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INTRODUCTION

This manual contains the WANEF administration controls, personnel responsibilities, and reactor operating procedures. Also included in the manual are a brief description of the facility and the control and safety systems for the reactors.

Operations will be conducted within the boundaries of this document, of WANL-TME-1295, Rev. * WANEF Operating Limits, and within the framework of WANL-TNR-099, Rev. *, Safety Report for the Westinghouse Astronuclear Experimental Facility (PAX and FCX).

Changes to the Reactor Operations Manual which deviate from the limits specified in the Operating Limits document or from the intent of the currently approved Reactor Operations Manual must be reviewed by the Nuclear Safety Committee (NSC) and then together with the necessary supporting analysis referred to the Aerojet-General Corporation (AGC) and the Space Nuclear Propulsion Office (SNPO) with a request for approval.

Changes to the Reactor Operations Manual which do not change the intent of the currently approved Reactor Operations Manual and do not exceed the limits of the operating limits document and do not introduce the possibility of an accident not analyzed in the safety report and do not increase the probability or the consequences of any accident analyzed in the Safety Report or its supplements, must be reviewed by the NSC and recommended by them for approval to the Project Manager. Recommendation for approval for such changes in the Reactor Operations Manual may be made to the Project Manager by an appointed subcommittee of the NSC providing that the decision is unanimous and action is documented and submitted to the Chairman of the NSC.

Copies of all changes and revisions to the Reactor Operations Manual will be sent to AGC and SNPO/C.

*Latest approved issue.
CHAPTER 1

ADMINISTRATIVE CONTROLS

1.1 GENERAL

It is generally recognized that by their very nature, critical facilities require latitude in their operation. It is necessary, therefore, to establish carefully the ground rules under which facility operations are performed. Described below are the administrative controls which will ensure the safe operation of WANEF. These controls, coupled with the complete set of Standard Operating Procedures of Chapter 5, provide the required personnel and equipment safety.

1.2 OPERATING RULES AND REGULATIONS

Presented below are regulations governing the operations of WANEF. They cover certain personnel requirements and restrictions, general operating regulations and safety instrumentation and devices required for operations. Listed with each rule is a statement of the intent to aid personnel in adhering to the desired purpose of the rule.

1.2.1 Personnel Rules

Rule 1. The Scientist-in-Charge must approve all experimental, operating, fuel handling, and emergency procedures before they are put into effect.

Intent of Rule 1. The intent of this rule is to ensure that all procedures governing operations at WANEF receive a complete review prior to being issued so that they may be compared with the latest technical and programmatic requirements and to ascertain that they are consistent with AGC/SNPO requirements, WANL Nuclear Safety Committee decisions and management instructions.

Rule 2. One Experimentalist-in-Charge will be designated by the Scientist-in-Charge to execute each critical experiment and operating personnel will be notified of his identity.
Intent of Rule 2. It is necessary that one and only one competent person be assigned the overall responsibility for each experiment and that operating personnel know who this person is.

Rule 3. All persons in the following areas are subject to the direction of the Experimentalist-in-Charge: Operational Areas, and the Control Room during operations.

Intent of Rule 3. The intent of this rule is to assure that the Experimentalist-in-Charge is cognizant of all operations being carried out in the "Operational Areas" as shown in Figure 1.1 and in criticality zones containing fuel, and also to assure that dual responsibility does not occur from independent operations being performed by separate working teams. It is the responsibility of each person working in the various operational areas to contact the Experimentalist-in-Charge and receive his approval prior to beginning work.

Rule 4. A. During all critical experiments, at least two persons will be present in the control room. With the exception noted in Paragraph B below, one shall be rated equal to or greater than Reactor Operator and the other equal to or greater than Experimentalist.

B. The minimum qualification for the person at the console is that of Reactor Operator-in-Training. Under this circumstance, the second person present must be rated equal to or greater than Experimentalist-in-Charge and the Reactor Operator-in-Training has demonstrated the capability of recognizing the need for and executing emergency shutdown action.

C. During all critical experiments, the Experimentalist-in-Charge will remain at WANEF.

Intent of Rule 4. It is the intent of this rule to assure that the reactor is always adequately attended during operations. Reactor operation begins when the "Reactor Status Lights" are placed in the "Reactor On" condition. The exception to this is when the "Reactor On"
Figure 1.1 Operational Areas
condition is required to perform reactor maintenance and the Daily Checkout. In no case will there be dual responsibility in the control room for reactor operations. The person required in the control room rated equal to or greater than Experimentalist will be in charge of the reactor operation. Prior to beginning reactor operation, the personnel required in the control room will sign the Operations Log indicating that all conditions for reactor operation have been satisfied. Other personnel sign for proof of presence.

Rule 5. There shall be a person qualified as Reactor Operator in the control room at all times when the "Master Key Switch" is ON, and there is a reactor in the test cell.

Intent of Rule 5. The purpose of this rule is to ensure that a person who is familiar with the reactor control systems and can interpret the indication on the various control channels be in the control room when the control elements can be engaged. This rule shall be in effect during all operations where the Master Key is in the console even though other interlocks, such as the Cell Veto, prevent startup.

Rule 6. No person is to be allowed in the Test Cell while changes in the critical assembly are made remotely, if these changes are of a type that may credibly violate the minimum shut down requirements given in Section 3.4 of the Operating Limits Document.

Intent of Rule 6. It is the intent of this rule to protect personnel from the effects of an inadvertent criticality. Personnel may be present when only one control element is being moved remotely for checkout or maintenance with the remainder of the mechanisms locked and the keys secured.
Intent of Rule 10. It is essential that each individual participating in an experimental procedure have a complete understanding of the objectives. This requirement, which ensures that safe practices are maintained and that the maximum benefits from the experiment are achieved, is primarily satisfied by ensuring that each participating person has read and understood the applicable Experimental Details Checklist and knows precisely what his task is in the overall plan. By each person reviewing the experimental plans prior to the start of a test, the methods employed in conducting the test receive a final review insofar as their safety aspects are concerned. Another important reason for reviewing and agreeing on the plans prior to the start of the experiment is to ensure that all participating members know precisely what experimental data are required to satisfy the test objectives.

Rule 11. Two persons authorized and instructed by the Scientist-in-Charge must be present when the reactivity of the reactor assembly is being changed by adding, removing, or re-arranging material. One of the persons at the reactor assembly must be rated equal to or higher than Experimentalist and must inspect the critical assembly before, during and after any changes in core loading. A third person qualified as Reactor Operator must be present at the console. To ensure that the Experimentalist-in-Charge is cognizant of the type and magnitude of the change to the reactor assembly, he will sign the Manual Change Checklist prior to the change being realized.

Intent of Rule 11. It is possible, by improper handling of a core change, to assemble an unsafe core configuration. This condition could be generated in a number of ways, with the most common errors being
inadequate guidance of the personnel making the change, improper maintenance of change records, and inadequate inspections before, during and after the changes. To prevent such conditions from arising at WANEF, the primary intent of this rule is to ensure that the following practices are maintained:

1) All adjustments in the core are performed only by those personnel who have been adequately trained and authorized by the Scientist-in-Charge.

2) Complete records indicating each individual core change will be maintained by the Reactor Operator in the control room.

3) Upon completion of the core change a person qualified as equal to or greater than Experimentalist will examine the core and the change records to ensure that they have been properly completed.

Rule 12. Two persons authorized and instructed by the Scientist-in-Charge must be present when fuel elements are being handled, assembled, or disassembled, in the fuel storage and/or fuel assembly areas.

Intent of Rule 12. Since it is possible that errors in the handling, assembling or disassembling of fuel materials can result in conditions which potentially can lead to nuclear hazards, the possibility of such errors is minimized by having two authorized persons present when such operations are performed to cross-check actions and decisions.

Rule 13. Names of persons authorized by the Scientist-in-Charge to be contacted in emergency situations in the facility will be posted in a location that is accessible to the security guards.
1.2.2 General Operating Procedures

Rule 1. Before any critical experiment is performed, the Standard Operating Procedure under which it shall be performed will have been reviewed and approved according to the procedures of Section 5 of the Operating Limits Document. The review by the NSC will include assurance that the boundaries of operational approvals will not be exceeded.

Intent of Rule 1. It is the intent of this rule to ensure that an established method for performing the particular experiment is set forth and given considerable review prior to the initiation of the experiment. Such a review is supplemented by the use of the Experimental Details Checklist, see Section 1.3. The personnel involved in the experiment can review the procedure and thus gain an understanding of exactly what the objectives of the experiment are and the method to be used in accomplishing these objectives.

Rule 2. Prior to and at the completion of each working day the Experimentalist-in-Charge will inspect the test cell and reactor assemblies. Each day, prior to beginning experimental operations, satisfactory operation of all pertinent systems must be demonstrated and recorded. A daily checkout sheet will be employed and logged.

Intent of Rule 2. It is the intent of this rule to ensure that the reactor assembly and associated instrumentation, safety circuits, and controls are always checked out for operation. It is the responsibility of the Scientist-in-Charge to see that these checkouts are performed by qualified personnel. A person rated equal to or greater than Experimentalist-in-Charge will inspect the test cell and reactor assembly. The reactor systems checkout will be done under the cognizance of a person rated equal to or greater than Reactor Operator. A Daily Checkout form will be utilized for the above checks. A visual check of the facility and core by the person
required in the control room rated equal to or greater than Experimentalist, as well as a check of safety instrumentation will be made any time operations are interrupted and personnel could have had access to the core assembly.

Rule 3. Each approach to critical after a major assembly change must be accompanied by neutron multiplication measurements, which can be used to predict the point of criticality by appropriate extrapolation. During the fuel loading phase of initial criticality, a special loading source will be utilized, normally located in the central region of the initial fuel loading.

Intent of Rule 3. It is the intent of this rule to provide the experimental basis, that is, a series of subcritical multiplication measurements for a prediction of the critical condition for a new assembly in order to prevent a surprise criticality. The various degrees of subcriticality are obtained by changes in fuel or poison loading, geometry changes, and changes in control element position. The procedure should be such that at the end of each step the experimental values of the next step can be predicted by extrapolation. Frequently, assemblies may be constructed or a loading change made using previously tested fuel or poison components. In such instances portions of the detailed approach procedure may not be necessary. The details will differ in specific cases. The Scientist-in-Charge must determine that the approach procedure selected for each assembly operated will prevent a surprise criticality.

Rule 4. Remote increases in reactivity shall be made in a safe and reversible manner wherein the rate of increase is less than the available rate of decrease.
Rule 7. Criticality must be attained only by the motion of control elements.

Intent of Rule 7. Reactivity can be controlled more easily and in a more predictable manner with control element motion than by any other means. Specifically, criticality shall not be achieved by the addition or the removal of experiments or other devices used to measure or monitor reactor parameters.

Rule 8. No core will be operated critical with a control element pattern which prevents achieving shutdown with a single control element stuck in the full out position.

Intent of Rule 8. Any core which is assembled in a manner that could produce criticality by the withdrawal of a single control element is to be considered as an unsafe configuration. In such a core not only should the "stuck rod" incident be considered but also in the event that personnel not aware of the present core loading, should, for maintenance or other purposes, begin checking drive speeds, etc., over the operating range of a control element a serious accident could occur.

Rule 9. A "key box" that can only be opened by the Scientist-in-Charge or the Experimentalist-in-Charge will be provided for storage of the following keys:

a) Control console master switch  
   f) Yard gates keys
b) Control element locks (12)  
   g) Test cell personnel door
c) Interlock panel door  
   h) Labyrinth door key
d) PAX cover locks  
e) Fuel assembly room door
Intent of Rule 9. It is the purpose of this rule to provide absolute control of critical areas and equipment by ensuring that the Scientist-in-Charge and/or the Experimentalist-in-Charge is made aware of the work in progress in the areas or on the equipment listed above. Access to keys a), b), c), d) require the physical presence at WANEF of the Scientist-in-Charge or Experimentalist-in-Charge.

Access to e), f), g), h) requires the physical presence of the Scientist-in-Charge or Experimentalist-in-Charge if fuel is present in that area.

Rule 10. Keys to the control locks will be under the administrative control of the Scientist-in-Charge or an Experimentalist-in-Charge at all times when not in the "key box" specified above. The keys will be given to the Experimentalist designated by the Experimentalist-in-Charge to perform an experiment or series of experiments. At the completion of reactor operations, the keys will be returned to the Experimentalist-in-Charge. When fewer than twelve control elements are operational in a reactor, the excess keys will be captured in the console by-pass key switches.

Intent of Rule 10. It is the purpose of this rule to ensure that the Scientist-in-Charge and/or Experimentalist-in-Charge is cognizant of all operations that require unlocking any of the control elements on either the PAX or FCX reactors. Also, as a guarantee against control elements of both reactors being in the unlocked condition at any given time, all control element keys not in use on one reactor will be captured in the console key switches.

Rule 11. Water or other liquids are not permitted in the test cell when a reactor is present except under one of the following conditions:

1) Required liquids are used in containers and with procedures such that it will be incredible for the fluid to get into the core. The Nuclear Safety Committee will review and recommend for approval the container design and the procedures to be used such that the incredibility of fluid getting into the core is assured.
2) When the reactors are shutdown, liquids may be used in limited amounts such that if the entire contents of the container is introduced into either core the reactivity insertion is $< 1.00\%$.

Intent of Rule 11. The presence of water or any other liquids in the test cell when a reactor is present presents a potentially hazardous condition arising from an accidental criticality. It is the purpose of this rule 1) to guarantee through proper container design and procedures that such liquids cannot get into the reactor, or 2) to limit the amount of such liquids to quantities which, if spilled into a shutdown reactor, could not bring it critical. See SOP-5.7, "Procedure for Control of Liquids in the Test Cell" for detailed procedures.

Rule 12. Each component or system which affects the safety response and operation of the facility will undergo periodic maintenance and calibration according to a pre-established maintenance procedure. In particular, this includes the shutdown systems, the safety and interlock circuits and radiation monitoring systems. The periodicity shall be at least once annually.

Intent of Rule 12. It is the primary purpose of this rule to ensure that all systems which affect the safe operation of the facility are maintained in an operational condition. In particular these systems include the shutdown systems, the safety and interlock circuits and the radiation monitoring system.

Rule 13. If an unanticipated reactivity change of the FCX occurs on a day-to-day basis, as evidenced by a corresponding change in rod bank and/or period measurements, which exceeds $0.20\%$, the reactor shall be shutdown and the Experimentalist-in-Charge notified and the situation evaluated. Attention is called to the fact that a change less than $0.20\%$ will require reactor shutdown if the limit on $k_{ex}$ is exceeded.
Intent of Rule 13. It is the purpose of this rule to ensure that a proper evaluation of the reactivity swing in the FCX reactor is performed on a day-to-day basis. The FCX can contain KIWI type fuel and on a day-to-day basis reactivity changes in the core may occur due to changing test cell conditions. Since the FCX is limited to $0.50k_{ex}$, small changes in the core reactivity could cause the $k_{ex}$ limit to be violated. Thus close surveillance of daily changes must be maintained.

Rule 14. Prior to any PAX reactor operations, at least one hose of the PAX Auxiliary Shutdown System (PASS) shall be connected to PAX. Experiments for which the PASS hoses cannot be physically connected to the reactor will be performed in accordance with S.O.P. 5.5.8 as contained in the latest revision of the WANEF Reactor Operations Manual (Chapter 5). The PAX reactor shall not be started up (or, if operating, shall be shut down) when the console light indicates insufficient power available for PASS operation.

Intent of Rule 14. It is the intent of this rule to prevent operation of PAX without the PASS in operable condition.
1.3 EXPERIMENTAL DETAILS CHECKLIST

The EDC provides the basic mechanism by which a reactor experiment is reviewed and approved for nuclear safety. Usually written in response to a test request, it describes the materials required, the hazards involved, the general method and the experimental procedure to be employed, and the data required to complete the experiment successfully. (A sample outline is shown in Figure 1-2). No reactor experiment may be performed without a properly approved EDC. Previously approved EDC's can be utilized for the performance of equivalent experiments.

An EDC is prepared using the test request, if one is available, together with the physical design requirements for reactor experiments as given in Section 7.4 of the revised WANL Safety Report as guides. Applicable portions of Standard Operating Procedures (SOP's) or previously approved EDC's may be incorporated by reference. The EDC must be reviewed and recommended for approval by the Scientist-in-Charge. If the Manager, Thermal and Nuclear Design, decides that it is within the limits of the Operating Limits document, and is consistent with portions of one or more SOP's in the Reactor Operations Manual and does not involve either unevaluated questions of safety* or operations which are expected to exceed the radiation exposure limits (AEC Manual Chapter 0524), then he will approve it and send information copies to cognizant non-line personnel. If it does not fall clearly into this category, he must submit it to the Nuclear Safety Committee (NSC) for review and a determination as to whether or not it does fall into the above category. If the NSC finds that it does fall into the category, it will recommend for approval to the Project Manager. If the NSC finds, however, that it does not fall into the above category, a description of the experiment will be submitted to AGC and SNPO with a request for approval. The request for approval will include a supporting safety analysis and/or a description of the appropriate engineered safeguards.

* Unevaluated questions of safety exist if: 1) there is a possibility of an accident occurring which has not been analyzed in the WANL Safety Report or its Supplements, or if 2) there is an increase in either the probability of an accident previously analyzed or if 3) there is an increase in the consequences of an accident previously analyzed.
EXPERIMENTAL DETAILS CHECKLIST

TITLE OF Experiment:

OBJECTIVE:

EQUIPMENT REQUIREMENTS:

HAZARDS CONSIDERATIONS:

EXPERIMENTAL DETAILS:

DATA REQUIRED:

WRITTEN BY: _______________________________ Date: __________

SIC: _______________________________ Date: __________

MANAGER, THERMAL & NUCLEAR DESIGN: _______________ Date: __________

Figure 1.2 Form of Experimental Details Checklist
occurrences during reactor operation or experimental changes; explanations of all
unscheduled shutdowns including the causes and the corrective action taken; receipt of
fuel; control system malfunction (e.g., noisy micromicroammeter); inspection tours; and
power outages. Entries in the Log can be made by any WANEF staff member who shall
identify himself with his initials. The Facility Log will be cross-referenced to the Reactor
Operations Log, when required.

1.5.4. Other Records

In addition to the above a complete file of Experimental Detail Checklists
will be kept as well as Maintenance Logs on the major reactor systems.
1.6 ACCESS TO WANEF

For personnel safety the various areas in the WANEF facility are classified as either "Operational" or "Non-Operational" with different regulations on personnel access for each.

1.6.1 Operational Areas

Those areas which are classified as "Operational" are shown in Figure 1-1. Access to one of these areas when it contains fuel requires the physical presence at WANEF of the Scientist-in-Charge or an Experimentalist-in-Charge. The keys and lock combinations for all Operational areas together with the reactor control keys are kept in a "key box." Only the Scientist-in-Charge and Experimentalist-in-Charge may open this "key box."

1.6.2 Non-Operational Areas

The areas at WANEF which are not classified as Operational areas as shown in Figure 1-1 are designated as Non-Operational Areas. Access to these areas at any time (except for the Site security guard) requires the presence of at least one WANEF staff member. Access to the WANEF premises is controlled by a "card lock" on the main entrance of the facility.

1.6.3 Visitors

All visitors to the Waltz Mill Site must stop at the Site guard post to sign a "Visitors Register". Upon reaching the WANEF entrance persons other than the WANEF staff must ring a bell for admittance and upon entry will be required to sign the WANEF "Visitors Register" and pick-up two pocket dosimeters which must be worn at all times while at WANEF. (Note: The term "visitor" is used to designate all persons who do not have a WANEF "door card". )

All Westinghouse Astronuclear employees and certain Waltz Mill Site employees shall be identified by picture badges issued and controlled by the Astronuclear Security office, and the Westinghouse identification badge, which contains a photograph and identifying information. All other persons will be handled in accordance with the
CHAPTER 2
PERSONNEL RESPONSIBILITIES

2.1 GENERAL

The protection of all personnel at a critical facility from nuclear as well as non-nuclear accidents is the responsibility of all persons connected with the operation of the facility and this responsibility follows the usual lines of organizational authority.

The purpose of this chapter is to set forth the responsibilities of the personnel insofar as safety is concerned and to indicate the various methods to be employed in ensuring personnel safety.

2.2 PROJECT LINE RESPONSIBILITY

2.2.1 Higher Management Responsibility

The Manager, Thermal and Nuclear Design has a major responsibility for nuclear safety at WANEF. He approves the Experiment Details Checklists providing that they are within the limits specified in Chapter 5 of the Operating Limits document. He also must concur with the Scientist-in-Charge on certain changes to the reactor, the test stands and facility as specified in the Operating Limits document.

The member of line management next above the Manager, Thermal and Nuclear Design, is responsible for any corrective action which must be taken as a result of the periodic inspections which are made by competent technical personnel outside of the WANEF line organization to assure conformance to the established nuclear safety requirements.

2.2.2 Scientist-in-Charge

2.2.2.1 General

The direct responsibility for preventing injury to personnel at WANEF rests with the Scientist-in-Charge. He is responsible for ensuring that no accidents or injuries to personnel result from the operation of the facility or reactors. Within the
latitude of the minimum safeguard requirements which have been established by WANL policy and AGC/SNPO regulations, the Scientist-in-Charge has the authority to institute whatever provisions he deems necessary to discharge his safety responsibilities. In no case may he deviate from the safety measures which have been established by WANL management as in the Operating Limits document or the WANEF Safety Report. Whenever, in the judgment of the Scientist-in-Charge, conditions exist in the area of the reactor which compromise personnel safety, he will not start up the reactor, or if operating he will shutdown and take whatever corrective action is required to eliminate the unsafe condition. He will report promptly to higher management and to AGC/SNPO any change in the physical condition of the reactor or its operating characteristics that might, in his judgment, affect the safe operation of the reactors. He will shutdown the reactor immediately whenever so instructed by AGC/SNPO or higher management.

2.2.2.2 Specific Responsibilities

The Scientist-in-Charge is responsible for:

1. The safe operation of the WANEF facility.
2. Reviewing and recommending for approval to the Manager, Thermal and Nuclear Design, the WANEF Experimental Details Checklists.
3. Requesting reviews by the WANL Nuclear Safety Committee of all procedures which require changes in this manual or the "WANEF Operating Limits" document or which involve an unevaluated safety question.*
4. Requesting a review and a recommendation for approval by the WANL Nuclear Safety Committee for changes in this manual.
5. Training and qualification of operating and maintenance personnel.

* Defined in Section 1.3
2.2.2.3 Authority

The Scientist-in-Charge is authorized to:

1. Review and recommend for approval the Experimental Details Checklist and submit copies to the Manager, Thermal and Nuclear Design, and the test requester.

2. Execute the weekly program submitted to the Manager, Thermal and Nuclear Design.

3. Approves modifications and additions to the WANEF facility which do not represent an unevaluated safety question and are within the limits of the Operating Limits document.

2.2.2.4 Accountability

The Scientist-in-Charge is accountable for:

1. The safe operation of the WANEF facility.

2. The existence of an approved Experimental Details Checklist and procedure for each reactor operation, reactor experiment and reactor modification.

3. Obtaining reviews by the WANL Nuclear Safety Committee of all:
   a. Changes in this manual
   b. Modifications and additions to the WANEF facility which represent an unevaluated safety question or are not within the limits of the Operating Limits document.

4. Obtaining a semi-annual review by the WANL Nuclear Safety Committee
2.2.3 Specific Responsibilities of Experimentalist-in-Charge

The Experimentalist-in-Charge is responsible for execution of approved programs including reactor operation in accordance with the approved procedures. In the absence of the Scientist-in-Charge he is authorized to conduct such programs and is responsible for the safe operation of the facility.

2.3 WANEF STAFF

2.3.1 General

An important part of the safe operation of any critical facility is the clear designation of the personnel responsibilities and limitations. To ensure that all personnel are cognizant of their responsibilities and that each person is properly qualified for the position he holds, a list of position descriptions and the required minimum qualifications for each position is presented below.

2.3.2 Position Descriptions

1. Scientist-in-Charge (WANEF Manager)

The Scientist-in-Charge has the overall final responsibility for the operation and safety of the WANEF. He makes decisions concerning personnel employed, operating procedures, equipment purchased, visitors admitted, personnel training program, and all other matters that concern the safe and efficient operation of the WANEF. These decisions are subject to review and approval by higher management, but this does not relieve him of the final responsibility for the decisions. He also serves as the Security Officer for WANEF.

2. Experimentalist-in-Charge

The Experimentalist-in-Charge assists the Scientist-in-Charge in meeting his responsibility for reactor operation. He has the authority to execute the experimental plan established by the Scientist-in-Charge, but not to change it in any way.

3. Experimentalist

The Reactor Experimentalist assists the Scientist-in-Charge or the Experimentalist-in-Charge to execute the experimental plan.
4. **Reactor Operator**

A Reactor Operator can be authorized to change the reactivity of a critical experiment from the control console as instructed by a person rated equal to or greater than Experimentalist. A Reactor Operator must be qualified to act in this capacity through training and formal qualification.

5. **Operator-in-Training**

An Operator-in-Training is the lowest category of personnel who can change the reactivity of a critical experiment from the control console. He is only permitted to operate the control console under the direct supervision and control of the Experimentalist-in-Charge.

6. **Fuel Handler**

The duties of the Fuel Handler include assisting with the loading and unloading of reactor fuel, poison wires and other operations dealing with changes to the reactor assembly. The Fuel Handler is only permitted to make changes in the reactor under the direct supervision of a person rated equal to or greater than Experimentalist and in accordance with a written procedure defining the changes and the sequence to be followed in making the changes.

7. **Other Personnel**

Both technical and non-technical personnel provide additional program assistance. These include scientists, engineers, technicians, a secretary, a handyman-chauffeur, health physics technician; and other personnel required for the normal functions and upkeep of the facility.

2.3.3 **Position Qualifications**

All personnel are required to know the Emergency Procedures, Health Physics Procedures and Security Regulations. In addition, to aid the Scientist-in-Charge in selecting and training personnel to fill the various categories of responsibility as described above, the following minimum qualifications have been established for the positions in the operation of the reactors.
1. **Fuel Handler**

Those individuals who, through past performance, have demonstrated that they possess the following characteristics and who satisfactorily demonstrate their knowledge of the fuel handling and storage regulations may be designated as Fuel Handlers by the Scientist-in-Charge.

1. A mature and stable character.
2. An ability to understand and follow instructions.
3. An understanding of the potential hazards involved in fuel operations.

2. **Operator-in-Training**

Selected and approved by the Scientist-in-Charge on the basis of previous performance record. In addition, he must possess the qualifications of the Fuel Handler. He must also demonstrate a detailed knowledge of the reactor control system and the consequences of the maximum credible accident analyzed in the Safety Report.

3. **Reactor Operator**

1. Operator-in-Training for the time necessary to have completed fifteen reactor checkouts, fifteen approaches to critical and fifteen hours of critical operation under the direct observation of at least an Experimentalist-in-Charge. It is intended that the approach time be included in the fifteen hours of reactor operation.
2. Demonstrate familiarity with the reactor, its systems, and its operation.
3. Pass an oral, written, and operating examination equivalent to those given by the AEC.
4. Approved as Reactor Operator by the Scientist-in-Charge.

4. **Experimentalist**

1. An Experimentalist must satisfy the requirements for Reactor Operator as given above and in addition must hold a bachelor's degree or have had equivalent training.
2. A person qualified as Experimentalist shall be capable of planning, calculating or predicting reactivity changes in proposed core changes and experiments.
3. Shall have demonstrated the necessary maturity and good judgement and be approved as Experimentalist by the Scientist-in-Charge.
Figure 4.5 Schematic Diagram of FCX Control Rod Drum
Figure 4.6 Control Drum In-Out Switch Operation
SOP-5.1 DAILY CHECKOUT PROCEDURE

5.1.1 General

Prior to checkout and operation, the test cell and reactor assemblies will be visually checked prior to and at the completion of each working day by the Experimentalist-in-Charge.

The daily checkout procedure ensures that a systematic check of all instrumentation necessary to the safe operation of the reactor is completed on a routine basis.

Listed below are the conditions under which the checkout must be completed.

1. Each day that reactor operations are scheduled.
2. Prior to reactor operation if the reactor has been shutdown for more than eight hours.
3. At any time when changes to the reactor and/or systems have been made which may have affected the calibration of any safety system. A recheck of the affected systems will be made according to the checkout procedure.

It is essential that the person completing the checklist understand the importance of each item included on the checklist and the method to be used in completing the check. Presented below are the proper methods to be followed in completing the checklist. After completing each of the checks covered below, the person making the check will indicate that the check has been successfully completed by indicating in the appropriate blank on the "Daily Checkout" form.

5.1.2 Preliminary Steps

1. Master By-Pass Circuit

1) Unlock the Interlock Panel (Panel A) and switch in the MASTER BY-PASS relay K66.
2) Place 11 control element keys in the 11 by-pass key locks.

2. Patch Panel Check
Check Patch Panels F and G to ascertain that the correct program boards are in place.

3. Control Element Selected
Unlock the control element selected for the checkout.

4. VETO Reset
Reset the CELL VETO switch.

5. Armature Current Meter
Ensure that the ARMATURE CURRENT Simplytrol is set correctly for the reactor being checked out.

5.1.3 Power Checks
1. Reactor Standby Signs
   1) Ensure that the console power light is illuminated.
   2) Turn the MASTER key switch ON.
   3) Depress REACTOR STANDBY switch and ensure that REACTOR STANDBY sign is illuminated.

2. Magnet Power
   1) Ensure that orange MAGNET CURRENT light is illuminated.
   2) Clear all scram conditions from safety instruments, interlocks and manual scram switches (use MAGNET SWITCH TEST circuit as necessary).
   3) Ensure that green MAGNET READY light is illuminated.
   4) Ensure that either the PAX or FCX light is on and that it agrees with the reactor being checked out.
6. Repeat steps 2, 3 and 4 for Linear CH No. 2.
7. Repeat steps 2, 3 and 4 for Linear CH No. 3.

5.1.8 Log N - Period Channels

1. Ensure that power to the Log N - Period amplifiers is ON.
2. Turn the LOG CH SEL SWITCH to CH No. 4.
3. Depress INFINITY CHECK switch; PERIOD METER should read \( \infty \). If it does not, adjust \( \infty \) control until it does.

4. Scram Check
   1) Reset and drive the control element to 10%.
   2) Depress the Log N CH No. 4 RECOVERY button and adjust the \( 10^{-13} \) adjustment until PERIOD TRIP occurs. Ensure that control element scrams at trip point and that the trip point is set at the specified value.
   3) Reset and drive the control element to 10%.
   4) Adjust the \( 10^{-7} \) adjustment until LEVEL TRIP occurs. Ensure that trip point is set at specified value.

5. Calibrations
   1) Depress RECOVERY button and adjust \( 10^{-13} \) screwdriver adjustment until meter reads \( 10^{-13} \).
   2) Turn the OPERATE switch to the \( 10^{-11} \) position and ensure that LEVEL METER reads \( 10^{-11} \). If it does not read \( 10^{-11} \), adjust the \( 10^{-11} \) screwdriver adjustment until it does.
   3) Turn the OPERATE switch to the \( 10^{-7} \) position and ensure that LEVEL METER reads \( 10^{-7} \). If it does not read \( 10^{-7} \), adjust the \( 10^{-7} \) screwdriver adjustment until it does.

6. Repeat steps 2 through 5 for LOG CH No. 5.
5.1.9 Instrument Readings
1. Depress the REACTOR ON switch and ensure that REACTOR ON sign is illuminated.
2. If the data channels are to be used, ensure that the high voltage is on and record the coarse and fine gain settings.
3. Record the reading on each of the safety and data collection channels with and without the source in the reactor. When driving the source into the reactor, check the FLUX-UP interlock settings on the Count Rate Meter and the recorder.

5.1.10 PASS Battery Check
1. Depress the PASS Battery Load Test Button and ensure the voltage does not drop below the red mark.

5.1.11 Cell Veto Check
1. Drive the control element to 10%.
2. Place the Cell Veto switch in the VETO position. Ensure that element "scrams."

5.1.12 After completing all steps on the Daily Checkout, complete the following steps to secure the system or proceed as directed by the Experimentalist-in-Charge:
1. Remove source from reactor.
2. Remove the master key.
3. Turn off recorder chart drive.
4. Lock control element and remove key.
5. Place Cell Veto in VETO position.
6. Remove the keys from the interlock key switches.
7. Place the Master By-pass in the OFF position.
8. Lock the Interlock Panel.
9. Ensure that startup range switch is in OPERATE position.
10. Return all keys to the Experimentalist-in-Charge.

5.1.13 Sign off the checkout sheet and file in the Reactor Operations Log together with other daily records (e.g., temperature charts, humidity charts, etc.)
DAILY CHECKOUT

Test Cell and Reactor Check (EIC)

1. Preliminary Steps
   1) BY-PASS Relay On
   2) Patch Panel CK PAX, FCX
   3) Control Element Selected No.
   4) VETO Re-set
   5) Armature Current Simplytrol Set

2. Power Checks
   1) REACTOR STANDBY On
   2) Magnet Power On
   3) Magnet Current CK
   4) Recorder CK

3. Interlock Bypass CK Element No.

4. Instrumentation Calibration & Scram Checks
   1) Startup Channel Calibration
      \[10^2, 10^6, \text{CAL}, \text{OPERATE}\]
   2) Gamma Monitors
      No. 1 2 3 4 5
      (1) Cal. Set
      (2) Alarm Set
   3) Linear Channels
      CH No. 1 2 3
      (1) Scram CK
      (2) Zero Set
   4) Log N Channels
      CH No. 4 5
      (1) Period Cal. \((\infty)\)
      (2) Scram CK
      (3) Cal. \(10^{-13}, 10^{-11}, 10^{-7}\)

5. Instrument Readings
   1) REACTOR ON On
   2) Data Channel* High Voltage On
      Gain CPM
      (1) CH 1
      (2) CH 2
      (3) CH 3
   3) Operational Channels
      Source Out Source In
      (1) CH 1 M R
      (2) CH 2 M R
      (3) CH 3 M R
      (4) CH 4 M R
      (5) CH 5 M R
      (6) SU (CPM)
      (7) Flux Up Setting Log N SU

6. PASS System Battery Test

7. Cell Veto CK

8. Console Secured

Completed by ____________________________
Date ____________________________ Time ____________________________

Test Cell and Reactor Secured

Time ____________________________
EIC ____________________________
## PRE-STARTUP/MANUAL CHANGE CHECKLIST

**Run No.** ___________________  **Exp. Details Checklist No.** ___________  **Date** ___________

### 1. GENERAL CHECKS

<table>
<thead>
<tr>
<th>Control Room</th>
<th>Test Cell</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily Checkout Comp</td>
<td>Truck Door Closed</td>
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<tr>
<td>Recorder On</td>
<td>PAX Cover Off</td>
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### 2. REACTIVITY CHANGES

Approved by (EIC) ____________________

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<tr>
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<td>Cell Veto - &quot;Veto&quot;</td>
</tr>
<tr>
<td></td>
<td>Crit. Ass'y Ck</td>
</tr>
<tr>
<td></td>
<td>&quot;Popper&quot; - Aud.</td>
</tr>
<tr>
<td></td>
<td>Drums/Rods Locked</td>
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<thead>
<tr>
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<th>Ksd</th>
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<tbody>
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### 3. MANUAL CHANGE CHECKS

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<th>&quot;Reactor Standby&quot; Lights On</th>
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<td>Log CRM</td>
<td>CPM</td>
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<tr>
<td>Lin Rec Ch</td>
<td>Amps.</td>
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<td>&quot;Popper&quot;-Aud</td>
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### 4. PRE-STARTUP CHECKS

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<tr>
<td>PASS Hoses Connected</td>
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<tr>
<td>Drums/Rods Unlocked</td>
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<tr>
<td>Personnel Check</td>
</tr>
<tr>
<td>Veto Reset</td>
</tr>
<tr>
<td>Doors Closed</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>&quot;Reactor On&quot; Lights On</th>
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<tbody>
<tr>
<td>Interlocks Satisfied</td>
<td></td>
</tr>
<tr>
<td>Scrams Clear</td>
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<td>Source In</td>
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<tr>
<td>Level</td>
<td></td>
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<td>Amps</td>
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<td>Level</td>
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<td>Amps</td>
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<td>WREC Level Ck</td>
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<td>Scram Check</td>
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### Remarks

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**Completed by** ___________________  **Time** ___________  **Page** ___________

5-8
5.2.2.4 Pre-Startup Checks

Test Cell

Critical Assembly
Inspect the critical assembly to ensure that all required work on and around the assembly has been completed and the assembly is in operating condition. Verify that the inactive reactor, that is the one not connected to the control console, is in an inactivated condition. An inactivated condition is defined as one where the reactor control elements are locked in their most shutdown position and the reactor is at least 10$ subcritical.

PAX Auxiliary Shutdown System (PASS) Connected
If the PAX assembly is the one being checked out for operation, ensure that both the PASS hoses are connected, unless otherwise specified by the SIC.

Control Element Drives Unlocked
Obtain the control element lock keys from the Experimentalist-in-Charge and unlock each control element. Visually inspect each drive unit for possible signs of malfunctioning.

Personnel Check
Visually inspect all areas of the test cell to ensure that no personnel are present.

Cell Veto Reset
After all personnel are removed, reset the Cell Veto.

Doors Closed
Close and lock the test cell storage room, labyrinth, and emergency doors. If any outside doors have been open, check the area inside the fence and then close the doors.
Control Room

Reactor Status Lights
Place the reactor status lights in the REACTOR ON condition.

Interlocks
Check the interlock panel lights to ensure that all lights indicate that the interlocks are satisfied. Ensure that the by-pass light is not illuminated.

Scraps Clear
Ensure that all scrap conditions as indicated by red lights on the console scram panel are clear.

Source In
Insert the neutron source into the core and observe that all instrumentation responds accordingly. Ensure that the "flux-up" interlock is satisfied.

Log CRM Level
Record the Log CRM count rate after the source has been inserted and the count rate has stabilized.

Linear Recorder Level
Select the linear channel to be displayed on the recorder and record its reading after the source has been inserted.

WREC Power Level
Check the WREC power level indicator and record its readings. If WREC is operating, notify the Experimentalist.

Scram Check
Withdraw all control elements to 10% and depress the manual scram button. Ensure that all elements scram.

5.2.2.5 Operating Staff
Four blanks are included. All reactor changes and/or reactor operations require a minimum of two qualified persons. Each person's name appearing on these
lines will be affixed by that person. This is, in effect, a "sign-off" by persons cognizant of the operation and an indication of their approval. If, at any time during the operation any of the required personnel must leave his designated post, operations will be terminated until a qualified replacement is available.

5.2.2.6 Disposition

After the checklist is completed, it will be filed in the Reactor Operations Log.
5.2.3 Reactor Startup

1. The Experimentalist-in-Charge will ensure that all members participating in the experimental operation are familiar with the applicable Experimental Details Check list and Standard Operating Procedures and are cognizant of their responsibilities.

   In the event that the planned experimental operation will lead to an integrated dose in excess of 100 mrem in the areas outside of the exclusion area, these areas will be cleared and monitored during the operation. Irradiations exceeding 150 watt-hours on PAX or 75 watt-hours on FCX require this type of area surveillance.

2. Select the desired control element speed as specified by the Experimentalist.

3. Slowly withdraw each control element, individually, to the predicted critical position. While withdrawing the elements, closely observe the Log CRM and the linear level recorder and if it appears that the reactor will go critical before the predicted position, stop the withdrawal and notify the Experimentalist.

4. Slowly withdraw the last control element in small increments until the reactor is critical as indicated by a slow but steady increase in count rate. The reading on the Log N period meters should not be shorter than 10 seconds (~39 period).

5. After criticality is achieved and indication is observed on the Log N channels, the source will be removed and the high voltage to the startup channel turned off. The critical control element positions will be logged and the $k_{ex}$ and $k_{sd}$ will be estimated from the critical control element positions. This estimate will be compared with $k_{ex}$ and $k_{sd}$ of the Pre-Startup/Manual Change Check List and any appreciable differences resolved prior to proceeding with the operations.

6. As power level increases, adjust the linear level meters to keep them on scale. Record reactor period and control element positions.

7. As power level approaches the desired level (never greater than 1 Kw), the control elements will be inserted to increase the reactor period, and the reactor will be manually stabilized at this desired power, using the control elements.
8. The operator will continuously monitor all control channels and if any malfunctions are observed, the operator will reduce power and notify the Experimentalist.

9. After the reactor power is leveled, the control elements will be adjusted so that the maximum deviation between drum positions is 1% unless specified differently by an approved experimental procedure or the Experimentalist.

5.2.4 Level Operation

1. During level operation of the reactor, the linear level channel displayed on the recorder will be the control channel of preference.

2. The following minimum data will be recorded at 15-minute intervals during level operation.
   1) Control element positions.
   2) Linear and log level readings from the recorder.

5.2.5 Power Level Adjustment

1. Record data as in 5.2.4.2, above.

2. Adjust control elements to obtain desired period (never less than + 10 sec). Observe all instruments closely to ensure that power level adjustment is as desired. Record period and control element positions.

3. When desired power is reached as indicated by linear channel displayed on recorder, adjust control elements to level power. (In no instance shall power exceed 1 Kw.)

4. Record data as in step 5.2.4.2.

5.2.6 Reactor Shutdown (Normal)

1. Record data as in step 5.2.4.2.

2. Unless otherwise specified by the Experimentalist, the reactor will be shut down by scramming all control elements.

3. After the reactor is shut down, as determined by observation of the neutron level decay on the recorder and observation of insertion of the control elements as indicated by the IN limit lights and indicators, the reactor operator will perform the following shutdown operations:
1) Turn off the recorder chart drive.
2) Turn micromicroammeters to a more sensitive range.
3) Ensure that the run log and experimental data are complete.
4) Remove the MASTER KEY from the console.
5) Turn on the startup range high voltage.
6) At the earliest practical time, the following steps should be completed in the test cell:

   (1) Make a radiological survey of the cell area.
   (2) Place the Cell Veto in the VETO position.
   (3) Remove the control element keys from each control element drive.
   (4) If core work or additional runs are not anticipated, remove the PAX Auxiliary Shutdown System hoses from the discharge nozzles and place the cover on the reactor.
7) Sign off the "Reactor Secured" entry on the last run sheet for the day.

5.2.7 Reactor Shutdown (Unanticipated)
1. Determine the cause of the unanticipated shutdown and record it in both the Reactor Operations Log and the Facility Log.
2. The Experimentalist will decide whether to re-start the reactor (see 5.2.3) or to complete the shutdown (see 5.2.6.3).
SOP-5.3 "FACILITY SECURED" CHECK

5.3.1 General
A number of items must be checked to ensure that the reactor and its systems are properly secured before the Scientist-in-Charge or the Experimentalist-in-Charge leaves for the day.

5.3.2 Test Cell Checks
1. Ensure that the truck door is closed and locked. If the door is open, check the yard area prior to locking the door.
2. Ensure the PAX Auxiliary Shutdown System hoses are disconnected and that the cover is seated and locked on the PAX assembly. After the cover is locked, the keys will be given to the Experimentalist-in-Charge.
3. Check each of the control element drives and ensure that it is locked. Ensure that all the control element keys are removed and give them to the Experimentalist-in-Charge.
4. Ensure that the Cell Veto is in the "VETO" position.
5. Check the test cell and ensure that no personnel are present and then lock the test cell access door. After the door is locked, the key will be given to the Experimentalist-in-Charge.

5.3.3 Control Room Checks
1. Ensure that the interlock panel is locked and that there are no interlock by-passes in the "ON" position.
2. Reset all interlocks.
3. Check the "Power Failure" and "Water Level" lights on the console and ensure that they are off.
4. Turn off the T.V. monitors.

5.3.4 Keys
The keys identified in paragraph 1.2.2.9 shall be stored in the "key box."
MANUAL REACTIVITY CHANGE PROCEDURE

5.4.1 General

Presented below are the procedures to be employed whenever manual changes in the reactivity of a shutdown reactor are to be made by either a) installing experimental material into, or near, the reactor or b) removing it from within or the vicinity of the reactor. No change may be made which will compromise the minimum shutdown margin or exceed the limit on excess reactivity or which upon failure would result in a reactivity insertion greater than the limits specified in the Operating Limits document. In the following section these restrictions are set forth in detail separately for PAX and FCX. For both reactors, the choice of the appropriate course of action to be applied depends upon the type of manual change to be made. Separate paragraphs treat the course of action for: changes to the reactor assembly, in-core experiments and out-of-reactor experiments. Fuel loading and initial criticality procedures are given explicitly in SOP-5.5 for PAX and SOP-5.6 for FCX.

5.4.2 Selection of Appropriate Course of Action

5.4.2.1 Preliminary Determinations

Prior to making any manual change in the reactivity status of a reactor, the following determinations will be made by the Experimentalist to ensure that the proposed change will be safe and within the operational limits:

1. A check of the present reactor status shall be made to determine the shutdown reactivity, the critical control element positions, and the present reactor loading configuration. Reference should be made to the "WANEF Reactor Operations Log" for prior operating history and present loading.

2. The effect of the proposed change on the present reactor status will be considered in detail. A complete and conservative evaluation of the reactivity worth of the desired change will be made using experimentally determined reactivity coefficients based on NERVA type reactors where known. Conservative values based on polyethylene worth will be used for materials of unknown worth. In the case of in-core and out-of-reactor
experiments, consideration must be given not only to the configuration of interest but also to the accidental displacement of the experiment into a more reactive position. Reference should be made to the applicable Experimental Details Checklist.

5.4.2.2 Course of Action for Changes to PAX

1. General

In the preliminary determination, the Experimentalist shall ensure that neither the minimum shutdown limit of 3.25$ for the isolated reactor nor the maximum excess reactivity limit of 6.2$ is exceeded at any time during the change. A single direct reactivity change of up to $+50\%$ is permitted on PAX. Larger reactivity changes (up to $+2.50\%$) can be accomplished by compensating for the change with poison wires first. After the change is made, the wires are removed in increments whose worth is no greater than $+50\%$. Still larger reactivity insertions can be made by poisoning the core to the extent that after the change is made, it will be shut down by at least $10\%$. The initial criticality and clean criticality procedures (SOP-5.5.2 and 5.5.3) will then be followed to remove the poison wires.

2. Changes to the PAX Assembly

1) Only one type of reactor change can be made at one time.

2) Up to 75 fuel elements may be interchanged before a criticality measurement must be made providing that the net reactivity increase from the interchange is less than $50\%$. The core assembly frame will be used when more than three adjacent clusters or more than a total of four clusters are out of the core at one time.

3) Before a control drum is removed from or inserted into its beryllium sector, the shutdown of the reactor will be increased by at least $1.0\%$ by the insertion of poison wires into the core. After the control drum change is completed, a reactivity measurement will be made with the poison wires in place. After assurance that the control drum change has not compromised the minimum shutdown margin, the poison wires will be removed in reactivity steps of $50\%$ or less. Only one control drum may be removed at one time.
4) Reflector sector changes may be made, one sector at a time, providing the net increase in reactivity is first compensated for by the introduction of a corresponding negative reactivity by means of poison wires. Any drum change associated with a sector change is assumed to contribute a net reactivity increase of 1.0$. After the interchange has taken place, a reactivity measurement will be made. After assurance that the change has not compromised the minimum shutdown margin, the poison wires will be removed in reactivity steps of 50$ or less. Only one sector may be removed at one time.

3. PAX In-Core Experiments

   The Experimentalist shall ensure that the evaluation of the reactivity change considers not only the reactivity associated with the configuration of interest but also that due to a displacement of the in-core experiment. Such a displacement must not compromise the minimum shutdown margin of 3.25$ nor may it produce a net reactivity change of 1.0$. Inserts which are supported independently of one another are considered to be separate in-core experiments. The Experimentalist shall further ensure that the structural design of these supports will have a minimum load safety factor of five based on ultimate strength and gears, pulleys, cables and parts subject to wear will have a safety factor of eight. Reference should be made to the Experimental Details Checklist.

4. PAX Out-of-Reactor Experiments

   The Experimentalist shall ensure that the following conditions are met:

   1) The effects of neutron reflection will not reduce the shutdown reactivity below the minimum margin for planned placement (2.8$ with personnel present) nor override the control capability of the drums during failure.

   2) The mechanical design of the experiment employs engineered safeguards against a failure that would permit the material to be displaced to a more reactive
position. The structural design of these safeguards will have a minimum load safety factor of five based on ultimate strength, and gears, pulleys, cables and parts subject to wear will have a safety factor of eight.

3) Each experiment, which upon failure would insert more than 1.0$ in reactivity into PAX, must include two position interlocks for each independently supported experiment which will initiate a reactor scram if the experiment experiences any displacement during reactor operation. One position interlock for each experiment is to be wired into the coil circuit of Position Interlock Relay No. 1 (K68) and the other position interlock is to be wired into the coil circuit of Position Interlock Relay No. 2 (K69). These position interlocks shall be supported independently of the experiment and must be checked out daily when in use. The maximum scram delay time of the position interlock circuitry will not exceed the value established in the Operating Limits Document.

4) When an experiment involves a combination of a radial and end-on reflector, each will be supported independently of each other to prevent the simultaneous collapse of both reflectors. Each part will be provided with position interlocks.

5) Any out-of-reactor experiment involving hydrogenous liquids must be designed so that such liquid hydrogenous materials cannot get into either PAX or FCX.

Reference should be made to the Experimental Details Checklist.

5.4.2.3 Course of Action for Changes to FCX

1. General

In the preliminary determination the Experimentalist shall ensure that neither the minimum shutdown limit of 10.0$ for the isolated reactor nor the maximum excess reactivity limit of 50$ is exceeded at any time during the change. The procedures for the manual addition of reactivity depend upon the size of the positive reactivity insertion involved; "small" insertions where $P \leq +20\gamma$, "minimal" insertions where $P \leq +2\gamma$, "moderate" insertions where $20\gamma < P \leq 50\gamma$, and "large" insertions where $50\gamma < P \leq +5.00\gamma$. In all cases the net reactivity step is no more than $+50\gamma$. 

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1. "Minimal" reactivity insertions are those which do not exceed +0.02$. Such additions can be made directly (within the limitation on excess reactivity) and need not be followed by a reactivity measurement.

2. "Small" reactivity insertions are those which do not exceed +20$. Such additions can be made directly (within the limitations on excess reactivity) and must be followed by a reactivity measurement.

3. "Moderate" positive reactivity insertions are those greater than +20$ and not greater than +50$. "Moderate" reactivity insertions must be preceded by the insertion of sufficient compensating negative reactivity (by supplementary poison of known worth or the removal of peripheral fuel or reflector clusters) such that after the addition of the positive reactivity, the value of $k_{\text{excess}}$ will not exceed 20$. The reactivity of the assembly will be measured after the positive insertion is made. This measurement will be in the form of a period determination or a delayed critical rod position. If $k_{\text{excess}}$ is negative, a measurement of the count rate will be made on the startup channel as a guide to the next step which the Experimentalist will specify.

4. "Large" positive reactivity insertions are those greater than 50$ and not greater than +5.00$. "Large" reactivity insertions must be preceded by the insertion of sufficient compensating negative reactivity such that after the positive insertion is made, $k_{\text{excess}}$ will not exceed -1.00$. Count rate data will be taken on the startup channel with the control rods fully withdrawn before and after the "large" positive insertion is made. The inverse count rate data will be plotted as a function of poison removed (or clusters or positive shims added as the case may be).

Additional positive reactivity insertions will be made in "moderate" or "small" steps as defined above, each followed by count rate measurements with the control rods fully withdrawn. The extrapolation of the inverse count rate plot will provide a continual assessment of the excess reactivity of the core in the approach to critical.

2. Changes to the FCX Assembly

1) Only one type of reactor change can be made at one time.

2) Fuel and/or reflector elements may be interchanged providing that the net increase in reactivity does not exceed 20$. The core assembly frame and
lateral support bars will be employed as needed to provide support during such changes. The interchange will be followed by a reactivity measurement.

3) Control rods may be removed providing the minimum shutdown margin of 10σ is maintained by supplementary nuclear poison or by removing fuel or reflector clusters. The amount of negative compensation will depend upon the worth of the configuration of control rods remaining. In returning a control rod to the core, additional negative compensation will be required to maintain the minimum shutdown margin of 10σ assuming that the inadvertent omission of the cadmium part of the control rod has occurred. Such an omission would result in a positive reactivity insertion of about 2.0σ/rod at the core center. No more than two control rods can be returned to the core at one time.

3. FCX In-Core Experiments

The Experimentalist shall ensure that the evaluation of the reactivity change considers not only the reactivity associated with the configuration of interest but also that due to failure or displacement of the in-core experiment. Such a failure or displacement must not compromise the minimum shutdown margin of 10.0σ nor may it produce a net reactivity change in excess of Δ where Δ = 50σ - ρ\_excess*. Inserts which are supported independently of one another are considered to be separate in-core experiments. The Experimentalist shall further ensure that the structural design of these supports will have a minimum load safety factor of five based on ultimate strength and gears, pulleys, cables and parts subject to wear will have a safety factor of eight. Reference should be made to the Experimental Details Checklist.

4. FCX Out-of-Reactor Experiments

The Experimentalist shall ensure that the following conditions are met:

1) The reactivity effect of the experiment when placed next to the FCX must not compromise the 50σ limit on excess reactivity.

* ρ\_excess is the excess of the core with the experiment at its normal position.
2) The reactivity effect of the experiment, if it should move closer to the reactor, must not compromise the 50% limit on excess reactivity.

3) The reactivity effect of removing the experiment must not compromise the 50% limit on excess reactivity.

NOTE: Conditions 2) and 3) apply to each independently supported experiment.

4) The container design and procedural safeguards for any FCX experiment involving liquids ensure that the entrance of such materials into either the FCX or the PAX core is incredible.

Reference should be made to the Experimental Details Checklist.

5.4.3 Summary of Basic Rules

General operating regulations designed to protect personnel against the potential hazards of manual reactivity additions include the following requirements:

1. The Applicable Experimental Details Checklist must be reviewed and approved by the Scientist-in-Charge and the Manager of Thermal and Nuclear Design.

2. The procedure must be executed under the direction of an Experimentalist and the cognizance of the Experimentalist-in-Charge.

3. Two persons, one of whom is rated equal to or greater than Experimentalist, must be present in the test cell when the reactivity of an assembly is being changed; a third person qualified as a Reactor Operator must be on duty at the console; and the test cell-to-console intercom must be operational.

4. An audible indication of source range multiplication must be provided.

5. All control elements must be locked in the position of maximum shutdown.

6. The manual scram switch located in the test cell (Cell Veto) which can override any attempt to start the reactor must be in the VETO position.
7. No change in the reactivity will be made under the duress of a time limit.

8. The maximum number of personnel allowed within three feet of the reactor at any time shall be approved by the Scientist-in-Charge and shall be the more restrictive of (a) three persons, or (b) a number consistent with the minimum shutdown of that particular reactor.

5.4.4 Change Procedure

1. Complete the appropriate portions of the "Pre-Startup/Manual Change Checklist" (i.e., "Reactivity Changes" and "Manual Change Checks").

   1) See Section 5.2.2.2 for instructions for "Reactivity Changes."

   2) Manual Change Checks

   Control Room

   Reactor Status Lights

   Place the Reactor Status lights in the REACTOR STANDBY condition.

   Log CRM Level

   Record the count rate on the Log CRM to establish a base-point prior to starting the core changes. During the course of the changes, this instrument should be monitored for any indications of a change in the count rate.

   Linear Recorder Channel

   Indicate the linear channel selected to be displayed on the recorder and record the linear level as displayed on the recorder.

   "Popper" Audible

   The "popper" in the control room and in the test cell should be checked to ensure that it is audible in both places. The frequency of the "popper" should be set at a point where changes in the frequency are readily detected.
Test Cell

Cell Veto - "Veto"

The Cell Veto switch will be placed in the VETO position. This step ensures that the reactor cannot be started until the personnel in the cell are ready.

Critical Assembly Check

The critical assembly will be inspected by a person rated equal to or greater than Experimentalist to ensure that all required work around the assembly has been completed prior to initiation of the change. Also a careful examination of the reactor may bring to light possible hazards which could arise during the change.

Control Elements

Prior to beginning the core changes, check all the control elements to ensure that they are all locked and cannot be driven out.

2. Inspect the item(s) to be moved to ensure that correct material has been selected and that quality of item(s) is suitable for reactor use.

3. Prepare and assemble any hardware, fixtures, assembly frame (when required), and any other special items required to make the core change. See the Experimental Details Checklist.

4. Establish communications with the Control Room.

5. Slowly insert, install or withdraw the item(s). The person making the core change should always be prepared to terminate the operation in the event that the personnel in the control room observes any unusual readings on the nuclear instrumentation.

NOTE: When there is the possibility of spreading contamination, the suction line to a suitable vacuum system should be placed near the object being moved.
6. If the change was made to PAX and was $\leq 50\%$ and the sum of such changes since the last reactivity determination is $\leq 50\%$, secure the reactor in accordance with the "Reactor Operating Procedure, SOP-5.2.6" unless otherwise directed by a person rated equal to or greater than Experimentalist.

7. If the change was made to FCX and exceeds $2\%$, "minimal", or if the sum of changes to PAX exceeds $50\%$ since the last reactivity check,

1) Complete the Pre-Startup portion of the "Pre-Startup/Manual Change Checklist," SOP-5.2, and start the reactor in accordance with the "Reactor Operating Procedure," SOP-5.2.3, and any special instructions contained in the appropriate Experimental Details Checklist.

2) After achieving criticality, proceed as per "Reactor Operating Procedure," SOP-5.2.3, to obtain the information required to evaluate the change.

3) Shut the reactor down and evaluate the effect of the change.

4) If it is found that the preliminary considerations of Section 5.4.2 were correct, proceed as per Steps 1 through 7 in making any further changes. If it is found that the change was not in accordance with the preliminary considerations of Section 5.4.2, re-evaluate any further changes prior to making them.

5) After all changes are completed, secure the reactor in accordance with the "Reactor Operating Procedure," SOP-5.2.6.
SOP-5.5 PAX EXPERIMENTAL PROCEDURES

5.5.1 PAX Fuel Loading

1. Objective

To assemble fuel safely in a NERVA-type reactor.

2. Special Precautions and Limitations

1) The reactor will be assembled with adequate shutdown utilizing poison shipping wires in addition to the drums. Shutdown of the assembled reactor will be at least 10$ for a fuel loading that has been previously utilized and at least 20$ for a fuel loading that has not been previously utilized.

2) A loading source will be properly installed at the beginning of the loading. Normally, the loading source will be located in the central region of the initial fuel increment.

3) A minimum of 3 pulse channels will be used with a source-core-detector geometry which will ensure an adequate detector response.

4) The limits and procedures in the WANEF Operating Limits document and the Reactor Operations Manual are governing.

3. General Method

The fuel will be added to the reactor in an incremental manner from the center outwards to the outer reflector using the core assembly frame to support the fuel clusters. The initial fuel increment will not exceed 10% of the total fuel complement in the assembled reactor. Each succeeding increment will be no more than 20% of the total fuel complement or one-half of the extrapolated additional fuel loading required for criticality, whichever is the smaller. Count rate data will be obtained after each increment with the control drums at 0 degrees and a plot of inverse count rate versus amount of fuel in the reactor will be constructed. After the fuel is loaded, filler strips will be installed and the core lateral support applied.

4. Hazards Considerations

This procedure, when performed within the limitations described herein and in the WANEF Operating Limits document, presents no significant safety hazards.
5.5.2 PAX Initial Criticality

1. Objective
   To achieve initial criticality safely by the removal of poison wires.

2. Special Precautions and Limitations
   1) A minimum of 3 pulse channels will be used with an adequate
      source-core detector geometry which will ensure significant detector response.
   2) Initial criticality will be attained with $k_{ex} < 50\%$.
   3) The limits and procedures in the WANEF Operating Limits docu-
      ment and the Reactor Operations Manual are governing.

3. General Method
   Poison will be removed from the core in an incremental manner. Count
   rate data will be obtained after each incremental removal for drum positions of 0°, 90° and
   180° and a plot made of the inverse count rate versus the amount of poison in the reactor.
   Each succeeding increment removed will be no more than 20% of the initial
   poison content or one-half of the extrapolated additional poison removal required for
   criticality with the drums full out. Data obtained with the control drums full out will be
   utilized for the prediction of criticality. The final poison increment to be removed will be
   specified by a person rated equal to or greater than Experimentalist such that the 50% excess
   reactivity limit is not exceeded. After attainment of criticality, a measurement of the shut-
   down will be performed, e.g., by a "rod drop" experiment.

4. Hazards Considerations
   This procedure, when performed within the limitations described herein
   and in the WANEF Operating Limits document, presents no significant safety hazards.
5.5.3  PAX Clean Criticality

1. Objective
   To determine the clean (no poison) delayed critical control drum bank position after initial criticality is achieved.

2. Special Precautions and Limitations
   The limits and procedures in the WANEF Operating Limits document and the Reactor Operations Manual are governing.

3. General Method
   1) New Assemblies
      The remaining poison wires will be removed in increments such that the reactivity steps are not greater than 50%. The withdrawals will be in accordance with SOP-5.4. The delayed critical bank position will be determined after each increment until all of the poison wires have been removed. The core shutdown reactivity will be monitored at each step by 1) a plot of delayed critical bank position vs. poison wire content, 2) rod drop shutdown measurements, or 3) by integrating differential bank worth measurements.

   2) Previously Operated Assemblies
      The remaining poison wires may be removed in a single step if the initial critical bank position agrees with prior measurements to ±50%. The drum bank will be rotated in reactivity steps not larger than 50%. The inverse multiplication will be plotted vs. bank position after each step. If any extrapolation of clean critical bank position deviates more than 50% from the previous clean critical bank position, the reactor must be shutdown until the discrepancy is satisfactorily explained by the Scientist-in-Charge or his designated alternate and judged not to affect safety.

4. Hazards Considerations
   This procedure, when performed within the limitations described herein and in the WANEF Operating Limits document presents no significant safety hazards.
The final increment to be inserted will be specified by a person rated equal to or greater than Experimentalist such that the 50\(\%\) excess reactivity limit is not exceeded. After attainment of criticality, a measurement of shutdown will be performed (e.g., by a "rod drop" experiment).

4. Hazards Considerations

The procedure, when performed within the limitations described herein and in WANEF Operating Limits document presents no significant safety hazard.

5.6.2 FCX Loading and Criticality (Reflected Core)

1. Objective:
   1) To safely assemble fueled clusters and unfueled reflector clusters in an FCX-type reactor.
   2) To achieve criticality in a reflected reactor with \(k_{ex} \leq 50\%\).

2. Special Precautions and Limitations
   1) Based on analytical and experimental data, the total fuel and reflector complement required in the assembled reactor will be determined prior to starting the loading operation.
   2) A loading source will be properly installed at the beginning of the loading. Normally, the loading source will be located in the center region of the initial fuel increment.
   3) An minimum of 3 pulse channels will be used with a source-core-detector geometry which will ensure an adequate detector response.
   4) Initial criticality will be attained with \(k_{ex}\) less than 50\%. The final core reactivity will be adjusted such that \(k_{ex} \leq 50\%\).
3. General Method

Fueled clusters will be added to the core in an incremental manner. The initial cluster increment will not exceed 20% of the total complement in the fully assembled reactor (unfueled reflector clusters included) or 30% of the fueled cluster loading. Each succeeding increment will be either 20% of the total complement of the fully assembled reactor or 30% of the fuel clusters for the assembled reactor or one-half of the extrapolated additional clusters required for criticality, whichever is the least. Count rate data will be obtained after each loading increment for 0, 50 and 100% control rod withdrawal and a plot made of the inverse count rate as a function of the total number of clusters loaded into the reactor. Count rate data obtained with the control rods withdrawn to 100% will be utilized for the prediction of criticality.

The final increment to be inserted will be specified by the Experimentalist such that the 50 $\gamma$ excess reactivity limit is not exceeded. After criticality has been attained, a measurement of shutdown will be performed (e.g., by a "rod drop" experiment). In order to obtain the desired reflector thickness, reflector and fuel clusters will be interchanged at the core-reflector interface using SOP-5.4, Manual Reactivity Change Procedure.

If after adding the reflector clusters criticality is not attained, (1) the reflector clusters will be removed (2) counts will be taken and compared to previous counts for the same core configuration and, if necessary normalized. Additional fueled clusters will then be added to the core periphery in the incremental manner. Based on the previous inverse multiplication curve a sufficient quantity of fueled clusters will be loaded to allow criticality to be obtained when all reflector clusters have been replaced. Reflector clusters will also be replaced in increments as previously defined with counts taken after each incremental change.

4. Hazards Considerations

The procedure, when performed within the limitations described herein and in the WANEF Operating Limits Document, presents no significant safety hazard.
5.6.3 FCX Loading and Initial Criticality (NERVA Mockup)

1. **Objective**
   1) To assemble fueled clusters safely in an FCX core with NERVA mockup reflector.
   2) To achieve initial criticality with $k_{ex} \leq 50 \%$.

2. **Special Precautions and Limitations**
   1) The reactor will be assembled with the reflector in place and the control drum locked to the desired position.
   2) The reactor will be assembled with adequate shutdown utilizing poison shipping wires in addition to the control rods and mockup drums. Shutdown of the assembled reactor will be at least 30\%, with at least 10\% contributed by poison wires. No credit will be taken for the shutdown in the mockup drums.
   3) A loading source will be properly installed at the beginning of the loading. Normally, the loading source will be located in the central region of the initial fuel increment.
   4) A minimum of 3 pulse channels will be used with a source-core-detector geometry which will ensure an adequate detector response.
   5) Mockup drums will be locked in position during the critical approach.
   6) Initial criticality will be attained with $k_{ex} \leq 50 \%$.
   7) The limits and procedures in the WANEF Operating Limits document and the Reactor Operations Manual are governing.

3. **General Method**

   The fuel will be added to the reactor in an incremental manner from the center outwards to the outer reflector using the core assembly frame to support the fuel clusters. The initial fuel increment will not exceed 10\% of the total fuel complement in the assembled reactor. Each succeeding increment will be no more than 20\% of the total fuel complement or one-half of the extrapolated additional fuel loading required for
criticality, whichever is the smaller. Count rate data will be obtained after each increment with the control rods at 0 and 100% and a plot of inverse count rate versus amount of fuel in the reactor will be constructed. After the fuel is loaded, the graphite filler segments will be installed and the core lateral support applied.

Poison will be removed from the core in an incremental manner. Count rate data will be obtained after each incremental removal for rod positions of 0%, 50%, and 100% withdrawn and a plot made of the inverse count rate versus the amount of poison in the reactor. The initial increment of poison removed will be no more than 20% of the initial content. Each succeeding increment removed will be no more than the smaller of 20% of the initial poison content or one-half of the extrapolated additional poison removal required for criticality with the rods full out. Data obtained with the control rods full out will be utilized for the prediction of criticality. The final poison increment to be removed will be specified by the Experimentalist such that the 50 $\sigma$ excess reactivity limit is not exceeded. After attainment of criticality, a measurement of the shutdown will be performed, e.g., by a "rod drop" experiment.

5.6.4 FCX In-Core Experiments

1. Objective

1) To determine the reactivity worth or effect of materials and structures in FCX.

2) To determine the spatial and spectral behavior of the neutron and gamma fluxes in the reactor.

2. Special Precautions and Limitations

1) The structural design of the experimental supports shall have a minimum load safety factor of five based on ultimate strength and gears, pulleys, cables and parts subject to wear will have a safety factor of eight.

2) Inserts which are supported independently of one another are considered to be separate in-reactor experiments.
1. Reactor Excursion or Uncontrolled Criticality
   (1) Scientist-in-Charge, WANEF (if not at WANEF)
   (2) Senior site supervisors
   (3) Site Health Physics
   (4) Site Security Guard

2. Fire
   (1) Site Fire Brigade
   (2) Senior site supervisors
   (3) Scientist-in-Charge, WANEF (if not at WANEF)
   (4) Site Health Physics

3. Radioactive Materials Spill
   (1) Scientist-in-Charge, WANEF (if not at WANEF)
   (2) Site Health Physics

4. Additional Notification (Only as required)
   Additional notification responsibilities are assigned as follows:
   (1) Senior Staff Member:
       Pennsylvania State Police
       Westmoreland Hospital
       WANL Thermal & Nuclear Design
       WANL Industrial Hygiene
   (2) Scientist-in-Charge
       Pennsylvania Department of Health
       SNPO Health and Safety
       REON, AGC
   (3) Site Security Guard
       WAPD Security Officer
       WANL Security Officer
5.9.5 Emergency Drills

Periodic emergency drills will be conducted to ensure that all personnel recognize and understand the various alarm signals and the emergency action associated with the alarm.

5.9.6 Emergency Notification Roster

1. Scientist-in-Charge, WANEF
   - Name: W. P. Kovacik
   - Address: 211 Blackridge Drive, Greensburg, Pennsylvania
   - Home Phone: 837-0494
   - Office Phone: 722-3030

2. Senior Site Supervisors
   1) General Manager, Advanced Reactor Division
      - Name: J. C. R. Kelly
      - Address: Marlee Acres, Box 232 R. D. No. 3, Export, Pa.
      - Home Phone: 327-4660
      - Office Phone: 722-3011, Ext. 292 - 293
   2) Manager, WREC
      - Name: E. G. Taylor
      - Address: 9 Stoden Drive, Greensburg, Pa.
      - Home Phone: 834-1053
      - Office Phone: 722-3041
   3) Manager, Analytical Services and Post-Irradiation Facility
      - Name: D. T. Galm
      - Address: 403 Pleasant Drive, Greensburg, Pa.
      - Home Phone: 834-0424
      - Office Phone: 722-3011, Ext. 212 - 213
   4) Manager, Test Engineering, Waltz Mill Site
      - Name: J. Santavy
      - Address: 805 Brookview Drive, Greensburg, Pa.
      - Home Phone: 834-5417
      - Office Phone: 722-3011, Ext. 254
   5) Manager, Plant Services
      - Name: C. J. Ferrell
      - Home Phone: 887-8995
      - Office Phone: 722-3011, Ext. 267 - 268
6) Supervisor, WANHES

Name: L. A. Salvador
Address: 299 Constitution Dr., Pittsburgh, Pa.
Home Phone: 653-5475
Office Phone: 722-3035

3. Site Health Physics

Manager, Industrial Hygiene and Safety

Name: A. T. Sabo
Address: 326 Maple Avenue Pittsburgh, Pennsylvania
Home Phone: 731-8075
Office Phone: 722-3011, Ext. 234

4. Site Fire Brigade

1) Site Central Control Office (HP Office)
   Phone: 722-3011, Ext. 242 - 243

2) Fire Marshall

Name: E. F. McDonough, Jr.
Address: 1908 Bower Street, N. Braddock, Pa.
Home Phone: 824-6648
Office Phone: 722-3011, Ext. 232

3) Captain - Fire Brigade

Name: William J. Miller
Address: Box 101 Arona Rd. & 2nd Street, Irwin, Pa.
Home Phone: 836-8038
Office Phone: 722-3011, Ext. 256

5. Yukon Fire Department

Phone: 722-3101 (Cicci Motors) 722-3128 (Central Hotel)

6. Pennsylvania State Police

Phone: 834-4400

7. Westmoreland Hospital

Phone: 837-0100 - Nursing Supervisor

8. WANL Thermal & Nuclear Design

Manager: J. G. Gallagher
Home Phone: 835-8009
Office Phone: 892-5600, Ext. 5307, 6287
9. **WANL Industrial Hygiene**
   - **Manager**: M. R. Beebe
   - **Home Phone**: 531-8737
   - **Office Phone**: 892-5600, Ext. 5159, 6457

10. **Pennsylvania Department of Health**
    - **Phone**: Area 717, 787-2480, Ext. 849 - Tom Gerusky (Health Physicist)
        787-2480, Ext. 5027 - Mr. Gilbertson

11. **SNPO Health and Safety**
    - **R. Hartfield**
    - **Phone**: Area 216, 433-4000, Ext. 6821

12. **WANL Medical**
    - **A. A. Spritzer, M. D.**
    - **Medical Director, Westinghouse Astronuclear Laboratory, Large, Pennsylvania**
    - **Phone**: 892-5600, Ext. 6345
    - **Office Phone**: 242-7520
    - **Home Phone**: 242-8553

13. **NRO**
    - **C. C. Ross**
    - **Vice President, Nuclear Rocket Operations**
    - **P. O. Box 15847**
    - **Sacramento, California 95813**
    - **ATTENTION**: S. Klein
    - **Phone**: Area 916, 355-5255