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WANL-TME-267
REVISION E
JANUARY 1967

Westinghouse Astronuclear Laboratory

WESTINGHOUSE ASTRONUCLEAR EXPERIMENTAL FACILITY REACTOR OPERATIONS MANUAL

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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.C WANEF Operating Limits, and within the framework of WANL-TNR-099, Rev. A, 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.

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. During all critical experiments, at least three persons will be present in the control room. One shall be rated equal to or greater than Experimentalist and another equal to or greater than Experimentalist-in-Charge. The third person may be from the operating staff. The minimum qualification for the person at the console is that of Reactor Operator-in-Training.

Intent of Rule 4. It is the intent of this rule to assure that the reactor is always adequately attended during operation. Reactor operation begins when the "Reactor Status Lights" are placed in the "Reactor On" condition. During the operation of the reactor, one and only one person will be in charge of the reactor operation. In no case may there be dual responsibility in the control room for reactor operations. The two qualified persons required in the control room (Experimentalist-in-Charge and Experimentalist) assures

Figure 1.1 Operational Areas

that the Experimentalist-in-Charge has available a qualified person with whom he can cross-check his decisions. The third person required in the control room is to be available for emergency action. Prior to beginning reactor operation, the Operator, Experimentalist and Experimentalist-in-Charge in the control room must 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 34 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 check-out or maintenance with the remainder of the mechanisms locked and the keys secured.

Rule 7. The critical assembly must be shutdown on demand of any member of the operating staff.

Intent of Rule 7. It is possible that, during reactor operation, WANEF Operating Staff personnel working in other areas of the facility may observe a condition that could be hazardous to personnel and equipment. Although this hazardous condition may or may not be directly connected to the operation of the reactor, if the person observing the condition feels that the reactor operation should be terminated, he may demand that the reactor be "Scrammed" and the person at the controls must immediately scram the reactor. It is expected that this rule will govern any differences of opinion on hazards situations such that the reactor is shutdown until the difference is resolved.

Rule 8. Personnel not part of the WANEF Operating Staff will take no action affecting facility operation or safety without first obtaining the permission of the Scientist-in-Charge or his designated Experimentalist-in-Charge.

Intent of Rule 8. The safe operation of a critical facility requires that all operations be regulated so that personnel safety is not compromised. While the Operating Staff is aware of WANEF regulations and procedures, this is not the case with visitors to WANEF. In some cases, what may seem like the proper procedure may, in fact, be dangerous to personnel or the facility. To prevent the occurrence of such situations, it is required that all personnel, not part of the WANEF Operating Staff (e.g., maintenance men), receive the permission of the designated Experimentalist-in-Charge prior to

performing any work in any of the "Operational Areas" of the facility. After the requests of visitors have been approved, those WANEF Operating Staff members concerned will be notified of the presence of the visitors and the purpose for their being at WANEF.

Rule 9. All facility personnel are required to be familiar with the facility emergency plans and equipment.

Intent of Rule 9. The emergency plan (Section 5.9) in use at WANEF covers some major emergency conditions (such as accidental criticality, fire, excursion), in detail and is flexible enough to cover all emergency conditions in a general way. Because an emergency plan of action is of little use if the personnel are not completely familiar with, and have a complete understanding of, the details of the plan, it is the primary intent of this rule to ensure that all personnel know precisely what actions are required of them in the event that an emergency condition arises at WANEF or at any other Waltz Mill Site facility. Since visitors at WANEF cannot be expected to know the emergency plan, it is the responsibility of each member of the WANEF Operating Staff to ensure that each visitor assigned to him follows the proper procedure under emergency conditions.

Rule 10. All experimental procedures and activities must be understood and agreed upon in advance by those persons participating in the experiment.

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 is 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 qualified as Experimentalist-in-Charge and must inspect the critical assembly before, during and after any changes in core loading. A third person qualified as Reactor Operator must be on duty at the console.

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 Experimentalist-in-Charge 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.

Intent of Rule 13. The primary purpose of this rule is to provide the security guard or other personnel with a list of personnel who are thoroughly familiar with the various areas in case there is an emergency. The time required to contact a person who knows what actions should and can be taken for various types of emergency conditions, can be kept to a minimum. Also the possibility of untrained personnel performing corrective procedures that could extend the hazards is minimized. The names are posted in the control room and the Guard Post.

Rule 14. The maximum number of personnel within three feet of the pressure vessel or critical assembly during any test cell activity 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.

Intent of Rule 14. It is calculated that the reactivity effect produced by one person in the near vicinity of the PAX or the FCX type cores is of such magnitude that under certain conditions where a number of persons are near the core the minimum shutdown required by the WANEF Operating Limits might be violated. A further consideration is that any part of a human body or other hydrogenous material can cause a significant reactivity increase by insertion into the nozzle end of the core or into a hole left by the removal of a cluster. Continuous vigilance must be exercised to prevent such an occurrence. It is the primary intent of this rule to limit the number of people to a safe reactivity value. Note that full body contact with the end of PAX is prohibited.

Rule 15. The maximum number of personnel allowed in the Control Room at any time when the "Master Key Switch" is ON shall be four persons.

Intent of Rule 15. The intent of this rule is to avoid confusion in the control room when the operating staff is in the process of checking-out, starting up, or operating the reactor.

Rule 16. Two persons authorized and instructed by the Scientist-in-Charge must be present in the test cell during any test cell activity with the PAX cover removed.

Intent of Rule 16. The primary intent of this rule is the protection of personnel in the Test Cell. Since operations in the Test Cell are by nature potentially hazardous, it is desirable to have a minimum of two individuals in the cell at all times when there is access to the PAX core. Thus if any hazardous condition arises, one man is available to sound the alarm and take whatever other steps are required to protect other personnel. Also, this rule provides a method for cross-checking work and decisions.

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. Each day, prior to beginning experimental operations, satisfactory operation of all pertinent systems must be demonstrated and recorded. A system checkoff sheet will be employed and logged.

Intent of Rule 2. It is the intent of this rule to be sure that the reactor is always adequately reviewed and checked out for operation. It is the responsibility of the Scientist-in-Charge to see that these checkouts are performed by qualified personnel. This checkout will be done under the cognizance of a person qualified as Operator or higher. The pre-startup checkout forms for the reactor will be signed personally by the Experimentalist-in-Charge prior to the start of the reactor operations.

A visual check of the facility and core by the Experimentalist-in-Charge, 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.

Intent of Rule 4. It is the purpose of this rule to ensure that, at any time when increases in the reactivity of the core are being made remotely, the method used for inserting the positive reactivity be also capable of removing it at a faster rate than the rate of insertion. It is intended that remote positioning of detectors that have a small reactivity effect can be accomplished with equal insertion and withdrawal speeds.

Rule 5. Manual additions of positive reactivity can be made to the core only when the reactor is subcritical, and it has been clearly demonstrated that the reactor will remain subcritical throughout the operation.

Intent of Rule 5. The intent of this rule is to protect personnel from the effects of an accidental criticality by ensuring that all manual changes in core reactivity are evaluated prior to making the change. The method of making manual changes to the core reactivity is covered by the "Manual Reactivity Change Procedure," SOP-5.4.

Rule 6. Reactivity may be added in only one manner at a time. The reactivity rate of insertion for PAX must not exceed 0.064\$/sec. when the core is shutdown by less than 3.25\$. The reactivity rate of insertion for FCX must not exceed 0.20\$/sec. when the core is shutdown by less than 10.0\$.

Intent of Rule 6. A critical assembly operator should not be expected to anticipate the effects of simultaneous additions of reactivity. There are circumstances under which it would be possible to increase reactivity by more than one method simultaneously, for example, when moving counters in the core or when performing danger coefficient dynamic measurements. Normal operating procedures will not allow such operational freedom unless all

but one of the effects has been demonstrated to be very small. Under all circumstances, the combined reactivity insertion rate should not exceed that specified in the rule. The values of 0.064\$/sec for the PAX cores and 0.20\$/sec for FCX has been chosen as a maximum rate of reactivity insertion by any given manner. The conservativeness of this rate of reactivity insertion is justified by the following:

1. PAX (0.064\$/sec.)

- a) it would take about 15 seconds to become prompt critical from the delayed critical condition,
- b) a full second at the maximum rate produces a period of about 155 seconds, and,
- c) the response time of the safety instrumentation for inserting control drums completely into the core is less than one second.

2. FCX (0.20\$/sec.)

- a) It would take about 5 seconds at the maximum rate to become prompt critical from the delayed critical condition but since the FCX is limited to a maximum excess of 0.50\$ the prompt critical condition could not be attained and thus the minimum period that could be attained would be about 5 seconds, and
- b) The response time of the safety instrumentation for inserting the control elements completely into the core is less than one second.

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 element locks will be under the control of the Scientist-in-Charge or an Experimentalist-in-Charge at all times when not in the "key box" specified above. When fewer than twelve (12) 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 $\leq 1.00\%$.

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 $0.50 k_{ex}$, 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 the PAX. Experiments in which the PASS hoses cannot be physically connected to the reactor must be recommended for approval by the Nuclear Safety Committee and approved by AGC/SNPO-C. 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.

1.2.3 Safety Devices and Instrumentation Controls

Rule 1. The required minimum operational instrumentation for reactor operation shall include:

- 1) One source range neutron-sensitive detector and indicator with associated "flux-up" source-up interlock (minimum count rate of 120 cpm required).
- 2) Three neutron-sensitive detectors driving amplifier systems with the capability of flux level monitoring, and including one period and three flux level scrams. The source level must be visible on one of the recorded flux level channels.
- 3) One gamma level detector and indicator with a gamma high level alarm.
- 4) A total of three pulse channels for initial criticality of new assemblies.

Intent of Rule 1. It is the intent of this rule to ensure that the required minimum instrumentation for safe operation of the reactor be available at all times when reactor operation is contemplated. During startup of the reactor, it is required that a startup range channel be functioning properly and that this channel be so interlocked that reactor startup is prohibited if the required count rate is not obtained.

Three level channels and one period channel are required at all times to provide a multiplicity of shutdown signals to scram the reactor in case of excessive reactivity additions. In addition, two of the channels will be displayed on a recorder and at least one channel will be of such sensitivity that it displays the source level on the recorder prior to startup.

The limits at which scrams will be initiated should, in general, be set as low as possible. This condition should be satisfied on safety channels required by this rule. Sensitivity adjustments, if any, on safety instrumentation channels should be designed or located so that a channel cannot be inadvertently made inoperative by adjustment of the sensitivity control. Safety channels have been designed and tested to assure that they do not saturate in the operating range for which they are affording protection. When utilizing equipment with damping controls, these controls should be set to provide the minimum amount of damping consistent with operational requirements of avoiding excessive scrams from spurious noise signals.

- Rule 2. The test cell shall include equipment designed to protect personnel in the cell from inadvertent radiation exposure. Specifically, the following items are included in the test cell design:
- 1) Means shall be provided for manual activation of shutdown systems including at least one in the test cell for the automatic systems.
 - 2) An audible indication in the critical assembly area of source range multiplication is required for operations involving personnel in the test cell. An audible indication shall also be provided in the control room.
 - 3) A test cell area-to-control room intercommunication system shall be in operation and be of sufficient sensitivity so that communications or noise from any part of the test cell area which might indicate an emergency can be heard clearly in the control room.

- 4) A neutron-source-out-of-storage indicator will be conspicuously located in the test cell.
- 5) An audible alarm system will be available to indicate to area personnel that reactor operation is about to begin.

Intent of Rule 2. Protection of personnel from radiation hazards is of the utmost importance in the operation of a critical facility. Shielding walls and exclusion fences are used to ensure that there is no hazard to anyone outside of the exclusion area during normal reactor operation. Also, warning lights are provided inside the exclusion fences to warn personnel outside the test cell of possible hazardous conditions. In the test cell itself an additional problem exists since during operations in the cell radiation conditions could arise which would be hazardous to personnel. This problem is intensified in that several separate operations could be in progress in the cell at the same time and since it is not possible to see all points in the cell from any single location, personnel in one group could be subjected to high radiation levels caused by the other group. Although personnel are trained to inspect the test cell and warn all persons prior to commencing any operation involving a radiation hazard, it is conceivable that a person out of sight may not be warned. To prevent this type of incident from occurring and to alert personnel of a possible hazardous condition before it actually occurs, the safety devices listed above are specified as the minimum requirement for any test cell operations. These devices provide both visual and audible warning to personnel in all areas of the cell whenever any changes in the radiation levels in the cell occurs. Also to protect personnel from an inadvertent reactor startup from the control room, a CELL VETO is provided in the test cell and this VETO can override any attempt to start the reactor.

Rule 3. Radiation monitoring instrumentation for the protection of personnel in the various areas where radioactive materials are present shall include:

- 1) Gamma monitors in each such area, set to alarm at a level consistent with Federal Regulations or, if in the Test Cell, at 100 mrem/hr.
- 2) Portable survey instruments in the control room.
- 3) A manually actuated general alarm.

Intent of Rule 3. The protection from radiation hazards of personnel working in the various areas where radioactive materials are present is of the utmost importance. It is the intent of this rule to ensure that this protection is provided at all times by the radiation monitoring equipment. If at any time it is found that the stationary gamma monitor in any particular area is not functioning properly, operations in that area will be halted until adequate portable instruments are available. Also in the event that a portable instrument is being used in any area, for purposes of monitoring an operation, whether or not it is replacing a stationary monitor, there shall be a minimum of two persons in the area. The function of the one person will be to monitor the radiation levels while the other person performs the required operation.

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 WANEF 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 WANEF 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.

Astronuclear
Laboratory

WANL-TME-267

Rev. E

EXPERIMENTAL DETAILS CHECKLIST

TITLE OF EXPERIMENT:

OBJECTIVE:

EQUIPMENT REQUIREMENTS:

HAZARDS CONSIDERATIONS:

EXPERIMENTAL DETAILS:

DATA REQUIRED:

EXPERIMENTALIST: _____ Date: _____

SIC: _____ Date: _____

MANAGER, THERMAL & NUCLEAR DESIGN: _____ Date: _____

Figure 1.2 Experimental Details Checklist

1.4 WEEKLY OPERATIONAL MEMORANDA

The Scientist-in-Charge will submit a weekly forecast of experimentation for the forthcoming week to the Manager, Thermal and Nuclear Design. This forecast, known as the "Weekly Operational Memorandum" supplements the Experimental Details Checklists in providing the principal written means used by the Scientist-in-Charge in communicating with the Thermal and Nuclear Design Department on matters relating to nuclear safety. Because it broadly identifies the experimental activities to be followed, it provides a means for keeping non-line personnel abreast of the experimental program. Information copies will be sent to the Chairman of the Nuclear Safety Committee, the WREC manager and the Waltz Mill Site Health Physics Supervisor.

The Weekly Operational Memorandum is divided into major sections as described below:

1. Prior Operations:

Under this section the operation covered by the period of the previous memorandum will be discussed. Mention should be made of unanticipated events occurring during prior operations such as loading errors, unusual mechanical troubles and scrams and other similar events which relate to nuclear safety. Also, mention should be made of the status of any experiments covered under the previous memorandum.

2. Proposed Operations:

In this section specific statements should be made indicating the experiments to be performed in the forthcoming week.

3. Additional Items:

Other items outside the scope of the experimental test plan should also be discussed in brief. These items could include such things as status of modifications underway at WANEF, proposed changes in operating procedures, proposed changes in non-critical systems, and changes in personnel responsibilities.

1.5 LOGS AND RECORDS

1.5.1 General

Accurate records of all pertinent information concerning the operation of a facility is a necessity. This information offers not only evidence of adequate safety practices, but provides basic data sources of value in current operations and data which can be applied to future safe practices. Standard practices to be followed in keeping the various logs at WANEF are given below.

1.5.2 WANEF Reactor Operations Log

The WANEF Reactor Operations Log is the primary evidence of compliance with the restrictions imposed by the WANEF Operating Limits document and any other restrictions placed on the reactor operation by WANL or AGC/SNPO. Thus, it is important that accurate entries are made in the Log and all pertinent information concerning the operation of the reactor is entered.

The Log will consist, where applicable, of one or more of the following completed forms which are chronologically filed and identified by consecutive page numbers:

- Daily Checkout
- Manual Change Checklist
- Reactor Loading Sheet
- Pre-Startup Checklist
- Reactor Run Sheet
- Periodic Maintenance Checklists.

1.5.3 WANEF Facility Log

The WANEF Facility Log is a book in which daily events affecting, or possibly affecting, the operation of the facility are recorded. Entries in the Facility Log should be precise and should contain enough detail to provide clarity of the entry. Examples of some of the types of entries to be made in the Facility Log include: unusual

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" and pick up two pocket dosimeters which must be worn at all times while on the Site. 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." (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

WANL Security Manual. All uncleared visitors to WANEF will be escorted by a member of the WANEF staff at all times while in the facility. All visitors, irrespective of clearance status, who require entry into any of the Operational Areas as defined above will be escorted by a permanent member of the WANEF staff. Such entry into an Operational area must have the prior approval of the Experimentalist-in-Charge. Visitors to WANEF must comply with specific instructions given them.

1.6.4 Security Checks

When the building has been secured, the security patrolman will make periodic rounds through the entire "Non-Operational Areas," as previously defined, performing checks to ensure all desks, safes, classified files and doors providing access to "Operational Areas" or points of entry to the WANEF building are secured in accordance with the WANL Security Manual. Guard reporting stations, utilizing Detex keys and clock, are located at various points throughout the WANEF premises to ensure periodic checks in these areas. A checklist indicating all areas requiring inspection is provided. The Scientist-in-Charge or one of the designated Experimentalists-in-Charge will be notified by the guard in case of emergency.

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. Approving, in conjunction with the Nuclear Safety Engineer, changes to the Criticality Hazards Control Procedure.
6. 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.
4. Approve, in conjunction with the Nuclear Safety Engineer, changes to the Criticality Hazards Control Procedure.

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 of the WANEF program for the next six months.

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 the designated Experimentalist-in-Charge. 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 the Experimentalist-in-Charge 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. Approved as Experimentalist by Scientist-in-Charge.

5. Experimentalist-in-Charge

1. An Experimentalist-in-Charge must satisfy the conditions for Experimentalist and in addition hold a master's degree or have had equivalent training.
2. A person qualified as Experimentalist-in-Charge shall have a detailed knowledge of the critical facility. His judgment and understanding of the facility and its programs shall be such that the Scientist-in-Charge may delegate the performance of experiments to him with confidence that they will be performed safely and efficiently.
3. Pass an oral review by an examining board composed of the Scientist-in-Charge, Chairman of the Nuclear Safety Committee and Manager, Nuclear Safety Analysis.
4. Approved as Experimentalist-in-Charge by the Scientist-in-Charge.

6. Scientist-in-Charge

1. The Scientist-in-Charge must be a qualified Experimentalist-in-Charge.
2. The Scientist-in-Charge must be a Manager of mature judgment, with a general knowledge of reactor physics and safety procedures, experimental physics background, and a specific knowledge of the design objectives of the project. He shall have the ability to train personnel assigned to him and to instill in them a cautious attitude with regard to safe experimental procedures.
3. Appointed by the Project Manager.

2.4 NON-LINE RESPONSIBILITY

2.4.1 Health Physics

Health Physics coverage for the WANEF operations is provided by the Waltz Mill Site Health Physics Section. This section is responsible for all normal health physics functions at the Waltz Mill Site including the advising of operating personnel on health hazards incident to the handling, use of and exposure to radioactive material and their associated ionizing radiation. The site Health Physics Section may recommend that

an operation be stopped until necessary corrective measures are taken if it feels that an undue personnel hazard exists. In addition, the site Health Physics Section is responsible for ensuring that adequate steps are taken to ensure compliance with appropriate Federal and Commonwealth radiation regulations.

As a supplement to the health physics coverage as described above, a Health Physics Manual will be used by the WANEF facility as a guide to safe operations. This manual, with which all WANEF technical personnel are required to be familiar, includes standards, procedures, and regulations intended as precautionary measures to govern all work involving radiation or contamination hazards.

2.4.2 Nuclear Safety Committee

The WANL Nuclear Safety Committee, which is composed of senior personnel knowledgeable in the various technical and scientific areas pertinent to WANEF operation, reviews and consults on all major problems concerned with nuclear safety of the WANEF facility. Its membership and specific responsibilities are contained in Section 5 of the Operating Limits document.

CHAPTER 3

FACILITY DESCRIPTION

3.1 GENERAL

The WANEF facility contains a test cell, a vault, a fuel assembly room, a reactor control room, a counting room, storage space and offices which are described in Section 3.2. General building services, shared with the Westinghouse Reactor Evaluation Center (WREC) which is a part of the Westinghouse Atomic Power Divisions, are described in Section 3.3

3.2 PHYSICAL DESCRIPTION

3.2.1 Experimental Areas

Figure 3.1 is an aerial photograph and Figure 3.2 is a floor plan of the WANEF facility. The basic structure of the building is concrete building block while the test cell walls and roof are of reinforced concrete. The test cell is 50 ft. high, 40 ft. wide and 40 ft. long with a 22 ft. deep basement. A storage shelf is located across the northern end. The cell is equipped with a 10 ton crane and test stands for the PAX and FCX reactors. A concrete labyrinth is located at the entrance to the test cell for protection against radiation streaming during reactor operations. A vault, of solid block construction covered with a poured concrete roof and equipped with a merchandise type vault door, is used for the storage of fuel. A description of the storage array may be found in the "WANEF Criticality Hazards Control Procedures," WANL-TME-646. An adjacent room with a pass-through to the vault is used for clustering fuel elements.

3.2.2 Reactor Control Room

3.2.2.1 General Description

The control room (Figure 3-2) for the PAX and FCX reactors is arranged as shown in Figure 3.3. It contains the reactor control console, the main 120-volt AC entrance service power panel (BP1); the key-locked relay interlock panel (A), and main circuit wiring panel (B). Also located in this room are the Auxiliary Detector System control console, with its separate 120-volt AC power entrance panel (BP2), and a panel (AA) which contains coaxial circuits leading to the test cell area and the counting room for interconnection of pulse circuitry.

Figure 3.1 WANEF-WREC Facility, Aerial View

3-3

Figure 3.2 Floor Plan of WANEF Facility

610789-88

CONTROL ROOM LAYOUT

611145-2B

Figure 3.3 WANEF Control Room Arrangement

3.2.2.2 Reactor Console Description

Figure 3-4 shows a photograph of the reactor console. The numerals superimposed on this figure represent the items enumerated below.

1. The center area of the reactor console contains, on the upper vertical face, a two-channel strip chart recorder for continuous recording of either Log N Channel No. 4 or No. 5 and one of the linear channels No. 1, No. 2, or No. 3.

2. The 12 (only 7 are used for FCX) position indicators for the control elements are located just below the recorder and are arranged in two rows across the vertical face.

3. The control element IN,OUT and SCRAM/MAGNET lighted pushbuttons are located below the position indicators on a 20 degree sloping panel. These are arranged in 12 vertical rows.

4. Included on this panel on the right side are the controls for the Po-Be neutron startup source. These controls consist of two pushbutton switches that are lighted green for the OUT (Stored) position of the neutron source and yellow for the IN (reactor) position of the neutron source.

5. The multiple element insertion control is also on the right side of this panel.

6. The SCRAM button is on the left side of the 20 degree sloping panel.

7. Just above it is the KEY SWITCH which energizes all the reactor control circuitry.

8. On the vertical panel face above the KEY SWITCH is located the MASTER POWER switch and pilot light for the console.

9. To the left of the two-pen recorder is a Log power meter showing reactor power level at the WREC facility next door.

10. On the right of the recorder is the remote log count rate meter of the startup channel.

Figure 3.4 Reactor Console

11. Below this are the selector switches which determine which log and linear channels are connected into the scram circuits and which of these are recorded.

12. The section to the right of the center vertical face contains the loudspeaker and volume control of the "popper" circuit.

13. The five gamma remote area monitors are located on the upper lefthand panel.

14. The ARMATURE CURRENT Simplytrol is located below the gamma monitors.

15. The MAGNET CURRENT Simplytrol is located beneath that.

16. The control element switches, scram lights and re-sets, and other status lights and switches are located in a block on the rest of this panel.

17. The first panel to the right of the central panels contains the three linear channel micro-microammeters.

18. Below these are the scaler and circuitry for the "popper".

19. The small panel between the two righthand sections of the console contains the re-set switches for the door and gate interlocks.

20. The far righthand panel contains the two Log N-period amplifiers.

21. Below these are the 11 by-pass key switches.

22. Below this is the remainder of the startup channel instrumentation: high voltage supply, amplifier, discriminator, log count rate meter, pulse generator for calibration and circuitry for the three "traffic" lights in the test cell.

23. The PASS dump switch and low voltage indicator lamp are located beneath the remote WREC Log power meter.

All control switches and lights are unambiguously lettered so that operations personnel do not have to have normal color perception.

3.3 SERVICE SYSTEMS

The following systems which service WANEF are shown in Figures 3.5 through 3.12:

Utility Water System

Electrical Distribution System

Heating and Ventilation Systems

Natural Gas System

Figure 3.5 Facility Water System Layout

Figure 3.6 Location of Power Distribution Panels

Figure 3.7 PAX/FCX Wiring Panel Locations

610789-17B

Figure 3.8 Electrical System Schematic

Figure 3.9 Heating and Ventilating System Layout

3-14

562474-A

Figure 3.10 Heating and Ventilating Schematic, Fuel Vault and Assembly Room

611145-7B

Figure 3.11 Heating and Ventilating System Schematic of Test Cell

Figure 3.12 Natural Gas System Layout

CHAPTER 4

CONTROL AND SAFETY SYSTEMS

The design and operation of the nuclear control and safety systems is a major factor in the safe operation of the critical facility. Presented below is a brief description of the systems employed at WANEF to insure safety in the operation of the facility. For a more detailed presentation of the nuclear instrumentation reference should be made to the WANEF Safety Report - WANL-TNR-099.

4.1 NUCLEAR INSTRUMENTATION

A block diagram of the nuclear instrumentation is shown in Figure 4.1. As can be seen from the figure, the system is composed of one BF_3 startup channel, three linear level channels, and two log level channels. The design of the system provides the following safety features for all operations:

1. A minimum of two linear level, one log level, and one period channels capable of initiating scrams.
2. Display of one linear and one log channel on a recorder.
3. Speakers located in both the control room and the test cell to provide an audible indication of the count rate.
4. A "Flux-up" interlock on the startup range channel which prevents control element "out" movement below the minimum 120 CPM count rate.

In addition to the nuclear instrumentation system as shown in Figure 4.1, an experimental system, consisting of three BF_3 channels and their associated equipment, is available.

4.2 PAX/FCX PATCH PANEL

A "patch panel" arrangement is provided to switch the control and detector systems from the PAX reactor to the FCX reactor. An interlock circuit shown in Figure 4.2 prevents operation of either reactor if the "patch panels" are not properly aligned.

Figure 4.1 Nuclear Instrumentation Block Diagram

- K16 - PAX SELECT RELAY
- K17 - FCX SELECT RELAY
- KS - KEY SWITCH
- K14 - CRM FLUX UP
- K15 - TIME DELAY RELAY
- K24 - KEY-CAPTURE BYPASS CIRCUIT RELAY
- K50 - AC POWER RELAY
- K51 - BYPASS RELAY

610789-3B

Figure 4.2 PAX/FCX Patch Panel Logic

4.3 Control Element Drive System

A functional presentation of the control element drive system is given in Figures 4.3, 4.4, and 4.5. The system design has incorporated a number of features which insure that the required safety of operation of the system is maintained. These features are as follows:

1. All actuating drive switches are spring loaded in the deenergized direction to insure that positive pressure is necessary to add reactivity to the core.
2. All actuating "IN" switches must always have the capability of driving the control element "IN" regardless of the operating conditions.
3. The control element "IN-OUT" switches are designed to allow only one element to be moved in an outward direction at a time. This can be seen in Figure 4.6.
4. Relays inserted into the system must be energized to add reactivity. Relay failure interrupts the operation.
5. The control element speeds are designed to allow speeds from 7.5 degrees/minute to a maximum of 90 degrees/minute for PAX and 5 inches/minute to 40 inches/minute for FCX. Also, the speed changes are provided in five equal steps.
6. In the event that a motor overload condition arises due to a "stuck rod" or other malfunction, the control elements automatically scram and the drive "out" motor power supply is turned off automatically.
7. Each control element is equipped with a "capture key lock" and prior to "withdrawal" of the element, the key must be in the lock.
8. Prior to withdrawal of any control elements, the "flux up" interlock and the "warning horn" interlocks must be satisfied.
9. The control element drive is coupled to the control element through an electromagnetic clutch which must be energized to permit withdrawal. Power or electromagnet failure results in the rapid insertion of the control element.
10. Multiple control element insertion is possible by depressing the "Multiple In" switch which energizes all drives in the "IN" direction. This can be seen in Figure 4.3.

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Figure 4.4. Schematic Diagram of PAX Control Drum Drive

Figure 4.5 Schematic Diagram of FCX Control Rod Drum

Figure 4.6 Control Drum In-Out Switch Operation

11. The interpretation of the status lights (IN and OUT limits, SCRAM and MAGNET lights) are given in Tables 4.1 and 4.2 for various conditions on both PAX and FCX.

Table 4.1
Control Element Indicator Lights

<u>Light</u>	<u>Color</u>	<u>Indication</u>	
		<u>PAX</u>	<u>FCX</u>
"IN"	Green	Control Drum fully inserted	Control Rod fully inserted
"OUT"	Amber	Control Drum fully withdrawn	Rack fully withdrawn
"MAGNET"	Blue	Clutch magnet energized	Rod coupling magnet energized
"SCRAM"	Red	Clutch magnet not energized	Rod coupling magnet not energized

Table 4.2

Status of PAX and FCX Control Elements

					Status of Elements		
<u>"MAGNET"</u>	<u>Lights</u>			<u>Magnet Energized</u>	<u>PAX</u>	<u>FCX</u>	
	<u>"SCRAM"</u>	<u>"IN"</u>	<u>"OUT"</u>		<u>Drum</u>	<u>Rod</u>	<u>Rack</u>
On	Off	On	Off	Yes	Full in	Full in	Not full out*
On	Off	Off	On	Yes	Full out	Full out	Full out
On	Off	Off	Off	Yes	Partially withdrawn*	Partially withdrawn*	Partially withdrawn*
On	Off	On	On	Yes	Not applicable	Full in	Full out
Off	On	On	Off	No	Full in	Full in	Not full out*
Off	On	Off	Off	No	Partially withdrawn* and hung up	Partially withdrawn and hung up	Partially withdrawn*
Off	On	On	On	No	Not Applicable	Full in	Full out

* Position must be determined from digital readout device.

4.4 Scram Circuits

Figure 4.7 shows a simplified schematic of the scram circuits that have been incorporated in the design of the WANEF control and safety systems. The system has been designed to provide the following safety features.

1. Individual control element scram switches are provided to allow one control element or any combination of elements to be scrambled. This feature provides flexibility in the experimental operation of the reactor.
2. Heavy duty scram relays (K21, K22, and K23) are provided for total scrams. These relays each have two normally open contacts wired in series in the positive leg of the magnet power supply to reduce the possibility of the failure of scram action due to contact welding. Also, the normally open contacts insure that a scram occurs under a condition of power or component failure.
3. All relay contacts which indicate a scram under abnormal conditions are normally open contacts and must have power applied to the relay to pick up the contacts.

4.5 Interlock System

The interlock system has been designed to insure that all critical items required for the safe operation of the reactor are properly aligned prior to commencing reactor operation. Also, if any critical item becomes misaligned during operation of the reactor, the operation will be automatically terminated.

The various items interlocked and the method of interlocking are tabulated in Tables 4.3 and 4.4 and shown in Figure 4.7.

To provide the flexibility required in the maintenance of such reactor systems as the control element drive system, bypasses have been provided for a number

Figure 4.7 Simplified Scram and Interlock Circuits
 Functional Logic

TABLE 4.3

SCRAM CONDITIONS

<u>Item</u>	<u>Actuating Means</u>	<u>Actuating Signal</u>
Reactor Power	Electronic Trip	High power on either of two controlling linear compensated ion chamber channels.
Reactor Power	Electronic Trip	High power level on controlling Log N compensated ion chamber channel.
Reactor Period	Electronic Trip	Short period on controlling reactor period compensated ion chamber channel.
Test Cell Veto	Manual Switch	Opened and reset manually by operating personnel. Located adjacent to the test stand in the test cell.
Door Interlocks [*]	Limit Switches	Opening one of the following: Truck Doors Test Cell Door Yard Gates Labyrinth Doors Emergency Exit
PAX Out-of-Reactor Position Interlock ^{**}	Limit Switches	Movement of "End-On" or "Side-by-Side" reactor experiment.
Control Element Drive "Out" Motor Current	Simplytrol Meter	50 percent overload of normal operating current for reactor in operation.
Console	Key Switch	Key turned to "Off"
Console	Manual Switches	Manual Activation

* May be bypassed during checkout and maintenance. Only one control element can be moved from "Full In" position because of restrictions by mechanical locks on control elements and by electrical switches and magnet current limiting circuit.

** Used when required.

Table 4.4
Interlock Conditions

<u>Interlock</u>	<u>Method</u>	<u>Condition</u>
Control Element Drive* "Out" Motor Current	Recorder Microswitch	Either a minimum log N level on recorder or
	CRM Relay	A minimum source range count must exist
Control Element Drive "Out" Motor Current	Relay	Either the PAX-Select relay or the FCX-Select relay must be energized
PAX-Select and FCX-Select Relays	Microswitch and panel F and G patches	Panels F and G and source guide tube position must all be for the same reactor
Neutron Source	Relay	Reactor Status must be "Reactor On" to permit any motion of the neutron source.

* May be bypassed during checkout and maintenance. Only one control element can be moved from "Full In" position because of restrictions by mechanical locks on control elements and by electrical switches and magnet limiting current.

of the interlocks. These bypasses have been designed in such a manner that reactor operation is not possible whenever any interlock is bypassed. This is accomplished by limiting magnet current to that required for one magnetic clutch and by requiring that eleven of the twelve control element drive keys be inserted in a special capture key lock prior to bypassing an interlock circuit. A master bypass switch is provided to override all door interlocks simultaneously.

4.6 Radiation Monitors

Located throughout the facility, as shown in Figure 4.8, are a number of gamma radiation detectors which provide an immediate audible alarm in the event of high radiation levels resulting from accidental nuclear criticality.

Each monitor, as shown in Figure 4.9, consists of a gamma sensing ion chamber detector, a local indication and audible alarm, and an indication and audible alarm in the Control Room. The monitors in the test cell also light a warning sign in the labyrinth. Each detector is equipped with a Sr^{90} calibrating source to enable remote calibration of the detectors. Each monitor has a variable alarm set-point. The presently used set-points together with monitor location and range are shown in Table 4.5.

Table 4.5

Monitor Locations, Ranges and Set Points

<u>Location</u>	<u>Range</u>	<u>Typical Alarm Set-points</u>
Reactor Gamma Monitor	0.01R/hr to 10,000 R/hr	0.1 R/hr
Test Cell Fuel Storage Rack	0.001R/hr to 1.0 R/hr	0.02 R/hr
Counting Room	0.001R/hr to 1.0 R/hr	0.02 R/hr
Fuel Assembly Room	0.001R/hr to 1.0 R/hr	0.02 R/hr
Fuel Storage Room	0.001R/hr to 1.0 R/hr	0.02 R/hr

Figure 4.8 Location of Radiation Monitors

Figure 4.9 Gamma Radiation Monitors Block Diagram

During reactor operation the audible signals in the test cell and control room are deactivated for alarms from the monitors in the test cell; the visual signals, however, are unaffected.

The system is provided with a standby emergency power supply which is automatically switched in when the line voltage decreases to approximately 70% of its normal value. As shown in Figure 4.9 the only modification to the system, required to change the former high range gamma alarm in the test cell to a criticality alarm for the test cell fuel storage rack, is the removal of relay K67 contacts from the control room audible alarm. When used as a high range monitor the audible alarm in the control room was not deactivated during reactor operations.

In addition to the five (5) area monitors listed above, an air monitor samples air in the test cell on a continuous basis. This monitor has a range from 50 to 50,000 CPM and will provide a local and remote (Control Room) alarm if the airborne activity level exceeds 10,000 CPM.

4.7 PAX Auxiliary Shutdown System (PASS)

The PASS shown in Figure 4.10 consists of two complete and independent units, each of which consists of a poison storage hopper, gear motor, dump valve, a flexible stainless steel discharge tube and a discharge nozzle. Both units are supported by a welded structure above and to the west of PAX. The 12 volt DC gear motors are supplied from a storage battery through a dump switch on the console. A pilot light on the console lights when the voltage from the power supply drops below a pre-set value. The poison material used is natural boron carbide of a -14+20 mesh size.

Figure 4.10 PAX Auxiliary Shutdown System

CHAPTER 5

STANDARD OPERATING PROCEDURES (SOP)

SOP-5.1 DAILY CHECKOUT PROCEDURE

5.1.1 General

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.

3. Magnet Currents

1) Ensure that the magnet current is within tolerances for each control element.

2) Ensure that the MAGNET CURRENT Simplytrol is set correctly.

4. Recorder

1) Ensure that the chart drive is functioning properly.

2) Ensure that the chart and ink supplies are adequate.

5.1.4 Interlock By-Pass Check

1. Ensure that all SCRAM/MAGNET buttons are in the SCRAM position.

2. Reset the unlocked control element and drive to 10% of full out.

3. Reset another control element; both elements should SCRAM.

4. Reset the MAGNET CURRENT relay meter.

5.1.5 Instrument Calibrations & Scram Checks

1. Startup Range Calibration

1) Ensure that power to the startup channel is ON and that the high voltage is correctly set.

2) Turn the CALIBRATE switch to 10^2 and adjust the CAL 10^2 adjustment until the Log CRM reads 10^2 .

3) Ensure that Low Level Test Cell light is illuminated.

4) Turn the CALIBRATE switch to 10^6 and adjust the CAL 10^6 adjustment until the Log CRM reads 10^6 .

5) Ensure that the High Level Test Cell light is illuminated.

NOTE: Repeat steps 2) and 4) several times until no further adjustments are required with the CALIBRATE switch in the 10^2 and 10^6 positions.

6) Place the CALIBRATE switch in the OPERATE position and ensure that the Medium Level Test Cell light is illuminated in the range 10^4 to 10^6 .

7) Hold the pulse generator switch in the ON position and ensure that the Log CRM reads on the red CALIBRATE mark.

8) Release the pulse generator switch.

5.1.6 Gamma Monitors

1. Ensure that power to the monitoring system is ON.
2. Depress the CAL button and ensure that the meter reads the value specified on the meter face.

CAUTION: DO NOT SET OFF ALARMS.

3. Check each alarm setpoint to ensure that it is set at the value specified on the meter.

5.1.7 Linear Level Channels

1. Ensure that power to each micromicroammeter is on and that the POLARITY switch of each is in the (+) position.
2. Turn the RANGE switch to the 10×10^{-9} position and position "LIN CH SEL SWITCH" to CH No. 1.
3. Reset and drive the control element to 10%.
4. Adjust ZERO CONTROL to obtain LEVEL TRIP. Check that the following occur:
 - 1) Control element scram occurs at trip point.
 - 2) LEVEL TRIP point is positioned properly.
 - 3) Recorder follows meter.
 - 4) Appropriate LIN CH TRIP LIGHT is illuminated at TRIP POINT.
5. Depress the ZERO CHECK BUTTON and adjust linear channel meter to read zero.

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 ∞ .

If it does not, adjust ∞ 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 Cell Veto Check

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

5.1.11 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.

5.1.12 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

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 _____, CAL _____, OPERATE _____
 Test Cell Count Rate Lights
 Low _____, Med _____, High _____

2) Gamma Monitors

No.	1	2	3	4	5
(1) Cal.	_____	_____	_____	_____	_____
(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. (∞)	_____	_____
(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)	_____	_____

- 4) Flux Up Setting Log N _____ SU _____

6. Cell Veto CK _____
7. Console Secured _____

Completed by _____

Date _____ Time _____

PRE-STARTUP/MANUAL CHANGE CHECKLIST

Run No. _____ Exp. Details Checklist No. _____ Date _____

1. REACTIVITY CHANGES

Type _____

Magnitude _____ β K_{ex} _____ β K_{sd} _____ β

2. GENERAL CHECKS

Control Room
Daily Checkout Comp _____
Recorder On _____

Test Cell
Truck Door Closed _____
PAX Cover Off _____

3. MANUAL CHANGE CHECKS

Control Room
"Reactor Standby" Lights On _____
Log CRM _____ CPM
Lin Rec Ch _____ Amps.
"Popper"-Aud _____

Test Cell
Cell Veto - "Veto" _____
Crit. Ass'y Ck _____
"Popper" - Aud. _____
Drums/Rods Locked _____

4. PRE-STARTUP CHECKS

Control Room
"Reactor On" Lights On _____
Interlocks Satisfied _____
Scrams Clear _____
Source In _____
Log CRM _____
Lin Rec Ch No. _____ Level _____ Amps
Log Rec Ch No. _____ Level _____ Amps
WREC Level Ck _____
Scram Check _____

Test Cell
Crit. Ass'y Ck _____
PASS Hoses Connected _____
Drums/Rods Unlocked _____
Personnel Check _____
Veto Reset _____
Doors Closed _____

Responsible Persons

Operator _____
EIC _____
Exp. _____
Other _____

Remarks _____

Completed by _____ Time _____ Page _____

SOP-5.2 REACTOR OPERATING PROCEDURE

5.2.1 General

The reactor operating and experimental procedure is a logical sequence of steps to be followed during critical experiments involving reactor startup, operation, and shutdown. In all instances when the reactor is operating, the rules and regulations contained in the Reactor Operations Manual are governing.

5.2.2 Pre-Startup/Manual Change Checklist

5.2.2.1 General

Before operations can begin, the Pre-Startup/Manual Change Checklist must be completed. This checklist serves three purposes: 1) it ensures that all the required checks of systems and components are successfully completed prior to making any core changes, 2) it serves as the final check and alignment of the various operating systems immediately prior to reactor operation, and 3) it serves as a means for assuring that the required personnel are aware of the reactor condition and proposed operations.

The rules to be followed in using the "Pre-Startup/Manual Change Checklist" are listed below.

1. At all times when the checklist is employed, Part 1 (Reactivity Changes) and Part 2 (General Checks) must be completed in addition to identifying the Run No. and applicable Experimental Details Checklist.
2. If a change in the core is to be made which does not require reactor startup, then the Pre-Startup portion of the checklist need not be completed.
3. If no core changes have been made, then Part 3 (Manual Change Checks) need not be completed prior to reactor startup.
4. Rules for Part 3 (Manual Change Checks) are in Section 5.4.

5.2.2.2 Reactivity Changes

This section of the checklist should be completed by the Experimentalist or Experimentalist-in-Charge prior to making any reactivity changes and/or starting up the reactor. The person completing this section should give a brief description of the change along with its estimated value. The excess and shutdown reactivities of the reactor after the change has been effected should be listed also. The values used for the reactivity change, k_{ex} and k_{sd} should be based on experimental and analytical evaluations.

If no reactivity changes were made prior to starting up the reactor, then this should be indicated and the k_{ex} and k_{sd} values should be the same as the previous run.

5.2.2.3 General Checks

Control Room

Daily Checkout complete

The person completing this checkout should ensure that the Daily Checkout has been completed within the appropriate time limit.

Recorder On

Check the Log-Linear recorder to ensure that the drive is on and that the chart and ink supplies are adequate.

Test Cell

Truck Door Closed

If the truck door is not locked, the yard area inside the fence will be checked to ensure that no personnel are present and then the door will be closed and locked.

PAX Cover Condition

If the cover is on the PAX reactor and this reactor is to be operated, obtain the keys from the Experimentalist-in-Charge and unlock and remove the cover. If FCX is to be operated, ensure that the cover is on the PAX reactor.

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.

Scrams Clear

Ensure that all scram 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-in-Charge prior to starting up.

Scram Check

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

5.2.2.5 Responsible Persons

Four blanks are included. All reactor changes and/or reactor operations require a minimum of three 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-in-Charge.

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-in-Charge.

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 ($\sim 39\mu$ 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-in-Charge.

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-in-Charge.

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-in-Charge, the reactor will be shut down by scrambling 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-in-Charge 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."

SOP-5.4 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-in-Charge 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-in-Charge 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-in-Charge 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 in excess of 1.0\$. Inserts which are supported independently of one another are considered to be separate in-core experiments. The Experimentalist-in-Charge 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-in-Charge 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-in-Charge 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 $\rho \leq +20¢$, "minimal" insertions where $\rho \leq +2¢$, "moderate" insertions where $20¢ < \rho \leq 50¢$, and "large" insertions where $50¢ < \rho \leq +5.00\$$. In all cases the net reactivity step is no more than + 50¢.

(1) "Minimal" reactivity insertions are those which do not exceed +.02\$. Such addition 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_{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_{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-in-Charge 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_{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 10\$ 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 10\$ 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 2.0\$/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-in-Charge 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 10.0\$ nor may it produce a net reactivity change in excess of Δ where $\Delta = 50\% - \rho_{\text{excess}}^*$. Inserts which are supported independently of one another are considered to be separate in-core experiments. The Experimentalist-in-Charge 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-in-Charge 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 50% 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-in-Charge.
3. Two persons, one of whom is an Experimentalist-in-Charge, 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 shut-down.
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 the Experimentalist-in-Charge 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 the Experimentalist-in-Charge.

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 document 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. 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 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 the Experimentalist-in-Charge such that the 50% 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.

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 $\pm 50\text{¢}$. 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.

5.5.4 PAX In-Core Experiments

1. Objective

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

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.

3) Any displacement of the experiment must not compromise the minimum shutdown margin (3.25%) nor may it produce a net reactivity change in excess of 1.0%.

4) The detailed design of experiments involving liquids together with procedural safeguards must be reviewed by the WANL Nuclear Safety Committee to insure that no credible accident can result in a reactivity increase in excess of 1.0%.

5) Positive addition of reactivity will be made by only one means at a time. Thus, control drums may not be withdrawn while neutron or gamma detectors are being moved remotely.

6) The limits and procedures in the WANEF Operating Limits document and the Reactor Operations Manual will be governing. In particular, the installation and removal of experiments will be governed by SOP-5.4 and the operation of the reactor by SOP-5.2.

3. General Methods

1) Reactivity Worths

Material and structural reactivity worths, usually expressed in units of cents per kilogram, will be obtained by measuring the change in core reactivity (e.g. period measurements or changes in delayed critical control drum positions) due to the insertion or removal of a known mass of material.

2) Power and Flux Measurements

The spatial and spectral distribution of the neutron and gamma fluxes will be determined by positioning detectors with different spectral responses at specified locations in and about the reactor. The detectors will be in the form of limited amounts of material (wire, foil, fuel material, powder, etc.) which are removed after the irradiation for activation analysis or may be small electronic devices which provide on-line data during operations. These latter may be moved remotely during operations to provide axial or radial flux distributions.

4. Hazards Considerations

This procedure, when performed within the limitations described herein and in the WANEF Operating Limits document is within the intent of the WANEF Safety Report and presents no unevaluated safety hazard.

5.5.5. PAX Out-of-Reactor Experiments

1. Objective

- 1) To determine the reactivity worth or effect of materials and structures adjacent to or in the vicinity of PAX.
- 2) To determine the effect of environment upon the reactor.
- 3) To determine the spatial and spectral behavior of the neutron and gamma fluxes outside of the reactor.

2. Special Precautions and Limitations

1) The structural design of the experiment shall employ 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.

2) When an experiment involves a combination of radial and end-on reflectors, each will be supported independently of each other to prevent the simultaneous collapse of both reflectors.

3) Any displacement of the experiment during placement must not compromise the minimum shutdown margin with personnel present (2.8%) nor override the control capability of the drums during failure.

4) Any experiment which, if it did fail, would insert more than 1.0\$ in reactivity into PAX must include position interlocks. They must be mounted independently of the experiment and checked out daily when in use.

5) Devices which are supported independently of one another are considered to be separate out-of-reactor experiments.

6) The detailed design of experiments involving hydrogenous liquids together with procedural safeguards must be reviewed by the WANL Nuclear Safety Committee to insure that no credible accident can result in the liquids getting into either PAX or FCX.

7) Positive additions of reactivity will be made by only one means at a time. Thus, control drums may not be withdrawn while detectors, etc., are remotely positioned.

8) The limits and procedures in the WANEF Operating Limits document and the Reactor Operations Manual will be governing. In particular, the installation and removal of experiments will be governed by SOP-5.4 and the operation of the reactor by SOP-5.2.

3. General Methods

The general methods for Reactivity Worth experiments and Power and Flux Measurements are the same as those given for PAX In-Reactor Experiments, see SOP-5.5.4.

4. Hazards Considerations

This procedure, when performed within the limitations described herein and in the WANEF Operating Limits document, is within the intent of the WANEF Safety Report and presents no unevaluated safety hazard.

5.5.6 PAX Neutron Generator Measurements (PNG)

1. Objective

To measure the response of PAX to controlled variations in neutron population using an artificial source.

2. Special Precautions and Limitations

1) Because a neutron generator experiment may involve structures both inside of and external to the reactor, the Special Precautions and Limitations of SOP-5.5.4 will apply to those portions of the experiment within the reactor while those of SOP-5.5.5 will apply to those portions external to the reactor.

2) The control drums may not be withdrawn while the neutron generator is operating if the generator causes a visual response in the operational detector channels.

3. General Method

The dynamic characteristics of a reactor can be determined by observing the response of the reactor flux to a modulated source of neutrons injected into the reactor by a generator. The measurement of the decay of the prompt neutron populations produced by bursts from the generator will determine β/λ in a just critical reactor or the shutdown in a subcritical reactor. Changes in shutdown caused by material changes to the reactor are directly related to the reactivity worth of the material. The flux response due to a modulated neutron source can also be cross-correlated with the source driving function to determine the reactor transfer function. This measurement is analogous to the reactivity oscillator.

After installation of the generator target in the reactor, the reactor will be brought to the condition of interest (subcritical, delayed critical, or supercritical) according to SOP-5.2. The neutron generator will then be operated in the desired manner (steady state, pulsed or modulated) and the reactor flux response determined.

4. Hazards Considerations

The nuclear safety implications of the neutron source experiment are quite minimal since operation of the neutron source does not change the reactivity of the reactor. Under certain conditions, the operational channels will respond to significant changes in flux level due to the neutrons from the generator. This would occur, for example, when the flux level in the core is low and the generator is operated at high beam currents. Therefore, the insertion of positive reactivity will not be made when the generator is causing a significant response to the operational detector channels. The yield of the neutron generator and flux level in the reactor will be adjusted such that scram limits on the operational channels will not be exceeded.

It is concluded that this procedure, when performed within the limitations described herein and in the WANEF Operating Limits document, is within the intent of the WANEF Safety Report and presents no unevaluated safety hazard.

5.5.7 PAX Reactivity Oscillator Experiments

1. Objective

To measure the response of the PAX to controlled variations in reactivity using a reactivity oscillator.

2. Special Precautions and Limitations

1) Because a reactivity oscillator experiment involves structures both inside of and external to the reactor, the Special Precautions and Limitations of SOP-5.5.4 will apply to those portions of the experiment within the reactor while those of SOP-5.5.5 will apply to those portions external to the reactor.

2) The control drums may not be withdrawn while the oscillator is operating.

3) A limit of 50¢ (5.5 sec.period) on potential core supercriticality will be observed at all times. For example, operation of the oscillator in the reactor which is 10¢ supercritical restricts the maximum reactivity swing of the oscillator to 40¢.

3. General Method

A reactivity oscillator is a device which can vary, in a periodic manner, a limited amount of reactivity in the core. It normally consists of two sections of absorber that are movable with respect to each other such that the total reactivity of the device can be varied. Varying the frequency and waveform of the mechanical movement over a small distance results in a similar variation in reactivity.

After installation of the oscillator (in accordance with SOP-5.4), the reactor is adjusted to the condition of interest in accordance with SOP-5.2. The oscillator is then operated and the variation in reactor flux determined as a function of wave shape and frequency of the oscillator. By cross-correlating the reactivity and flux waveforms, one can determine the response characteristics (transfer function, impulse function) of the reactor from which kinetic parameters (β/λ , delayed precursor data, shutdown) can be extracted.

4. Hazards Considerations

The reactivity swing of the oscillator is restricted to that which would produce supercriticality of less than 50¢ should the oscillator fail in its most reactive configuration. As the oscillator is independent of the operational control elements, its failure will be effectively countered by normal reactor shutdown.

The instantaneous reactivity insertion rate produced by the oscillator can exceed the 6.4¢/sec rate limitation. However, this facility limit is interpreted to refer to a steady state addition rate which results in a net insertion of reactivity. The

amplitude frequency of the oscillator will be adjusted such that the scram levels on the operational channels will not be exceeded. It is concluded that no unevaluated safety hazard is presented by this procedure when it is performed within the limits described herein and in the WANEF Operating Limits document.

SOP-5.6 FCX EXPERIMENTAL PROCEDURES

5.6.1 FCX Loading and Criticality (Bare Core)

1. Objective

To assemble fuel safely in an FCX reactor and achieve criticality with a $k_{ex} \leq 50\%$.

2. Special Precautions and Limitations

- 1) Based on analytical and experimental data, the total fuel 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) A 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 so that $k_{ex} \leq 50\%$.
- 5) The limits and procedures of WANEF Operating Limits document and the Reactor Operations Manual are governing.

3. General Method

Fuel 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. Each succeeding increment will be no more than the smaller of 20% of the total complement of the fully assembled reactor or one-half of the extrapolated additional fuel required for criticality with the rods fully withdrawn. 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-in-Charge 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 a $k_{ex} \leq 50 \%$

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) A 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 $k_{ex} \leq 50 \%$.

5) The limits and procedures of the WANEF Operating Limits Document and the Reactor Operations Manual are governing.

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-in-Charge such that the 50 β 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-in-Charge such that the 50 β 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.

3) Any displacement of the experiment must not compromise the minimum shutdown margin (10.0%) nor may it produce a net reactivity change in excess of Δ where $\Delta = 50 \beta - \rho$ excess and ρ excess is the excess reactivity with the experiment in place.

4) The detailed design of experiments involving liquids together with procedural safeguards must be reviewed by the WANL Nuclear Safety Committee to insure that no credible accident can result in a reactivity increase in excess of Δ .

5) Positive addition of reactivity will be made by only one means at a time. Thus, control rods may not be withdrawn while neutron or gamma detectors are being moved remotely.

6) The limits and procedures in the WANEF Operating Limits document and the Reactor Operations Manual will be governing. In particular, the installation and removal of experiments will be governed by SOP-5.4 and the operation of the reactor by SOP-5.2.

3. General Methods

1) Reactivity Worths

Material and structural reactivity worths, usually expressed in units of cents per kilogram will be obtained by measuring the change in core reactivity (e.g., period measurements or changes in delayed critical control drum positions) due to the insertion or removal of a known mass of material.

2) Power and Flux Measurements

The spatial and spectral distribution of the neutron and gamma fluxes will be determined by positioning detectors with different spectral responses at specified locations in and about the reactor. The detectors will be in the form of limited amounts of material (wire, foil, fuel material, powder, etc.) which are removed after the irradiation for activation analysis or may be small electronic devices which provide on-line data during operations. These latter may be moved remotely during operations to provide axial or radial flux distributions.

4. Hazards Considerations

This procedure, when performed within the limitations described herein and in the WANEF Operating Limits document, is within the intent of the WANEF Safety Report and presents no unevaluated safety hazard.

5.6.5 FCX Out-of-Reactor Experiments

1. Objective

- 1) To determine the reactivity worth or effect of materials and structures adjacent to or in the vicinity of FCX.
- 2) To determine the effect of environment upon the reactor.
- 3) To determine the spatial and spectral behavior of the neutron and gamma fluxes outside of the reactor.

2. Special Precautions and Limitations

- 1) The reactivity effect of the experiment when placed next to the FCX must not compromise the 0.50\$ limit on excess reactivity.
- 2) The reactivity effect of the experiment if it should move closer to the reactor must not compromise the 0.50\$ limit on excess reactivity.
- 3) The reactivity effect of removing the experiment must not compromise the 0.50\$ limit on excess reactivity.

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

- 4) The detailed design of experiments involving hydrogenous liquids together with procedural safeguards must be reviewed by the WANL Nuclear Safety Committee to insure that no credible accident can result in the liquids getting into PAX or FCX.
- 5) Positive additions of reactivity will be made by only one means at a time. Thus, control drums may not be withdrawn while detectors, etc., are remotely positioned.
- 6) The limits and procedures in the WANEF Operating Limits document and the Reactor Operations Manual will be governing. In particular, the installation and removal of experiments will be governed by SOP-5.4 and the operation of the reactor by SOP-5.2.

3. General Methods

The general methods for Reactivity Worth experiments and Power and Flux Measurements are the same as those given for FCX In-Reactor Experiments, see SOP-5.6.4.

4. Hazards Considerations

This procedure, when performed within the limitations described herein and in the WANEF Operating Limits document, is within the intent of the WANEF Safety Report and presents no unevaluated safety hazard.

5.6.6 FCX Neutron Generator Measurements (PNG)

1. Objective

To measure the response of FCX to controlled variations in neutron population using an artificial source.

2. Special Precautions and Limitations

1) Because a neutron generator experiment may involve structures both inside of and external to the reactor, the Special Precautions and Limitations of SOP-5.6.4 will apply to those portions of the experiment within the reactor while those of SOP-5.6.5 will apply to those portions external to the reactor.

2) The control drums may not be withdrawn while the neutron generator is operating if the generator causes a visual response in the operational detector channels.

3. General Method

The method of this experiment is independent of the reactor used. See SOP-5.5.6.3 for the method as described for PAX experiments.

4. Hazards Considerations

The hazards considerations are independent of the reactor used. See SOP-5.5.6.4 for the hazards discussion for PAX PNG experiments.

It is concluded therefore that this procedure, when performed within the limitations described herein and in the WANEF Operating Limits document, is within the intent of the WANEF Safety Report and presents no unevaluated safety hazard.

5.6.7 FCX Reactivity Oscillator Experiments

1. Objective

To measure the response of the FCX to controlled variations in reactivity using a reactivity oscillator.

2. Special Precautions and Limitations

1) Because a reactivity oscillator experiment involves structures both inside of and external to the reactor, the Special Precautions and Limitations of SOP-5.6.4 will apply to those portions of the experiment within the reactor while those of SOP-5.6.5 will apply to those portions external to the reactor.

2) The control drums may not be withdrawn while the oscillator is operating.

3) A limit of 50 ρ (5.5 sec period) on excess reactivity will be observed at all times. For example, operation of the oscillator in the reactor which is 10 ρ supercritical restricts the maximum reactivity swing of the oscillator to 40 ρ .

3. General Method

The method of this experiment is independent of the reactor used. See SOP-5.5.7.3 for the method as described for PAX experiments.

4. Hazards Considerations

The reactivity swing of the oscillator is restricted to that which would produce supercriticality of less than Δ should the oscillator fail in its most reactive configuration. As the oscillator is independent of the operational control elements, its failure will be effectively countered by normal reactor shutdown.

The instantaneous reactivity insertion rate produced by the oscillator can exceed the 20 ρ /sec rate limitation. However, this facility limit is interpreted to refer to a steady state addition rate which results in a net insertion of reactivity. The amplitude frequency of the oscillator will be adjusted such that the scram levels on the operational channels will not be exceeded. It is concluded that no unevaluated safety hazard is presented by this procedure when it is performed within the limits described herein and in the WANEF Operating Limits document.

SOP-5.7 PROCEDURE FOR CONTROL OF LIQUIDS IN THE TEST CELL

5.7.1 General

Section 4.2.12 of the Operating Limits states:

"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 the core the reactivity insertion is $< 1.00\beta$ in either PAX or FCX."

The introduction of liquids into the PAX or FCX core could present a very serious hazard and thus all liquids in the cell must be kept to a minimum. In order to effectively control the amounts of liquids allowed in the cell and to establish the manner in which these liquids will be handled, the following procedures have been established. These procedures define what liquids are required in the test cell for effective operation as well as the type of containers which are to be employed, and the procedures for handling and periodically checking the condition of the liquids.

5.7.2 Procedures When Reactors are Present

5.7.2.1 Test Cell Crane

The overhead crane in the test cell has approximately 5 gallons of oil which is used for lubrication of the crane gear box. The crane is equipped with a splash pan which is designed to prevent any normal oil leakage from dropping to the test cell floor or onto either of the cores. This pan is capable of holding about 1 gallon of oil. To insure that no inadvertent oil leakage from crane comes in contact with either FCX or the PAX cores the following guidelines have been established:

- 1) When not in use, the crane will be positioned such that it is not over either core.
- 2) The oil in the splash pan will be checked on a periodic basis.
- 3) At any time when repairs are in progress on the crane, wherein the oil is exposed, the crane will be positioned at the northeast corner of the cell away from the reactors.

5.7.2.2 Drum Drive Shock Absorbers

Each of the drum drive shock absorbers contains about 140 ml of oil which is used to absorb the shock of the scram spring and to lubricate the scram mechanism. This oil is in a unit where leakage is kept to a minimum by the use of seals. In the event of a small leak in the shock absorber, there is a gland which can be tightened to stop the leakage. The entire drive unit will be removed from the cell if major repairs are required.

5.7.2.3 FCX Rod Drives

The FCX rod drive mechanisms each contain about one pint of grease in the speed reducer gears. This is a very thick grease and it is contained in a sealed housing with the only penetrations being the motor shaft and the shaft to the pinion gear. Leakage through these penetrations is minimal but to ensure that no excessive leakage goes unnoticed these penetrations will be inspected on a periodic basis. If at any time the mechanism is disassembled to the point where there exists a possibility of the grease escaping from the mechanism, then measures will be taken to ensure that this leakage does not go beyond the rod drive platform.

5.7.2.4 FCX Shock Absorbers

The FCX shock absorbers, which are mounted in the core tank under the FCX core, contain about 350 ml of oil apiece. These units are completely sealed and their only penetrations are the shaft of the plunger and a small drain plug on the bottom. Leakage from these units is very improbable but to ensure that no excessive leakage goes unnoticed, each unit will be inspected periodically. If at any time any of these units require disassembly, the disassembly process will be performed outside the test cell.

5.7.2.5 Seepage Water in Test Cell Basement

A situation exists in the WANEF test cell basement wherein water enters due to ground seepage. This is a chronic condition that has existed since construction of the test cell. A sump pump is installed in a hole at a low point in the basement floor and removes water accumulation automatically. However, this pump has on previous occasions stopped either due to power failure or the buildup of minerals in the mechanism. This allows water to accumulate on the basement floor. Two water detectors are installed to give indication that water exists by an annunciator light on the console and another at the site guard station. The sump pump is then reset or cleaned and all water is removed.

5.7.2.6 PNG Transformer

A high voltage transformer is required for operation of the PNG and will be located so that the level of oil is below the top of the reactor cores. This transformer contains 60 gallons of oil and is completely sealed at all times. If at any time the container must be opened for any reason, the entire process will be performed outside the test cell area.

5.7.2.7 Vacuum Pump for PNG

A vacuum pump is required for initial pumpdown of the PNG. This pump contains approximately five quarts of oil and is completely contained except for a ventilation pipe extending through the top of the pump housing. This pump will be utilized as a roughing pump for the PNG and therefore is periodically required in the test cell. The position of this pump when operating will be such that the level of oil is below the top of the reactor cores. Since the pump is portable all maintenance, including oil changes, will be accomplished outside the test cell.

5.7.2.8 Turning Stand Gear Reductor

The turning stand, used to invert the assembled reactor or reflector, contains approximately 2.5 quarts of oil in the gear reductor. This stand is located in the southeast corner of the test cell at a distance in excess of 15 feet from either PAX or FCX. The gear reductor is totally enclosed and sealed; therefore it is inconceivable that this oil could affect the FCX or PAX reactors.

5.7.2.9 Test Cell Emergency Lights

Each of the emergency lights in the test cell is equipped with a storage battery containing about one gallon of water. The batteries are sealed units except for small breather holds on the top of each cell and thus no hazard should arise from inadvertent water spillage. Periodically water must be added to the cells. When this is necessary the water will be added using a small squeeze bottle containing no more than 500 ml of water. If, at any time, it is necessary to disassemble an emergency light unit such that the water in the battery is exposed, then this operation will be performed outside the test cell area.

5.7.2.10 Vehicles in the Test Cell

Occasionally it is necessary to bring vehicles into the test cell to load or unload materials and hardware. When these occasions arise the following rules will be followed to ensure that no inadvertent hazard arises:

- 1) The vehicle will be moved into the cell only as far as is necessary to accomplish the loading or unloading operation.
- 2) The time required for the vehicle to be in the cell will be minimized.
- 3) The vehicle will not be left unattended while in the cell.
- 4) No liquids will be removed from the vehicle when in the cell.
- 5) The vehicle will contain no exposed liquids while in the cell.

5.7.2.11 Use of Liquids in the Test Cell

When a reactor is shutdown the use of small quantities of liquids are sometimes necessary in the test cell. Examples of these requirements are, 1) oil cans containing cutting oil for drilling operations or for lubrication purposes, 2) small squeeze bottles which contain water or solvents for cleaning purposes, 3) small cans of paint for "touch up" purposes, and 4) damp mop for cleaning and decontamination purposes. These containers will contain no more than 500 ml which, if inadvertently dumped into the reactor, would increase core reactivity no more than \$1.00 in either PAX or FCX. However, these liquids will be used only when the reactors are secured. In this situation PAX and FCX will be shutdown by a minimum of 3.25\$ and 10.00\$, respectively.

SOP-5.8 MAINTENANCE PROCEDURES

5.8.1 General

Each component or system which affects the safe operation of the facility will be subjected to a periodic maintenance checkout. This checkout may take the form of either a visual inspection or a test of operation depending on the nature of the component or system to be checked. To ensure that each critical system receives the necessary maintenance checks at appropriate intervals, a number of maintenance procedures have been formulated and are contained in the following sections. These procedures, which are set up on weekly, monthly, semi-annual and annual bases, are to be used in conjunction with Maintenance Logs for the major systems and checklists derived from these procedures. Presented below are basic rules that should be followed by the person(s) performing the checks.

1. The person completing the check should initial the checklist and indicate the time it was completed.
2. For all checkouts requiring data on operation, such data should be presented in detail in the appropriate Maintenance Log.
3. All comments on the operation of a component and/or system will be made in the Maintenance Log in sufficient detail as is required for clarity.
4. After the completion of any maintenance repairs, replacements, or field changes, the affected components or systems will be subjected to a checkout and/or test to ensure that the hazards associated with the operation of the facility have not been increased above those analyzed in the WANEF Safety Report.
5. The following procedures do not apply to the reactor not connected to the console except that they will be carried out prior to operation of that reactor if the allotted time has elapsed.

5.8.2 Weekly Maintenance Checks

1. Control Element Drives

Visually inspect each control element drive unit. Check, in particular, for any dust or dirt accumulation, oil leakage, loosened bolts, frayed cables, or misaligned mechanical stops.

2. Basement Water Detectors

Actuate each water detector and ensure that the control room light and guard house light and buzzer come on.

3. Reactor Status Lights

Place the status lights on REACTOR STANDBY and then on REACTOR ON and ensure that each remote light and the revolving beacon on the front gate function properly.

4. Gamma Hazard Light

Check the labyrinth GAMMA RADIATION HAZARD light to ensure that it functions.

5. Rear Yard Gamma System

Check the rear yard gamma system to ensure that the revolving beacon and bell function.

6. Test Cell Inspection

Visually inspect the test cell area for cleanliness.

5.8.3 Monthly Maintenance Checks

1. BF₃ Voltage Plateau

Check and set as required the detector voltage on each BF₃ channel*.

This should be accomplished as follows:

- 1) Place the PuBe source at a position near the detector which produces 1000 cps.
- 2) Lower the detector voltage to a value that produces zero counts.
- 3) Increase the voltage in 100 volt steps and plot voltage vs. counts.
- 4) Set the detector voltage at a value which is on the detector voltage plateau.

* See footnote next page.

Indicate below when each of the BF_3 channel H.V. settings was checked.

Startup Range	PAX _____	FCX _____
ADS No. 1	PAX _____	FCX _____
ADS No. 2	PAX _____	FCX _____
ADS No. 3	PAX _____	FCX _____

2. BF_3 Discriminator

Check and set as required the discriminator bias on each BF_3 channel*

- 1) Position the PuBe source in the same position as in 1(1).
- 2) Vary the discriminator bias from its minimum value to its maximum.
- 3) Record and plot discriminator voltage vs. counts. Repeat for various

settings of the amplifier gain and set the discriminator voltage at the midpoint of the discriminator plateau.

Indicate below when each of the BF_3 channel discriminator settings were checked.

Startup Range	PAX _____	FCX _____
ADS No. 1	PAX _____	FCX _____
ADS No. 2	PAX _____	FCX _____
ADS No. 3	PAX _____	FCX _____

3. Area Gamma Monitors

- 1) Calibrate each area gamma monitor per the "Daily Checkout."
- 2) Ensure that each area monitor actuates its own remote bell and the control room bell.
- 3) Place a gamma source near each detector and record local and remote meter readings.
- 4) Compare readings with previous measurements.
- 5) Check emergency power supply and service, as required.

*Checks on the ADS channels will be performed when these channels are required for loading and initial criticality.

4. Rear Yard Gamma System

Calibrate the system with a known gamma source placed as close to the detector as possible.

5. Assembly Room Ventilation

1) Check the operation of the vacuum table and the auxiliary exhaust system.

2) Visually inspect main supply, main exhaust, and auxiliary exhaust units on roof.

3) Check condition of vacuum table filter and replace, if necessary.

6. Test Cell Ventilation

Trip the Test Cell Fuel Storage monitor alarm and ensure that the exhaust fan stops, the space heater stops and heater dampers close.

7. Neutron Detectors

Check each detector battery supply under loaded conditions to ensure that it is functioning properly.

8. Portable Radiation Instruments

Have Health Physics check and calibrate each of the portable radiation instruments of the facility.

9. Emergency Lights

Check each of the emergency lights through the facility for proper operation. Notify proper site personnel to service defective units. See also Section 5.7.2.9.

10. Building Alarm System

Actuate the Building Alarm from each station and ensure that the alarm can be heard throughout the facility. Check the emergency power supply and service, as required.

11. Crane Drip Pans

Inspect the drip pan on the crane and if any abnormal amount of oil is found in the pan, check the crane for oil leakage and repairs.

5.8.4 Semi-Annual Maintenance Checks

1. Nuclear Instrumentation

The following instrumentation should be checked and calibrated according to the instructions in the "WANEF Console Operating and Service Manual."

Startup Range System

Linear Channels No.'s 1, 2, and 3

Log Channels No.'s 4 and 5

Log-Lin Recorder

Area Gamma Monitoring System

2. PAX Control Element Drives

Inspect each of the items listed below on all of the PAX drive mechanisms.

1) Magnet Clutch

- (1) Gap between rotor and armature
- (2) Mechanical couplings of rotor to shaft

2) Mechanical Stops

- (1) Fastening bolts, torque as required
- (2) Max. and min. positions
- (3) Shaft key

3) Scram Mechanism

- (1) Fastening bolts, torque as required
- (2) Oil leakage

4) Limit Switches

- (1) Spring loaded actuators
- (2) Switch electrical and mechanical operation

5) Position Indicators

- (1) Gear alignment
- (2) Operate all elements of the system

3. FCX Control Rod Drives

Inspect each of the items listed below on each of the FCX control rod drive mechanisms.

1) Magnet

- (1) Universal joint and pins
- (2) Cable connections
- (3) Magnet and armature alignment

2) Limit Switches

Check operation and positioning of each of the limit switches.

3) Position Indicators

- (1) Gear alignment
- (2) Operate all elements of the system

4) Shock Absorbers

Check each of the shock absorbers to ensure proper operating characteristics and inspect for oil leakage.

4. Cell Sump Pump System

Inspect the following items for proper operation

- 1) Float and float switch
- 2) Pump
- 3) Check valve

5. Assembly Room Ventilation

Inspect all coarse and absolute filters on the system

6. Radioactive Sources

Leak test each source per the Source Storage and Handling Procedure.

7. PAX Auxiliary Shutdown System (PASS)

Check the operation of the PASS by connecting the flexible hoses to an appropriate catch tank (5 gal. container) and actuating the PASS dump switch at the console.

1) Ensure that the B_4C pellets are discharged from the hoppers and that all electrical systems function properly.

2) Inspect the nozzles on the core for any signs of blockage.

The initial interval of this checkout shall be bi-monthly for the first six months after which it shall automatically become semi-annual.

5.8.5 Annual Maintenance Checks

1. PAX and FCX Control Element Drive Systems

1) Inspection

Inspect each of the items listed below on all of the drives.

(1) Electric Motors

Check in particular the brushes, fastening bolts, couplings, and the electrical connections.

(2) Gear Reducers and Gear Boxes

Check the oil level and condition on the PAX gear reducers and check the gear conditions and lubricant on the FCX drives.

2) PAX Scram Mechanism

Inspect at least one of the PAX scram mechanisms for spring wear, evidence of binding, and condition of the rack and pinion. If any evidence of excessive wear is found, inspect the remaining mechanisms.

3) Operational Tests

After completing the inspections of steps 1) and 2), check the operation of each mechanism as follows.

(1) Operate each mechanism over its entire operating range and check the operating currents, the speeds, and the position of all mechanical stops and limit switches.

(2) Scram each mechanism from the full out position and measure and record the scram time. In the case of PAX, the scram time is to be taken from full out to 15° . Compare these scram times with the previously measured scram times. Ensure that the average velocity of the PAX mechanisms is no less than the operating limit of $500^{\circ}/\text{sec}$. Ensure that the total scram and delay time of the FCX mechanisms is within the operating limit of 1 second.

(3) Initiate the scram of one mechanism from the full out position by a nuclear safety channel trip. Measure and record the scram delay time from the initiation of the scram signal to the beginning of control element motion. Ensure that it is within the operating limit of 200 msec.

(4) Repeat twice more using other nuclear safety channels such that all three of the scram relays K21, K22, and K23 have been checked out. (Refer to Figure 4. 7.)

4) FCX Control Element Inspection

Disassemble an FCX control rod to assess the overall mechanical integrity including dimensional changes to the polyethylene.

2. Interlocks

Check each door and gate which is interlocked to see that a reactor scram occurs when the door is opened.

SOP-5.9 EMERGENCY PROCEDURES

5.9.1 General

The function of emergency procedures is to provide a plan of action to be followed under emergency conditions in which calm planning is difficult. The following paragraphs describe the alarm system used at WANEF and the interconnecting alarms which connect the WANEF facility with the other facilities at the Waltz Mill Site. Also described are categories of emergency conditions and prescribed action for each, followed by emergency notification, and drills that will be practiced by WANEF. All WANEF personnel are required to be familiar with the various alarms and the action associated with the alarm conditions.

5.9.2 Alarm Systems

The alarm systems at the WANEF facility are composed of three separate alarm systems as described below.

5.9.2.1 Local Area Evacuation Alarm

1. Description

A condition of high radiation above a preset level in any area controlled by WANEF "Area Radiation Monitors" will cause a buzzer to sound in that particular area and in the control room. Airborne activity in the test cell is continuously monitored and activates a remote audible alarm if excessive airborne contamination exists. Refer to Figure 4.5 for the radiation monitor locations.

2. Alarm Point

Radiation levels required to trigger the "Area Radiation Alarms" are set to meet the requirements of Federal Regulations as amended, except as established for units in the test cell. The

trip levels associated with each area monitor are listed in Chapter 4, Section 4.6.

3. Action

- (1) All personnel in the immediate area of the alarm will immediately evacuate the area and, if the reactor is in "Standby" or "Reactor ON" condition, they will notify the control room of the nature of the alarm. For non-operating situations, the Scientist-in-Charge will be notified.
- (2) The senior staff member (Experimentalist-in-Charge or Scientist-in-Charge) will notify all personnel of the condition.
- (3) If, upon immediate investigation, it is determined that a hazardous condition exists, the Building Alarm will be sounded and the building procedure carried out. Normally one would expect the senior staff member to direct that this alarm be activated, but any staff member may activate it if his evaluation indicates the necessity to do so.

5.9.2.2 WANEF-WREC Building Alarm

1. Description

The WANEF-WREC Building Alarm is an interconnected alarm system which provides for the notification of both WREC and WANEF personnel in the event that a hazardous condition arises at either facility. The system has horns located throughout both facilities which can be actuated manually from three stations at WANEF and either manually or automatically from various stations at WREC. Figure 5.1 shows the location of the alarm horns and the actuating stations at WANEF.

Figure 5.1 Location of the Alarm Horns and Actuating Stations at WANEF

2. Action

- (1) Upon continuous sounding of the Building Alarm, the reactor will be immediately shutdown. The flux level channels and the recorder will be left operating.
- (2) Unless conditions or instructions dictate otherwise, all personnel will promptly assemble in the control room. Personnel cognizant of the emergency condition will be responsible for redirection of assembly if such is advisable.
- (3) The senior staff member (Experimentalist-in-Charge or Scientist-in-Charge) present will ascertain the nature and the extent of the problem and assume responsibility for the appropriate countermeasures and communications as follows:
 - 1) One person will be directed to make necessary preliminary radiation surveys.
 - 2) Communications will be immediately set up by the senior staff member with the WREC facility to keep them informed, or, if the alarm originated from WREC, to determine the extent of the hazardous condition.
 - 3) One person will be selected by the senior staff member to communicate the existing conditions to other appropriate persons and/or agencies.
 - 4) One person will be directed to ensure that all classified material is secured if this action is not detrimental to the health and safety of personnel.
- (4) Personnel not necessary to assist in bringing the emergency condition under control will evacuate the facility to a designated reassembly point when it is safe or expedient to do so. Prescribed action for the emergency conditions is outlined in Section 5.9.3.

- (5) Detailed and separate reports will be prepared by all personnel at the earliest opportunity, but not later than 24 hours after the alarm. Consolidation of these reports will be accomplished by the directing staff member.

5.9.2.3 General Site Alarm

1. Description

The general site alarm is the ALERT signal (a high-pitched rapid warbler sound) which can be actuated at WREC, WANEF and the Health Physics office in the WAPD Facilities Building. All emergency conditions requiring general site cognizance will be announced over the public address system in conjunction with the ALERT signal. The ALL CLEAR signal is a steady tone over the public address system.

2. Action

Detailed instructions for emergency conditions are contained in the Waltz Mill Site Emergency Procedures. In brief, the following actions should be exercised by WANEF personnel upon receipt of the alarms listed above:

(1) Alert

- 1) Report to the control room and standby for instructions over the Voice Command System. If ordered to evacuate by the senior staff member secure all systems and proceed to the designated assembly point.

- 2) All members of the Fire Brigade should prepare to report to the scene of a fire unless otherwise directed. (Two members of the WANEF staff are in the Fire Brigade.)

(2) All Clear

- 1) All personnel, upon hearing this signal, shall return to their designated work areas.

5.9.3 Categories of Emergency Conditions and Prescribed Action

5.9.3.1 Accidental Criticality

1. If WANEF area monitoring systems indicate an excursion has occurred, the building alarm will be sounded and the steps outlined in Section 5.9.2.2 will be carried out. Also, in addition to the steps outlined in Section 5.9.2.2 the following steps will be followed:
 - (1) For an excursion involving the PAX assembly, the EIC will direct the activation of the PAX Auxiliary Shutdown System.
 - (2) If the excursion has been contained by the building, personnel not required to assist with the emergency will be instructed to go to the site dispensary for dosage evaluation.
 - (3) If the excursion is not contained by the building, a radiation survey of the area will be performed to determine evacuation procedures.
 - (4) The senior staff member will promptly assign evacuation routes based on the location of the accident.
 - (5) While evacuation of all personnel is being effected, methods of correcting the radiological condition will be evaluated.
 - (6) When operational control of the critical area has been established, direction of the operation will be released

to the Site Emergency Control Staff. Any required action by Health Physics will be in accordance with the Waltz Mill Site Emergency Team Procedure, including Appendix A, Nuclear Accident and Dosimetry Evaluation.

5.9.3.2 Fire

1. Detection of a fire of a magnitude to endanger personnel or nuclear source material in the facility will be cause to sound the Building Alarm.
2. Personnel will assemble in the control room unless circumstances or instructions indicate otherwise.
3. Personnel unnecessary to the fire control will be instructed to go to the site dispensary.
4. In fighting the fire, the following regulations will be followed:
 - 1) Only CO₂ extinguishers may be used in the test cell or fuel storage vault. Use of water is prohibited. See Figure 5.2 for extinguisher locations.
 - 2) Met-L-X extinguishers can be used for areas other than the test cell or fuel storage vault if pyrophoric materials are involved.
 - 3) Fire fighting will be directed by WANEF staff members who are cognizant of the hazards involved in fighting fires on or around WANEF type fuel. The Yukon Fire Department will not be allowed access to the WANEF premises except by permission of the Scientist-in-Charge or designated alternate, and then only to put out fires exterior to the building which will also be directed by designated responsible personnel.

Figure 5.2 Fire Extinguisher Locations

- 4) If nuclear source materials are involved, an adequate radiation survey will be conducted during all phases of the activity. Respirators are mandatory. Personnel monitoring equipment must be provided. Health Physics will aid in ascertaining that adequate radiation services are available.
- 5) No attempts to combat fires in Radioactive Materials Areas will be made without adequate radiation survey during all phases of the operation.

5.9.3.3 Radioactive Material Spill

1. The Building Alarm will not be sounded. Minimizing personnel movement in the immediate vicinity of the hazard is necessary.
2. The senior staff member present will define necessary initial prophylactic measures.
3. Radiation safety personnel (Health Physics Staff) will perform a definitive area survey and then a detailed personnel survey, and will outline appropriate personnel procedures for evaluation of the extent of the ingested radioactive materials.

5.9.4 Emergency Notification

The person designated to notify appropriate persons and agencies will complete the appropriate calls indicated as follows. These, in turn, assume the responsibility for further notification. WANL will report promptly to Aerojet-General and the Contracting Officer any changes in the physical condition of the reactor or its operating characteristics that might affect the safe operation of the reactor.

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) Manager, WREC

Name: E. G. Taylor
Address: 9 Stoden Drive, Greensburg, Pennsylvania
Home Phone: 834-1053
Office Phone: 722-3041

2) Manager, Plant Services

Name: C. J. Ferrell
Address: RD No. 2, Mt. Pleasant, Pennsylvania
Home Phone: 887-8995
Office Phone: 722-3011, Ext. 267, 268

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. 233, 254

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. 248

5) Supervisor, WANHES

Name: R. Eichbauer
Address: 217 Blackwood Drive, Greensburg, Pa.
Home Phone: 834-3140
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 Alternate Phone: Ext. 243

2) 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. 269

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)
787-6436, Ext. 5027 - Mr. Mason

11. SNPO Health and Safety

R. Hartfield/David Smith
Phone: Area 216, 433-4000, Ext. 6821, 6110

12. WANL Medical

A. A. Spritzer, M. D.
Medical Director, Westinghouse Astronuclear Laboratory
Large, Pennsylvania
Phone: 892-5600, Ext. 6345, 214-7520 (Home)

13. REON

C. C. Ross
Vice President, Reactor Engines Operations - Nuclear
P. O. Box 15847
Sacramento, California 95813
ATTENTION: J. B. Philipson
Phone: Area 916, 355-4276