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AN ANALYSIS OF OPERATIONS DIVISION TRAINING PROGRAMS

E. N. Cramer

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INTRODUCTION

A training program is generally thought of as either a series of lectures about some subject or frequent, supervised repetitions of some particular task. Unless considerable attention is paid to many seemingly extraneous factors, the trainee may acquire much relatively useless information or may be capable of handling only those specific tasks for which he was trained. Before a suitable outline of an appropriate and meaningful training program can be developed, these factors should be considered; otherwise, the training program is likely to be somewhat ineffective.

The first item which should be considered is the type of organization which the training program must either establish or re-enforce. The various levels of personnel and their job functions may then be determined; and, for each level of personnel, the necessary items of training and education together with the degree of performance and knowledge can be fixed. A survey of the existing experience, performance, and knowledge can then be made in order to determine how much training and education is necessary. The possible methods to be used can be established; and, finally, the actual training and educational program can be detailed.

This paper discusses:

1. The operating philosophy of the organization,
2. Experience in using various methods of training and education,
3. Type of personnel to be trained, material to be learned.

Included as Appendices are:

A. A list of factors which affect the operating philosophy, methods of teaching, and personnel selection;

B. A sample Reactor Operator study guide;

C. A brief sketch of material used in radiation control lectures;

D. A check list for Radiation Safety and Control;

E. A Reactor Operator Qualification Check List;

F. A description of a teaching aid--the xenon machine.

It is necessary to define the following terms for their usage in this paper since the word "training" is generally used to include both training and education:

Training--Acquiring practical skill in the performance of some specific task. A well trained person is one who can easily perform some specific task, either a particular calculation or physical movement.
Education--Acquiring the ability to apply knowledge and reasoning powers to solve a problem. A person who is educated in a particular field should be able to solve most of the solvable problems which arise in this field but may not be able to perform specific functions with specific equipment.

Education is a highly personal thing. It must be acquired (or learned) by the individual. A college graduate may be well trained without being educated, under the definitions above. Both education and training may be obtained informally.

In essence, the quantity and quality of the various individuals in an organization should be determined by the work they are expected to do and the authority and responsibility given to them. Training and education are merely the means whereby preselected individuals are given the knowledge necessary for their job.

OPERATING PHILOSOPHY OF THE ORGANIZATION

This is probably the most important single factor affecting training and education and also the most difficult to define. While ten different organizations may each operate "identical" reactors for "identical" purposes, there will usually be ten different ways of operation. (Indeed, in a comparatively short time the reactors are probably no longer identical.)

Types of Organization

The operating philosophy of an organization can best be determined by examining in detail the responsibility and authority of the various operators and supervisors and determining the degree of authority of each level of personnel. For simplicity three categories (degrees of authority) are chosen:

1. Highly centralized,
2. Balanced,
3. Considerably decentralized.

Highly Centralized Authority

One or two people direct the entire organization. No important work is possible without the consent or presence of these individuals. All changes to procedures, test programs, etc., are either initiated or approved by these individuals. Operators, test engineers, and maintenance personnel do no important nonroutine operations without the concurrence of these key individuals.

Because of the very nature of this procedure, the size of this organization is usually quite small. In the reactor field, this may be typical of a small criticality facility or university-"teaching" reactor. Any routine 24-hour operation is also ruled out.

Balanced Authority

No one person carries the entire load, although the chain of authority may eventually pass through one individual. Considerable responsibility and authority are delegated at various levels of management with progressively less authority and narrowing fields as the level of management decreases. Certain types and magnitudes of problems are routinely solved by persons exercising their authority; higher magnitude problems require higher levels of authority and competence.

This is characteristic of continuously operating reactors of a rather flexible nature. Research, testing, and, occasionally, experimental reactors fall into this pattern.

Considerably Decentralized Authority

Almost everyone is equally able to do a particular job, usually because of long-term repetition. The pattern of operation is almost habitual; few changes to the existing hardware are made. It is difficult to tell the difference between a high-level operator and a low-level supervisor.

This pattern is typical of power- and production-type reactors following initial startup, assuming no large-scale design changes. It may be typical of any type of reactor which is operated in the characteristic mode of continuous operation without major deviation from well established patterns.

Factors Determining the Operating Philosophy

1. In the ORNL Operations Division, the authority breakdown by personnel level is as follows:

a. All matters pertaining to experiments[1] other than the implementation of safety and prescribed-emergency procedures are not under the authority of reactor operating personnel.

b. Maintenance (other than minor adjustments), prescription of core loadings, and changes in operation (other than the implementation of prescribed-emergency procedures) are under the authority of the Reactor Supervisor.

c. The actual physical actions to be performed, on the authority of, and according to, procedures authorized by the Reactor Supervisor, are supervised by the Shift Engineer or Shift Foreman. These persons supervise all startups and power-level changes.

d. The actual physical actions are performed by reactor operators, under supervision for anything but routine checks. All reactivity changes are made under supervision (except for the implementation of prescribed-emergency procedures). The operator has little authority or responsibility to do other than perform routine tasks according to existing rules and procedure. He is primarily a "watchtender". During an emergency situation, the operator is, however, expected to take any action necessary before a supervisor arrives to take charge.

The responsibility breakdown, by reactor, is as follows:

ORR--Because it is comparatively new, because of the frequent variation in both the reactor and experiments, and because of the undesirability (due to the presence of an appreciable concentration of xenon) of shutdown to investigate minor problems, supervision at the ORR requires a high degree of technical education, both for the Reactor Supervisor and for Shift Engineers.

LITR--Due to the (relatively) unchanging nature of both the reactor and the experiments, only the Reactor Supervisor needs to be technically educated. A well-trained Shift Foreman is able to solve most minor problems on shift.

OGR--Due to the unchanging nature of the reactor and experiments, long operating history, difficulty of obtaining prompt criticality, and the large heat capacity of the fuel, the OGR may be supervised by a well-trained reactor supervisor who obtains technical assistance from technically educated personnel. A well-trained shift foreman is able to solve minor problems on shift.

2. A second major factor in determining the operating philosophy is the availability of competent technical assistance[2]-- experts in reactor physics and heat transfer, computing and programming, etc. Unless these experts are readily available and familiar with reactor problems, the operating organization will have to acquire or develop these necessary personnel.

3. The type and complexity of reactor experiments and of the operating cycle are likewise important. When it is possible to shut a reactor down for the weekend without more than minor inconvenience, it is unnecessary, except where safety is involved, to spend additional money on highly reliable components. In similar fashion, component failure can be allowed to shut the reactor down without inconvenience and instrument technicians brought in later to fix the instrument. In some reactors this is not permissible; in these coincidence circuitry and installed spares are used, and well trained personnel must be instantly available.

Operations Division Operating Philosophy

For the reasons listed and because it is inherently better to limit the authority of watchtenders, the ORNL Operations Division philosophy has been to:

1. Rely heavily on instrumentation, both in number of instruments and in conservatism of design (e.g., thermocouple failure gives the safety action, rather than just an alarm);

2. Place the desk operator in the role of watchtender--observing the behavior of the instrumentation and making routine "checks" on the performance of various equipment;

3. Allow relatively little freedom to lower-level supervisors[3] by attempting to follow procedural methods for all routine work and

maintaining trouble-shooter personnel on call;

4. Use the technical staff for experiment review, for assistance in the more technical operational problems, and for all long-range problems;

5. Place the burden of operating experiments on the experimenter after completing a safety review at the Laboratory management level.

This philosophy has permitted the use of well-trained but initially relatively uneducated operators and supervisors who have become educated through practice at progressively increasing levels of performance.

EXPERIENCE IN USING VARIOUS METHODS OF TRAINING AND EDUCATION

There is no substitute for actual experience. Regardless of eventual position, all nonadministrative persons in an operating staff should actually perform fuel loading, decontamination, daily checks, and other routine duties and should start up the reactors and observe their behavior during normal operation and shutdown.

Training given by observation and performance is called "on-the-job" training. Training by attendance at classes or by performing work in simulated situations may be called "formal" training. Generally, formal training is more efficient for technical people, while on-the-job training is most necessary for operator-type people.

Training-education of Operations Division personnel is divided into three categories by type of person to be trained:

1. Training of new operators and shift engineers,
2. Re-educating previously trained operators,
3. Training a startup crew for a new reactor.

New Operators and Shift Engineers

Regardless of background, the same material is covered. The difference in depth of coverage depends on the individual's ability to absorb the material. The following general format has been used to provide a basic orientation:

1. <u>Radiation Control</u>

   a. Types and sources of radiation, shielding;

b. Types and uses of monitoring instruments;

c. Operational limits; radiation and contamination zones, cleanup.

2. Concepts of Reactor Theory

a. Neutron interactions with matter, fission, cross sections, flux;

b. Neutron chain reaction, criticality, multiplication;

c. Control rods, effect of xenon and temperature coefficients.

3. Heat Transfer and Hazards

a. Production of heat in a reactor;

b. Removal of heat from a reactor;

c. Temperature transients, heat-power relationships;

d. Reactor incidents;

e. Discussion of specific incidents;

4. Control of Reactors

a. Methods of control;

b. Safety system;

c. Counting-rate and Log-N channels;

d. Temperature and flow channels;

e. Experiment channels;

f. Effects of scram, reverse, setback, inhibit, alarms;

g. Block and logic diagrams;

h. Heat balance.

5. Criticality Procedures

a. Observation of startup;

b. Effect of neutron source, multiplication;

c. Idealized critical experiments;

d. Fuel storage.

Generally, this technical orientation is given during the first month of training. The orientation lasts approximately 40 hours and is interspersed between the practical work of participating in shutdowns, daily checks, and routine work at the three reactors. The probationary period of an operator is three months, due to the union contract. It is desirable to quickly train him to be a competent operator at one reactor (at least) by the end of this time, to determine whether he should be retained.

The next step after orientation is to assign him to a shift. During this on-shift training, the method used is primarily on-the-job training by requiring him to assist in the performance of routine work. Nonroutine work and mechanical items not frequently encountered are reviewed with the Training Check List,[4] which also serves to record the items discussed and the amount of understanding achieved.

With new shift engineers, more latitude is possible because of the better background, greater receptiveness to educational material, and longer training period. A general criterion is that the shift engineer must participate in at least two end-of-cycle ORR shutdowns prior to taking independent responsibility for a shift. This places the minimum training time at four months--generally, it takes about six months.

Following this one-month orientation, the engineer is assigned to a shift where he is expected to learn the operator's job in the same fashion as the new operator. In addition, by observation of, and discussion with, the shift engineer and foreman, the technical and supervisory aspects of the job are defined and learned. Technical contact with the training coordinator is maintained by discussion of immediate past events--to assure that necessary work is observed and that the technical implications are realized.

Previously Trained Operators

These operators are being educated in an attempt to give them a broader background in the processes with which they work. The same general format[5] as is used for the basic orientation of new personnel is followed but is modified to include more advanced material to explain more advanced equipment and more complicated physical phenomena.

Two methods have been tried:

1. The first method consisted of assigning a list of review questions to be answered. Certain reference reading guides were provided and the shift engineer was required to work with the operator on shift and to assist in explaining the material.

Generally, this proved inefficient for the following reasons:

a. References were either too general to be worthwhile, to specific to be informative, too technical to be understood by the high-

school-level operators, or too dilute for the uneducated to be able to see what was worthwhile. The decision was reached to write appropriate, original training material, using Glasstone[6] as a general reference.

b. This method assumed the shift engineer or foreman to be qualified as a "teacher". While the engineers undoubtedly understand the "student's" mind and background well, it is difficult to uniformly educate a group when interpretations of a deliberately nonspecific review-type question differ.

c. It was found difficult to obtain sufficient time during the shift for these discussions since they conflict with the natural tendency to utilize the "spare" time of the shift crews on routine jobs. In addition, vacation relief has been handled by requiring operators to work overtime and by the substitution of day operators where needed. This further interfered with training.

d. Day operators were too busy providing shift relief and performing normal work to follow this schedule.

To determine the progress of the individual operator, a combination written and oral test was given each operator at a time when the operator routinely was on day shift. This furnished a somewhat delayed feedback of information on progress to the shift-engineer "teacher". The subjects covered using this method were Radiation Control and Reactor Physics.

2. The second method consisted of giving lectures to each shift in turn as it routinely was on days. After a certain time for further discussion and clarification with the shift engineer, this was followed by a short written test to summarize the more important topics.

This was inaugurated in November, 1961, starting with a one-month course for day operators, and was followed by a similar course for shift operators beginning in December, 1961, and ending in April, 1962. Subjects covered were: Radiation Control, Reactor Physics, Heat, and Instruments and Controls. During April a review of all four subjects was followed by a written test. Each subject was presented in three three-hour lectures with the review being 2 three-hour discussions and the test taking about three hours also.

a. The following expresses the results:

(1) The original notes on Radiation and Reactor Physics had been written to survey the subject with a minimum of explanation. Operators were not accustomed to taking class notes, and the original notes were too brief to be usable. The lecture notes were, therefore, changed to present readable explanations of "observable" or of "undesirable" reactor phenomena as a demonstration of reactor theory.

(2) Due to limitations on the number of personnel available to lecture, subjects were taught in a random fashion. This resulted in a great deal of review by the lecturer prior to discussing the actual subject. As more people became available to lecture, subjects were taught in ordered fashion in order to utilize knowledge of previously acquired material. The order of presentation finally chosen was Radiation, Reactor Physics, Heat, and Instruments and Controls.

(3) Continuing normal operation while requiring that operators attend lectures resulted in considerable overtime work by the operators. This reduced over-all efficiency somewhat. Perhaps a better alternative would have been to begin lectures to 4-12 shift personnel at 1:00 p.m., which would have minimized interruption of the day-shift routine and tired the students less.

(4) With no lecture notes and only a general outline available, the lectures became a personal interpretation of a particular subject by a particular individual. Considerable variance in emphasis on important points occurred.

(5) Since all operators on a particular shift attended all the classes, it was impossible to lecture at a level equally agreeable to all. The usual result was an "average"-type lecture, equally unsuitable to everyone,

including the lecturer. It would have been better (though impractical) to have operators of similar backgrounds attend the same series of lectures.

b. As a result of the past experience, the following positive results have been obtained:

(1) Almost every operator has gained the idea that management is interested in his learning more than just the physical actions necessary to operate reactors.

(2) Considerable information has been gathered on how not to go about the education of this particular group of people. This should make the future task easier.

(3) If any group-learning technique is employed, such as lectures or group discussions, an attempt will be made to place operators of equal background in the same group.

(4) The necessary training information has been defined and will probably be written before the next "training" period begins.

Training a Startup Crew for a New Reactor

1. It is obvious that a startup crew should:

a. Already be experienced in reactor operations so they can apply previous experience to meet the problem of operating the new reactor rather than learning both the characteristics of the new reactor and reactor operations in general;

b. Understand and be able to perform the expected physical operation; it is too late to begin finding pumps and valves when the need for using the equipment has suddenly arisen;

c. Include a large fraction of the permanent crew who will retain the hard-earned specific knowledge which is so often difficult to transfer to a replacement or put into writing;

d. Fit into the operating philosophy of the parent orgainzation;

e. Include, if only in advisory capacity, definitely assigned engineering talent from the group which designed the reactor: the crew should have available the information and talent

necessary for the task of reactor shakedown and debugging.

2. There are at least two types of startup crews:
   a. A crew which is specifically assembled for the purpose of starting up the reactor and then training the operating crew;
   b. An operating crew which is assembled, educated, and trained to start up the reactor (with technical assistance) and operate it.

Of the two types of crews, the latter is better for an isolated or "first" reactor. The former is useful only if the eventual operating crew is already busy, or if it is necessary to have additional help only during initial startup.

The former method was used during startup of the LITR and ORR. In addition in the case of the ORR, the reactor supervisor had acquired three years of experience as supervisor of the LITR--a reactor comparable to the ORR in its early stages. This was also true of the operators employed. Technical support personnel were assigned to each shift for the check-out phases until shift engineers were ready to assume charge of charge of shift operation. The reactor supervisor was assigned to the ORR at the beginning of construction in 1955, although operation did not start until 1958. Blueprints and descriptions of piping systems and major components were circulated among the other personnel to give them an opportunity to become familiar with the reactor.

In October, 1956, a mechanical mock-up of a complete ORR control rod drive was built for testing purposes. This gave the maintenance personnel an opportunity to become familiar with the operation of the various components.

When the primary piping was completed with the installation of the reactor tank in June, 1957, three shift-engineer trainees were assigned to the reactor supervisor. Procedures for hydraulic testing and the initial startup operations were written by this group with the advice of personnel of the technical staff.

Following installation of the reactor tank, control-rod drives, and other components, hydraulic testing began in October, 1957, lasting until January, 1958. Those assigned to the project were thoroughly familiar

with the water system by the end of the test period.

Members of the technical staff wrote the procedures for the initial postneutron testing.[7] The qualification of the first shift engineers was accomplished using the ORR Training Check List[4] and the various elementary reactor control diagrams. After the shift engineers were considered qualified, they, in turn, began to instruct and qualify operators.

TYPE OF PERSONNEL TO BE TRAINED-EDUCATED; MATERIAL TO BE LEARNED

Type of Personnel

General requirements of supervisors and operators have been described in References 3 and 4. Basically, operators are expected to take routine data, perform routine checks and work, observe the reactor instrumentation, and notify a supervisor of any abnormality. Requirements for hiring of operators are described in the paper[8] on the administration of ORNL research reactors. Operators must have an I.Q. of average or better and a good mechanical aptitude. Selection within the past years has been made from persons having previous process-operating experience. This experience aids in understanding of the continuous-process type of operation. Supervisors are hired on the basis of background and job requirements.

Material Needed in a Training Program

A general study manual containing the following basic theory of reactor operations is used:

1. A study guide;

2. Study notes on Radiation, Reactor Physics, Heat Transfer, Instruments and Controls;

3. Notes on specific details of each reactor and criticality procedures;

4. Supplementary notes on mathematics and some of the more significant points of theory (Appendices B and C include the present study guide and an outline of the notes on Radiation Control.);

5. A series of equipment check lists and questions about the reactors to ensure that each major system, component, and operating point

is discussed and learned (The questions are also used to point out specific facts that should be learned. The "Reactor Operator Training Manual"[6] contains this material previously used.);

6. A description of the reactor to supplement the other training material (This should include a description of the various systems, how they are expected to operate, what makes them function, and why they were installed.);

7. Comparative tables of the various operating limits or characteristics, such as primary coolant flow rates, allowable excess reactivity, rod speeds, setpoints for control actions on various nuclear and process instrumentation, etc.;

8. Notes on various reactor and radiation incidents to familarize the newcomer with the types of things that can happen, their symptoms (or lack of symptoms), and situations which can lead to trouble.

REFERENCES

1. C. D. Cagle, General Standards Guide for Reactor Experiments at ORNL.*
2. C. D. Cagle, "Personnel Organization (of a Reactor Operating Group)", (Unpublished ORSORT Notes).
3. C. D. Cagle, "Supervision of Reactor Operations", (Unpublished ORSORT Notes).
4. Reactor Operator Training Manual, ORNL-CF-59-7-110.
5. E. N. Cramer, Reactor Operator Study Handbook, (to be published).
6. Samuel Glasstone, Principles of Nuclear Reactor Engineering, D. Van Nostrand Company, Inc., Princeton, New Jersey, 1955.
7. C. D. Cagle and R. A. Costner, Jr., Initial Postneutron Measurements in the ORR, ORNL 2559.
8. W. R. Casto, Administration of ORNL Research Reactors.*

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*Papers presented at the "Conference on Light-Water-Moderated Research Reactors", ORNL (June, 1962).

APPENDIX A

List of Factors which Affect the Operating Philosophy, Methods of Training-Education, and Personnel Selection

1. Duties expected of various types of personnel, their authority and responsibility--

   It is obvious that individuals should be adequately trained and educated for their job. Less obvious is the natural tendency to teach well documented, general or basic material and to skimp on the teaching of the application of this theory to the understanding of the specific tasks usually performed. Teaching of knowledge which a specific class of personnel is not expected to need will tend to cause confusion about what is really expected of them. Unused knowledge or skills are soon lost or, worse still, so poorly remembered in emergency situations that an attempted use of them may lead to a more hazardous situation.

2. The type of reactor, complexity of the reactor systems and components--

   The simpler reactor with no experiments should require less personnel training-education than a complex reactor with experiments. The necessary training-education should, however, be as detailed in one case as the other.

3. Mode of operation--continuous or intermittent--

   It is obvious that 24-hour-a-day operation may require well qualified personnel to be present at all times. It is less obvious that, in an intermittently operated facility, the supervisors may need to spend a disproportionate amount of time on nonoperational matters so that operators should be just as well qualified as for continuous operation.

4. Technical assistance provided by the parent organization--

   Certain knowledge and skills[2] are needed over and above those necessary for routine operation in order to handle nonroutine problems associated with reactor operation. If full-time technical assistance of this type cannot be provided, it must be developed within the operating organization; otherwise, if this technical assistance is rendered only on a part-time basis, the natural tendency is to perform

the main job in preference to this secondary duty.

5. Promotional policies for the various personnel classes--
When a person cannot be directly rewarded for his accomplishments, there is little incentive for better than that minimum-acceptable performance. It is pointless to expect an individual to spend much extra effort in studying unless his effort can be rewarded. Unfortunately, labor-management agreements do not generally provide proper recognition for training-education programs, especially in cases where these agreements provide for virtually automatic promotion after stated service time.

6. Long-term forecast for the parent organization and the specific reactor--
If the forecast is sufficiently poor, one result can be the hiring of less qualified personnel or the lack of any effective long-term educational program. The situation should be frequently re-examined to insure that adequate numbers of trained personnel will be available when needed.

7. Backgrounds of the personnel available for hiring in the past, present, and future--
Generally, an individual's performance depends on his past experience and his desire for advancement. Anticipation of an upgrading program should result in choosing personnel who are fully capable of being trained or educated. Recognition of this in the Operations Division has lead to the general requirement (for operators) of previous process-operating experience and a closer check with immediate supervisors on the individual's past performance to select those with proper attitudes.

8. Government regulatory requirements--
Government regulatory requirements may demand training and education in excess of that delineated by the operating philosophy. It must then be made clear to the trainee that this additional knowledge and training does not permit him to violate local rules and procedures with respect to his authority and duties.

9. Degree of availability of teaching and student personnel--
A retraining and/or re-education program is quite sensitive to the

availability of the personnel involved, primarily in that flexibility may be lacking. Too much trainee overtime, not enough trainee study and guidance time, and interference with the writing of necessary material are all symptoms of a training program being conducted without sufficient support or without coordination of training with the work schedule.

10. Records of past experience and training--
Unless well kept records are available, the problem of determining how much re-education and/or retraining is necessary will be difficult as will the problem of assessing the value of the past training effort.

11. Sufficient support material must be available--
The major items necessary are sufficient, readable system descriptions and descriptions of applicable theory. In addition, meeting rooms conducive to study, models of major reactor components, and other teaching aids are quite helpful.

12. Support of line supervision--
The bulk of the training must be given by persons directly familiar with the mechanical devices used. The immediate supervisors of the trainees must be interested in the educational aspects also to stimulate discussion of and to point out the application of theory to routine operations. These individual on-the-spot discussions serve to make clear the meaning of theory; without these discussions the educational part of a training program is much less effective.

These factors are all interrelated; it is difficult to determine the individual action of some of the more subtle ones. For example, if the decision is made not to extensively educate a class of people (based on Factor 1), then personnel replacements may be made without specifically checking for the ability to be educated (Factor 7). Eventually it is possible for this class of people to contain many people who cannot absorb educational material well, since those who are better qualified are generally promoted faster. This can lead to difficulty when a training-education program begins.

APPENDIX B

Reactor Operator's Study Guide

This study guide is provided in order for you to direct your efforts appropriately in learning how our reactors are operated. This study guide is, of course, not all inclusive, but a thorough knowledge of the subjects listed should be considered a minimum.

I. Classroom Work

A. Radiation Control

1. Understand units r, rem, curie, RBE.
2. Have some idea of how to obtain curies from irradiation conditions and how to convert curies to roentgen/hr.
3. Know tolerances (in mr/hr and in particles/sec for neutrons and gammas); know how to add the types of radiation; know zoning requirements.
4. Be able to monitor for all types of radiation and to detect contamination.
5. Know the proper materials for shielding and how to estimate the amount needed.

B. Reactor Physics

1. Know the four-factor formula and be able to give a definition (qualitative) of each term.
2. Know use of terms k, k_{∞}, reactivity, reflector, moderation, period.
3. Know simple exponential expression for kinetic behavior of reactor with and without delayed neutrons.
4. Be able to explain effect of delayed neutrons and the hazards of prompt criticality.
5. Be familiar with past history of reactor incidents and our own past troubles.

C. Heat

Know:

1. Terms and concepts such as megawatt, BTU, temperature, heat, energy, heat-transfer coefficient, Mw-day;

2. How heat is produced in and removed from reactors;
3. How operating limits are set based on reactor design so that fuel elements are not damaged by excessive temperatures;
4. The differences between the heat-temperature responses of our reactors;
5. The effects of improper heat production or removal on the fuel elements, and how this is prevented.

D. Instruments and Controls

1. Understand and be able to explain any portion of control block diagrams and components they represent.
2. Understand and be able to reproduce a block diagram of instrument and safety systems.
3. Understand and be able to explain in general terms:
   a. Why we have both period and power-level information display;
   b. Why we have both linear and logaritmic information display;
   c. Why we have both setbacks and scrams;
   d. Power ranges for which the various instruments are designed;
   e. Information relied on during different parts of the startup and during steady state operation;
   f. Interlocks and their overrides;
   g. Servo control system;
   h. Experiment control information and what use is made of the information;
   i. E-panel use;
   j. What instruments (and values) give alarms, setbacks, reverses, and scrams, and why.

E. Details of Each Reactor

Know:

1. Approximate critical mass and size (with and without moderator and/or reflector);
2. Approximate rod speed and worth in inches/sec and $\Delta k/k$/sec;
3. Each type of reactor incident--how caused and effects;

4. Normal and emergency methods of heat removal;
5. Effects of ruptured fuel elements;
6. Safety and control systems: components, setpoints, methods of operation.

F. Criticality and Procedures

1. Be able to go through startup check procedure, startup, and shutdown in proper sequence.
2. Be able to explain, step by step, a critical experiment.
3. Understand the effect of subtracting or adding a reflector, moderator, fuel, or absorber to the core or reflector or to fuel-storage locations.
4. Know and be able to explain the supervisory regulations concerning reactor operation (i.e., for what jobs you must have supervision).

II. Practical Work

CF-59-7-110 "Reactor Operators' Training Manual" is considered a sufficient guide. Basically all operators should be so familiar with the hardware that they may respond to emergencies (and normal operation) with a minimum of direction and supervision.

APPENDIX C

Brief Sketch of Material Used in Radiation Control Lectures

1. Matter and Radioactivity--
   Discussions of various terms, differences between radiation and contamination.
2. Effects of Radiation on Matter--the penetrating properties of radiation--
   Ionization, difference in penetrating ability of charged and uncharged particles; range vs energy and tenth-value layers for various particles.
3. Measurement of Radiation--
   Proper usage of the terms roentgen, rad, rem, RBE.
4. How much Radiation is Normal? Harmful?--
   Average normal radiation received per year; difference between whole body doses and partial body doses; rems vs rems/hour and the difference in damage between acute doses and continuous doses.
5. Protection Against Radiation--
   Effects of minimizing exposure by shielding, distance, decay, partial body shielding, and prior planning.
6. Contamination--
   Special dangers due to short-range radiation, chemical combination, easy spread of material; discussion of obtaining alarm settings on a constant air monitor to illustrate the difficulty of this problem.
7. Special Features of Radiation and Contamination--
   Variation of TVL with γ energy; 6 C E formula for r/hr at 1 foot; usage of curie, mc/ml, etc.
8. Operating limits--
   Quick reference tables of all the various operating limits operators may need.
9. Checklist on Radiation Safety and Control (attached).
10. Review Questions--
    Provided to point out the specific items which should be remembered, to provoke thought, discussion, and independent reading and to pose particular problems.

CHECK LIST: RADIATION SAFETY AND CONTROL

_____
(Name)

To be completed by the instructor or supervisor of the trainee.

The individual's answers should be graded in one of the following categories:

A. Knows very well.
B. Adequate knowledge.
C. Inadequate knowledge.

A	B	C	
____	____	____	1. What is radiation?
____	____	____	2. What is contamination?
____	____	____	3. What is the difference between radiation and contamination?
____	____	____	4. How does radiation affect material it penetrates?
____	____	____	5. What are the various types of radiation?
____	____	____	6. What is the difference between charged particles and uncharged particles on how they penetrate material?
____	____	____	7. Why do we have various ways of measuring the radiation dose, such as rad, rem, roentgen? Give a simple definition of each dose unit.
____	____	____	8. Describe simply the effects of a large, sudden dose of radiation: a. Less than 25 rems. b. 25 - 50 c. 100 - 200 d. 200 - 400 e. 400 - 500 f. Over 1000 rems.
____	____	____	9. What are the Laboratory standards on allowable large doses which can be received under extreme emergency conditions?

____ ____ ____ 10. What are some extreme emergency conditions which could happen to us?

____ ____ ____ 11. What are some effects of chronic doses of radiation?

a. 500 R/day?

b. 100 R/day?

c. 60 R/day?

d. 10 R/day?

e. 3 R/day?

f. 1/2 R/day?

____ ____ ____ 12. What are the Laboratory standards on the AVERAGE maximum allowable doses weekly, quarterly, and yearly? What are the Operations Division's standards?

____ ____ ____ 13. What are the duties and responsibilities of the following as far as keeping radiation doses low?

a. The individual?

b. The immediate supervisor?

c. The reactor supervisor?

d. The health physicist?

____ ____ ____ 14. What are our relationships with E & M and HP when E & M people work on jobs on our reactors?

____ ____ ____ 15. What preparation must be made before working in radiation or contamination zones?

____ ____ ____ 16. What should you watch for when you "watch" people working in R or C zones?

____ ____ ____ 17. What are the sources of radiation?

____ ____ ____ 18. How can we reduce radiation doses?

____ ____ ____ 19. How are dose rates from different types of radiation summed meaningfully?

____ ____ ____ 20. How is working time computed?

____ ____ ____ 21. What is the maximum permissible radiation reading in a nonradiation zone?

____ ____ ____ 22. An object is removed from a reactor. Over a

period of time, the radiation level associated with this object decreases. Why is this so?

____ ____ ____ 23. What materials are handy and useful for quick shielding of the various types of radiation?

____ ____ ____ 24. How would you estimate the amount of shielding necessary for γ rays?

____ ____ ____ 25. How much concrete would shield out most of the β we normally handle?

____ ____ ____ 26. How much air shields out most α we might handle?

____ ____ ____ 27. What is the difference between shielding charged particles and shielding γ's and neutrons?

____ ____ ____ 28. What are the less radio-sensitive zones of the body?

____ ____ ____ 29. How does the radiation level change with increasing distance from a point source? line source? open beam hole?

____ ____ ____ 30. Demonstrate the use of all radiation measuring devices we have available.

____ ____ ____ 31. Why should we be very cautious when working in contamination?

____ ____ ____ 32. What things especially are bad about having a source of radiation in the body?

____ ____ ____ 33. What are the worst types of contamination with respect to type of radiation, physical form, and chemical nature?

a. Ease of spread?

b. Direct radiation hazard?

c. Internal radiation hazard?

d. Concentration in body?

e. Difficulty of detection?

____ ____ ____ 34. How can contamination get into the body?

____ ____ ____ 35. What are possible sources of contamination and what are the contaminants? How are we most likely to spread contamination?

____ ____ ____ 36. How do we detect contamination?

____ ____ ____ 37. How can we tell the difference between induced radiation and surface contamination?

____ ____ ____ 38. How can we protect ourselves against contamination? When do we use or not use "C" clothing?

____ ____ ____ 39. What two functions do contamination clothes perform?

____ ____ ____ 40. What is the maximum allowable reading outside of contamination zones?

____ ____ ____ 41. Describe requirements for entry, work in, and exit from a contamination zone.

____ ____ ____ 42. Demonstrate the correct way to remove contamination clothing; to exit from a contamination zone.

____ ____ ____ 43. How may we normally dispose of contamination in solid form? liquid form? gaseous form? dust?

____ ____ ____ 44. Demonstrate the use of all contamination monitoring instruments.

____ ____ ____ 45. Specify what each of the printed forms for radiation and contamination control is used for and how it is used.

____ ____ ____ 46. What are the instruments for

a. Personal protection?

b. Radiation survey?

c. Contamination monitoring?

d. High radiation level warning?

____ ____ ____ 47. What is the difference between d/sec and c/sec? How are these terms used?

____ ____ ____ 48. What does the CAM measure? What does it mean when the alarm level is exceeded? What other instruments warn of airborne contamination?

____ ____ ____ 49. What are the containment and double containments necessary at each reactor and experiment?

____ ____ ____ 50. What is the difference between off-gas and cell ventilation? Warm drain and hot drain?

____ ____ ____ 51. What should be done when a monitron or CAM alarms?

Evaluated by_____ Date_____

Comments:

APPENDIX D

Reactor Operator Qualification Check List

ORR	LITR	OGR		
			1.	Completed the Training Check List.
			2.	Made prestartup checks, brought the reactor critical and to power, made the poststartup checks.
			3.	Made all normal and routine checks.
			4.	Performed routine shutdown work.
			5.	Demonstrated knowledge of Radiation Safety and Control practices.
			6.	Passed a test based on the training check list.

Based on his job performance and understanding of reactor operations, _____ is considered qualified for routine-unsupervised work as desk and roving operator at the

OGR	_____	_____	_____
LITR	_____	_____	_____
ORR	_____	_____	_____
	(Date)	(Shift Engineer)	(Shift Foreman)

I have reviewed the training program and progress of _____. He has taken the Basic Knowledge test _____ and passed. I concur in his qualification.

_____
Training Coordinator

Approved	OGR	LITR	ORR
	_____	_____	_____

W. R. Casto
Supt., Reactor Operations Department

	_____	_____	_____

J. A. Cox
Supt., Operations Division

APPENDIX E

The Xenon Machine

An apparatus, such as that in Figure 6, may be assembled for demonstrating the xenon problem in a reactor by allowing tap water to flow into a clear plastic container, out of a small hole in the bottom, and into another plastic container. Water may leave the second container through either of two holes. The height of water in the second container represents the height of rod necessary for criticality since the water flowing from one vessel to another provides an analog to the formation and loss of Xe^{135} in a reactor.

The amount of water in the containers may represent either the total amount of atoms present or the concentration atoms/cm^3 of a particular isotope. The loss of water from a container represents the loss of an isotope because of radioactive decay or neutron capture. The size of the hole represents the magnitude of the decay constant, λ, (sec^{-1}) or the removal constant, $\sigma\phi$, (sec^{-1}). Although this machine is not a strictly correct mathematical analog, it plainly demonstrates the more important qualitative aspects of xenon poisoning.

It is possible to demonstrate the following:

1. Radioactive decay--
   a. Decay of an unstable isotope,
   b. Buildup of a stable isotope,
   c. Buildup to saturation of an unstable isotope,
   d. Buildup to saturation of a chain of unstable isotopes;
2. Xenon in a reactor--
   a. Critical rod position at equilibrium-xenon for different power levels;
   b. Transient xenon--
      (1) No loss of criticality for low power operation,
      (2) Loss of criticality for high power operation,
      (3) Burnup of transient xenon on restartup,
      (4) Change of critical rod position with change of power level.

The figures show the approximate water level in the second container as the machine is manipulated--analogous to xenon concentration in a reactor as the reactor power is varied.

Demonstration Procedures

1. Low Power, Startup to Equilibrium Xenon

Start the water running at the LOW-POWER rate marked. Note that the water level (Iodine^{135} concentration) in the first bottle quickly reaches its equilibrium level. Sometime later the xenon concentration (water level in second bottle) reaches its equilibrium level (Figure 1). This time period is about one day at the ORR but several minutes in this simulator. Note the height of water in second bottle.

2. Shutdown from Low-Power Level

At the same time shut off the water flow (or remove the hose) and stop off the flow from the rubber stopper in the xenon bottle. This represents the decrease of the neutron flux following a scram.

Note that the xenon level stays fairly constant until it starts falling after the iodine is gone. This demonstrates that for the reactor to remain critical, the rods would have had to be raised only a slight amount. (Figure 1)

3. High Power, Startup to Equilibrium Xenon

Replace the small hole stopper with the large hole stopper. Start the water flowing at the HIGH-POWER rate marked. Note that the iodine concentration is much higher than before; also the water stream leaving the iodine bottle is much greater.

Note that the equilibrium xenon level is also higher--meaning that the control rods would have to be higher for the reactor to remain critical. (Figure 2)

4. Shutdown from High Power

At the same time turn off the water flow and stop off the flow from the rubber stopper as before (i.e., shut down the 'reactor').

Note that this time the xenon level rises quickly to the top of the bottle; the rods would also need to be raised to their upper limits to have the reactor remain critical. (Figure 2)

After the iodine has decayed, the xenon begins to decay also; soon the reactor can be made critical again.

5. Recovery of a Shutdown Reactor

Start the reactor back up at high power and let it come to xenon equilibrium again. Shut it down again; when the water level has risen nearly to the top of the bottle, restart the reactor. (Figure 3)

Note that although the reactor is producing iodine again at the same rate as before, it is some time before the amount of iodine is enough to produce xenon at the same rate as before. During the time lag, the neutron flux has had a chance to burn out the transient xenon present, so that the reactor can remain critical.

At the ORR, returning the reactor to a power level of 15 megawatts is enough to hold the reactor critical for some time.

6. Xenon Changes Following a Change in Power Level

With the addition of two-way valves and properly calibrated openings it is possible to demonstrate change of critical rod position with a change in power level.

Start up the reactor with both valves in the low-power position. After equilibrium is reached, simultaneously change both valves to the high-power (high-flow) position. Note that the increased $\sigma\phi$ causes the critical rod position to decrease, (Figure 4) before the increased iodine concentration causes the equilibrium critical rod position to be higher than before.

Changing the valves back to the low-power position demonstrates that the critical rod position is momentarily higher (due to decreased $\sigma\phi$) before the reactor reaches a lower equilibrium xenon concentration and that the final critical rod position is lower than before. (Figure 5)

ORNL-LR-Dwg. 70924
Unclassified

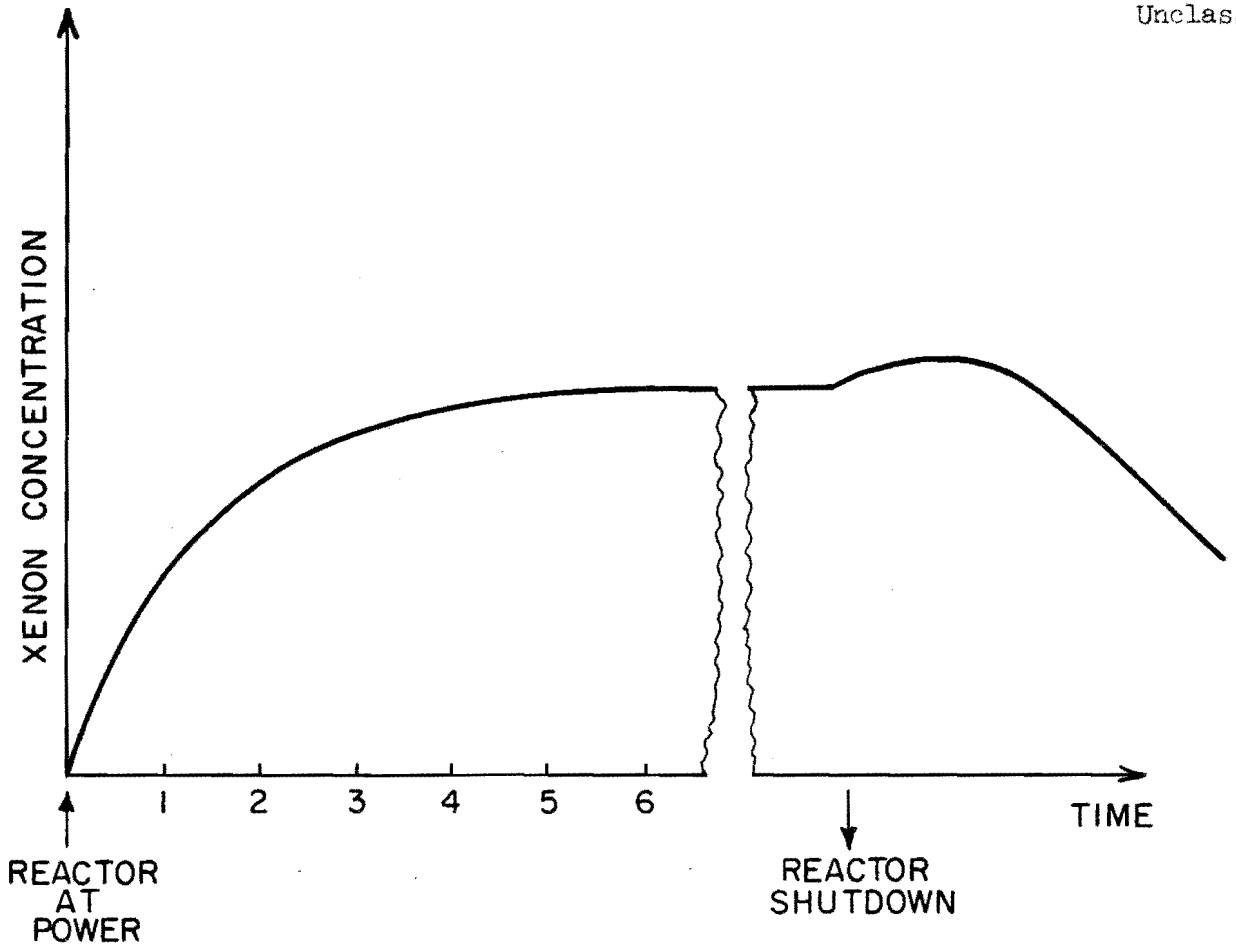


FIGURE 1

ORNL-LR-Dwg. 70925
Unclassified

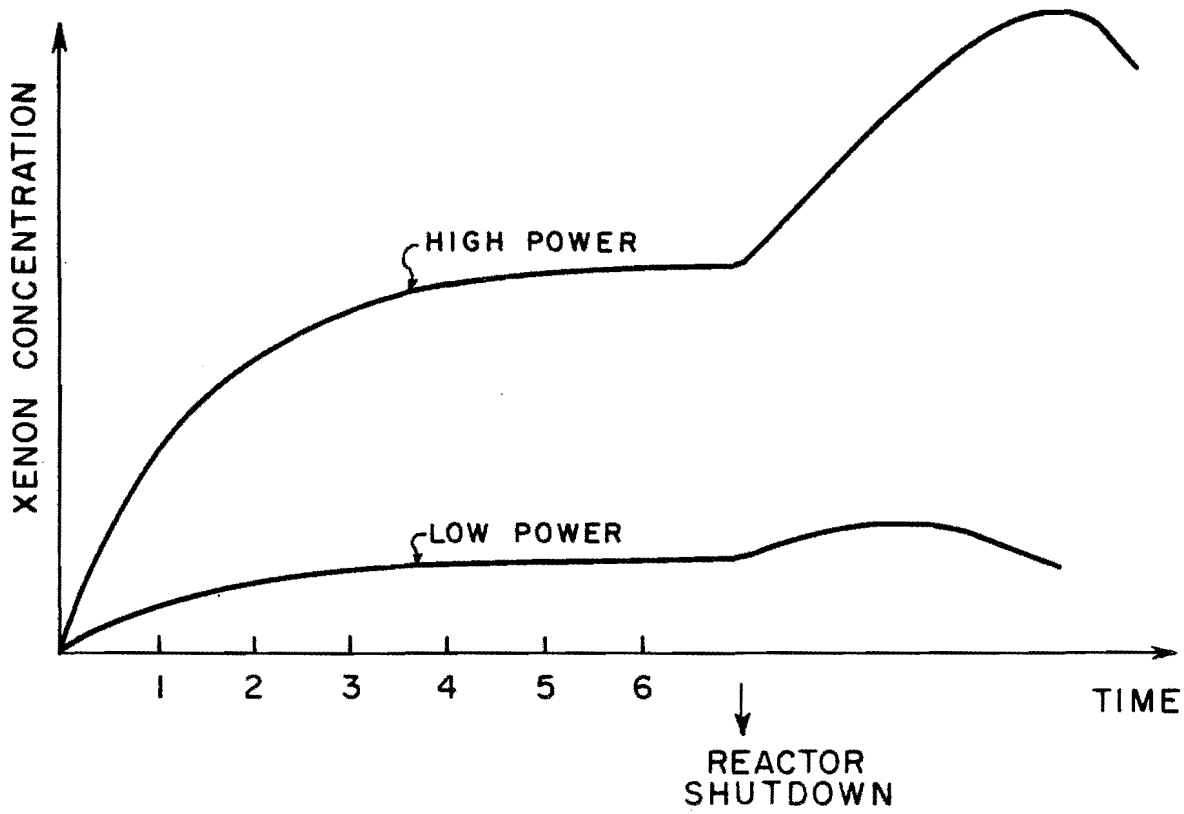


FIGURE 2

ORNL-LR-Dwg. 70926
Unclassified

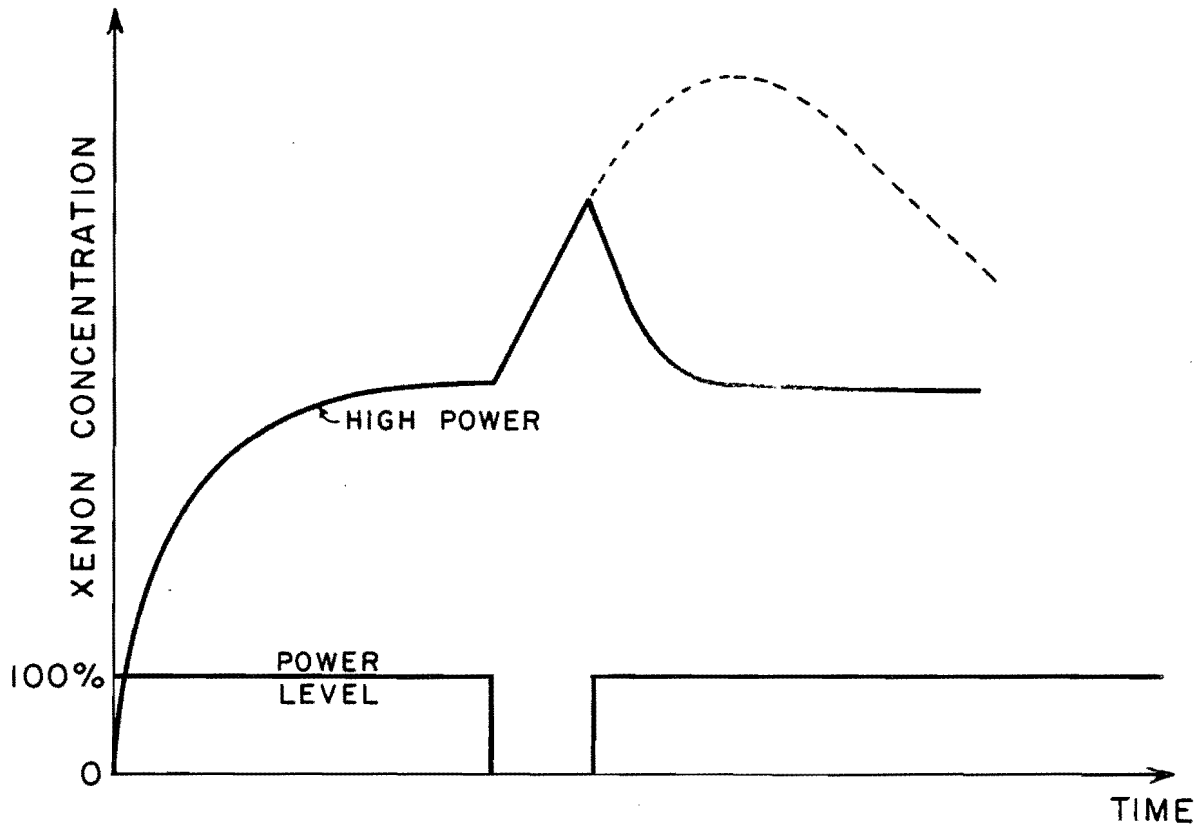


FIGURE 3

ORNL-LR-Dwg. 70927
UNCLASSIFIED

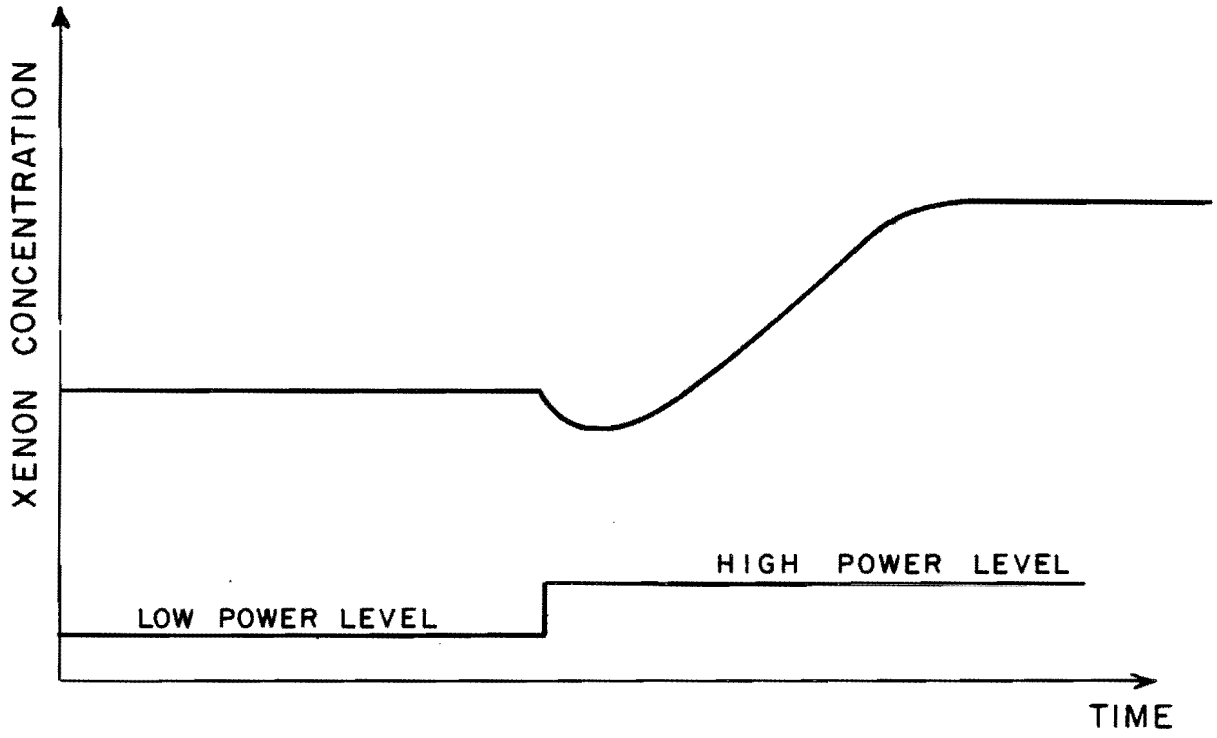


FIGURE 4

ORNL-LR-Dwg. 70928
UNCLASSIFIED

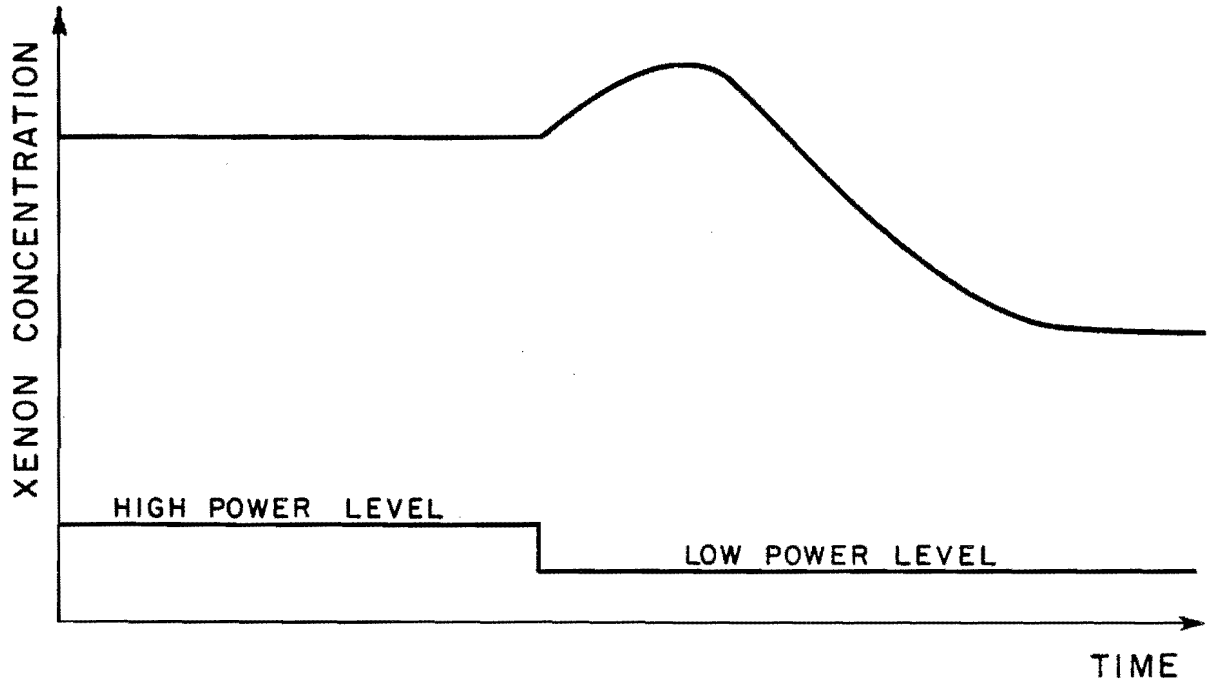
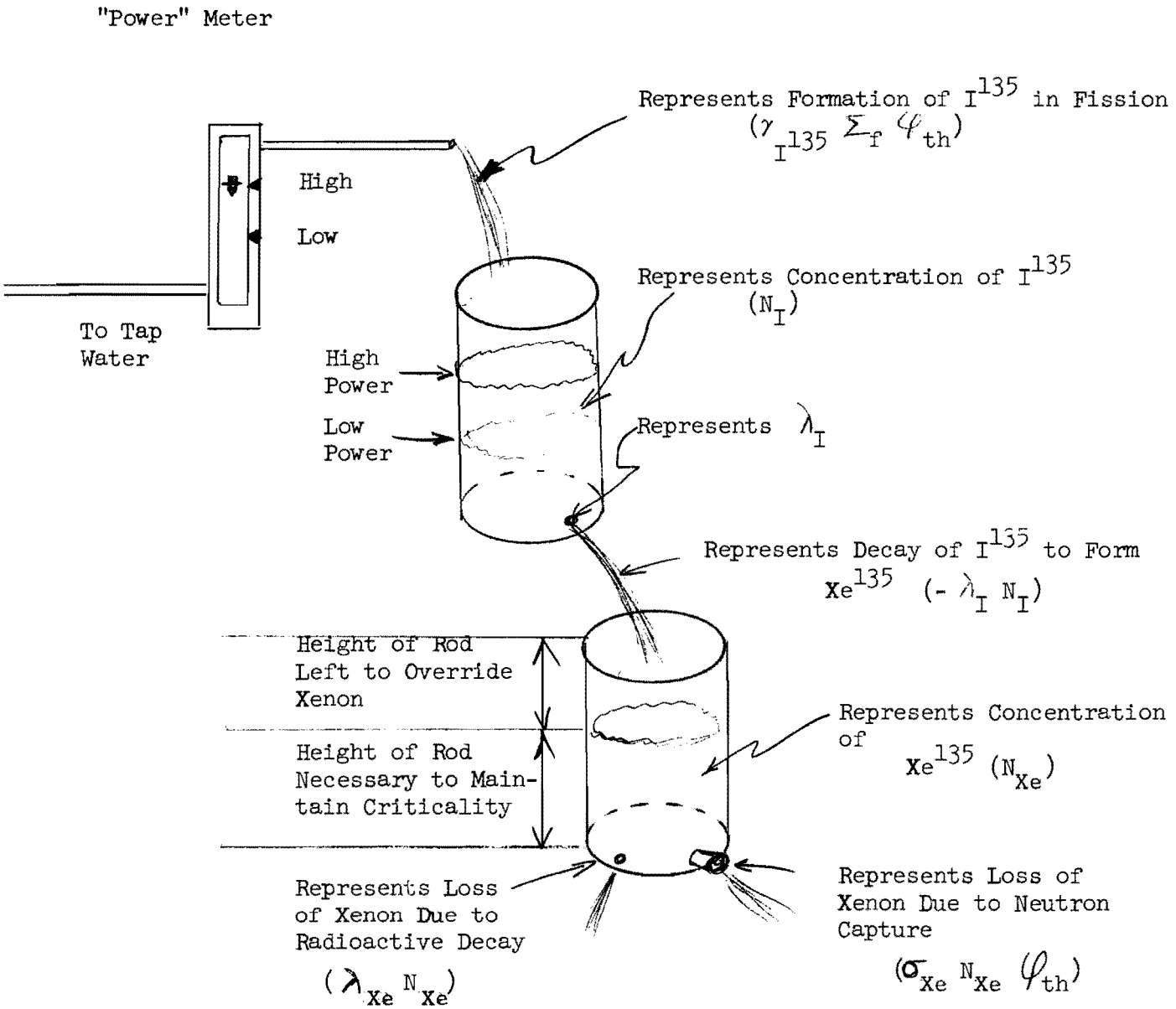


FIGURE 5

THE XENON MACHINE



High Power ~ .37 gpm

Low Power ~ .25 gpm

Polyethylene

Vessels are 3 1/2" dia, 6" high

λ_I is ~ 1/4" dia

λ_{Xe} is ~ 1/8" dia

$\sigma_{Xe} \varphi_{th}$ is $\begin{cases} \sim 1/4\text{" high} \\ \sim 3/16\text{" low} \end{cases}$

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