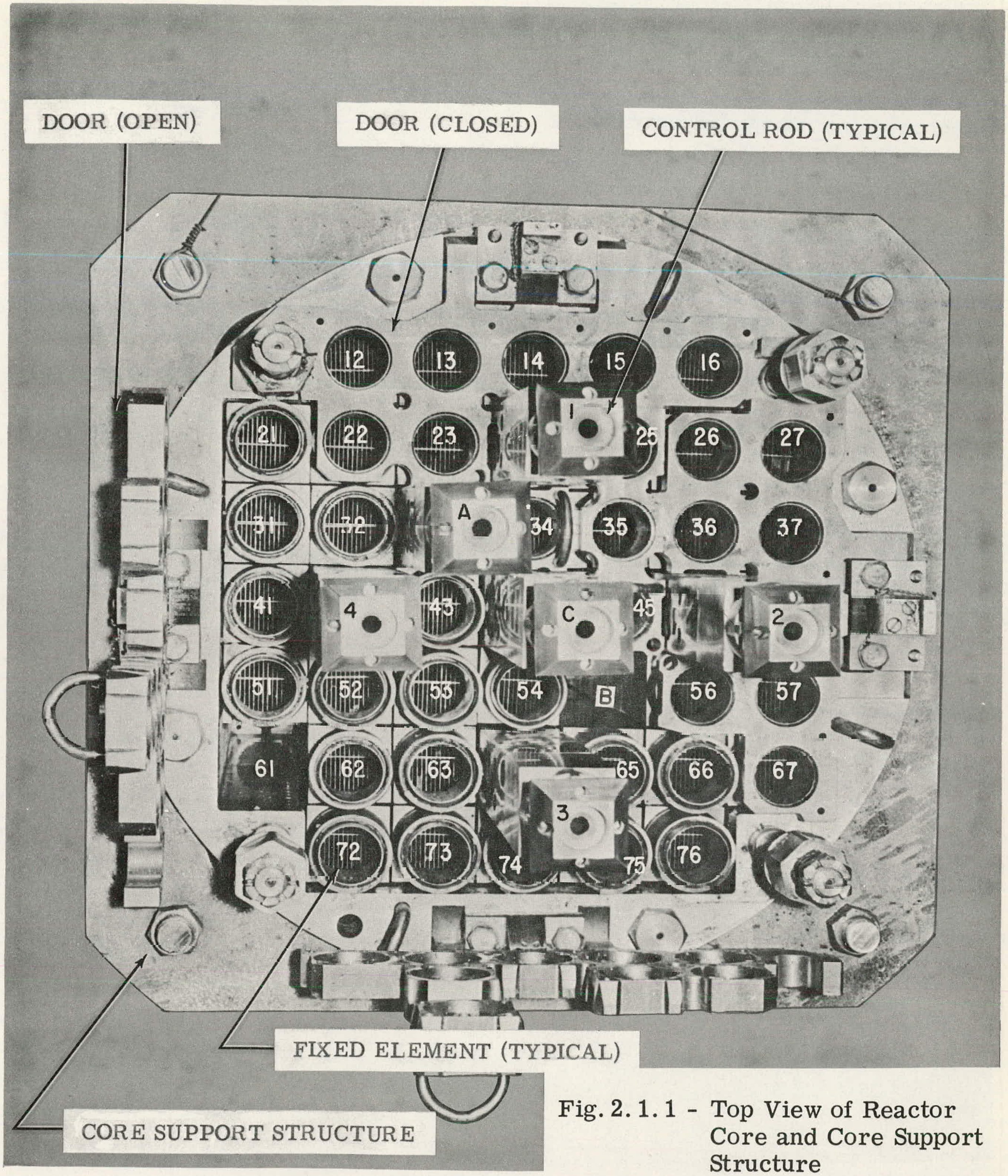


Fig. 2.1.1 - Top View of Reactor Core and Core Support Structure

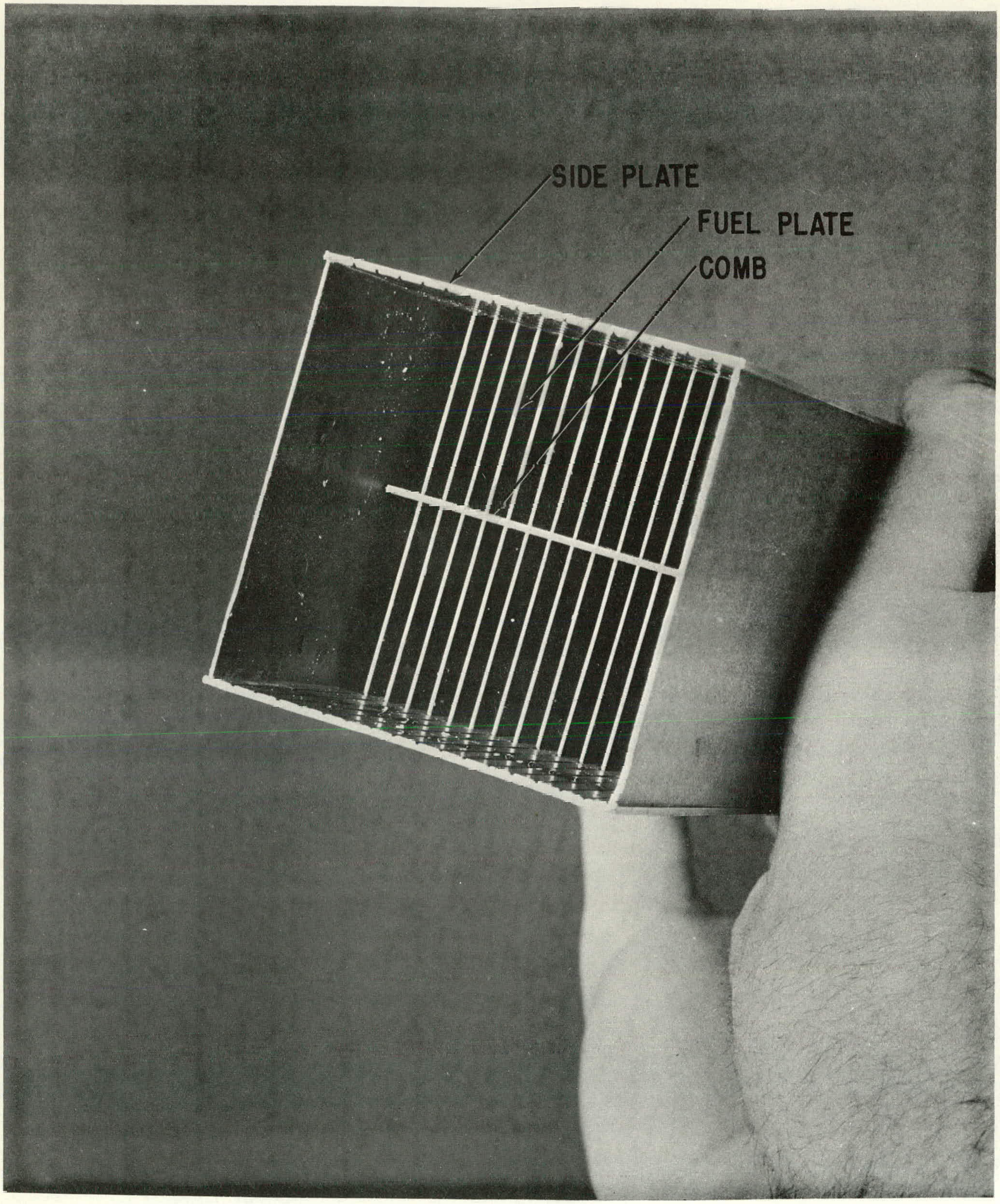


Fig. 2. 1. 2 - Fixed Element with End Box Removed

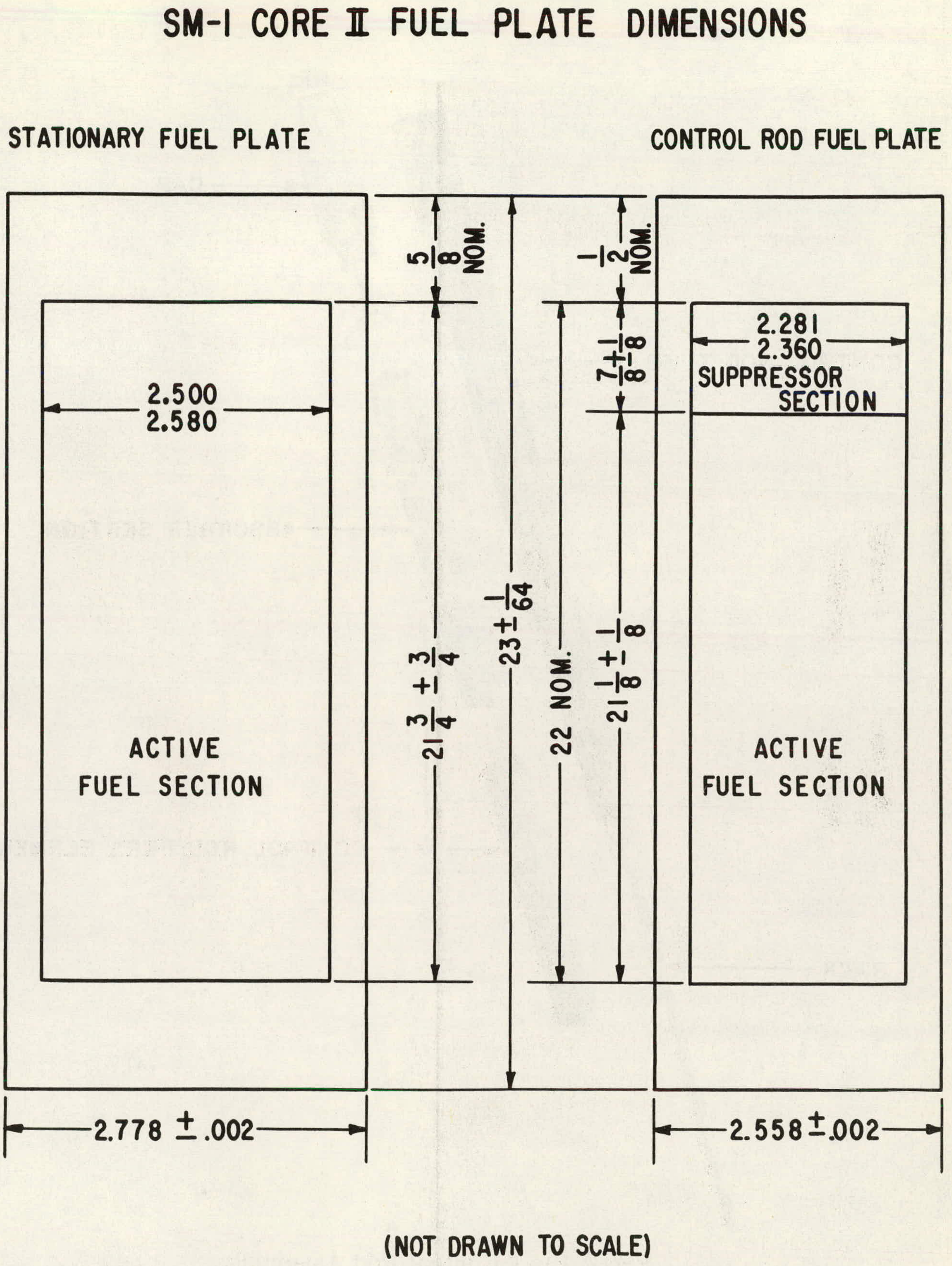


Fig. 2.1.3 - SM-1 Core II Fuel Plate Dimensions

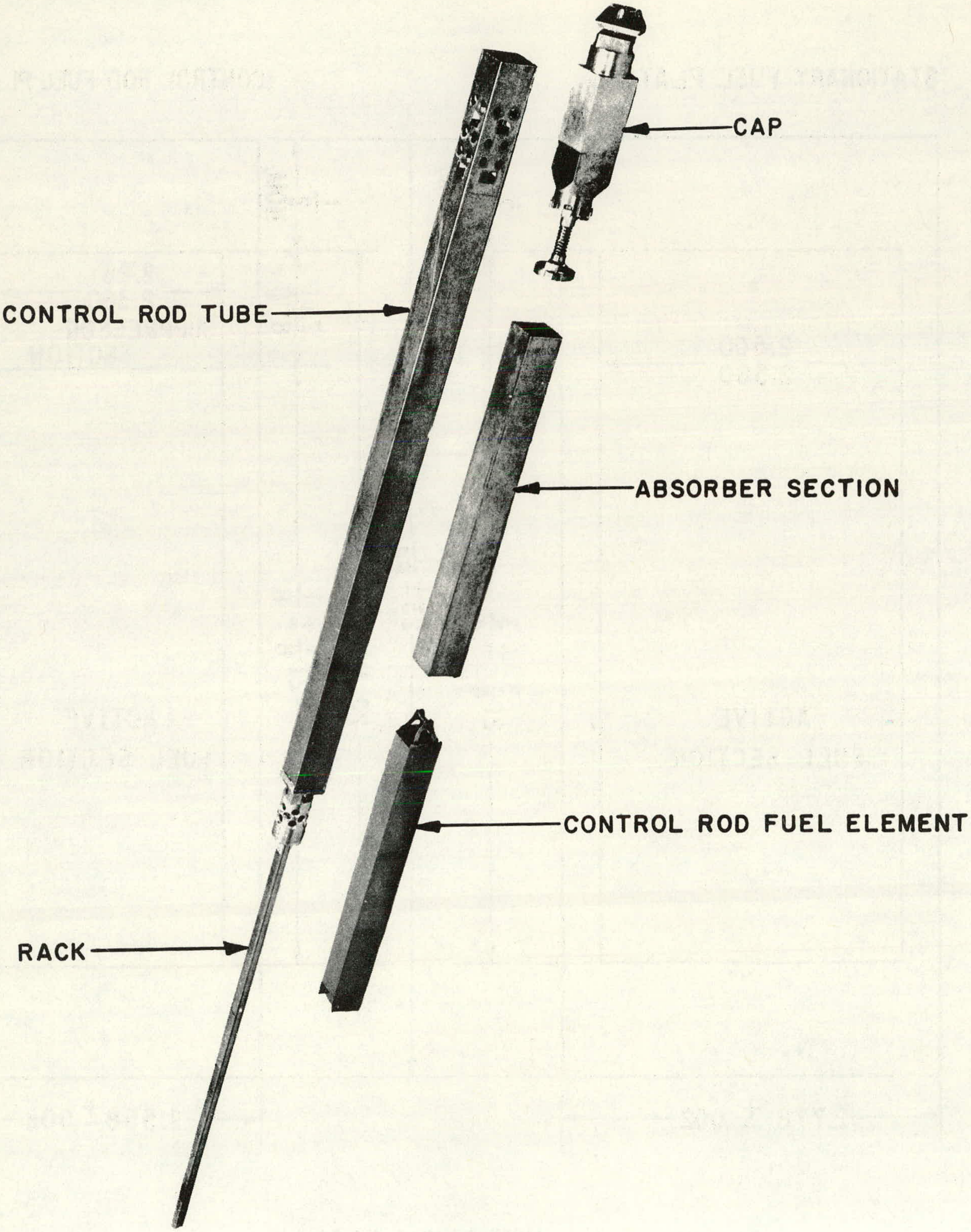


Fig. 2. 1. 4 - Control Rod Assembly

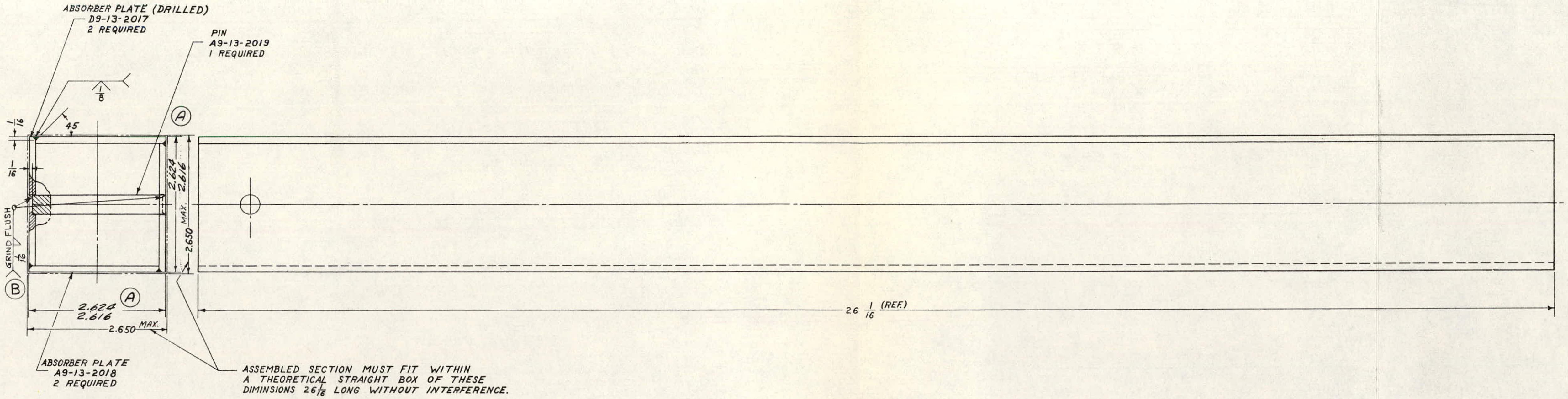


Fig. 2. 1. 5 - Control Rod Absorber Section, Core II

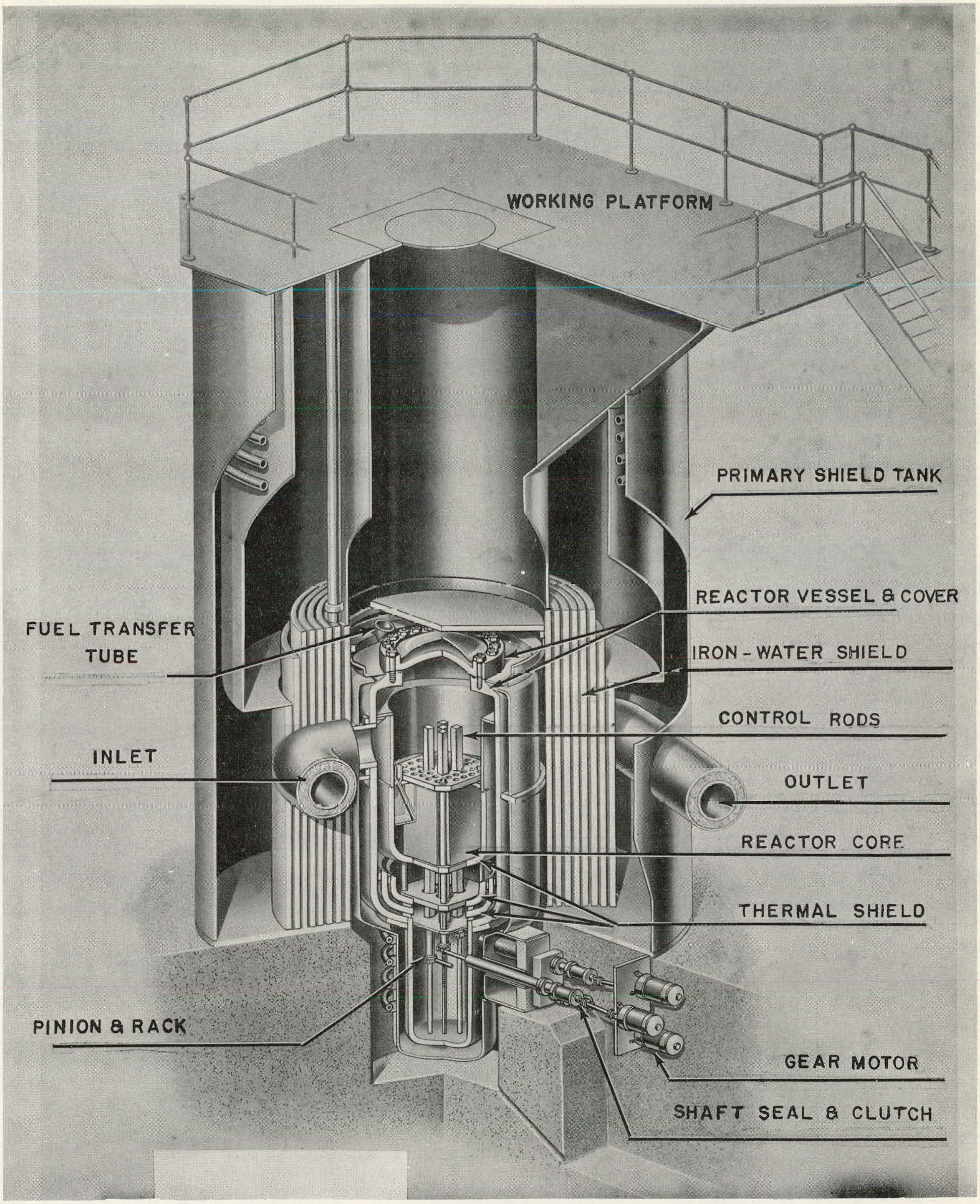


Fig. 2. 1. 6 - Reactor and Primary Shield Arrangement

MEASURED RADIAL POWER DISTRIBUTION IN THE SM-I CORE

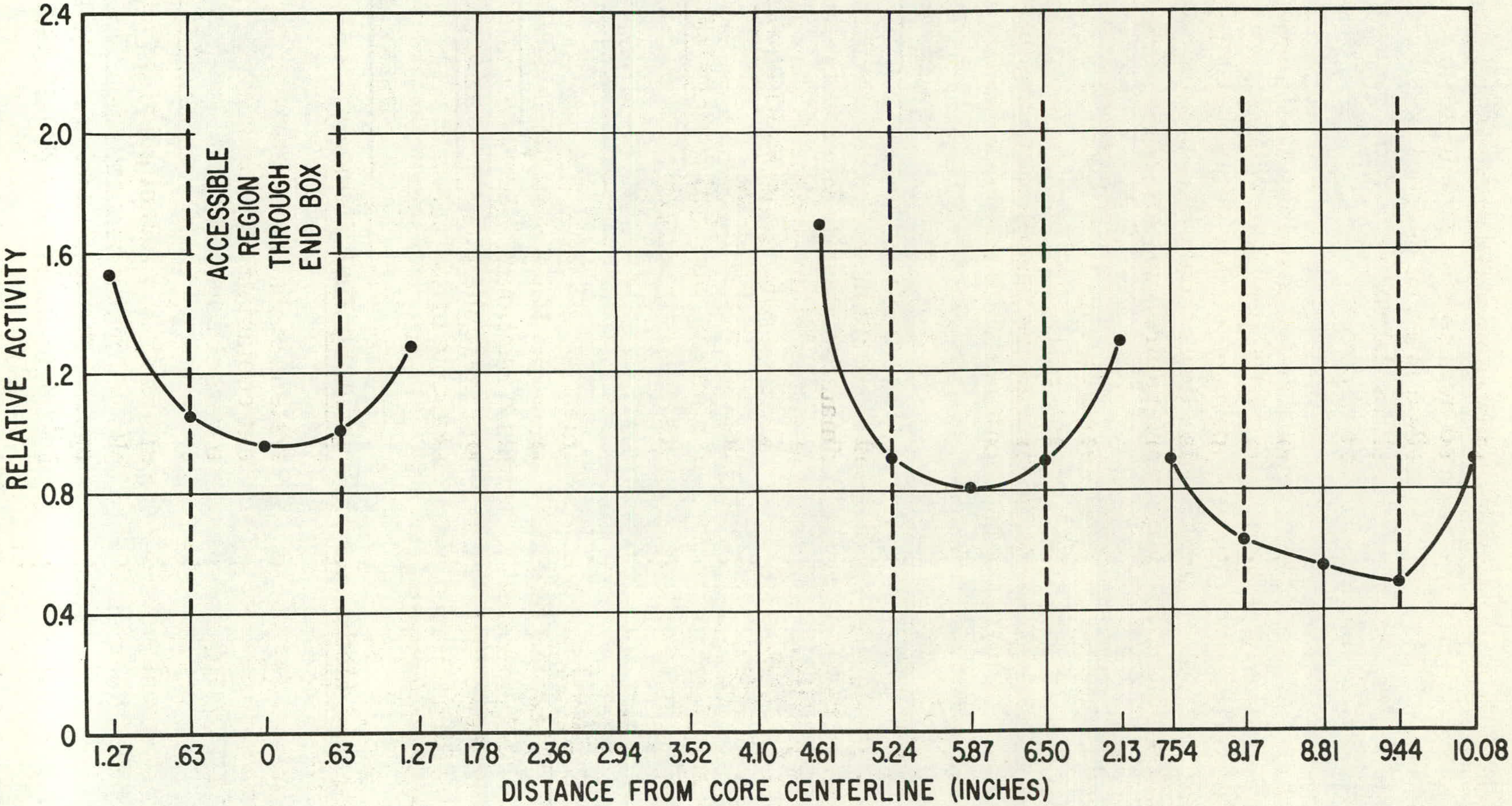


FIGURE 2.2.1

of maximum power; it is preferable to instrument through the end box. This severly limits the value of data obtained by insertion of detectors on stringers through the end box. Therefore, a method must be devised to allow instrumentation of the outside edge of plates as well as the corners of the fuel elements to permit measurement of maximum flux and power .

A manual and an automatic method are proposed for instrumenting the fuel elements. The former involves removal of the pressure vessel cover and manual insertion of stringers through stringer guides into water channels of the fuel elements to be instrumented. This allows measurements only with the cover removed, at no coolant flow, room temperature, and low power levels.

The automatic method allows measurements to be taken at any time during reactor operation by remote insertion and retraction of wire detectors through thimbles placed in the fuel elements through the vessel cover and core support plate. This method involves design modification to the core support structure and pressure vessel cover.

As previously stated, the first of these methods require the removal of the vessel cover and is, therefore, limited in worth by schedule conflicts and reactor downtime. It requires approximately 2 days to remove the vessel cover after allowing 1 or 2 days' cooling time required for access to the vapor container. For low power exposures, 14 working days would be required to map one quadrant of the SM-1 core at one position per element. As the data would only represent the center portion of the fuel element, and would constitute a meager amount for the time involved, manual instrumentation for this operation is clearly not adequate.

The methods proposed for instrumenting the fuel elements for both low and high power operations are described below as "Manual Method," Section 2.2.1, and "Automatic Instrumenting Technique," Section 2.2.3. The limitations and restrictions that are associated with both these methods are also given. It is presumed that either method must be capable of instrumenting the fuel elements in the radioactively hot condition.

2.2.1 Manual Method for Instrumenting Fuel Elements

The requirment for the manual system is that the system be capable of instrumenting a preselected fuel element coolant channel with wires from the platform (Fig. 2.1.6)with the pressure vessel cover off.

Manual instrumentation is accomplished by a funnel guide which is inserted into the upper fuel element and box, followed by a stringer, upon which is mounted the irradiation wire. Both the guide and the stringer mounts are equipped with the appropriate positioning and locking devices to insure positive and safe wire insertions into preselected locations.

For low power exposures at room temperature with no flow or pressure, the exposures can be made with the vessel cover removed. A conceptual design of a jig to locate the wires and supporting stringers is shown in Fig. 2.2.2. To simplify the figure, a 24 in. long wire of 0.020 in. dia was selected as the detector. In addition, the center position of the fuel element immediately adjacent to the upper comb was selected as the detector location. The stringer is a strip stainless steel (or aluminum) with a .020 in. deep groove on one side, into which the detector wire is inserted and fastened into place. The top end of the stringer is fastened to a stringer plug by two round head machine screws, two lockwashers, and two nuts. The stringer plug is a slotted, truncated cone which has a lifting ring welded to its base.

A 1-1/2 oz lead sinker is riveted to the bottom of the stringer to eliminate stringer flexing in the water. The lead would also act as a soft bumper to prevent fuel plate surface damage during instrumenting operations.

The double stringer guide is a weldment consisting of conical plugs, with locating shoulders and conical recesses in the top, joined together by a bridgework consisting of two channels and a lock housing. The single stringer guide is essentially the same as the double stringer guide, the primary difference being that a special locating block replaces one of the slotted plugs.

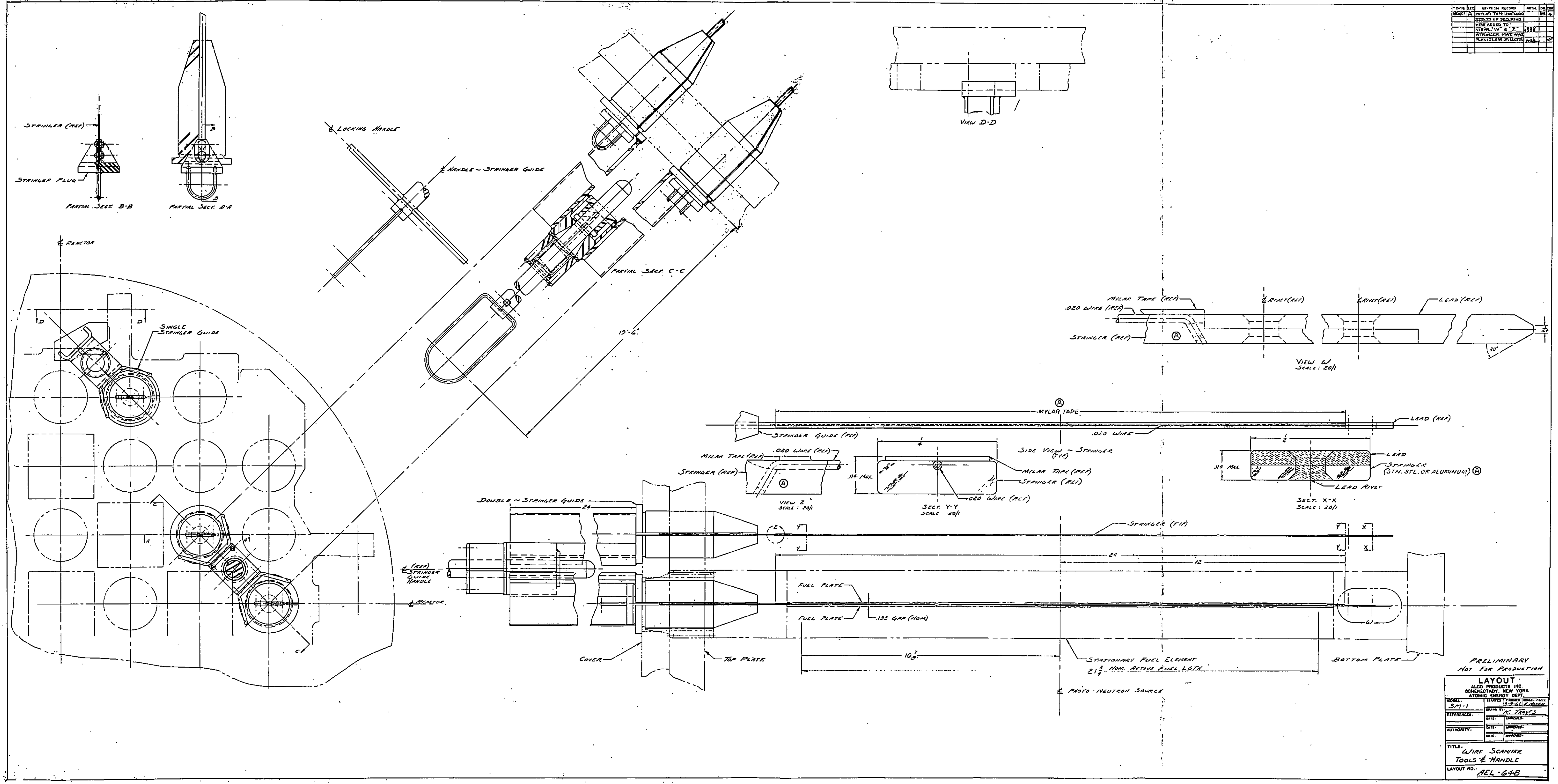
The stringer guide handle is a long bar which has a springloaded detent near the bottom and a turning handle and lifting ring at the top. The stringer guide handle is attached to a double stringer guide by inserting the lower end of the handle into the lock housing and moving the handle a quarter turn, which allows the stringer guide handle to spring into the positive locked position.

This assembly, which can now be handled with no risk of detachment, is used to insert the double stringer guide into the end boxes of the stationary fuel elements. The locating shoulders on the plugs will seat on the cover core support (Dwg. D8-15-2004, Fig. 2.2.3) (core support, Dwg. D9-15-2005, Fig. 2.2.4). Depressing the stringer guide handle and simultaneously turning the handle, a quarter turn allows the stringer guide handle to be detached from the double stringer guide. The same procedure is followed when the stringer guide handle is used on the single stringer guide.

Both stringer guides insure positive location of the stringers with respect to the center space between the fuel plates.

The double stringer guide may be inserted into any pair of fuel elements, except where the core support cover, shown on Dwg. D9-15-2005, Fig. 2.2.4) overlaps the core support cover shown on Dwg. D9-12-2004, (Fig. 2.2.3).

The single stringer guide can only be used near the hinge of the core support cover, Dwg. D-9-15-2005 (Fig. 2.2.3)



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		STRINGER MAT. WAS			
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	DATE-	APPROVED-	
AUTHORITY-	DATE-	APPROVED-	
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TOOLS & HANDLE

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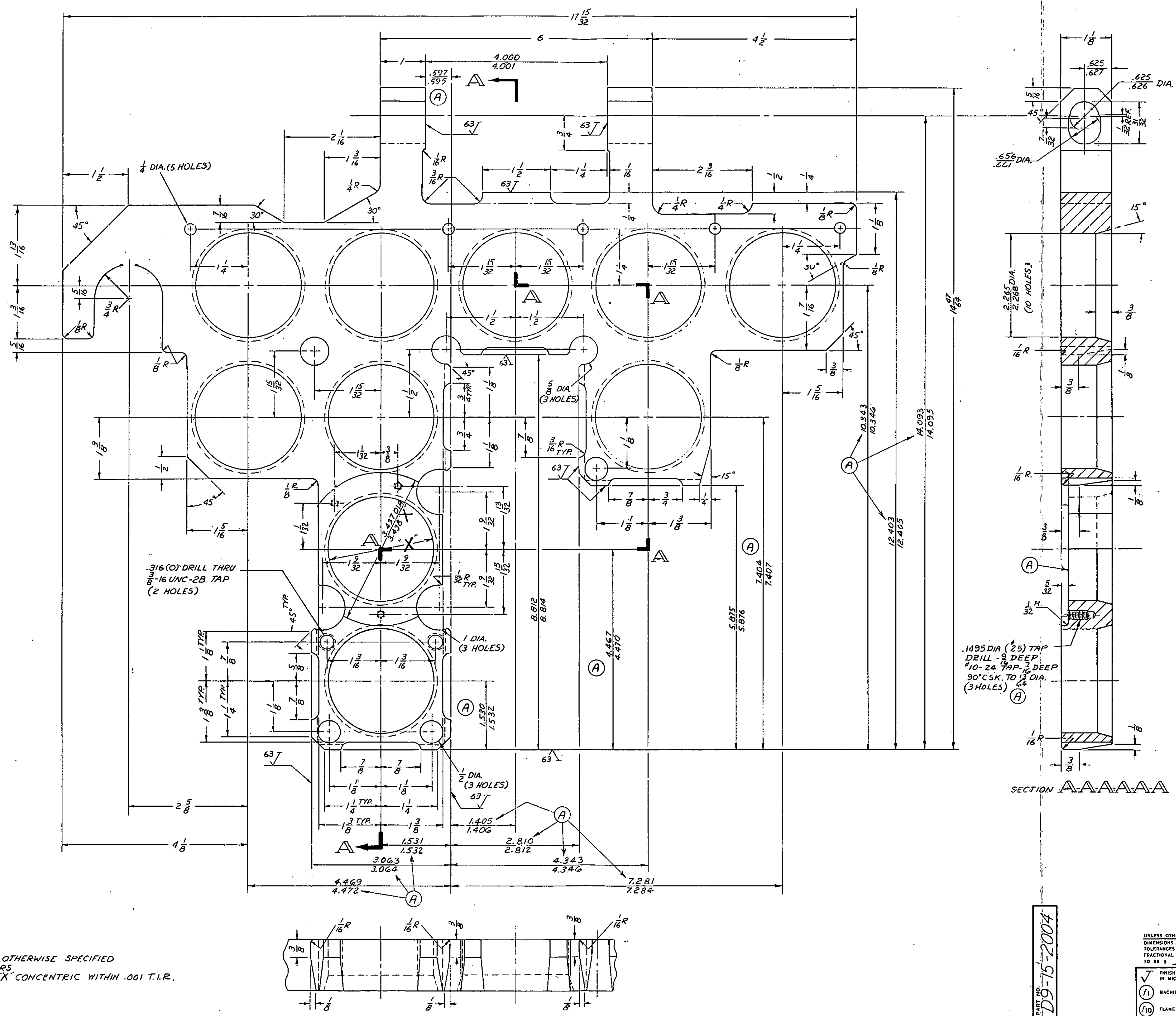

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D9-15-2004

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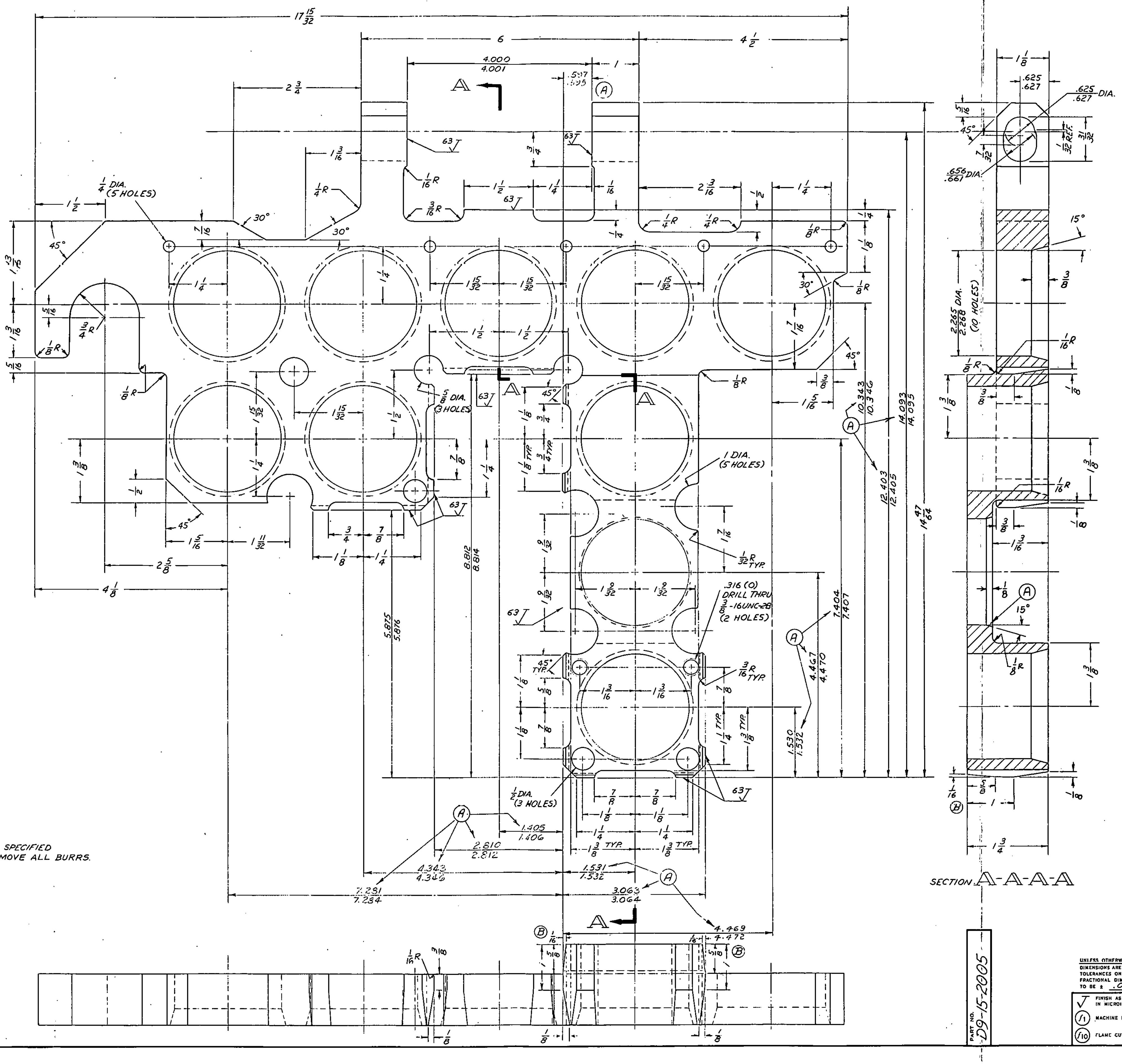

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SCALE FULL	REF. R9-15-1001	DR. Brownell	1-26-56
MATERIAL SPEC. STAINLESS STEEL TYPE 304		TR.	
		CHK. W.H.Pettit	MAR.20,56
		APPR. Tully	4-2-56
		APPR.	
		MET.	3-23-56

NAME
COVER, CORE SUPPORT

PART NO.
D9-15-2005

The next step is to place a stringer plug, with attached stringer, into one of the stringer guides. The stringer now may be lowered and the stringer plug seats in the stringer guide. Removal of the tool from the lifting ring on the stringer plug completes the operation.

Extreme care must be used when inserting or removing a stringer, because they are long, thin and delicate. Each stringer must be inserted smoothly. When the stringer is started into the stringer guide, there must be no torque applied to the stringer. Should the operator find that the stringer does not slide freely in the stringer guide or that there is any hint of a bind between the stringer and stringer guide, the operator must withdraw the stringer and start all over again. Table 2.2-1 is a parts list for this design.

TABLE 2.2.1
PARTS LIST FOR SCANNING ONE-FOURTH OF STATIONARY FUEL ELEMENTS

Part Name	Material	Quantity
Double stringer guide	6061-T6 Al	5
Single stringer guide	6061-T6 Al	1
Stringer plug	6061-T6 Al	11
Stringer guide handle	6061-T6 Al	1
Sinker	Lead	11
Stringer	Stainless Steel Aluminum	11
Scanning wire		11
Tape	Mylar (or equal)	
Tool - control rod element	R9-45-1014	1
Screws - rd. hd. mach. #4 - 40x5/16" lg.	2024-T4 Al	22
Nut - hex. mach. scr. #4-40	2024-T Al	22
Washer, lock (ASA st'd) #4	7075-T6 Al	22

This same type of assembly can be designed to position wires in other water gaps off the fuel element centerline by slight modifications in the stringer and guide design. The limit of accessibility would be those points that fall within the accessibility of the coolant opening in the fuel element end boxes; thus, the corners of the fuel elements would be excluded from flux mapping.

2.2.2 Limitations of Manual Method

This method is restricted to operating at low power levels, maximum 10 kw, with no flow. The no flow restriction limits the operation to low temperatures and unpressurized systems. This, in turn, restricts the usefulness of the data, since no reactor operating condition can be involved as a parameter for investigation. In the SM-1, a significant reactivity change from cold to hot causes a large change in bank position, which has a decided effect on the flux and power distribution in the core; it is extremely difficult to analytically correct cold measurements to a hot condition. Another parameter that this method can not investigate is xenon concentration in the core, as it is not possible to remove the vessel cover and instrument the elements for an exposure at peak or equilibrium xenon concentration. Thus, the manual method severly limits the flexibility of an experimental program.

No significant shielding problems are involved in this operation, as the average activity of the wires can be controlled by the operation. Manual removal of the wires from the stringers is permissible. However, a contamination problem would exist if the primary coolant water or shield water contained contaminants, as would occur after high power operation. This is a probem solved by rinsing the wires with clean water prior to removal from the vapor container. However, the problem of differential between the operation and the activity due to contamingents might become major if wires with low cross-sections are used in low flux areas.

2.2.3 Automatic Instrumenting Technique

As this system permits insertion of wires into the core at any time during operation, even at full power, without adverse affect, wires can be exposed for various xenon concentrations, rod configurations, power levels, temperatures and pressures. Conduits or thimbles are inserted into the selected fuel element water channels to automatically direct the wires to the selected point of measurement. These same conduits penetrate the pressure vessel through the vessel cover and continue on to a drive unit. A flexible cable with the wire detector attached to the end is driven through the conduit by an electro-mechanical drive assembly. This enables remote insertion or withdrawal of the detector, and allows full control over exposure time.

It is possible to transfer the activated detector wire directly to the scanning mechanism remotely by solenoid-actuated transfer mechanisms. By utilizing

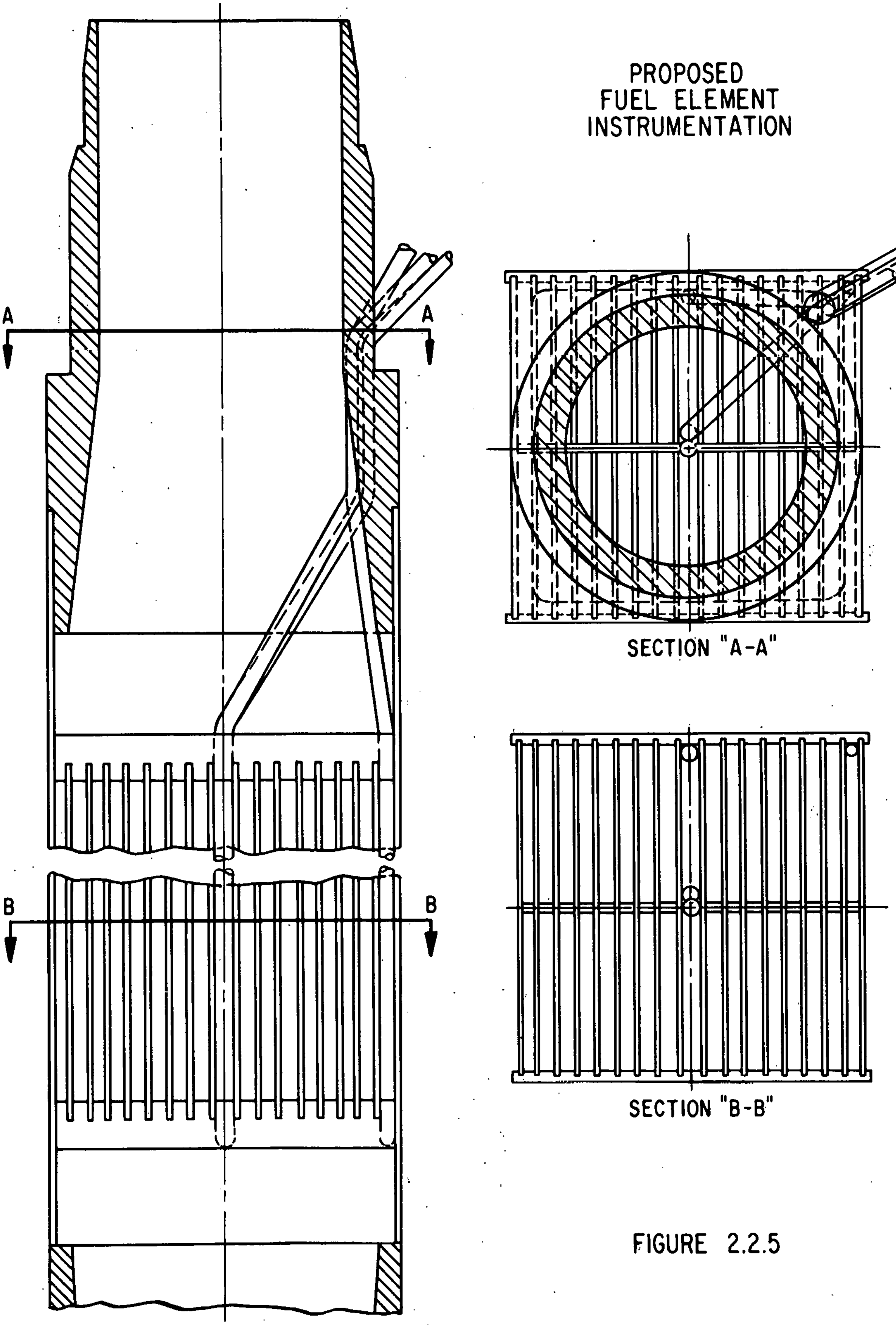
PROPOSED FUEL ELEMENT INSTRUMENTATION
A
A
B
B
SECTION "A-A"
SECTION "B-B"

FIGURE 2.2.5

CONDUIT PENETRATION FOR THE SM-1

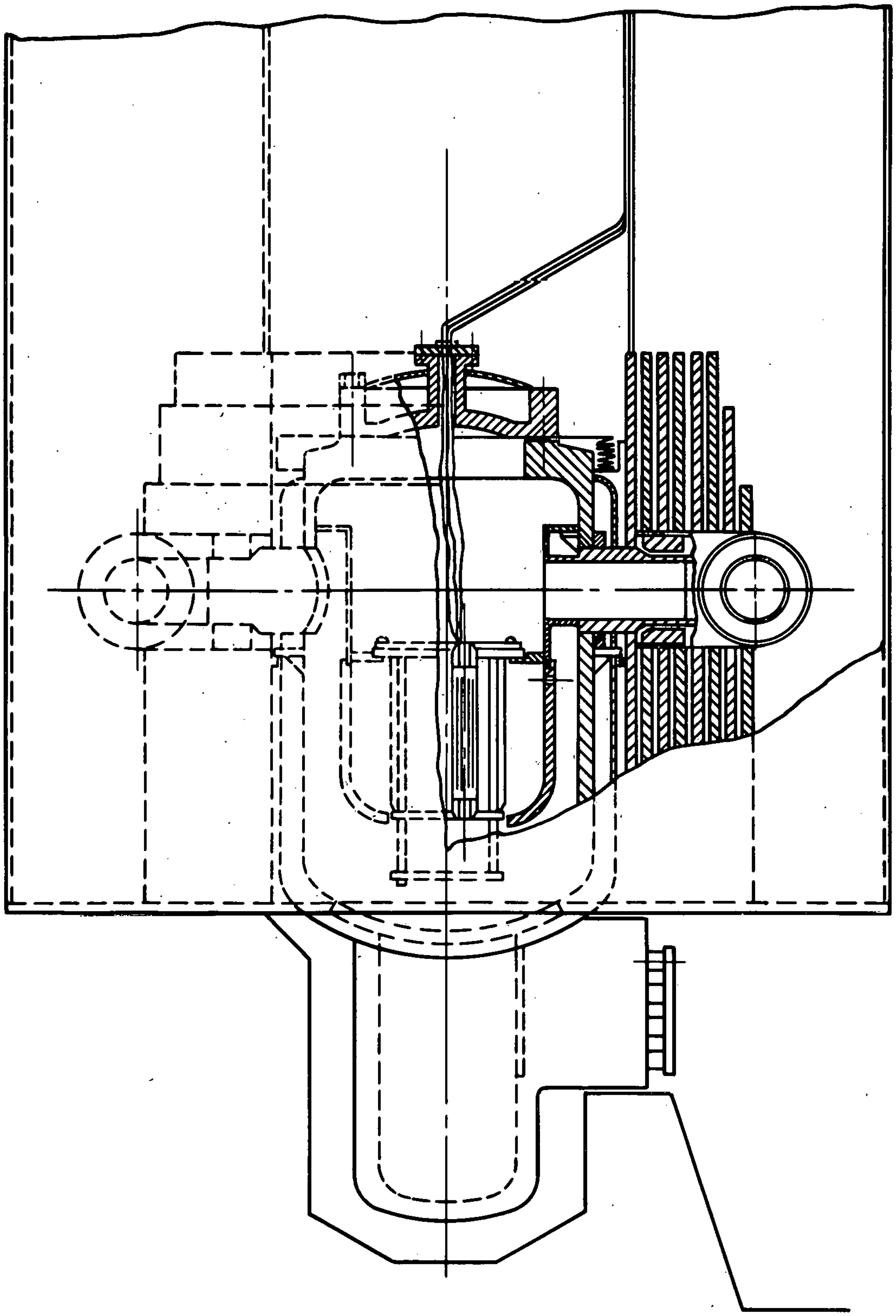

FIGURE 2.2.6

the drive mechanism as the unit for positioning the wire detector under the collimator, the necessity for a traversing mechanism would be eliminated. In addition, the wire detectors could be transferred directly to shielded storage containers after scanning operations, thus dispensing with remote handling equipment for hot wires.

Any number of thimbles or conduit paths could be installed in the reactor, allowing measurements at any predetermined position in the core. The wire detectors would be inserted and retracted individually, simultaneously, or in selected multiples.

In-core positioning to an accuracy of $\not{+}$ 1/4 -in. is feasible. A variable speed drive for insertion and withdrawal of the wires would guarantee a control over the perturbation reactivity effect the wires might exhibit on an operating reactor core.

Special fuel elements would be essential in each core lattice position in which wires are to be exposed. These would differ from the present elements in that they would have thimbles inserted into various water channels (Fig. 2.2.5). The conduit lead out of the fuel element, illustrated in Fig. 2.2.5, is similar to the path the thermocouple wires take in Task XIV(2). The conduit would then penetrate the hatch (upper grid assembly, Fig. 2.1.1) through the various openings that would exist in the modified core support structure (Fig. 2.2.6). This would require that the conduit be preformed prior to inserting the elements in the core to allow them the right path through the core support plate. Once the thimbles are installed in the predetermined positions of the elements to be instrumented, it would not be possible to remove them and re-install them in another fuel element. It would be a major operation to transfer the instrumented fuel elements from one core position to another. It is, therefore, mandatory that first, definitive core positions be selected prior to a final design study, and second that the design of the new core support structure anticipate all core positions in which measurements might be desired at a future date.

An alternate method of instrumentation is described in the Task 13 section of APAE No. 69.(3) This method, which allows insertion of the fuel element with thimbles into the core as a unit, is recognized as most advantageous for this application. However, as this method has been discussed in detail in reference (3), it is omitted from this discussion.

Similar type of systems have been designed and installed at KAPL, Yankee and Babcock & Wilcox by Teleflex, Incorporated. (Ref. Appendix A) For these installations, the conduits were installed before the reactor was operated extensively and consequently the pressure vessel was not activated to any great extent.

This is not the case for SM-1; where radiation from the core structure and pressure vessel virtually eliminate the possibility of working on the vessel proper. This requires design and fabrication of a new core support structure and a new vessel cover, which would require:

1. Fabricating a new vessel cover with penetrations for the conduit.

2. Installing the conduits into the newly fabricated vessel cover with exact amount of thimble length for the positions to be instrumented.

3. Erecting a jig to reproduce the geometrical locations of the vessel cover penetration flange with respect to the instrumented fuel element and form the conduit from the cover through the new core support to fit the fuel elements and the positions to be instrumented. This is not needed if the alternate method of instrumenting is utilized. (3)

4. Simultaneously securing the thimbles in the instrumented positions and the lower fuel elements and vessel cover into their respective positions in the reactor.

A second required penetration, through the vapor container, can be done by passing the conduits through the existing electrical conduits and following the same precautionary measures used for electrical leads.

2.2.4 Limitations of Automatic Method

In view of the penetrations to the pressure vessel and vapor container, along with the change in fuel element structure required for this system and the nuclear effects of the conduits and movement of wire detectors, a hazard analysis would be required.

The major restriction imposed upon normal plant utilization by this method is the initial installation of the instrumented fuel elements, new core support structure, and the new penetrated pressure vessel cover. However, the system would most likely be installed during a normal SM-1 core change; the inconvenience caused during the installation is more than offset by the benefits of the system. This system, after installation, would afford a convenient and expedient method of acquiring in-core information pertinent to future core and reactor development.

2.3 FUNCTIONAL AND ENVIROMENTAL REQUIREMENTS FOR THE WIRE SCANNER

To establsih criteria for a conceptual design study of the wire scanner, functional requirements have to be outlined. In any set of requirements, there exists a certain amount of latitude for argumentation; therefore, justification of these requirements is also presented.

2.3.1 Basic Functions of the Wire Scanner

The wire scanner must provide a rapid method of counting the activity of a wire detector as a function of length along the wire. The activity is in direct proportion to the neutron flux at the position at which the wire was exposed in the reactor core. From this, the basic functions of a wire scanner can be derived. The wire scanner must hold and move the wire detector in such a manner as to allow either continuous counting or counting of various preselected segments. It must provide a detector that will respond in direct proportion to the activity of the wire. To eliminate as much background radiation as possible, the detector must be housed in a shield. An aperture must exist through the shield to act as a collimator; the size of the aperture is dependent upon the size of the segment of wire that is to be viewed by the detector. Sufficient electronics must be provided to allow both a continuous scan and/or a recording of the counted activity for each preselected segment of the wire viewed by the collimator and detector.

Considering this, then, a wire scanner that would satisfy the basic requirements would consist of:

1. A traversing mechanism to support and move the wires past the collimator.
2. Background shield and collimator.
3. Detector and associated preamplifier.
4. Linear amplifier.
5. Single channel pulse height analyzer.
6. Count rate meter
7. X-Y Plotter
8. Scaler and timer

A block diagram is given in Fig. 2.3.1. The system would operate in the following manner.

The wire would be mounted on the traversing mechanism which would pass the wire longitudinally past the collimator opening at various preselected speeds.

To count certain segments of the wire, the traversing mechanism could be stopped manually, the scaler started, data recorded at the end of the counting period, the scaler reset and the traversing mechanism restarted. All these

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BLOCK DIAGRAM - BASIC WIRE SCANNER

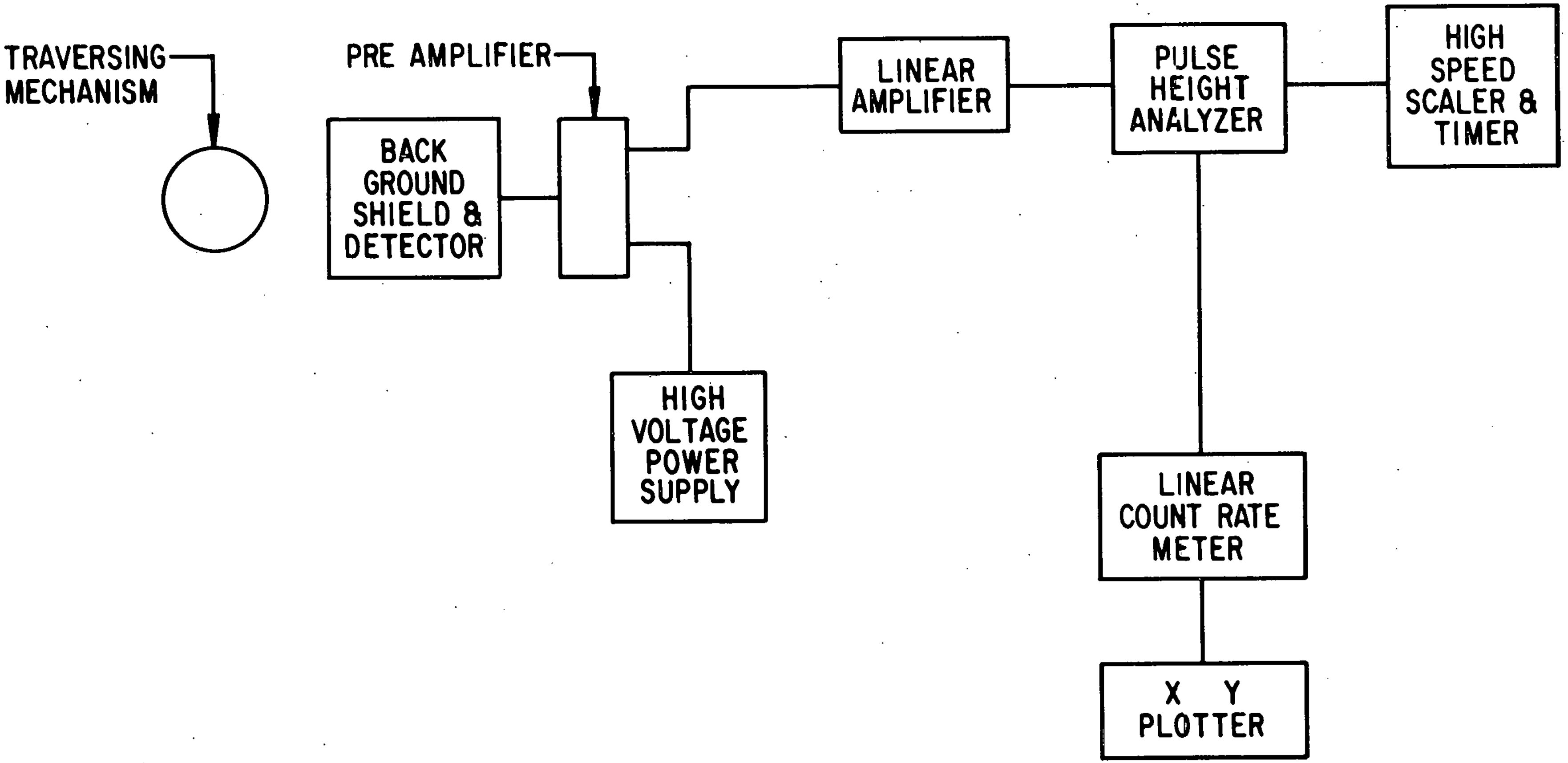

FIGURE 2.3.1

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operations would have to be performed manually with a basic system; in order to take 1-min counts every 1/4-in. along a 22-in. wire, an expenditure of a minimum of 3 man hours would be required. If one considers the amount of time required to prepare the recorded data for the IBM punch card operator and the time spent in actually punching the IBM cards, the total expendure of 12 man hours would be required to completely scan 2 wires.

2.3.2 Additional Functions of the Wire Scanner

In addition to the basic requirements of the wire scanner, as set forth in Section 2.3.1, additional optional functions could be performed by incorporating several automated components into the system. These components would supply the following functions:

1. Program Timer. This component would control the movement of the traversing mechanism, the start, stop, record, and reset of the counting equipment, and supply the time after shutdown information required to process the data.

2. Digital Counter Converter. This component will supply the counts received from the scaler to the IBM summary punch unit in a form the punch unit can interpret.

3. IBM Summary Punch Unit. This component will assimilate all pertinent data and transfer it to the IBM punch card. Therefore, the data is automatically prepared and ready to input into the IBM data processing code.

The use of this system would require one man hour to set up and start the scanning operation per wire and would constitute a saving of 10 man hours to count two wires and prepare data over the basic wire scanner as given in Section 2.3.1. This saving could be increased considerably if several wires were scanned simultaneously by more basic units prior to the IBM Summary Punch Unit.

2.3.3 Automated Functions

As the tight training schedule at SM-1 leaves little time for research and development tasks, several functions of the wire scanner should be automated to assure rapid, accurate data collection. If automatic instrumenting techniques were employed (Section 2.2.3), innumerable wires could be exposed during the course of a day's operation; the bottleneck of the system would occur in data processing. Hence, the need for automatic data processing becomes evident.

It must be kept in mind that most of the automated functions could be accomplished manually with the expenditure of more man hours and that a manual system is quite adequate if only a few wire detectors are to be exposed and scanned per shift

2.3.4 Operational Environmental Requirements

The wire scanner should be located in an area of fairly low residual background radiation to decrease the size of the background shield required for the detector and to permit personnel access to the wire scanner.

The temperature of the wire scanner equipment area is allowed some degree of freedom. The effect of temperature on the NaI (TI) crystal is of major concern, as the resolution of the crystal is proportional to its environmental temperature. Consideration must be given to the change in gain and linearity of the electronics with a change in temperature. Therefore, a temperature range of $60^{o}F$ - $80^{o}F$ has been established; the temperature must not vary more than $5^{o}F$ in any 4-hr period while the wire scanner is operating.

The humidity should be kept around 50% for the sake of the electronic components. Again, however, a latitude is permissible over a range of 35% to 65% relative humidity.

The area required to house the wire scanner and associated equipment can be broken down into smaller areas housing the traversing mechanism, detector, shield and collimator, the area to house the electronics and the storage area to house the wires. If automatic instrumenting methods were employed, additional space would be needed.

The space requirements for the traversing mechanism, collimator, shield and detector should not exceed 35 ft^2 per unit, which allows for working area adjacent to the equipment. The electronic equipment area should not exceed 30 sq ft, including servicing area and a 16 ft^2 personnel area at the console. The wire storage area should not exceed 16 ft^2. If automatic drive units are incorporated into the system, an additional 40 ft^2 would be required, including working area. Therefore, the total space requirements for the system would be approximately 120 ft^2 including working and servicing space for two men.

The problem of possible contamination must be considered if the manual instrumenting technique is employed. It is probable that the reactor primary water will contain certain contaminants, particularly after extensive high power operations; these will adhere to the stringers. Therefore, provisions must be made to rinse the exposed wires and stringers prior to transporting them from the vapor container to the wire scanning area. A hose, discharging demineralized water, would be sufficient; the exposed wires and stringers can be rinsed over the shield tank on withdrawal.

2.3.5 Shielding Requirements

Shielding is required while exposing and scanning the wires, as both operating personnel and the wire scanner area must be shielded from the activity of the exposed wires.

The simplest, most flexible and economical shielding for the radioactive wires is commercially available lead bricks, which would be stacked to form a 4 x 4 ft storage vault for the exposed wires. This vault would provide both temporary storage during sequential scanning operations and permanent storage to allow the wires to decay after exposure pending disposal or reuse.

The background shield for the detector head must reduce residual and contributing backgrounds from the extreme segments of the wire being scanned to less than 1 percent of the activity seen by the detector from the segment of the wire viewed through the collimator. Since the basic detector response is isotropic, the entire probe, crystal and photo multiplier tube, must be enclosed in a background shield, which is equipped with a collimator in the direction of the activated wire segment that is being counted (Section 3.1).

A wall of lead bricks, constructed as a shadow shield between the traversing mechanism and the console operator, allows the operator unrestricted time at the console and would obviate timed radiation exposure limits.

2.3.6 Detector Materials

A survey was conducted to determine materials suitable for use as detectors. Selection was fully dependent on usage; i.e., low power operation at room temperature and no flow, or high power operation at temperature, pressure and flow. Many good activation mediums cannot be fabricated into wires. The neutron cross sections as a function of neutron energy must be known to a rather high degree of accuracy and must be of sufficient magnitude to achieve the necessary activation within reasonable exposure times. The decay scheme of the radioactive nuclide must have a half-life long enough to allow good counting statistics without the need for large decay corrections. The mode of decay and the type and energy of the emitting radiation is of concern and must be considered when a detector is selected for use. In addition, a very close tolerance on wire size must be maintained to limit the uncertainties associated with the detector volume.

Table 2.3-1 presents a summary of the detector material survey as applicable for use in the SM-1. These materials are listed along with their energy group, effective threshold energy, nuclear reactions and half lives.

The detector materials listed in Table 2.3-1 are available in various forms; selection of specific wires would depend entirely on the experimental program in which they are to be used. Pure wire detector materials as well as alloyed wires are available. Examples are Ni-Al alloy, Al-Co alloy (Co 0.50%, Mn 0.50%, remainder Al), magnesium-indium, iron alloys with various alloying constituents and titanium. The use of alloyed wires will allow obtaining various neutron energy threshold reactions simultaneously.

Certain materials that are feasible detectors are omitted, as they are not presently available in wire form.

TABLE 2.3-1
DETECTOR MATERIALS APPLICABLE FOR USE IN THE SM-1

Monitor Group	Detector Material	Nuclear Reaction	Effective Threshold Energy (Mev)	Half-Life of Product
Thermal	Cobalt	$Co^{59}(n,\gamma)\ Co^{60}$	2.5×10^{-8}	5.3 yr
	Cobalt (Cd-shielded)	$Co^{59}(n,\gamma)\ Co^{60}$	4.0×10^{-7}	5.3 yr
	Indium	$In^{115}(n,\gamma)\ In^{116}$	2.5×10^{-8}	54 min
	Indium (Cd-shielded)	$In^{115}(n,\gamma)\ In^{116}$	4.0×10^{-7}	54 min
	Gold	$Au^{197}(n,\gamma)\ Au^{198}$	2.5×10^{-8}	2.7 da
	Gold (Cd-shielded)	$Au^{197}(n,\gamma)\ Au^{198}$	4.0×10^{-7}	2.7 da
Resonance	Cobalt (Cd-shielded)	$Co^{59}(n,\gamma)\ Co^{60}$	1.2×10^{-4}	5.3 yr
	Manganese	$Mn^{55}(n,\gamma)\ M^{56}$	2.6×10^{-4}	2.6 hr
	Copper	$Cu^{63}(n,\gamma)\ Cu^{64}$	5.7×10^{-4}	12.8 hr
	Vanadium	$V^{51}(n,\gamma)\ V^{52}$	3.0×10^{-3}	3.7 min
	Aluminum	$Al^{27}(n,\gamma)\ Al^{28}$	9.1×10^{-3}	2.3 min
Threshold	Nickel	$Ni^{58}(n,p)\ Co^{58}$	5.0	72 da
	Aluminum	$Al^{27}(n,p)\ Mg^{27}$	5.3	9.8 min
	Magnesium	$Mg^{24}(n,p)\ Na^{24}$	6.3	15 hr
	Aluminum	$Al^{27}(n,\alpha)\ Na^{24}$	8.6	15 hr
	Vanadium	$V^{51}(n,\alpha)\ Sc^{48}$	11.5	44 hr

3.0 CONCEPTUAL DESIGN CONSIDERATIONS

Design considerations for the background shield and collimators, the traversing mechanism and the wire scanner as an integrated system are presented here. It is emphasized that these are conceptual designs; therefore, the finer details have been omitted. However, Appendix B - Specifications, outlines the design requirements in detail. A certain amount of freedom must be incorporated into conceptual designs to permit substitution of commercially available components into the system where possible. This will permit a reduction in overall cost for the final designed system.

3.1 WIRE SCANNER AS AN INTEGRATED SYSTEM

Basically, the wire scanner will consist of a traversing mechanism, background shield, collimator, detector, pre-amplifier, high voltage power supply, linear amplifier, single channel pulse height analyzer, linear count rate meter, scaler, x-y plotter, program timer, digital counter converter, IBM summary punch unit, drive mechanism, remote transfer mechanisms and a storage vault.

The wire scanner will count wires up to 4-ft long and 1/16-in. diameter. Wire traversal will be accomplished by rotating a 16-in. wheel past the collimeter opening. The wheel, incorporating means for quick, easy attachment of wires and adjustment of the zero scanning point, will be driven by a synchronous motor through a mechanical speed changer to obtain widely variable scanning rates. The wheel will also be geared to a potentiometer to obtain an electrical output, proportional to the displacement of the segment being viewed by the detector from the zero position. In addition, the traversing mechanism will automatically stop at intervals along the wire for one minute counts. These stops are concidental with the automatic initiation of the recording by the digital counter converter and scaler. Also, a hold signal, applied to the y axis of the x-y plotter, will permit an accurate x-y plot even though the wheel is stopped intermittently for one minute counts. The automatic stops are adjustable from 1/4-in. to 3 in. along the wire, allowing a range of 8 to 88 points along a 22-in. wire.

The background shield (Fig. 3.2.1) will maintain background radiation to no more than 1% of the observed count rate. The detectors will consist of interchangeable NaI (TL) and plastic scintillators mounted on their respective photomultipliers with shields, collimators and preamplifiers. These will be such that they can be readily inserted into and removed from the main low background shield. The high voltage supply will be variable and encompass a range required by the respective detectors.

The linear amplifier will amplify the signal from the detector in use and will supply either a variable discriminator output directly to the linear count rate meter or a linear signal through the single channel pulse height analyzer to the

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BLOCK DIAGRAM – AUTOMATIC WIRE SCANNER

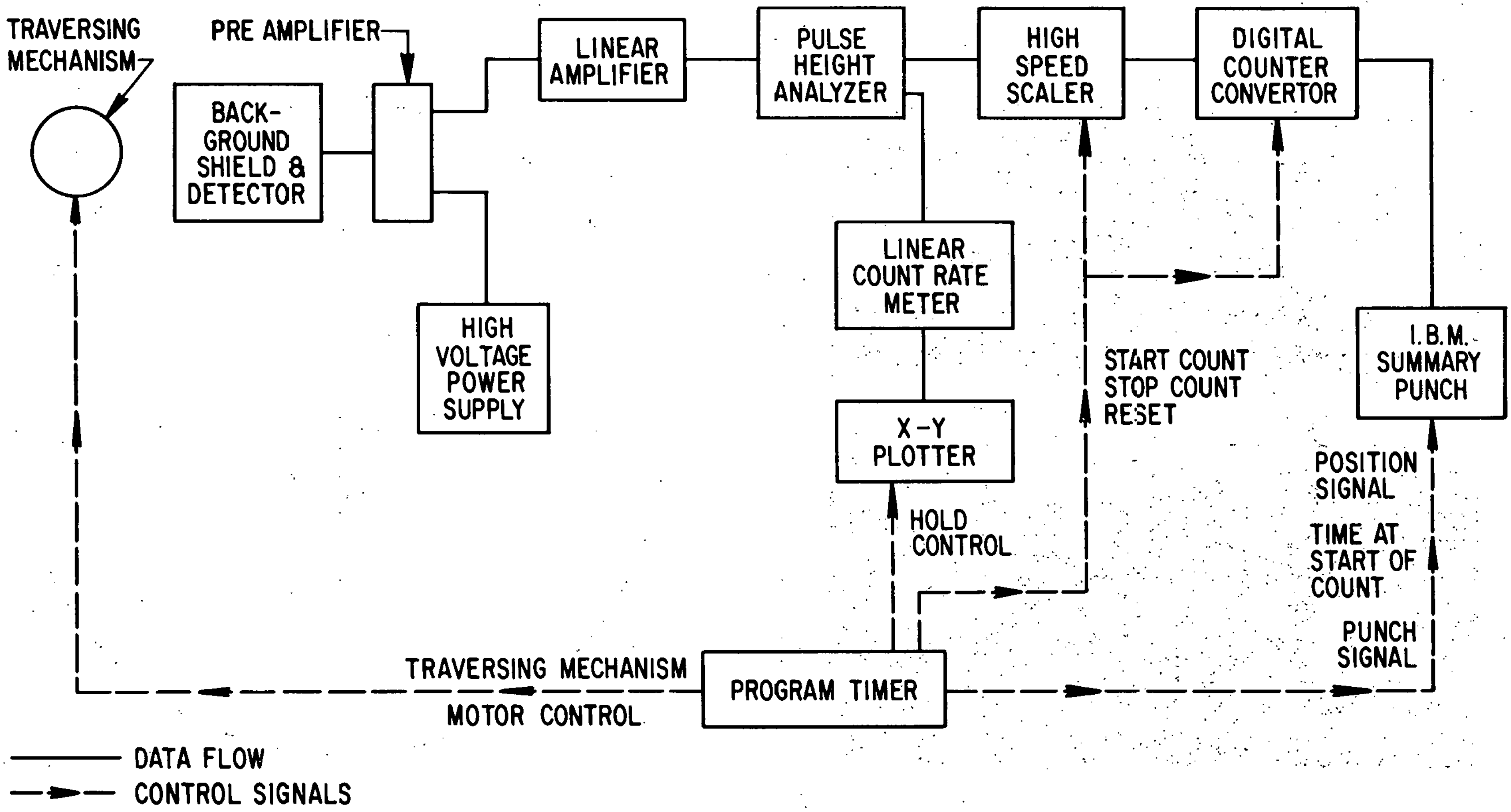

FIGURE 3.1.1

CONCEPTUAL DESIGN BACKGROUND SHIELD

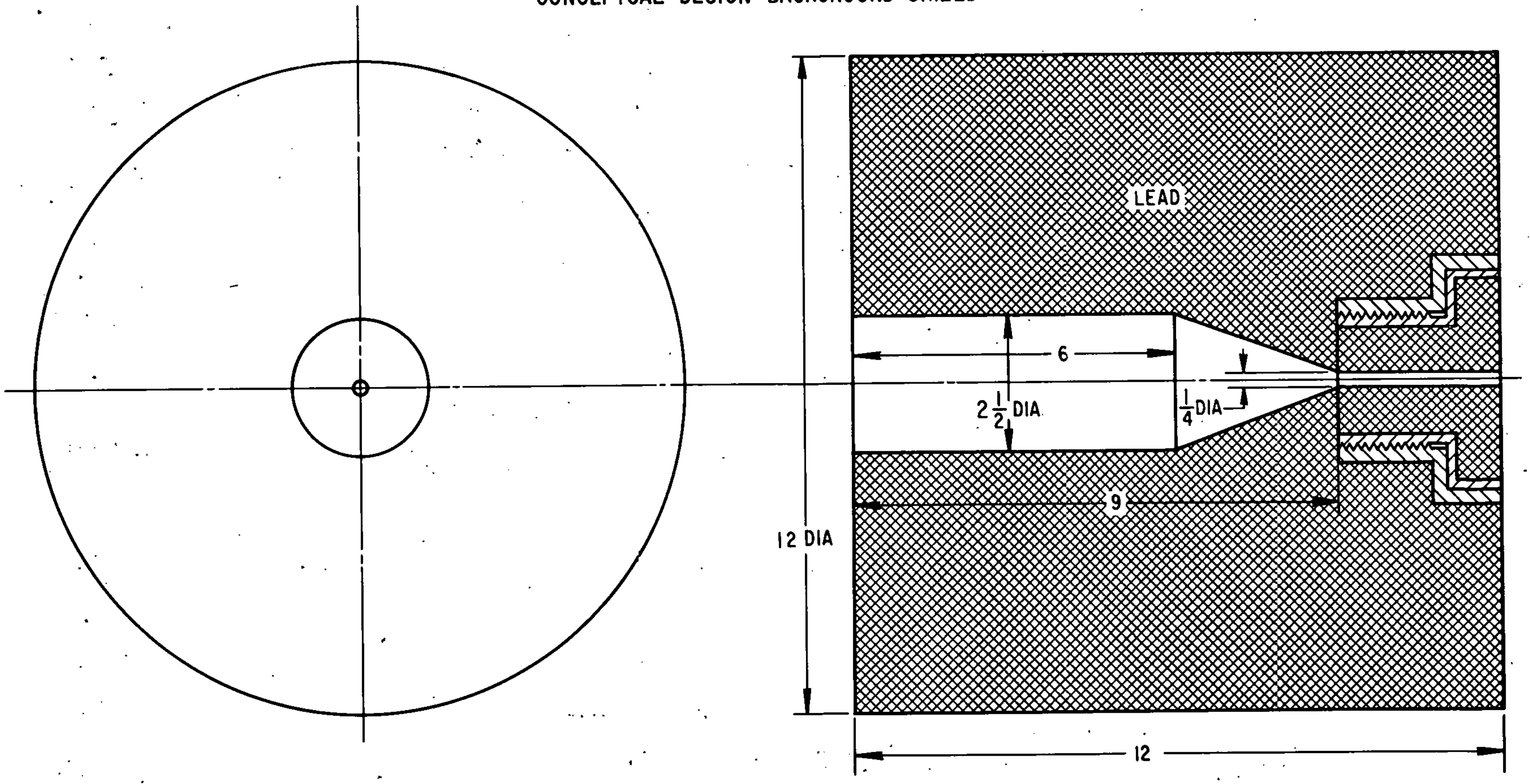

FIGURE 3.2.1

DIMENSIONS IN INCHES

linear count rate meter or the scaler. The single channel analyzer will enable the selection of the upper and lower limits between which an output will be provided to the count rate meter or scaler.

The count rate meter is a linear, six range instrument with automatic range switching and provisions for time constant selection. Meter reading and range in use are indicated on the panel and outputs are provided for recording. The recording output signal from the count rate meter will be suitable for driving a common time base recorder as well as the x-y plotter.

The output of the single channel analyzer will be fed through the scaler to the digital counter converter. The scaler and digital counter are automatically reset, started and stopped in coincidence with step cycles of the traversing mechanism.

The control system for scanner automation is the program timer, which feeds the start and stop signals to the scaler, digital counter converter, punch and traversing mechanism. This is best illustrated by the block diagram of the scanner, Fig. 3.1.1.

3.2 BACKGROUND SHIELD AND COLLIMATORS

The background shield and the collimators with various size apertures were treated as two basic units, which tends to simplify the system and reduce the weight of the individual shielding components. Figure 3.2.1 is a conceptual drawing of the lead background shield, which will house the various collimators and associated detection equipment.

The collimator concept is shown in Fig. 3.2.2. It is designed for a NaI (TL) scintillation probe as well as a plastic scintillator probe. The collimators, fabricated from lead, are readily interchangeable, thus allowing considerable flexibility in aperture size.

Design of the background shield and collimators were based on no more than 1 percent of the total gamma activity of the wire (in the scanner) reaching the detector probe other than through the collimator, using a selected gamma ray energy of 3 Mev.

3.3 TRAVERSING MECHANISM

A conceptual design of a traversing mechanism depends on whether the wires will be handled remotely (Section 2.2.3) or manually (Section 2.2.1). If the automatic instrumenting technique is selected, the traversing mechanism will be composed of flexible cable drive assemblies and a conduit. Figure 3.3.1 is a block diagram of such a system. The drive mechanism inserts the

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CONCEPTUAL DESIGN COLLIMATORS

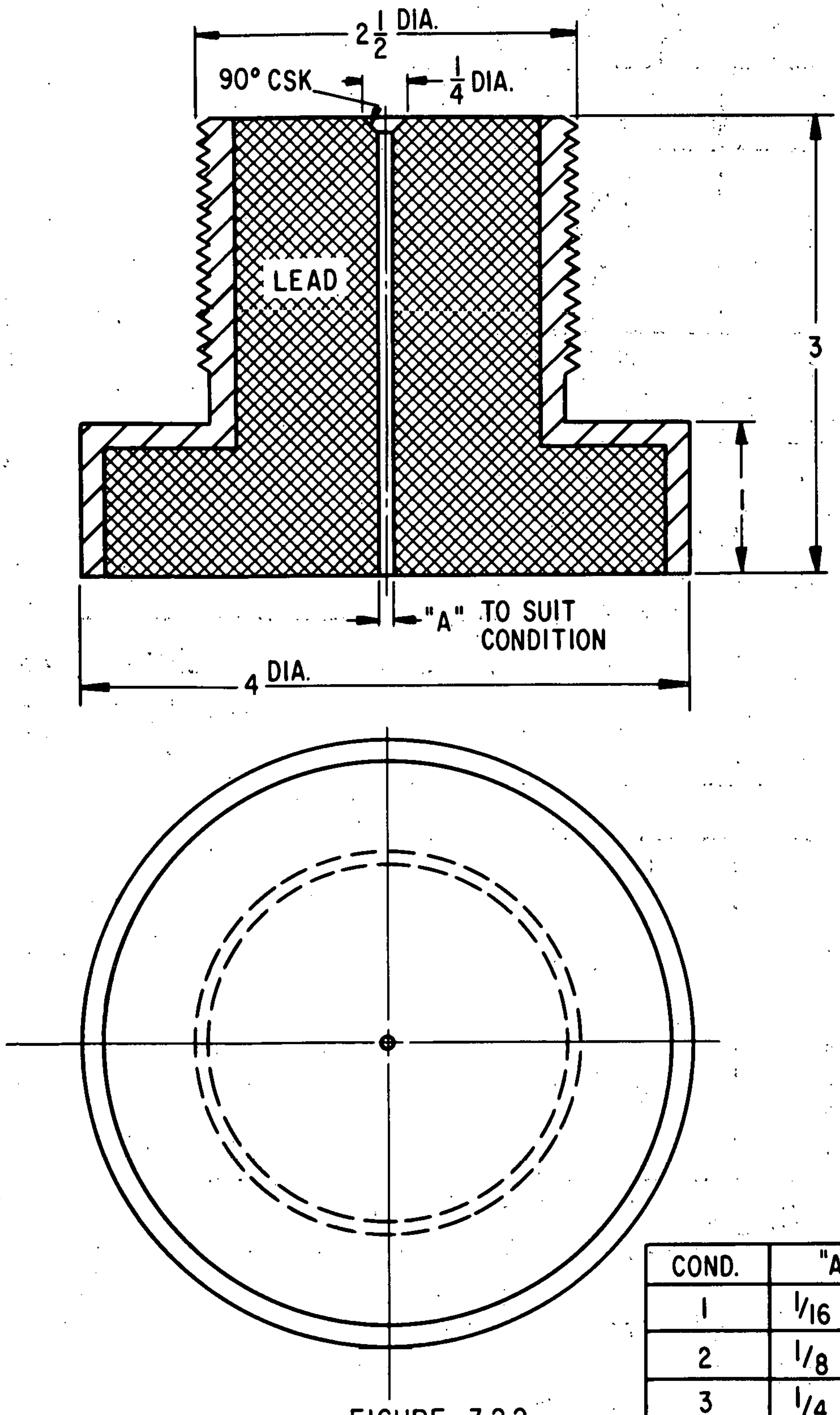

FIGURE 3.2.2

COND.	"A"
1	1/16 DIA.
2	1/8 DIA.
3	1/4 DIA.

BLOCK DIAGRAM
AUTOMATIC INSTRUMENTING SYSTEM

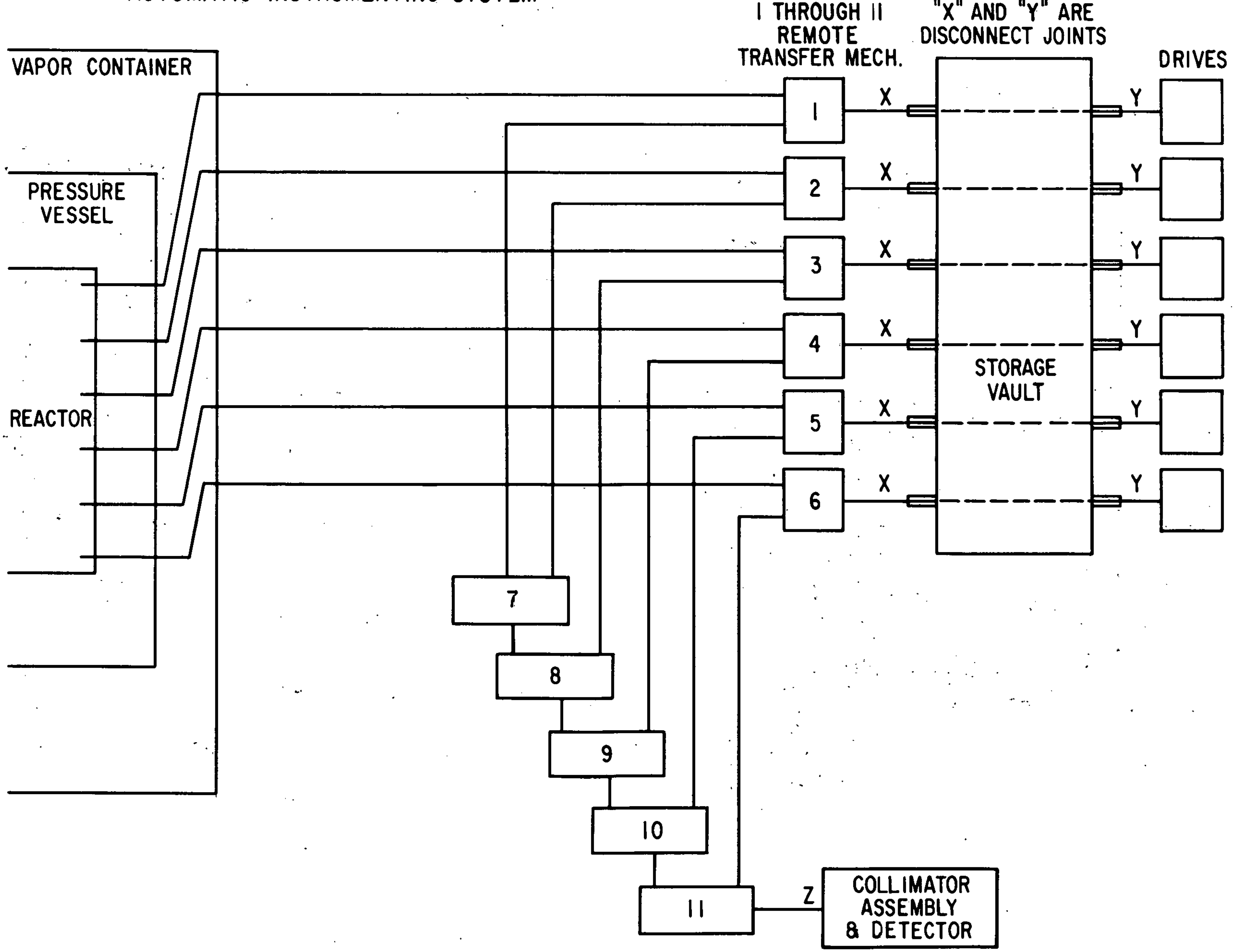

FIGURE 3.3.1

STORAGE VAULT

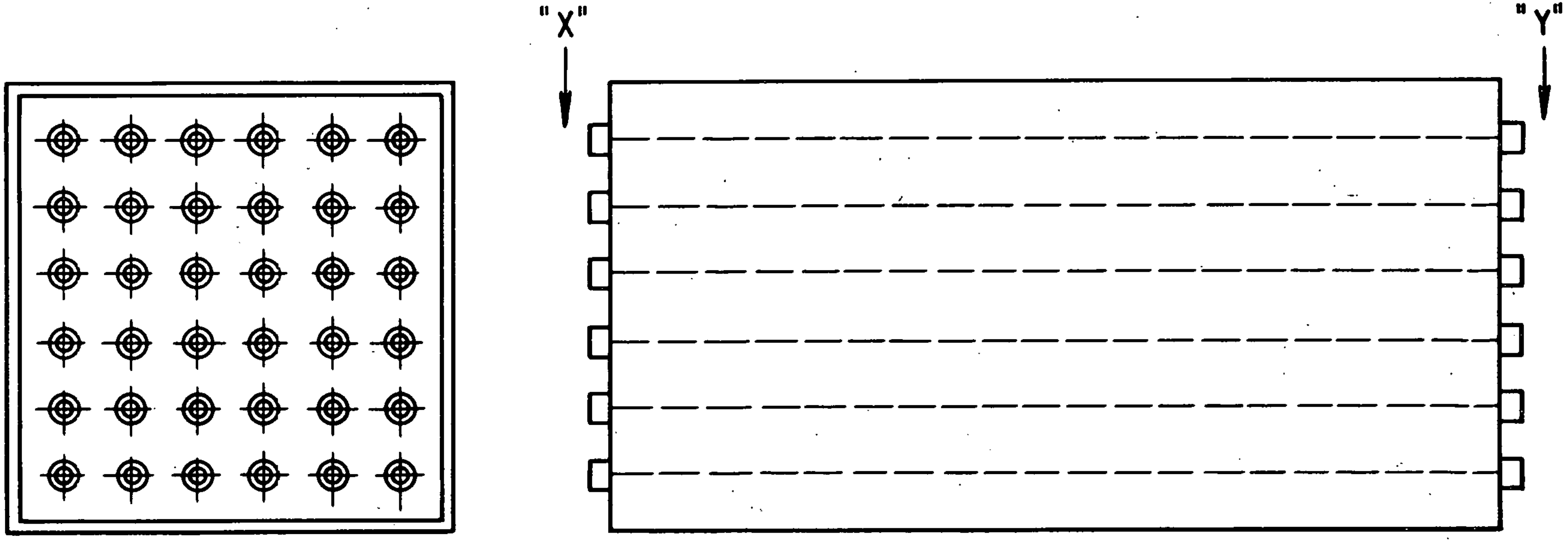

FIGURE 3.3.2

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wire into the reactor; after exposure, the wire is withdrawn to behind point x. The conduit is switched, using the remote transfer mechanisms, so that the flexible cable is now driven to the collimator assembly. As the top of the wire reaches point z, the drive mechanism is controlled and operated as described in Section 4.1.

A conceptual drawing of the storage vault is shown in Fig. 3.3.2. The vault, with a minimum of six conduit passages per conduit leading to the reactor, is capable of storing additional and dissimilar wire detectors. This allows the operator to select the type of wire detector required for specific measurements. The storage vault conduit is equipped with quick disconnect fittings to allow the removal of the conduit to the drive assemblies and to the first transfer mechanism. The quick disconnects allow rapid removal and connection of the wire detectors to and from the flexible drive cables, which increases the capabilities of the system.

The traversing mechanism dictated by the manual instrumenting technique consists of a 16-in. diam wheel, driven by a synchronous motor, and geared to variable scanning speeds (1-in./min to 6-in./min in 1-in./min increments). The detailed design of this unit should be left up to the manufacturer, as the design will incorporate commercially available equipment, and it is felt that the manufacturer should have freedom of component selection. However, the detailed specifications (Appendix B) establish the minimum functions to be performed by the traversing mechanism; these must be accomplished in the final design.

4.0 CONCLUSIONS AND RECOMMENDATIONS

The following conclusions are drawn:

1. Utilization of the wire scanner with the manual instrumenting method only allows measurement of the neutron flux distributions and neutron spectral analysis at room temperature, with no coolant flow or pressure and in regions of low flux. This can be accomplished only during extended periods of shutdown (Minimum 14 days) if one quadrant of the SM-1 is to be mapped at one position per element. In addition, the positions of most importance could not be mapped by this method.

2. Utilization of the automatic wire scanner and the automatic instrumenting method allows rapid measurement of neutron flux distributions and neutron spectral analysis in preselected elements of the core at any time without a significant effect on the normal operation of the reactor. However, this method, which would supply the most desirable type of information, would also entail a major design and fabrication effort.

3. The neutron flux measurements achievable by the automatic instrumenting method are of value in furthering the state of the art of reactor core design. These measurements are:

   a. Corner thermal flux peaking as a function of core life.

   b. Fast and thermal flux versus core life and burnup through fuel element.

   c. Shift in power distributions in elements as a function of core life and burnup.

   d. Effect on axial power distributions due to xenon transients.

   e. Change in neutron energy spectrum as a function of core burnup and spatial distribution.

   f. Provide possible insight, in conjunction with appropriate machine calculations, into the problem of rod programming and/or fuel management for longer core life.

4. The following cost estimates, based on vendor catalog prices, represent only rough estimates for preliminary comparison between the proposed systems.

   a. Basic wire scanning system, block diagram indicated in Fig. 2.3.1; estimated cost - $16,500.00

b. Fully automated wire scanning system, block diagrammed in Fig. 3.1.1: estimated cost $50,000.00.

c. Tool design and fabrication for manual instrumenting method; estimated $4,000.00.

d. Design, fabrication, and installation of automatic instrumenting method, including special fuel elements, new pressure vessel cover, and new core support plate (exclusive of cost of fuel elements): estimated cost $120,000.00.

The following recommendations are made:

1. Consideration should be given only to the automatic type of instrumenting system, based on the value of the data received using the automatic instrumenting method compared to data received using the manual instrumenting method, the location of wire detectors in the elements and the operating conditions of the reactor as parameters of investigation.

2. Only the automatic wire scanner should be considered for the SM-1. While the cost of the automatic scanner exceeds that of the manual scanner, the savings in man-hours and the increase in quality and quantity of the data made possible by the automatic system far outweighs the cost differential.

3. An integrated automatic instrumenting system and automatic wire scanner should be let for bidding to ascertain more realistic cost estimates.

4. A new SM-1 core support structure should be designed and fabricated to accommodate the automatic wire scanning system. (4)

5.0 REFERENCES

1. Kemp, S. N., McCool, W. J., Moote, F. G., "PWR Research and Development Program Test Report, Gamma Scanning Spent SM-1 Core I Fuel Elements, Test 318", APAE Memo No. 281, April 6, 1961.

2. Coombe, J. R., "Hazards Summary Report for the SM-1 Core Temperature and Flow Instrumentation (Task XIV), APAE No. 79, March 30, 1961.

3. Hoover, H. L., "SM-2 Core and Vessel Design Analysis", APAE No. 69, Volume 3 of 3, March 8, 1961.

4. Brown, W. S., Dixon, M. H., "Fiscal Year 1962 Program Plan for Engineering Support and Development of Army Pressurized Water Reactor Power Plants," AP Note No. 378, September 6, 1961.

APPENDICES

APPENDIX A - LITERATURE SEARCH

1. Kalba, V. M., "EBWR Test Reports" ANL 6229, dated November 1960, Test Report 77, "Determination of Thermal Neutron Flux in EBWR by Cobalt-Activation," R. E. Bailey and R. F. S. Robertson, Page 221.

This report outlines a method of using activated Al-Co alloy wires to determine the flux distribution in the EBWR. However, the wires were cut into segments and weighed, disolved in HCL and then counted after evaporation. Therefore, the significance of this report to the present work is only in the type of wire used as a detector (Al-Co alloy wires, Co 0.50%, Mn 0.50%, remainder Al).

2. Kruger, Paul, "Neutron Spectrum Determinations at Low-Flux Levels", NSEC (t) -29, June 29, 1960.

This report describes the types of detectors that could be used for low flux levels, less than 10^6 N/cm^2-sec, to determine the neutron spectrum. This report also outlines several detector materials that can be fabricated in the form of wires, therefore applicable to the wire scanning technique.

3. Kliskman, A. E., et. al., "A Wire- Activation Technique for Reactor-Flux-Profile Measurements", BMI-1086, April 25, 1956.

The wire activation technique was applied to measuring the reactor flux - profile of the CP-5. These measurements were made with 10 mil diameter magnesium 0.01 a/o indium wire both bare and cadmium covered to measure thermal and epithermal neutron flux. This report describes the wire scanner, method used, and limitations to the problem all of which apply to this report.

4. Price, H. C. Jr., "New Type Threshold Detector Reactions", Nuclear Report 85, NP-8671, January 1960.

The report treates the potential utilization of a large body of nuclear reactions not known to have been previously utilized or even seriously considered for threshold detector work in the measurement of neutron spectra. These nuclear data are arranged as catalog type information and provide a wide selection of possible detector materials.

5. Wehner, D. R., "S 3 G Wire Scanner," KAPL-M-DRW-1, October 1, 1958.

This report describes in detail the multiwire scanner employed at KAPL. The information of this report offered a substantial basis for preparation of the conceptual design submitted in this report.

6. Boyard, Dr. R. T., "Comparative Thermal Flux Distributions, Mn vs. U^{235} Detections," WAPD-PWR-PL-146 (Del.), November 13, 1959.

An experiment was performed to determine whether a thermal flux traverse as measured with manganese detectors differs from that obtained with U-235 detectors. Results indicated manganese measured 3 percent lower than with uranium in the water reflector region. This was believed due to the thermal cross section of uranium decreasing more rapidly with increase in energy than the thermal cross section of manganese and therefore the uranium is more sensitive to variations in the thermal flux. This was enlightening with respect to the use of detector materials.

7. Steele, L. E. and Hawthorne, J. R., "Neutron Flux Measurements for Materials Irradiation Experiments at Argonne National Laboratory, Brookhaven National Laboratory, Oak Ridge National Laboratory, and National Reactor Test Station", NRL Report 5483, May 23, 1960.

Using cobalt, cadmium-shielded cobalt, nickel, and sulfur detectors, flux measurements were made for the ANL-CP-5, BNL-GR, NRTS-MTR, and the ORNL-LITR. The neutron flux data for high-flux positions in these four research reactors showed a high-degree of correlation with changes in materials properties after irradiation. The type of detectors used along with the method assisted in establishing design criteria for this report.

8. Frost, R.T., "An Automatic Neutron Flux Scanner," KAPL-1117, March 1, 1954.

A description of a wire scanning device that corrects automatically for any smooth time decay of radioactivity during scanning without recourse to an empirical decay curve and without required knowledge of the exact time of reactor scram. This report assisted in the enhancement of the historical background necessary for the preparation of this report.

9. Hogg, C.H. and Weber, L.D., "ETR Fast Neutron Flux Measurements", IDO-16535, January 8, 1960.

The fast neutron fluxes greater than 1 mev in energy at certain locations in the MTR and ETR have been measured with the threshold detectors, Al, Ni, and S. Satisfactory agreement was realized when the three monitors were used to measure a given flux and nickel proving to be the more desirable detector. This report assisted in the survey of detectors section of this report.

10. Hogg, C.H., and Weber, L.D. "ETR Cycle 18 Thermal and Fast Neutron Flux Measurements", IDO-16563, dated June 20, 1960.

The method is described for measuring the thermal and fast neutron flux using wire activation technique and the MTR wire scanner. This added to the historical background for this report.

11. Barkelew, C.H., "The Slow-Neutron Flux in the Vicinity of a Strongly Absorbing Fine Wire, ORNL, CF-53-3-36, March 3, 1953.

The use of perturbation theory to calculate the variations in flux in the neighborhood of a small absorber is not entirely satisfactory when a characteristic dimension of the absorber is smaller than the mean free-path for the diffusion of neutrons. If, however, the absorber is extremely small compared to the mean free-path, the method described in this report may be used to estimate the flux at any position inside or outside the absorber.

12. "Thermal Neutron Flux Measurement at the MTR-ETR Site," IDO-16538, October 28, 1960.

The purpose of the report was to present the general methods of thermal neutron flux measurement being practiced at the MTR-ETR site, to describe special problems of interest to other experimenters and to discuss the errors involved. The author intentionally avoided detailed discussions of counting equipment, positioning of monitors in reactors and measured thermal neutron flux values. This report was for the general interest area of the problem.

APPENDIX B - SPECIFICATIONS

The wire scanner must meet the following set of specifications:

1. Traversing Mechanism

1.1 The traversing mechanism must accommodate wires up to four feet in length and 1/16 inch diameter. It is recommended that this be in the form of a 16 inch diameter wheel driven by a synchronous motor for the manual instrumenting method. For the automatic instrumenting method, the traversing mechanism will be replaced by the drive assembly.

1.2 The traversing mechanism must have variable scanning speeds - range from 1 inch per minute to 6 inches per minute in 1 inch per minute intervals, a slip clutch for rapid manual reset, a position signal to the x axis of the x-y plotter with an overall accuracy of ± 1/64 inch, and a position signal output for automatic recording by the data processing unit.

1.3 The traversing mechanism must be equipped for automatic programmed stops, during the traverse, ranging from 1/4 inch to 3 inch intervals with an accuracy of 1/64 inch, adjustable in steps of 1/4 inch and supply a signal to the program timer when each stop has been initiated.

1.4 The chucks for holding the wires must be designed and manufactured to allow rapid and simple attachment and removal of the wires. A maximum time of 5 secs should be required to manually attach a wire to the scanning mechanism. This for the manual method only.

1.5 The manufacturer must demonstrate upon delivery of the equipment that all specifications have been satisfied.

2. Background Shield

These specifications are dictated in Section 3.1 of this report and illustrated in Figure 3.1.1.

3. Collimators

These specifications are dictaged in Section 3.1 of this report and illustrated in Figure 3.1.2.

4. **Detectors**

Type: NaI (tl) crystal optically sealed to the photo multiplier tube, all encased in a plastic container with outside dimensions of 1-3/4" diameter.

Size: 1-1/2" diameter by 2" high

5. **Photomultiplier Tube**

Spectral Response: S11

Average Sensitivity: 60 Monys/lumen

Current Amplification: at 105 volts/stage = 215, 000
at 145 volts/stage = 2, 000, 000

Size: 2" diameter

6. **Preamplifier**

Maximum Gain: 1

Rise Time: 0.05 μsec.

Clipping: 200 μsec.

Band width: 5 μc

Input Impedance: Compatible with the detector system

Output: Linearity 1%
Impedance compatible with the amplifier system

Receptacles: Compatible with the system

Power Requirements: + 265 at 10 ma,
6.3 at 0.45 amps

Maximum Dimensions: 2-1/2" x 2-1/2" x 9" d.

Maximum Weight: 3 lbs.

7. High Voltage Power Supply

Range: 500 v to 2500 v, continuously variable by adjustment of "coarse" and "fine" potentiometer controls.

Polarity: Choice of positive or negative through the same connector by means of a front panel switch which also has an off position.

Stability: 0.02% per day

Line Regulation: 0.00035% per volt line change from 105 v to 125 v.

Load Regulation: Output voltage change less than 0.35% for a load current increase from zero to maximum.

Ripple: Less than 0.01% of output voltage.

Maximum Current Output: 5 ma

Power Requirements: 110 v, 60 cycle at 0.25 amps

Receptacle: Output, compatible to integrity of the system.

Maximum Dimensions: 19" w x 5" h x 14" d preferably smaller and transistorized.

Maximum Weight: 30 lbs. preferably lighter weight.

Power on-off switch and voltage meter on front panel.

Experimental proof specs have been met - must accompany supply on delivery.

8. Linear Amplifier (Non-overloading)

Rise Time: 0.2 μsecs.

Maximum Gain: 90 to 6,400 by choice of "coarse" and "fine" gain controls.

Decay Time: (Clipping): 1 sec by means of delay line.

Band Width: 2.0 mc

Noise: Less than 0.5 v rms

Input polarity: Negative

Output: High, low, level, and pulse height selector impedance compatible for system integrity with 0.5% linearity.

Controls: Power on - off
coarse gain
fine gain
pulse height selector
all mounted on front panel

Gain Stability: A change in line voltage of ± 15 volts from 110 v should affect the gain by less than 0.5%.

Temperature Requirement: Should remain stable in a temperature environment from 40 to 90° F.

Overload: Recovery times should not exceed 11 μsec for 100 x overload and 15 μsec for 1000 x overload.

External Power: + 265 @ 10 ma and 6.3 v at 1 ma.

Receptacles: Rear mounted input, high level output, low level output, pulse height selector output and preamplifier connector and compatible for system integrity.

Power Requirement: 110 v, 60 cps.

Dimensions: Not to exceed =
19" w x 8" h x 14" d preferably smaller and transistorized.

Weight: Not to exceed 55 lbs.

9. Single Channel Pulse Height Analyzer

Baseline: Large dial 10 - turn potentiometer, variable 0-100 v in 1,000 divisions, within 0.5% linearity, and 0.1% accuracy.

Channel Width: Large dial 10-turn potentiometer, variable 0 to 7 v in 700 divisions, within 0.5% linearity, and 0.1% accuracy.

Input Pulses: 0-100 v positive

Output Pulses: 15 v negative

Stability: Baseline better than 0.3%
Window width better than 1%

Motor Drive: 3 speed - 10, 20, and 40 minutes, reversible with automatic shut-off.

Receptacles: Input and Output compatible with system.

Power: 115 v, 60 cps

Maximum Dimensions: 19" w x 9" h x 14" d preferably smaller and transistorized.

Maximum Weight: 60 lbs.

Integral and differential pulse height selection switch.

10. Linear Count Rate Meter

Linear scale selectable by 6 position front panel switch and automatic range switch.

0-10 cpm
0-100 cpm
0-1000 cpm
0-10000 cpm
0-100, 000 cpm
0-1, 000, 000 cpm

Zero Set: Front panel mounted zero set knob.

Linear accuracy: Better than 1% on all ranges.

Input Impedance and Signal: Compatible with the integrity of the system.

Resolving Time: Faster than 3 μsec.

Time Constants: Selectable by 6 position front panel mounted switch.

0. 3 sec
1. 0 sec
3. 0 sec
10. 0 sec
30. 0 sec
100. 0 sec

Output: Front Panel Indicator Recorder Drive

0-10 mv
0-100 mv
0-1 ma

Receptacles: Input and output - Compatible with system.

Power Requirement: 115 v, 60 cps

Maximum Dimensions: 19" w x 9" h x 14" d preferably smaller and transistorized.

Maximum Weight: 50 lbs preferably less.

11. High Speed Scaler

Count Capacity: 999,999 counts

Resolving Time: Faster than 1μ sec.

Input Sensitivity: Compatible with system.

Input Impedance: Compatible with system.

Counting Speeds: Up to 100,000 cps

Controls: Power on-off
Count on-off
Mode switch; manual, preset time, 60 cycle test.

Output: Compatible to the digital counter converter input.

Remote Control: Capacity for remote control for count, stop, and reset.

Power Requirements: 115 v, 60 cycle

Maximum Dimensions: 19" x 4" h x 14" d preferably less and transistorized.

Maximum Weight: 20 lbs.

12. Digital Counter Converter

Detailed specifications for this component are dictated by the Summary punch unit and program timer. Therefore, the manufacturer will have to specify this component based strictly on the integrity of the system as well as the functions it is to provide. The digital counter converter will supply the counts received from the scaler to the IBM Summary Punch unit in a form the punch unit can interpret.

13. IBM Summary Punch Unit

Again, this unit will have to be designed and specifications prepared for the function it is to perform and to comply with the scanning system. In order to establish the design criteria for this unit, the following functions are described.

13.1 The IBM Summary punch unit should receive from the digital counter converter the counts for a specific position of the wire and transfer this information to an IBM punch card.

13.2 It should be received from the program timer, a signal of the time the counting was started and punch this information on the same punch card.

13.3 It should receive from the traversing mechanism, a signal indicative of the position of the wire that is being counted and transfer information to the same punch card.

13.4 It should accept a manual input of the code number for the wire to be counted at the beginning of each scan and punch this code number on all cards punched for that wire.

13.5 It should accept a manual input of the code number corresponding to the irradiation run number and transfer this information to all punched cards for all wire scans taken for this irradiation run.

14. Program Timer

The program timer is the heart of the automatic scanning system since it will control all of the functions. This then eliminates the possibility of outlining the specifications in detail, but rather, leaves that to the discretion of the manufacturer in the fulfillment of the functions listed below:

The program timer must transmit and receive signals in the following sequential order to control the complete wire scanning system.

14.1 Transmit signal to the traversing mechanism for movement to the next stop position.

14.2 Receive signal from traversing mechanism when next stop position has been obtained, interpret and submit the following signals.

1. Count signal to scaler.
2. Time count was started signal to IBM summary punch unit.
3. Establish a predetermined counting interval.

14.3 At end of counting interval, as prescribed by the timer.

1. Stop signal to scaler.
2. Punch out signal to IBM summary punch unit and digital counter converter.
3. Reset signals to scaler and use digital counter converter.

14.4 Repeat sequence from 14.1 until the wire has been completely scanned at all stops that were originally prescribed at the traversing mechanism.

It is suggested that a cam timer similar to the Industrial Timer Co., Model MC-4 and a Microflex Clock Timer with auxiliary relays could possibly fulfill the specified functions.

15. X-Y Plotter

Calibration: Built-in axis calibrated time sweeps

Ranges: Calibrated ranges for each axis

0.1 sec/inch
0.2 sec/inch
0.5 sec/inch
1.0 sec/inch
2 sec/in
5 sec/in
10 sec/in
20 sec/in
50 sec/in

Zero Set: One for each axis

Sweep: Start, stop, and reset

Paper Size: 8-1/2" x 11"

Maximum Dimensions: 12" w x 5" h x 12" d preferably smaller and transistorized.

Maximum Weight: 25 lbs.

16. Miscellaneous System Specifications

16.1 Electrical references built into the system for calibration of the count rate meter, amplifier, scaler, and pulse height analyzer.

16.2 Weight considerations are a must - Transistorized circuitry should be used where possible to minimize not only the weight, but also the size of the system.

16.3 The system should be housed in attractive cabinets of smallest possible dimensions not to exceed 200 lbs. per cabinet.

APPENDIX C - LIST OF VENDORS

Based on replies received from possible vendors interested in bidding on a wire scanning system, the following suggested list of vendors is given:

a. Lockheed Aircraft Corp.
Lockheed Nuclear Products
Dawsonville, Georgia

Contact: Mr. Frank P. Harmon

b. Teleflex Incorporated
Nuclear Products Division
P. O. Box 218
North Wales, Penna.

Contact: Mr. Robert J. McGurk

c. Special Nuclear Projects
Convair, Fort Worth, Texas

Contact: Mr. E. C. Kidd

d. General Nuclear Corporation
P. O. Box 3211
Santa Ana, California

Contact: Mr. Hugh M. Griffin

e. Charles Walsh Associates, Inc.
173 Lake Ave.
Greenwich, Conn.

Contact: Mr. Robert W. Kichtinger