C-E NFM - W
Rev. 0
December, 1980

LICENSE SNM-1067

COMBUSTION ENGINEERING, INC.
1000 Prospect Hill Road
Windsor, Connecticut 06095

8104020 255

POWER SYSTEMS

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APPLICATION FOR RENEWAL OF LICENSE SNM-1067

PART I. LICENSE CONDITIONS

1.0 Standard Conditions and Special Authorizations

1.1 In order to permit Combustion Engineering, Inc. to continue to fabricate PWR fuel elements at its Nuclear Fuel Manufacturing facility at 1000 Prospect Hill Road, Windsor, CT 06095, it is requested that license SNM-1067 be renewed for a period of five years and include authorizations to allow the following:

1.2 Receive, possess, use, and transfer Special Nuclear Material in accordance with 10 CFR Part 70 of the regulations of the U.S. Nuclear Regulatory Commission in order to permit the manufacture of PWR fuel assemblies utilizing low-enriched uranium (up to 4.1 weight percent U^{235}) in the form of uranium oxide powder, pellets, rods, and in assemblies.

1.3 Deliver Special Nuclear Material to a carrier for transport in accordance with 10 CFR Part 71 of the regulations of the Nuclear Regulatory Commission and in accordance with 49 CFR Parts 173-178 of the regulations of the U.S. Department of Transportation.

1.4 Receive, possess, use, and transfer Source Material under 10 CFR Part 40 of the regulations of the U.S. Nuclear Regulatory Commission in order to permit the manufacture of fuel assemblies utilizing source material.

1.5 The proposed activities will be conducted primarily at the Nuclear Fuel Manufacturing facility (Building #17) and an adjacent warehouse and shipping dock (Building #21).

1.6 Additional Research and Development activities may be conducted in the Nuclear Laboratory facilities and buildings at the Windsor site and authorization is requested to receive, possess, use, and transfer Special Nuclear Material enriched to less than 20 weight percent U^{235} in lots of 350 grams U^{235}. For uranium enriched to 5% or less, a limit of 740 grams U^{235} applies. All mass limits will be separated by at least 12 feet. Other proposed storage configurations must be approved in accordance with Section 2.2.2 of this application. The Nuclear Laboratories are therefore authorized to receive, possess, use, and transfer Special Nuclear and

Source Material from the manufacturing facility in accordance with the provisions of this license. It should be noted that work under these transfers will be of an analytical or development nature and that the material may ultimately be returned to the Nuclear Fuel Manufacturing Facility. These transfers will not require the issuance of applicable NRC transfer documents, but must be transferred in accordance with the provisions of this license, and will be handled as a departmental transfer and will be controlled by the Fundamental Nuclear Material Control Plan (FNMC) referenced in Section 9.0 of this application.

1.7 Combustion Engineering, Inc., requests authorization to receive, use, possess, store and transfer at its Windsor site, the following quantities of radioactive materials:

	Isotope	Form	Quantity	Location
1.)	Uranium enriched to ≤ 4.1 weight percent U^{235}	Uranium Oxides	500,000 Kg U	Manufacturing-Bldg. #17 Storage-Bldg. #21 & in trailers between Bldg. #17 and #21. Development Dept.- Any building
2.)	Uranium enriched to less than 20 weight percent U^{235}	Any	4800 gms U^{235}	Any building. (Bldg. #17 & #21 limited to 350 gm U^{235} each for enrichments exceeding 4.1 weight percent U^{235})
3.)	Natural and/or Depleted Uranium	Any	10,000 Kg U	Any building
4.)	Pu^{238}	Encapsulated Neutron Sources	5 sources, each containing less than 2.0 gm Pu^{238}	Any building
5.)	Pu	Any Form	160 micrograms as analytical samples	Any building

2.0 GENERAL ORGANIZATIONAL AND ADMINISTRATIVE REQUIRMENTS

2.1 Company Background

Combustion Engineering is a diversified company serving electric utility companies, oil and gas producers, chemical companies and general industry throughout the world. The major portion of C-E's business has long been steam generation equipment for electric utilities, and it is one of the largest manufacturers of such equipment in the world. In recent years the company has diversified into related fields while continuing to apply its basic skills and technology.

C-E was first organized as a corporation in 1912. When considering the companies which have merged into the corporate structure, however, C-E's history dates back to the 1880's. Thus, the organization, as it exists today, has more than 90 years of experience in the design, development and fabrication of steam generation equipment.

C-E has been active in the development of nuclear power for more than 30 years. The Company's decision to extend its systems to large nuclear utility power plants represents a logical development of its previous activities as a supplier of thermal steam generating plants. All nuclear activities are carried out by the Nuclear Power Systems Division.

The capabilities of the entire C-E organization are available to the Nuclear Power Systems Division and will be utilized by it as necessary to fulfill its responsibilities.

C-E has organized four service divisions (Finance, Research, International and Administration) and the following operating divisions:

2.1.1 Engineering Group - This group has a broad international involvement in the design, engineering, and construction supervision of projects in the chemical, petrochemical, petroleum, metallurgical and other process industries.

2.1.2 Process Equipment Group - This group manufactures and markets a wide range of energy-related products including oil and gas production processing equipment, heat exchangers, and pollution control equipment.

2.1.3 Industrial Products Group - This group provides a full range of services in the architectural, engineering, and planning disciplines with recognized special competency in environmental engineering, resource recovery and disposal of solid waste, transportation systems and the production of high temperature industrial ceramic materials for lining furnaces and other heat processing auxiliary equipment.

2.1.4 Power Systems Group - C-E Power Systems provides fossil and nuclear fueled steam generating equipment, nuclear fuel and components, and air quality control systems for the electric utility industry, and steel transmission structures. This group also provides industrial steam generating equipment, fuel burning and auxiliary equipment, and chemical recovery systems and boilers for pulp and paper mills as well as heavy thick-walled pressure vessels for the chemical, petrochemical and petroleum processing industry.

The Nuclear Power Systems Division of the Power Systems Group has approximately 1200 (as of January 31, 1980) employees, of whom approximately 70% are scientists and engineers. More than two-thirds of the professional staff have at least five years experience in the nuclear field and approximately 50% have continued their education beyond the Bachelors Degree level. This staffing provides competence in the field of nuclear science and technology and extensive experience in the following specific areas: theoretical and experimental physics, mathematics, reactor analysis, chemistry, metallurgy, instrumentation controls, mechanical design, thermal sciences and nuclear and radiological safety.

2.1.4.1 Nuclear Products Manufacturing

Nuclear Products Manufacturing (NPM) is equipped to provide a variety of services necessary in the development and manufacture of precision reactor components such as fuel rods and assemblies containing low enriched UO_2, control rods, control rod drive mechanisms and reactor core internals. Equipment is also available to fabricate certain alloys of metals used for control rods and other special nuclear components.

2.1.4.2 Development Department

The Development Department maintains complete facilities for the development, design, analysis and testing of nuclear components and systems. The development laboratories consists of three functional sections:

Fuels Development Section - Establishes experimental basis for fuel system designs, specifies materials for fuel fabrication; reviews drawings, specifications and other documents for fuel system components.

Engineering Development and Services Section - Verifies design calculations and reactor servicing equipment compatibility by testing; performs dynamic and structural testing of reactor components; develops testing programs for mechanical and hydraulic components: evaluates test data, and test results; provides in-service inspection and component field inspections.

Materials and Chemistry Development Section - Reviews material specifications; analyzes material problems, recommends materials for specific applications and environments; reviews fabrication and test procedures; develops and maintains chemistry specifications; performs metallurgical and chemical testing; develops procedures for chemical cleaning and decontamination; analyzes chemistry related problems; provides for the reactor vessel surveillance program; predicts the effects of irradiation on material properties; performs fracture toughness testing.

The Development Department staff is comprised of metallurgists, chemists, engineers, and technicians. The development laboratories occupies a 14,000 square foot area in Building #5 and an additional 11,000 square foot area in the Building #2 complex.

The Development Department maintains equipment for metallography, mechanical testing, nondestructive testing,, X-ray diffraction, vacuum and inert atmosphere melting, heat treating, brazing, radiography, powder processing, vibratory compaction, swaging and ceramics processing.

2.2 Administrative Responsibilities and Controls

The lines of authority for the control of Special Nuclear Material in the possession of the Nuclear Power Systems Division follow the same paths of authority as all other operations with several modifications dictated by the problems associated with handling Special Nuclear and Source Material. Two distinct operations are covered by this license, with separate administrative controls exercised over each.

Nuclear fuel manufacturing (NFM-W) is a low enrichment UO_2 fuel fabrication operation where powder is pelletized, pellets are loaded into rods which are then assembled into fuel bundles.

Research and Development activities are carried out by the Nuclear Power Systems Development Department.

2.2.1 Development Department (Nuclear Laboratories)

The Vice President, Development, is responsible through the Vice President, Products, Services and Development to the Vice President, Nuclear Power Systems for the quantity, accountability, nuclear safety, and radiological safety related to all Special Nuclear and Source Materials received by the Development Laboratories and used in any development process. He assures compliance with federal and state regulations and the requirements and limitations set forth in the license during all operations of the laboratories.

In this position, the Vice President-NPS Development Department has delegated to the Manager, Health Physics, responsibility to assure that all operations involving nuclear materials have been analyzed to establish the required safety limits and controls.

Changes proposed by laboratory personnel are formally described and submitted to the Manager, Health Physics for review and approval.

Written health and safety restrictions for all operations on radioactive materials are provided in the form of approved Radiation Work Permits or approved detailed procedures, and appropriate operational limits are posted in the vicinity of work stations. Each operation on fissile material is limited to 350 gm U^{235} for uranium enriched to more than 5% U^{235}, and to 740 gms U^{235} for uranium enriched to $\leq$ 5% U^{235}, and must be separated from any other fissile material by 12 feet. Rods containing sintered UO_2 pellets enriched to a maximum of 4.1% U-235 are stored in Building #2. Storage of material in this area is limited to a single slab less than 3.7 inches thick. No other fissle materials are to be used or stored in building #2. A continuous log is maintained for each work station or storage area to assure that the limit is maintained and that the enrichment of all material is recorded. No other criticality controls are required for the laboratories.

In addition to providing the above safety restrictions, the Manager, Health Physics is responsible for the surveillance of all Nuclear Laboratory activities in which radioactivity is involved to ensure that the health and safety standards set forth in the license application are met. He has the necessary authority to halt any operation which falls outside those limits, and he is responsible for indicating what remedial action is necessary to bring the operation within acceptable limits. The basic organizational structure for the Nuclear Laboratories is shown in Figure 2.2.1.

2.2.2 Nuclear Fuel Manufacturing-Windsor

The General Manager reports to the Vice President, Nuclear Fuel and is responsible for the accountability, nuclear criticality safety and radiological safety related to all Special Nuclear and Source Material received by the Nuclear Fuel Manufacturing Facility and used in any manufacturing process. He assures compliance with federal and state regulations and the requirements and limitations set forth in the license during all phases of manufacturing.

In this position, the General Manager has delegated to the Production Manager and the Engineering Manager responsibility to assure that all operations involving nuclear materials have been analyzed to establish the required safety limits and controls.

Before the cognizant engineering supervisor may initiate equipment changes, or before the Production Manager may initiate limit changes affecting nuclear fuel handling, they must describe the proposal to the Health Physics & Safety Supervisor. He must review and approve the proposed change or operation and transmit his approval in writing to the cognizant individual. His approval will incorporate the results of criticality safety and radiological safety reviews and will include recommendations to assure that appropriate controls are implemented. The individual who performs the initial criticality safety review shall meet the minimum qualifications for a Criticality Safety Specialist.

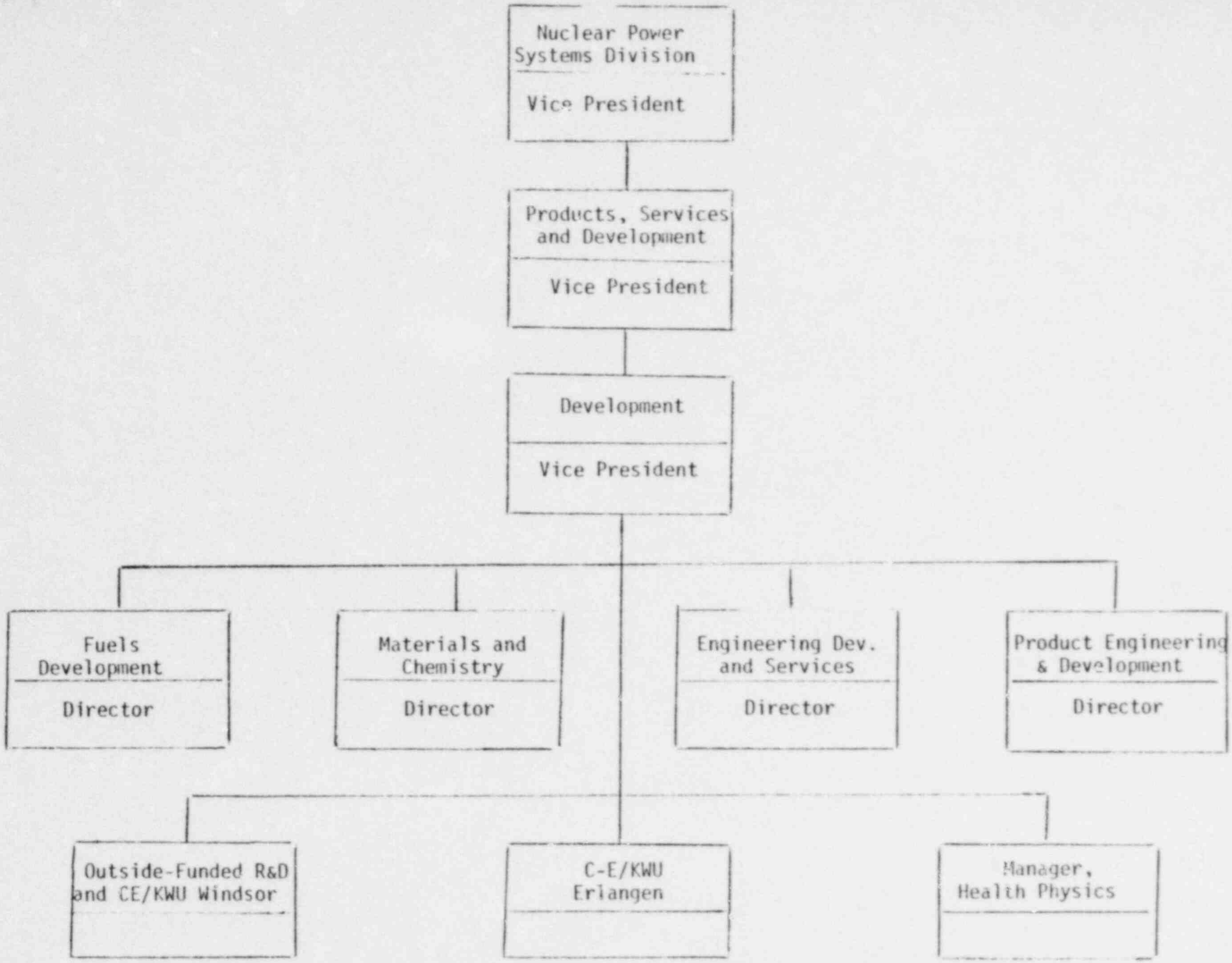

Nuclear Power Systems Division
Vice President
Products, Services and Development
Vice President
Development
Vice President
Fuels Development
Director
Materials and Chemistry
Director
Engineering Dev. and Services
Director
Product Engineering & Development
Director
Outside-Funded R&D and CE/KWU Windsor
C-E/KWU Erlangen
Manager, Health Physics

Figure 2.2.1

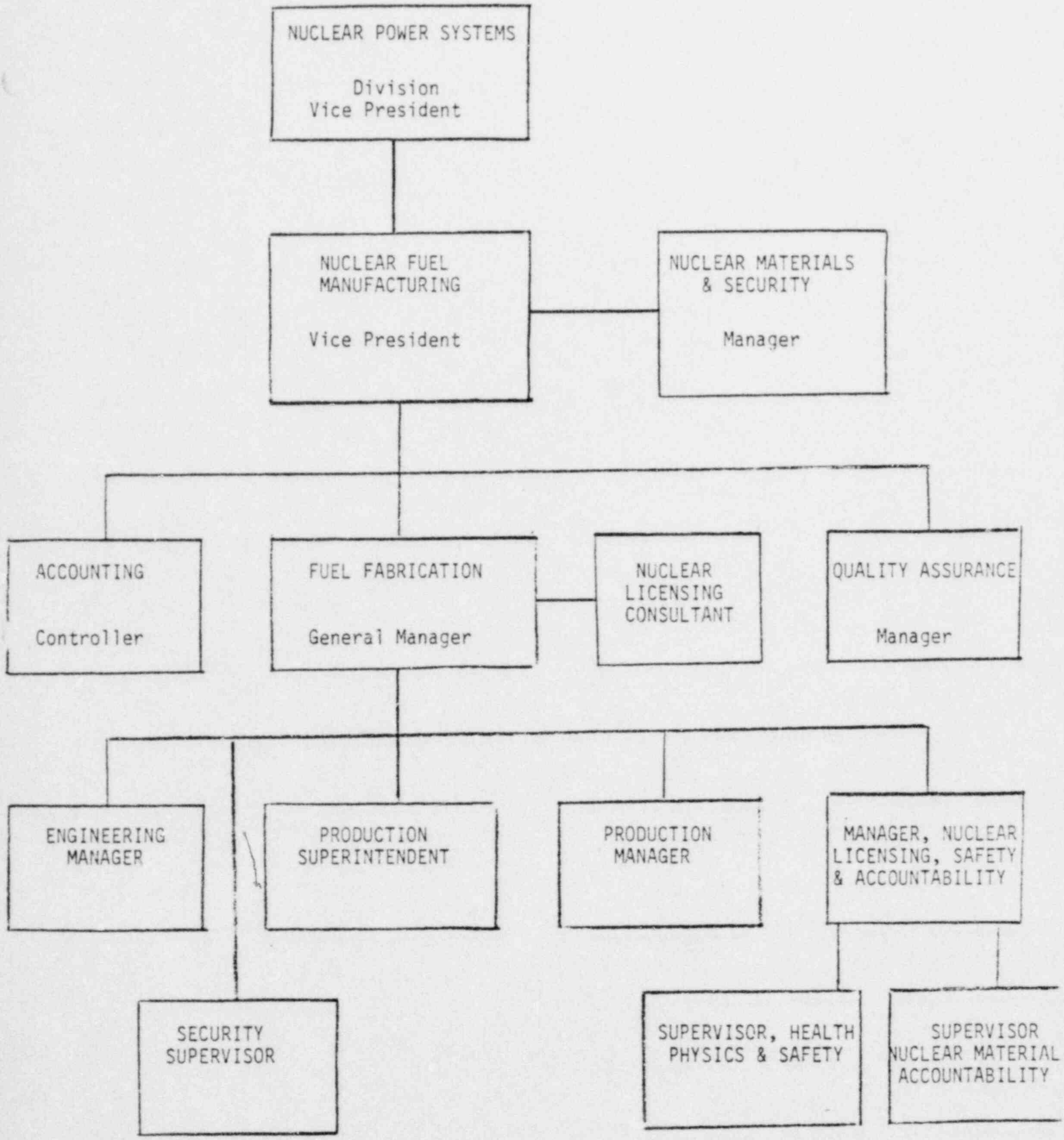
The individual who performs the independent criticality safety review shall be a person designated by the Nuclear Safety Committee and shall meet the minimum qualifications for a Criticality Safety Specialist and shall not be the initial reviewer. All such approvals shall be recorded in a log maintained under the direct supervision of the Health Physics & Safety Supervisor.

The Manager, NLS&A or the Nuclear Licensing Consultant shall review and approve facility and process changes, equipment rearrangements and additions affecting criticality safety which fall within the criteria of Section 4.2 provided that an independent review is performed by the Nuclear Safety Committee or persons designated by that Committee.

Written operating procedures are provided by the cognizant engineering supervisor for all operations, including equipment and floor cleanup. These include all criticality and radiological safety restrictions, safety restrictions and limits. Signs, including criticality limits as approved by the Manager, NLS&A or the Nuclear Licensing Consultant are posted near the appropriate work station under the direction of the cognizant supervisor and are verified by the Health Physics & Safety Supervisor.

In addition, all procedures shall provide for the labeling of mass limited containers to indicate the enrichment and the uranium content. All process equipment and operating areas shall be labeled to indicate the enrichment and geometry limited containers will be handled as though they are full unless specifically labeled otherwise. Labeling shall be carried out under the direction of the cognizant foreman. The Health Physics & Safety Supervisor is responsible for the surveillance of all Nuclear Fuel Manufacturing activities in which radioactivity is involved to ensure that the health and safety as well as criticality standards set forth in the license are met. He has the necessary authority to halt any operation which falls outside those limits, and is responsible for indicating what remedial action is necessary to bring the operation within acceptable limits. However, if the operation is halted because of criticality safety considerations, the Health Physics & Safety Supervisor will contact the Manager, NLS&A or the Nuclear Safety Committee who shall determine necessary corrective actions to be taken. He reports directly to the General Manager. The basic organizational structure for Nuclear Fuel Manufacturing is shown in Figure 2.2.2.

FIGURE 2.2.2


NUCLEAR POWER SYSTEMS
Division
Vice President
NUCLEAR FUEL MANUFACTURING
Vice President
NUCLEAR MATERIALS & SECURITY
Manager
ACCOUNTING
Controller
FUEL FABRICATION
General Manager
NUCLEAR LICENSING CONSULTANT
QUALITY ASSURANCE
Manager
ENGINEERING MANAGER
PRODUCTION SUPERINTENDENT
PRODUCTION MANAGER
MANAGER, NUCLEAR LICENSING, SAFETY & ACCOUNTABILITY
SECURITY SUPERVISOR
SUPERVISOR, HEALTH PHYSICS & SAFETY
SUPERVISOR NUCLEAR MATERIAL ACCOUNTABILITY

2.2.3 Nuclear Safety Committee

A Nuclear Safety Committee comprised of engineers and scientists, representing all areas of the Nuclear Power Systems Division nuclear and scientific community, has been organized and assigned as one of its responsibilities the function of providing assurance to management that all nuclear activities are carried out in a safe manner. The Committee acts in a staff capacity reporting to the Vice President, Nuclear Power Systems.

The functions of the Committee are to:

- Assure an independent review of all Nuclear Criticality Safety aspects or any changes which the Manager, Nuclear Licensing, Safety, and Accountability is requested to review and approve. This review will be performed by a qualified person designated by the Chairman of the Committee, and acting in behalf of the Committee.

- Audit all manufacturing operations involving SNM at least once a year. This audit must include as a minimum, a review of the nuclear criticality and radiological safety programs and their application and to assure that management policies are consistent with the objective of maintaining occupational radiation exposures as low as reasonably achievable. The Committee member who reviews the criticality safety program shall be a person other than the one who is authorized to perform the monthly criticality safety audit. The Committee member who reviews the radiological safety program shall be a person other than the one who is authorized to perform the monthly radiological safety audit.

2.3 Personnel Selection (Approval Authority) for Key Positions

2.3.1 Nuclear Laboratories - The Vice President-NPS Development Department has approval authority for the following key positions: Manager-Health Physics, Director-Fuels Development, Director-Engineering, Development & Services, Director Materials and Chemistry Development, and Director-Product Engineering & Development.

2.3.2 Nuclear Fuel Manufacturing - The Vice President-Nuclear Fuel has approval authority for the following key positions: General Manager-Nuclear Fuel Manufacturing, Manager-Nuclear Materials & Security, Manager-Quality Assurance, Engineering Manager, Production Manager, Manager-Nuclear Licensing, Safety, & Accountability, and Nuclear Licensing Consultant.

2.4 Independence of Safety Personnel

The Manager-Health Physics reports to the Vice President-NPS Development Department.

The Manager-Nuclear Licensing, Safety & Accountability, the Supervisor, Health Physics & Safety, the Nuclear Licensing Consultant, the Engineering Manager and the Production Manager all report to the General Manager-Nuclear Fuel Manufacturing who reports to the Vice President-Nuclear Fuel.

Conflicts of interest are thus minimized and independence of safety personnel is assured.

2.5 Education and Experience Requirements for All Key Safety and Operations Personnel

2.5.1 Manager, Health Physics - The minimum qualifications for this position shall be a Bachelors Degree in one of the sciences, engineering, or equivalent and a minimum of three years experience in positions which demonstrate sufficient judgement and capability to establish and maintain an effective nuclear criticality and radiological safety program.

2.5.2 General Manager, Nuclear Fuel Manufacturing - The qualifications for this position shall be a Bachelors Degree in one of the sciences or engineering and five years experience in nuclear fuel fabrication facilities. In addition, at least three years supervisory experience is required as well as an understanding of the nuclear criticality safety, health physics, and industrial safety aspects of fuel handling and knowledge of administrative controls imposed on nuclear fuel handling operations.

2.5.3 Manager-Nuclear Licensing, Safety, & Accountability (NLS&A) or Nuclear Licensing Consultant

The minimum qualifications for these positions shall be a Bachelors Degree in one of the sciences or engineering and a minimum of three years experience in positions which demonstrate sufficient judgement and analytical capability to establish and maintain technically sound and effective nuclear criticality safety, health physics, industrial safety, and nuclear material accountability programs. He must meet the minimum qualifications for a Nuclear Criticality Specialist.

2.5.4 Supervisor-Health Physics and Safety - The minimum qualifications for this position shall be a Bachelors Degree in one of the sciences, engineering or equivalent. A minimum of two years experience in radiation safety protection in positions which demonstrate sufficient judgement and capability to establish and maintain an effective nuclear criticality and radiation safety program.

2.5.5 Radiation Specialist - The minimum qualifications for this position shall be a Bachelors Degree in one of the sciences, engineering or equivalent and a minimum of two years experience in Radiation Safety Protection.

2.5.6 Nuclear Criticality Specialist - The minimum qualifications for this position shall be a Bachelors Degree in one of the sciences, engineering or equivalent and two years experience in outside-of-reactor nuclear criticality safety or two years experience in nuclear reactor physics and one year experience in outside-of-reactor nuclear criticality safety.

2.5.7 Nuclear Materials Manager - The minimum qualifications for this position shall be a Bachelors Degree in one of the sciences or engineering, and two years experience in nuclear materials management.

2.5.8 Nuclear Safety Committee Membership - The general qualifications for Committee membership are as follows:

- The individual must be a highly competent senior staff member.
- The individual must be capable of evaluating radiological and nuclear safety and must have had at least seven (7) years experience in the nuclear industry.
- The individual must not be directly involved in the production or development facility utilizing the nuclear material.
- The individual must disqualify himself if there is a conflict of interest with the production or development groups.
- The individual who performs the independent criticality safety review shall meet the minimum qualifications for a Nuclear Criticality Specialist and shall not be the person who is authorized to conduct the monthly criticality audits and shall not be the initial reviewer.
- The individual who performs the independent radiological safety review shall meet the minimum qualifications for the Manager-Health Physics and shall not be the person who is authorized to conduct the monthly radiological safety audit and shall not be the initial reviewer.

2.6 Training

2.6.1 Initial Training

All new personnel must attend a formal training session. This will cover principles of radiation safety, nuclear criticality safety, industrial safety, emergency procedures, and additional information pertaining to their job. All personnel who will be working with radioactive materials must complete a test to ascertain the effectiveness of the training. All training will be conducted under the direction of the Health Physics & Safety Supervisor for the manufacturing facility and under the direction of the Manager, Health Physics for the Development Department Laboratories.

Health Physics Technicians

Health Physics Technicians for Nuclear Manufacturing, or the Nuclear Laboratories shall receive the above training, and will be instructed by the Supervisor, Health Physics and Safety or the Manager, Health Physics, as appropriate, in the use of instruments, the evaluation of contamination, environmental sampling, and other aspects relevant to their assignments. Health Physics Technicians will also receive sufficient training in criticality control to enable them to carry out their auditing functions.

2.6.2 Periodic Retraining

In addition to a continual program of in-plant training, formal sessions shall be held for production personnel. Since all production personnel may be required to work in the pellet shop, the sessions will be uniform. This training is to be conducted on an annual basis.

All maintenance personnel working in restricted areas shall attend an annual safety training session. If they have not attended this training, they may enter the restricted area only with a trained escort. Maintenance training sessions will cover the same topics as the production personnel session. Special emphasis will be given to internal contamination of equipment.

Salaried personnel who enter restricted areas shall attend training sessions annually. These sessions will be directed toward observation and supervision in restricted areas rather than actual handling of radioactive material. Question and answer periods are held during every training session to ascertain the effectiveness of the training and to assure proper understanding of the material covered. All training shall be documented.

3.0 RADIATION PROTECTION

3.1 Administrative Requirements

3.1.1 Radiation Work Permit Procedures

All non-routine maintenance or repair operations on equipment in contaminated areas must be covered by a Radiation Work Permit (RWP), including those non-routine maintenance operations in which the ventilated containment is compromised. The RWP shall be requested by the cognizant foreman or engineer.

The RWP will be issued by the Nuclear Licensing, Safety, & Accountability (NLS&A) group. It will include all safety requirements, protective clothing and equipment, and health physics monitoring requirements necessary to assure that the proposed operation is conducted in a safe manner.

3.1.2 Audits

3.1.2.1 Laboratory Operations

Laboratory operations will be audited once per month by an individual who meets the minimum qualifications of the Health Physics & Safety Supervisor. He will verify the adequacy of the Radiation Protection Program and that all designated operating procedures are being followed. He will report his findings to the Vice President-NPS Development Department.

3.1.2.2 Nuclear Fuel Manufacturing Operations

Operations at the Nuclear Fuel Manufacturing facility will be formally audited as follows:

- ° Once each working day by a Health Physics Technician for Health Physics compliance and criticality compliance. He shall submit his findings in writing to the Supervisor Health Physics and Safety.

- Once each month for nuclear criticality safety by an individual who meets the minimum qualifications of a Nuclear Criticality Specialist. He shall audit for compliance with all regulations and operating procedures, and shall assess the adequacy of the criticality safety program. His findings will be documented and reported to the General Manager-Nuclear Fuel Manufacturing.
- Once each month for radiological safety by an individual who meets the minimum qualifications of a Radiation Specialist. He shall audit for compliance with all regulations and operating procedures and shall assess the adequacy of the radiological safety program. His findings will be documented and submitted to the General Manager-Nuclear Fuel Manufacturing.
- Once each year by the Nuclear Safety Committee. The committee will review all aspects of the criticality and radiological safety programs and will transmit their report in writing to the Vice President-Nuclear Fuel.

Follow-up actions on audits of the Nuclear Laboratories will be the responsibility of the Manager-Health Physics and for audits of the manufacturing facility, will be the responsibility of the General Manager, Nuclear Fuel Manufacturing.

3.2 Technical Requirements

3.2.1 Access Controls

All personnel entering the unclad fuel handling area (pellet shop) must do so through the change rooms provided for this purpose. Protective clothing for regular pellet shop production personnel shall be as follows:

- Coveralls
- Special shoes or shoe covers
- Safety glasses

Protective clothing for transients (visitors, inspectors, maintenance personnel, salaried employees, etc.), shall be as follows:

- Lab coat
- Special shoes or shoe covers
- Safety glasses

3.2.2 Monitoring Requirements

All personnel must wash their hands before exiting the contaminated area and monitor their hands, exposed areas of the body and personal clothing with the alpha personnel monitor located at the change line. Any person having suspected contamination on his body must thoroughly wash the area and recheck for contamination. If contamination persists, a member of the health physics staff will assist in decontamination.

3.2.3 Ventilation Requirements

Ventilation in the Manufacturing Facility (Building #17) is provided by four separate exhaust systems as described herein:

FA-1 Powder Preparation and Pressing - This system has a capacity of 12,100 CFM and incorporates prefilters and a double bank of 12 absolute filters, each 99.97% efficient at 0.3 microns. The air exhaust from this system which is either returned to or released from the plant is sampled 100% of the time and analyzed each day.

FA-2 Furnace H_2 Burnoff - This system has a capacity of 1340 CFM and incorporates prefilters and a single bank of 4 absolute filters, each 99.97% efficient at 0.3 microns. The air exhaust from this system is released from the plant and sampled 100% of the time and analyzed each day.

FA-3 Pellet Grinding and Rod Loading - This system has a capacity of 19,422 CFM and incorporates prefilters and a single bank of 21 absolute filters, each 99.97% efficient at 0.3 microns. The air exhaust from this system is released from the plant and sampled 100% of the time and analyzed each day.

FA-4 Recycle Powder Area - This system has a capacity of 6000 CFM and incorporates prefilters and a double bank of 6 absolute filters, each 99.97% efficient at 0.3 microns. The air exhaust from this system is released from the plant and sampled 100% of the time and analyzed each day.

The capacity of the ventilation systems have been matched to provide a negative pressure differential between the Pellet Processing Facility and all surrounding work areas. If airborne radioactivity results, averaged over a two week period, exceed the applicable concentration listed in Table II, Column I of 10CFR20 Apendix B for air being discharged to an unrestricted area (from manufacturing or laboratory operations), an investigation will be conducted and corrective action taken.

Ventilation system filters and/or prefilters will be changed, rotated, or knocked down whenever a pressure drop of 4 inches of water is measured across the combination of the prefilters and first bank of absolute filters. When the face velocity at a ventilated hood drops below 100 fpm, the hood filters or ventilation system filters will be changed, brushed, or knocked down to increase the air flow to 100 fpm minimum or the hood will not be used to handle radioactive material. Face velocities will be checked weekly in the manufacturing facility and monthly in the laboratories.

Discharge air from the Nuclear Laboratories will be monitored on a continuous basis whenever operations having a potential for dusting are carried out. Samples will be analyzed daily.

The adequacy of the sampling techniques to obtain representative samples will be verified monthly.

3.2.4 Instrumentation

Capabilities of radiation detection and measurement instrumentation shall be as follows:

Alpha counting system	10 - 10^5 dpm
Alpha survey meters	0 - 50,000 counts per minute
Beta-Gamma survey instruments	.05 mR/hr - 200 mR/hr
Neutron survey instruments	.5 - 5000 mrem/hr

The detectors for the criticality alarm system are calibrated quarterly and following major repair. All other instruments are calibrated twice per year, and following major repair. Counting equipment is checked daily to verify background and efficiency.

3.2.5 Internal Exposure (Breathing Zone Air Sampling)

Breathing zone (BZ) air samples will be taken for the first four weeks of a new operation, with sampling carried out at least 50% of the time during which the operation is carried out. Thereafter, process operations involving unclad UO_2 will be surveyed with BZ samplers at least 10% of the time. Air samples will be taken at positions which closely approximate the breathing zone area. It is the intent of Combustion Engineering to assure that operations with uranium do not cause exposures which exceed a level of 0.25×10^{-10} μCi/cc. Operations which, because of their associated physical characteristics (including material handling and ventilation), result in continued higher levels, will be investigated and corrective action will be taken. On the other hand, it is recognized that the behavior of individual operators can be a significant contributing factor to an individual's exposure, and that this may not be amendable to the desired degree of improvement. Where the individual operator is found to contribute significantly to higher exposures, closer personnel surveillance will be maintained. Thus, an individual whose 40 hr exposure exceeds 2.5 MPC days will be continuously monitored with a BZ sampler. If his 40 hr exposure exceeds 4 MPC days he is removed from exposure to airborne contamination. It is the responsibility of the licensee to evaluate these situations to determine the relative contributions of individuals and equipment. Operations will be monitored using general air sampling stations to provide samples which are representative of working areas in order to verify adequate ventilation and contamination control.

3.2.6 External Exposure (Dosimetry Requirements)

Each individual who enters a restricted area under such circumstances that he is likely to receive a dose in any calendar quarter in excess of 25 percent of the applicable value specified in 10 CFR 20.101(a) shall be supplied with a TLD badge and indium foil for purposes of personnel dosimetry. Badges will be processed monthly. When a high exposure is suspected, the individual's badge will be immediately processed. All visitors will be supplied with indium foil badges.

Area TLD badges and neutron foils are also strategically placed throughout the facility for the purpose of recording background radiation levels as well as radiation resulting from a criticality accident. These badges will also be processed monthly during normal operations and immediately following a criticality accident. Procedures to determine high radiation doses immediately following a criticality accident are described in the Emergency Procedures Manual.

3.2.7 Bioassay Program

The bioassay program shall satisfy the requirements of Regulatory Guide 8.11, "Applications of Bioassay for Uranium" except that bioassay measurements shall be conducted semi-annually (alternating between urinalysis and in-vivo lung counting).

3.2.8 General Air Sampling

General air samples are taken in the fuel handling areas and other designated areas during operations with unclad fuel. Operations will be monitored by continuous samplers to provide samples which are representative of working areas and to verify adequate ventilation and contamination control. All samples will be analyzed for each working shift (after a 24-hour decay to establish a radon-free count). It is the intent of Combustion Engineering to assure that operations with uranium do not cause general air levels to exceed a level of 0.25×10^{-10} μCi/cc. Operations which, because of their associated physical characteristics (including material handling and ventilation), result in continued higher levels, will be investigated and corrective action will be taken.

3.2.9 Contamination Surveys

3.2.9.1 Restricted Areas (As defined in 10 CFR 20.3(a)(14)

Removable Alpha Contamination Action level	Action to be Taken
10,000 dpm/100 cm^2	Immediate Clean-up
5,000 dpm/100 cm^2	24-hour Clean-up

Material on processing equipment or fixed on surfaces shall be limited as required to control airborne radioactivity and external radiation exposures.

3.2.9.2 Unrestricted Areas (Release of Materials & Equipment, but does not include the abandonment of buildings).

1) The maximum amount of removable alpha contamination (capable of being removed by wiping the surface with a filter paper or sofe absorbent paper) shall not exceed 100 dpm/100 cm^2.

2) The maximum amount of fixed alpha contamination shall not exceed 2500 dpm/100 cm^2.

3) The average amount of fixed alpha contamination shall not exceed 500 dpm/100 cm^2.

4) The maximum radiation level at one centimeter from the most highly contaminated surface measured with an open window beta-gamma survey meter through a tissue equivalent absorber of not more than seven milligrams per square centimeter shall not exceed 1 mr/hr.

5) The average radiation level at one centimeter from the contaminated surface measured in the same manner shall not exceed 0.2 mr/hr.

6) A reasonable effort shall be made to eliminate residual contamination.

7) Radioactivity on equipment or surfaces shall not be covered by paint, plating, or other covering materials unless contamination levels, as determined by a survey and documented, are below the limits specified above prior to applying the covering.

3.2.10 Respiratory Protection

The Respiratory Protection Program shall be conducted in accordance with USNRC Regulatory Guide 8.15.

4.0 NUCLEAR CRITICALITY SAFETY

4.1 Administrative Requirements

4.1.1 Double Contingency Policy

All process equipment and storage locations shall be designed such that no single failure accident will cause accidental criticality. At least two independent events shall be necessary to cause a criticality accident.

4.1.2 Written Procedures and Approval Authority

All process operations involving SNM are covered by a shop traveler and/or an operation sheet. All necessary precautions and limits regarding criticality and radiological safety are included in these procedures. They are approved by the Health Physics and Safety Supervisor. However, procedures involving a change in the criticality safety controls used for that particular process in the past shall be approved by the Manager, NLS&A or the Nuclear Licensing Consultant. In their absence, a member designated by the Nuclear Safety Committee shall approve the change. Each foreman shall instruct his people to assure their understanding of the operations and their safety limits and restrictions. The adequate performance of individuals is continually ascertained by the foreman.

It is the responsibility of the foreman to assure that each work station is properly posted, and that operations are performed in compliance with posted limits and written instructions.

4.1.3 Request for Changes and Criticality Analysis

All proposed changes in process, equipment, and/or facilities that could affect nuclear criticality, radiological or industrial safety must be approved in accordance with the requirements set forth in section 2.2.2 of the renewal application. The necessary analysis and resultant safety limits will be established by a person having the minimum qualifications of a Criticality Safety Specialist.

Procedures have been established for requesting changes and all request forms, approval forms, and associated documentation are maintained under the supervision of the Supervisor, Health Physics & Safety.

4.1.4 Posting of Limits

All work stations and storage areas will be posted with a nuclear safety limited approved by the Manager NLS&A or the Nuclear Licensing Consultant.

4.1.5 Internal Review Requirements

All process/equipment/facility changes which affect nuclear criticality safety must be reviewed and approved in writing by the Manager, NLS&A or the Nuclear Licensing Consultant. An independent review shall be performed by an individual designated by the Nuclear Safety Committee. He shall meet the minimum qualifications for a Criticality Safety Specialist and shall not be the initial reviewer.

As stated in section 4.1.3, all such approvals shall be recorded in a log maintained under the supervision of the Supervisor, Health Physics & Safety.

4.1.6 Marking and Labeling of SNM

All mass-limited containers shall be labeled as to enrichment and content. All geometry limited containers and processes are safe up to the maximum allowable enrichment of 4.1% U^{235}.

4.1.7 Audits

4.1.7.1 Laboratory Operations

Nuclear criticality safety for all laboratory operations is limited to quantities smaller than a minimum critical mass with the exception of one slab limited storage area in Building 2. Each such mass limited area must be isolated from all other fissile material by at least 12 feet. Criticality control by any other means (volume, slab, geometry, etc.) shall not be permitted. Thus, the nuclear criticality safety program in the laboratories consists of simple mass limits. The monthly radiological safety audit of laboratory operations required by section 3.1.2.1 shall include verifications to assure that all nuclear safety limits are being adhered to.

4.1.7.2 Nuclear Fuel Manufacturing Operations

Operations at the Nuclear Fuel Manufacturing facility will be formally audited for nuclear criticality safety as required by the audit schedule in section 3.1.2.2.

4.1.8 Training and Retraining

All training and retraining with respect to nuclear criticality safety shall be conducted in accordance with the requirements of section 2.6.

4.2 Technical Requirements

4.2.1 Preferred Approach to Design

It is the intent of Combustion Engineering to use physical controls and permanently engineered safeguards on processes and equipment in the establishment of nuclear safety limits. Use of fixed neutron poisons and/or administrative controls will be minimized.

4.2.2 Basic Assumptions and Analytical Methods

All Laboratory operations are limited to 350 gm U^{235} for uranium enriched to more than 5% U^{235} but less than 20% U^{235}, and to 740 gm U^{235} for uranium enriched to 5% U^{235} or less. Each such limited operation must be separated from any other limit by at least 12 feet.

Criticality safety of the less complex manufacturing operations is based on the use of limiting parameters which are applied to simple geometries. Safe Individual Units (SIU) are selected on the basis of optimum moderation and full reflection using published nuclear criticality safety data. These units are spaced using the surface density method.

The remaining manufacturing operations are evaluated using two dimensional transport and/or 3 dimensional Monte Carlo Codes. The sixteen group Hansen-Roach cross section library is used for homogeneous systems while the CEPAK Code is used to generate four group cross sections for heterogeneous systems. A detailed validation of these calculational codes and cross sections is provided in Part II of this application.

4.2.3 Data Sources

Safe Individual Unit (SIU) limits have been established using published data from one or more of the following sources:

- Chalmers, J. A., Pugh, J., Walker, G.
  UKAEA Handbook AHSB (1), Edition II, 1965
- Clark, H. K.
  Critical and Safe Masses and Dimensions of Lattics of U and UO_2 Rods in Water, DP-1014, February 1966
- Carter, R. D., Reil, G. P., Ridgeway, K. R.
  Handbook of Nuclear Criticality Safety, ARH-600
  Volume I, Rev. I, 6/28/68
  Volume II, 5/23/69
  Blyckert, W. A., Carter, R. D., Ridgeway, K. R.
  Volume III, 9/1/71

4.2.4 Safety Margins - Individual Units

Safety margins applied to units calculated to be one percent subcritical, and incorporated in the SIU's are as follows:

Mass	2.3
Volume	1.3
Cylinder Dia.	1.1
Slab Thickness	1.2

These values are further reduced where necessary to assure maximum fraction critical values of 0.4 for geometrically limited units, and 0.3 for mass limited units. An additional reduction has been applied to several mass and volume limits to assure that spacing requirements remain constant for all enrichments.

4.2.5 Limits for Safe Individual Units (SIU's)

Table 4.2.5

Safe Individual Unit Limits for ≤ 4.1% enriched UO_2 at optimum moderation. All Mass and Volume limits have been adjusted to provide constant spacing areas for the enrichment shown. Heterogeneous limits have been developed with optimum rod sizes (up to 0.4" diameter) taken to allow for pellet chips, etc.

	HOMOGENEOUS		HETEROGENEOUS	
	Limit	f*	Limit	f*
Mass (Kg UO_2)				
<2.5 % U^{235}	54	.19	50	.26
2.5 - 3.0 "	41	.23	38	.29
3.0 - 3.2 "	36	.23	36	.29
3.2 - 3.4 "	35	.25	33	.29
3.4 - 3.6 "	32	.26	30	.30
3.6 - 3.8 "	28	.26	27	.29
3.8 - 4.1 "	24	.25	24	.27
Volume (liters)				
<3.5%	31	.39	22	.40
3.5 - 4.1	25	.38	18	.38
Cylinder Diameter (inches)				
<3.5%	10.7	.34	9.5	.36
3.5 - 4.1	9.8	.33	8.9	.34
Slab Thickness (inches)				
<3.5%	5.1	.36	4.1	.22
3.5 - 4.1	4.6	.32	3.7	.20

* Fraction of the equivalent unreflected critical spherical volume or mass

4.2.6 Interaction Criteria

Activities involving SNM may be conducted in single or two level areas of the facility. The surface density method is used to evaluate arrays of SIU's where each mass limit has a fraction critical of $\leq$ 0.3, and each geometry limit has a fraction critical of $\leq$ 0.4. All SIU's must have a separation of at least one foot, edge to edge.

Spacing for mass limited activities carried out in the single level portions of the facility are such that the contained UO_2 and moderator, if "smeared" over the allowed spacing areas would not exceed 50% of water reflected infinite slab surface density assuming optimum mass moderation. For cylinder and volume limited activities, a spacing limit based on 25% of the minimum water reflected infinite slab thickness applies. Slabs specified in Table 4.2.5 require no additional spacing, and may border the spacing boundary of any other array unit.

Portions of the facility contain two levels, each of which may be used for SNM. In all cases, the floor deck of the second level consists of a 3/8" steel plate (minimum), which is at least 10 ft. above the ground floor. Mass limits on each level are spaced to 25% of the applicable slab thickness, and cylinder or volume limited units are spaced to 16% of the applicable slab thickness.

All array calculations have been performed assuming a doubly infinite planar system, based on the consideration that components of subcritical infinite arrays can be combined where the unit size and cell spacing is preserved. Array reflection consists of a 16" thick concrete floor, and a 4" thick concrete roof 25 ft. above the floor.

Table 4.2.6

Spacing requirements for mass, volume, or cylinder SIU's specified in Table 4.2.5 are shown below. Spacing areas will be established to provide equal distances from the edges of the units to the spacing boundary in all directions. Co-planar slabs specified in Table 4.2.5 shall require no additional spacing.

Limit	Spacing Areas
Mass	3.5 ft^2
Volume	9.0 ft^2
Cylinders (per ft. of length)	5.0 ft^2
Cylinders (11"ϕ x 40" lg., <3.5% U^{235} only)	27 ft^2

For two story operations, a 3/8 inch steel deck, 10' above the floor, separates the operating levels and provides effective neutron isolation between the two levels.

Justification for this spacing criteria is provided in Part II of this application.

Whenever more than one SIU is allowed in any given hood or box, positive spacing fixtures shall be used to assure spacing. Carts, limited to one mass or volume SIU shall measure at least three feet on a side, and shall be designed to assure that the SIU is centered.

In cases where the spacing area extends beyond the equipment boundaries, such as the storage facilities, the spacing boundary will be indicated with a colored line. The line may be crossed by carts only to permit an operator to transfer that SIU to an available storage position.

4.2.7 Fixed Poisons - Criteria

Fixed poisons will be used as a criticality control method only when all other methods have proven unsatisfactory. General criteria for the use of fixed poisons shall be as follows:

- All poisons shall be positively fixed in place to prevent unauthorized removal or loss of poison.
- Poisons shall be contained by a material which is not affected by credible accident conditions such as fire, flooding, etc.
- The poison shall be analyzed initially to demonstrate and document that the actual poison content and density required by analysis have been achieved.
- A periodic inspection program will be established to verify that the poison content or density has not changed beyond established limits. Rejection criteria will also be established.

4.2.8 Structural Integrity Policy

All storage racks, furnaces, containment, and processing equipment which provide nuclear safety limiting parameters shall be designed to assure against failure under normal and reasonable overload conditions and under conditions of shock or collision foreseeable in the plant area. All equipment designed in-house shall incorporate a minimum safety factor of 3.0 All equipment design shall conform to standard design practices, thereby assuring adequate structural integrity. Materials of construction will be selected to assure, as far as possible, resistance to fire and corrosion.

4.2.9 Zoning for Fire Protection

An overhead sprinkler system as well as portable extinguishers are located throughout the plant. Onsite and Offsite fire protection service personnel have been instructed to use only portable dry chemical fire extinguishers in the unclad fuel handling area to maintain the highest possible margin of nuclear criticality safety. Fire hoses are not permitted in this area.

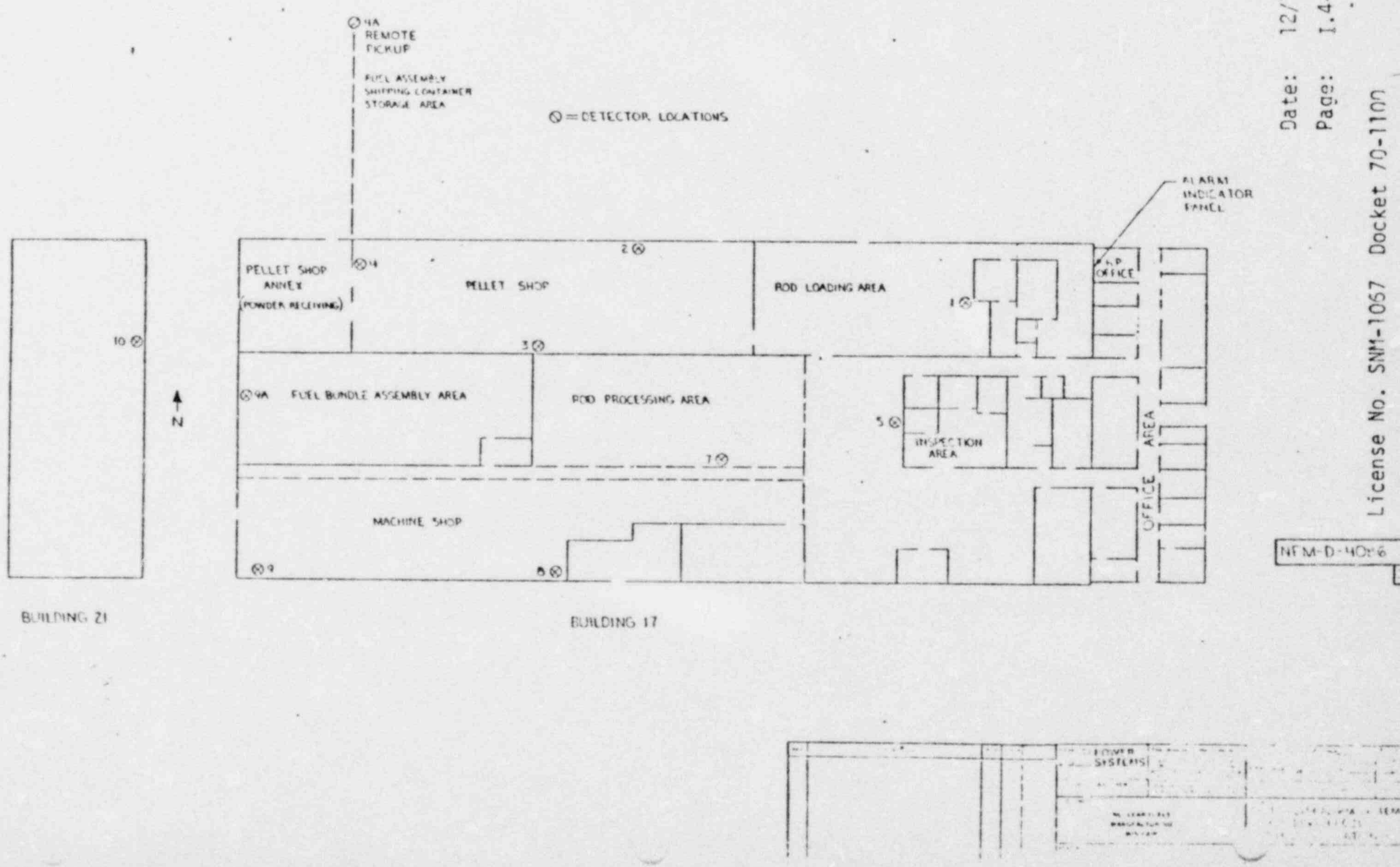
4.2.10 Criticality Alarm System

A criticality alarm system which meets the requirements of 10 CFR 70.24 and ANSI N16.2-1969 is maintained in the laboratory areas and the manufacturing facility.

The detectors operate in the range of 1-10,000 mR/hr. The locations of the detectors within the manufacturing facility are shown in Figure 4.2.10. The radiation intensity is shown on a central panel located in the health physics office. There is an alarm which serves as a local and general audible radiation evacuation alarm. When the alarm is sounded, the Emergency Plan is immediately put into effect. The monitors are connected to the emergency power system, which is supplied to all emergency lights and alarms in the event of a general power failure within the facility. This electrical system renders the system operative at all times. Operation is further enhanced by visual observation by Health Physics personnel. Alarm operational tests of the radiation monitors are performed monthly by Health Physics personnel. A Ra-226 source is used to perform these tests. The entire system is calibrated quarterly and following major repair.

Figure 4.2.10

Criticality Alarm System



Date: 12/18/80

Page: I.4-11

License No. SNM-1067 Docket 70-1100

IMAGE EVALUATION
TEST TARGET (MT-3)

6″

IMAGE EVALUATION
TEST TARGET (MT-3)

6″

5.0 ENVIRONMENTAL PROTECTION

5.1 Effluent Control Systems Commitments

5.1.1 Sanitary Wastes

All sanitary wastes are processed through an on-site sewage treatment facility to assure compliance with all state effluent discharge regulations.

5.1.2 Control of SNM-Bearing Effluents and Wastes

During the processing of Source and Special Nuclear Materials into fuel elements and fuel assemblies, a certain amount of scrap and waste is generated. Salvage of these materials, or discharge of them as wastes with non-recoverable uranium, will be carefully controlled. Water utilized for cleaning or processing in the unclad fuel handling area is centrifuged and sampled before being discharged to holding tanks where the water is again sampled before final discharge.

Combustion has available laboratories to perform analytical services, as required, to determine uranium content and isotope ratios. These Laboratories are capable of the following:

° Wet chemical or gamma pulse height analyses for uranium content and wet chemical analyses for iron, nickel, chromium, cobalt, tin, boron, and other elements of interest.

° Emission spectrographic analyses for isotopic content and procedures for neutron absorbing impurities, and solution and oxide excitation techniques for impurities in alloying and cladding materials.

° X-ray fluorescent spectrometry on solids, liquids, and powders for uranium content.

° Fluormetric analyses for measuring trace contaminants, such as uranium and beryllium and determining their content in wastes.

° Combustion techniques for carbon, hydrogen, and oxygen in uranium-containing bodies and cladding.

° Spectrophotometric determination of uranium content of salvage materials.

5.1.3 Low-Level Radioactive Waste

Low level radioactive wastes will be packaged in accordance with all applicable regulations and delivered to a carrier for transport to an approved disposal facility. Current copies of disposal facility regulations shall be maintained.

An outside pad has been provided for the storage of low level wastes. The pad is 14' x 80' and is contiguous to the south wall of the Building #21 warehouse. This pad is contained within an 8' high chain link fence.

Records are maintained to assure that no single package will contain more than 350 grams of U^{235}. All packages will be placed on pallets and package stacking will be limited to two high. Maximum residence time of a package on the pad will be twelve months. Packages will not be opened outside the building under any circumstances. Packages will contain no liquid wastes.

In addition, all packages will be sealed, monitored for contamination and labeled as to enrichment and U^{235} content. All outside storage will be checked four times each year at which time contamination levels will be evaluated, and the adequate condition of the packages will be verified. In addition, a weekly visual check on such storage will be made. Package maintenance operations will be performed in appropriate indoor locations.

5.1.4 Liquid Wastes

All liquid wastes, in-process, and clean-up rinse water solutions are sampled to verify that MPC_w is not exceeded, and are then introduced to the liquid waste system as described below. Release of liquid waste will be authorized by the Health Physics Technician.

Sinks and showers in the laboratories and the manufacturing facility are drained to any one of ten (10) 2000-gallon retention tanks, located in the liquid Waste Building, Bldg. #6. The tanks fill automatically in sequence. When eight tanks become filled to capacity, a blinking warning light located on the outside wall of the building is activated to warn that two retention tanks remain in reserve to receive radioactive liquid waste before overflow might be expected. A sampling station is provided at the base of each retention tank. A 500-ml sample is withdrawn and forwarded to the Radiochemistry Laboratory for gross alpha and beta analyses. Water is discharged to the environment at, or below 3×10^{-6} µCi/ml (this is ten percent of MPC_w for insoluble natural uranium). The discharge level for unidentified mixtures of radionuclides is 3×10^{-9} µCi/ml. (This is ten percent of MPC_w for unidentified mixed radionuclides). Where the levels of activity exceed these limits, the water is diluted before being discharged.

In-process acid solutions from the acid tanks of the Manufacturing Facility re sampled and analyzed for pH and uranium content. Those solutions not contaminated with uranium will be disposed of by normal industrial practices.

5.1.5 Airborne Effluents

Airborne effluents shall be continuously monitored in accordance with section 3.2.3 and discharge to the environment shall be as specified therein.

5.2 Environmental Monitoring Program

5.2.1 Fallout Stations

Ten stations for collecting rainfall and particulate fallout are distributed concentrically on the Windsor site property.

These samples shall be analyzed for gross beta and gross alpha radioactivity and total uranium.

5.2.2 Liquid Samples

Liquid samples shall be taken from the site wells and ponds, the site creek and points upstream and downstream from the confluence of the site creek and the Farmington River.

These samples shall be analyzed for gross beta and gross alpha radioactivity and pH, nitrates, fluorides, and total uranium.

5.2.3 Mud Samples

Mud samples shall be taken from the site ponds, the industrial stream and points upstream and downstream from the confluence of the industrial stream and the Farmington River.

The samples shall be analyzed for gross alpha and gross beta radioactivity and total uranium.

5.2.4 Vegetation Samples

Vegetation samples shall be collected at each of the fallout station locations on-site and four locations in the grassy area surrounding Building #17.

Additional samples are collected off-site in the tobacco fields north, south, east and west of the site boundary.

These samples shall be analyzed for gross alpha and gross beta radioactivity and total uranium.

5.2.5 Soil Samples

Soil samples shall be obtained at each of the fallout station locations on site and four locations surrounding Building #17. Samples shall also be collected from the tobacco fields north, south, east and west of the site boundary.

These samples shall be analyzed for gross alpha and gross beta radioactivity and total uranium.

5.2.6 Sampling Schedule

The above environmental monitoring program shall be carried out in accordance with the schedule provided in Table 5.1. All sample results shall be documented.

LE 5.1

C-E ENVIRONMENTAL MONITORING PROGRAM

SAMPLE	FEQUENCY	LOCATION	ANALYSES	VOLUME
1. Farmington River Surface Water, Industrial Stream and Site Ponds	Quarterly in March, May, August and November	Four Locations on the Farmington River, the site ponds and Industrial Stream	Gross Alpha and Beta, Nitrate, Fluoride, pH, Total Uranium	1.25 Liters
2. Well Water	Quarterly in March, May, August and November	Each Site Well	Gross Alpha and Beta, Total Uranium, Nitrate, Fluoride and pH	1.25 Liters
3. Sediment from Farmington River, Site Ponds and Industrial Stream	Quarterly in March, May, August and November	Same Locations as Surface Water	Gross Alpha and Beta, Total Uranium	One Pint
4. Vegetation On-Site	Semi-Annually in May and September	Each Fallout Station Location and Four Locations in Grassy Areas Surrounding Building #17	Gross Alpha and Beta, Total Uranium	One Pint of Packaged Vegetation
Off-Site	Semi-Annually in May and September	Tobacco Fields on N,S,E,& West Site Boundary	Gross Alpha and Beta, Total Uranium	One Pint of Vegetation, Tobacco Leaves at end of Harvest
5. Soil	Semi-Annually in May and September	Same Locations as Vegetation	Gross Alpha and Beta, Total Uranium	One Pint (Upper inch)
6. Fallout	Quarterly in March, May, August & November	Ten Locations on Site	Gross Alpha and Beta, Total Uranium	Total Continuous Collection

6.0 INDUSTRIAL SAFETY

The Manager, Health Physics shall be responsible for compliance with all applicable industrial safety (OSHA) regulations for all activities in the nuclear laboratories covered by License No. SNM-1067. The Supervisor, Health Physics and Safety shall be responsible for compliance in the manufacturing facility.

7.0 DECOMMISSIONING PLAN

Combustion Engineering's Decommissioning Plan dated 1/12/79 was submitted previously and should be considered part of this renewal application.

8.0 EMERGENCY PLAN

Combustion Engineering's Emergency Plan dated 7/30/79 was submitted previously and should be considered part of this renewal application.

9.0 FUNDAMENTAL NUCLEAR MATERIAL CONTROL PLAN (FNMC)

Combustion Engineering's FNMC dated February 1980 was submitted on June 11, 1980 and should be considered part of this renewal application.

1.0 OVERVIEW OF OPERATIONS

1.1 Corporate Information and Financial Qualifications

1.1.1 Name and Address of Licensee:

COMBUSTI ENGINEERING, INC.

1000 PROSPECT HILL ROAD

WINDSOR, CONNECTICUT 06095

Combustion Engineering is incorporated in the State of Delaware.

Location of Principal Office: Windsor, Connecticut

1.1.2 Names, Addresses and Citizenships of Principal Officers

Name	Position	Address	Citizenship
SANTRY, A. J., Jr.	President	900 Long Ridge Road Stamford, Conn.	U.S.
ENNIS, T. A.	Vice President Administration	900 Long Ridge Road Stamford, Conn.	U.S.
GROSS, L. J.	Vice President Finance	900 Long Ridge Road Stamford, Conn.	U.S.
WINTERSON, H. M.	Group Vice President Power Systems	1000 Prospect Hill Road Windsor, Conn.	U.S.
HALLINAN, R. J.	Vice President, Secretary, & General Counsel	900 Long Ridge Road Stamford, Conn.	U.S.
KIAMIE, Mitchell	Vice President & Controller	900 Long Ridge Road Stamford, Conn.	U.S.

1.1.3 Information Known to Applicant Regarding Foreign Control

There is no information known to Combustion Engineering, Inc. of any control exercised over it by any alien, foreign corporation, or foreign government. The stock of Combustion Engineering is traded on the New York Stock Exchange. According to the stock records of Combustion Engineering maintained by its Transfer Agent, The Chase Manhattan Bank, as of December 31, 1979, there were approximately 26,742 stockholders of record, holding 16,337,119 shares of Combustion capital stock issued and outstanding. Of this number, (See Appendix A) less than 1 percent of all stockholders gave foreign addresses.

1.1.4 Financial Qualifications

Combustion Engineering's most recent published financial position is as of December 31, 1979 and is attached as Appendix A.

1.2 Operating Objective and Process - Summary

The process at the manufacturing facility begins with receipt of UO_2 powder enriched to a maximum of 4.1% U^{235} from Combustion Engineering's oxide conversion plant in Hematite, Missouri. This powder is then made up into batches with various additives and pressed into pellets. The pellets are dewaxed in a furnace where volatile additives are removed. The pellets then pass through a sintering furnace where they densify and attain the desired characteristics. Final sizing is accomplished through the use of a centerless grinder. The finished pellets are then loaded into zirconium tubes which are sealed and combined into finished PWR fuel assemblies. The assemblies are finally loaded into approved shipping containers and delivered to a carrier for transport to their final destination.

Development and analytical operations are carried out by the Nuclear Laboratories. These operations may require uranium in any form and enriched to <20% U^{235}.

1.3 Site Description

1.3.1 Population

The area surrounding Combustion Engineering's 532-acre site is sparsely populated. Windsor, Connecticut is the nearest town of significant size, approximately five miles away, with a population of 22,502 and a population density of 760.2 per square mile. East Granby, Connecticut is the nearest town to the site, approximately three miles away, with a population of 3,532 and a population density of 198.4 per square mile. The distribution of population in the area is shown in Table 1.3. Figure 1.3.1 is a map of the general area showing the location of the towns listed in Table 1.3.

1.3.2 Industry

The chief occupation of the populace in the immediate vicinity is farming. Farming is prevalent not only in this vicinity, but throughout the Connecticut Valley. Large industrial plants are widely dispersed in the area.

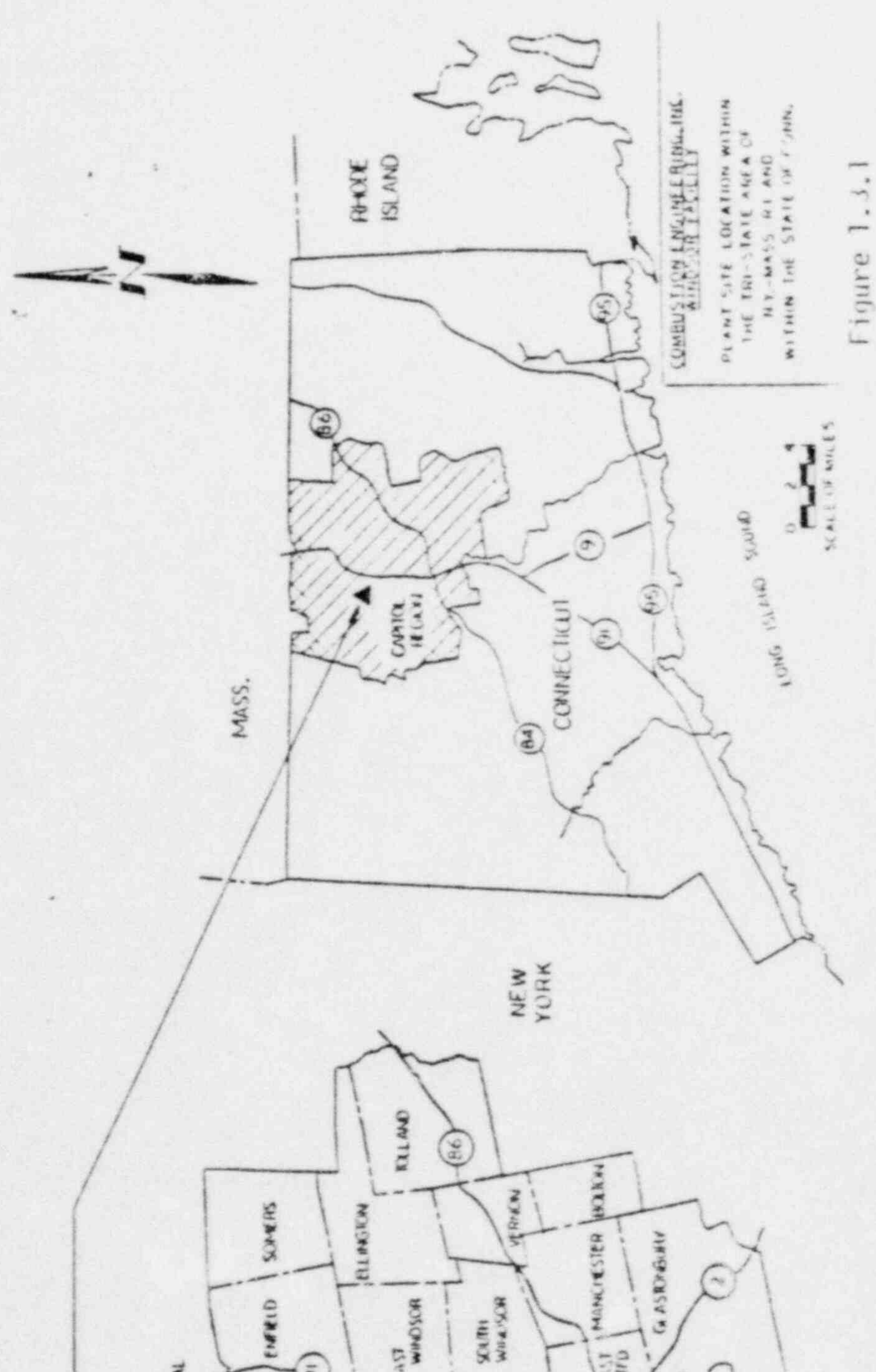

COMBUSTION ENGINEERING, INC.
WINDSOR FACILITY
PLANT SITE LOCATION WITHIN THE TRI-STATE AREA OF NY-MASS-RI AND WITHIN THE STATE OF CONN.
RHODE ISLAND
MASS.
CONNECTICUT
NEW YORK
CAPITOL REGION
LONG ISLAND SOUND
SCALE OF MILES
LOCATION OF COMBUSTION ENGINEERING PLANT SITE IN WINDSOR, CONN.
BRADLEY INTERNATIONAL AIRPORT
SUFFIELD
ENFIELD
SOMERS
ELLINGTON
TOLLAND
EAST GRANBY
WINDSOR LOCKS
WINDSOR
EAST WINDSOR
SOUTH WINDSOR
VERNON
BOLTON
MANCHESTER
GLASTONBURY
EAST HTFD
HTFD
WEST HARTFORD
BLOOMFIELD
WETHERSFIELD
NEWINGTON
GRANBY
SIMSBURY
AVON
FARMINGTON
CANTON

Figure 1.3.1

TABLE 1.3

POPULATION AND POPULATION DENSITY OF TOWNS WITHIN 10 MILE RADIUS OF COMBUSTION ENGINEERING, INC.

Town	Approximate Distance of Town Center to Site	General Direction from Site	Square Miles	Estimated Population (1970)	Population Density Persons/Sq. Mile
Hartford	9	S	18.6	158,017	8495.6
Windsor	5	SE	29.6	22,502	760.2
Bloomfield	5	S	26.9	18,301	680.3
West Hartford	8	SW	21.6	68,031	3149.1
East Hartford	9	SE	18.2	57,583	3164.0
Manchester	13	S	27.6	47,994	1738.9
South Windsor	7	SE	29.2	15,553	532.6
East Windsor	6	SE	25.6	8,513	319.6
Windsor Locks	4	E	9.6	15,080	1520.8
East Granby	3	N	17.8	3,532	198.4
Simsbury	6	SW	34.2	17,425	510.9
1/3 Avon incl. Center	8	SW	7.4	3,000	405.4
Granby Center	6	N	10.0	4,500	450.0
1/2 Suffield incl. Center & W. Suffield	6	N	22.0	4,300	195.4
1/3 Enfield incl. Thompsonville	8	NE	11.0	16,000	1454.5
1/2 Ellington excl. Center	12	E	17.0	3,900	229.4
1/3 Vernon excl. Center	13	E	6.0	7,200	1200.0
TOTALS			333.3	471,481	

1.3.3 Climatology and Meteorology

Climatological data for the area is based mainly on measurements made at the U.S. Weather Bureau Station located at Bradley International Airport, about five miles northeast from the site. The following information was taken from the U.S. Weather Bureau Local Climatological Data for the Hartford, Connecticut area:

> "The most significant feature of Hartford's climate is its rapid changeability. Weather is seldom average or normal for any appreciable length of time".

The mean temperature for the 50 year period, 1931 through 1979 was 50.0°F, as recorded at Bradley International Airport. The maximum and minimum monthly mean temperatures were 19.1°F and 83.2°F respectively.

The total precipitation for 1979 was 38.43 inches with a maximum of 5.15 inches falling in February. The mean annual precipitation from 1931 to 1979 was 42.34 inches. The maximum monthly precipitation was 21.87 inches in August 1955.

The flood level for the area's worst flood (August 1955) was about 110 feet above mean sea level. Since the Combustion site is located approximately 180 feet above mean sea level, the probability of direct damage resulting from a local flood is very low.

The average hourly wind speed for 1979 was 8.8 miles per hour. The highest recorded velocity was 70 miles per hour in November 1950. The prevailing wind direction for six months, May to October is South, and for the six months November to April, is Northwest. The average wind velocity at the Combustion site is 11.2 miles per hour.

With low-to-moderate wind speeds, inversion conditions may exist from sunset to sunrise. A strong lapse rate exists around noon; the temperature difference is maximum with air flow upward at a maximum rate. As the night approaches, weak lapse conditions occur with low air flow.

Hartford's location relative to the continent and the ocean has a significant influence on the area's meteorological and climatological conditions. With the prevailing west-to-east air flow, continental modifications of the air are important. However, sudden and oftentimes serious upsets result when storms move north or when other pressure developments produce the strong and persistent northeast winds associated with storms known locally as "coastals" or "northeasters". Seasonable air mass characteristics vary from the extremely cold and dry continental polar quality of winter to the warm, humid maritime tropical characteristics of summer -- the one type from Canada and the other from the Gulf of Mexico, the Caribbean Sea, or the Atlantic Ocean.

Local topography also influences the climate. The Berkshire Hills to the west and northwest are a source of summer thunderstorms which, when accompanied by wind and hail, sometimes do considerable damage to the crops in the Connecticut Valley. Frequently during the winter, when rain falls through the cold air trapped in the Valley, the resultant icing creates hazardous conditions for transportation and utility installations. On clear nights in the late summer or early autumn, cool air drainage into the Valley, plus Connecticut River moisture, produce ground fog which sometimes becomes quite dense through the Valley and hampers ground and air transportation.

1.3.4 Geology

The surrounding area has been subjected to the actions of glacial ice. All dominant geologic features are a result of erosion and depositions so caused during the Pleistocene era.

The State of Connecticut has a favorable earthquake history. Ten earthquakes are listed, the first recorded in 1791 and the last in 1925. All of these, with the exception of the first, were local in nature and of moderate intensity.

1.3.5 Hydrology

The surface drainage in the surrounding area is excellent. The predominately sandy nature of the soil and heavy forest cover results in very moderate run-off even after heavy prolonged precipitation.

The site creek, into which all site effluents are discharged, flows into the Farmington River which flows along the northwest corner of the Combustion site, shown in Figure 1.3.5. Two and one-half miles below the site the river flows over the dam of the Farmington River Power Company and approximately six miles below that into the Connecticut River. The minimum recorded flow in the river is 5.1 cubic feet per second.

Public use of the Farmington River is limited to fishing and boating. Analysis of 27 water samples taken between January 1966 and March 1967 at the Windsor Bridge by the State Department of Health indicated a bacteria count which ranged from 410 to 11,000 per 100 milliliters in a given microscopic field for a total mean average of 409.4 which renders it unsuitable for potable use or bathing.

1.3.6 Topography

Elevations in the region vary from about 100 feet above seal level at the Farmington River to hilltop heights of from 200 to 280 feet, with the level areas being at an elevation averaging approximately 120 feet above sea level. The land rises to the west of the site to a north-south ridge approximately two miles distant and averages 450 feet in elevation. The land slopes gently away from the site on all sides as evidenced by the direction of the flow of small streams which drain the region.

The Farmington River flows along the northern boundary. The land on all sides consists of mostly open level fields tilled for farming except for a small extension of wooded area on the northeast.

Figure 1.3.5

POOR ORIGINAL

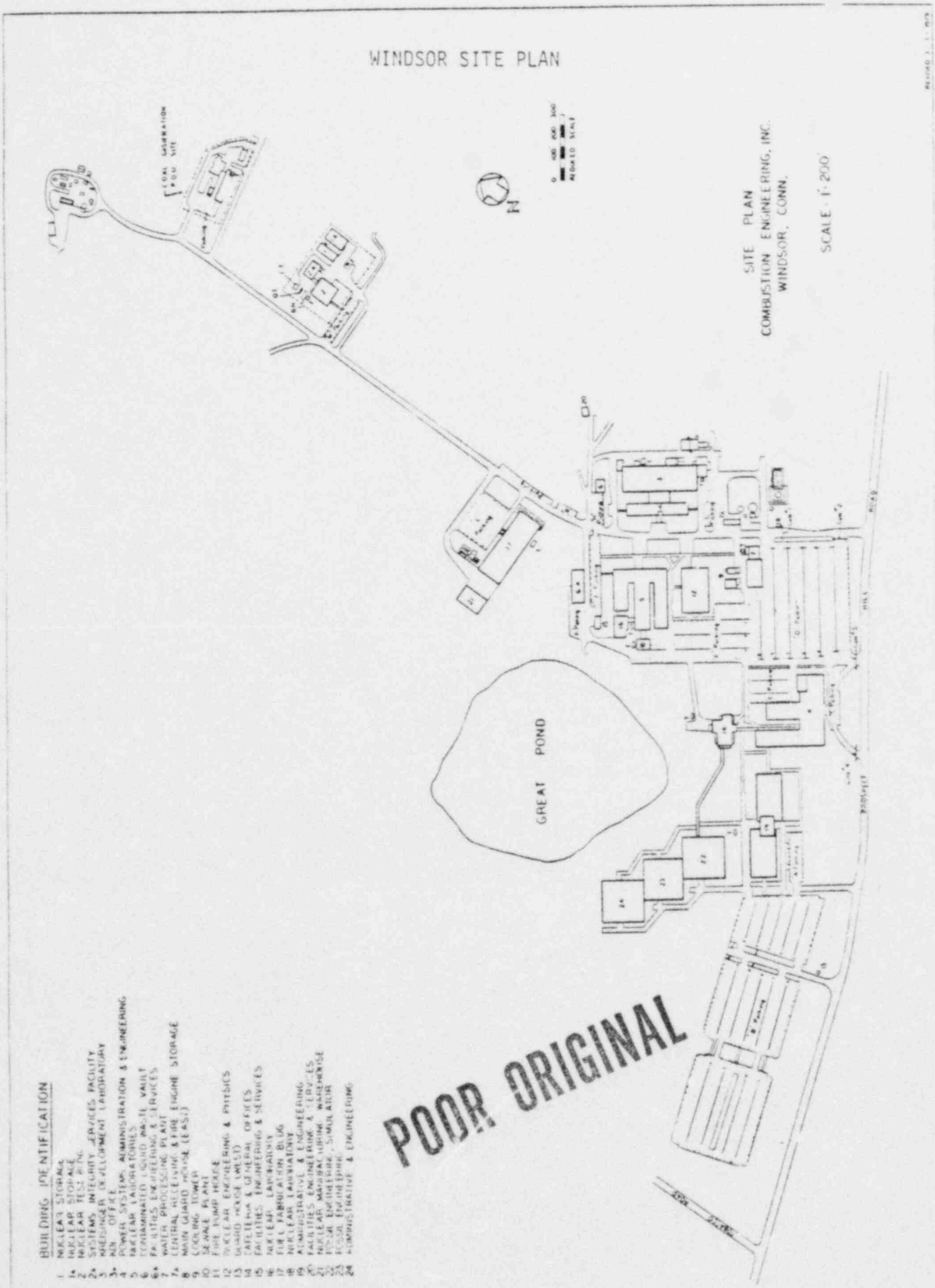
1.4 Locations of Buildings Onsite

The locations of all buildings on the Windsor Site are shown in Figure 1.4.

1.5 History of License

Combustion Engineering first applied for a license to process low enriched uranium by the methods described in section 1.2 in 1968. License SNM-1067 was then issued for a period of 5 years by the U.S. Atomic Energy Commission (AEC). The license was renewed in January 1976 for a second 5 year period. This application represents the second request for renewal for a 5 year period.

FIGURE 1.4


WINDSOR SITE PLAN
COAL GASIFICATION PDU SITE
GRAPHIC SCALE
GREAT POND
SITE PLAN
COMBUSTION ENGINEERING, INC.
WINDSOR, CONN.
SCALE: 1"=200'
BUILDING IDENTIFICATION
1 NUCLEAR STORAGE
1A NUCLEAR STORAGE
2 NUCLEAR TEST RIG
2A SYSTEMS INTEGRITY SERVICES FACILITY
3 KREISINGER DEVELOPMENT LABORATORY
3A N/A OFFICE
4 POWER SYSTEMS ADMINISTRATION & ENGINEERING
5 NUCLEAR LABORATORIES
6 CONTAMINATED LIQUID WASTE VAULT
6A FACILITIES ENGINEERING & SERVICES
7 WATER PROCESSING PLANT
7A CENTRAL RECEIVING & FIRE ENGINE STORAGE
8 MAIN GUARD HOUSE (EAST)
9 COOLING TOWER
10 SEWAGE PLANT
11 FIRE PUMP HOUSE
12 NUCLEAR ENGINEERING & PHYSICS
13 GUARD HOUSE (WEST)
14 CAFETERIA & GENERAL OFFICES
15 FACILITIES ENGINEERING & SERVICES
16 NUCLEAR LABORATORY
17 FUEL FABRICATION BLDG
18 NUCLEAR LABORATORY
19 ADMINISTRATIVE & ENGINEERING
20 FACILITIES ENGINEERING & SERVICES
21 NUCLEAR MANUFACTURING WAREHOUSE
22 FOSSIL ENGINEERING, SIMULATOR
23 FOSSIL ENGINEERING
24 ADMINISTRATIVE & ENGINEERING
POOR ORIGINAL

2.0 FACILITY DESCRIPTION

2.1 Plant Layout

The principal activities of the nuclear fuel manufacturing operation are carried out in Building #17, a one level building measuring 120 ft. x 340 ft. (40,800 ft^2). The shop section contains approximately 36,000 ft^2 (120 ft. x 300 ft.), has concrete flooring, corrugated asbestos siding, and a poured gypsum roof deck approximately 25 feet above floor level.

The front section of the facility contains approximately 4800 ft^2 (120 ft. x 40 ft.), has concrete flooring, exterior concrete block with full windows, and a poured gypsum roof deck approximately 11 feet high.

A warehouse, Building #21, is provided for the storage of incoming fuel shipping containers, raw materials, and finished components. This building is a prefabricated rigid frame steel structure approximately 120 feet long and 80 feet wide with a height of 16 feet at the eaves. It is located approximately 100 feet west of Building #17.

Details of the manufacturing facility layout are shown in Figure B.1 of this application.

2.2 Utilities

Electrical power to the Windsor site is provided by the Northeast Utilities substation at North Bloomfield and the step-down transformer at Building #17, substation #6. The substation transformer (3,750 KVA) steps down from 22.9 KV, to 480 volt, 3-phase, 3-wire. The output is then connected to the low voltage metal clad switchgear for distribution throughout the building. A further step-down to 208/120 volt is made for lighting and general convenience power.

Diesel generators serve as a backup emergency power system (three phase 480 volts transformed down to 240/120 volts) and are automatically started in the event of a power failure. The radiation monitoring system and auxiliary lighting are connected to the emergency power system to provide uninterrupted service.

The principal site water supply is provided by the Metropolitan District, the source of city water in the greater Hartford area. Chemical and radiological analyses for both raw and treated well water have been made, and any changes in composition or activity from any cause will be discovered rapidly.

2.3 Heating, Ventilation, and Air Conditioning (HVAC)

The Building #17 office area, consisting of 4800 ft^2 is heated and cooled by hot and chilled water respectively supplied by the Windsor site central boiler house. Office areas have built-in convecters which heat and cool the areas depending on the time of year. Each office area has an exhaust system which ventilates the area and allows fresh air to be brought in.

The main shop area of Building #17 consists of approximately 36,000 ft^2 and is divided into two main areas. The first area is the unclad fuel area (pellet shop) which contains 12,000 ft^2, the second area is the manufacturing area, which contains 24,000 ft^2. The unclad fuel area is air conditioned on a year round basis because of process heat generated by the continuously running sintering furnaces. Some heat is provided in the winter in the locker rooms and annex areas of this section, but only when the outside temperature drops drastically. Ventilation of the area is continuous with air being exhausted through banks of pre and absolute filters. The entire area (pellet shop) is maintained at a negative pressure of approximately 0.1" H_2O by the action of the exhaust systems. The manufacturing area is not air conditioned, except for the bundle assembly room. The air outside the bundle assembly room is heated by ceiling blowers which obtain hot water from the main power house and circulate it through the convecter. During warm weather, the windows are left open for natural air circulation. The bundle assembly room has a rooftop HVAC unit. Ventilation is accomplished by bringing outside air into the HVAC unit where it is circulated and then passed into the room.

2.4 Waste Disposal

All non-radioactive wastes are disposed of in accordance with applicable state and local regulations. The volume of radioactive waste generated will be minimized. Radioactive waste is then delivered to a licensed facility for ultimate disposal in compliance with all regulations.

2.5 Chemical Storage

All chemicals will be stored in accordance with federal and state regulations, including OSHA.

2.6 Security

The entire Windsor Site is guarded 24 hours a day by the site security force. Additional security provided for the manufacturing facility is described in Combustion Engineering's Security Plan dated May 16, 1980 and submitted under separate cover and should be considered part of this renewal application.

2.7 Fire Protection

A full-time Fire Marshal is on site during normal working hours. He is on 24-hour alert. His duties include daily inspection of the buildings and routine checks of all fire extinguishment equipment. He is also responsible for training and equipping an active Fire Brigade. This Fire Brigade is comprised of Combustion employees, several of whom are also members of local community fire departments.

Fire protection, including sprinklers, is designed into all buildings which are subject to fire damage.

A direct emergency telephone line to the Windsor Fire and Safety Complex (Fire, Police, Ambulance, etc.) is controlled by the site security personnel. A copy of the Certificate of Insurability from American Nuclear Insurers is provided in Figure 2.7.

Nuclear Energy Liability - Property Insurance Association

Property Division

The Exchange, Suite 245, 270 Farmington Avenue, Farmington, Connecticut 06032

Declarations attached to and made a part of Policy No. 1474

Rate See Rate Computation Endorsement No. 1 Premium $337,010.

Name of Insured COMBUSTION ENGINEERING, INC.

Mailing Address 900 Long Ridge Road, Stamford, Connecticut

Unless otherwise provided herein, loss, if any, shall be adjusted with and payable to the named Insured.

The policy period shall be for the term of one year from July 1, 19 80 to July 1, 19 81, beginning and ending at noon, Standard Time at the location of property covered as specified herein.

Description and location of property covered.

Location No. 1 Amount of Insurance $209,000,000. Deductible $25,000.

All Real and Personal Property on the Insured's Plant premises known as Buildings 1, 2,5,6,17,18 and 21 and all Intervening Roadways connecting these Buildings and all Parking Areas adjacent to them as shown by the heavy black line on Combustion Engineering Drawing FP-3, Fire Protection System, dated September 12, 1972 and located in Windsor, Connecticut and including the extension to Building No. 1, designated as Building 1A, which is outside the heavy black line (PROPERTY FILE NO. N-6).

Location No. 2 Amount of Insurance $90,000,000. Deductible $25,000.

All Real and Personal Property on plant premises occupied principally for the processing of uranium hexafluoride, located on Missouri State Highway No. 21-A about one-half mile east of Hematite and six miles west of Festus in Missouri including the 1.47 acre Parcel of land (but excluding any dwellings situated thereon) described by the Survey dated May 30, 1979, Order No. 1346, and tract in United States Survey 423, Township 40 North, Range 5 East, Jefferson County, Missouri (PROPERTY FILE NO. N-1).

Countersignature

Countersigned July 1, 19 80, at Farmington, Connecticut

by B.C. PROOM, President

Authorized Representative

BY [signature]

His Attorney

NELPIA 38-A Rev. 8/1/77 (NIRB)

3.0 Organization and personnel

Functions of key positions, specifics on education and experience required for key personnel, organization procedures, and unit functions (including safety committees) are described in Part I, sections 2.2, 2.3, 2.4, and 2.5 of this renewal application.

3.1 Organization Charts

- Current organizational charts and structure are provided in Figures 3.1.1 and 3.1.2.

3.2 Resumes of Key Personnel

Resumes of key personnel are provided in this section on the pages following the above described organization charts.

Figure 3.1.1

DEVELOPMENT DEPARTMENT LABORATORIES
ORGANIZATION

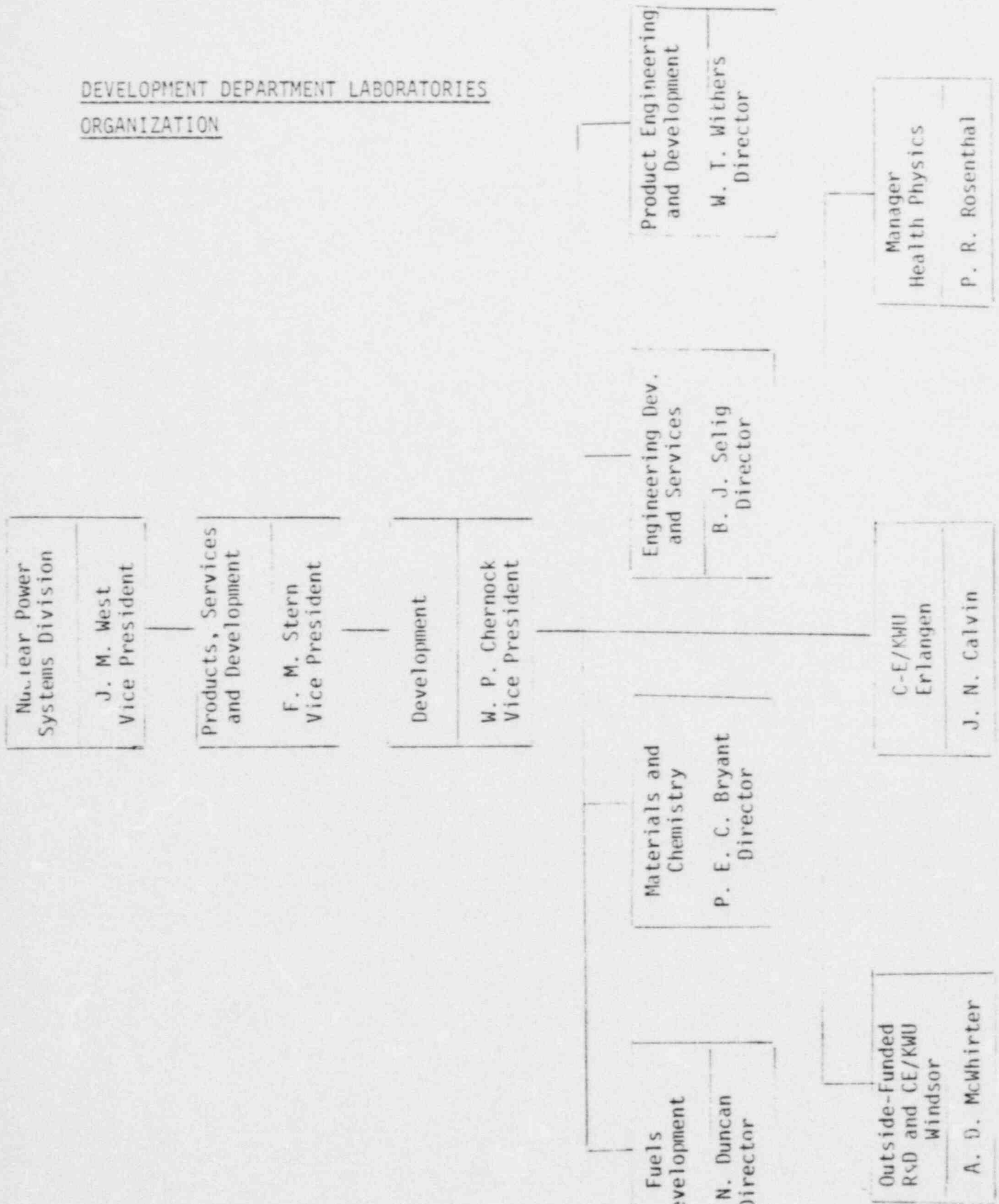
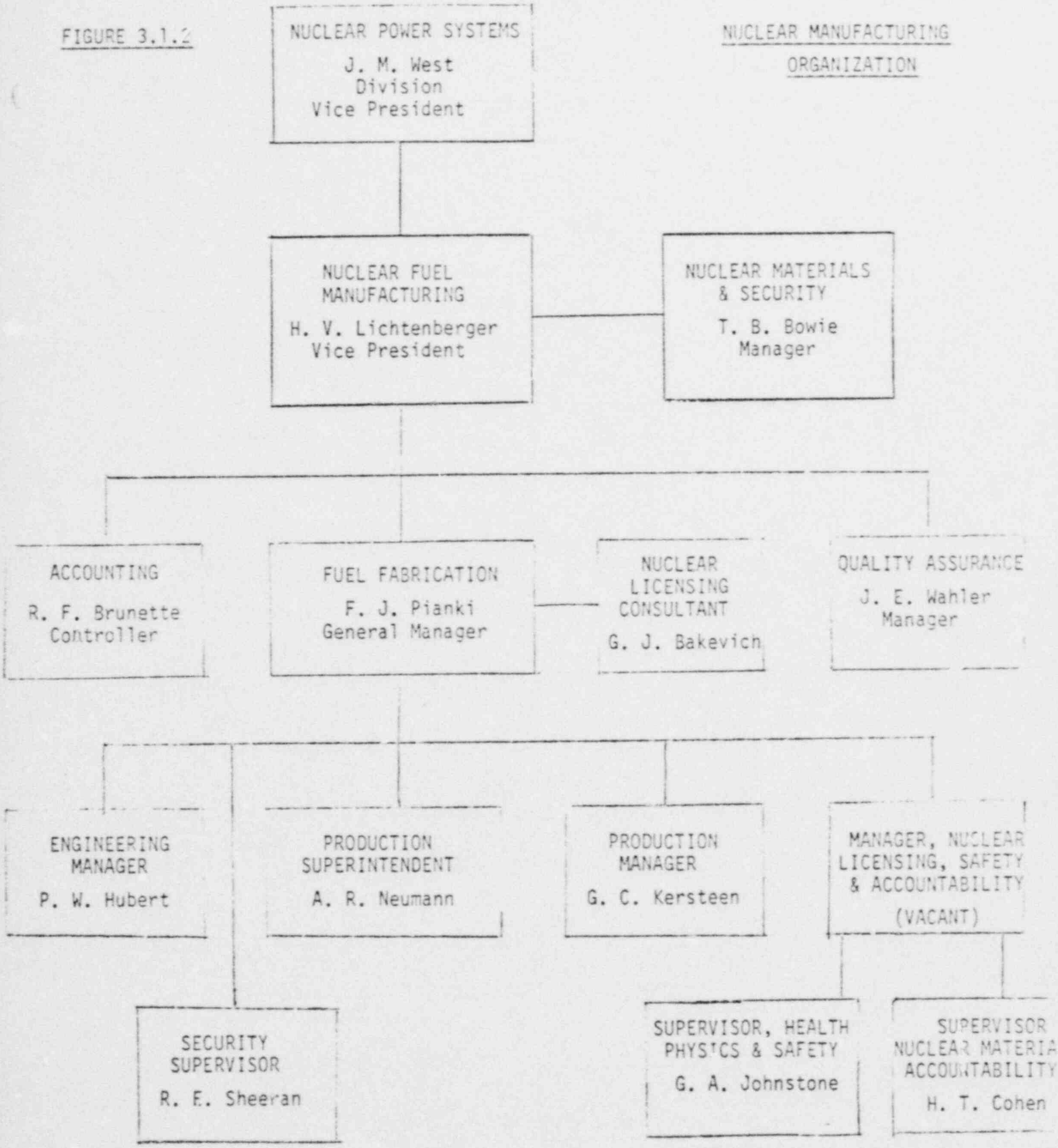


FIGURE 3.1.2

NUCLEAR MANUFACTURING ORGANIZATION



WARREN P. CHERNOCK

POOR ORIGINAL

EDUCATION:

B.S., Metallurgical Engineering, Columbia University, 1949
M.S., Metallurgy, New York University, 1955

PROFESSIONAL EXPERIENCE:

Combustion Engineering, Inc., 1956 - Present
Vice President, Development, Nuclear Power Systems, 1974 - Present
Director, Nuclear Laboratories, 1969 - 1974
Manager, Nuclear Laboratories, 1964 - 1969
Manager, Metallurgy and Ceramics, 1956 - 1964

Mr. Chernock is responsible for the administrative and technical direction of the Development Department which includes Engineering Development & Services, Fuels Development, Materials and Chemistry as well as Product Engineering & Development which is the C-E nuclear R&D program. In addition, he is responsible for the administration of the joint C-E/KWU (Kraftwerk Union A/G) technical exchange agreement on pressurized water reactor technology.

In previous assignments, Mr. Chernock was directly responsible for all research and development activities related to nuclear materials for pressurized water reactors. He was responsible for the materials development and selection for the S1C submarine reactor and the Liquid Metal Fast Breeder Reactor Design Study for the USAEC.

Sylvania Electric Products, 1951 - 1956
Senior Metallurgical Engineer, Atomic Energy Division

Mr. Chernock performed major research and development activities on the texture and anisotropy in uranium, zirconium, tungsten and other metals. He was responsible for the development and fabrication of reactor fuel elements to be used on the Submarine Intermediate Reactor and the Submarine Advanced Reactor Projects at the Knolls Atomic Power Laboratory.

Argonne National Laboratory, 1949 - 1951
Metallurgical Engineer, Metallurgy Division

Mr. Chernock performed extensive experimental and theoretical investigations of the phenomenon and cause of the dimensional instability of uranium slugs that occur during thermal cycling and irradiation. His correlations of texture and growth were instrumental in establishing

WARREN P. CHERNOCK
(Continued)

fabrication processes aimed at minimizing the growth problem. Part of this effort represented the first basic quantitative work on the preferred orientation in metals.

PROFESSIONAL AFFILIATIONS:

Fellow, American Society for Metals
Fellow, American Nuclear Society
Technical Advisor, ANS Information Center on Nuclear Standards
Member, ASTM Committee E-10, Radioisotopes and Radiation Damage
Member, Technical Advisory Committee of the Metal Properties Council
Chairman, Subcommittee on "Nuclear Materials," the Metal Properties Council
Member, Steering Committee to USASI N11 on Nuclear Applications
Member, Advisory Committee to the Department of Metallurgy and Materials Science, College of Engineering and Applied Science, University of Pennsylvania

In 1962, selected to review Joint U.S.-Euratom installations in Europe. Also selected to participate in the First United States-Japan Meeting on Nuclear Ceramic Fuels held in Tokyo, Japan in 1963 and the Second Exchange Meeting at the Hanford Laboratories in November 1964.
Presented the United States Paper on Cladding Materials at the Third International Conference on the Peaceful Uses of Atomic Energy, Geneva, Switzerland, 1964.
Presented the United States Paper on Development of Improved Light Water Reactor Fuels at the Fourth International Conference on the Peaceful Uses of Atomic Energy, Geneva, Switzerland, 1971.
Also served on the AEC Subcommittee responsible for preparing the 1968 "Report to the President" on fast reactor fuels and materials.
Adjunct Professor of Metallurgy and Chairman of Metallurgy Department at the Hartford Graduate Center of Rensselaer Polytechnic Institute, 1956 to Present.
Formerly visiting Associate Professor of Nuclear Engineering at the Massachusetts Institute of Technology.

POOR ORIGINAL

BERNARD J. SELIG

EDUCATION:

B.S., Mechanical Engineering, Polytechnic Institute of Brooklyn, 1957
M.S., Mechanical Engineering, Union College, 1963

PROFESSIONAL EXPERIENCE:

Combustion Engineering, Inc., 1965 to Present
Development Department, Nuclear Power Systems
Director, Engineering Development and Services

Mr. Selig is responsible for all engineering development and testing in support of large pressurized water reactors designed by Nuclear Power Systems. The development and testing functions include thermal and hydraulics, mechanical vibrations, safety, electronic and instrumentation and remote systems and reactor pressure vessel materials technologies. In addition, Mr. Selig's department is responsible for the reactor servicing activities of the Development Department which include inservice inspection, materials surveillance programs, loose parts monitoring systems, vibration monitoring systems, fuel, steam generator and reactor systems inspections as well as component maintenance and testing. Mr. Selig also has responsibility for the facilities and capital assets of the Development Department.

Mr. Selig previously was Supervisor of the Fuel Channel Development Group of the Heavy Water Organic Cooled Reactor Project with overall responsibility for the design, development, test and operation of organic loop facilities used in the development and testing of fuel channel assemblies and components for the HWOCR.

General Electric Company, Knolls Atomic Power Laboratory, 1960 to 1965

Mr. Selig conducted tests on reactor and power plant production and prototype components in the mechanical stress and fluid flow fields. He also designed experimental facilities and test sections and undertook the preparation of cost estimates, schedules and operational procedures. He supplied supervision and technical guidance during fabrication, erection or modification of test facilities, test sections and allied equipment and directed technical personnel in the performance of experimental tests. He prepared and assisted in the preparation of project proposals.

United States Army, Post Engineers, 1959 to 1960
First Lieutenant, Assistant Chief of Mechanical Branch

Mr. Selig performed engineering tasks in connection with Post Engineer projects and made inspection of work sites, calculated design data and compiled complete information for heating, air-conditioning and ventilation projects. He made project drawings, specifications and cost estimates as well as final inspections. He compiled the necessary data for completion of Department of Army engineering reports.

Northrup Aircraft, Inc., 1957 to 1958

Mr. Selig performed engineering work in connection with boundary layer research. He also performed low-speed tests on various wing shapes, collected, calculated and correlated test data. He assisted the project engineer in the design of new test equipment, new wing configurations and planning for future experiments. He obtained data on high-speed air tests to determine the change from laminar to turbulent flow for various parameters.

Polytechnic Institute of Brooklyn, 1955 to 1957
Engineering Research Assistant

Mr. Selig performed engineering work related to transpiration cooling research and conducted tests, evaluated data and converted information to charts and graphs. He assisted in the design of new test equipment. He also assisted the project supervisor in writing reports for the Office of Scientific Research and the Office of Naval Research.

ACHIEVEMENTS AND PROFESSIONAL AFFILIATIONS:

Member, American Society of Mechanical Engineers

Member, American Nuclear Society

Sigma Xi

Listed in Who's Who in American Colleges, 1957

Past Chairman, Hartford Section of American Society of Mechanical Engineers (1969 to 1970)

Chairman, National Agenda Conference - American Society of Mechanical Engineers (1971)

Member, Engineering Advisory Committee, College of Engineering, University of Hartford

Papers: "The Design and Development of the HWOCR Pressure Tube Assembly," presented at the ASME Winter Annual Meeting and Energy Systems Exposition, Pittsburgh, Pennsylvania, November 12-17, 1967.

"Inservice Inspection Program for a PWR," presented at the ANS Power Reactor Systems and Components Meeting, Williamsburg, Virginia, September 1-3, 1970.

"Plan for Nuclear Inservice Inspection," published in Power Magazine, February 1973.

"N-Plant Monitoring Improves Reliability," published in Electrical World Magazine, May 15, 1974.

Papers (cont'd):

"Nuclear Systems Inspection Services," published in Kerntechnik Magazine, January 1977.

"Staff Development for Plant Startup and Reactor Servicing," presented at the Transfer of Nuclear Technology Conference, Shiraz, Iran, April 10-14, 1977.

"Inservice Inspection of System 80 Nuclear Steam Supply Systems," presented at the Conference on Periodic Inspection for Pressurized Components, May 8-10, 1979.

EDUCATION:

A.S., Baltimore Junior College, 1952
B.S., Mechanical Engineering, University of Maryland, 1959

PROFESSIONAL EXPERIENCE:

Combustion Engineering, Inc., 1970 to Present
Development Department, Nuclear Power Systems
Manager, Health Physics, March 1974 to Present

Mr. Rosenthal is responsible for all health physics activities within the Development Department. He administers all NRC licenses for byproduct and special nuclear materials used by the Development Department and is designated by the NRC license as the Radiological Safety Officer and Radiation Protection Officer. In this capacity, he implements all NRC regulations to ensure compliance by the Development Department. He reviews and approves all proposed alteration, modification and additions to facilities where the use of radioactive materials are involved. He is responsible for providing health physics and radioactive material control services during all Development Department field service activities.

Supervisor, Mechanical Development, April 1970 to March 1974

Mr. Rosenthal was responsible for all activities related to mechanical development of Nuclear Steam Supply Systems. In this capacity, he supervised and directed the efforts of engineers and technicians in the planning, execution and analysis of evaluation and development programs. He was responsible for the design, installation and operation of test equipment used in the evaluation and development programs. He provided advice, consultation and recommendations in the area of technical expertise to NPS management, projects and other organizations.

Prior to assuming this position, Mr. Rosenthal was a senior staff engineer in the Nuclear Laboratories where he was responsible for the design, performance and reporting of tests to evaluate the performance and characteristics of reactor components at reactor operating conditions.

Electric Boat Company, Division of General Dynamics
Senior Nuclear Project Engineer, July 1968 to April 1970

As Senior Nuclear Project Engineer, Mr. Rosenthal was responsible for the design, procurement, test and evaluation of a submersible sea water pump motor. He was also responsible for reactor assembly of a prototype submarine reactor plant. In this capacity, he prepared installation procedures for the major reactor plant components and was responsible for the design of special handling equipment.

Refueling Director, February 1964 to July 1968

As Refueling Director, Mr. Rosenthal was responsible for the development of refueling procedures, tools and equipment to be used during refueling of submarine reactors. He personally supervised the refueling of four naval reactors.

Navy Department, Facilities Engineering Command, 1959 to 1960; 1963 to 1964

Mr. Rosenthal was responsible for technical control and execution of the Bureau's nuclear engineering research and development program. He investigated reactor designs, fuel fabrication, reactor control, radioactive waste, thermionic and thermoelectric concepts for application to existing requirements.

As a Mechanical Engineer, 1959 to 1960, Mr. Rosenthal was responsible for resolving engineering maintenance problems associated with boilers and unfired pressure vessels. He was also responsible for the preparation of economic studies of steam and electric utilities. Mr. Rosenthal performed utility conservation studies and also designed air conditioning systems.

Martin-Marietta Corporation
Reactor Systems Engineer, Nuclear Division, 1960 to 1963

Mr. Rosenthal was responsible for the design and fabrication of a radioactive waste disposal system for the processing of liquid radioactive waste. In this capacity, he performed analytical work, procured components and prepared fabrication instructions. He also performed engineering liaison duties with manufacturing organization during the construction of portable nuclear power plants. He was responsible for changes made to primary and secondary reactor systems in order to resolve fabrication and installation problems.

ACHIEVEMENTS AND PROFESSIONAL AFFILIATIONS:

American Nuclear Society

Connecticut Health Physics Society

Completed special training in Radiological Control Practices and Reactor Plant Testing

Paul E. C. Bryant

POOR ORIGINAL

Education

Queen's University, Kingston, Ontario, B.Sc., 1960, Major - Metallurgical Engineering.

McMaster University, Hamilton, Ontario, M. Eng., 1965, Major - Metallurgical Engineering.

Professional Experience

Combustion Engineering, Inc., 1977 to Present
Development Department, Nuclear Power Systems
Director, Materials and Chemistry Development

Responsible for the technical and administrative activities of the managers (System Materials and Chemistry Development) and supervisors within the Materials and Chemistry Development organization. This includes the direction, planning, and execution of development and testing in the areas of component and system materials, irradiation effects on materials, and primary and secondary systems chemistry aimed at cost reductions, product and process improvements, ability to meet warranted performance and development of new products.

Manager, System Materials, 1974 to 1977

Responsibilities included materials selection, joining, protection and evaluation (exclusive of reactor core), systems chemistry specification and performance, plus corrosion product mobility and deposition. In addition, for a two-year period, provided overall technical direction and coordination together with management of financial resources related to entire C-E effort on nuclear steam generator R&D, plus this technical interface with KWU.

Section Manager, System Materials, 1972 to 1974

Responsibilities included materials selection, joining, protection and evaluation (exclusive of reactor core), reactor vessel surveillance programs, plus systems chemistry specification and performance.

Supervisor, Component Materials Section, 1970 to 1972

Responsibilities included materials selection, performance, assessment and compatibility in primary, secondary, and auxiliary system environments, exclusive of the reactore core. Acted as Manager of Materials Group during absence of current manager, assuming additional responsibilities for core materials.

Senior Development Engineer, Kreisinger Development Laboratory, 1969 to 1970

Responsible for high pressure and supercritical fossil fired boiler corrosion, nuclear steam generator corrosion and secondary side chemistry.

Paul E. C. Bryant

POOR ORIGINAL

Chalk River Nuclear Laboratories, Atomic Energy of Canada, Limited, 1965 to 1969
Metallurgical Engineer

Responsible for materials/coolant chemistry compatibility in PHW and BLW reactors.

McMaster University, Hamilton, Ontario, Canada, 1963 to 1965
Graduate Student

Steel Company of Canada, Limited, Metallurgical Laboratory, 1963
Research Engineer

Royal Canadian Navy, Officer, 1960 to 1963

Achievements and Professional Affiliations

Member, National Association of Corrosion Engineers, recognized as a specialist in corrosion control.

Member, American Nuclear Society

Member, Association of Professional Engineers of Ontario

Member, Nuclear Subcommittee of American Society of Mechanical Engineers

Publications

Numerous technical papers and publications conerning materials selection and corrosion for nuclear power plant service, reactor chemistry, corrosion product mobility and deposition, and high temperature solid state electrochemistry.

POOR ORIGINAL

RESUME OF ROBERT NORMAN DUNCAN

B. S., Metallurgy, Massachusetts Institute of Technology, 1955.
Additional Study, Stanford University, Graduate Materials Science Courses, 1964-1968.
Registered Professional Engineer (California) #MT-1047.

PROFESSIONAL EXPERIENCE

Director, Fuels Development Department, Combustion Engineering, Inc., July 1974 to Present

Responsible for the direction of core materials development for the Nuclear Power Department. Current responsibility includes direction of major C-E programs to develop and test fuel, cladding and control materials. Functional responsibility includes Materials Technology, Fuel Performance Testing and Analysis and Analytical Chemistry.

Responsible for development programs to improve C-E fuel performance by planning and executing major PED experimental programs in this area. In addition, responsible for evaluation and monitoring of fuel performance in C-E supplied plants, as required by specific projects. Responsible for technical integration of these development activities with KWU. Responsible for negotiating and following several joint R&D efforts in core materials area.

Manager, Core Materials, December 1972 to July 1974

Responsible for the line management of the Core Materials Development organization. Responsible for the planning and execution of PED projects related to fuel testing, examination and performance analysis. Initiated several major fuel irradiation test programs in both test and power reactors. Responsible for project field support, on-site fuel examinations and plant licensing activities related to fuel performance. Responsible for the integration of fuel performance related R&D with the appropriate KWU programs. Functional groups reorganized such that fuel and cladding development activities were within one organization.

Staff Assignment Reporting to Director, Nuclear Laboratories, May 1972 to December 1972

In a staff function, reviewed C-E positions on licensing, prepared and reviewed PED programs, participated in early KWU/C-E information exchanges on fuel performance and planned integrated C-E/KWU irradiation test programs. Represented C-E in discussions with NRC on the impact of fuel densification. Planned and initiated an experimental irradiation test program on fuel densification and negotiated agreements for joint programs in this area with EEI and others. Evaluated the impact of C-E participation in the Halden Reactor Project and assisted in the negotiations of the agreements.

General Electric Company, Breeder Reactor Development Operation and Nuclear Fuels Department, December 1963 to May 1972

Managed Fast Reactor Ceramic Fuels and Cladding Metallurgy Units. Directed research and development effort on stainless steel clad uranium-plutonium oxide fuels for fast breeder reactor application; including basic physical property measurements and an extensive irradiation test program conducted in EBR-II.

Prior GE assignments included:

Technical leader on General Electric-sponsored zirconium fuel cladding development. Included design of irradiation tests, materials selection and overall coordination of the program including interface with Consumers Power Company related to the irradiation testing of fuel assemblies in the Big Rock Point reactor.

Project Engineer of the AEC-EURATOM Specific Zirconium Alloy Design Program involving the metallurgical development and irradiation testing of alternate zirconium alloys for use in nuclear service.

Project Engineer of the AEC-EURATOM Stainless Steel Failure Investigation Program involving multiple areas of investigation related to stress-assisted intergranular corrosion of austenitic stainless steels in water reactors.

Technical leader of the AEC High Power Density Fuels Development Program, including responsiblility for post-irradiation examinations of VBWR fuel assemblies, as well as the irradiation testing of developmental fuel assemblies in the Consumers Big Rock Point reactor to evaluate fuel assembly design and alternate cladding materials performance.

Westinghouse Electric Corporation - Atomic Power Department, September 1958 to December 1963

Conducted an extensive irradiation test program on Zircaloy clad UO_2 fuel rods for power reactor cores, sponsored by the AEC. Responsible for the planning, technical follow and liaison of the irradiations and post-irradiation examination at the Westinghouse Test reactor. Specifically, this included the design, fabrication and evaluation of UO_2 fuel rod samples irradiated in support of the Carolinas Virginia Pressure Tube reactor.

Senior Engineer responsible for planning and evaluating results from other Westinghouse-sponsored fuel irradiation tests.

POOR ORIGINAL

General Electric Company - Atomic Power Equipment Department, December 1956 to September 1958

Developed rotary swaging techniques for fabricating stainless steel clad UO_2 fuel rods for irradiation testing.

Performed the major portion of the development work on an aluminum powder metal material. Developed processing and extrusion techniques for aluminum powder metal alloys (SAP) as well as evaluating the high temperature water corrosion resistance of these materials. During 1957, was on temporary assignment to the General Electric Research Laboratory in conjunction with this program.

Westinghouse Electric Corporation - Commercial Atomic Power Activity, June 1955 to December 1956

Worked on co-extrusion techniques to fabricate aluminum clad uranium-aluminum fuel tubes for use in the Westinghouse Test reactor.

Designed automatic inert gas welding chambers and performed welding development on Zircaloy-2 fuel rod end closures.

Publications

Published and presented numerous papers as sole and principal author on both water reactor and fast reactor nuclear materials R&D.

HAROLD V. LICHTENBERGER

B.A., Physics, James Milliken University, 1942

PROFESSIONAL EXPERIENCE

Combustion Engineering, Inc., 1961 to Present
Vice President - Nuclear Fuel - Nuclear Power Systems Division

Mr. Lichtenberger is responsible for the manufacturing and quality control operations for reactor fuel, control rod drives and other nuclear components including planning, scheduling and the development of improvements in design and processing techniques. He also is responsible for the design and experimental programs for the development of control rod drive mechanisms.

Mr. Lichtenberger is a member of the Nuclear Safety Committee.

General Nuclear Engineering Corporation, 1956 to 1961
Vice President

Mr. Lichtenberger had overall responsibility for directing the design and construction of the research and training reactors evolved by GNEC, which included the University of Florida Training Reactor and the Georgia Tech Research Reactor. He directed the research and development program for the Gas Cooled Reactor Project undertaken for the East Central Nuclear Group and the Florida West Coast Nuclear Group.

Argonne National Laboratory, 1951 to 1956
Director, Idaho Division

Mr. Lichtenberger supervised important experiments in reactor performance, including the breeding gain measurements of EBR-1 and the BORAX Experiments. He was also in charge of the design, construction, and operation of a facility for performing Zero Power Fast Reactor Criticality Studies.

The University of Chicago, 1942 to 1951
Staff Member, Metallurgical Laboratory
Director, Fast Reactor Project, Argonne National Laboratory

Upon graduation from college, Mr. Lichtenberger joined the staff at the University of Chicago and has been actively engaged in reactor design work since that time. He participated in the construction of the world's first nuclear reactor and the first heavy water moderated nuclear reactor. After these reactors were placed in operation, Mr. Lichtenberger participated in many of the early experiments in neutron physics. In 1946, he undertook experiments on heat transfer and the handling of sodium with a view to using this metal as a reactor coolant. Subsequently (1947 to 1951), he was Director of the Fast Reactor Project at Argonne and, as such, was in charge of the design, construction, and operation of the Experimental Breeder Reactor No. 1

(EBR-1), a sodium-cooled reactor which was the first reactor to produce electric power.

PROFESSIONAL AFFILIATIONS:

Fellow, American Nuclear Society

FRANCIS J. PIANKI

B.S., Metallurgical Engineering, Polytechnic Institute of Brooklyn, 1952
Graduate Studies, Polytechnic Institute of Brooklyn

PROFESSIONAL EXPERIENCE:

Combustion Engineering, Inc., June 1969 to Present
General Manager, Nuclear Fuel Manufacturing

Mr. Pianki is responsible for all Nuclear Fuel Manufacturing activities at our Windsor location. He directs the groups responsible for the manufacturing, production control, material control and manufacturing engineering of fuel assemblies and control element assemblies. He is also responsible for Licensing, Nuclear Safety, Health Physics and Accountability in the manufacturing area.

United Nuclear Corporation 1959-1969
Manufacturing Manager, Nuclear Fuels Department

Mr. Pianki was responsible for directing the activities of the manufacturing group which was engaged in the production of nuclear fuel elements for both power and test reactors. These responsibilities involved the production, production control, materials control and planning for the manufacturing group.

Prior to this assignment, Mr. Pianki was Engineering Superintendent, Production Supervisor and Project Manager within the manufacturing group.

He was responsible for establishing material control systems, for nuclear and non-nuclear materials, a production control system and the development of administrative policies and practices.

Sylvania Corning Nuclear Corporation, 1956 to 1959
Production Engineering Supervisor

Supervised the activities of the production engineering groups in a manufacturing organization engaged in the fabrication of nuclear fuel elements for both power and test reactors

Westinghouse Electric Corporation, Bettis Field, 1955 to 1956
Senior Engineer

Development of fabrication techniques for nuclear fuel elements used in Naval Reactors.

Sylvania Electric Products 1952 to 1955
Engineer, Nuclear Fuel Division

Research and development in the fabrication of nuclear fuel elements for both test and power reactors.

RESUME

EDUCATION:

Worcester Polytechnic Institute, Worcester, Mass.

B.S. - Mathematics, 6/71
Minor in Nuclear Engineering.

University of Utah, Salt Lake City, Utah

M.S. - Nuclear Engineering, 1/73.
Minor in Mechanical Engineering, 4.0 average.

Thesis - "Neutron Radiography with Californium-252 and a Subcritical Neutron Multiplier" at National Reactor Testing Station in Idaho under AEC Fellowship.

Certified with National Registry of Radiation Protection Technologists.

EMPLOYMENT:

Combustion Engineering, Inc., Windsor, CT.

1977 - Present

1979 - Present:

Manager, Nuclear Licensing, Safety & Accountability - Total responsibility for compliance with NRC, DOT, and OSHA regulations at CE's uranium fuel fabrication facility. Responsible for all licensing submittals and management of the following programs:

- Nuclear criticality safety
- Health physics
- Industrial safety
- Packaging and transportation of radioactive material
- Nuclear material accountability of $75 million uranium inventory and associated computer system
- Emergency planning, including interface with State of Connecticut, Office of Civil Preparedness

Responsible for audits of CE's oxide conversion facility in Hematite, Missouri and Research & Development Labs in Windsor, Connecticut.

Member of Nuclear Speakers Service.

Employment (cont'd) 1977 - 1979:

Supervisor, Nuclear Licensing & Safety - Responsible for all aspects of licensing at fuel fabrication facility, including criticality safety analysis necessary to support license changes. Responsible for the Health Physics monitoring program and Industrial Safety program to assure compliance with NRC, State, and OSHA regulations, including auditing of manufacturing operations and supervision of health physics personnel.

1974 - 1977 Idaho National Engineering Laboratory, Idaho Falls, Idaho.

Criticality Safety Engineer/Health Physicist - Responsible for criticality safety evaluations (including computer analysis with KENO-IV, DOT, etc.) for unirradiated and spent fuel storage, fuel transport casks, and nuclear waste burial.

Health Physics experience at several large test reactors, including monitoring of high radiation fields and fission product contamination control.

Member of Qualifications Review Committee; Completed ERDA Systems Safety Training (Management Oversight and Risk Tree).

1973 - 1974 U.S. Atomic Energy Commission, Schenectady, NY.

Assistant Project Engineer - Responsible for appraisal and direction of contractor activities in the areas of Health Physics, Critical Facilities and developmental stages of the Light Water Breeder Reactor; also approved procedures for various testing programs.

RESUME

EDUCATION: Rutgers, The State University of New Jersey, New Brunswick, New Jersey

M.S. - Radiation Science, 12/78

Critical Essay - "Low Level Radioactive Waste Disposal with emphasis on shallow-land burial and waste management criteria" at Brookhaven National Laboratory under DOE fellowship.

Muhlenberg College, Allentown, PA

B.S. - Physics, 6/77
Minor in Mathematics

Brookhaven National Laboratory, Upton, N.Y.

Health Physics Training Program, 6/78 - 8/78

Environmental Monitoring and Analysis- Film Badge and TLD Exposure Analysis, HEPA Filter Testing, Instrument Calibration, Reactor and Particle Accelerator Radiation Surveys, Activation Analysis, Contamination Control, Industrial Hygiene, and Emergency Planning.

EMPLOYMENT:

3/79 - Present Combustion Engineering, Inc., Windsor, CT

5/80 - Present

Supervisor, Health Physics and Safety - Total responsibility for compliance with NRC, DOT, and OSHA regulations at CE's uranium fuel fabrication facility. Responsible for all licensing submittals and management of the following programs:

- Nuclear criticality safety compliance
- Health physics
- Industrial safety
- Packaging and transportation of radioactive material
- Supervision of health physics technicians and radiation specialist.
- Emergency planning, including interface with State of Connecticut, Office of Civil Preparedness.

Responsible for audits of CE's oxide conversion facility in Hematite, Missouri and Research & Development Labs in Windsor, Connecticut.

Employment (cont'd)

3/79 - 4/80 Radiation Specialist - Responsible for development of Emergency Plan and mplementing procedures for UO_2 fuel fabrication facility. Preparation of consolidated renew applications for shipping container certificates of compliance. Responsible for ALARA program.

9/77 - 2/79 Rutgers, The State Univers ty of New Jersey, New Brunswick, New Jersey

Radiation Safety Specialist - Maintained personnel dosimetry program for 200 radioisotope workers; Comprehensive radiological surviellance of laboratories; Liaison between campus radioisotope investigators and commercial radioactive waste disposal firm; X-ray unit surveys at Raritan Valley Hospital; Packaging and transportation of hazardous laboratory chemicals and radioactive waste.

1974 - 1977 (4 months/yr.) Radiac Research Corp., Brooklyn, N.Y.

Health Physics Techician - Established a radioactive waste disposal service program for customers, including procedures for proper packaging in accordance with DOT Regulations. Maintained personnel dosimetry and exposur records of personnel. Maintenance and calibration of radiological instrumentation at customers facilities. Assisted in proper packaging and disposal of hazardous chemicals including segregation according to type and compatibility.

PROFESSIONAL AFFILIATIONS: Health Physics Society
Member, Radiological Emergency Response Team, State of Connecticut - Office of Civil Preparedness

ROBERT F. BRUNETTE - Controller - Nuclear Products Manufacturing - Windsor

Education

B.S., Business Administration - Accounting, American International College, 1960

M.S., Education, State College at Westfield, MA 1965

Professional Experience

Combustion Engineering, Inc., Power Systems Group, Windsor, CT-1961 to Present

Mr. Brunette is presently the Controller for Nuclear Products Manufacturing-Windsor and is responsible for all accounting functions related to this Division. From 1966 to 1970 Mr. Brunette was the Manager, Budget and Finance of the Naval Reactors Division of C-E., Inc. Previously, he held other responsible positions in the controllers group.

Coca-Cola Bottling Company, Springfield, MA - 1960-1961

Mr. Brunette was the Accountant and Assistant Office Manager.

ALBERT R. NEUMANN

Education:

New Britain High School, New Britain, CT

Naval Basic Engineering School

Naval Refigeration School

PROFESSIONAL EXPERIENCE

Combustion Engineering, Inc. - Nuclear Fuel Manufacturing 1975 to Present
Production Superintendent

General Foreman - 1962 to 1975

Responsible for production of nuclear fuel assemblies and control element assemblies, equipment maintenance, and compliance w all posted safety and criticality requirements in the shop area.

Engineer - 1957 to 1962

In 1957 Mr. Neumann joined the company in the Manufacturing Engineering section where his job consisted of trouble shooting and reviewing manufacturing processes, specifying, requisitioning and approving purchase of equipment, tools and accessories. Also estimating fabrication costs, manufacturing methods, and tooling of core components.

1940-1957

These years were spent by Mr. Neumann learning the machinist-toolmaker trade. He was employed by several job shops in which he advanced to the position of foreman.

RESUME OF ROBERT S. HARDING: Manager, Nuclear Design Department

SUMMARY OF QUALIFICATIONS:

Dr. Harding is responsible for directing the PWR NSSS reactor design activities in Nuclear Engineering. He has 17 years experience in reactor design and analysis, including 3 years in HWR reactor design. In addition, he has 4 years experience in the direction and planning of reactor critical experiments.

PROFESSIONAL EXPERIENCE:

COMBUSTION ENGINEERING, INC., February 1958 to Present
Power Systems Group, Nuclear Power Systems

Manager, Nuclear Design Dept., Nuclear Engineering, 1972 to Present

Dr. Harding is responsible for the administrative and technical management of the Nuclear Design Department which consists of a staff of 25 to 30 persons at various levels up to and including Senior Consultant Physicists. This department is responsible for the following design activities on PWR Nuclear Steam Supply Systems - fuel management, reactivity control, power distribution monitoring, generation of core nuclear safety parameters, radiation physics, criticality evaluations for ex-core fuel handling operations, preparation of nuclear design data for NSSS proposals, and support of other functional groups on the design of plant systems and components, licensing, and plant startup.

Manager, PWR Physics Methods Development Section, Physics and Computer Analysis Department, 1968-1972

Dr. Harding was responsible for developing and testing of design methods and computer codes employed in the nuclear design of PWR reactor cores.

Manager, HWOCR Reactor Physics Section, Physics Department, 1965-1968

Dr. Harding was responsible for the nuclear design and methods development activities on the Heavy Water Organic Cooled Reactor project and served as the principal liaison representative between the Physics Department and the HWOCR Project Office. He was also responsible for the nuclear design analyses relating to the conversion of a Savannnah River Reactor to a D_2O moderated power reactor.

Staff Physicist, General Nuclear Engineering Corporation (Combustion Engineering Subsidiary), 1962-1964

While on assignment to the General Nuclear Engineering Corporation, Dr. Harding participated in the State-of-the-Art Physics Program, a study of reactivity control methods for the NASA reference reactor design, and the review of literature on critical experiments for the Technical Progress Review, Power Reactor Technology.

POOR ORIGINAL

Supervisor, Advanced Critical E... iment Facility, Nuclear Power Department, 1962

Dr. Harding was responsible for the technical programs and safe operation of both reactor cells.

Staff Physicist, Advanced Critical Experiment Facility, Nuclear Power Department, 1958-1961

Dr. Harding participated in the SIC Flux Measurement, Nuclear Superheat, BONUS Critical, and Army Boiling Water Reactor (PL-2) Critical Programs. On the BONUS Program he was the Project Principal Experimental Physicist; he was also a member of the Critical Facilities Safeguards Committee and in 1961 was designated as the Alternate Supervisor of the Critical Facilities for purposes of assuring safe operation of the facilities.

PROFESSIONAL AFFILIATIONS:

American Physical Society, Member

American Nuclear Society, Member

ANS 19.3 Working Group, 1973 to Present

TECHNICAL PUBLICATIONS

R. S. Harding, "Asymmetry Measurements in the Scattering of 155 Mev ... by C, Al, Cu, Cd, and Pb, NYO-8056, Physical Review, Volume 111, pg. ... (1958)

W. C. Coppersmith, R. S. Harding, and T. R. Hencey, "Analytical Methods Used in the Preliminary Analysis of the Transient Behavior of the HWOCR", Nuclear Engineering Design, 6, 134-8, 1967.

R. R. Lee and R. S. Harding, "Factors Affecting Reactivity Coefficients in the HWOCR," Transactions of the American Nuclear Society, 9, pg. 450, 1966.

R. S. Harding, P. H. Gavin, and R. L. Hellens, "Systematic Study of Thermal Reactor Benchmark Experiments," Transactions of the American Nuclear Society, 12, pg. 744-5, 1969

R. D. Cyboron, R. S. Harding, and F. Bevilacqua, "High Capacity Storage of Nuclear Fuel Assemblies," Transactions of the American Nuclear Society, 22, pg. 306, 1975.

R. S. Harding, R. J. Klotz, L. C. Noderer, and J. E. Rosenthal, "Analytical Techniques Employed in Reactor Fuel Handling and Storage Related Nuclear Criticality Analyses," Transactions of the American Nuclear Society, 23, pg. 583, 1976.

Plus numerous publications at Combustion Engineering and General Nuclear Engineering Corporation.

RESUME OF ROBERT S. HARDING

POOR ORIGINAL

PERSONAL BACKGROUND

B.S., Physics, Trinity College, Hartford, Conn., 1951

Ph.D., Physics, University of Rochester, 1958

Phi Beta Kappa, Sigma Xi, Sigma Pi Sigma

RESUME OF ROBERT J. KLOTZ: Senior ulting Physicist, Nuclear Design

SUMMARY OF QUALIFICATIONS:

Mr. Klotz is responsible for the radiation and criticality design of all new and spent fuel racks, fuel transfer equipment and all other operations involving moving, testing or storing of fuel. He also has 25 years experience in radiation physics as pertaining to shield des of light water reactors, D_2O reactors, and gas cooled reactors.

PROFESSIONAL EXPERIENCE:

COMBUSTION ENGINEERING, INC., 1965 to Present
Power Systems Group, Nuclear Power Systems Engineering

Senior Consulting Physicist, 1977 to Present

Mr. Klotz's present responsibilities are for the physics design of new and spent fuel racks, fuel transfer machines, and any other pieces of equipment involved in moving, testing or storing fuel. He is also the criticality Safety Specialist providing technical support and having criticality audit responsibilities of both the Windsor Fuel Fabrica Facility and the Hematite Fuel Manufacturing Plant. He is also involved in solving special physics problems both the day-to-day and long term nature.

Section Manager, Radiation and Criticality Physics, 1965-1977

Mr. Klotz was responsible for the radiation shielding and the ex-core criticality work done within the company. He was responsible for providing all the source terms for the Nuclear Steam Supply Systems under contract and being offered by the company to the electric utility industry. He was also responsible for providing the nuclear heat generation rates for all structures in the NSSS, and providing the radiation dose rates for assessing physical changes in NSSS materials and equipment in the radiation environment.

GENERAL NUCLEAR ENGINEERING CORPORATION, 1959 to 1965

Mr. Klotz was responsible for the shield design of the heavy water research reactor at the Georgia Institute of Technology. He also was in char the thermal and biological shield design analysis for the Boiling Nuclear Superheat Reactor (BONUS) located in Rincon, Puerto Rico. In addition, he reviewed all the literature on radiation shielding for the publication Power Reactor Technology, a quarterly review of literature pertinent to the civilian uses of atomic energy undertaken under contract to the U.S. Atomic Energy Commission. He was also responsible for the physics design calculations, including shielding, for three D_2O moderated reactors cooled by pressurized D_2O, boiling D_2O, and CO_2 gas.

RESUME OF ROBERT J. KLOTZ

POOR ORIGINAL

CONVAIR DIVISION OF GENERAL DYNAMICS, 1954 to 1959

Mr. Klotz was in charge of a group responsible for the design of a shield for a mobile reactor of the Army Compact Core Design, and participated in a proposal for a radiation shielding experimental program for compact core reactors. He also directed a group responsible for the design of shield for a Nuclear Ramjet Missile. Previous assignments included the analysis of aircraft nuclear shielding experiments which involved work on shield penetration and air, ground, and structure scattering. This included the development of shielding programs for computers. He also contributed to the Aircraft Shield Design Manual. While attending the Oak Ridge School of Reactor Technology (ORSORT), he worked on the physics of a high temperature nuclear rocket.

PROFESSIONAL AFFILIATIONS:

Member of American Nuclear Society ANS-5 Standards Committee (Energy and Fission Product Release).

Member of the American Nuclear Society ANS 8.17 Criticality Standards Subcommittee

American Nuclear Society

TECHNICAL PUBLICATIONS:

"Analytical Techniques Employed in Reactor Fuel Handling and Storage Related Nuclear Criticality Analysis," co-authored, presented at the ANS 1976 Annual Meeting, Toronto, Canada, ANS Transaction, Volume 23.

"A Low Pressure Drop Reactor Cavity Shield System," co-authored, presented at the ANS 1978 Winter Meeting, published in ORNL/RSIC-43, February 1979.

PATENTS:

R. J. Klotz, "Nuclear Reactor Cavity Streaming Shield," U.S. Patent 4,126,515, Issued November 21, 1978.

PERSONAL BACKGROUND:

AB, Physics and Mathematics, Kansas State Teachers College of Emporia, 1952

MS, Physics, Kansas State College, 1954

Graduate: Oak Ridge School of Reactor Technology, 1957

Graduate Studies: Texas Christian University

RESUME OF L. C. NODERER: Consulting Physicist, Nuclear Design Department

SUMMARY OF QUALIFICATIONS:

Mr. Noderer has thirty three years experience in a broad range of nuclear reactor physics methods and design activities associated with PWR, BWR, HWR, graphite, homogeneous, experimental and fast reactors.

PROFESSIONAL EXPERIENCE:

POOR ORIGINAL

COMBUSTION ENGINEERING, INC., 1955 to Present
Power Systems Group, Nuclear Power Systems

Consulting Physicist, Nuclear Design Dept., Nuclear Engineering, 1964 to Present.

In his present capacity as Consulting Physicist, Mr. Noderer's responsibilities involve criticality evaluations related to the C-E fuel fabrication facility and fuel handling at customer owned facilities, special assignments on NSSS Physics Design, Methods Development activities and DOE studies under the Non-proliferation Alternative Systems Assessment Program.

Prior to this, Mr. Noderer acted in an advisory capacity to the Director of Physics and Computer Analysis, carried out special assignments at his request and was a member of the AEC Cross Sections Evaluation Working Group.

He has participated in a study for the AEC of low enrichment, water moderated reactor systems with high conversion ratio. He was also responsible for conducting theoretical studies for advanced reactor concepts and for developing the physics methods and group cross sections used in the Fast Reactor study. He carried out an analysis of the sodium temperature coefficient in fast reactors and originated the concept of a voided region between the core and reflector to reduce or make negative this effect. He participated in the physics for the organic cooled, D_2O moderated reactor optimization study, the Savannah River conversion study (SARIF), and the evaluation and development of physics methods for the HWOCR.

Supervisor, Reactor Physics Theory Group, 1959 to 1964

As supervisor of the Reactor Physics Theory Group, Mr. Noderer was responsible for theoretical physics work in support of the SIC project.

OAK RIDGE NATIONAL LABORATORY, 1946-1955, Senior Physicist

Mr. Noderer attended the Oak Ridge Training School upon joining the staff of the Oak Ridge National Laboratory as a Physicist. He later worked in the Long Range Physics Planning Group in the development of physics concepts for future application in the power reactor field. Mr. Noderer was associated with Project Dynamo, the purpose of which was to compare the economic feasibility of different types of thermal reactors. He also performed analytical physics work for the Materials Testing Reactor and did some of the initial calculations for the Homogeneous Reactor Test and the Geneva Reactor. Mr. Noderer has written many reports describing the several methods he developed analyzing reactors of various types, and he co-authored a source manuscript on neutron reactor theory with Alvin M. Weinberg, the Director of the Oak Ridge National Laboratory.

U.S. AIR FORCE, 1942-1945, Materials Process Representative

Throughout the war years, Mr. Noderer served as a materials process representative for the U.S. Air Force. His function, basically, was to determine if various aircraft companies were satisfactorily complying with the Air Force metallurgical specifications and techniques.

PROFESSIONAL AFFILIATIONS:

American Nuclear Society, 1956-1970
Cross Section Evaluation Working Group, 1966-1971
American Physical Society, 1950-1954

PUBLICATIONS (Papers):

R. S. Harding, R. J. Klotz, L. C. Noderer and J. E. Rosenthal, "Analytical Techniques Employed in Reactor Fuel Handling and Storage Related Nuclear Criticality Analyses", Presented at American Nuclear Society Summer Meeting, Toronto, Canada, June 1976.

L. C. Noderer and S. Visner, "Effect of a Voided Gap on Reactivity Coefficient for Voiding Core Sodium in a Fast Reactor, for Various Geometries", Presented at American Nuclear Society Meeting, November 30, 1964.

R. Bruce Kellog and L. C. Noderer, "Scaled Iterations and Linear Equations", Presented at American Mathematical Society, Chicago, Illinois, January 1960.

L. C. Noderer, "Analysis of Boiling Water Reactors", Presented at ANPP Reactor Analysis Seminar, Baltimore, Maryland, October 1960.

D. W. Drawbaugh and L. C. Noderer, "Angular Step Functions in Neutron Transport Approximations", Presented at American Nuclear Society, Detroit, Michigan, December 1958.

RESUME OF L. C. NODERER

POOR ORIGINAL

M. C. Edlund and L. C. Noderer, "Analysis of Boron Experiments and Applications to Safety Analysis of Research Reactors", Presented at American Nuclear Society, Chicago, Illinois, June 1956.

F. J. Jawkowsky (L. C. Noderer, one of six contributers), "Research Experience with Plastic-Moderated Critical Assemblies", Presented at 1958 Geneva Conference, Paper P/2337.

Plus numerous internal publications at ORNL and Combustion Engineering, Inc.

PATENTS

L. C. Noderer, "Liquid Metal Fast Breeder Reactor", U.S. Patent # 3,271,260, Issued September 6, 1966.

PERSONAL BACKGROUND

B.S., Physics, 1939, University of Chicago
Graduate Study in Physics, 1945-1946,
University of Chicago;
part-time, 1949-1952, University of Tennessee;
ORSORT 1949-1950, Instructor, 1953

4.0 RADIATION PROTECTION PROCEDURES AND EQUIPMENT

4.1 Procedures

A manual entitled "Nuclear Licensing & Safety Procedures" which contains procedures necessary to implement the radiation protection program described in Part I of this license renewal application is maintained by the NLS&A group.

4.2 Operation Sheets (O.S.)

All routine operations involving nuclear fuel handling are covered by a shop traveler and/or various operation sheets (O.S.) which are issued by Manufacturing Engineering or Quality Control.

These procedures include the necessary precautions which must be observed to assure that the operation is conducted in a safe manner. The Health Physics and Safety Supervisor will review these precautions regarding all aspects of safety and indicate his approval in writing. However, procedures involving a change in the criticality safety controls used for that particular process in the past shall be approved by the Manager, NLS&A or the Nuclear Licensing Consultant. In their absence, a member designated by the Nuclear Safety Committee shall approve the change. Each foreman shall instruct his people to assure their understanding of the operations and their safety limits and restrictions. The adequate performance of individuals is continually ascertained by the foreman.

It is the responsibility of the foreman to assure that each work station is properly posted, and that operations are performed in compliance with posted limits and written instructions.

4.3 Posting and Labeling

All work stations involving nuclear fuel handling will be posted with a Nuclear Safety Limit in accordance with section 4.2.5 of Part I of this renewal application. All mass limited containers will be labeled as to contents and enrichment. Radiological posting of areas will be in accordance with 10 CFR 20.203.

4.4 Personnel Monitoring

All personnel must wash their hands before exiting the contaminated area and monitor their hands, exposed areas of the body and personal clotning with the alpha personnel monitor located at the change line. Any person having suspected contamination on his body must thoroughly wash the area and recheck for contamination. If contamination persists, a member of the health physics staff will assist in decontamination.

4.5 Surveys

Removable contamination levels in plant areas and on items to be released to an unrestricted area are established by smearing an area of 100 cm^2 (4' x 4") with a two inch diameter smear paper. Pellet Shop and Cold Shop floor smears are taken on a weekly basis as a minimum. Limits are provided in section 3.9.1 of Part I of this renewal application.

Direct radiation surveys of plant environs, sealed sources, and offsite shipments of radioactive materials shall be made as necessary to comply with the regulations in 10 CFR 20.201. All survey results shall be documented.

4.6 Reports and Records

All health physics records for the current calendar year, including training, and all reports required by the regulations of the U. S. Nuclear Regulatory Commission and this license will be retained by the NLS&A group. Reports and records for previous years will be made available to inspectors upon request. However, all reports and records over five years old may be stored on microfilm.

4.7 Instruments

Types of radiation detection instruments, their capabilities, and frequency of calibration are described in section 3.2.4 of Part I of this renewal application.

4.8 Protective Clothing

Protective clothing requirements for personnel entering the unclad fuel handling area are described in section 3.2.2 of Part I of this renewal application.

4.9 Dosimetry

4.9.1 TLD Badges

Each individual who enters a restricted area under such circumstances that he is likely to receive a dose in any calendar quarter in excess of 25 percent of the applicable value specified in 10 CFR 20.101(a) shall be supplied with a TLD badge and indium foil for purposes of personnel dosimetry. Badges will be processed monthly. When a high exposure is suspected, the individual's badge will be immediately processed.

All visitors will be supplied with indium foil badges.

Area TLD badges and neutron foils are also strategically placed throughout the facility for the purpose of recording background radiation levels as well as radiation resulting from a criticality accident. These badges will also be processed monthly during normal operations and immediately following a criticality accident. Procedures to determine high radiation doses immediately following a criticality accident are described in the Emergency Procedures Manual.

4.9.2 <u>Breathing Zone Monitoring</u>

Breathing zone monitoring of personnel will be conducted in accordance with section 3.2.5 of Part I of this renewal application.

5.0 OCCUPATIONAL RADIATION EXPOSURES

Due to the extremely low levels of penetrating radiation which exist at Combustion Engineering's fuel fabrication facility (<5 mr/hr), the greatest emphasis in exposure control has been directed towards minimizing ingestion of airborne uranium particulates. To this end, CE has always maintained internal exposures as low as reasonably achievable through the use of ventilated hoods and process containment and an extensive breathing zone (BZ) air sampling program. General air samplers are strategically placed through the facility to provide indications of airborne activity levels and are analyzed three times per day. A bioassay program which includes periodic urinalysis and in-vivo counting has been providing information regarding internal deposition of radioactive materials for over 10 years and confirms Combustion Engineering's long standing committment to the ALARA concept.

5.1 External Radiation Exposures

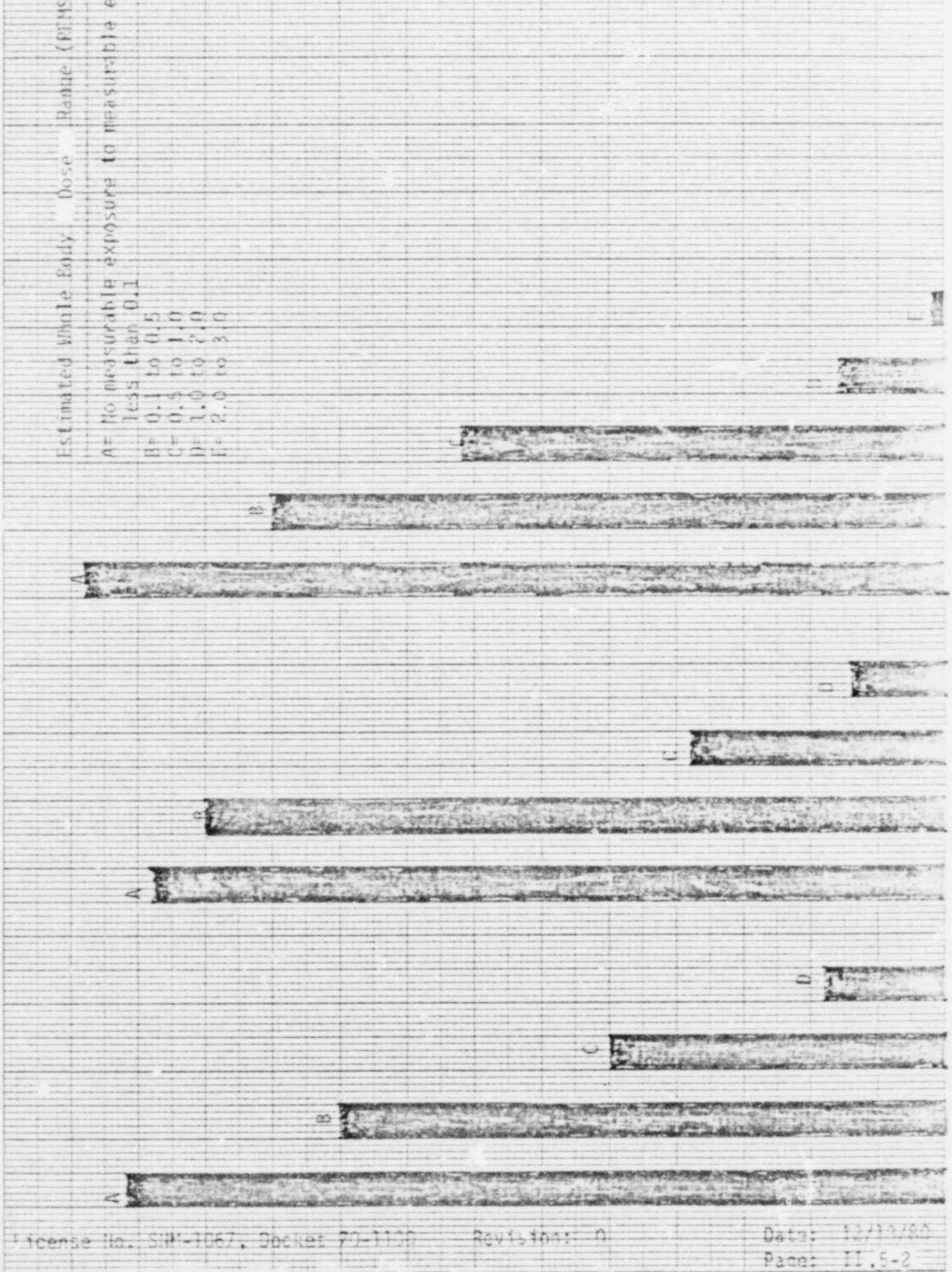
There has not been a single instance throughout the history of license SNM-1067 which has resulted in any individual exceeding the 10 CFR 20 quarterly limit of 1.25 Rem. A statistical summary has been provided herein as Figure 5.1 which indicates more individuals have been falling into the lower exposure categories over the past 3 years. The slight increase in the higher categories can be attributed to the higher throughput of uranium over the past 3 years (112 MTU in 1977 to 157 MTU in 1979) and the higher enrichments being processed as utility demand for extended-life cores increases. (License SNM-1067 was amended in 1979 to allow an increase in the maximum allowable enrichment to 4.1% U^{235}).

5.2 Internal Radiation Exposures

The most accurate results concerning actual internal deposition of radionuclides are found in bioassay results. The accuracy of these results far exceeds the accuracy obtained from personnel breathing zone air samples (BZ's), since BZ samples serve only as an immediate aid in assessing internal exposure potential and do not conclusively indicate that the material was actually ingested. During the past 3 years, all urinalysis results were less than 1 microgram U/liter (the lower limit of detection for our flourimetric method of analysis) with 3 exceptions in 1978 where 3 individuals' results were 2, 3, and 4 micrograms U/liter respectively.

Figure 5.1

Summary of Annual Radiation Doses



In-vivo lung counting results over the past 10 years clearly indicate that no individual has ever received a maximum permissible lung burden (MPLB), which is about 200 μgm U^{235} for low enriched uranium. Due to the extreme sensitivity required to detect such low amounts of U^{235}, most results are reported as zero with a statistical accuracy associated with them. Figure 5.2 is a summary of lung counting for the past 5 years and clearly indicates that the ALARA concept practiced at CE has paid off.

5.3 General Air Sampling Results

Results in graphic form are shown for all air sampling stations in figure 5.3 thru 5.8. All results are below 15% of MPCa for restricted areas (1×10^{-10} μCi/cc) and most results are well below 10% of MPC. The only results which were slightly over 15% of MPC are explained below:

2) March 1980 - Powder Prep Station #1 and Presses 1 and 2 (Figures 5.3 and 5.4) The pellet shop had been undergoing a complete cleanup prior to an enrichment change at this time. Our license action limit was exceeded four (4) times. An investigation revealed that the sample heads were colliding with a nearby vacuuming hose which was highly contaminated.

1) June 1978 - Powder Prep Station #1 (Figure 5.3) Several powder-lot cleanups caused rapid plugging of hood filters and reduced ventilation at the time. Problems were also encountered with the granulator screen and the belt dryer.

Figure 5.2

In-Vivo Lung Counting Summary

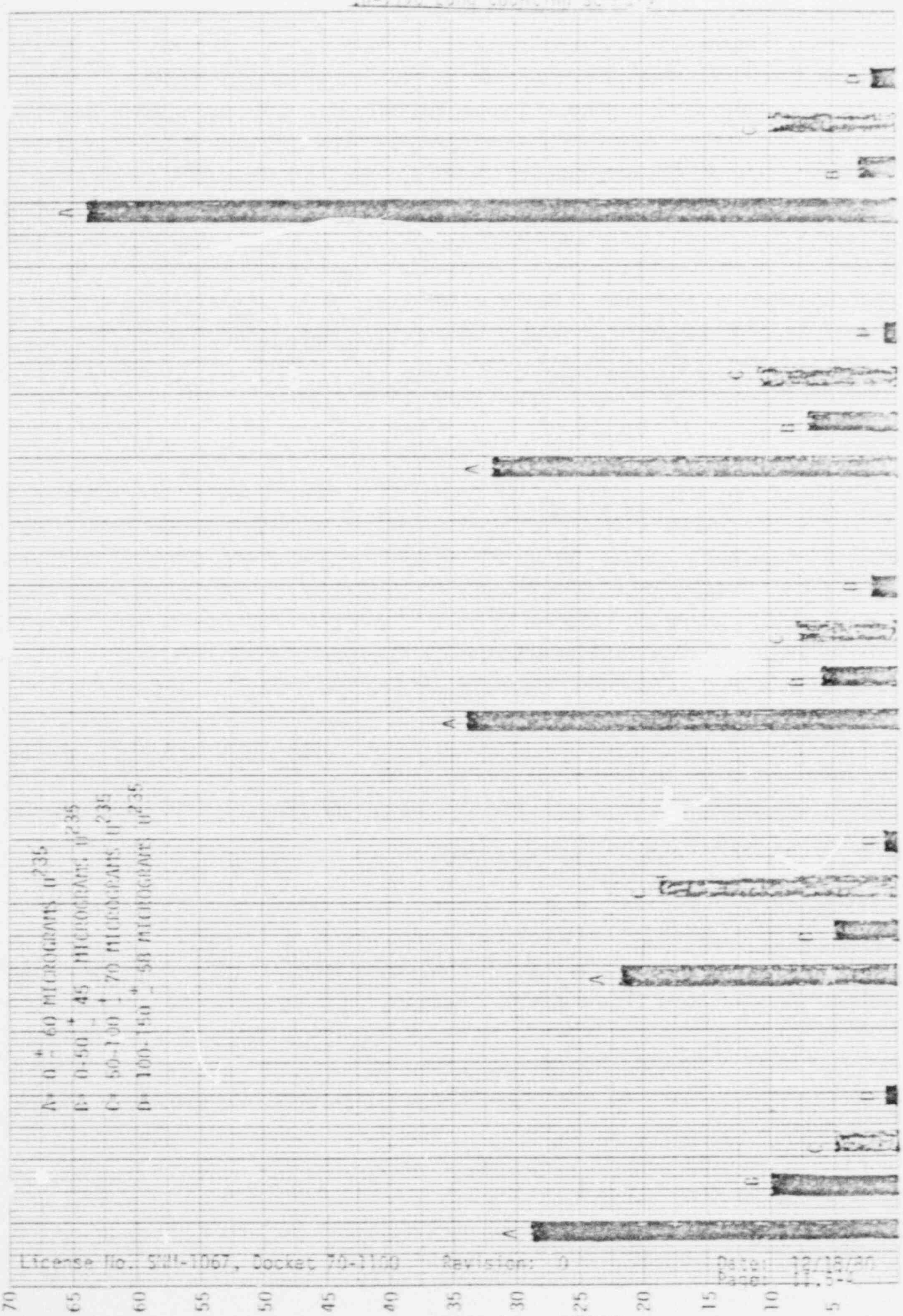
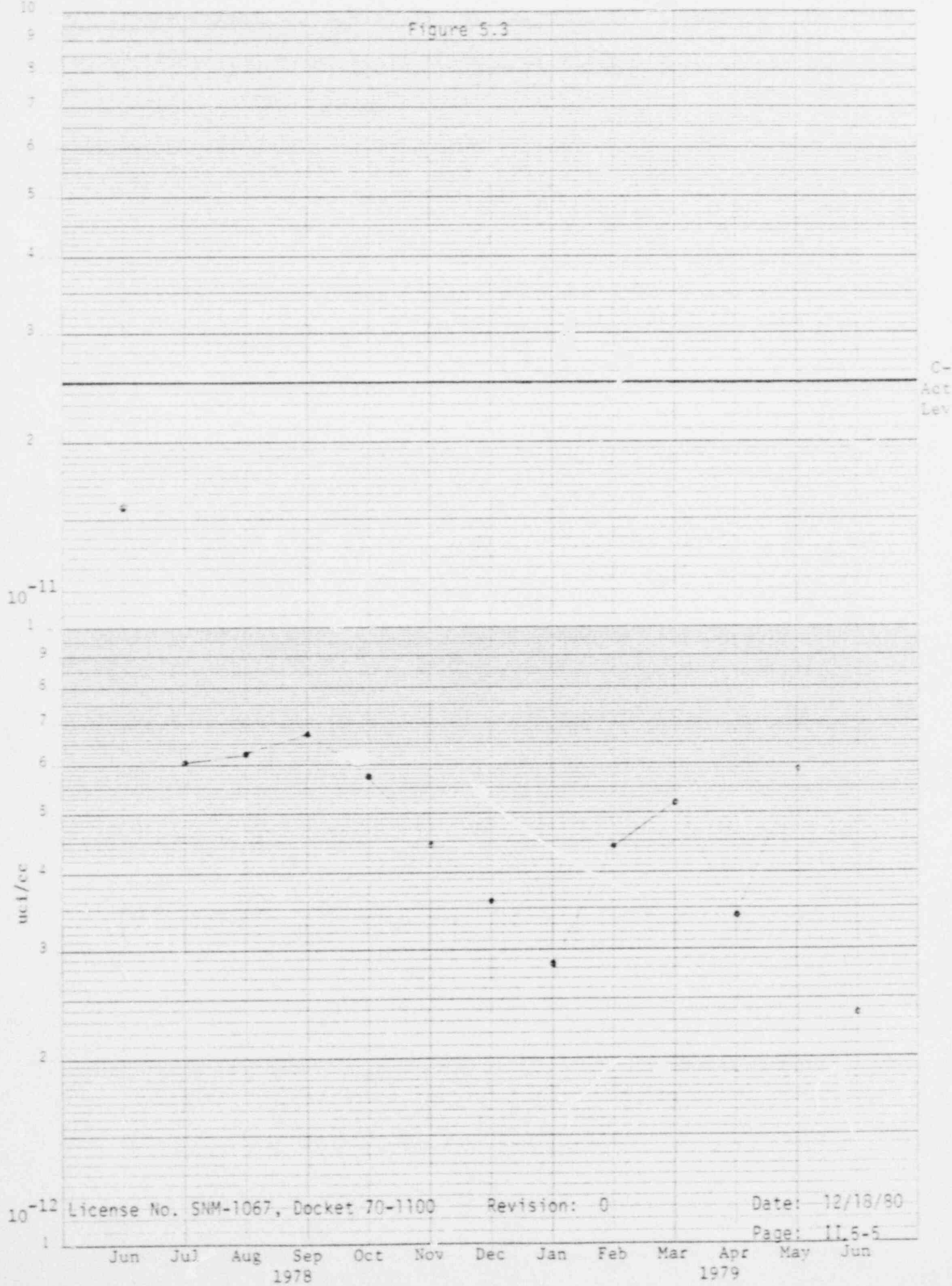


Figure 5.3



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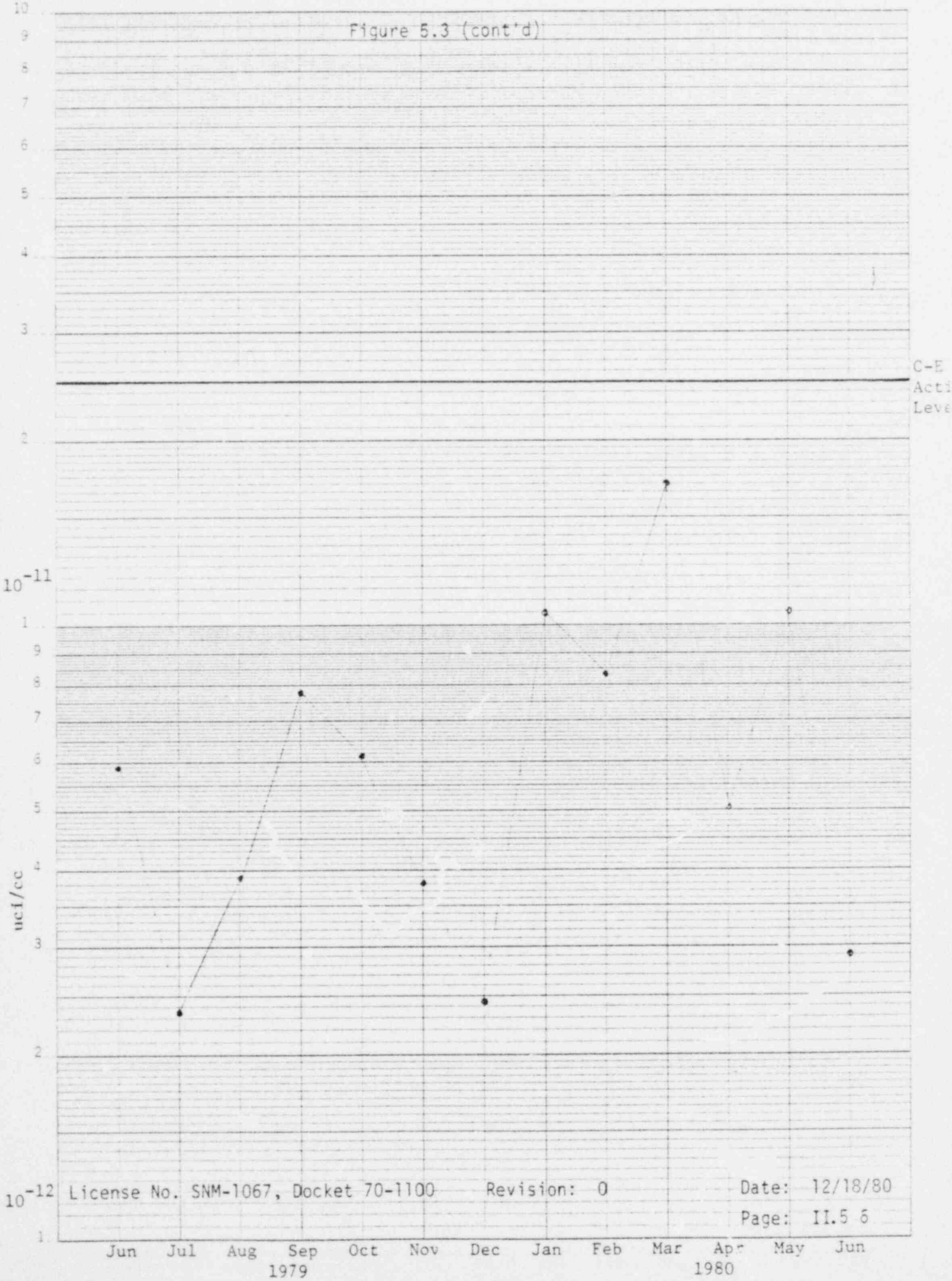
General Air Powder Prep. Sta. #1 June 1979 - June 1980

Figure 5.3 (cont'd)



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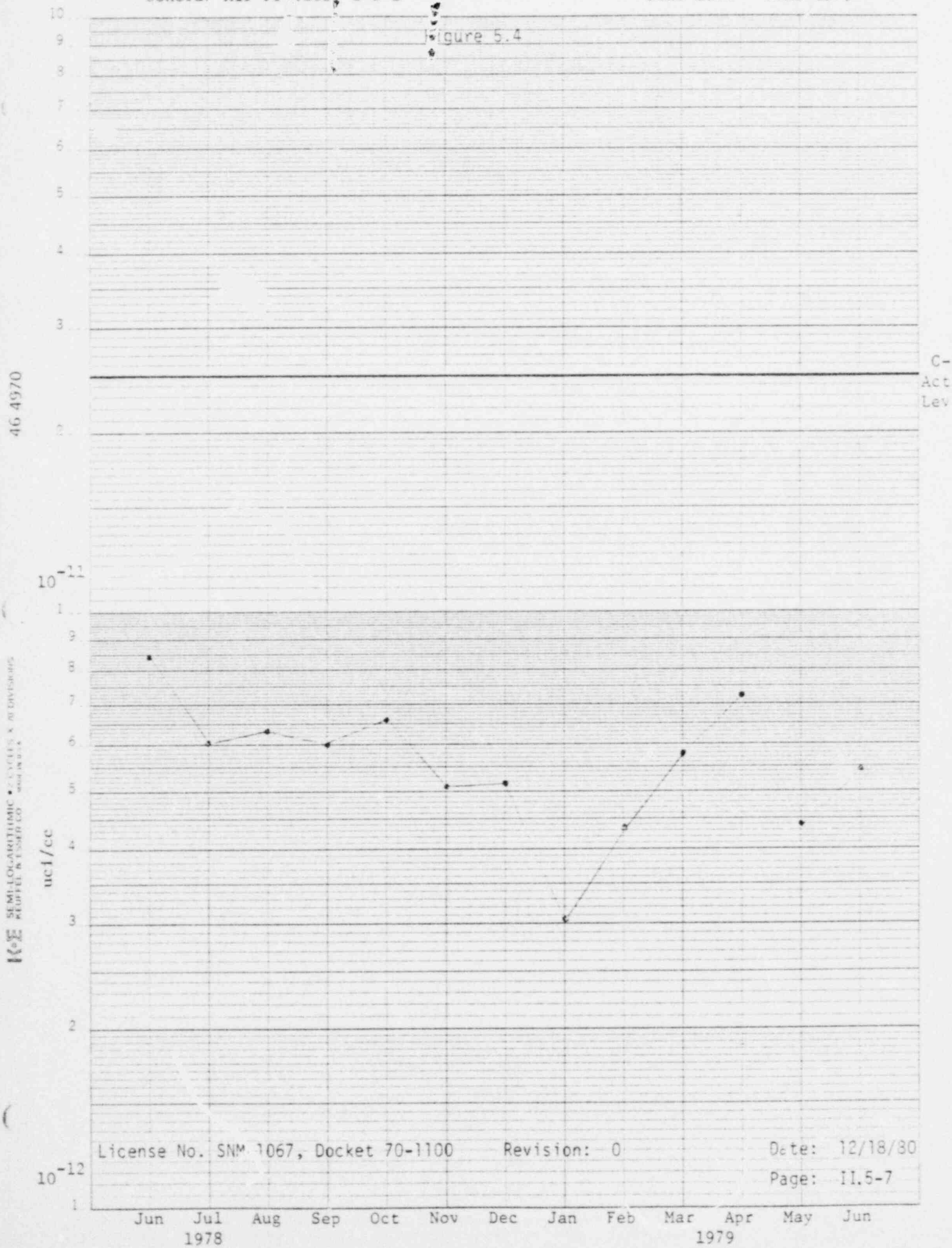
General Air Presses, 1 & 2 June 1978 - June 1979

Figure 5.4



License No. SNM 1067, Docket 70-1100 Revision: 0 Date: 12/18/80

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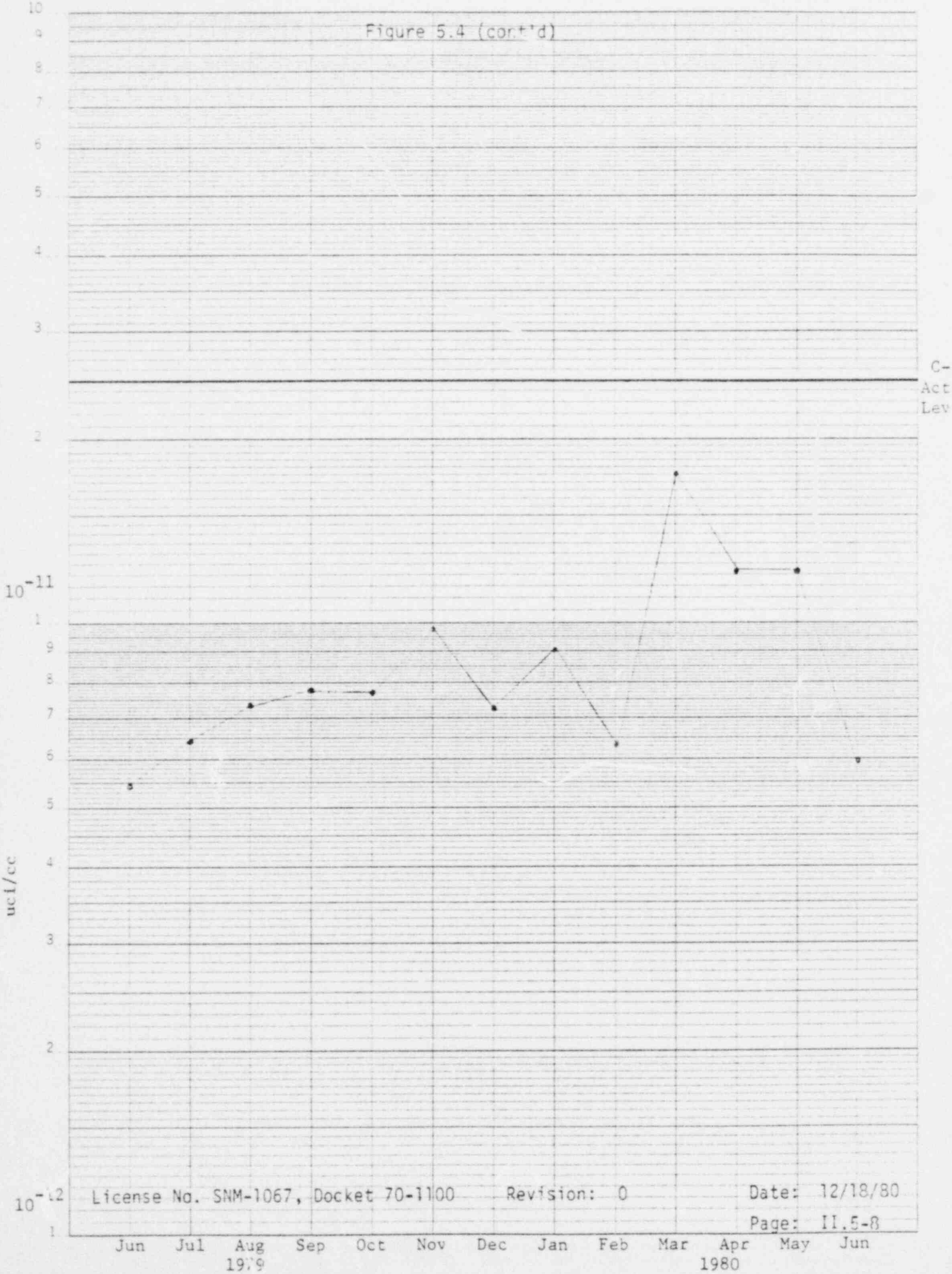
General Air Presses 1 & 2

June 1979 - June 1980

Figure 5.4 (cont'd)



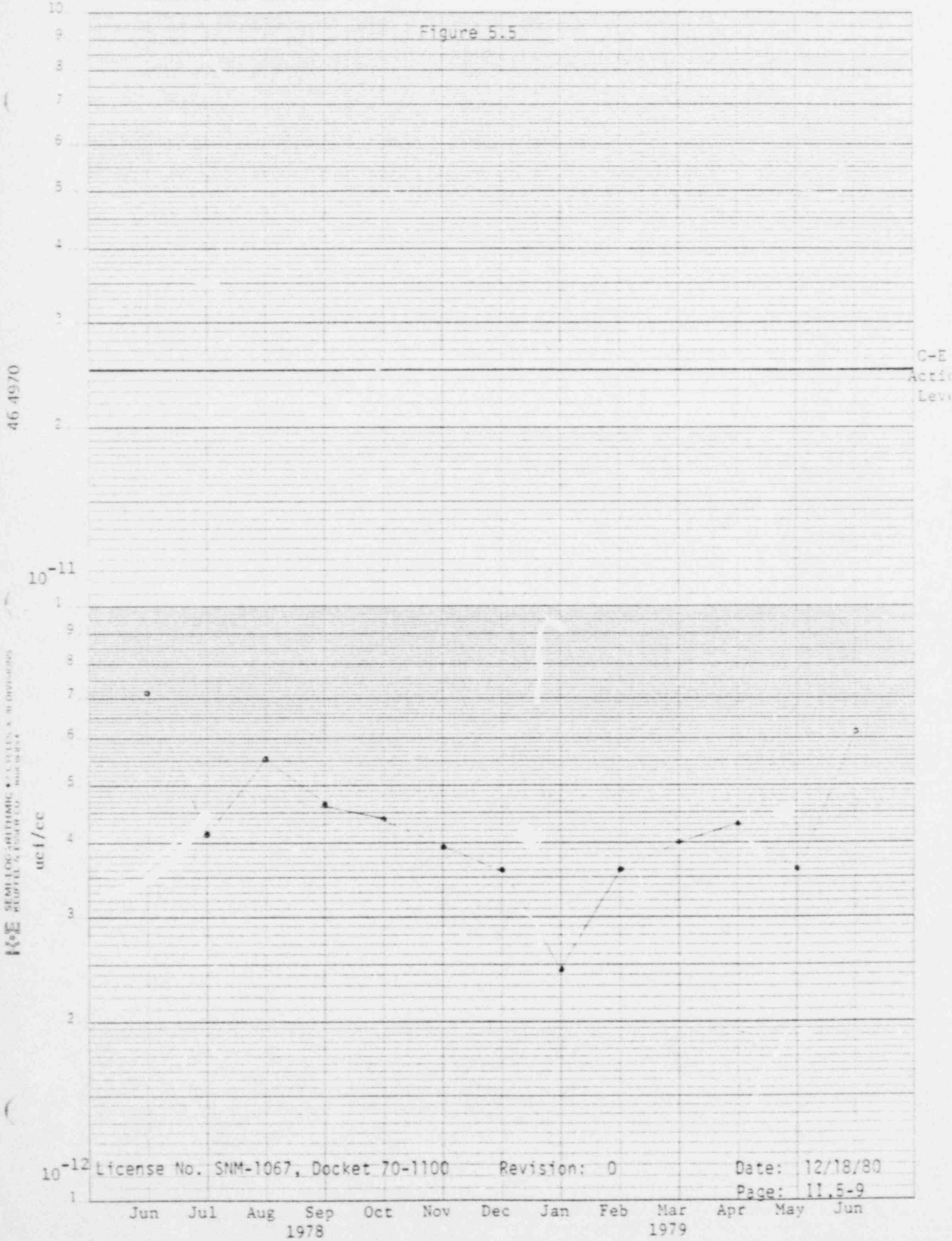


Figure 5.5
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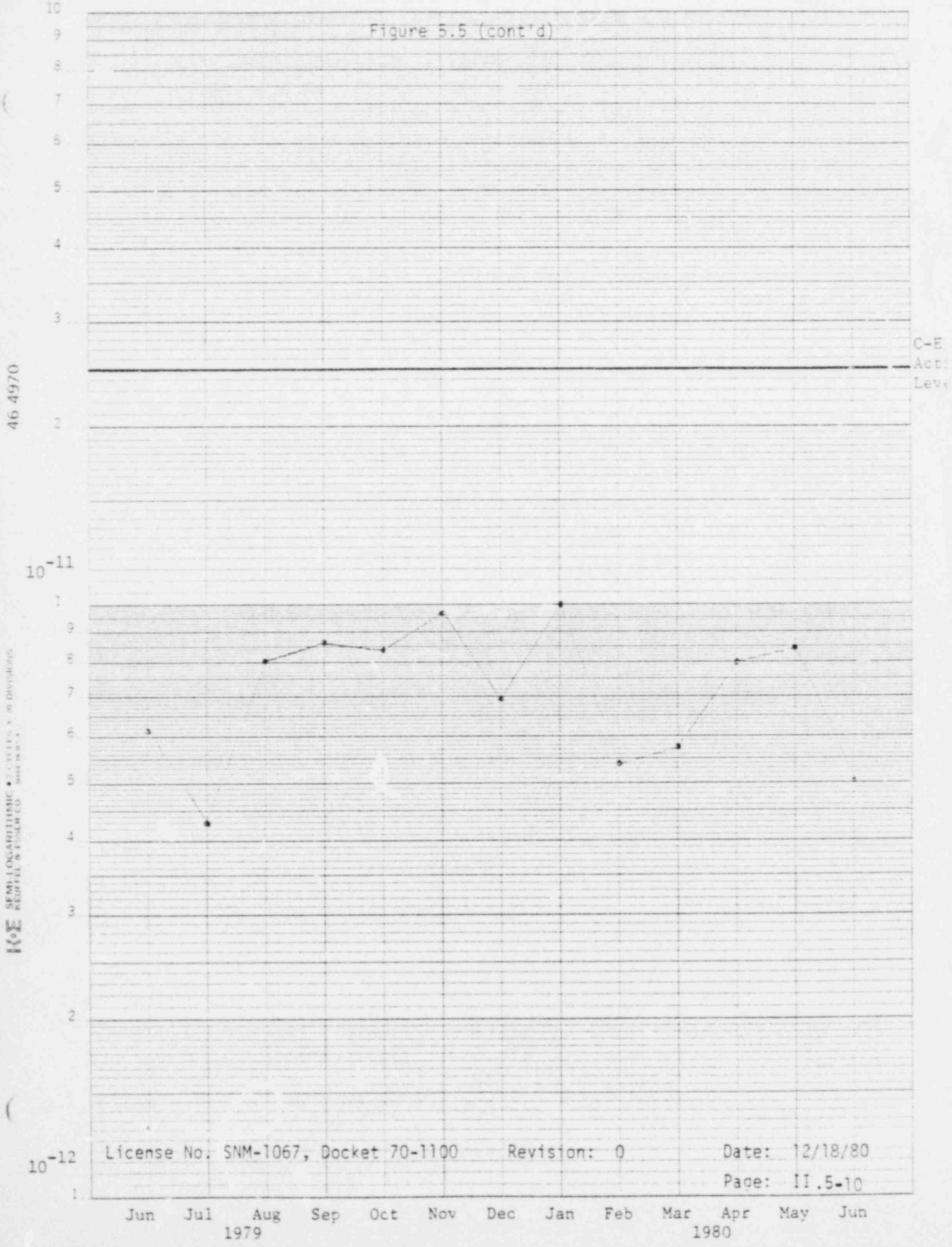
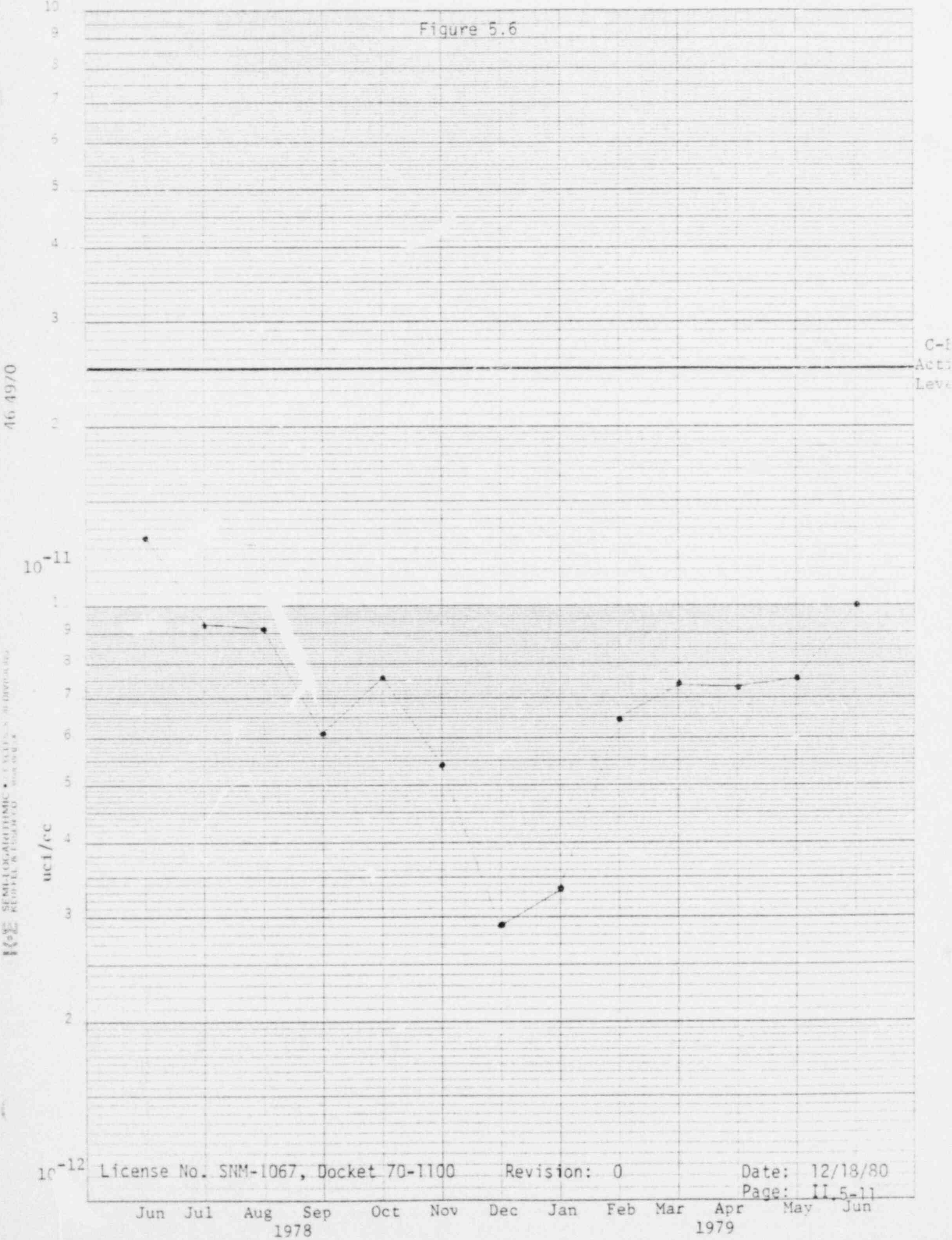
Figure 5.5 (cont'd)



General Air Grinder June 1978 - June 1979



General Air Grinder June 1979 - June 1980

Figure 5.6 (cont'd)

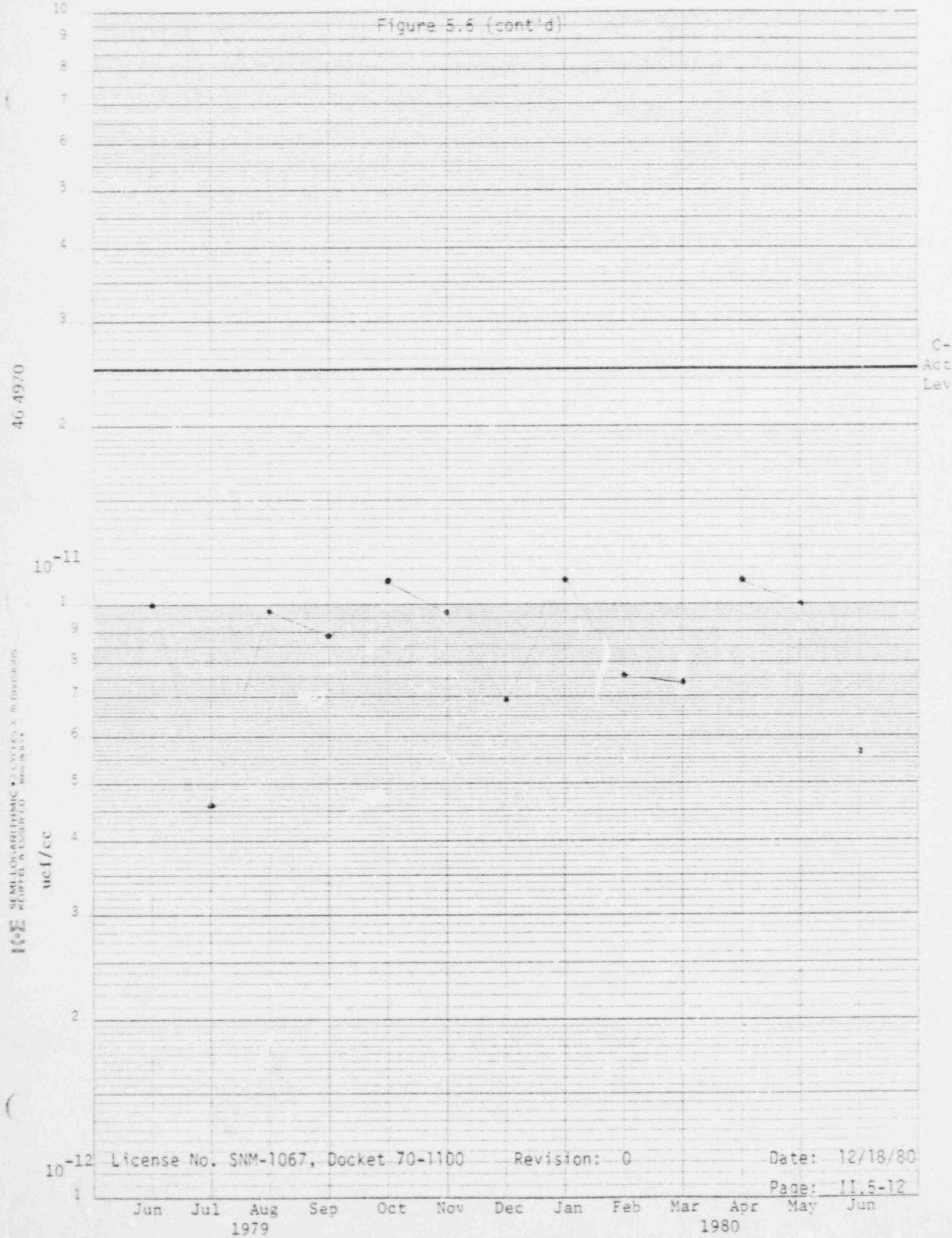


Figure 5.7

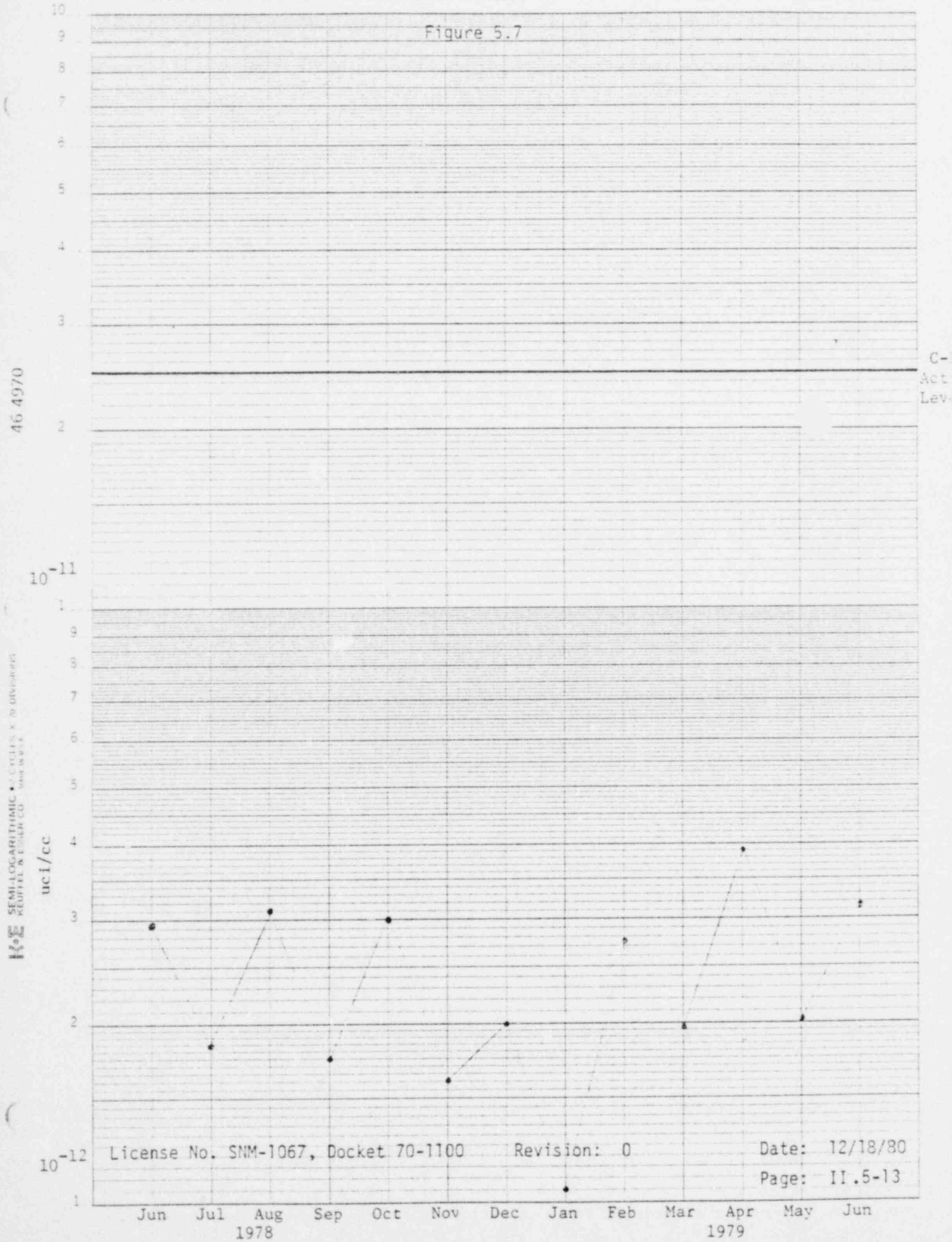

C-
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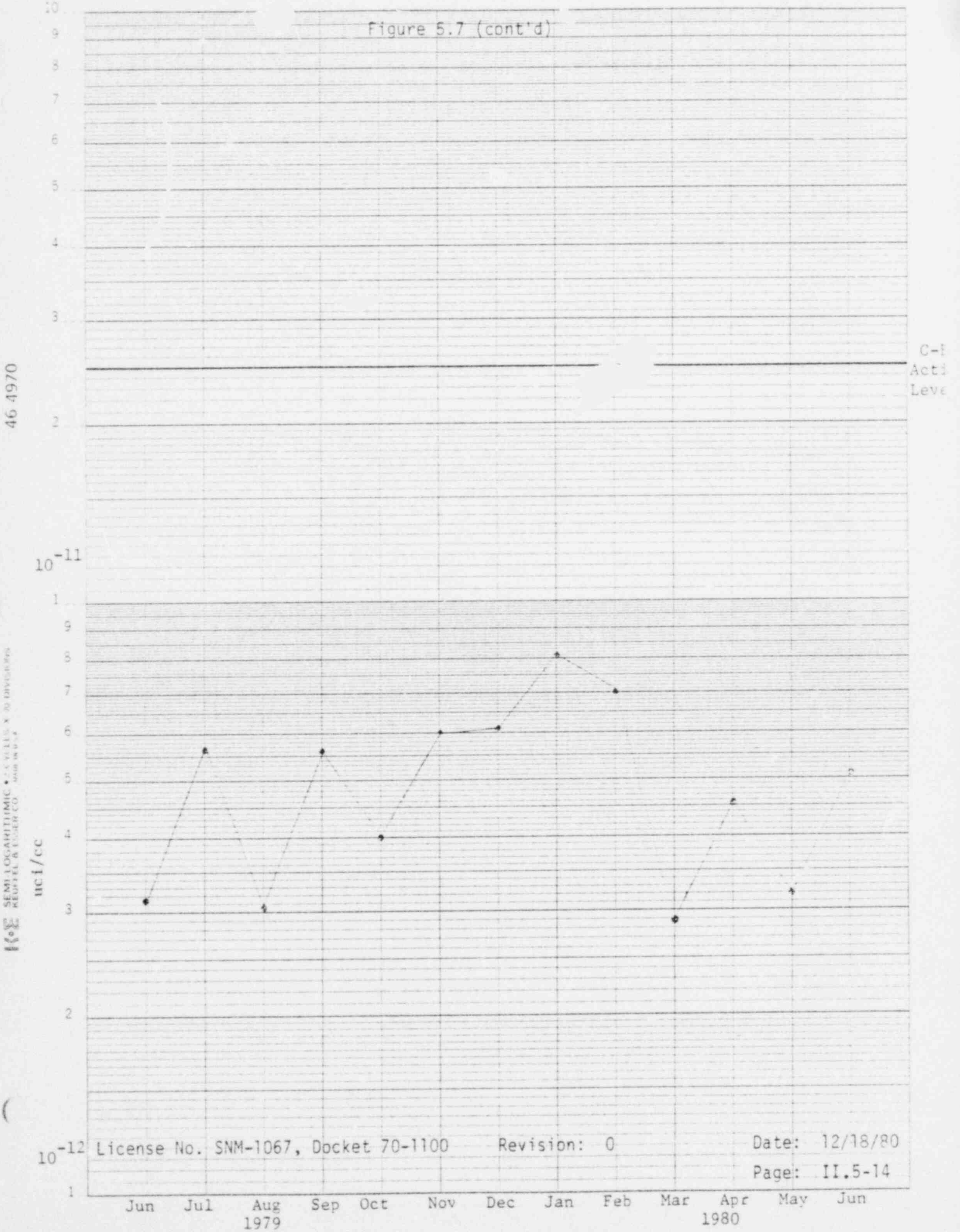
Figure 5.7 (cont'd)



General Air Micronizer June 1978 - June 1979

Figure 5.8

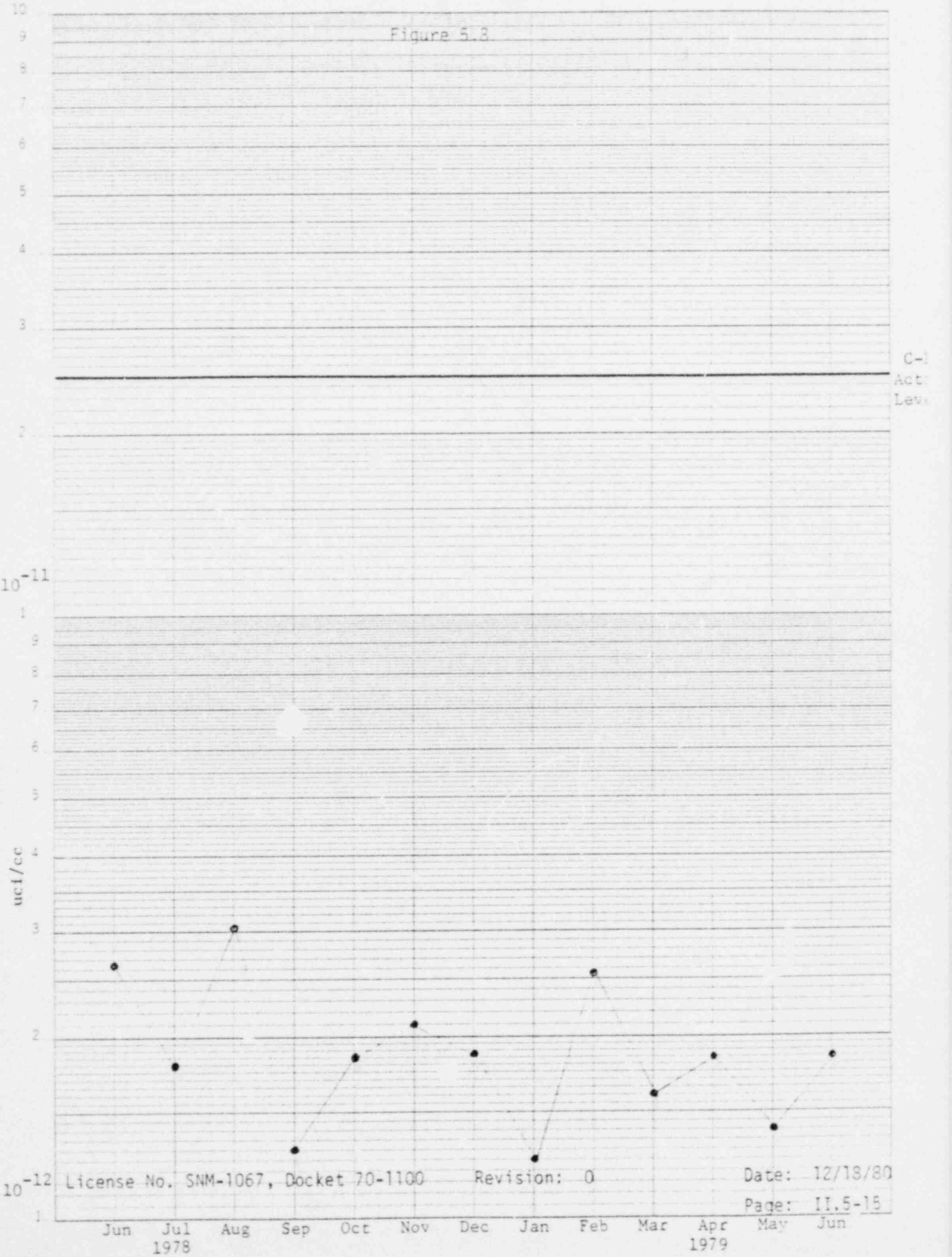
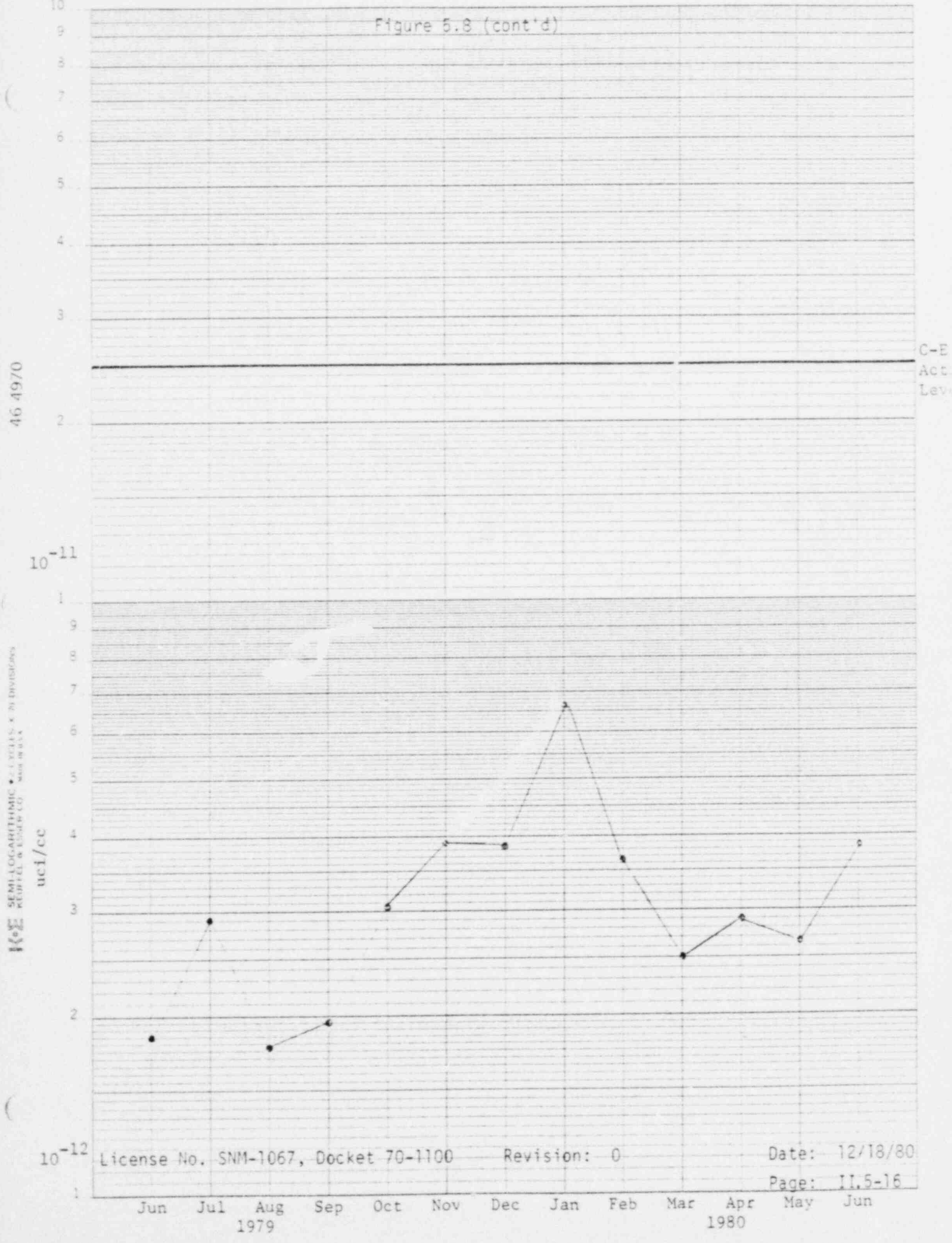


Figure 5.8 (cont'd)



6.0 ENVIRONMENTAL SAFETY

6.1 Liquid Effluent Discharges

All liquid wastes, in-process, and cleanup rinse water solutions are sampled to verify that MPC_W is not exceeded, and are then introduced to any one of ten 2000 gallon retention tanks, located in the Liquid Waste Building, Bldg. #6. Sinks and showers in the laboratories and the manufacturing facility are also drained to these retention tanks and provided additional dilution. Before these tanks are discharged to the site creek, a 500-ml sample is withdrawn and forwarded to the Radio-chemistry laboratory for gross alpha and beta analyses. Water is discharged to the environment at, or below 3×10^{-6} μCi/ml (this in ten percent of MPC_W for insoluble uranium). The allowed discharge level for unidentified mixtures of radionuclides is 3×10^{-9} μCi/ml. (This is ten percent of MPC_W for unidentified mixed radionuclides). Where the levels of activity exceed these limits, the water is diluted before being discharged.

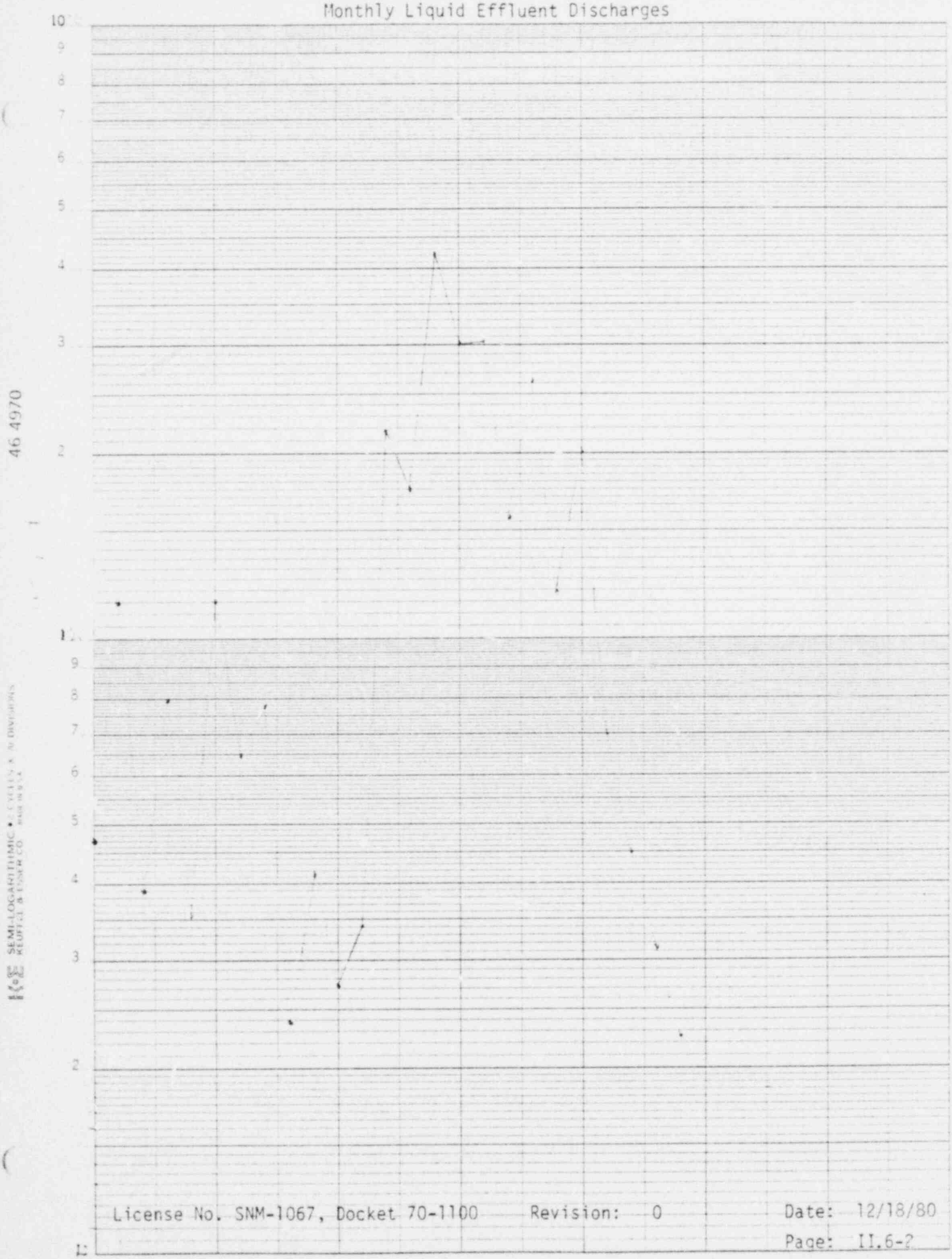
Monthly liquid effluent discharges are shown graphically in Figure 6.1 for the past 3 years. The increase in the amount of uranium being discharged is due in part to the increased throughput in the manufacturing facility.

6.2 Airborne Radioactivity Discharge

All airborne releases are monitored continuously following double HEPA filtration. Samples are analyzed daily and totaled weekly and monthly for all four ventilation systems. The monthly average concentration in μCi/cc for all 4 systems is shown graphically in Figure 6.2 for the period 6/78 - 6/80. All levels are less than 10% of MPCa for unrestricted areas with the exception of June 1980. During this month, a HEPA filter change was performed on the FA-4 system where the filters were not sealed properly. After discovery of this higher than normal discharge, corrective actions were taken to preclude recurrence.

Figure 6.1

Monthly Liquid Effluent Discharges



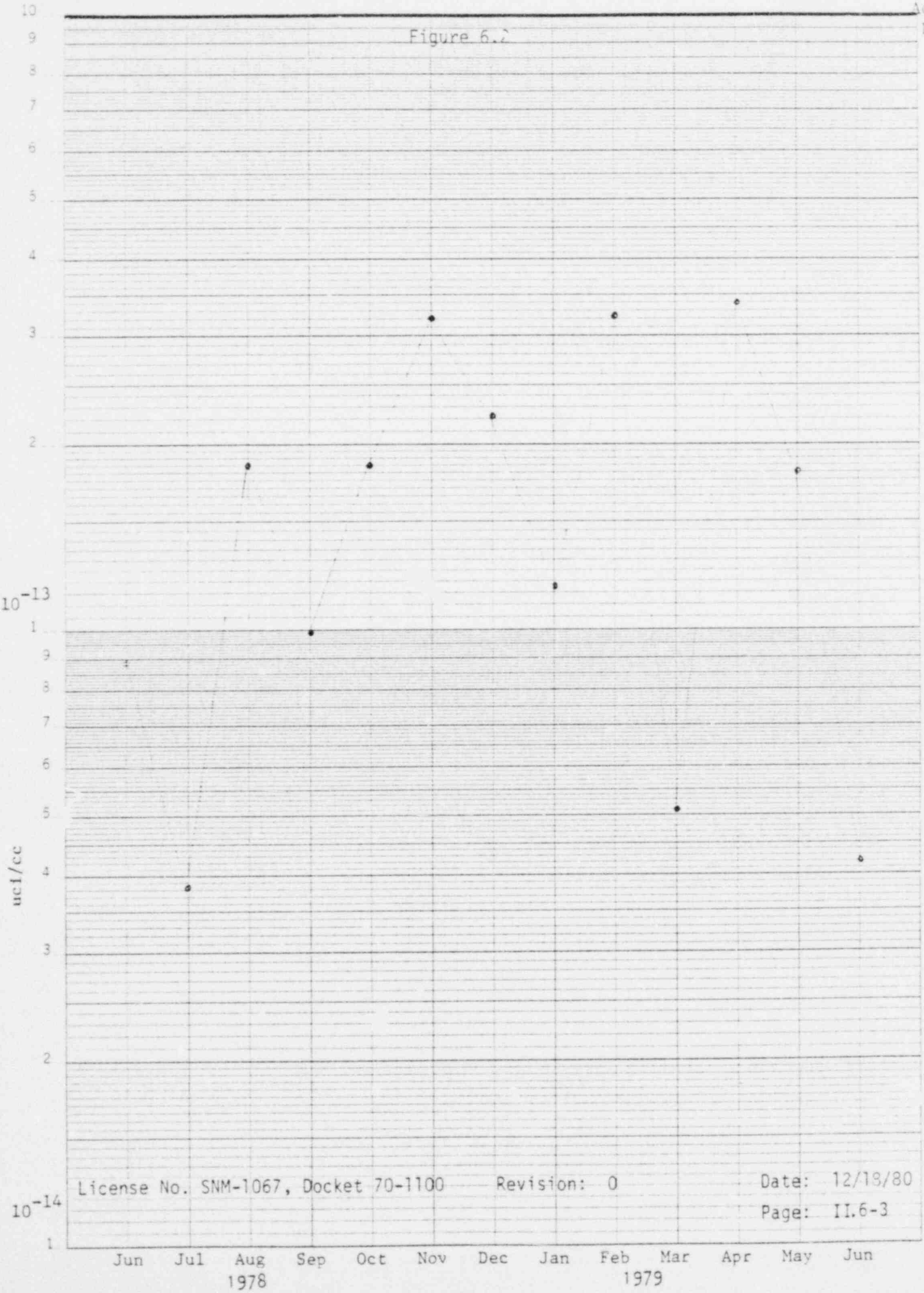
License No. SNM-1067, Docket 70-1100   Revision: 0   Date: 12/18/80

Page: II.6-2

Monthly Average for Total Airborne Effluents of F.A. Systems

C-E Acti Lev

Figure 6.2



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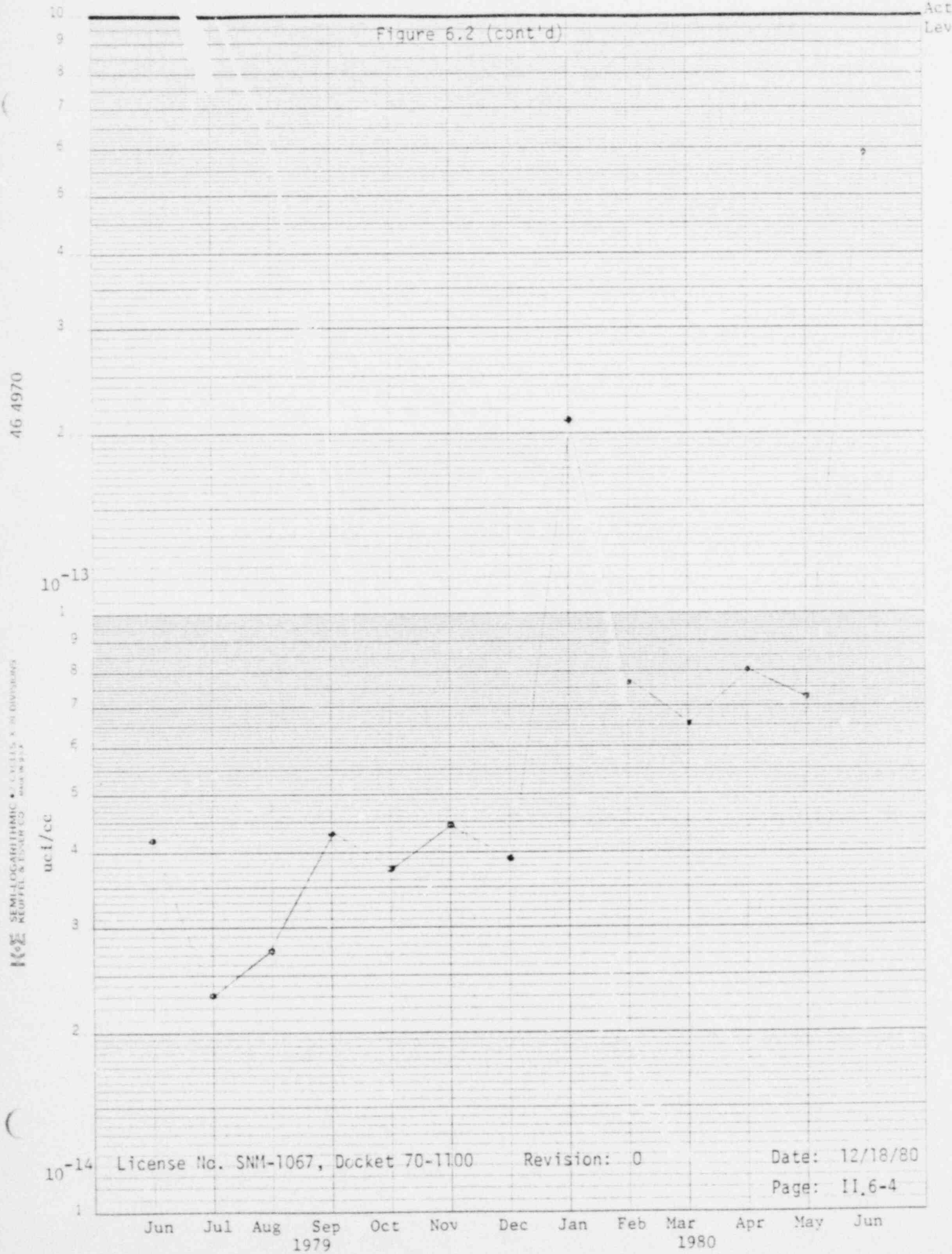
Monthly Average for Total Airborne Effluents of F.A. Systems

Figure 6.2 (cont'd)



7.0 NUCLEAR CRITICALITY SAFETY

7.1 Use of Surface Density Technique

7.1.1 Use of Surface Density Criteria of 50% for Mass Limited Units on Single Levels

Mass limited units having a maximum fraction critical (f) of 0.3 are to be spaced to a maximum array surface density of 50% of the optimum critical surface density based on mass per unit area. This criteria is supported as follows:

Consider the following infinite planar arrays of units containing moderated UO_2 having an enrichment of 5%. For these arrays, the following parameters apply:

Material - UO_2, 5% U^{235}, fully moderated

Unit Size - a - 17.955 kg U, 38.548 cm. diam., 0.6 gm U/cm^3
b - 17.955 kg U, 35.023 cm. diam., 0.8 gm U/cm^3
c - 18.094 kg U, 33.612 cm. diam., 0.91 gm U/cm^3
d - 17.994 kg U, 28.402 cm. diam., 1.50 gm U/cm^3
These units represent 30% (f=0.3) of the minimum unreflected critical mass of 60 kg at optimum moderation (Fig. 1.d.13, UKAEA Handbook).

Allowable Surface density - The minimum mass surface density for $U(5)O_2$ is calculated to be 10.4 kgU/ft^2. The safe limit is therefore 5.2 KgU/ft^2.

Spacing Requirement - 56.87 cm center to center spacing in a square lattice.

Reflection - Sixteen inch thick concrete reflectors on top and bottom of array, spaced 28.43 cm from the center of the units.[a]

Calculated Results - KENO calculations for the above arrays yielded the following:

Unit	k_{eff}
a	0.9460 ± 0.0055
b	0.9500 ± 0.0070
c	0.9408 ± 0.0083
d	0.8850 ± 0.0080

From this analysis (b) it is concluded that use of a limit equal to 50% of the minimum critical slab surface density (at optimum moderation) expressed in terms of mass per unit surface area is safe, with a maximum nominal array reactivity of 0.950. These calculations clearly demonstrate that the license criteria provides adequate safety for plant applications. However, reviews of calculated arrays as described in Reference 1 could call these limits into question, and therefore require further attention.

Specifically, several arrays of under-moderated low-enriched uranium show surface densities which, in some cases, are less than 50% of the infinite slab thickness for material of like moderation and density. However, the license criteria specifically limits use of the method to spacings based on optimum mass per unit area moderation. Examination of the spacings in Reference 1 show that when compared to slabs having optimum mass per unit area moderation, all arrays have surface densities at or above 85% of the optimum infinite slab value. This is shown in Table 7.1.

(a) At the given sphere spacing, a 16" concrete reflector in contact with the sphere array produced no significant change in reactivity.

(b) These KENO calculations were performed by Battelle Northwest Laboratories using 16 group Hansen-Roach cross sections. When used to check experimental UO_2F_2 cylinders, and calculated values published in DP-1014, the calculated reactivities were within one percent of unity.

Reference 1): R. L. Stevenson and R. H. Odegaarden, "Studies of Surface Density Spacing Criteria Using KENO Calculations". Unpublished.

TABLE 7.1

KENO Calculated Arrays of Low Enriched Uranium Subcrits

Array	Composition	Subcrit	f**	gm U/cc	KgU/ft^2	k_{eff}	t_a/t_c*
1	$U(5)O_2$	cylinder 11.5 cm.r x 138.6 cm lg	0.3	2.0	12.7	1.019 ± 0.006	1.15
2	$U(5)O_2F_2$	cylinder 11.4 cm.r x 152.4 cm lg	0.3	1.0	10.1	1.005 ± 0.009	0.85
3	$U(5)O_2$	cylinder 16.0 cm.r x 211 cm lg	0.3	5.0	40.1	1.000 ± 0.006	3.6

* Derived array Surface Density/Surface Density of Optimum Moderated Infinite Slab

** Fraction of critical values taken from Ref. #1

7.1.2 Double Level Areas

a) Mass Limited Units

By doubling the required spacing area for mass limited units on each level, the overall mass surface density is preserved.

b) Geometry Limited Units

Spacing requirements for geometry limited units on two levels are based on 16% of the infinite slab surface density at optimum geometry. Units are limited to a fraction critical of 0.4. This limit has been validated by two KENO calculations, for 10.7" diameter x 72" long cylinders (f = 0.36). These cases are described below:

Material	-	UO_2, 3.5 w/o U^{235} optimum moderation
Individual Unit Limit	-	10.7" ϕ x 72" lg.
Fraction Critical	-	0.36
Array Reflection	-	16 inch thick concrete floor, 4 inch thick concrete roof, 25 feet above the floor.
Array Pattern	-	Infinite square pattern on two levels, with 10 ft. vertical separation between levels. In one case, the upper pattern rests on a 1/2" thick steel plate; in the other, on a 3/8" thick steel plate.
Array Surface Density	-	With the units spaced on a 80.4" pitch, the total array surface density (both levels) is 2.36 ℓ/ft^2, or 16% of the critical infinite slab surface density.
Calculated Array Reactivity	-	With 1/2" steel, k_e=0.9262 ± 0072. With 3/8" steel, k_e= 0.9273 ± 0.0074. With both the upper and lower arrays in contact with the 3/8" steel deck, k_e =0.9223 ± .0070.

7.1.3 Calculation of Fraction Critical

The concept of fraction critical for an SIU is based on an arbitrary definition which ratios the SIU mass, or equivalent spherical mass to that of an unreflected critical sphere of the same material, assuming optimum moderation. Several prescriptions for calculating this value have been described in the literature. Depending on the method selected, somewhat varying results may be obtained.

In evaluating SIU's for this license, nonspherical SIU's are reduced to equivalent spherical shapes using buckling conversions, in conjuction with somewhat arbitrarily selected extrapolation lengths which vary with fissile density and moderation, physical form, and unit shape. For this license, extrapolation lengths are taken directly from Figure 2 of LAMS-2537. As they are consistently used, any bias introduced is consistent, and based on sphere data taken from the UKAEA Handbook, is also relatively minor.

As a further check on the reasonableness of the use of these values for low enrichment uranium, we have compiled critical data from WCAP-2999, DP-1014, and the UKAEA Handbook for UO_2, and from LA-3612 for U-metal mixtures and UO_2F_2 solutions. These data are presented in Table 7.1.3 and show that for the oxide, there is close agreement for the reflected sphere radius, for the material buckling, for the reflected extrapolation length, and that 4-4.5 cm represents a reasonable value for reflector savings. These considerations lend support to the use of the extrapolation lengths as provided herein.

Another variable which must be defined for the license is the unreflected critical mass or volume. These values vary from one author to another. For this license, all unreflected critical sizes are taken from the UKAEA Handbook.

Examples of the fraction critical calculations follow:

Consider the 10.7" diameter cylinder limit. From data taken from Figure 1.D.14 of UKAEA AHSB Handbook 1, the minimum critical unreflected volume for homogeneous 3.5% $^{235}UO_2$ is 79 liters.

The volume of a sphere having the same buckling as the 10.7"ϕ cylinder of homogeneous UO_2 is :

$$B^2_{SIU} = \left(\frac{2.405}{\frac{10.7 \times 2.54 + 2.25}{2}} \right)^2 = 0.0230 \text{ cm}^{-2}$$

$$V\ SIU = \left(\frac{\pi}{B} - 2.1 \right)^3 \times 4.19 = 26.9 \text{ liters}$$

The fraction critical of the SIU is:

26.9 ℓ/ 79 ℓ

= 0.34

TABLE 7.1.3

Critical Parameters for Optimum Moderated Low Enrichment Uranium

	R_{cr} (cm)	R_{cb} (cm)	B^2_m (cm^{-2})	r (cm)	$R_{cb}-R_{cr}$ (cm)
WCAP-2999[a] 3% UO_2	24.66		0.0104	6.3	
DP-1014[b] 3% UO_2	24.03		0.0103	6.88	
UKAEA (c) Handbook 3% UO_2	24.29	28.79			4.5
LA-3612 (d) 5% U-Metal	17.91	22.16			4.25
LA-3612 (e) 5% UO_2F_2	22.42	25.69			3.27*

(a) Figure III-15 & Figure III-10

(b) Pages 37 and 57

(c) Figures 1.D.10 and 1.D.14 respectively for reflected and bare volumes.

(d & e) Page 26

* UO_2F_2, being a solution, has somewhat smaller reflector savings than do oxide or metal systems.

Consider also the SIU for mass limited homogeneous UO_2 at an enrichment of 3.0% U^{235}. A mass limit of 41 Kg UO_2 is indicated in Table 4.2.5 of Part I. From Figure 1.D.13 of UKAEA Handbook AHSB (1), the unreflected critical mass for this material is 185 Kg UO_2. Fraction critical for this SIU is calculated as follows:

$$F = 41 \text{ Kg } UO_2 / 185 \text{ Kg } UO_2$$

$$= 0.222$$ (May be conservatively rounded to 0.23 as shown in Table 4.2.5 of Part I)

7.1.4 General Considerations for 16 x 16 Fuel

Several aspects of fuel handling as they relate to the 16 x 16 fuel design are not specifically evaluated in view of the general observation that the reduced pellet and rod diameters render this material less reactive than the 14 x 14 fuel which has been extensively evaluated herein.

This finding is based on study of DP-1014 and evaluations made in connection with the calculated values reported in Figure 8.2.7.

7.2 Validation of Calculational Methods for Nuclear Criticality Safety

To validate the methods used in criticality analysis of fuel manufacturing processes, the 2.35 w/o U^{235} UO_2 critical separation experiments by Battelle (Reference 1) were analyzed in three dimensions. The mean k_{eff} value of these nineteen experiments was 1.00157 with a standard deviation of 0.00419.

The experiments are concerned with the critical separation between water-flooded subcritical clusters of fuel rods in the presence of various fixed neutron poisons. The experiments were carried out in a 1.8m x 3m x 2.1m deep tank provided with features specifically designed and built for these experiments. These experiments involved aluminum-clad 2.35 wt% U^{235} enriched UO_2 rods about 12mm in diameter by 914mm in length. The critical separation between three subcritical clusters of these rods aligned in a row was determined and analyzed with and without the following neutron absorber materials (neutron poisons) located between the clusters: 304 L Stainless Steel with 0, 1.05 and 1.62 wt% boron; and boral.

7.2.1 Description of Experiments

The experiments analyzed each consisted of three assembly-like configurations separated by water and/or poison plates with the spacing adjusted to criticality. Figure 7.2.1 illustrates typical top and end view of the arrangements. The 914mm length fuel rods 11.176mm in diameter of 2.35 w/o U^{235} in UO_2 were clad with 6061 aluminum having an O.D. of 62.7mm and 0.762mm thick with different alloys of aluminum for top and bottom plugs. A fixed square center-to-center pin pitch of 20.32mm was maintained. The number of pins in the width of the cluster varied (in different experiments) between 14 and 17 and the length from 20 to 24 pins. The experimental data on experiments analyzed is given in Tables 7.2.1, 7.2.2 & 7.2.3.

7.2.2 Method of Calculation

The calculational methods which are essentially the same as those used to determine reactivity for fuel assembly storage racks, fuel shipping containers, and other fuel configurations found in fuel manufacturing areas; broad group neutron cross sections are based on the CEPAK Code (Reference 2). Using an appropriate buckling value and taking proper account of resonance absorption, three broad fast groups are collapsed from the 54 multi-group FORM type calculations and one broad thermal group is collapsed from 29 multi-group type calculations THERMOS. Fast cross sections for certain trace elements such as sodium and zinc are obtained by averaging over an appropriate multi-group spectrum with the GGC-3 code (Reference 3). In addition, each component such as water gap, end plug, or poison plate has its thermal cross section determined by a slab THERMOS calculation employing a characteristic fuel environment.

Normally, for two dimensional representations, the transport Code DOT-IIW (Reference 4) is used. Since, however, the short fuel length

FIGURE 7.2.1

GRAPHICAL ARRANGEMENT OF SIMULATED SHIPPING PACKAGE CRITICAL EXPERIMENTS

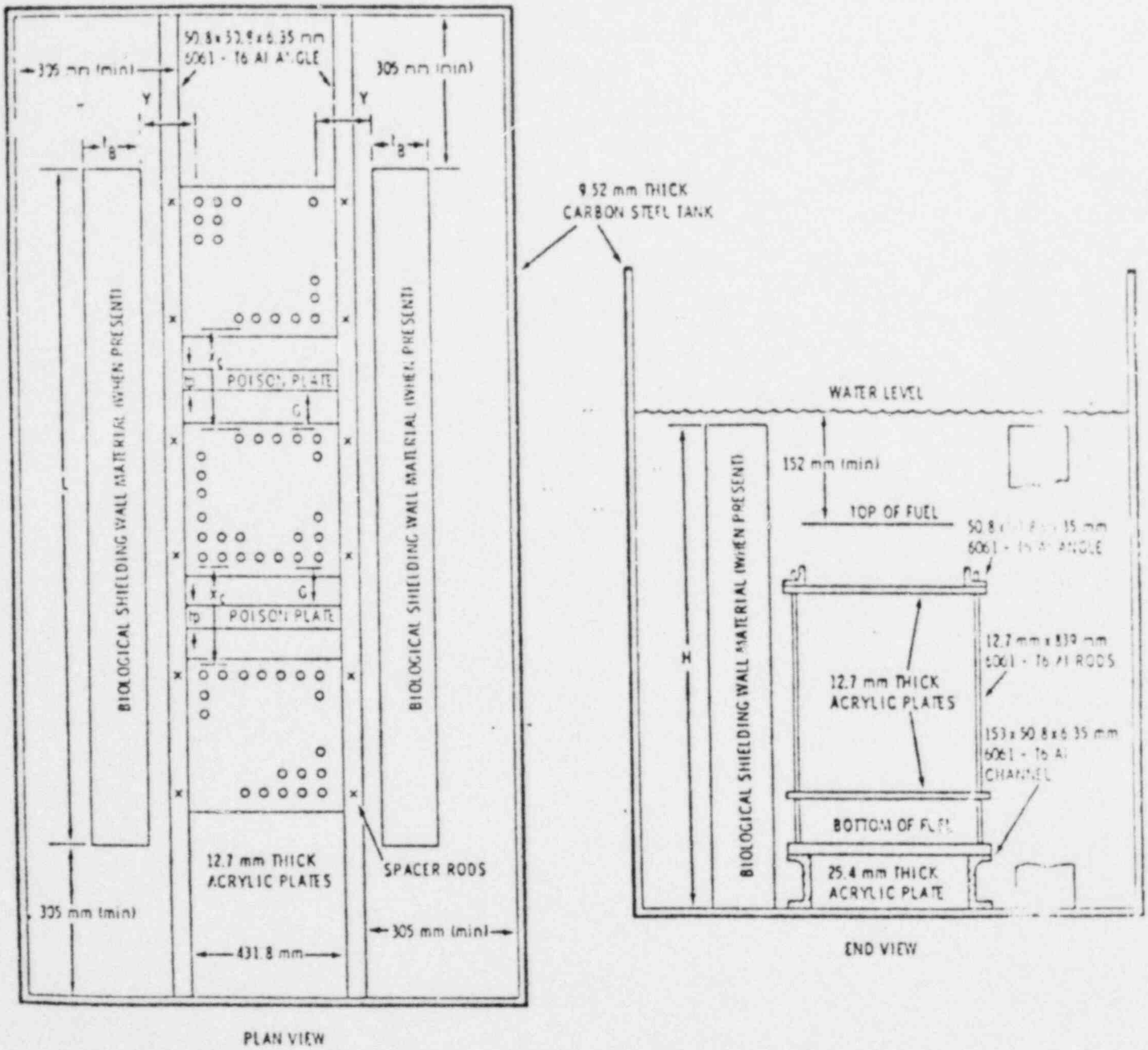


FIGURE 1

TABLE 7.2.1

EXPERIMENTAL DATA ON CLUSTERS OF 2.35 wt% ^{235}U ENRICHED UO_2 RODS IN WATER

FUEL CLUSTERS LENGTH x WIDTH 20.32mm SQ. PITCH (FUEL RODS)	CRITICAL SEPARATION BETWEEN FUEL CLUSTERS (1) (Xc, mm)	EXPERIMENT NUMBER
20 x 17	119.2 ± 0.4	015
20 x 16	83.9 ± 0.5	005
20 x 16	84.4 ± 0.5	049 (2)
22 x 16 (3)	100.5 ± 0.5	018
20 x 14	44.6 ± 1.0	021

(1) PERPENDICULAR DISTANCE BETWEEN THE CELL BOUNDARIES OF THE FUEL CLUSTERS. ERROR LIMITS ARE ONE STANDARD DEVIATION

(2) RERUN OF EXPERIMENT 005

(3) CENTER FUEL CLUSTER AT 20 x 16 RODS. TWO OUTER FUEL CLUSTERS AT 22 x 16 RODS EACH

TABLE 7.2.2

EXPERIMENTAL DATA ON CLUSTERS OF 2.35 wt% ^{235}U ENRICHED UO_2 RODS IN WATER WITH 304L STEEL PLATES BETWEEN FUEL CLUSTERS (1)

FUEL CLUSTERS	304L STEEL PLATES (2)				
LENGTH x WIDTH 20.32mm SQ. PITCH (FUEL RODS)	BORON CONTENT wt%	THICKNESS (lp, mm)	DISTANCE TO FUEL CLUSTER (3) (G, mm)	CRITICAL SEPARATION BETWEEN FUEL CLUSTERS (4) (Xc, mm)	EXPERIMENT NUMBER
20 x 16	0	4.85 ± 0.15	6.45 ± 0.06	68.8 ± 0.2	028
20 x 16	0	4.85 ± 0.15	27.32 ± 0.50	76.4 ± 0.4	005*
20 x 16	0	4.85 ± 0.15	40.42 ± 0.70	75.1 ± 0.3	029
20 x 16	0	3.02 ± 0.13	6.45 ± 0.06	74.2 ± 0.2	027
20 x 16	0	3.02 ± 0.13	40.42 ± 0.70	77.6 ± 0.3	026
20 x 17	0	3.02 ± 0.13	6.45 ± 0.06	104.4 ± 0.3	[illegible]
20 x 17	0	3.02 ± 0.13	40.42 ± 0.70	114.7 ± 0.3	035
20 x 17	1.05	2.98 ± 0.06	6.45 ± 0.06	75.6 ± 0.2	032
20 x 17	1.05	2.98 ± 0.06	40.42 ± 0.70	96.2 ± 0.3	033
20 x 17	1.62	2.98 ± 0.05	6.45 ± 0.06	73.6 ± 0.3	038
20 x 17	1.62	2.98 ± 0.05	40.42 ± 0.70	95.2 ± 0.3	039

(1) ERROR LIMITS SHOWN ARE ONE STANDARD DEVIATION

(2) PLATES ARE 356mm WIDE BY 915mm LONG.

(3) PERPENDICULAR DISTANCE BETWEEN THE CELL BOUNDARY OF THE CENTER FUEL CLUSTER AND THE NEAR SURFACE OF THE STEEL PLATE

(4) PERPENDICULAR DISTANCE BETWEEN THE CELL BOUNDARIES OF THE FUEL CLUSTERS

*To distinguish from experiment #005 of Table 1.

TABLE 7.2.3

EXPERIMENTAL DATA ON CLUSTERS OF 2.35 wt% ^{235}U ENRICHED UO_2 RODS IN WATER WITH BORAL PLATES BETWEEN FUEL CLUSTERS (1)

FUEL CLUSTERS	BORAL PLATES			
LENGTH x WIDTH 20.32mm SQ. PITCH (FUEL RODS)	THICKNESS(2) (tp, mm)	DISTANCE TO FUEL CLUSTER (3) (G, mm)	CRITICAL SEPARATION BETWEEN FUEL CLUSTERS(4) (Xc, mm)	EXPERIMENT NUMBER
20 x 17	7.13 ± 0.11	6.45 x 0.06	63.4 ± 0.2	020
20 x 17	7.13 ± 0.11	44.42 ± 0.60	90.3 ± 0.5	016
22 x 16 (5)	7.13 ± 0.11	6.45 ± 0.06	50.5 ± 0.3	017

(1) ERROR LIMITS SHOWN ARE ONE STANDARD DEVIATION

(2) INCLUDES 1.02 mm THICK CLADDING OF TYPE 1100 Al ON EITHER SIDE OF THE B_4C-Al CORE MATERIAL. PLATES 365mm WIDE BY 915 mm LONG.

(3) PERPENDICULAR DISTANCE BETWEEN THE CELL BOUNDARY OF THE CENTER FUEL CLUSTER AND THE NEAR SURFACE OF THE BORAL PLATE

(4) PERPENDICULAR DISTANCE BETWEEN THE CELL BOUNDARIES OF THE FUEL CLUSTERS

(5) CENTER FUEL CLUSTER AT 20 x 16 RODS. TWO OUTER FUEL CLUSTERS AT 22 x 16 RODS EACH

made necessary a three dimensional treatment, the Monte Carlo Code KENO IV (Reference 5) was used with six axial levels. Batches of one hundred neutron histories were used with the first four discarded. Calculated K_{eff} values are shown in Table 7.2.4 For economy, about 150 batches were run for most cases, however, because of their greater use in fuel storage analyses, about 500 batches were employed for the plain stainless steel and boral experiments.

The mean value of the calculated k_{eff} is 1.00157 with a standard deviation of .00419; thus at a 95/95 confidence level using a σ multiplier of 2.423, the k_{eff} values are between 1.012 and 0.991.

7.2.3 References:

1. S. R. Bierman, E. D. Clayton and B. M. Durst, Critical Separation Between Subcritical Clusters of 2.35 w/o U^{235} Enriched UO_2 Rods in Water with Fixed Neutron Poisons, PNL-2438, October 1977.

2. CEPAK - A Synthesis of the following codes:

   FORM - A Fourier Transform Fast Spectrum Code for the IBM-7090, McGoff, D. J., NAA-SR-Memo 5766 (September 1960)

   THERMOS - A Thermalization Transport Theory Code for Reactor Lattice Calculations, Honeck, H., BNL-5816 (July 1961).

   CINDER - A One-Point Depletion and Fission Product Program, England, T. R., WAPD-TM-334 (Revised June 1964).

3. J. Adir, S. Clark, R. Froelich, and L. Tody, Users and Programmers Manual for the GGC-3 Multigroup Cross Section Code, GA-7157, July 25, 1967.

4. R. G. Sottesy, R. K. Disney, A. Collier, Users Manual for the DOT-IIW Discrete Ordinates Transport Computer Code, WANL-TME-1982, December 1969.

5. L. M. Petrie and N. F. Cross, KENO IV, An Improved Monte Carlo Criticality Program, ORNL-4938, November 1975.

TABLE 7.2.4

Calculated k_{eff} Values

Expt #	Type Poison Plate	K_{eff}	Monte Carlo (STD Deviation)
15	None	1.00227	.00534
04	None	0.99912	.00540
49	None	1.00221	.00473
18	None	1.00813	.00489
21	None	0.99589	.00461
03	304 S Steel 0.0 w/o Boron	1.00393	.00308
05	304 S Steel 0.0 w/o Boron	1.00329	.00303
29	304 S Steel 0.0 w/o Boron	1.00271	.00302
27	304 S Steel 0.0 w/o Boron	1.00418	.00273
26	304 S Steel 0.0 w/o Boron	0.99811	.00279
34	304 S Steel 0.0 w/o Boron	0.99793	.00297
35	304 S Steel 0.0 w/o Boron	1.00436	.00290
32	304 S Steel 1.05 w/o Boron	0.99970	.00524
33	304 S Steel 1.05 w/o Boron	1.01173	.00491
38	304 S Steel 1.62 w/o Boron	1.00289	.00512
39	304 S Steel 1.62 w/o Boron	1.00208	.00506
20	Boral	0.99585	.00301
16	Boral	1.00020	.00288
17	Boral	0.99519	.00286

Mean K_{eff} Value 1.00157

Std. deviation .00419

8.0 PROCESS DESCRIPTION AND SAFETY ANALYSES

This section contains detailed descriptions of all operations in the Manufacturing Facility (Building #17 and #21). Sufficient detail is provided to permit an independent verification of the adequacy of the controls for the purpose of assuring safe operations.

Nuclear criticality limits are taken from Table 4.2.5 of Part I. In certain operations, the intricacies of the equipment require further analysis, which is provided herein. Details of specific calculations used to support various aspects of this analysis, and several statements and considerations in Section 4 of Part I are discussed in this section.

This section provides typical analyses for operations conducted within the scope of this license. Present arrangements of the equipment in the pelletizing facility are shown in Figure B-1. This arrangement may be changed in accordance with the procedures in Section 4 of Part I of this license renewal application.

8.1 UO_2 Powder Processing

8.1.1 Receipt of Material

All UO_2 powder is received in licensed shipping containers from C-E's dry process oxide conversion plant at Hematite, Missouri. The as-received 9.75" diameter stainless steel UO_2 powder cans to be stored in the virgin powder storage area (W.S. P-1 in Figure B-1) shall be sampled before being placed in the storage area to demonstrate on a 95/95 confidence level that the moisture content of powder lots is less than 5 wt.%. In addition, all damaged packages where containment is breached will be sampled.

8.1.2 Virgin Powder Storage Area

The virgin powder storage area is isolated from the remainder of the plant on all sides by concrete block walls, a double steel roof, and a metal fire door. This door is normally in the open position, and is automatically closed upon activation of the fire alarm, and on failure of electrical power. The automatic closing feature of this door shall be verified quarterly and records of its performance shall be maintained. These engineered safety features are considered adequate to prevent the introduction of water in the event of a fire. This area will be kept free of combustibles, and is located such that there are no potentially hazardous items such as boilers in the vicinity of the area.

The storage area itself is a 5 x 6 array of parallel roller conveyors, each 128 inches long. The steel structure associated with the conveyors provides a minimum edge-to-edge separation distance of 12 inches between all powder containers, both horizontally and vertically.

Criticality Safety Analysis

The following conservative assumptions were incorporated into the calculational model of the Virgin Powder Storage Area:

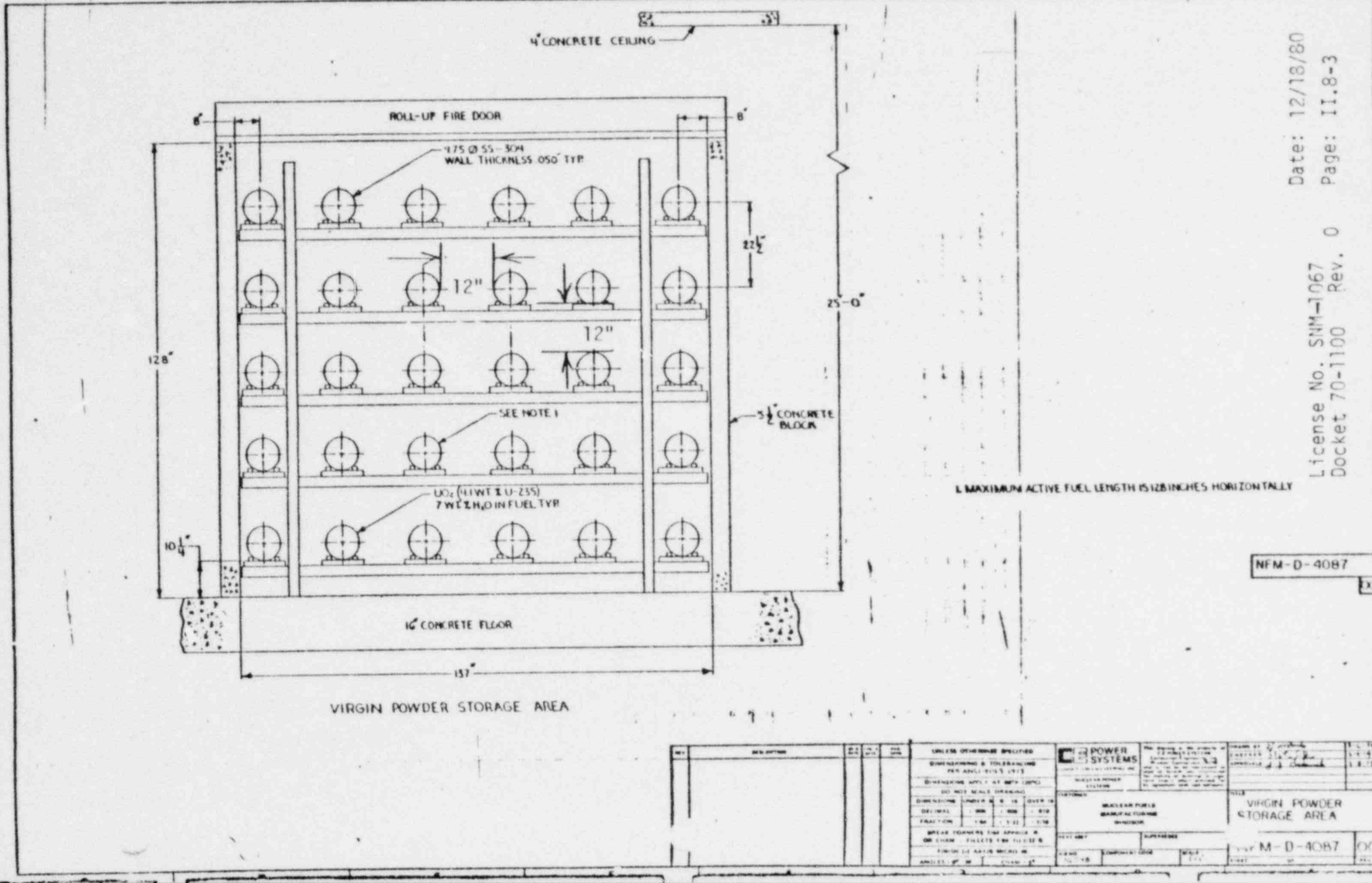
1) All steel structural materials were neglected.
2) The fuel was assumed to be a homogeneous mixture of UO_2 containing 7.0 wt% H_2O.
3) All storage positions were filled and each individual can was assumed to be full.
4) Effects of interspersed water moderation and flooding were not addressed.

The KENO-IV Code with sixteen group Hansen-Roach cross sections was used to determine the reactivity of the Virgin Powder Storage Area under the conditions noted above. Dimensional details of the model are provided in Figure 8.1. A k_{eff} of 0.9338 ± 0.0077 was obtained for an infinite system in the horizontal direction.

8.1.3 Batch Make-Up

Powder containers are removed from the virgin powder storage area and placed on a conveyor (W.S.P-2) (safe cylinder limit) for transfer to the Batch Make-Up Hood (W.S. P-3). A maximum of three 9.75 inch diameter x 11 inch long stainless steel powder containers shall be clamped to fixtures in the hood (safe geometry) where

8.1 Virgin Powder Storage Area



an appropriate batch of less than 35 kg UO_2 is weighed out and put into 5-gallon pails. The batch weights and enrichment are recorded on the container. A water tight cover is secured to these batch containers and they are then conveyed (W.S. P-4) to a lift (W.S. P-5) for transfer to the blender hoods (W.S. P-6). The batch make-up operation is enclosed in a ventilated hood. Sufficient negative pressure is provided to assure a minimum face velocity of 100 fpm.

Criticality Safety Analysis

The following conservative assumptions were incorporated into the calculational model of the Batch Make-Up Hood and associated conveyors (W.S. P-3 and P-4):

1) The 3 stainless steel UO_2 powder cans inside the hood were considered to be full at optimum moderation and maximum enrichment (4.1% wt.% U^{235}).

2) The 5-gallon batch make-up bucket inside the hood was assumed to contain UO_2 powder at optimum moderation and maximum enrichment (4.1% wt.% U^{235}).

3) The stainless steel of the 9.75" diameter x 11" long powder containers was modeled. All other structural steel in the hood was neglected.

4) All sealed containers of UO_2 on conveyors (W.S. P-2 and P-4) adjacent to the hood were assumed to contain 7.0 wt.% H_2O.

The KENO-IV Code with 16 group Hansen-Roach cross sections was used to determine the reactivity of the system under various conditions of moderation.

Optimum moderation of the fuel containers within the hood occured at a fuel concentration of 1.8 gm U/cc in water, assuming no external mist. The highest reactivity of 0.7934 ± 0.0070 for an infinite system (at 1.8 gm U/cc in water) occurred for the full flood case. Additional calculations for the external full flood condition were run for various concentrations of fuel in water ranging from 1.2 - 3.5 gm U/cc. The peak system reactivity of 0.8595 ± 0.0117 for the flooded cases occurred at a fuel concentration of 2.6 gm U/cc in water. Dimensional details of the calculational model and results of the calculations are shown in figures 8.2 thru 8.5.

8.1.4 Powder Preparation and Blending

UO_2 powder from one sealed batch container (moderation control assured) is transferred to a blender where it is mixed with a binder (W.S. P-6). Two separate blenders feed a common powder spread funnel by means of individual powder transfer pipes entering at a 45° angle. An identical powder preparation line runs parallel to this one at a centerline distance of 13 feet.

The blending operation is enclosed in a ventilated hood. Sufficient negative pressure is provided to assure a minimum face velocity of 100 fpm.

8.1.4.1 Drying

Agglomerated UO_2 powder is spread onto the dryer belt (W.S. P-7) from the powder spread funnel to a controlled depth of 1/2". A complete enclosure is provided around the dryer belt assembly and this enclosure is maintained at a slight negative pressure. The discharge end of the dryer belt utilizes a wiper blade to prevent the flow of significant amounts of material to the plenum under the belt. Nevertheless, the wiper blade and plenum shall be inspected once per week to assure that the wiper blade is functioning properly and no fuel is accumulating in the plenum below the belt. Records of these inspections are maintained. The belt dryer operates on a 1/2" slab limit. (The criticality safety analysis also assumed an accidental accumulation of up to 1/2" of powder under the dryer belt in the event of malfunction of the wiper blade). The safety of the dryer assembly is assured by this restricted slab thickness.

The dryer heater controls are wired to the motor control such that the dryer belt cannot be activated unless the heaters are turned on, and to stop the belt under conditions of high heat (high heat automatically shuts off the heating elements).

8.2 Criticality Safety Model-Batch Make Up Area

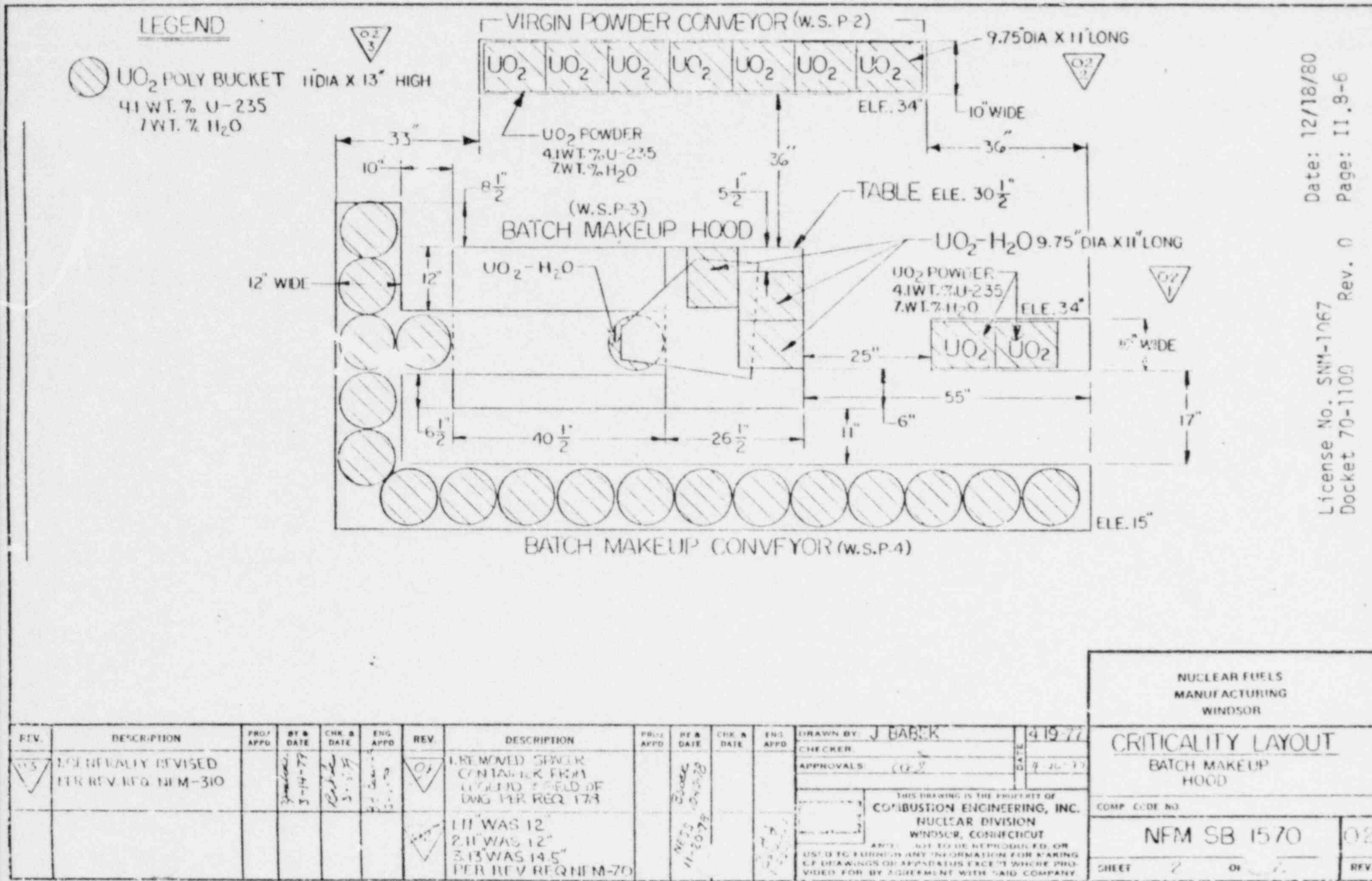
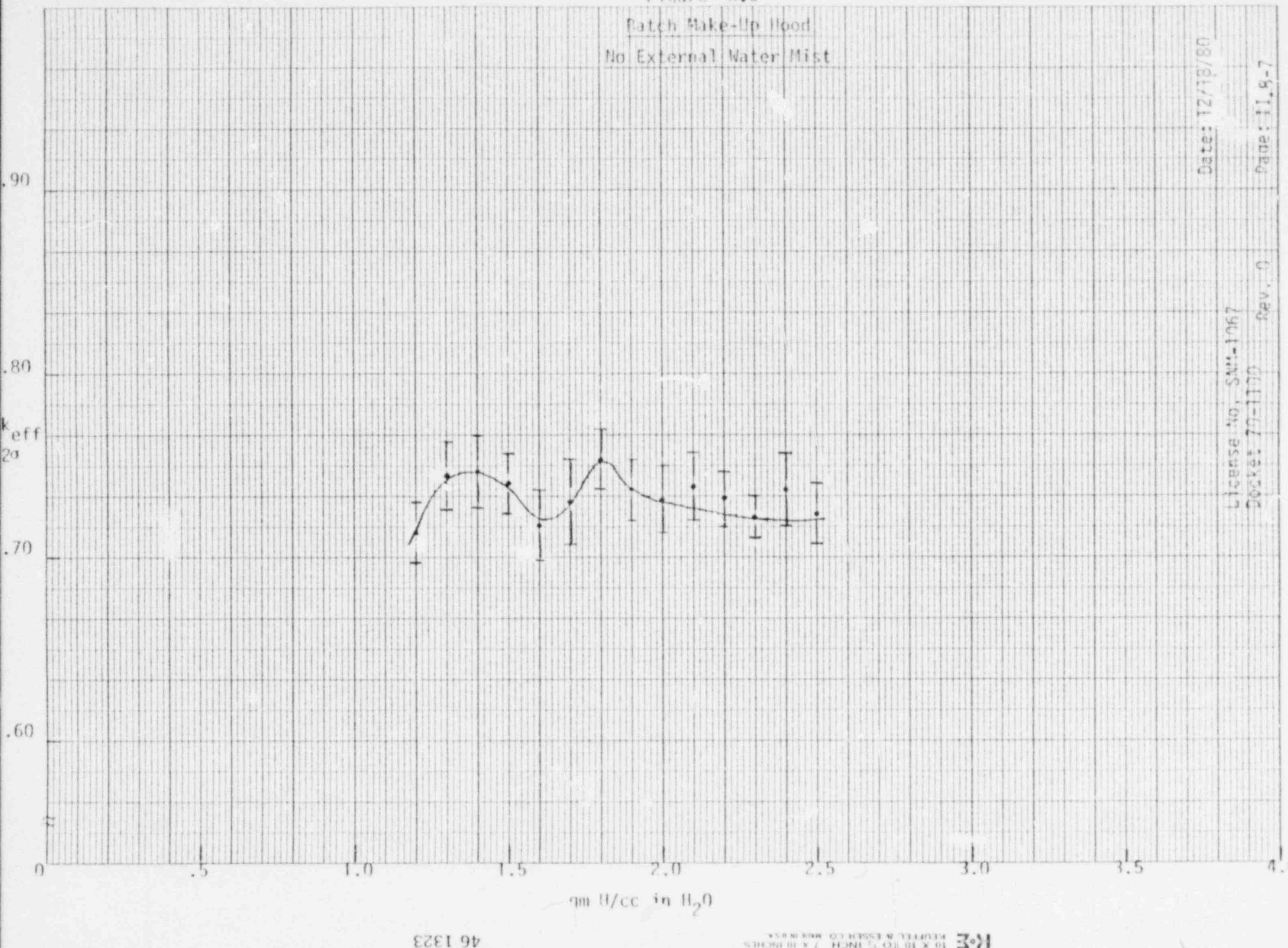


Figure 8.3



Batch Make-Up Hood
No External Water Mist
Date: 12/18/80
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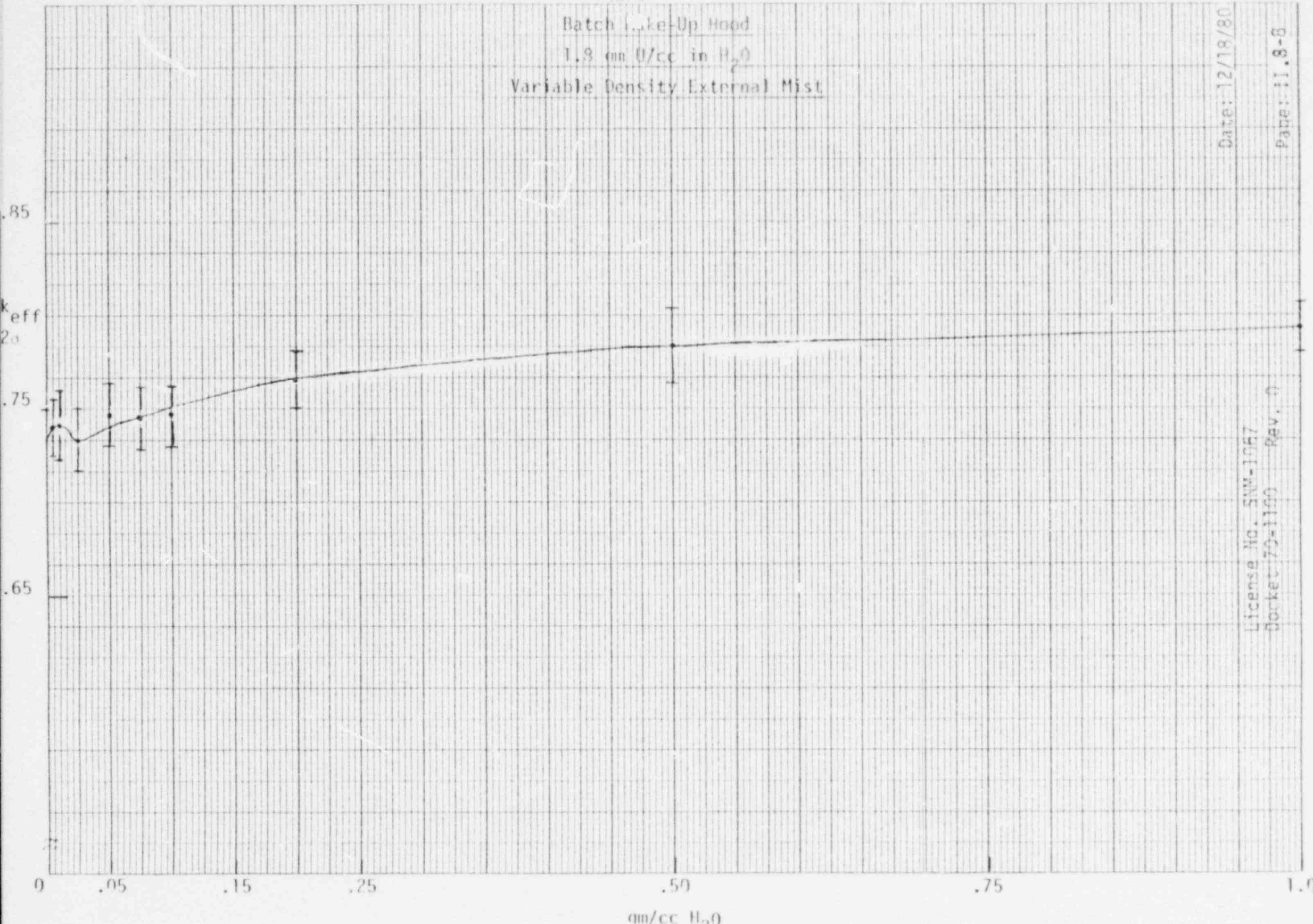
Docket 70-1100
Rev. 0
.90
.80
k_{eff}
2σ
.70
.60
0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
gm U/cc in H_2O
46 1323
K&E 10 X 10 TO ½ INCH 7 X 10 INCHES KEUFFEL & ESSER CO. MADE IN U.S.A.

Figure 8.4



46 1323

K&E 10 X 10 TO ½ INCH 7 X 10 INCHES KEUFFEL & ESSER CO.

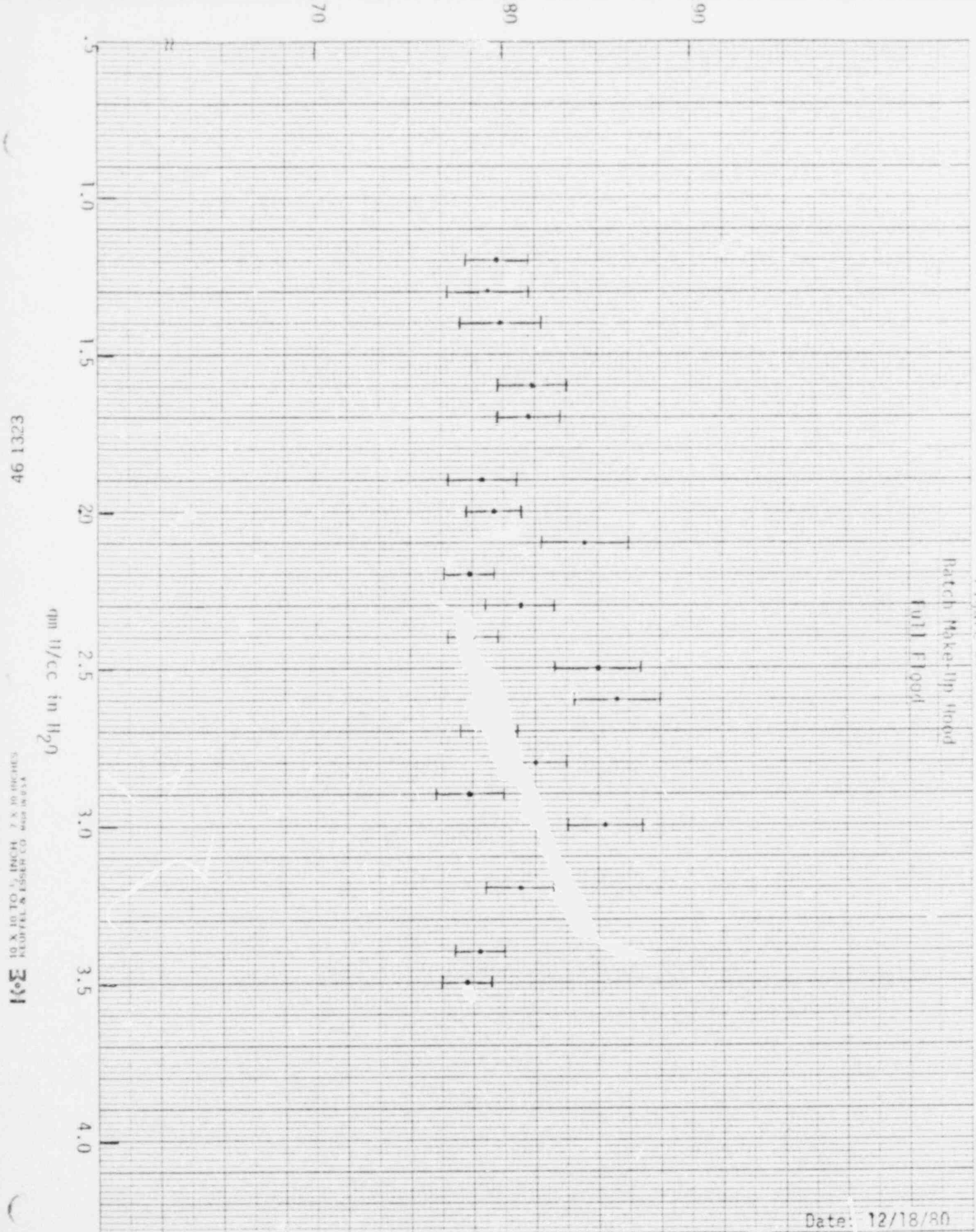


Figure 8.5
Batch Make-Up Hood
Full Flood
gm U/cc in H_2O
.70
.80
.90
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
46 1323

8.1.4.2 Granulation

Dried oxide is gravity-fed into a granulator (W.S. P-8) where it is sized for subsequent pressing. The granulated powder is then gravity-fed through a discharge funnel ending in a 2 inch square opening. A short adapter of 2 inch circular cross section is welded to the funnel to allow connection of a 2" diameter hose which is then connected to a portable hopper below (W.S. P-9).

A complete enclosure is provided around the granulator. It is maintained at a negative pressure to preclude dusting.

Criticality Safety Analysis

The powder blending, drying, and granulation stations (W.S. P-6, P-7, P-8 and P-9) were divided into two parts for calculational purposes: The back end of the station included the blenders, the powder transfer pipes leading to the powder spread funnel, and the first 10 feet of the 30" wide dryer belt. The spread funnel is fixed in position to restrict the powder discharge from it to a 24" wide by 1/2" deep layer of UO_2. The following conservative assumptions were incorporated into the calculational model of the back end:

1. The blender hoods are restricted to $\leq$35 kg UO_2 per station. It was assumed that this mass of UO_2 was located at the base of each blender hood directly above each powder transfer pipe.
2. It was assumed that the above masses were hemispherical in shape, and were at optimum moderation and maximum enrichment (4.1 wt.% U^{235}). The radii of these hemispheres varies as a function of the assumed concentration of UO_2 in water in order to maintain a fixed mass of 35 Kg UO_2 in each.

3. Although the belt dryer is limited to 1/2" of UO_2 powder, the model allows for an accidental accumulation of 1/2" under the dryer belt in the event of malfunction of the wiper blade.

4. The powder transfer pipes and powder spread funnel were assumed to be filled to capacity with UO_2 at optimum moderation and maximum enrichment (4.1 wt.% U^{235}).

5. An infinite array of stations was analyzed although there are only 2 parallel stations.

Sixteen group Hansen-Roach cross sections were used in KENO-IV to determine the reactivity of the system under various conditions. Optimum moderation (assuming no external mist) occurred at a fuel concentration of 0.8 gm u/cc in water (very undermoderated system initially). Variable density external water mist was then introduced to determine peak reactivity of the system. The highest k_{eff} of 0.8698 ± 0.0103 occurred for the full flood case although a secondary peak of 0.7656 ± 0.0077 was found at 0.025 gm/cc interspersed water moderation. As this system was initially undermoderated, it was difficult to determine whether the large amount of water necessary to bring the system to peak reactivity was a result of the large amount introduced into the fuel directly (0.8 gm U/cc in water) or the result of full density external water introduced in the flooded case. As a final check, the fuel concentration in water (gm U/cc) was varied while holding the external moderation condition at full flood. A peak reactivity of 0.8684 ± 0.0101 was obtained at a fuel concentration of 1.2 gm u/cc in water, although the reactivities of the other cases resulted in statistical overlap, and were therefore essentially of the same magnitude. The conclusion drawn from the above analysis is that peak reactivity for this system occurred as a result of external flooding and reflection rather than by optimization of the fuel concentration in the various individual fuel-bearing components of the system.

The front end of the station included the last 10 feet of the 30" wide dryer belt, the granulator, the discharge funnel and hose, and a cylindrical press feed hopper. Two different hoppers are available for use depending on the enrichment being processed. For $\leq$3.5 wt.% U^{235}, an 11" diameter, 40" long cylindrical hopper with a conical top is used. For enrichments up to 4.1 wt.% U^{235}, a 10.5", 17.7" long cylindrical hopper (safe volume) with a flat top is used. The longer hoppers will be stored under lock and key prior to the start of processing of any enrichment greater than 3.5 wt.% U^{235}. Reactivity calculations were performed at the maximum allowable enrichment for each case. The following conservative assumptions were incorporated into the calculational models of the front end:

1) All system components except for the dryer belt were assumed to be filled to capacity with UO_2 at optimum moderation and maximum enrichment (3.5 or 4.1 wt.% U^{235}).
2) Although the belt dryer is limited to 1/2" of UO_2 powder, the model allows for an accidental accumulation of 1/2" under the dryer belt in the event of malfunction of the wiper blade.
3) An infinite array of stations was analyzed although there are only 2 parallel stations.

Sixteen group Hansen-Roach cross sections were used in KENO-IV to determine the reactivity of the system under various conditions. For the first case, the system was analyzed at 4.1 wt.% U^{235} with the 10.5" diameter, 17.7" long press feed hopper. Optimum moderation (assuming no external mist) occurred at a fuel concentration of 1.8 gm U/cc in water. Variable density external water mist was then introduced to determine peak reactivity of the system with the 10.5" hopper. The highest k_{eff} of 0.9386 ± 0.0075 occurred for the full flood case.

For the second case, the system was analyzed at 3.5 wt.% U^{235} with the 11" diameter, 40" long press feed hopper. The maximum k_{eff} in the absence of external water mist occurred at 2.2 gm U/cc in water. This result was derived from calculations at 2.0, 2.2, and 2.4 gm U/cc with associated k_{eff} values of 0.800 ± 0.010, 0.833 ± 0.014, and 0.804 ± 0.014 respectively. Variable density external water mist was then introduced to determine peak reactivity of the system with the 11" hopper. The highest k_{eff} of 0.934 ± 0.17 occurred for the full flood case. This result was derived from calculations at 0.001, 0.01, 0.05, 0.10, and 1.0 gm/cc of H_2O with associated k_{eff} values of 0.825 ± 0.016, 0.821 ± 0.020, 0.8?5 ± 0.012, 0.850 ± 0.014, and 0.934 ± 0.017 respectively.

Dimensional details of both calculational models and the results obtained for the 4.1% cases are shown in figures 8.6 thru 8.12.

8.1.5 Final Mixing

Filled press feed hoppers may be rolled to assure complete blending of the die lubricant (W.S. P-10).

8.1.6 Pressing

The filled portable hoppers are transferred to the pelletizing presses (W.S. P-11) and secured to assure their stability and the containment of powder. Powder is gravity fed to the press, and compacted to green pellets which are placed into furnace boats. The boats have a maximum height of 3.7 inches. Only one boat shall be at each press at any one time. Each press is provided a spacing area of at least 20 ft^2.

The press is provided with enclosures which assure adequate ventilation at the opening face, and at the junction of the portable hopper with the press. Air flow rates are sufficient to assure face velocities of at least 100 fpm.

Two work benches (W.S. P-12) are provided for inspection of pellets. These stations are limited to one safe mass each.

8.1.7 Dewaxing and Sintering

Furnace boats containing green pellets are charged in a single line to a dewaxing furnace (W.S. P-13), and then to a sintering furnace

Figure 8.6 Powder Preparation Station-Back End

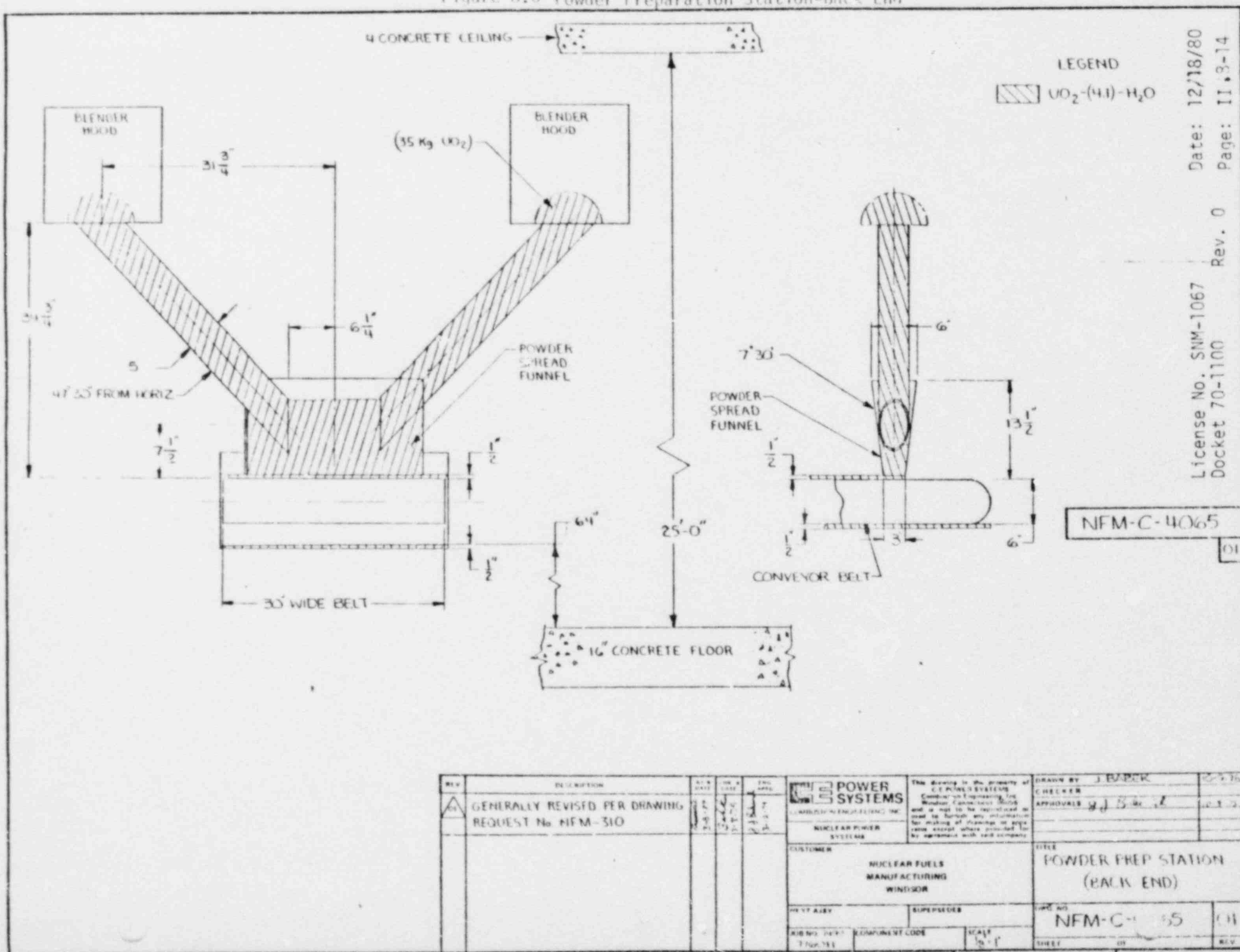


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Figure 8.7

Powder Preparation Station-[illegible]

No External Mist

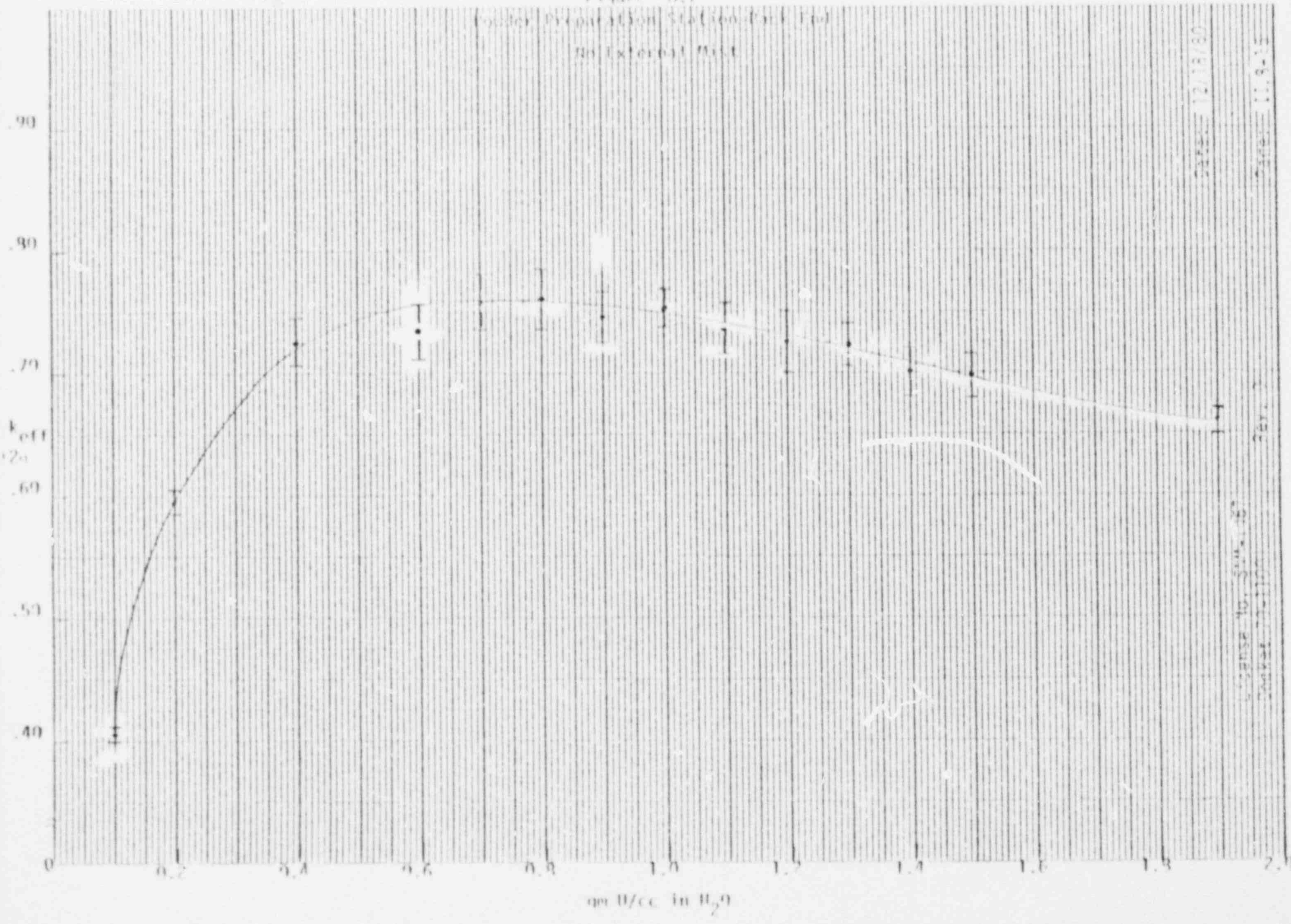

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Figure 8.8

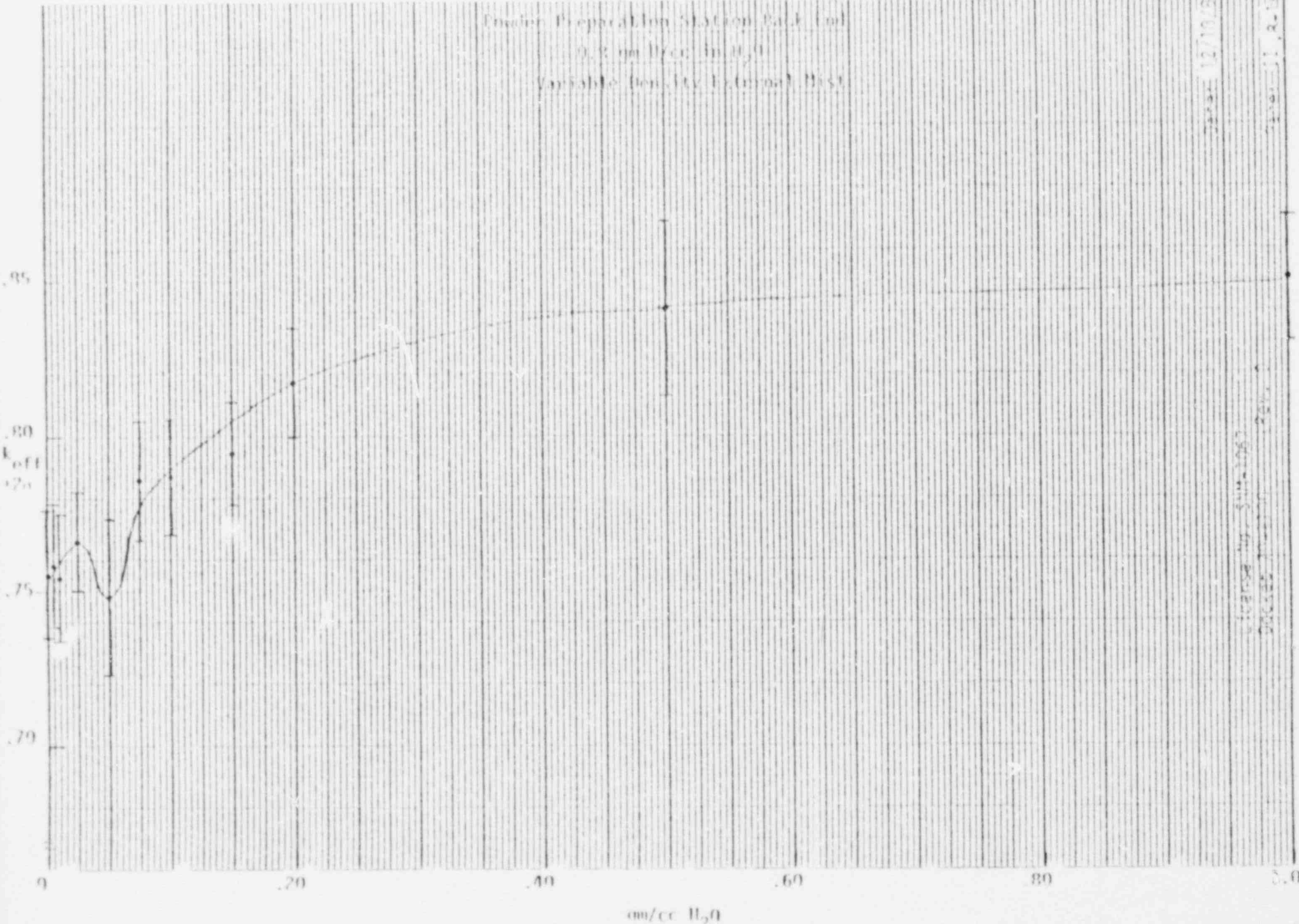


Figure 8.9

Powder Preparation Station Rack [illegible]

Full Flood

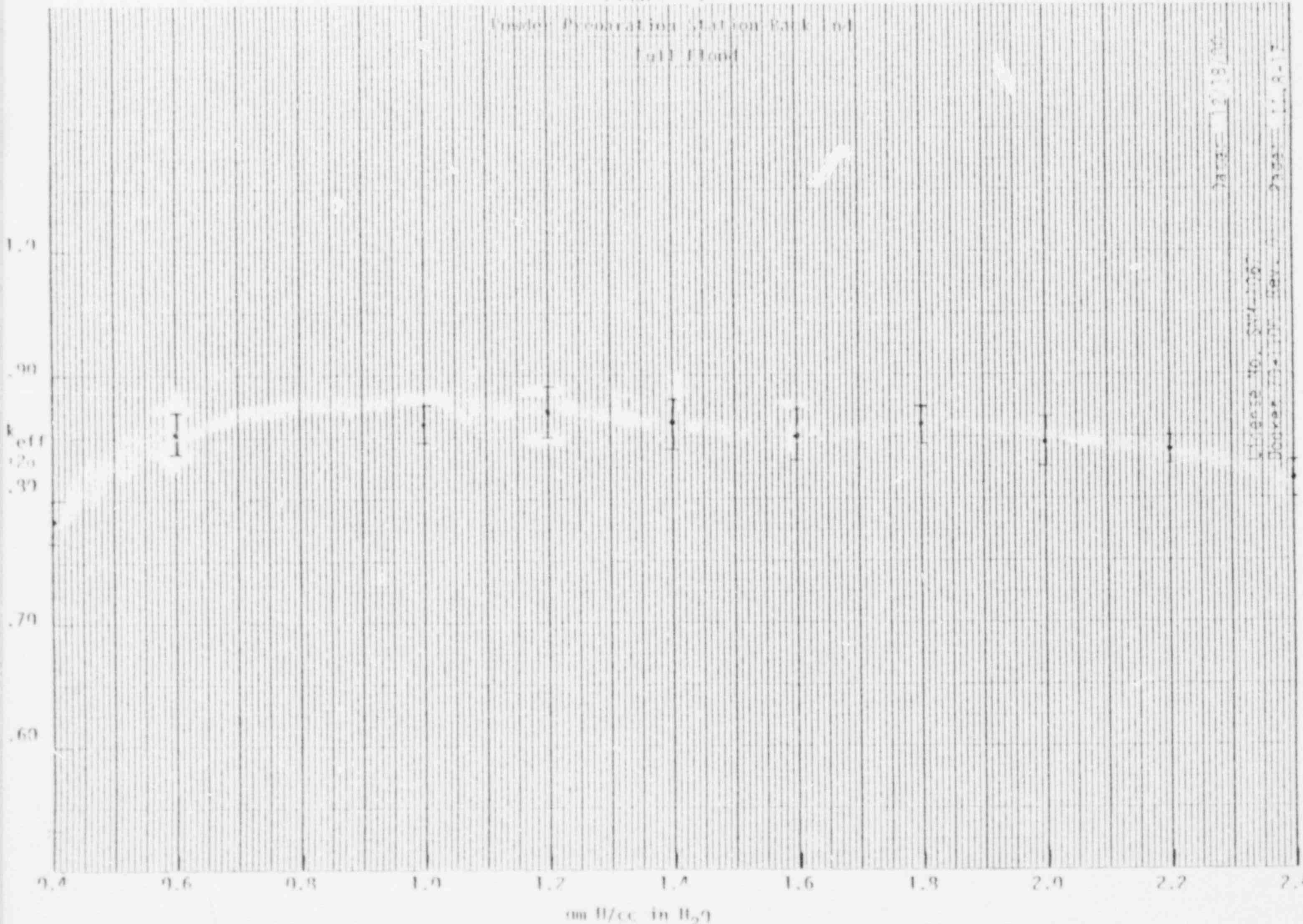
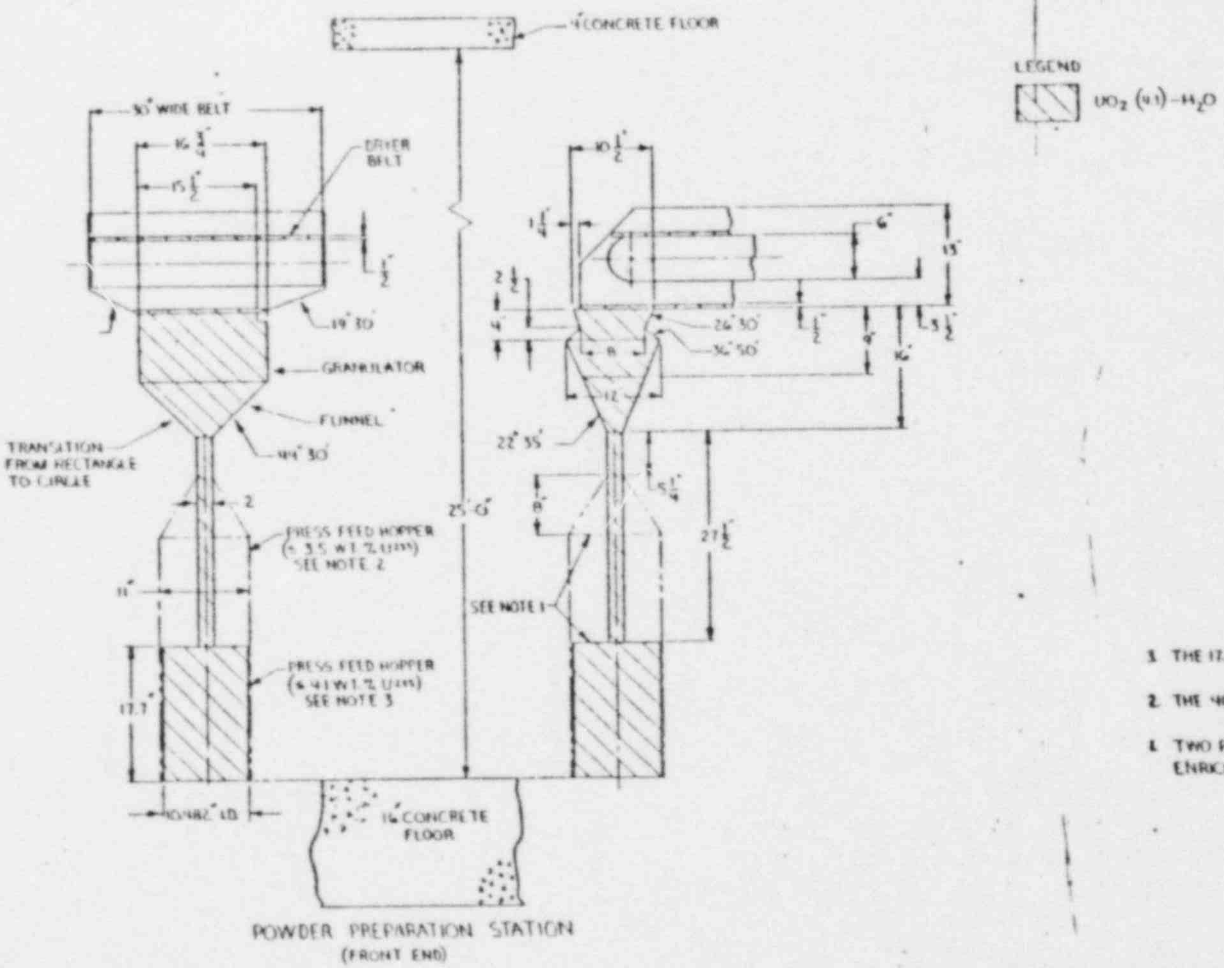


Figure 8.10 Powder Preparation Station - Front End
Criticality Model



3. THE 17.7 HIGH HOPPER IS USED FOR (≤ 4.1 WT. % U235)

2. THE 40" HIGH HOPPER IS USED FOR (≤ 3.5 WT.% U235)

1. TWO PORTABLE PRESS FEED HOPPERS ARE AVAILABLE, DEPENDING ON ENRICHMENT BEING PROCESSED.

NFM-D-4066

POWER SYSTEMS

NUCLEAR FUELS MANUFACTURING WINDSOR

POWDER PREPARATION STATION (FRONT END)

NFM-D-4066 00

Figure 8.11

Powder Preparation Station Front End

No External Water Mist

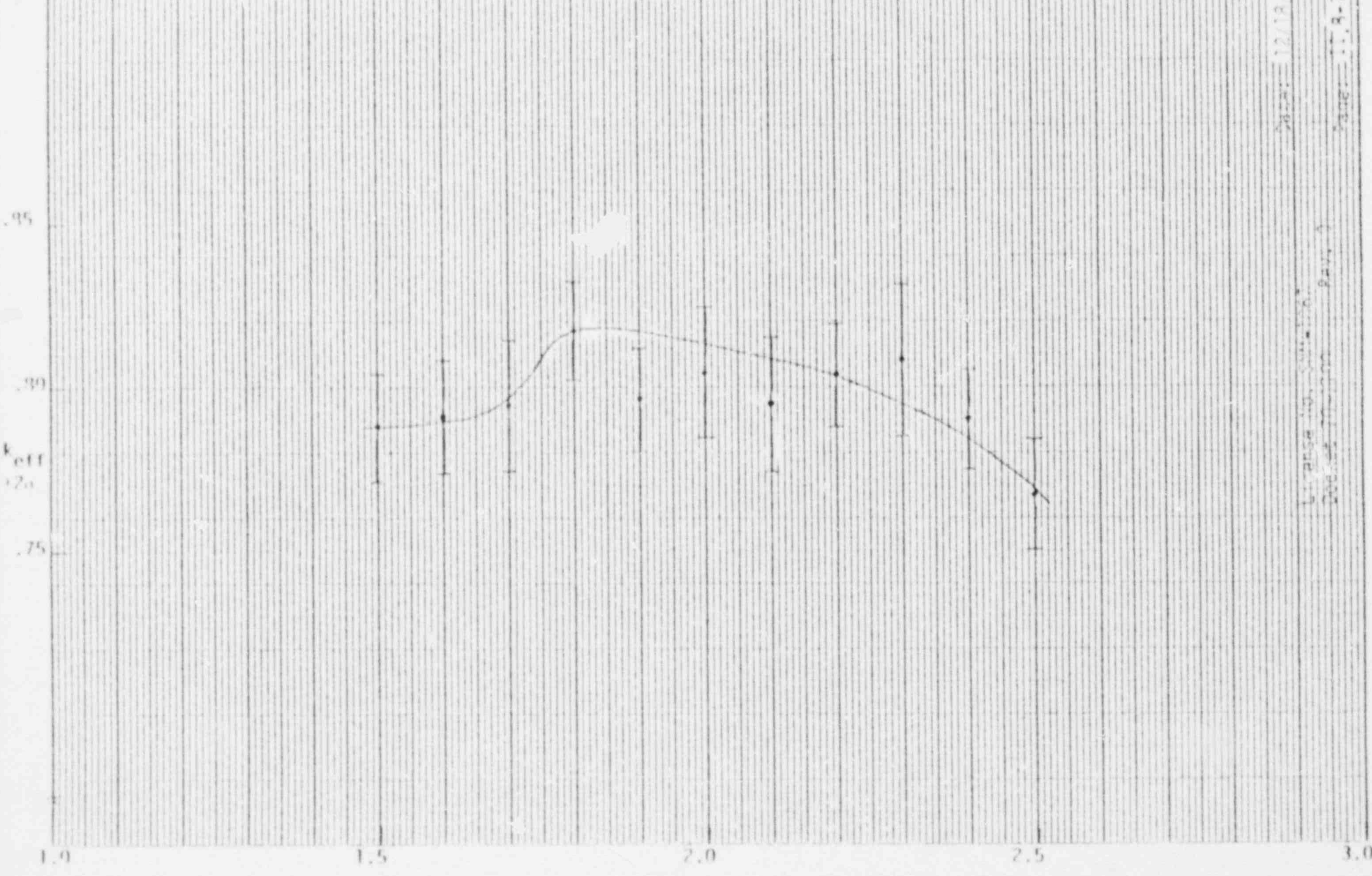


Figure 8.12

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(W.S. P-14), where under controlled conditions, the pellets attain the desired properties. Because the UO_2 is in a compacted form, dusting is minimal, and ventilation is not required. Hydrogen burn-off exhaust is vented from the building, and is filtered and monitored as specified in Section 3.2.3 of Part I. The furnaces and their interconnecting conveyors are slab limited, with pellet heights never exceeding 3.7 inches. It should be pointed out that the thickness of sintered pellets in the furnace boats will be considerably less than that of the green pellets because of the densification which occurs during sintering.

Furnace boats containing sintered pellets are stored at W.S. P-15. A maximum slab thickness of 3.7 inches is permitted.

8.1.8 Final Sizing

Sintered pellets are transferred to the grinder feed system (W.S. P-16) where they are aligned for the grinding operation which is carried out under a stream of coolant. The coolant is centrifuged (W.S. P-26 safe volume) to remove solids, and is recirculated at a uranium concentration considerably less than one gm/liter. The infeeder, grinder and outfeeder (W.S. P-16 and 18) have pellet configurations limited to 3.7 inch slab thicknesses.

Grinder sludge is removed from the centrifuge and dried in an oven (W.S. P-24). The dried material subsequently stored in the concrete block storage area awaiting final disposition.

A complete enclosure is provided around the grinder to preclude the dusting of UO_2. The enclosure is maintained at a negative pressure with respect to the room.

The centrifuge is limited to a safe volume of less than 25 liters, and is provided a spacing area of 9.0 ft^2. The grinder coolant may collect in a one inch deep sump in the grinder and in a 25 liter sump behind the grinder, as shown in Figure B-1. Experience has shown that no appreciable sludge accumulates in the grinder sump. The centrifuge is cleaned periodically as required to permit continued operation.

Because of its low uranium concentration ($\leq$5.0 gm U/liter, the coolant is of no concern with respect to nuclear criticality safety. Nevertheless, Figure 8-1 does show spacing for the grinder sump to allow for any UO_2 settling which may occur. Grinder coolant is normally recirculated, but may be disposed of by evaporation, or by discharge to the radiation waste system. In the latter case, the uranium concentration is verified to be less than 3×10^{-5} uCi/cc.

Properly sized pellets are transferred on a conveyor (W.S. P-18) to a storage rack (W.S. P-20). Both are limited to a slab thickness of 3.7 inches.

8.2 Scrap Recycle

All clean scrap is accumulated for reprocessing and recycle with the feed material. Scrap may be milled to yield desired particle size best suited for the processing, oxidized and reduced to assure removal of volatile additives and to achieve the desired ceramic properties of the resulting recycle UO_2, and blended to assure uniformity. The following equipment is included in the pellet shop and annex:

a) Oxidation and reduction furnace (W.S. P-65)
b) Milling equipment (W.S. P-62)
c) Coildown equipment (W.S. P-23 & P-24)
d) General purpose hood (W.S. P-67)
e) Filte knockdown hood (W.S. P-69)
f) Storage facilities (as shown)
g) Blender (W.S. P-64)
h) Micronizer (W.S. P-68)

The furnace is similar in its operation to the furnaces previously described. Although the feed and exit zones of the furnace are not ventilated, sufficient reserve ventilation (Approximately 1800 SCFM) exists to provide such ventilation if surveys indicate the need.

The remaining operations except blending, are all carried out in hoods with sufficient ventilation to assure a face velocity of 100 fpm.

These operations are controlled by use of mass or volume limits in accordance with Section 4.2.5 with spacing provisions taken from Section 4.2.6 of Part I of this application as shown in Figure B-1. Positive spacing fixtures are used to assure spacing wherever more than one SIU is allowed in any given hood or box. A material balance log is maintained at the Milling Hood and Micronizer to provide additional assurance that the criticality limit of one safe mass will not be exceeded at these locations.

8.3 Storage and Transfer

8.3.1 Concrete Block Storage Area

A concrete block storage area is provided as shown in Figure B-1 (W.S. P-27 and P-70). This storage area is intended for volume limited SIU's and has a maximum height of 7 feet. The blocks are of solid 10" thick concrete, having a minimum density of $125\#/ft^3$. Mortar is used to join the blocks and to secure the structure to the building wall. Steel shelves, of at least 16 ga. thickness are built into the structure with a vertical spacing of at least 16 inches. Each storage position measures 16" wide x 14" deep, and is lined on three sides with 1/4" thick mild steel. The criticality safety analysis demonstrates that the spacing boundary can be located 48 inches from the front of the shelves. All pellets are contained in 3-1/2 gallon or smaller containers; homogeneous UO_2 is contained in 5-gallon or smaller containers.

Criticality Safety Analysis

The following conservative assumptions were incorporated into the calculational model of the concrete block storage area:

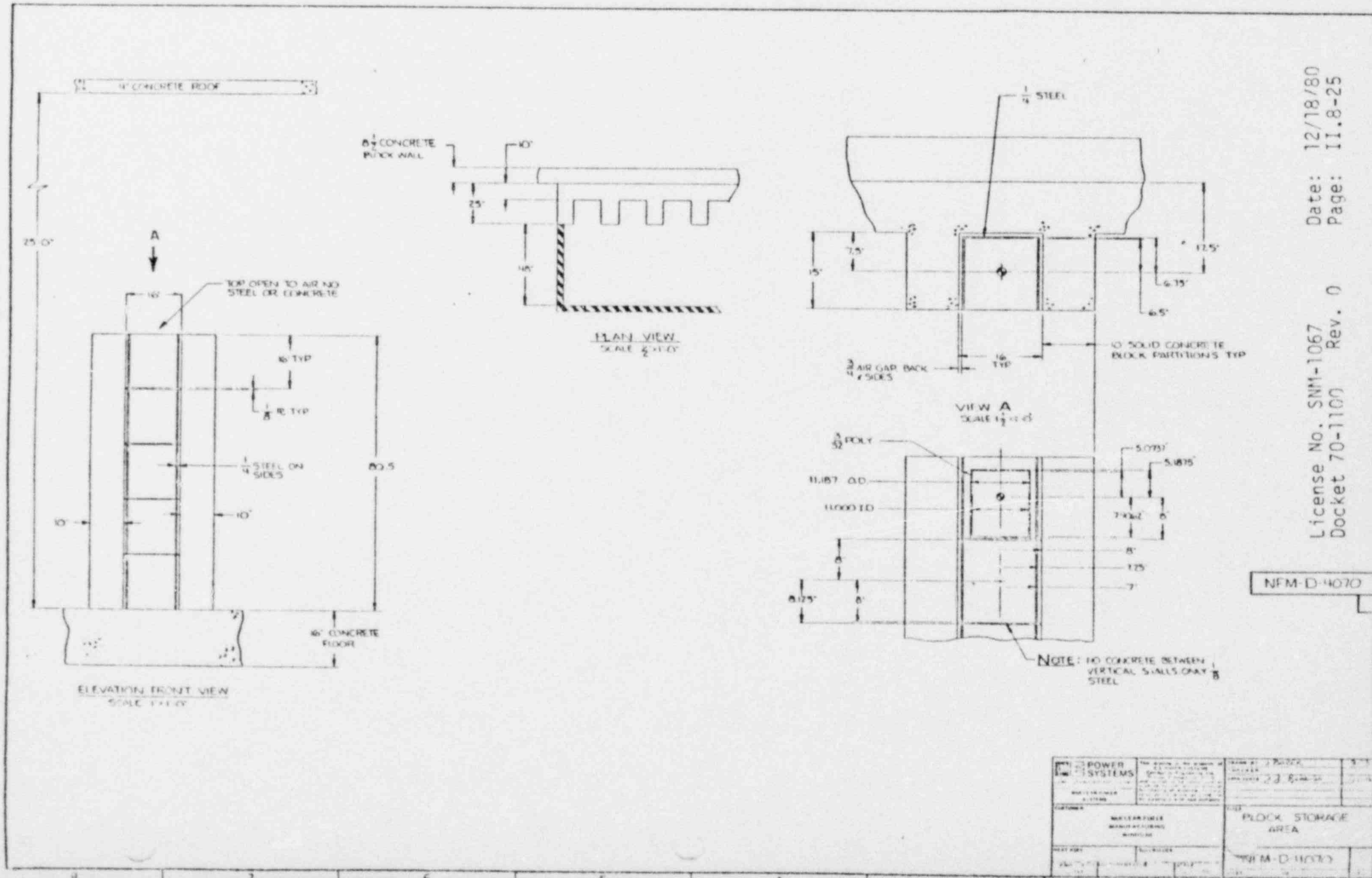
1) Each storage position was assumed to contain a 5-gallon poly bucket filled with UO_2 at optimum moderation and maximum enrichment (4.1 wt.% U^{235}).

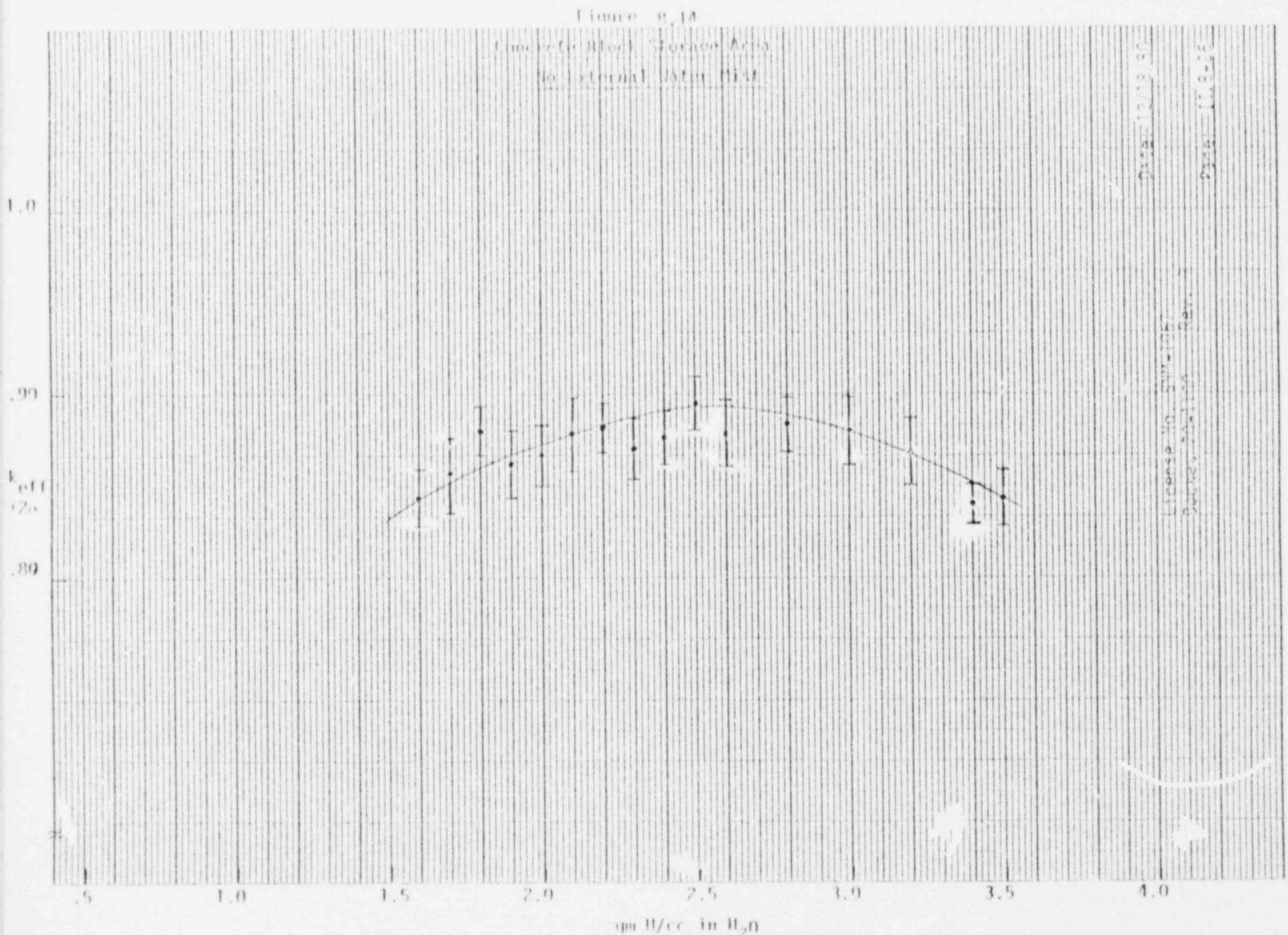
2) The system was assumed to be infinite in the horizontal plane.

3) Variable density external water mist was introduced to determine peak reactivity of the system.

The KENO-IV Code with 16 group Hansen-Roach cross sections was used to determine the reactivity of the concrete block storage area under various conditions of moderation. Optimum moderation of the fuel occurred at a concentration of 2.5 gm U/cc in water assuming no external water mist. The peak reactivity of the system, k_{eff} = 0.9207 ± 0.0081, occurred at an external water mist density of 0.75 gm/cc. Dimensional details of the calculational model and results obtained for the various conditions analyzed are shown in figures 8.13 through 8.15.

Figure 8.13 Concrete Block Storage Area





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K+E 10 X 10 TO 1/2 INCH 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

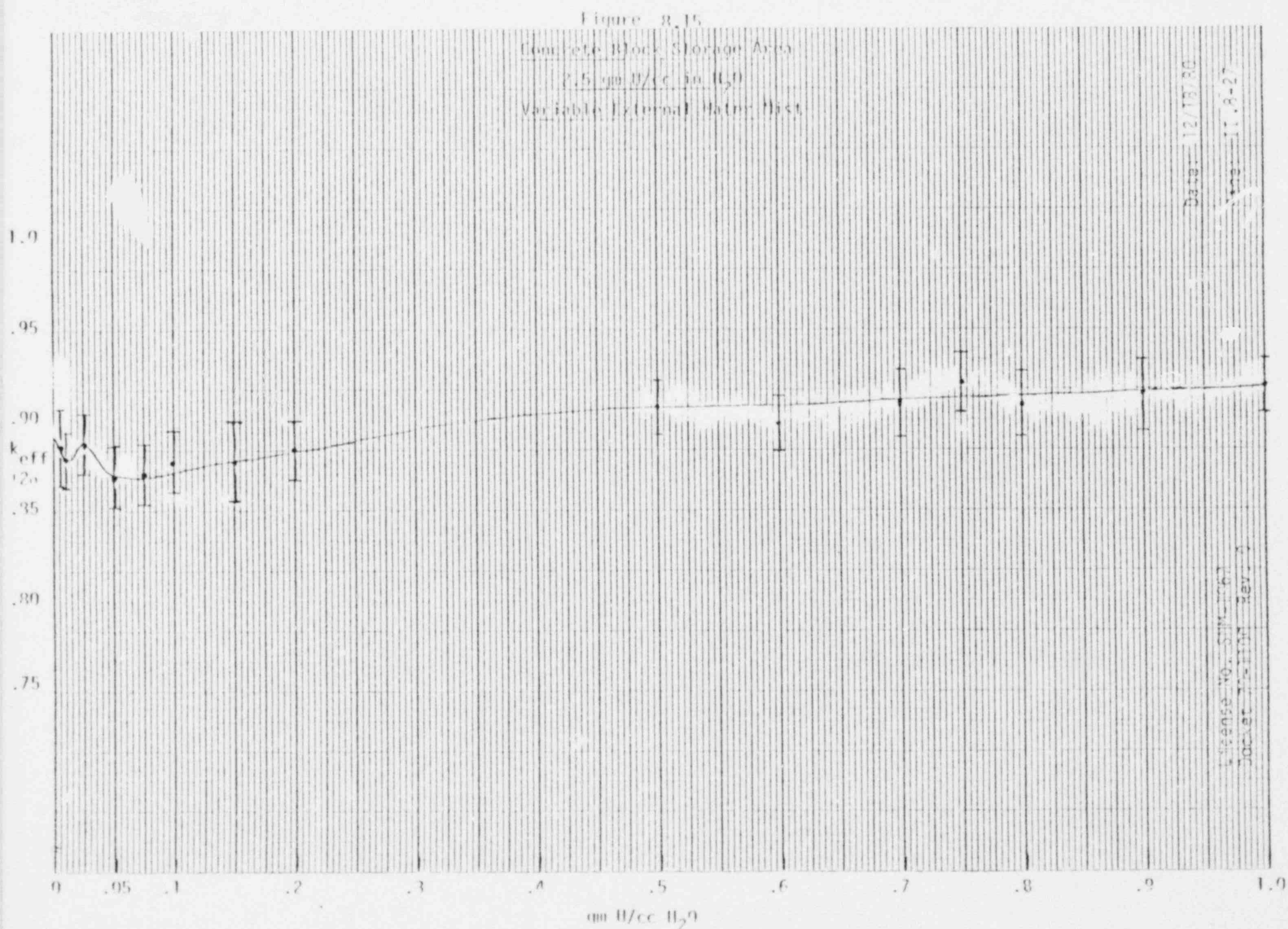

Figure 8.15
Concrete Block Storage Area
7.5 gm U/cc in H_2O
Variable External Water Dist
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1.0
.95
.90
k_{eff}
.85
.80
.75
0
.05
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
gm H/cc H_2O

46 1323

8.3.2 Pellet Storage Shelves

Steel shelves (W.S. P-22 and 114) are provided for pellet storage. The shelves are three high. They have a width of 18" and are limited to a slab thickness of 3.7 inches. The criticality safety and analysis demonstrates that the spacing boundary can be located 60 inches from the front of the shelves.

Criticality Safety Analysis

The following conservative assumptions were incorporated into the calculational model of the pellet storage shelves:

1) Each shelf was assumed to hold a 3.7 inch thickness of UO_2 at optimum moderation and maximum enrichment (4.1 wt% U^{235}).
2) The system was assumed to be infinite in the horizontal plane.
3) Variable density external water mist was introduced to determine peak reactivity.
4) All steel construction material (except the 1/4 inch shelf thickness) was neglected.

The KENO-IV Code with 16 group Hansen-Roach cross sections was used to determine the reactivity of the pellet storage shelves under various conditions of moderation. Optimum moderation of the fuel occurred at a concentration of 2.7 gm U/cc in water, assuming no external water mist. The peak reactivity of the system, $K_{eff} = 0.8188 \pm 0.0088$, occurred at an external water mist density of 0.175 gm/cc (which is impossible to duplicate in reality). Dimensional details of the calculational model and results obtained for the various conditions analyzed are shown in figures 8.16 through 8.18.

Additional storage (W.S. P-15, P-19, and P-21) is provided for slab storage of finished pellets. A 5.5 inch slab limit is imposed, based on the fact that sintered pellets, when randomly loaded into sintering boats, or storage trays, pack to an average density of 5.9 gm/cc, with a 2σ variation of 0.394 as determined from a series of 14 measurements. Thus, at a 95% confidence level, the V_{H_2O}/V_{UO_2} ratio does not exceed 0.995 and from Figure 1.E.16 of UKAEA Handbook AHSB 1, the critical infinite slab thickness for 4.1% enriched $\leq$0.4" diameter pellets is 6.7". Applying a safety factor of 1.2 yields a slab limit of 5.5 inches.

8.16 Pellet Storage Shelves

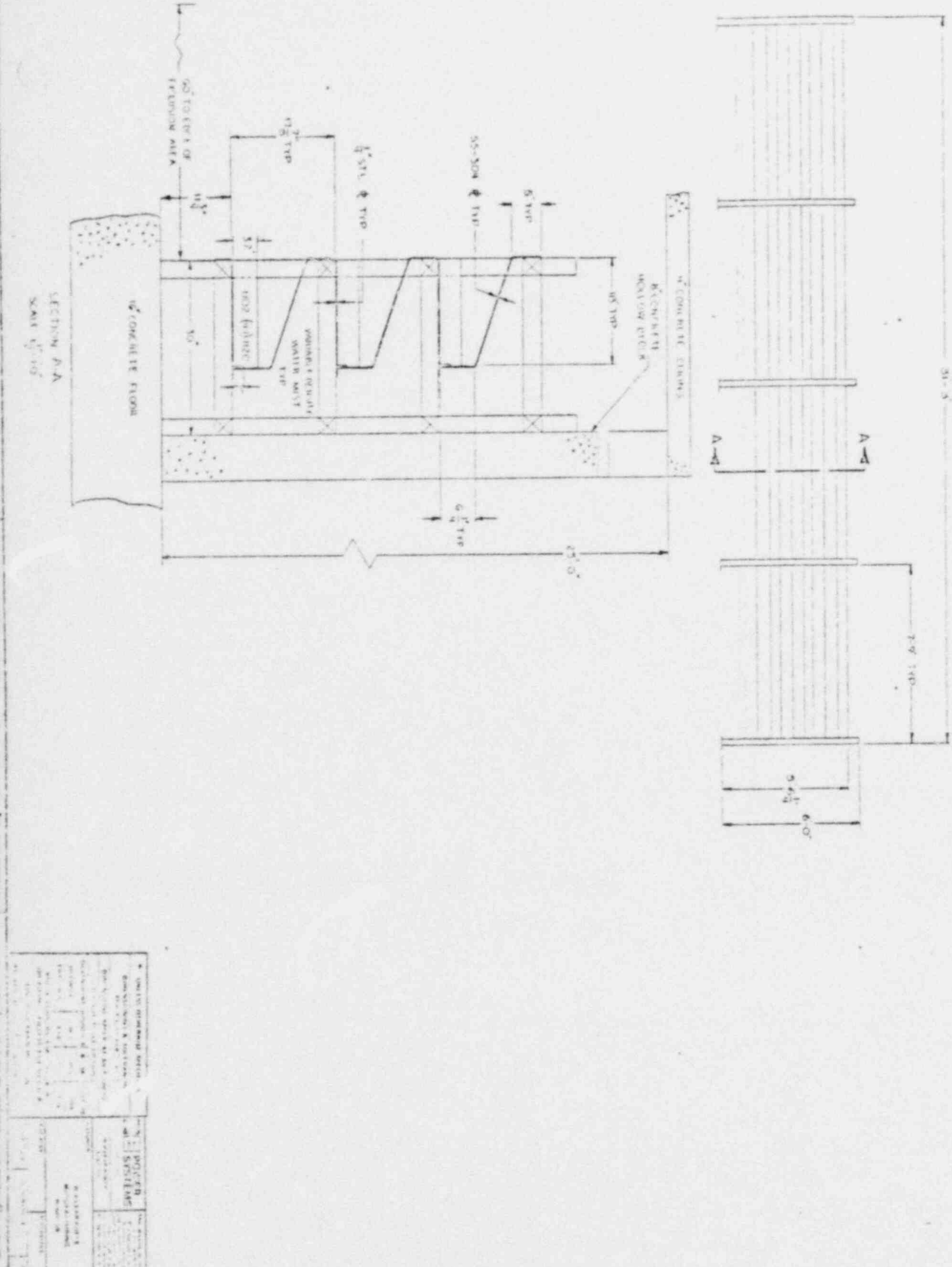

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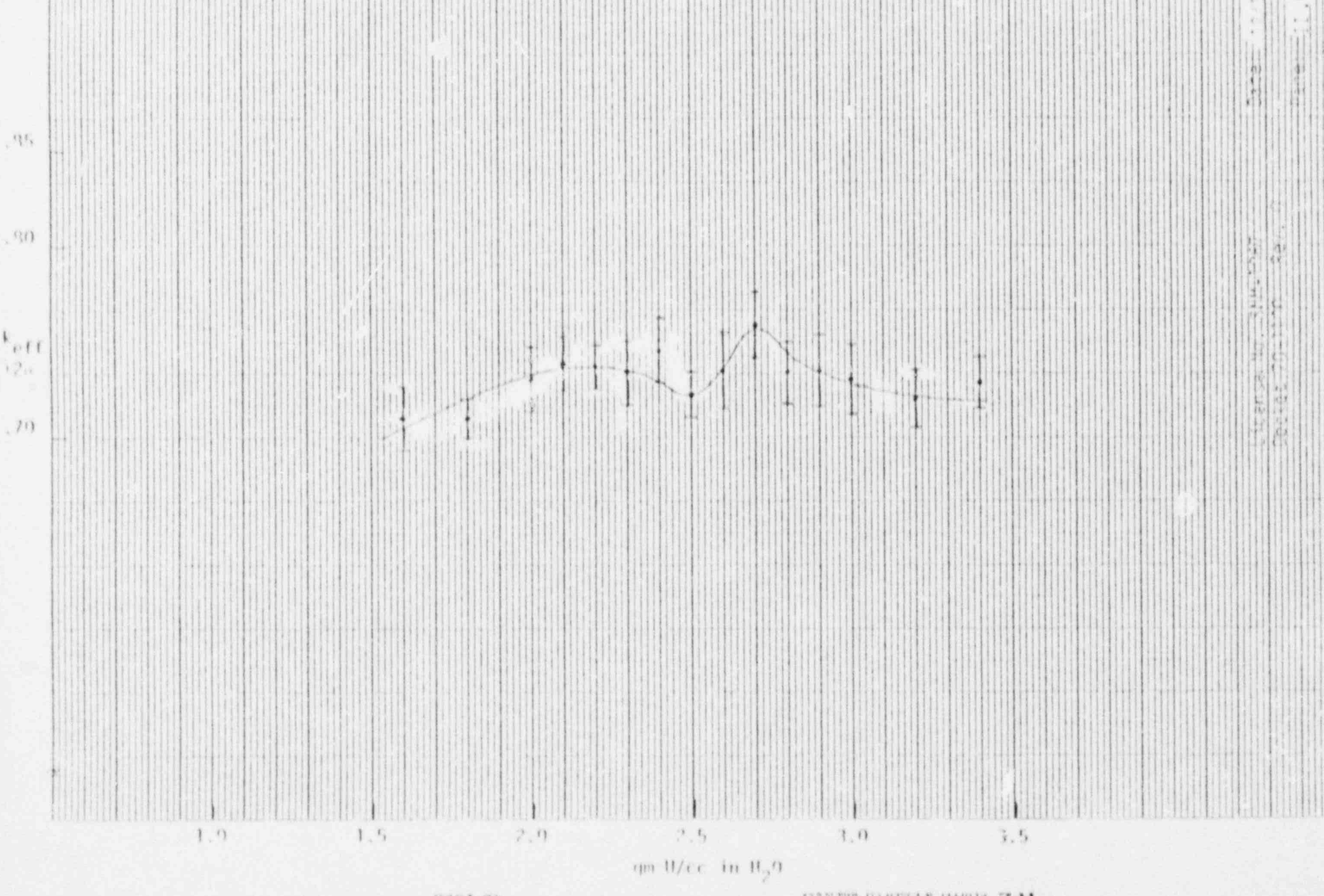
Figure 8.17

Pellet Storage Shelves

No External Water Mist



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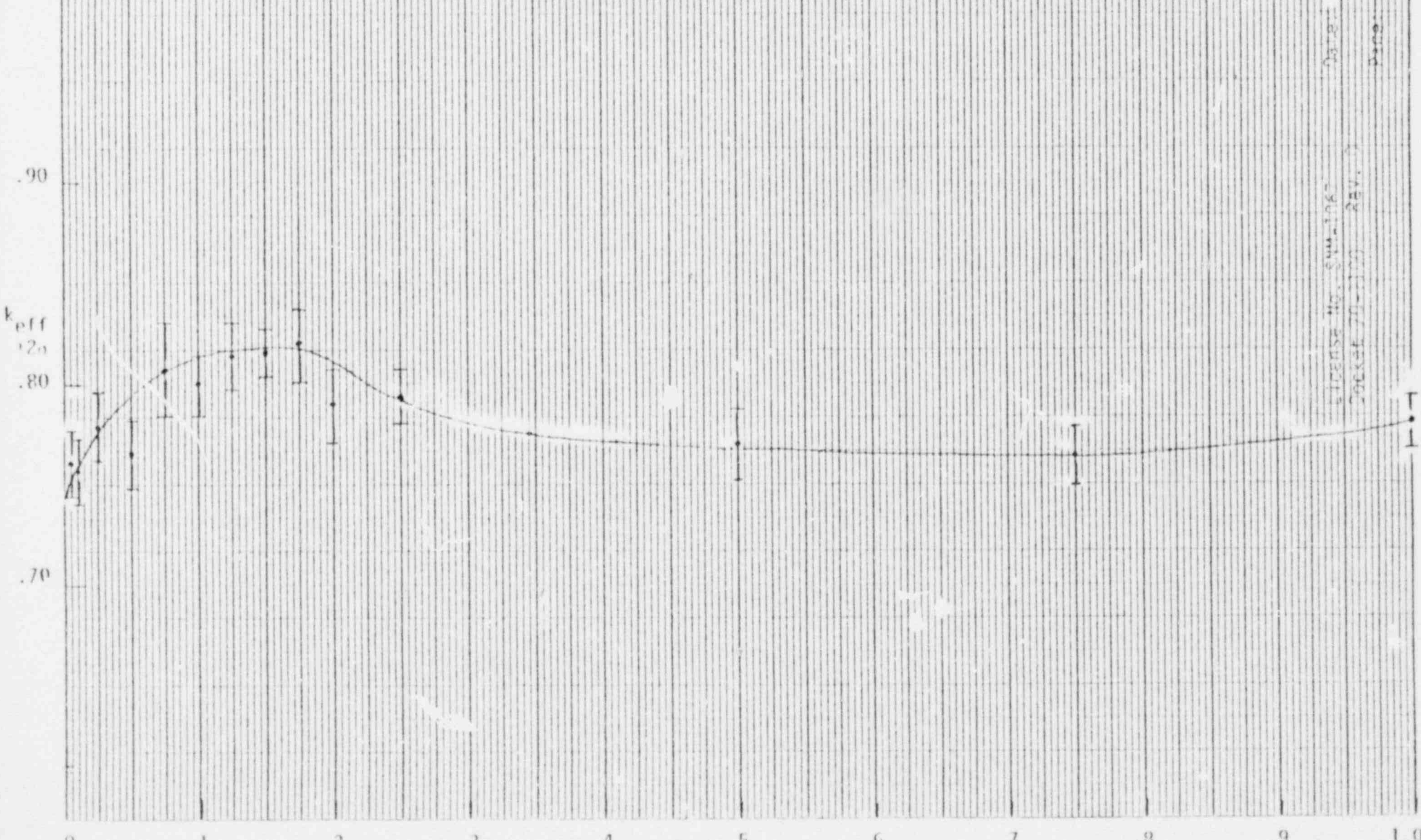
K+E 46 1323

Figure 8.18

Pellet Storage Shelves

2.7 gm U/cc in H_2O

Variable Density External Mist



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8.3.3 Close Packed Rods

Touching clad rods in horizontal storage packed in a hexagonal lattice have been analyzed as reported in Figure II-5 of WCAP 2999. For $k_{eff} = 0.99$, the slab thickness with full water reflection is in excess of 19 inches, and an allowable slab limit of 15 inches will be applied.

8.3.4 Transfer of Material

Material may be transferred on carts which accomodate one mass or slab limited SIU, or may be transferred by hand, one SIU at a time. Carts used for mass limited SIU's shall provide for centering of the unit, and shall measure at least three feet on a side.

Because most spacing areas do not extend beyond the physical boundary of the equipment, spacing between transfer carts and the equipment is of no concern. In cases where the spacing area extends beyond the equipment boundaries, such as the storage facilities, the spacing boundary will be indicated with colored tape. The tape may be crossed by carts only when they contain no more than one mass or volume limited SIU, and then only to permit an operator to transfer that SIU to an available storage position.

8.4 PreTreatment of Low Level Liquid Wastes

In order to effect a reduction in the quantities of UO_2 released to the retention tanks in Building #6, low level liquid wastes, consisting primarily of floor mop water will be pumped into a 10 inch diameter, 11 foot long settling tank with a release line located 18 inches from its lowest point. The water is then passed through a high efficiency closed loop centrifuge system, sampled to verify acceptable discharge levels, and transferred to the retention tanks in Building #6. The settling tank is located in the rod loading area, and is shown as W.S. 113 in Figure 8-1.

Based on past experience, wash water may contain up to 10^{-3} µCi/cc (~0.5 gm U/ℓ). Much of this activity quickly settles to the bottom of the tank. Accordingly, criticality considerations are applied only to the lower 18 inches of the tank, with the balance of the tank considered to have a sufficiently low uranium concentration to preclude further criticality considerations.

Although the diameter of the tank (10 inches) slightly exceeds the Table 4.2.5 limit (9.8 inches), it is well below the minimum critical diameter (10.8 inches) for a fully reflected infinite cylinder. In addition, the optimum concentration necessary to achieve criticality in a 10.8 inch cylinder is between 2000 and 2500 gm U/ℓ for 4.1% enriched UO_2, a factor of 4000 higher than the uranium concentrations observed in the mop water handled. The volume of the settling tank is 23.2 liters. The allowable surface density (t_a) is taken as 25% of the critical infinite slab thickness (t_c). Accordingly, t_a = 1.38" or 3.26 liters/ft^2. The required spacing area for the tank is therefore 7.11 ft^2.

Sludge and other uranium bearing solids will be collected in volume limited SIU's. This material may be subsequently loaded into trays to a maximum depth of 3.7 inches, dried in an oven (W.S. P-23 or 24) and stored in authorized packages awaiting final disposition.

8.5 Rod Loading and Assembly Fabrication

8.5.1 Pellet Alignment and Drying

Pellets from the pellet fabrication facility, or from outside vendors are placed on a downdraft table (W.S. 100) where they are loaded for placement into 2 drying furnaces (W.S. 101 and 102). On the table, the pellet configuration is limited to a 3.7 inch slab thickness. The UO_2 pellets are placed on aluminum troughs in approximately 12 foot lengths before being loaded into furnaces for drying under a vacuum.

Each furnace contains 216 locations, 200 of which may be occupied by fuel pellet stacks. The remaining 16 locations contain B_4C poison rods which are fixed in place and blocked off to prevent introduction of any fuel. The poison material is B_4C powder packed into 5/8" O.D. x 20 ga. Type 304 stainless steel tubes (nominal 0.555" I.D. x .035" wall). The B_4C powder in each tube shall be packed to a minimum density of 1.15 gm/cc B_4C (46% of theoretical density), and the minimum active poison length shall be 157 inches. The B_4C powder shall be analyzed and certified to demonstrate and document that 1) the B_4C content is $\geq$95% and 2) the B_{10} concentration is that of natural boron. The tubes shall be weighed before and after loading with the B_4C powder to assure that the minimum density requirement has been met. Records of these weighings shall be maintained.

The end of the tubes shall be sealed by welding to assure no subsequent loss of B_4C. The tubes shall be removed from the furnace at least once every two years and visually examined and weighed to assure that no physical damage to the tubes or loss of B_4C has been experienced. The tubes will be replaced if indications of damage (cracks, discoloration, etc.) are detected or a change in weight occurs. This is adequate since the maximum operating temperature of the furnace does not exceed 500°F, and the atmosphere the tubes will experience is air, vacuum, or argon. Type 304 stinless steel will operate almost indefinitely under these conditions. The poison tubes are larger than any of the Zr-4 fuel tubes being used, making them easily identifiable All poison rod end caps will be legibly marked as B_4C and serial numbered 01-32. Each poison rod will then be placed in those locations of the drying furnaces marked as "poison" on drawing NFM-E-4080 Rev. 01. dated 6/13/79 (Figure 8.19).

Aluminum plates will then be welded to each end of the furnace positions holding the poison rods to prevent their removal ay any time. To provide assurance of the continued presence of the B_4C poison rods, a quarterly visual inspection will be performed to assure that each position contains a serial numbered B_4C rod and that no damage has been done to the welded end plates. Records of the B_4C rod loading and the periodic inspections will be maintained.

The inside diameter of the furnaces is 20 inches with an overall length of 13 feet. The furnaces are dry and about 12 inches above the floor level. Water entry is possible only when the doors at either end are open; however, under this condition, free drainage will occur. With the doors closed, the furnace is a sealed chamber and moderation control is assured.

Criticality Safety Analysis

The following conservative assumptions were incorporated into the calculational model of the pellet drying furnaces:

1) It was assumed that the 200 pellet storage positions were

fully loaded with maximum diameter pellets (0.3765") at a maximum enrichment of 4.1 wt% U^{235}.

2) The remaining 16 furnace locations were modeled with B_4C powder at 45% of theoretical density (although it "pours" to a greater T.D.). All SS poison tubes were omitted in the calculations for additional conservatism.

3) The furnaces were assumed to be infinitely long and spaced 36.5" on center. An infinite array was assumed, although there are only two furnaces.

4) Variable density water mist was introduced to determine peak reactivity of the system.

5) All aluminum pellet troughs were omitted and the variable density mist was substituted in their place.

6) Four group cross sections were generated using the CEPAK Code for the fuel and poison regions of the model and for the concrete floor and ceiling.

The KENO-IV Code was used to determine the reactivity of the Pellet Drying Furnaces under various external mist conditions with and without the fixed B_4C poison rods in place. The peak reactivity of the furnaces with poison rods, $k_{eff}=0.8693 \pm 0.0057$, occurred for the full density water condition. Additional calculations were performed assuming loss of all poison. The margin of safety is unacceptable only for mist densities exceeding 30%. Since fire hoses are not permitted in this area, these conditions were not considered credible. The furnaces drain freely to the floor and could not retain this amount of water. Dimensional details of the calculational model and results obtained are shown in Figures 8.19 and 8.20.

8.19 Pellet Drying Furnaces

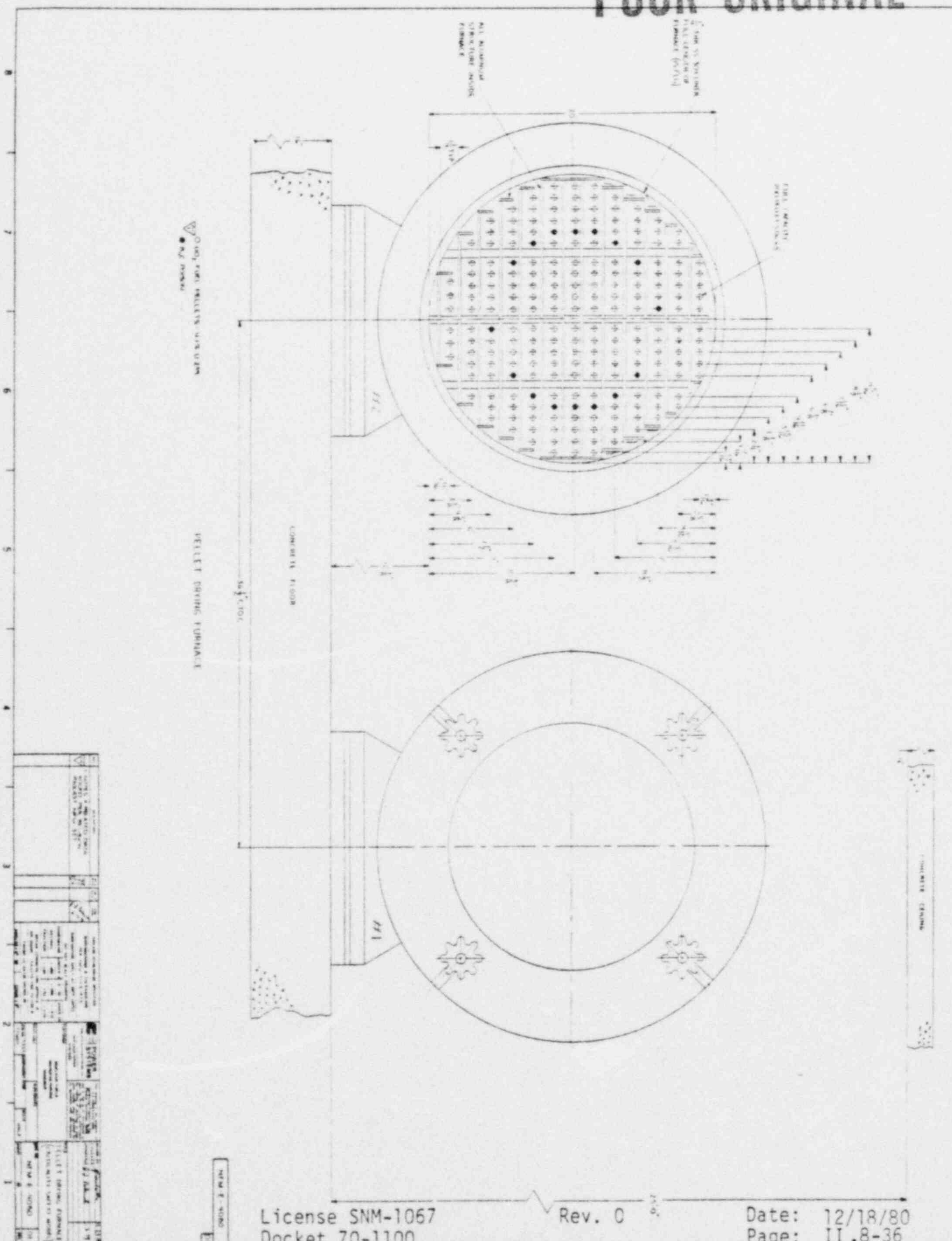
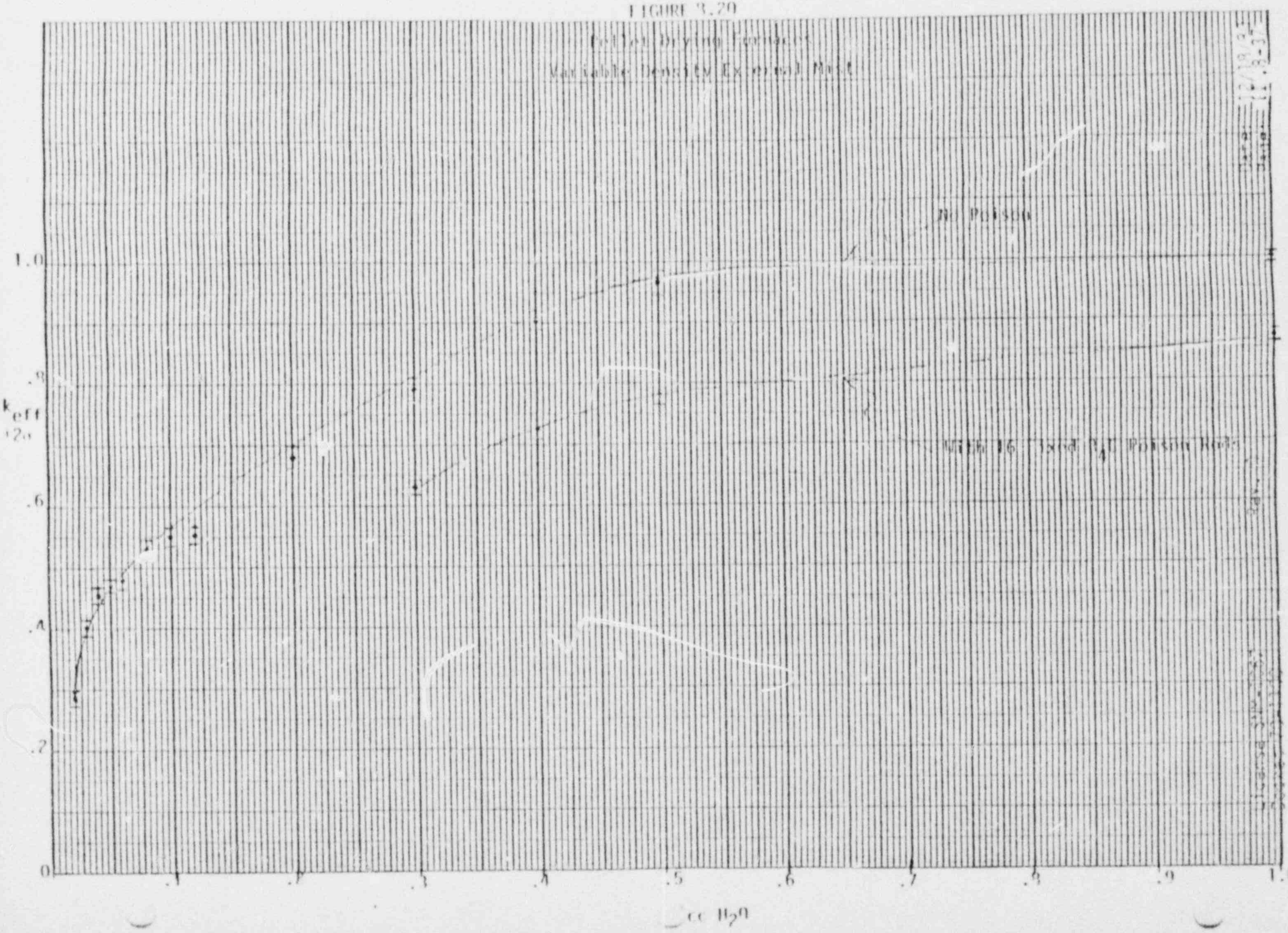


FIGURE 3.20

Pellet Drying Furnaces

Variable Density External Mist



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8.5.2 Rod Loading and Fuel Rod Transport Carts

Pellets are transferred to a downdraft loading table (W.S. 103) where they are limited to a 3.7 inch thick slab configuration, inspected, and loaded into rods. The loaded rods are placed into carts (W.S. 104) each of which can hold up to 250 fuel rods in parallel sleeves which are spaced on four rings in an annular fixture with an I.D. of approximately 10 inches and an O.D. of approximately 22 inches. Guard rails prevent the carts from coming any closer then three feet center-to-center. The carts are used in normally dry areas to transfer the rods to operations which include end plug welding (W.S. 105), weld deflashing (W.S. 107 and 108) and leak testing (W.S. 109). These operations are performed on one rod at a time. Rods are immediately returned the cart after each step is completed. Finished rods are fluoroscoped (W.S. 111) and are checked for enrichment (W.S. 112) with a slab limit of 3.7 inches.

Criticality Safety Analysis

The following conservative assumptions were incorporated into the calculational model of the fuel rod carts:

1) Only the 1/4 inch thick, 4" O.D. inner steel cylindrical annulus was accounted for in the model. All other steel construction material was neglected.

2) The carts were assumed to be infinitely long and spaced 36 inches, center-to-center to form an infinite array in the horizontal plane.

3) The fuel rods are contained in 1/2 inch, Sch 40 PVC tubes, each 134 inches long. There are 250 tubes arranged in 4 concentric rings with an average pitch of 1.18361 inches. The fuel tube region of the cart is thus a cylindrical annulus beginning at 4" from the centerline of the cart and extending to a radius of 7.312 inches. In the calculational model, it was assumed that all 250 positions were occupied by the largest diameter rods (.3765" O.D. UO_2 pellets at 10.03 gm/cc stacked density with a Zr-4 cladding thickness of .028 inch) at maximum enrichment (4.1 wt.% U^{235}).

4) Four group cross sections were generated using the CEPAK Code for various external water mist conditions for the six regions used in the model: the fuel annulus, the inner steel ring, the three variable density mist regions, and the concrete floor and ceiling.

The KENO-IV Code was used to determine the reactivity of the fuel rod transport carts under various external water mist conditions. The peak reactivity of the fuel rod cart, $k_{eff} = 0.7756 \pm 0.0052$, occurred for the full density water condition. Dimensional details of the calculational model and results obtained are shown in figures 8.21 and 8.22.

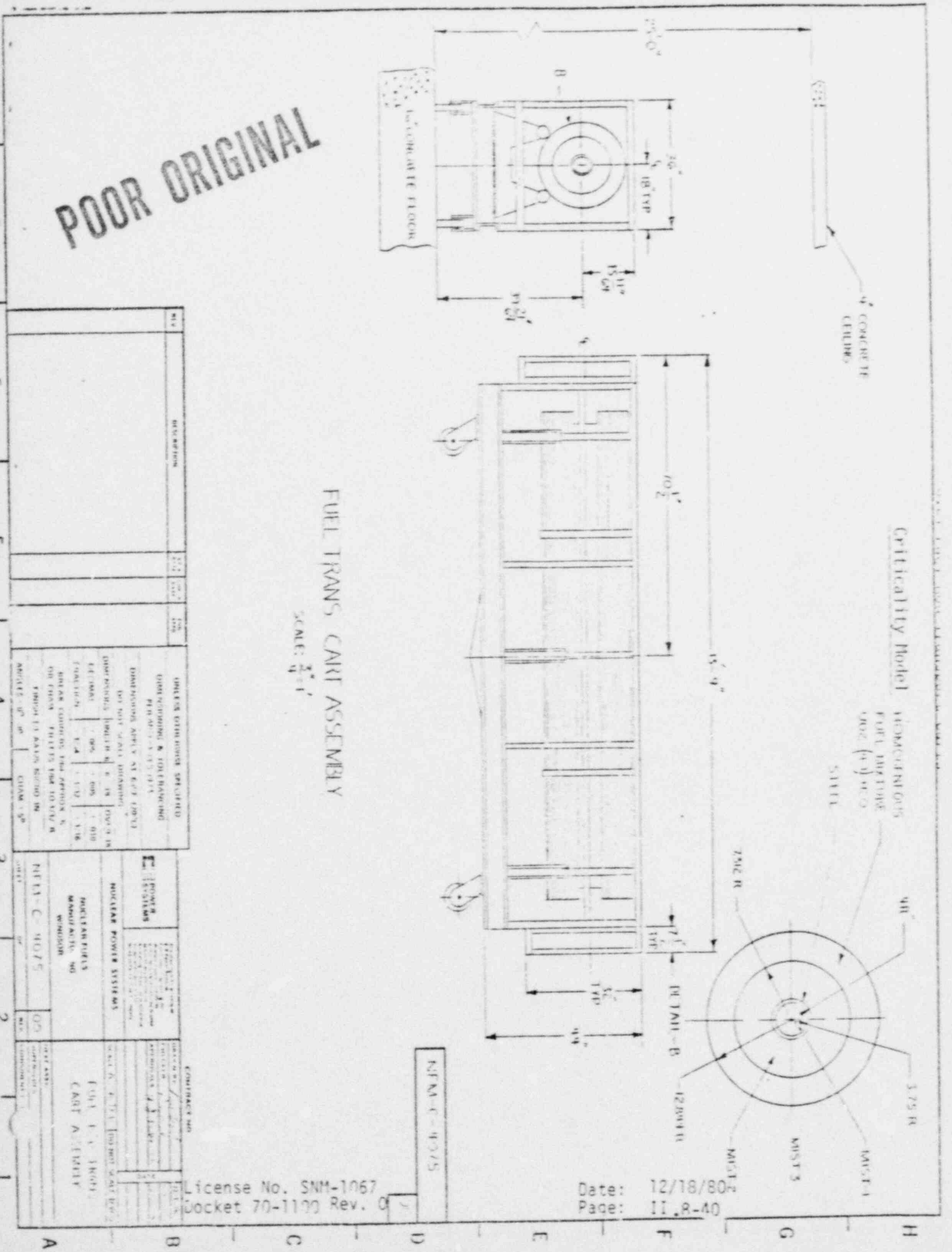
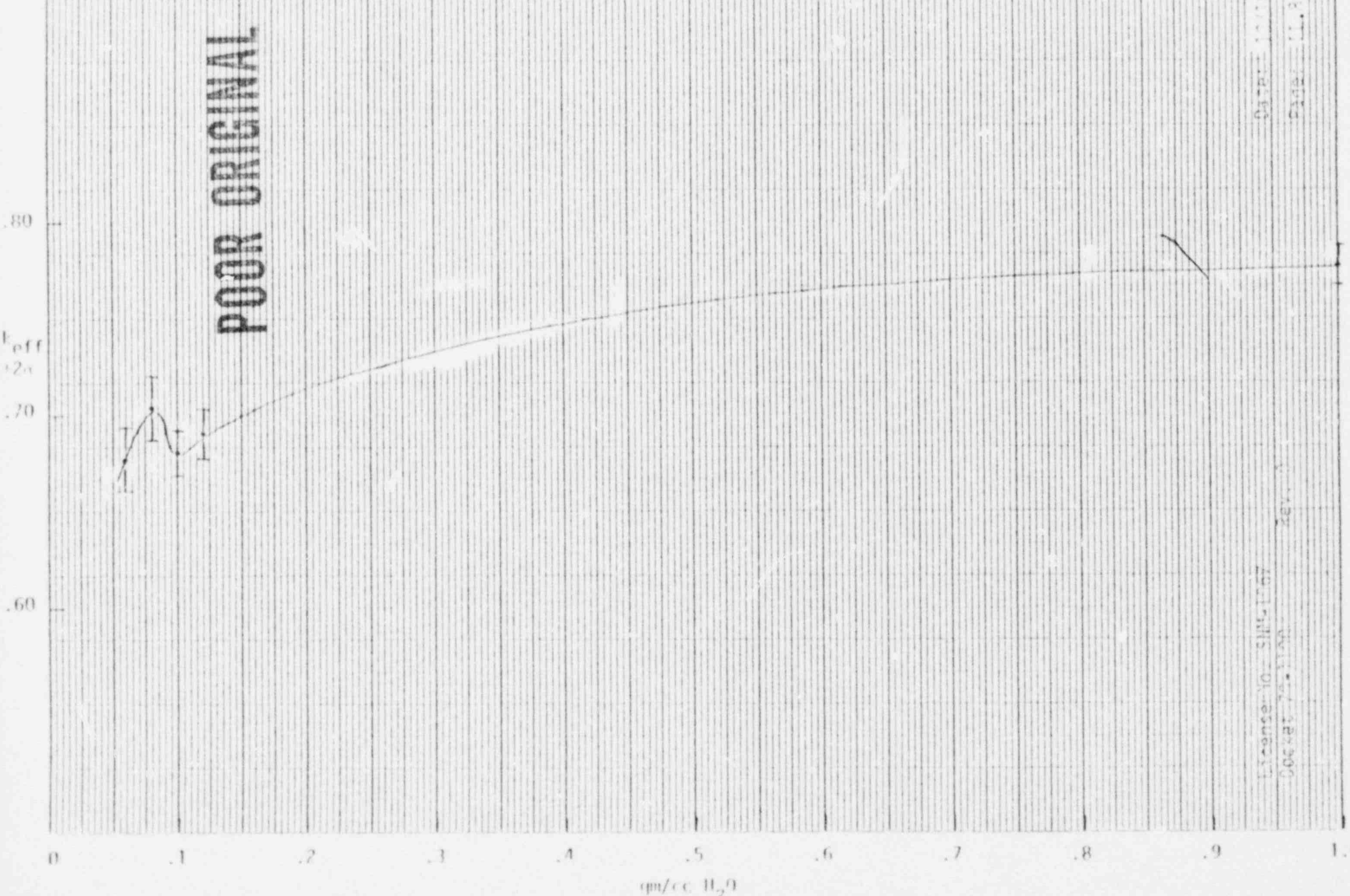

POOR ORIGINAL
FUEL TRANS CART ASSEMBLY
Criticality Model
HOMOGENEOUS
FUEL MIXTURE
STEEL
4" CONCRETE CEILING
DETAIL-B
NUCLEAR POWER SYSTEMS
NUCLEAR FUELS MANUFACTURING
WINDSOR
NFM-C-4075

Figure 8.22

Fuel Rod Transport Cart

Variable Density External Mist



8.5.3. Autoclave Corrosion Test

The six autoclaves used for corrosion testing of finished fuel rods are shown as W.S. 116-121 in Figure 8-1. The stainless steel tanks are 14 feet long and have an inside diameter of 14 inches with a wall thickness of 1.5 inches. The center line distance between autoclaves is a minimum of 66 inches. Each autoclave is limited to 32 fuel rods by administrative control. The fuel rods are held by stainless steel fixtures consisting of eight plates which are five inches wide and 1/8 inch thick. During operation, the interior of the autoclave could conceivably experience all conditions of water moderation, from completely dry to full density water.

Criticality safety of the autoclaves is based on dimensional comparison with the fuel assembly storage area. The fuel assemblies have been designed for maximum reactivity and and have a k_{eff} of less than 0.90 in full density water. (See Section 8.5.7). The rod spacing in the fuel assembly is thus the optimum. If the fuel rods were aligned in the autoclave at this optimum spacing, it would thus take 256 rods to achieve a k_{eff} of approx. 0.90. The maximum number of rods allowed (32) provides a large margin of safety under all conditions of moderation and reflection. Even with all six autoclaves filled, the number of fuel rods present (192) would be less than the number required for one fuel assembly of the 16 x 16 type. In Section 8.5.7 a 10 x 13 array of fuel assemblies spaced 20" apart (minimum) led to a k_{eff} of 0.89. The autoclaves are spaced a minimum of 66 inches center-to-center and would be considerably less reactive than the fuel assembly storage area because of greater leakage.

8.5.4 Fuel Rod Storage Area

The multi-level storage area (W.S. 122 in Figure 8-1) for boxes for fuel rods consists of up to 10 tiers of 32 locations each. The steel fuel rod boxes have a maximum length of 14'14" and an inside width and depth of 8 inches and 5-3/8 inches respectively. A vertical spacing of 12-1/2 inches between boxes is maintained, the first tier being 18 inches above the concrete floor. Lateral spacing is restricted by physical barriers to a minimum of 4 inches. The rod boxes rest on roller conveyors to facilitate movement in and out of the storage array and are held in place by a fixed brace at the back end and by a positive latched door at the front end.

The entire storage array is covered by sheet metal on all four sides to assure the exclusion of water. Positive latching doors overlap the rectangular openings in the front of the rack and allow access only for insertion and removal of the fuel rod boxes. Each positive latching door covers the opening in front of four rod boxes on the same horizontal plane. The roof of the storage rack consists of corrugated fiberglass on a 3% pitch to assure adequate drainage to the floor. All joints and connections on the external covering of the rack are sealed with waterproof caulking. Moderation control is thus assured under all conditions. Water accumulation in the vicinity of the storage rack is not considered credible in view of the close proximity of an open equipment pit in the floor which is 30 feet x 60 feet x 18 feet deep. A 3 foot deep sump at the bottom of the pit is equipped with a level detector which activates a pump to transfer any accumulated water to the industrial sewer system.

Criticality Safety Analysis

The following conservative assumptions were incorporated into the calculational model of the fuel rod storage area:

1) The fuel rods, if in a tightly packed hexagonal array, would result in over 300 rods in each box. An infinite array of boxes in the horizontal plane was assumed. The fuel was homogenized over the volume of the box and was assumed to be dry.

2) All rod boxes were assumed to be filled to capacity at maximum enrichment (4.1 wt.% U^{235}). The smallest diameter rods (0.382 inch) were used to obtain maximum fuel loading. The Zr-4 cladding (0.025 inch thickness) was homogenized with the fuel.

3) A lateral separation distance of 3.5 inches between rod boxes was assumed. Interspersed moderation was not considered credible since moderation control is assured by the design of the storage area.
4) All steel construction material was neglected.
5) A 15 tier array was analyzed although a maximum of 10 shall be permitted.

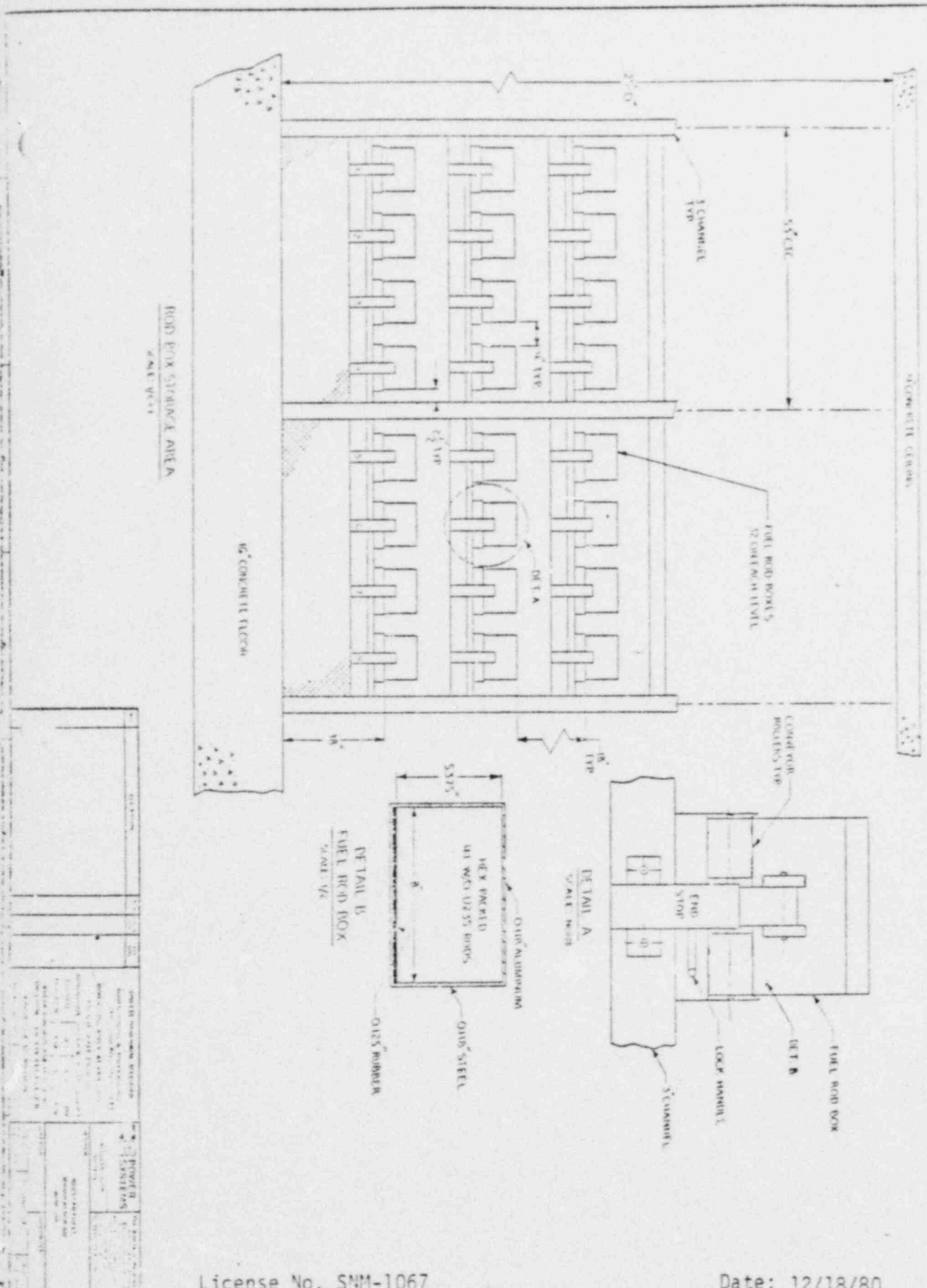
The 16 group Hansen-Roach cross sections were used in KENO-IV to determine reactivity of the system under the conditions noted above. A k_{eff} of 0.7994 ± 0.0050 was obtained for a 15 tier infinite A second calculation of a finite 15 tier array with 16 inch concrete reflectors on all sides yielded a k_{eff} of 0.7372 ± 0.0045. Details of the calculational model are shown in figure 8.23.

8.5.5 Double Shelf Rod Storage Racks

The double shelf storage racks for fuel rods hold a maximum of 12 steel boxes identical in all respects to those in the multi-tier array described above. Each box is equipped with a tight fitting aluminum cover which overlaps the outside edge of the box by a minimum of one inch. One box may remain uncovered for short periods of time to allow for the addition or removal of rods for inspection purposes provided that personnel are in attendance. Spacing between boxes in both a vertical and horizontal direction is a minimum of 6 inches. Minimum center-to-center spacing between storage racks is 55 inches and the racks are considered to be present in an infinite array in the horizontal plane. The location of these racks is shown as W.S. 129 in Figure B-1.

The following conservative assumptions were incorporated into the calculational model of the double shelf fuel rod storage racks:
1) The fuel rods, if in a tightly packed hexagonal array, would result in over 300 rods in each box. The racks permit storage of 12 boxes each (6 in the vertical direction) and an infinite array of storage racks was assumed in the horizontal plane. The fuel was homogenized over the volume of the box and was assumed to be dry.

8.23 Fuel Rod Storage Area



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2) All rod boxes were assumed to be filled to capacity at maximum enrichment (4.1 wt.% U^{235}). The smallest diameter rods (0.382 inch) were used to obtain maximum fuel loading. The Zr-4 cladding (0.025 inch thickness) was homogenized with the fuel.

3) All steel construction material was neglected.

4) Variable density external water mist was introduced to determine peak reactivity of the system under optimum conditions.

The sixteen group Hansen-Roach cross sections were used in KENO-IV to determine reactivity of the system under the conditions noted above. The highest k_{eff} of 0.8886 ± 0.0070 was obtained at an external mist density of 0.06 gm H_2O/cc. Dimensional details of the calculational model and results obtained are shown in figures 8.24 and 8.25.

8.5.6 Fuel Assembly Fabrication

Fuel rods are loaded into the assembly skeleton in a fixture which provides a lubricating water spray (W.S. 123, 124). These fixtures are designed to assure that water cannot be retained. Nevertheless, safety for this operation has been established with full moderation and reflection. The criticality safety calculations for a fully reflected fuel assembly are presented as part of the criticality safety analysis of the Fuel Assembly Storage Area in Section 8.5.7. A maximum k_{eff} of 0.8961 ± 0.0092 was obtained for a 10 x 13 array of flooded assemblies. Details of the analysis are discussed in the following section.

8.5.7 In-Plant Storage of Fuel Assemblies

Fuel assemblies are stored in a vertical position using racks (W.S. 130) of adequate strength to preclude loss of the design spacing. The assemblies may be wrapped with plastic with the bottom ends open to assure free drainage. There are 94 storage positions and an adjacent inspection area consisting of 8 positions. Within the same room (but at greater separation distances) there are two horizontal loading tables (W.S. 123 and 124) where the fuel rods are initially loaded into the assembly skeletons, a vertical wash tank (W.S. 132) where the assemblies receive a final demineralized water rinse, two fixed

8.24 Double Shelf Rod Storage Racks

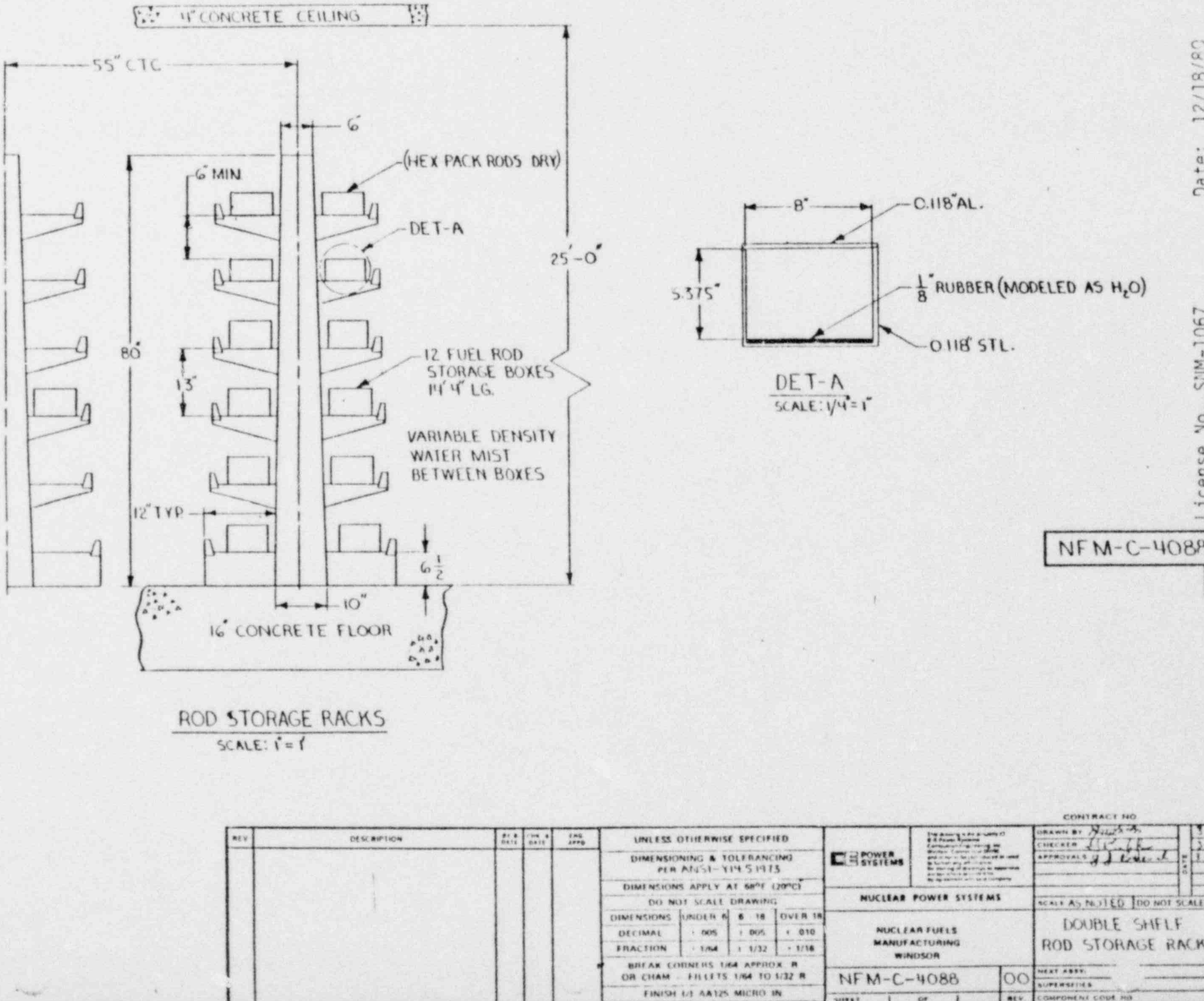
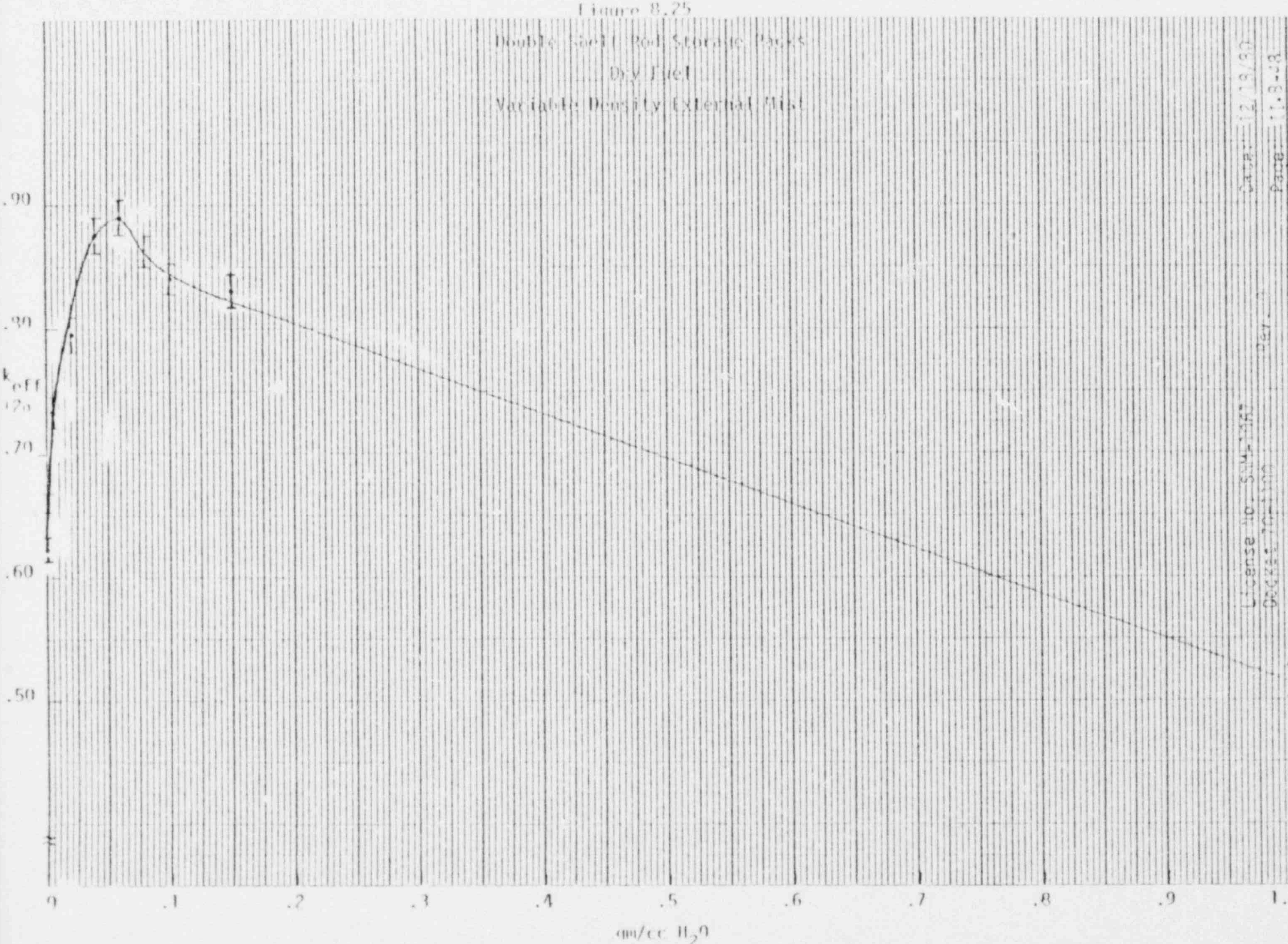


Figure 8.25

Double Shell Rod Storage Racks

Dry Fuel

Variable Density External Mist



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vertical inspection stands equipped with elevator platforms (W.S. 131 and 133) to allow final Q.C. dimensional checks, and two marked floor areas where the assemblies are loaded into shipping containers prior to outdoor storage. Each of these stations is physically limited to one fuel assembly except the shipping containers which hold two. The assembly storage room can thus contain a maximum 111 fuel assemblies (94 storage positions, plus 17 additional locations). All assemblies outside of shipping containers shall be stored vertically within the design spacing criteria of the Assembly Storage Room shown on Drawing NFM-E-4074, Revision 1, dated 12/20/78 (Figure 8.26).

1) A 10 x 13 array of assemblies was modeled at the design spacing. The array contains 130 assemblies while the maximum number in the room is limited to 111. This effectively brings the 17 additional assemblies allowed in the room closer to the 94 assemblies in the storage area.

2) All steel construction material was neglected.

3) Variable density water mist was introduced within and between the assemblies to determine peak reactivity of the system under optimum conditions.

4) Four group cross sections were generated using the CEPAK Code for the 3 regions of the assemblies; fuel, water holes, and external water mist between assemblies. These 3 regions were then smeared over the entire array using the DOT Code to obtain one set of flux weighted lattice cross sections.

5) Four group cross sections were generated using the CEPAK Code for the 8" concrete walls, 16" concrete floor, and the external water mist between the top of the fuel assemblies and the ceiling. The ceiling was considered to be 8 inch thick concrete, though 4 inches is usually assumed.

The 4 group cross section sets described above were then used in KENO-IV to determine the reactivity of the fuel assembly storage area under the above noted conditions for both 14 x 14 and 16 x 16 assemblies. The highest k_{eff} of 0.8961 ± 0.0092 was obtained for an array of 16 x 16 assemblies at full density water moderation and reflection. Dimensional details of the calculational model and results obtained are shown in detail in figures 8.26 through 8.29.

8.5.8 Shipping Container Storage

Shipping containers (Models 927A1 and 927C1), each containing two fuel assemblies, are stored outdoors in arrays up to three high. The width and length will vary; thus, the quantity of containers is limited only by the width and length of the space allocated for storage. The containers are stored on a pavement or blacktop surface. The steel shipping container, approximately 3 feet in diameter and up to 217" long, houses two fuel bundles of the types previously described in this license. The two bundles in each container are separated by six inches. An eight foot high chain link fence encloses the storage area, and all stored fuel is within 100 feet of a criticality alarm detector.

Criticality Safety Analysis

The following conservative assumptions were incorporated into the calculational model of the shipping container storage area:

1) The fuel assemblies are assumed to be made of 4.1 wt.% U^{235} enriched UO_2 with no poison shims. The most reactive assemblies (the 16 x 16 design) were used.

2) The three high double infinite array of shipping containers was assumed to be reflected by 4 inches of concrete above and 16 inches of concrete underneath, with a 25 foot separation distance between the two reflectors.

3) Variable density water mist was introduced to determine the peak reactivity of the system. The density of water within and exterior to the containers was made identical.

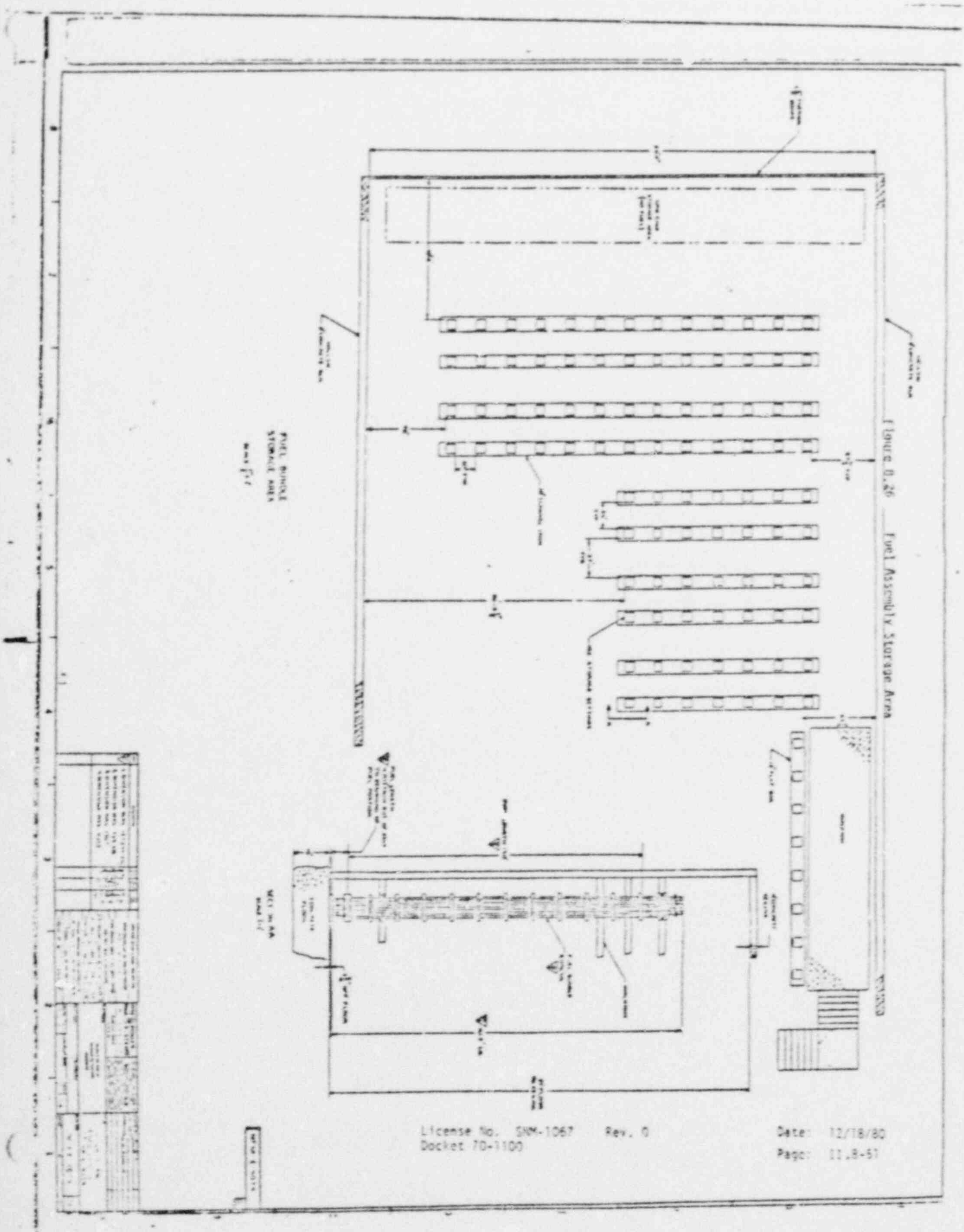

Figure II.26 Fuel Assembly Storage Area

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Figure 8.27

Design Parameters of Fuel Assemblies

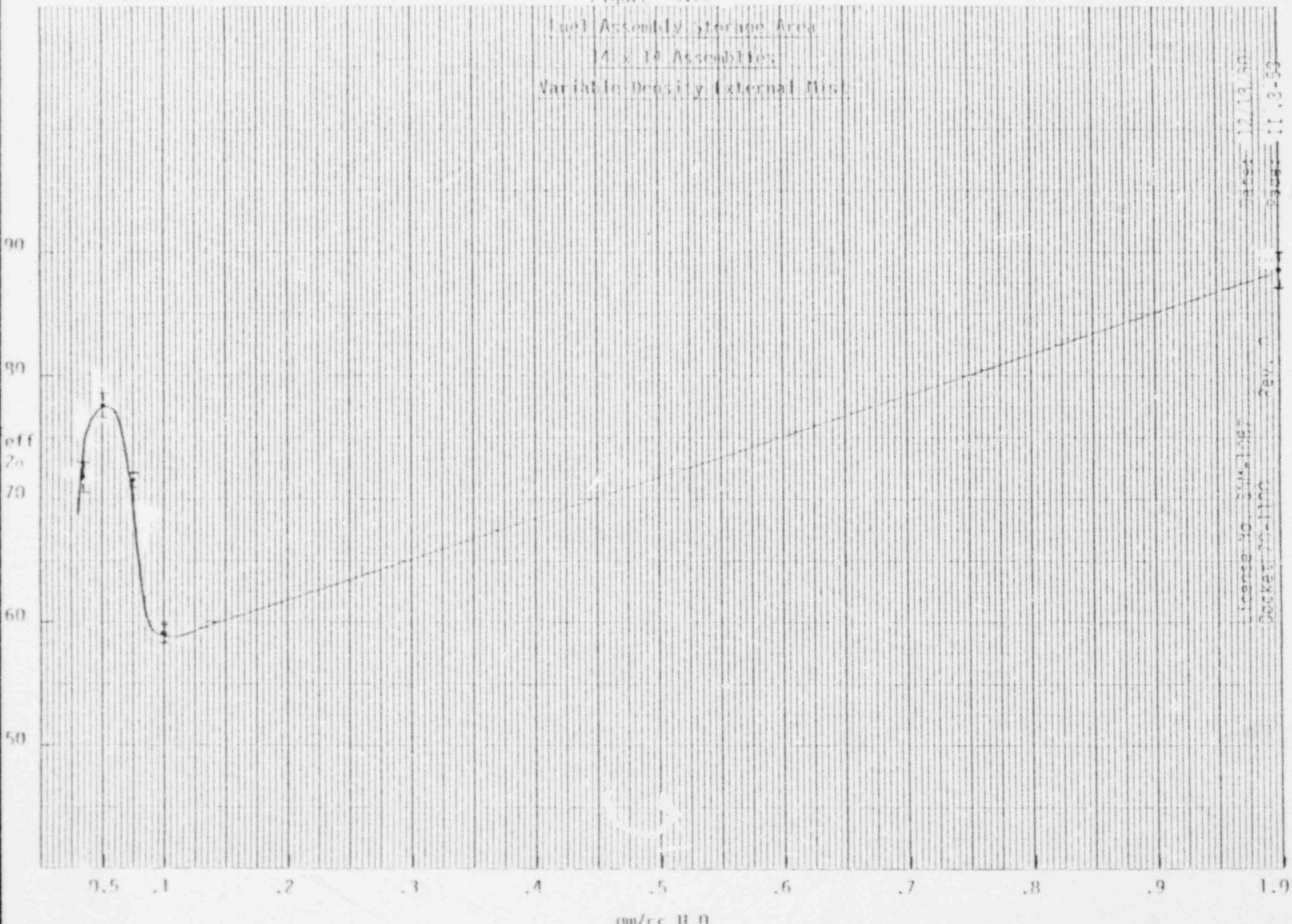
Fuel Assembly		
Fuel Rod Array per Assembly	14 x 14	16 x 16
Total No. Fuel Rod Positions per Assembly	176	236
Fuel Assembly Pitch, in.	8.180	8.116
Fuel Rod Pitch, in	0.580	0.506
Fuel Rod		
Clad Material	Zr-4	Zr-4
Clad O.D., in.	0.440	0.382
Clad Thickness, in.	0.028	0.025
Diametrial Gap, in.	0.0075	0.0070
Active Length, in.	136.7	150.0
Total Length, in.	146.963	161.5
Fuel Pellet		
Material	UO_2	UO_2
Dish Depth, in.	0.015	.019
Diameter, in.	0.3765	.325
Length, in.	0.450	.390
Density, g/cc/% Theoretical	10.412/95.0	10.41/95.0
Density Stacked, g/cc/% Theoretical	10.03/91.5	10.03/91.5
Spacer Grid		
Material	Zr-4	Zr-4
No. per assembly	8	11
		Inconel
		1
K_{eff}	≤ 0.90	≤ 0.90

Figure 8.28

Fuel Assembly Storage Area

14 x 10 Assemblies

Variable Density External Mist



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K+E 10 X 10 TO ½ INCH 7 X 10 INCHES 46 1323

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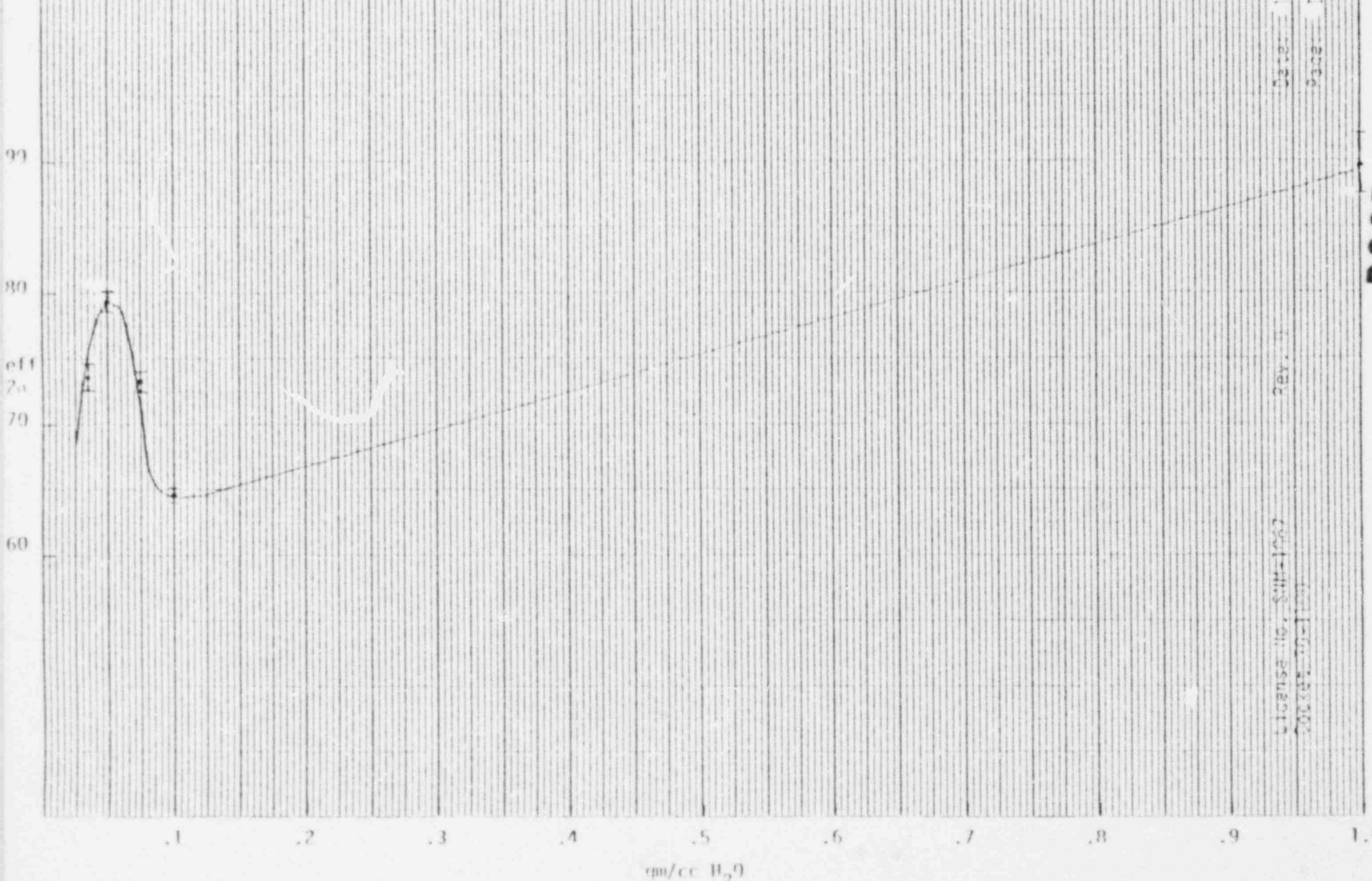
Figure 8.29

Fuel Assembly Storage Area

16 x 16 Assemblies

Variable Density External Mist



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4) Four group cross sections were generated at the various mist densities using CEPAK for the following regions of the model. fuel cell, water holes, steel strongback which holds the bundles, the mist region between the assemblies, the mist region exterior to the assemblies and container, the outer steel shell of the container, and the concrete reflectors.

The above cross sections were used in KENO-IV to determine peak reactivity of the system under the conditions noted. The highest k_{eff} of 0.8601 ± 0.0082 was obtained for the full flood case while a secondary peak of 0.6206 ± 0.0051 was obtained at a water mist condition of 0.035 gm/cc H_2O. Details of the calculational model and results obtained are shown in figure 8.30 and 8.31.

This analysis also provides the basis for considering an open or closed assembly shipping container as an SIU which requires no spacing beyond the physical boundaries of the container. Accordingly, individual containers may be stored in the facility in unrestricted numbers (W.S. 134 represents a typical location for open containers).

8.5.9 Fuel Salvage

Off specification fuel rods are cut open and placed into a fixture to facilitate the removal of UO_2 pellets (W.S. 106). The recovered pellets are sorted to segregate scrap from reusable material. Ventilation is provided, and the operations are monitored in accordance with Section 15. This operation is considered a mass limited SIU, with limits taken from Section 19.

8.5.10 In-Process Storage of Fuel Pellets in Containers

UO_2 pellets received in the United Nuclear Container #2901 may be stored in the plant, two containers strapped to each pallet, one pallet high. The pallets may be stored anywhere in Buildings #17 or #21 with no additional spacing required beyond their physical dimension which is greater than 40" x 40". The containers are received in a horizontal position. This condition will be maintained in Buildings #17 and #21.

Figure 8.30 Fuel Assembly Shipping Containers

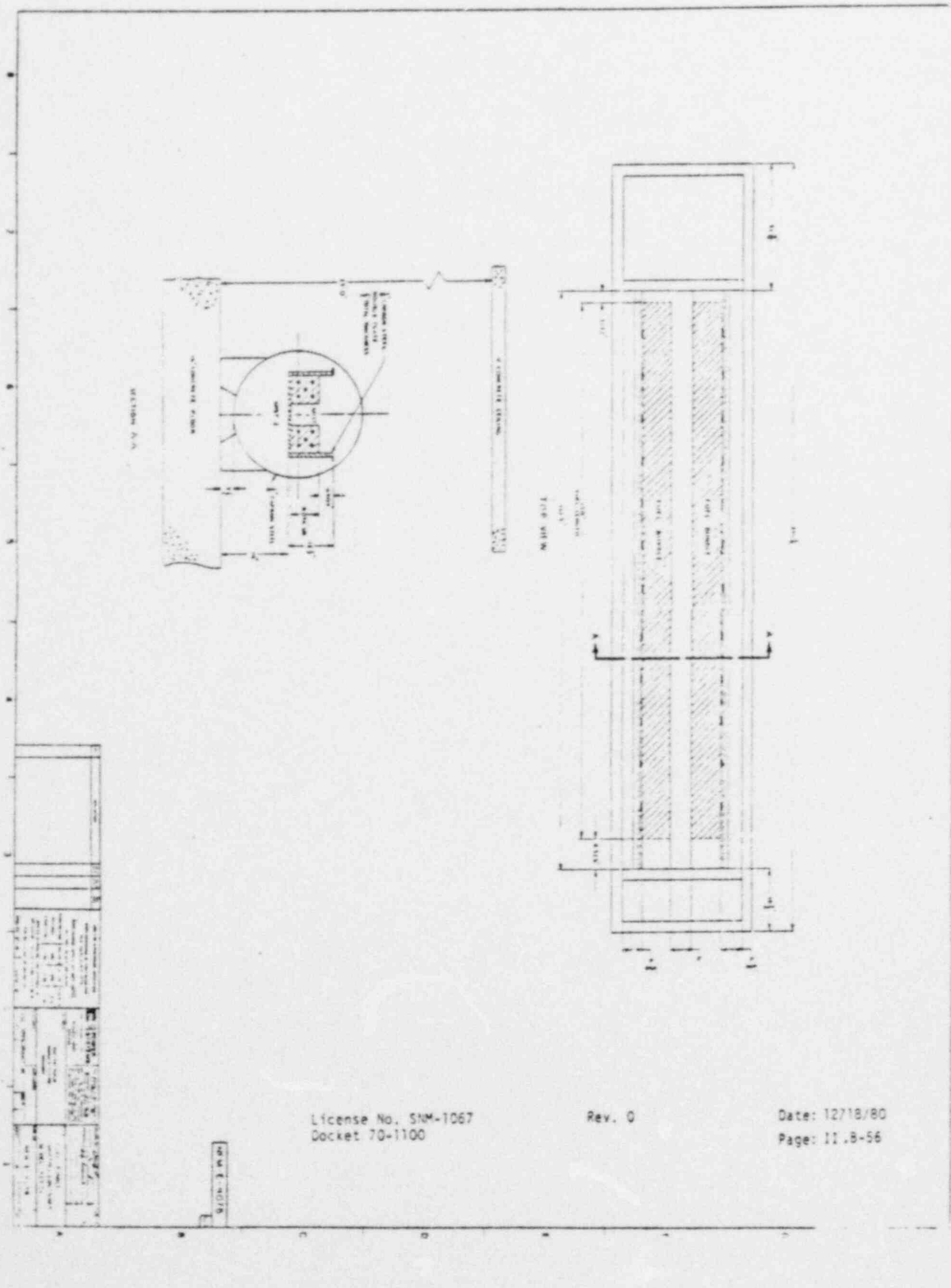
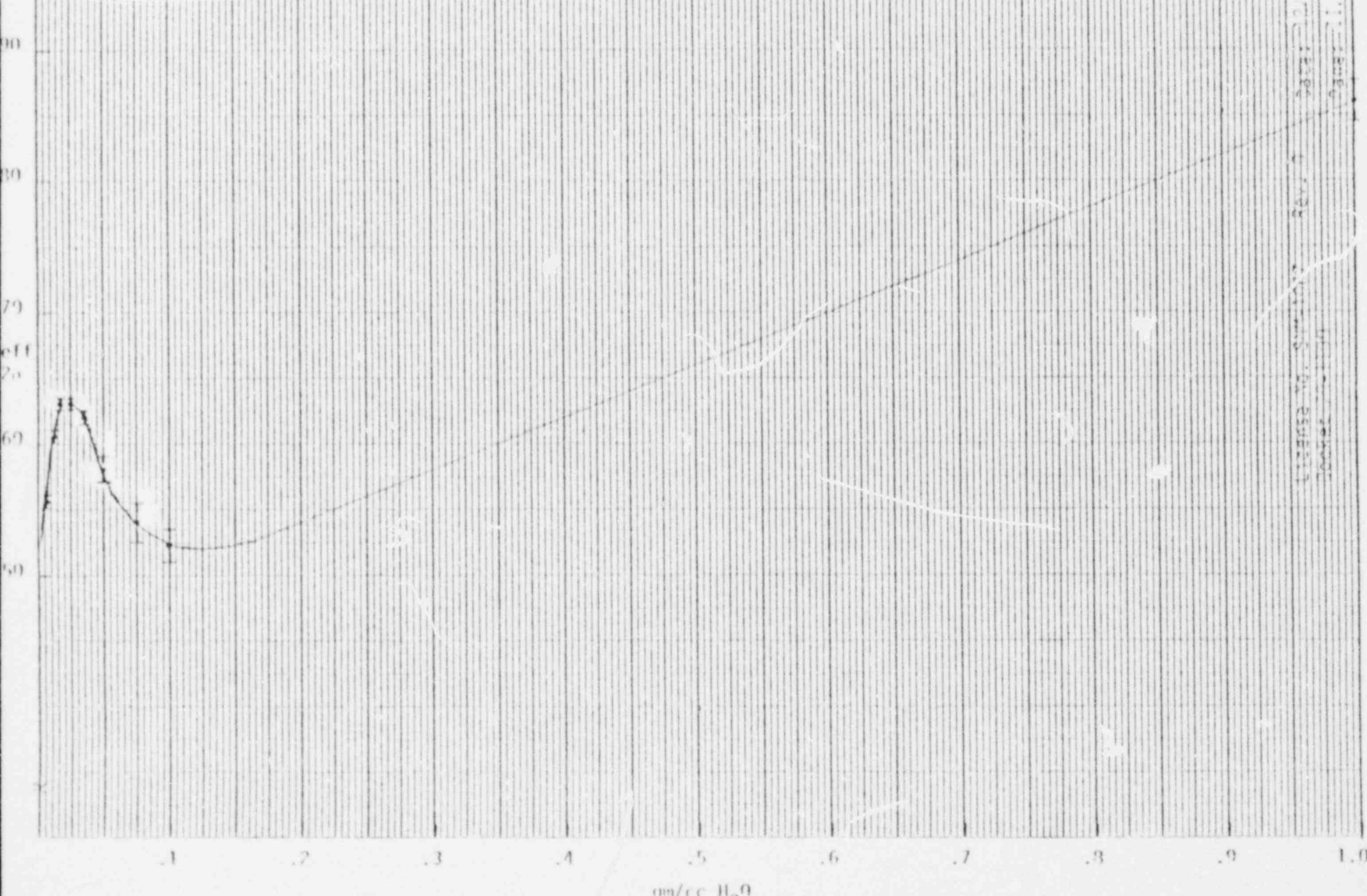


Figure 8.31

Fuel Assembly Shipping Containers

Variable Density External Mist



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8.6 High Enriched Uranium

Up to 350 gms U^{235} of <20% enriched uranium compounds may be allowed in Building #17 and #21 for purposes of evaluation, analysis, or waste management which consists of scanning drums in preparation for their burial. Such material will be transferred, controlled, and accounted for in accordance with currently approved nuclear material control plans, and except for the drums, all material will be placed in discrete locations specifically designated and posted for this material. None of these materials will be processed through manufacturing operations in Building #17 and #21.

9.0 ACCIDENT ANALYSES

9.1 Spectrum and Impact of Accidents Analyzed

Section 6 of NFM-Windsor's Environmental Impact Information evaluates the consequences of all credible accidents. In all cases examined, the probability of a major accident was found to be extremely low. This low probability is derived from the fact that: 1) all process equipment is designed to incorporate permanently engineered safeguards; 2) strict administrative control of production processes is maintained; 3) the double contingency principle is adhered to in the preparation of safety evaluations; and 4) generous safety factors are included in all facility limits.

Off-site impact of the spectrum of accidents discussed in the Environmental Impact Information is shown below:

Accident	Classification	Off-Site Impact
Injured Employee	Personnel Emergency	None
Contaminated Employee	Personnel Emergency	None
Process Leak or Spill	Plant Emergency	None
Fire	Plant Emergency	None
Release of 25 µCi of Airborne Radioactive Particulates into CE Site Environs	Site Emergency	<50% of MPC for insoluble U^{235} at site boundary
Criticality Accident	Site Emergency	Whole body dose .216 RAD Thyroid Dose 1.32 RAD
Emergency Alert	Emergency Alert	None (off-site impact from Emergency Alerts which are reclassified into Plant or Site Emergencies are described above).

9.2 Analysis of Postulated Incidents Having Offsite Impact

9.2.1 Criticality Accident

Since the amount of U^{235} on site is greater than the minimum mass necessary to achieve criticality, it is necessary to consider the possibility of a criticality incident. While such an accident is theoretically possible, it is highly unlikely because of the administrative and operational controls established by C-E over the

COMBUSTION ENGINEERING, INC. AND SUBSIDIARY COMPANIES

COMPUTATION OF NET INCOME PER SHARE

PRIMARY EARNINGS PER SHARE:

The average number of shares (16,371,638) used in the calculation of net income per share in 1979 includes 117,525 shares issuable as a result of the assumed exercise of outstanding options at year-end based on the treasury stock method using average market price per share during 1979.

FULLY DILUTED EARNINGS PER SHARE:

Assuming exercise of outstanding stock options at year-end based on the treasury stock method using the year-end market price, net income per share in 1979 would have been computed as follows:

	(Thousands)
Net income	$97,641
Average number of shares outstanding	16,254
Additional shares (net) as a result of assumed exercise of options	224
	16,478
Fully diluted earnings per share	$ 5.93

COMBUSTION ENGINEERING, INC. AND SUBSIDIARY COMPANIES

SCHEDULE XVI - SUPPLEMENTARY INCOME STATEMENT INFORMATION

YEARS ENDED DECEMBER 31, 1978, and 1979

Column A	Column B	
	Charged To Costs and Expenses	
Item	1979	1978
Maintenance and repairs	$57,020,000	$41,456,945
Depreciation, depletion and amortization of property, plant and equipment	66,137,562	52,567,333
Taxes, other than income taxes:		
Payroll taxes	59,894,774	52,188,031
Other	18,829,812	16,391,908
Rents	43,355,446	37,279,810
Research and development costs	37,691,788	31,909,938

COMBUSTION ENGINEERING, INC. AND SUBSIDIARY COMPANIES

SCHEDULE XIII -- CAPITAL SHARES - DECEMBER 31, 1979 (3)

Column A	Column B	Column C	Column D		Column E		Column F		Column G	
			Number of Shares Included in Column C, Which are		Shares Issued or Outstanding As Shown on or Included in Related Balance Sheet Under Caption "Capital Stock"		Number of Shares Held by Affiliates for Which Statements are Filed Herewith		Number of Shares Reserved for Options Warrants, Conversions and Other Rights	
Name of Issuer and Title of Issue	Number of Shares Authorized by Charter	Number of Shares Issued and not Retired or Canceled	Held By or For Account of Issuer Thereof	Not Held By or For Account of Issuer Thereof	Number (1)	Amount At Which Shown	Persons Included in Consolidated Statements	Others	Directors, Officers and Employees	Others
COMBUSTION ENGINEERING, INC.:										
Preferred stock--no par value	2,000,000	-	-	-	-	$ -		-	None	None
Common stock--$1 par value per share	50,000,000	16,480,606	143,487	16,337,119	16,480,606	$66,416,6[illegible]	-	-	None	None
TYLINTER, INC.:										
Common stock--$100 par value per share	250	250	-	250	-	(2) $ 250,000	125	-	None	None
SEATON ENGINEERING COMPANY:										
Common stock--no par value	1,000	1,000	-	1,000	-	(2) $ 490	510	-	None	None
CE-KSB PUMP COMPANY, INC.:										
Common stock--$1 par value per share	1,000	1,000	-	1,000	-	(2) $ 500,000	800	-	None	None
BASIC BALLISTICS COMPANY:										
6% Preferred Stock--$100 par value	750	534	-	534	-	-	534	-	None	None
Common stock--$8 par value	250	250	-	250	-	(2) $ 1,000	125	-	None	None
VETCO IRAN, LIMITED:										
Capital shares--1,000 RLS par value per share	1,000	1,000	-	1,000	-	(2) $ 3,250	750	-	None	None
VETCO COATING GmbH	DM 900,000	DM 900,000	-	DM 900,000	-	(2) $ 120,120	DM 600,000	-	None	None

NOTES:

(1) Before deducting shares held in Treasury.

(2) Represents minority interests.

(3) Consolidated subsidiaries of which all the outstanding shares of each issue of the Capital stock were held by one or more persons included in the consolidated financial statements have been omitted from the above schedule. The answer to Column G for such subsidiaries would be "None".

COMBUSTION ENGINEERING, INC. AND SUBSIDIARY COMPANIES

SCHEDULE XII
(Continued)

SCHEDULE XII -- VALUATION AND QUALIFYING ACCOUNTS AND RESERVES

YEAR ENDED DECEMBER 31, 1979

Column A	Column B	Column C			Column D	Column E
		Additions				
Description	Balance at Beginning of Period	Beginning Balance of Acquired Companies(1)	Charged to Costs and Expenses	Charged to Other Accounts	Deductions from Reserves	Balance at End of Period
YEAR ENDED DECEMBER 31, 1979: RESERVES DEDUCTED IN THE BALANCE SHEET FROM THE ASSET TO WHICH THEY APPLY:						
Reserves for doubtful accounts and allowances	$14,331,538	$ 132,731	$ 5,792,980	$ -	$6,428,208(2)	$13,829,041
RESERVES INCLUDED IN CURRENT LIABILITIES:						
Reserve for additional costs and possible future expenses on completed contracts (6)	$13,581,232	$ 276,000	$10,478,650	$2,323,000(5)	$3,947,980(3)	$22,710,902
Reserve for supplementary pension plan	1,768,774	-	91,085	-	196,788(4)	1,663,071
	$15,350,006	$ 276,000	$10,569,735	$2,323,000	$4,144,768	$24,373,973

NOTES:

(1) Represents reserve accounts of acquired companies, see Note 2 of Notes to Financial Statements.

(2) Represents uncollectible receivables and sales allowances granted.

(3) Represents additional costs incurred and adjustments.

(4) Represents pension payments.

(5) Reclas[illegible]d from contract accruals.

(6) See co[illegible]nt in Item 1(b) on page 2 with respect to cost estimates for long-term contracts and provisions for future warranty costs.

COMBUSTION ENGINEERING, INC. AND SUBSIDIARY COMPANIES

SCHEDULE XII -- VALUATION AND QUALIFYING ACCOUNTS AND RESERVES

YEAR ENDED DECEMBER 31, 1978

Column A	Column B	Column C			Column D	Column E
		Additions				
Description	Balance at Beginning of Period	Beginning Balance of Acquired Companies(1)	Charged to Costs and Expenses	Charged to Other Accounts	Deductions from Reserves	Balance at End of Period
YEAR ENDED DECEMBER 31, 1978: RESERVES DEDUCTED IN THE BALANCE SHEET FROM THE ASSET TO WHICH THEY APPLY:						
Reserves for doubtful accounts and allowances	$12,469,507	$ 53,000	$4,657,058	$ -	$2,848,027[2]	$14,331,538
RESERVES INCLUDED IN CURRENT LIABILITIES:						
Reserve for additional costs and possible future expenses on completed contracts	$11,966,201	$ -	$4,578,757	$ -	$2,963,726[3]	$13,581,232
Reserve for supplementary pension plan	1,864,481	-	91,406	-	187,113[4]	1,768,774
	$13,830,682	$ -	$4,670,163	$ -	$3,150,839	$15,350,006

NOTES:

(1) Represents reserve accounts of acquired companies, see Note 2 of Notes to Financial Statements.

(2) Represents uncollectible receivables and sales allowances granted.

(3) Represents additional costs incurred and adjustments.

(4) Represents pension payments.

COMBUSTION ENGINEERING, INC. AND SUBSIDIARY COMPANIES

SCHEDULE XI -- GUARANTEES OF SECURITIES OF OTHER ISSUERS (1)

DECEMBER 31, 1979

Column A	Column B	Column C	Column D	Column E	Column F	Column G
Name of Issuer of Securities Guaranteed by Person for Which Statement is Filed	Title of Issue of Each Class of Securities Guaranteed	Amount Guaranteed and Outstanding	Amount Owned by Person or Persons for Which Statement is Filed	Amount in Treasury of Issuer of Securities Guaranteed	Nature of Guarantee	Nature of Any Default by Issuer of Securities Guaranteed in Principal, Interest, Sinking Fund or Redemption Provisions, or Payment of Dividends
Equipetrol-Industria E Comercio, S.A.	Bank Loan	$ 174,000	$ -	$ -	(2)	None
The Lummus Company/ Thyssen Rheinstahl Technik, G.m.b.H. Joint Venture	Overdraft Facility	21,433,000	-	-	(2)	None
		$21,607,000	$ -	$ -		

NOTES:
(1) The foregoing data excludes discounted notes receivable.
(2) Guarantee of principal and interest.

COMBUSTION ENGINEERING, INC. AND SUBSIDIARY COMPANIES

SCHEDULE IX -- BONDS, MORTGAGES AND SIMILAR DEBT

DECEMBER 31, 1979

Column A	Column B	Column C	Column D		Column E	Column F	Column G	Column H	
			Amount Included in Column C, Which is					Amounts Held by Affiliates for Which Statements are Filed Herewith	
Name of Issuer and Title of Issue	Amount Authorized by Indenture	Amount Issued and Not Retired or Canceled	Held by or for Account of Issuer Thereof	Not Held by or for Account of Issuer Thereof	Amount Included in Sum Extended Under Caption "Long-term Debt" in Related Balance Sheet	Amount in Sinking and Other Special Funds by Issuer Thereof	Amount Pledged by Issuer Thereof	Persons Included in Consolidated Statements	Other
Combustion Engineering, Inc.:									
7.45% Sinking Fund Debentures due 1996	$ 50,000,000	$ 50,000,000	$ -	$50,000,000	$ 50,000,000	$ -	$ -	$ -	$ -
6 3/8% (as amended in January, 1980) Sinking Fund Debentures due 1992	50,000,000	36,668,000	2,511,000	34,157,000	34,157,000	2,511,000	-	-	-
9% Term Loan due 1988 (2)	7,000,000	6,200,000	-	6,200,000	5,800,000(1)	-	-	-	-
11 1/4% Term Loan due 1990 (2)	5,000,000	4,050,000	-	4,050,000	3,670,000(1)	-	-	-	-
Basic Incorporated: 10% Note Payable: $750,000 annually from 1980 to 1985 (3)	4,500,000	4,125,000	-	4,125,000	3,937,500(1)	-	-	-	-
Vetco Inc.: 9 1/2% Note Payable $1,000,000 annually from 1980 to 1983 and $2,000,000 annually thereafter	20,000,000	20,000,000	-	20,000,000	19,000,000(1)	-	-	-	-
Capitalized Lease Obligations: Payable through 2001 (4)									
Combustion Engineering, Inc.					6,071,119(1)				
Subsidiary Companies					15,777,058(1)				
Notes and Other Term Payables:									
Combustion Engineering, Inc.					1,016,870(1)				
Subsidiary Companies					4,956,522(1)				
					$144,386,069				

NOTES:
(1) Excludes amount classified as current portion of long-term debt at December 31, 1979.
(2) Payable in semiannual instalments.
(3) Payable in quarterly instalments.
(4) See Note 6 of Notes to Financial Statements.

COMBUSTION ENGINEERING, INC. AND SUBSIDIARY COMPANIES

SCHEDULE VI -- ACCUMULATED DEPRECIATION, DEPLETION AND AMORTIZATION OF PROPERTY, PLANT AND EQUIPMENT

YEARS ENDED DECEMBER 31, 1978 AND 1979

Column A	Column B	Column C		Column D	Column E	Column F
		Additions				
Description	Balance at Beginning of Period	Beginning Balance of Acquired Companies (1)	Charges To Costs and Expenses (2)	Retirements	Other Changes Add (Deduct)	Balance at End of Period
YEAR ENDED DECEMBER 31, 1978:						
Land improvements	$ 3,856,925	$ 13,839	$ 447,256	$ 21,142	$ -	$ 4,296,878
Buildings	66,684,794	45,519	7,794,666	1,289,747	-	73,235,232
Machinery and equipment	213,792,211	874,341	44,325,411	1,271,580	-	257,720,383
	$284,333,930	$933,699	$52,567,333	$ 2,582,469	$ -	$335,252,493
YEAR ENDED DECEMBER 31, 1979:						
Land improvements	$ 4,296,878	$ -	$ 909,597	$ 75,426	$ -	$ 5,131,049
Buildings	73,235,232	-	10,495,413	2,184,057	-	81,546,588
Machinery and equipment	257,720,383	-	54,732,552	17,858,371	-	294,594,564
	$335,252,493	$ -	$66,137,562	$20,117,854	$ -	$381,272,201

NOTES:

(1) Represents in 1978, the reserves for depreciation of property, plant and equipment of a company acquired in a transaction constituting a pooling of interests.

(2) See Note 1(g) of Notes to Financial Statements for a statement of depreciation policies.

COMBUSTION ENGINEERING, INC. AND SUBSIDIARY COMPANIES

SCHEDULE V -- PROPERTY, PLANT AND EQUIPMENT

YEARS ENDED DECEMBER 31, 1978 AND 1979

Column A	Column B	Column C		Column D	Column E	Column F
		Additions				
Classification	Balance at Beginning of Period	Beginning Balance of Acquired Companies (1)	At Cost	Retirements	Other Changes Add (Deduct)	Balance at End of Period
YEAR ENDED DECEMBER 31, 1978:						
Land and land improvements	$ 30,624,508	$ 61,594	$ 2,816,756	$ 790,101	$ -	$ 32,712,757
Buildings	203,156,797	528,589	9,710,994	3,875,700	-	209,520,680
Machinery and equipment	472,072,426	12,676,376	42,540,704	5,595,343	-	521,694,163
Construction in progress	15,625,597	-	6,565,643 (2)	-	-	22,191,240
	$721,479,328	$13,266,559	$61,634,097	$10,261,144	$ -	$786,118,840
YEAR ENDED DECEMBER 31, 1979:						
Land and land improvements	$ 32,712,757	$ 8,257,752	$ 2,894,491	$ 349,411	$ -	$ 43,515,589
Buildings	209,520,680	11,591,727	11,825,824	4,810,711	-	228,127,520
Machinery and equipment	521,694,163	38,409,140	56,514,184	30,444,542	-	586,172,945
Construction in progress	22,191,240	611,048	16,637,296 (2)	-	-	39,439,584
	$786,118,840	$58,869,667	$87,871,795	$35,604,664	$ -	$897,255,638

NOTES:

(1) Represents, in 1978 and 1979, the property, plant and equipment of acquired companies; see Note 2 of Notes to Financial Statements.

(2) Net of transfers to completed property, plant and equipment.

COMBUSTION ENGINEERING, INC. AND SUBSIDIARY COMPANIES

SCHEDULE II -- AMOUNTS RECEIVABLE FROM UNDERWRITERS, PROMOTERS,

DIRECTORS, OFFICERS, EMPLOYEES,

AND PRINCIPAL HOLDERS (OTHER THAN AFFILIATES) OF EQUITY SECURITIES

OF THE PERSON AND ITS AFFILIATES

YEAR ENDED DECEMBER 31, 1978

Column A	Column B	Column C	Column D		Column E	
			Deductions		Balance at End of Period	
Name of Debtor	Balance at Beginning of Period	Additions	Amounts Collected	Amounts Written Off	Current	Not Current
YEAR ENDED DECEMBER 31, 1978:						
Gordon Bronson (1) (2)	$ 89,364	$ -	$ 831	$ -	$ 88,533	$ -
Harold Bateson (1) (2)	17,935	-	-	-	17,935	-
	$107,299	$ -	$ 831	$ -	$106,468	$ -

NOTES:

(1) Includes indebtedness of a partnership of which Mr. Bronson and Mr. Bateson (now deceased) were partners. Such partnership indebtedness at December 31, 1978 amounted to $48,386. Subsequent to December 31, 1978, $17,099 of the partnership indebtedness was collected. Mr. Bronson resigned on November 13, 1978.

(2) In addition, a former subsidiary, successor to the partnership business referred to in Note 1, sought indemnification by Mr. Bronson and the estate of Mr. Bateson in the amount of approximately $3,700,000, including litigation expenses, with respect to a judgement entered against Mr. Bronson and the estate of Mr. Bateson arising out of events which occurred prior to acquisition of such subsidiary by the Company. Reserves were provided in 1978 for all amounts then due from Messrs. Bronson and Bateson including the foregoing amount for which the former subsidiary claimed indemnification. A final settlement was reached with Mr. Bronson during 1979 which involved the repayment of $5,000 over a 3-year period.

Estimated replacement cost of sales with comparative historical amounts are as follows:

Cost of Sales	December 31, 1979	December 31, 1978
Total as shown in accompanying consolidated financial statements	$2,373,358,000	$2,006,266,000
Less - Amounts for which replacement cost data are not required; primarily contracts for products and services designed to meet customer specifications	1,634,143,000	1,307,840,000
Historical cost basis of amounts for which replacement cost data is required	$ 739,215,000(1)	$ 698,426,000(1)
Estimated replacement cost	$ 767,959,000(1)	$ 722,373,000(1)
(1) Depreciation and amortization included above -		
Historical cost basis	$ 22,893,000	$ 23,671,000
Replacement cost basis	$ 37,686,000	$ 36,170,000

Replacement cost of sales for the years ended December 31, 1979 and 1978 was estimated through adjustment of historical costs for the cost increases which occurred between the incurrence of inventory costs and the subsequent sales. For this purpose, reference was made to current production cost records, LIFO cost of sales data, frequency of inventory turn and internal indexes which reflect the magnitude of price increases during the years.

The replacement costs shown above do not reflect any operating cost reductions which result from the replacement of existing assets with new assets having greater efficiency. If the Company's productive capacity were to be replaced in the manner assumed in the calculation of replacement cost of existing productive capacity, many costs other than depreciation (e.g., direct labor costs, repairs and maintenance, utilities and other indirect costs) would be reduced. Although these expected cost changes cannot be quantified with any precision, in the opinion of management, operating costs would be significantly reduced

Estimated replacement cost of inventories with comparative historical amounts are as follows:

Inventories	December 31, 1979	December 31, 1978
Total as shown in accompanying consolidated financial statements	$528,369,000	$458,640,000
Less - Amounts for which replacement cost data are not required; primarily contracts for products and services designed to meet customer specifications	349,327,000	270,325,000
Historical cost basis of amounts for which replacement cost data is required	$179,042,000	$188,315,000
Estimated replacement cost	$224,720,000	$230,796,000

Estimated replacement costs of finished goods and work-in-process inventories at December 31, 1979 and 1978, were calculated using year end production cost records adjusted for estimated replacement cost depreciation. For raw materials inventories, replacement costs were determined from published prices, latest vendor invoice prices or internally prepared indexes.

The impact of restating inventories (other than the theoretical adjustment of depreciation to reflect replacement cost of property, plant and equipment) is minimized by the Company's use of the last-in, first-out (LIFO) method of valuing certain inventories.

For the majority of the Company's investment in plant facilities and equipment, replacement costs were estimated using specific current cost information. In the case of machinery and equipment, current quoted market prices were obtained, where practicable, for new assets of equivalent capacity taking into consideration technological change. For recently acquired major equipment items which would be replaced in kind, and for all other less significant machinery and equipment, replacement costs were estimated by applying indexes to historical costs. Such indexes included public information such as Wholesale Price Indexes and internal indexes derived from recent cost data for items of similar productive capacity. The replacement cost of recently constructed buildings was estimated by applying published construction cost indexes to the acquisition prices of the buildings. For older buildings, current estimated construction costs for equivalent space were determined using internal construction information and cost per square foot data obtained from construction contractors and an independent appraisal firm.

Accumulated depreciation and amortization used in arriving at net property, plant and equipment, based on the replacement cost of productive capacity, has been estimated on a straight-line basis using substantially the same estimates of useful life and salvage value as utilized in preparing the historical cost data. Average replacement cost of productive capacity during the year was the basis upon which replacement cost depreciation and amortization was computed.

All replacement cost amounts related to foreign assets have been initially calculated in the relevant foreign currency and then translated to U.S. dollars using year end rates of exchange. Replacement cost amounts related to foreign replacement cost depreciation have been translated using average annual rates of exchange.

Inventories and Cost of Sales -

A substantial portion of the Company's products and services are furnished to meet the requirements of customer specifications and, in connection therewith, the Company does not acquire materials or expend efforts to any consequential degree until a commitment or contract is received from the customer. Accordingly, replacement cost data as to inventories and cost of sales for such products and services are not provided for in the tables which follow.

	Property, Plant & Equipment at December 31, 1979		Depreciation and Amortization For the Year Ended
	Gross	Net	December 31, 1979
Total as shown in accompanying consolidated financial statements	$ 897,256,000	$515,983,000	$66,138,000
Less - Items for which replacement cost data are not required; primarily land, construction in progress, mineral resource assets and assets which will not be replaced	92,836,000	73,178,000	1,127,000
Historical cost basis of amounts for which replacement cost data is required	$ 804,420,000	$442,805,000	$65,011,000
Estimated replacement cost	$1,686,208,000	$725,109,000	$96,644,000

	Property, Plant & Equipment at December 31, 1978		Depreciation and Amortization For the Year Ended
	Gross	Net	December 31, 1978
Total as shown in accompanying consolidated financial statements	$ 786,119,000	$450,866,000	$52,567,000
Less - Items for which replacement cost data are not required; primarily land, construction in progress, mineral resource assets and assets which will not be replaced	74,288,000	55,801,000	3,912,000
Historical cost basis of amounts for which replacement cost data is required	$ 711,831,000	$395,065,000	$48,655,000
Estimated replacement cost	$1,426,510,000	$633,416,000	$77,458,000

SUPPLEMENTARY NOTE TO FINANCIAL STATEMENTS

REPLACEMENT COST INFORMATION (UNAUDITED)

The following estimated replacement cost information on inventories and plant and equipment at December 31, 1979 and 1978, and the related estimated effect of such data on cost of sales and depreciation and amortization is required by the Securities and Exchange Commission under Rule 3-17 of Regulation S-X of the Securities and Exchange Act of 1934.

This data differs as to concept and result from the historical cost/constant dollar information which is required to be furnished in the Company's annual report to shareholders for 1979 (see pages 38 and 39).

The SEC cautions against simplistic use of the data required. It is important in the use of replacement cost information that the following factors be considered:

(a) The information should not be interpreted to indicate that the Company actually has present plans to replace its productive capacity or that actual replacement would or could take place in the manner assumed in estimating the information. In the normal course of business, the Company will replace its productive capacity over an extended period of time. Decisions concerning replacement will be made in the light of economic, regulatory and competitive conditions existing on the dates such determinations are made and could differ substantially from the assumptions on which the data included herein are based.

(b) The use of replacement cost depreciation in restating inventories and cost of sales as required by the SEC is a theoretical concept intended to focus attention on the effect of inflation. Depreciation is normally intended only to allocate the original purchase cost over the useful life of the related fixed asset and not to provide for the replacement of property, plant and equipment.

(c) The information required on the restatement of property, plant and equipment has had to be estimated on the basis of numerous assumptions. The lack of definitive guidelines for determining the data to be reported will certainly lead to differences that will make meaningful comparisons to the data furnished by other companies hazardous.

(d) The replacement cost data presented herein are not necessarily representative of the "current value" of existing inventories and productive capacity.

Property, Plant and Equipment -

Replacement costs have been estimated for the Company's property, plant and equipment excluding certain assets for which replacement cost information is not required. The following tables set forth the reconciliation of gross and net property, plant and equipment at December 31, 1979 and 1978 and depreciation and amortization for the years then ended to amounts for which replacement cost data are required:

Nor has adjustment been made to the provision for income taxes included in the adjusted income from continuing operations, as current tax laws do not permit the deduction of the additional costs resulting from inflation. As a result, although the effective income tax rate based on historical cost financial data is 47.7%, after the above adjustments to cost of sales and depreciation and amortization, the effective tax rate would be 55.1%. This higher effective tax rate is indicative of the result of taxation of inflation adjustments.

The purchasing power gain on net monetary liabilities has not been recognized in the adjusted income from continuing operations. Since the Company is in a net monetary liability position, a significant gain is generated and shown separately. Had such gain been reflected in net income adjusted for general inflation, it would have offset the increased depreciation and amortization and cost of sales resulting from the indexing process.

The following table presents a summary of selected financial data for the years 1975 to 1979 adjusted to average 1979 dollars as measured by the required CPI index:

	1979	1978	1977	1976	1975
(Dollars in Thousands, Except per Share Amounts)					
Net Sales	$2,757,504	$2,595,475	$2,450,337	$2,335,637	$2,308,780
Historical Cost Information Adjusted in Accordance with FAS 33:					
Net Income	$ 72,351				
Net Income per Share	4.42				
Net Assets at End of Year	721,688				
Purchasing Power Gain on Net Monetary Liabilities	25,802				
Cash Dividends Declared per Common Share	$ 2.20	$ 2.00	$ 1.80	$ 1.68	$ 1.69
Market Price per Common Share at Year-end	$ 55.98	$ 34.97	$ 43.39	$ 41.80	$ 28.34
Average Consumer Price Index	217.4	195.4	181.5	170.5	161.2

Data not required

The Company does not regard the foregoing adjusted net income as a proper reflection of the impact of inflation on its operations or as an indication of the effects of inflation on future cash flows for several reasons:

1. Much of the business of the Company and its subsidiaries results from meeting customer requirements specified under contracts. Such contracts are both long and short-term. The contract price, particularly in the case of long-term contracts, either includes an amount for the estimated increase in the cost of labor, materials and services over the period required for performance of the contract, or is subject to adjustment based on a price escalation clause in the contract.

2. With respect to other products and services, the Company and its subsidiaries attempt to recover cost increases by increasing selling prices. Their ability to do so is subject to the limitation of competitive factors, customer demand and the Company's voluntary compliance with federal price guidelines.

3. The use of constant dollar depreciation as required by FAS 33 is a theoretical concept intended to focus attention on the effect of inflation. Depreciation is normally intended only to allocate the original purchase cost over the useful life of the related fixed asset and not to provide for the eventual replacement of property, plant and equipment.

4. Although the cumulative impact of inflation over a number of years has resulted in higher costs for replacement of existing plant and equipment, such inflationary increases have partially been offset by technological improvements and design changes.

5. In the normal course of business, the Company will replace its property, plant and equipment over an extended period of time. Decisions concerning replacement will be made in the light of economic, regulatory and competitive conditions existing on the dates such determinations are made. Therefore, the indexed amounts given effect to herein in accordance with FAS 33 are not meaningful as a measure of future replacement costs.

The underlying concepts of accounting methods which adjust for inflation are not radically new. Management considers relevant economic factors in making basic business decisions. Investors also recognize that inflation affects future cash flows and the capability of a company to continue its operations at the levels it has attained in the past. Interpretation of data such as is required by FAS 33, however, is very much dependent on the facts and circumstances in each case, as well as uncontrollable future events. Therefore, any interpretation of such data without the knowledge of the particular facts and circumstances can be misleading.

Supplementary Information Concerning the Impact of the Changes in the General Level of the Purchasing Power of the Dollar (Unaudited)

Introduction

In September, 1979, the Financial Accounting Standards Board issued Statement of Financial Accounting Standards No. 33, Financial Reporting and Changing Prices (FAS 33). The Statement requires large, publicly held companies to include certain information concerning the impact of inflation as a supplement to the customary financial information in the annual report. This Statement acknowledges the need for experimentation in providing information on the effects of inflation, as well it might.

FAS 33 requires the calculation and statement of an adjusted net income amount (presumably for comparison with net income as reported in the accompanying Consolidated Financial Statements). It is to be noted that the predecessor to FAS 33, namely, the Securities and Exchange Commission Accounting Series Release No. 190, issued in March, 1976, dealing with the same general subject of inflation-adjusted amounts, made no attempt to determine an adjusted net income and actually cautioned against simplistic use for this purpose of the data presented.

The objectives of FAS 33 are to be accomplished in a two-step approach: a general indexing approach called constant dollar accounting, and a specific pricing method called current cost accounting. Only constant dollar accounting information is being presented herein. Current cost calculations will be furnished beginning with the year 1980.

FAS 33 Requirements

FAS 33 requires certain historical cost dollar amounts to be adjusted to amounts which have purchasing power equivalent to that of the average dollar for 1979. This is to be accomplished by indexing certain historical cost amounts using the Consumer Price Index for All Urban Consumers (CPI). It should be noted that the CPI is not necessarily representative of the actual impact of inflation on the Company's costs. In addition, the constant dollar information does not purport to represent appraised value, current cost value or replacement cost of the related assets.

In determining "income from continuing operations on a historical cost/constant dollar" basis, adjustments are to be made for the effects of depreciation and amortization and cost of sales that result from applying the indexing process to property, plant and equipment and certain inventory. Also, the related required disclosure of "net assets at end of year on a historical cost/constant dollar" basis is similarly only to be adjusted by the effects of indexing net property, plant and equipment and inventory.

FAS 33 requires the estimation of the "purchasing power gain (loss) on net monetary items." Monetary items are those assets or liabilities which are stated in dollars that are fixed or determinable without reference to future prices. All other assets and liabilities are considered to be non-monetary. Monetary assets and liabilities depend heavily on the general purchasing power of the dollar and its decrease in value during periods of inflation. Holders of net monetary assets lose purchasing power during inflationary periods since these assets will purchase fewer goods and services in the future; conversely, a person with net monetary liabilities will benefit during periods of inflation because payment of the net liabilities will be in dollars having a lesser value.

Inflation Adjusted Data for 1979

The following table presents a reconciliation between net income as shown in the accompanying Consolidated Financial Statements and net income adjusted to a historical cost/constant dollar basis, and sets forth the purchasing power gain on net monetary liabilities for the year, all as prescribed by FAS 33:

	1979
(Dollars in Thousands)	
Net Income as Shown in the Accompanying Consolidated Financial Statements	$97,641
Adjustments Required by FAS 33 to Restate to Average 1979 Dollars—	
Cost of sales (excluding depreciation and amortization)	(8,692)
Depreciation and amortization	(16,598)
Net Income Adjusted for General Inflation (stated in average 1979 dollars)	$72,351
Purchasing Power Gain on Net Monetary Liabilities	$25,802

As can be seen above, the only adjustments made to net income as reported in the accompanying Consolidated Financial Statements are increases to cost of sales and depreciation and amortization as a result of applying the indexing process to property, plant and equipment and certain inventory. No adjustment to sales has been made.

Capital additions by business segment for the years 1979, 1978 and 1977 were as follows: (a) steam generating systems, equipment and services for the electric utility industry $20.7 million, $13.9 million and $17.0 million; (b) design, engineering and construction services $9.2 million, $5.3 million and $4.3 million; (c) equipment for industrial markets $22.4 million, $23.2 million and $85.8 million and (d) products and services for industrial markets $94.5 million, $32.5 million and $15.0 million.

(b) Significant financial data by geographic area follows (1):

	1979	1978	1977
Sales (2)—			
United States	$2,234,650,000(3)	$1,851,973,000(4)	$1,646,731,000(5)
Canada	191,107,000	163,706,000	169,860,000
Europe	259,950,000	234,134,000	181,419,000
Other Foreign	71,797,000	81,938,000	46,754,000
Total	$2,757,504,000	$2,331,751,000	$2,044,764,000
Net Income—			
United States	$ 71,887,000	$ 60,356,000	$ 52,762,000
Canada	13,552,000	9,639,000	5,670,000
Europe	7,357,000	7,538,000	6,309,000
Other Foreign	4,845,000	2,783,000	2,448,000
Total	$ 97,641,000	$ 80,316,000	$ 67,189,000

December 31,	1979	1978	1977
Identifiable Assets—			
United States	$1,213,796,000	$1,022,587,000	$ 991,094,000
Canada	118,962,000	121,426,000	112,174,000
Europe	200,418,000	177,390,000	211,609,000
Other Foreign	50,771,000	66,047,000	63,644,000
Total	$1,583,947,000	$1,387,450,000	$1,378,521,000

1. Data presented for geographic areas outside of the United States includes operations of foreign subsidiaries and operations of domestic subsidiaries located in foreign areas.

2. Includes only sales to unaffiliated customers (intergeographic sales are not material).

3. Includes export sales of $258,901,000 of which $19,989,000, $47,703,000 and $191,209,000 represent sales to customers in Canada, Europe and other foreign countries, respectively.

4. Includes export sales of $193,052,000 of which $11,686,000, $50,228,000 and $131,138,000 represent sales to customers in Canada, Europe and other foreign countries, respectively.

5. Includes export sales of $189,630,000 of which $9,041,000, $50,842,000 and $129,747,000 represent sales to customers in Canada, Europe and other foreign countries, respectively.

Auditors' Report

To the Board of Directors and Stockholders of Combustion Engineering, Inc.:

We have examined the consolidated balance sheets of Combustion Engineering, Inc. (a Delaware corporation) and subsidiary companies as of December 31, 1979 and 1978, and the related consolidated statements of income, retained earnings and changes in financial position for the years then ended. Our examinations were made in accordance with generally accepted auditing standards and, accordingly, included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

In our opinion, the accompanying consolidated balance sheets and consolidated statements of income, retained earnings and changes in financial position present fairly the financial position of Combustion Engineering, Inc. and subsidiary companies as of December 31, 1979 and 1978, and the results of their operations and the changes in their financial position for the years then ended, in conformity with generally accepted accounting principles applied on a consistent basis.

Arthur Andersen & Co.

Stamford, Connecticut
February 13, 1980

15. Financial Reporting by Business Segments

The Company's equipment, products and services are classified into the following business segments: (a) design, manufacture, installation and service of steam generating systems and equipment for the electric utility industry, including nuclear steam supply systems; (b) design, engineering and construction services (principally through its subsidiary, The Lummus Company), primarily for the chemical, petrochemical and petroleum industries; (c) equipment supplied to industrial markets and (d) products and services supplied to industrial markets.

(a) The following tables present financial data by business segment:

	1979	1978	1977
Sales (1)—			
Steam generating systems, equipment and services for the electric utility industry	$ 926,220,000	$ 815,767,000	$ 747,808,000
Design, engineering and construction services	351,719,000	308,438,000	300,698,000
Equipment for industrial markets	815,563,000	688,815,000	606,338,000
Products and services for industrial markets	664,002,000	518,731,000	389,920,000
Total	$2,757,504,000	$2,331,751,000	$2,044,764,000
Operating Profit—			
Steam generating systems, equipment and services for the electric utility industry	$ 65,166,000	$ 56,985,000	$ 46,451,000
Design, engineering and construction services	27,979,000	27,663,000	24,664,000
Equipment for industrial markets	81,167,000	62,823,000	53,477,000
Products and services for industrial markets	25,948,000	20,819,000	13,147,000
Total	$ 200,260,000	$ 168,290,000	$ 137,739,000
Equity in Net Earnings of Associated and Other Companies (2)	4,340,000	1,397,000	1,775,000
Interest Expense	(16,663,000)	(18,400,000)	(11,563,000)
Unallocated—			
Corporate expense	(16,356,000)	(14,443,000)	(12,141,000)
Miscellaneous, net	15,000,000	22,172,000	17,199,000
Consolidated income before income taxes	$ 186,581,000	$ 159,016,000	$ 133,009,000

December 31,	1979	1978	1977
Identifiable Assets—			
Steam generating systems, equipment and services for the electric utility industry	$ 432,133,000	$ 385,962,000	$ 358,021,000
Design, engineering and construction services	151,989,000	135,746,000	135,230,000
Equipment for industrial markets	548,756,000	515,815,000	550,387,000
Products and services for industrial markets	451,069,000	349,927,000	334,883,000
Total	$1,583,947,000	$1,387,450,000	$1,378,521,000
Investments in Associated and Other Companies (Equity Basis) (2)	50,713,000	33,172,000	20,988,000
Corporate and Unallocated Assets, net (3)	448,300,000	416,325,000	254,765,000
Consolidated	$2,082,960,000	$1,836,947,000	$1,654,274,000

1. Includes only sales to unaffiliated customers (intersegment sales are not significant) and no single customer accounts for 10% or more of the consolidated sales.

2. Companies accounted for under the equity method of accounting (20% or more owned) are located principally in the United States, Europe and other foreign areas. The principal companies included in this category are not vertically integrated with the operations of the Company and its consolidated subsidiaries. Such companies are engaged in the manufacture and sale of steam gen[illegible]quipment for utility and industrial use and other equipment, products and services for industrial markets.

3. Includes primarily cash [illegible]ecurities and corporate facilities.

Depreciation and amor[illegible] segment for the years 1979, 1978 and 1977 were as follows: (a) steam generating systems, equ[illegible]ment [illegible]rvices for the electric utility industry $18.0 million, $12.2 million and $11.8 million; (b) design, enginee[illegible]ing and construction services $3.3 million, $3.7 million and $2.9 million; (c) equipment for industrial markets $22.3 million, $20.1 million and $12.2 million and (d) products and services for industrial markets $21.6 million, $16.0 million and $12.2 million. Similar amounts charged to corporate and unallocated assets were $.9 million in the year 1979, $.6 million in the year 1978 and $.5 million in the year 1977.

10. Quarterly Financial Data (Unaudited)

Summarized unaudited quarterly financial data for the years 1979 and 1978 is as follows:

	First Quarter	Second Quarter	Third Quarter	Fourth Quarter
1979				
Net sales	$582,789,000	$675,781,000	$684,881,000	$814,053,000
Operating income	$ 32,110,000	$ 42,345,000	$ 35,186,000	$ 61,104,000
Net income	$ 18,099,000	$ 23,036,000	$ 21,494,000	$ 35,012,000
Net income per share	$ 1.11	$ 1.42	$ 1.30	$ 2.13
1978				
Net sales	$491,923,000	$623,709,000	$559,072,000	$657,047,000
Operating income	$ 27,080,000	$ 37,411,000	$ 30,279,000	$ 52,674,000
Net income	$ 14,985,000	$ 19,726,000	$ 17,278,000	$ 28,327,000
Net income per share	$ .93	$ 1.22	$ 1.08	$ 1.74

11. Net Income per Share

Net income per share was based on the average number of common shares outstanding, including, in 1979, the assumed exercise of outstanding stock options, and, for the period prior to redemption in 1978, common shares issuable on conversion of the Series A Convertible Preferred Stock.

12. Pending Litigation

In May, 1975, three utility companies filed a complaint against the Company and certain other defendants alleging that the Company is liable for breach of contract, breach of warranties, negligence and other claims in connection with the supply and erection of a fossil fueled electric generating plant in New York known as the Roseton Plant. Damages are claimed against all defendants in an unspecific amount alleged to be in excess of $125 million, the major part of which appears to be for consequential damages. The case continues to be in the pretrial discovery phase.

In the past several years, several thousand claimants have brought suit against industrial corporations for serious personal and fatal injuries allegedly resulting from exposure to insulation products containing asbestos. The Company has not manufactured such products for a number of years. The Company has been included as a defendant in approximately 1,900 of such claims, of which approximately 1,000 were asserted in 1979. It can be expected that a substantial number of additional asbestos related claims will continue to be asserted against the Company.

Although the amount of liability, if any, at December 31, 1979, with respect to the actions then pending to which the Company and its subsidiaries are party cannot be ascertained, in the opinion of the Company, any resulting liability will not materially affect the Company's consolidated financial statements.

13. Contingent Liabilities and Commitments

The Company and certain subsidiaries are contingently liable under guarantees and on discounted notes receivable arising in the ordinary course of business. The financial risk involved is not material in relation to the consolidated financial position.

14. Estimated Replacement Cost (Unaudited)

The Company's 1979 annual report on Form 10-K filed with the Securities and Exchange Commission includes additional information (required by the SEC) with respect to the estimated current replacement cost of plant and equipment and certain inventories at December 31, 1979 and 1978, and the related estimated effect of such costs on cost of sales and depreciation and amortization for the years then ended. This data differs from the historical cost/constant dollar information which is required to be furnished in the Company's annual report to shareholders for 1979.

8. Capital Stock

(a) Series A Convertible Preferred Stock

The Series A Convertible Preferred Stock was redeemed on July 24, 1978, at the redemption price of $45 per share. Changes during 1978 in the Series A Convertible Preferred Stock issued and in the treasury were as follows:

	Preferred Stock			
	Issued		Treasury Stock	
	Shares	Amount	Shares	Amount
Balance at December 31, 1977	240,248	$ 1,490,618	54,930	$48,293
Conversion into common stock	(224,157)	(1,390,784)	(54,930)	(48,293)
Redeemed	(16,091)	(99,834)	—	—
Balance at December 31, 1978	—	—	—	—

(b) Common Stock

Changes during 1978 and 1979 in common stock issued and in the treasury, as included in the accompanying Consolidated Balance Sheet, were as follows:

	Common Stock			
	Issued		Treasury Stock	
	Shares	Amount	Shares	Amount
Balance at December 31, 1977	15,978,112	$60,919,295	110,580	$11,474
Conversion of Series A Convertible Preferred Stock	302,499	1,395,272	74,155	48,293
Transfer from retained earnings in connection with redemption of Series A Convertible Preferred Stock	—	99,834	—	—
Transfers in connection with a pooling of interests in:				
1978	—	70,000	(69,371)	—
a prior year	—	—	8,491	—
Balance at December 31, 1978	16,280,611	$62,484,401	123,855	$59,767
Issued in connection with an acquisition	199,995	4,539,287	—	—
Return to treasury of escrow shares	—	(1,134,744)	33,498	—
Exercise of stock options	—	527,694	(13,866)	—
Balance at December 31, 1979	16,480,606	$66,416,638	143,487	$59,767

9. Incentive Compensation Plan

The Company's Incentive Compensation Plan was approved by the stockholders in 1941 and, as amended, in 1968. The Plan provides that in any fiscal year there may be allocated an amount for use in the Plan determined by a formula, but subject to certain limitations. The Compensation Committee of the Board of Directors, comprised of non-participants in the Plan, subject to the approval of the Board of Directors, allocates the amount to be used for the purpose of the Plan in any one year and determines the participants from among the officers and other key salaried employees and the amount of their participation. The amounts allocated to the Incentive Account aggregated $6,000,000 in 1979, and $4,500,000 in 1978.

6. Long-term Leases

Total rent, other than on capital leases, charged to expense was $43,355,000 in 1979, and $37,280,000 in 1978.

At December 31, 1979, the approximate minimum future payments under capital leases and noncancelable operating leases are as follows:

	Capital Leases	Noncancelable Operating Leases
1980	$ 2,989,000	$ 24,416,000
1981	3,207,000	19,343,000
1982	2,909,000	15,152,000
1983	2,864,000	11,385,000
1984	2,877,000	8,120,000
After 1984	22,033,000	30,976,000
Total minimum lease payments	$36,879,000	$109,392,000
Less—Estimated executory costs	1,065,000	
Net minimum lease payments	$35,814,000	
Less—Amount representing interest	12,642,000	
Present value of net minimum lease payments	$23,172,000	

7. Stock Option Plan

The "1970 Stock Option Plan", as amended, provides for the granting, to officers and other salaried employees of the Company and its subsidiaries and employees of operations acquired by the Company, of options to purchase shares of its common stock at the market price of the stock on the dates of grant. Amendments to the "1970 Stock Option Plan", in 1979, extended the expiration date to April 24, 1989 (formerly April 28, 1980), increased the number of shares authorized for options from 600,000 to 1,200,000 and provided for the granting of stock appreciation rights.

Options granted in 1972 under the "1970 Stock Option Plan" were five-year qualified options and ten-year tandem options, and those granted in 1979 and 1978 were ten-year non-qualified options.

In 1979 and 1978, stock appreciation rights relating to 14,500 and 241,750 shares, respectively, were granted and are outstanding at December 31, 1979. Stock appreciation rights entitle the optionee to receive an amount equal to the difference between the option price and the fair market value on the exercise date for the number of shares for which the stock appreciation right is exercised. The payment may be made in shares, cash, or a combination of both, at the discretion of the Compensation Committee of the Board of Directors. The stock appreciation rights become exercisable on the date that the related stock options become exercisable. However, as to rights granted in 1978 in connection with existing non-qualified options, such rights became exercisable six months from the date of stockholder approval. Appreciation of outstanding rights resulted in charges against earnings of $6,000,000 in 1979.

The stock options granted in 1979 and 1978 are exercisable twelve months from date of grant. A summary of option transactions during the years 1978 and 1979 is shown below:

	Number of Shares	Option Price Per Share	Option Price Total	Market Price*
Year ended December 31, 1978:				
Granted	440,248	$34.00	$14,968,432	$14,968,432
Expired	(118,236)	36.88-39.00	4,374,536	
Year ended December 31, 1979:				
Granted	12,500	$37.75	$ 471,875	$ 471,875
Became exercisable	434,748	34.00	14,781,432	25,432,758
Exercised	(13,866)	34.00-39.00	527,694	714,223
Cancelled	(9,250)	34.00-39.00	333,250	
At December 31, 1979:				
Outstanding	547,382	$34.00-39.00	$19,171,613	
Available for future grants	597,023			

*At the dates options were granted, became exercisable or were exercised.

5. Long-term Debt

Long-term debt consisted of the following:

December 31,	1979	1978
7.45% Sinking Fund Debentures due 1996, sinking fund requirement of $3,335,000 annually from 1982 to 1995	$ 50,000,000	$ 50,000,000
6¾% (as amended in January, 1980) Sinking Fund Debentures due 1992, less debentures held in treasury of $2,511,000 in 1979 and $2,742,000 in 1978; sinking fund requirement of $2,222,000 annually to 1980, and thereafter, $2,750,000 annually to 1991	34,157,000	36,148,000
Capitalized lease obligations, payable through 2001 (Note 6)	23,172,000	19,594,000
9½% Note payable; $1,000,000 annually from 1980 to 1983 and $2,000,000 annually thereafter	20,000,000	20,000,000
Notes and other term payables	22,396,000	17,261,000
	$149,725,000	$143,003,000
Less-Current portion	5,339,000	3,364,000
	$144,386,000	$139,639,000

The Sinking Fund Debentures are direct unsecured obligations of the Company and are redeemable at the option of the Company, as a whole or in part, at any time prior to maturity at redemption prices as set forth in the respective Indentures, plus accrued interest to the redemption date.

In January, 1980, the Company received the required consents from holders of its 5⅞% Sinking Fund Debentures due 1992 to amend the Indenture under which these debentures were issued in 1967. In general, the amendments conform certain covenants contained in the Indenture to those of the Indenture under which the 7.45% Sinking Fund Debentures due 1996 were issued in 1971. In addition, the amendments increased the interest rate from 5⅞% to 6¾%, effective from January 15, 1980, and increased the mandatory annual sinking fund payment from $2,222,000 to $2,750,000 beginning with the July 15, 1981 sinking fund payment.

Certain of the Indentures under which the long-term debt was issued provide, among other things, for restrictions on the payment of cash dividends and the incurrence of funded debt. Under the most restrictive condition, as amended pursuant to consents received in January, 1980, the amount of consolidated retained earnings not restricted as to payment of cash dividends at December 31, 1979, was $363,420,000. Under the most restrictive condition, as amended, neither the Company nor any restricted subsidiary may become liable for any Senior Funded Debt, with certain exceptions, unless immediately thereafter Consolidated Net Tangible Assets will aggregate at least 200% of Consolidated Senior Funded Debt.

Annual maturities of total long-term debt, other than capitalized lease obligations, approximate $4,015,000, $6,080,000, $9,710,000, $9,448,000 and $10,539,000 for the years 1980 through 1984, respectively.

Notes and other term payables consisted of loans and mortgages payable by the Company and its subsidiaries. The weighted average interest rate on such payables is approximately 9.4% per annum. Certain fixed assets were pledged to secure $4,721,000 of term payables at December 31, 1979.

2. Acquisitions

In early 1979, the Company acquired substantially all of the outstanding common and 5% convertible preference shares of Basic Incorporated for approximately $74,000,000. Basic Incorporated is an integrated producer of refractory materials, specialized chemicals and a manufacturer of electronic products.

The Company's investment in Basic Incorporated has been allocated to the various tangible and intangible assets acquired. Property, plant and equipment acquired in this transaction are being amortized based on their fair market values and estimated useful lives.

The operations of Basic Incorporated have been included in the accompanying Consolidated Statement of Income beginning with the month of February, 1979. If the operations of the Company for 1978 had been consolidated with those of Basic Incorporated, the pro-forma consolidated net sales would have been $2,418,077,000. After giving effect to pro-forma adjustments for interest expense, depreciation expense, amortization of intangibles and income taxes, the pro-forma consolidated net income would have been $83,153,000 ($5.12 per share) in 1978. The Company's operating results for 1979 have not been restated on a pro-forma basis because the amounts involved are not significant.

In January, 1979, the Company acquired two other companies, issuing 166,497 shares of common stock (net of escrow shares returned to Treasury) for one and paying $3,175,000 in cash for the other company. Since these acquisitions have also been treated as purchases for accounting purposes, results of their operations from the dates of acquisition have been included in the accompanying Consolidated Statement of Income. Also during 1979, the Company purchased additional shares of Yara Engineering common stock for $9,323,000 which increased its equity to approximately 44%.

3. Joint Venture

During 1976, The Lummus Company, a wholly owned subsidiary, entered into a Joint Venture Agreement with Thyssen Rheinstahl Technik, G.m.b.H., a member of the Thyssen A.G. Group, for the purpose of performing a $1,100,000,000 lump sum turnkey contract awarded to them by the Ministry of Industry and Minerals of the Government of Iraq. The contract requires the partners to perform engineering, design, procurement, construction, training and initial operations for a petrochemical plant in Iraq. The Joint Venture Agreement provides for certain limits of Lummus' financial responsibility for the project.

Engineering and other services being performed by The Lummus Company in connection with the Joint Venture are not included in sales for 1979 or 1978 as the Company's interest in the Joint Venture operating results will be accounted for by means of the equity method of accounting. As of December 31, 1979, engineering, procurement and material deliveries are substantially completed, with construction expected to be completed in stages during 1980. Upon completion of the plant, the Joint Venture will be responsible for start-up, final training of personnel and initial operations. The Company anticipates that recognition of its share of Joint Venture profits will commence as mechanical construction nears completion.

The Joint Venture's total assets of $1,000,000,000 as of December 31, 1979, which are not consolidated with those of the Company, consist primarily of costs expended to date and the balance of cash received under the terms of the contract.

4. Short-term Borrowings

Notes payable and current portion of long-term debt included the following:

December 31,	1979	1978
Notes payable to banks	$ 6,274,000	$1,139,000
Current portion of long-term debt	5,339,000	3,364,000
	$11,613,000	$4,503,000

The weighted average interest rate for notes payable to banks was approximately 15% at December 31, 1979, and 10% at December 31, 1978. The maximum amount of notes payable to banks outstanding at any month-end was $6,274,000 in 1979, and $10,834,000 in 1978.

Lines of credit established at various banks in the United States aggregated $95,000,000 at December 31, 1979. The amounts borrowed are generally repayable on a short-term basis with interest at the prevailing prime rate.

(j) Pension Costs

The Company and its subsidiaries have retirement plans or make contributions to union pension plans which cover substantially all their employees. Certain of the plans are entirely non-contributory and others permit or require employee contributions toward the cost of current service benefits. The benefits for employees are determined under the terms of the plans which take into consideration, among other things, years of credited service and, in certain cases, earnings of employees. Generally, pensions are covered by funds invested by trustees and by policies issued by insurance companies. The unfunded cost of past service benefits at December 31, 1979, is estimated at $171,483,000. At December 31, 1979, the actuarially computed value of vested benefits exceeds the fund assets and balance sheet accruals by approximately $102,943,000. The increases in the foregoing amounts during 1979 of $41,179,000 and $25,193,000, respectively, were due primarily to increased benefit levels for a significant portion of the covered salaried and hourly employees and to the acquisition of Basic Incorporated.

Amounts accrued and charged to costs and expenses with respect to such plans aggregated $41,710,000 in 1979, and $32,995,000 in 1978, which include, as to certain of the plans, amortization of the past service costs generally over a thirty-year period. It is the policy of the Company and its subsidiaries to fund their accrued pension costs.

(k) Income Taxes

The provision for Federal, state and foreign taxes on income is summarized below:

	1979	1978
United States	$63,267,000	$54,240,000
Foreign*	17,510,000	19,516,000
State	8,163,000	4,944,000
	$88,940,000	$78,700,000

*Includes foreign taxes payable by United States subsidiaries doing business in foreign countries.

The provision consists of:

	1979	1978
Provision for income taxes estimated to be currently payable	$47,658,000	$ 6,520,000
Provision for deferred income taxes resulting from timing differences	38,213,000	71,145,000
Provision for deferred investment tax credit, less amortization	3,069,000	1,035,000
	$88,940,000	$78,700,000

The effective income tax rate was 47.7% in 1979 and 49.5% in 1978. The effective tax rate differed from the United States income tax rate of 46% (48% in 1978) primarily because of amortization of the investment tax credit, percentage depletion allowance in excess of cost depletion, state and foreign income taxes, equity in earnings and losses of associated and other companies and foreign currency translation losses.

Deferred income taxes result from timing differences in reporting the following items for tax and financial statement purposes:

	1979	1978
Profit recognized on long-term contracts on percentage of completion basis for financial statement purposes and on completed contract basis for income tax purposes	$31,000,000	$65,000,000
Excess of depreciation using accelerated methods for tax purposes over straight-line basis for financial reporting purposes	6,114,000	7,148,000
Other	1,099,000	(1,003,000)
	$38,213,000	$71,145,000

The Company follows the practice of amortizing the investment tax credit over the estimated lives of the applicable property additions, rather than in the year the additions are placed in service. At December 31, 1979, the unamortized balance of the investment tax credit was $17,016,000.

Provision has been made for United States income taxes that may be due on the portion of the earnings of consolidated foreign subsidiaries which is expected to be remitted. Undistributed earnings intended to be reinvested indefinitely in foreign subsidiaries totaled $45,500,000 at December 31, 1979.

(e) Inventories

Inventories at December 31, 1977 aggregated $435,940,000. Inventories at December 31, 1979 and 1978, are summarized below:

December 31,	1979	1978
Inventoried costs relating to long-term contracts, less amounts attributed to earned billings (sales)	$171,726,000	$152,036,000
Raw materials and supplies	69,770,000	76,062,000
Other work in process	185,236,000	150,807,000
Finished goods	101,637,000	79,735,000
	$528,369,000	$458,640,000

Inventoried costs relating to long-term contracts are priced at the lower of cost (average or actual) or market. Reference should be made to Note 1d regarding accounting for long-term contracts.

Inventories of raw materials and supplies, other work in process and finished goods are priced at the lower of cost or market. Such inventories include, among other things, material costs, direct labor and indirect costs (primarily manufacturing overhead). Costs were determined using the average; first-in, first-out (FIFO); and last-in, first-out (LIFO) methods of pricing. In general, domestic inventories other than (a) those at locations involved in long-term contract work and (b) those of Basic are priced using the LIFO method.

The excess of current costs over the LIFO basis of inventories valued by this method was $56,969,000 at December 31, 1979, and $42,460,000 at December 31, 1978.

(f) Translation of Foreign Currencies

The foreign currency amounts with respect to subsidiary companies and companies which are carried at equity in net assets are translated in terms of United States dollars as follows: assets (other than inventories and net fixed assets) and liabilities at the rates of exchange at the respective year-ends; inventories and net fixed assets at historical rates of exchange; and income and expenses at the average rates of exchange during the years.

Gains or losses from foreign currency translation and from exchange transactions are credited or charged to income currently. Such exchange adjustments are included in the Consolidated Statement of Income (primarily charged to cost of sales in 1978, and interest income in 1979) and aggregated a net loss of $2,968,000 and $4,952,000 in 1979 and 1978, respectively.

(g) Property, Plant and Equipment

Land, buildings, machinery and equipment are carried at cost. Depreciation expense generally is calculated on the straight-line basis for financial reporting purposes and on accelerated methods for income tax purposes; annual rates for major items being from 5% to 10% for machinery and equipment and from 2% to 4% for buildings.

Expenditures for maintenance, repairs, renewals and betterments which do not materially prolong the useful life of the asset, or are of a minor nature, are generally charged to costs and expenses. When an item or unit of property is replaced or substantial betterments result from major repair or renewal, the cost of the replaced property is retired and the cost of the replacing property is capitalized. At the time properties are retired or otherwise disposed of, the reserves for depreciation are charged with accumulated depreciation applicable to such assets. The difference between the amounts at which such assets are carried (less accumulated depreciation) and the proceeds, in the case of sales of property, is charged or credited to income.

(h) Research and Development Costs and Intangible Assets

Company-sponsored research and development expense relating to the development of new products or services or the improvement of existing products or services aggregated $37,700,000 in 1979 and $32,000,000 in 1978.

Costs incurred in connection with research and development work generally are expensed as incurred. However, patents and other costs of product development which arise from acquisitions are amortized over their estimated lives. Goodwill arising from certain prior year acquisitions accounted for as purchase transactions (Vetco Inc., Gray Tool Company and National Tank Company) is being amortized over forty years.

(i) Accrued Liabilities

Accrued liabilities included the following:

December 31,	1979	1978
Wages, salaries and commissions	$ 71,185,000	$ 56,262,000
Additional costs on open contracts	164,468,000	167,260,000
Other	183,257,000	147,653,000
	$418,910,000	$371,175,000

1. Accounting Policies and Supplementary Information

(a) Principles of Consolidation

The financial statements of all but certain minor domestic and foreign subsidiaries have been included in the consolidated financial statements. In consolidating the financial statements of the parent company and its consolidated subsidiaries, all significant income and expense amounts and all significant balance sheet amounts of an intercompany nature, including unrealized intercompany profits, have been eliminated.

Investments in unconsolidated subsidiaries, associated companies (those having license agreements with the Company) and other companies which are 20% or more owned are recorded at cost adjusted for the Company's equity in undistributed earnings or losses. Dividends received from such companies aggregated $706,000 in 1979 and $370,000 in 1978. Retained earnings at December 31, 1979, include $3,126,000 with respect to the undistributed earnings of unconsolidated subsidiaries and other associated companies which are 20% or more owned.

The aggregate investment (including the equity in undistributed earnings or losses) in companies which are 20% or more owned exceeds the equity in the net assets of such companies as shown in their financial statements by $5,338,000. Such excess is considered to be allocable to the underlying assets, primarily fixed assets including mineral deposits, and is being amortized over their estimated useful lives.

Investments in associated and other companies which are less than 20% owned are carried at the lower of aggregate cost or market value. Such investments included securities which are traded in foreign markets having an aggregate cost of $14,107,000 at December 31, 1979, and $13,951,000 at December 31, 1978. The aggregate market value of these marketable securities was $40,645,000 at December 31, 1979, and $31,160,000 at December 31, 1978. At December 31, 1979, there were gross unrealized gains of $26,538,000.

(b) Cash and Short-term Investments

Cash included temporary investments and time deposits amounting to $396,721,000 and $364,729,000 at December 31, 1979 and 1978, respectively.

(c) Reserves for Doubtful Accounts and Allowances

Accounts receivable are shown in the Consolidated Balance Sheet net of reserves for doubtful accounts and allowances of $13,829,000 at December 31, 1979, and $14,332,000 at December 31, 1978.

(d) Long-term Contracts

Costs associated with long-term contracts are accumulated in work in process inventory and include both direct and indirect costs. Direct costs include, among other things, direct labor, field labor, drafting, subcontracting and direct materials. Indirect costs consist primarily of manufacturing overhead. General and administrative expenses are not inventoried. Inventoried costs relating to long-term contracts, less amounts attributed to earned billings (sales), aggregated $171,726,000 at December 31, 1979, and $152,036,000 at December 31, 1978 (Note 1e).

Profits on long-term contracts for financial reporting purposes are recorded principally on the basis of the estimated stage of completion. However, no profits are recorded on contracts for equipment manufactured in the Company's plants prior to billing the customer, and in most cases, prior to shipment of the equipment. These contracts extend over a period of several months to four or more years. Revisions in cost estimates during the progress of work under long-term contracts have the effect of including in subsequent accounting periods adjustments necessary to reflect the results indicated by the revised estimates of final cost. Projected or realized losses under long-term contracts, if any, are provided for in the period when first determined.

At December 31, 1979 and 1978, accounts receivable included (a) balances billed but not paid by customers under retainage provisions in long-term contracts and (b) receivables under long-term contracts which were not billable (primarily retainages which will be billed upon completion and acceptance of the equipment). The approximate amounts involved in these categories are shown below:

December 31,	1979	1978
Billed but unpaid retainage	$ 14,171,000	$ 15,870,000
Unbilled receivables (primarily retainage)	91,606,000	82,628,000
	$105,777,000	$ 98,498,000
Less—amounts included in unearned billings	(75,323,000)	(72,413,000)
	$ 30,454,000	$ 26,085,000

Approximately $20,309,000 of the $30,454,000 shown above at December 31, 1979, is expected to be collected during 1980.

Consolidated Statement of Changes in Financial Position

Combustion Engineering, Inc. and Subsidiary Companies

For the Years Ended December 31,	1979	1978
Source of Funds:		
Operations—		
Net income	$ 97,641,064	$ 80,316,292
Charges (credits) not requiring funds—		
Depreciation and amortization	66,137,562	52,567,333
Deferred income taxes (noncurrent) and investment tax credit	9,982,000	53,039,000
Equity in net earnings of associated and other companies, adjusted for dividends received	(3,634,319)	(1,026,464)
All other, net, including amortization of patents and other product development costs	10,932,423	16,411,761
Funds provided from operations	$181,058,730	$201,307,922
Retirements of property, plant and equipment, less accumulated depreciation and amortization	15,486,810	7,678,675
Common Stock issued in connection with an acquisition, net	3,404,543	—
Proceeds from exercise of stock options	527,694	—
Total source of funds	$200,477,777	$208,986,597
Application of Funds:		
Additions to property, plant and equipment, including $54,222,322 with respect to Basic Incorporated in 1979	$146,741,462	$ 74,900,656
Cash dividends declared	35,892,028	29,105,495
Reduction of long-term debt, net	4,253,380	7,630,133
Redemption of Series A Convertible Preferred Stock	—	724,095
Increase in investments, net, including Yara Engineering in 1979 and 1978	12,613,294	19,987,264
Acquisition of Basic Incorporated—		
Noncurrent assets other than property, plant and equipment	3,203,937	—
Long-term debt	(9,000,000)	—
All other, net	(3,933,953)	(4,237,935)
Total application of funds	$189,770,148	$128,109,708
Net Increase in Working Capital	$ 10,707,629	$ 80,876,889
Details of Increase (Decrease) in Working Capital:		
Cash	$ 39,428,158	$137,415,855
Accounts receivable	63,429,937	3,361,449
Inventories	69,729,082	22,700,110
Notes payable and current portion of long-term debt	(7,109,746)	10,431,891
Accounts payable and accrued liabilities	(51,888,136)	(42,005,614)
Federal, state and foreign income taxes	(53,036,843)	5,073,954
Advance payments on contracts	(51,670,427)	(56,591,681)
Other, net	1,825,604	490,925
	$ 10,707,629	$ 80,876,889

Reference is made to the accompanying notes to financial statements.

Consolidated Statement of Income

Combustion Engineering, Inc. and Subsidiary Companies

For the Years Ended December 31,	1979	1978
Net Sales (1d)	$2,757,504,278	$2,331,751,133
Costs and Expenses:		
Cost of sales (1e)	$2,373,357,740	$2,006,265,603
Selling, general and administrative expenses	213,401,782	178,041,245
	$2,586,759,522	$2,184,306,848
Operating income	$ 170,744,756	$ 147,444,285
Other Income and (Deductions):		
Interest expense	($ 16,663,121)	($ 18,399,812)
Interest earned	26,956,016	26,373,891
Equity in net earnings of associated and other companies (1a)	4,340,294	1,396,768
Miscellaneous, net	1,203,119	1,701,160
	$ 15,836,308	$ 11,572,007
Income before income taxes	$ 186,581,064	$ 159,016,292
Federal, State and Foreign Taxes on Income (1k)	88,940,000	78,700,000
Net income	$ 97,641,064	$ 80,316,292
Net Income per Share (1l)	$5.96	$4.97

Reference is made to the accompanying notes to financial statements.

Consolidated Statement of Retained Earnings

Combustion Engineering, Inc. and Subsidiary Companies

For the Years Ended December 31,	1979	1978
Balance at beginning of year	$ 431,568,303	$ 379,230,787
Addition resulting from pooling of interests	—	1,859,913
Net income	97,641,064	80,316,292
	$ 529,209,367	$ 461,406,992
Deduct:		
Cash dividends declared—		
Preferred Stock—None in 1979 and $.85 per share through redemption in 1978	—	104,979
Common Stock—$2.20 per share in 1979 and $1.80 in 1978	35,892,028	28,895,516
Pooled company prior to acquisition	—	105,000
Excess of redemption price of Series A Convertible Preferred Stock over stated value	—	624,261
Transfer to Common Stock of amount equal to stated value of redeemed shares of Series A Convertible Preferred Stock	—	99,834
Adjustment for fractional shares on conversion of Series A Convertible Preferred Stock	—	9,039
Balance at end of year	$ 493,317,339	$ 431,568,303

Reference is made to the accompanying notes to financial statements.

December 31,	1979	1978
Liabilities		
Current Liabilities:		
Notes payable and current portion of long-term debt (4)	$ 11,612,521	$ 4,502,775
Accounts payable	137,178,742	133,025,910
Accrued liabilities (1i)	418,910,059	371,174,755
Federal, state and foreign income taxes (1k)	63,542,799	10,505,956
Advance payments on contracts	503,323,661	451,653,234
Dividends payable	9,769,188	8,085,031
Total current liabilities	$1,144,336,970	$ 978,947,661
Deferred Income Taxes and Investment Tax Credit (1k)	$ 232,981,000	$ 222,999,000
Long-term Debt (5)	$ 144,386,069	$ 139,639,449
Minority Interests in Subsidiary Companies	$ 1,581,926	$ 1,367,730
Shareholders' Equity (5, 7 and 8):		
Preferred Stock, no par value—		
Authorized—2,000,000 shares		
Issued—none in 1979 and 1978	$ —	$ —
Common Stock, $1 par value—		
Authorized—50,000,000 shares		
Issued—16,480,606 shares in 1979 and 16,280,611 shares in 1978, stated at	66,416,638	62,484,401
Retained earnings (see accompanying statement)	493,317,339	431,568,303
	$ 559,733,977	$ 494,052,704
Deduct shares held in treasury, at cost:		
Common Stock—143,487 shares in 1979 and 123,855 shares in 1978	59,767	59,767
	$ 559,674,210	$ 493,992,937
	$2,082,960,175	$1,836,946,777

Reference is made to the accompanying notes to financial statements.

Consolidated Balance Sheet

December 31,	1979	1978
Assets		
Current Assets:		
Cash and short-term investments (1b)	$ 445,681,286	$ 406,253,128
Accounts receivable (less unearned billings of $195,400,543 in 1979 and $186,225,642 in 1978) (1c and 1d)	439,725,672	376,295,735
Inventories (1d and 1e)	528,368,829	458,639,747
Prepaid expenses	14,863,397	11,353,636
Total current assets	$1,428,639,184	$1,252,542,246
Investments in Associated and Other Companies (1a):		
At equity	$ 50,713,296	$ 33,172,345
At cost	17,831,999	18,538,077
	$ 68,545,295	$ 51,710,422
Property, Plant and Equipment (1g):		
Land and buildings	$ 272,729,674	$ 244,049,757
Machinery and equipment	624,525,964	542,069,083
	$ 897,255,638	$ 786,118,840
Less—Accumulated depreciation and amortization	381,272,201	335,252,493
	$ 515,983,437	$ 450,866,347
Other Assets:		
Goodwill and, in 1978, patents and other intangible assets (1h)	$ 64,514,458	$ 75,224,685
Deferred charges	5,277,801	6,603,077
	$ 69,792,259	$ 81,827,762
	$2,082,960,175	$1,836,946,777

Reference is made to the accompanying notes to financial statements.

Schedules I, III, IV, VII, VIII, X, XIV, XV, XVII, XVIII, and XIX are not submitted because they are not applicable or not required.

NOTES:

(a) Separate financial statements of the registrant have been omitted since it is primarily an operating company and the minority interests in subsidiaries and long-term debt of the subsidiaries held by others than the registrant is less than five percent of consolidated total assets.

(b) Financial statements for unconsolidated subsidiaries and 50% owned companies have been omitted as not being required since all such unconsolidated subsidiaries and 50% owned companies, considered in the aggregate as a single subsidiary, would not constitute a significant subsidiary.

REPORT OF INDEPENDENT PUBLIC ACCOUNTANTS ON SCHEDULES

In connection with our examination of the consolidated financial statements of Combustion Engineering, Inc. and subsidiary companies for the years ended December 31, 1979 and December 31, 1978, as reproduced from the 1979 annual report to stockholders, we have also examined the supporting schedules listed above. In our opinion, these schedules present fairly, when read in conjunction with the related consolidated financial statements, the financial data required to be set forth therein, in conformity with generally accepted accounting principles applied on a consistent basis.

Arthur Andersen & Co.

Stamford, Connectic
February 13, 1980

INDEX TO FINANCIAL STATEMENTS

*As reproduced from the 1979 annual report to stockholders.

INDEX TO SCHEDULES AND EXHIBIT

Steam Generating Systems, Equipment and Services for the Electric Utility Industry

Power Systems Group supplies steam generating systems, equipment and services for the electric utility industry. In the fossil field, the Company designs, manufactures and installs systems and equipment fueled by coal, natural gas or oil; including natural circulation, controlled circulation and combined circulation types. In the nuclear field, the Company designs, manufactures and supplies complete pressurized water nuclear steam supply systems, including the fabrication of nuclear fuel. The foregoing systems and equipment are sold principally to electric utilities and to prime contractors for electric utilities.

Design, Engineering and Construction Services

Engineering Group designs, engineers and constructs chemical process plants, petroleum refineries and other industrial facilities for the petrochemical, metallurgical, pulp and paper and other process industries. This Group also provides engineering, design and project management technology related to the development and production of crude oil and natural gas; and designs, manufactures and installs gas processing and conditioning plants.

Equipment, Products and Services for Industrial Markets

Several Groups and C-E Glass supply equipment, products and services for industrial markets, the most significant of which are shown below.

Equipment

Industrial Products Group—

Equipment for the metal casting industry
Screening equipment for general industrial applications

Process Equipment Group—

Field production processing equipment for the oil and natural gas industries
Oil field equipment, primarily wellhead assemblies and high pressure pipe connections
Subsea oil and gas field drilling and production equipment, and specialized equipment for use on mobile drilling rigs
Gas-to-gas heat exchangers sold to manufacturers of steam generating equipment and others
Equipment for the pulp and paper industry
Grinding equipment and pulverizers for general industrial applications

Power Systems Group—

Steam generating equipment and services for general industrial applications
Nuclear reactor vessels and other nuclear components sold to manufacturers of steam generating equipment and for use in research projects

Products and Services

Industrial Products Group—

Wood doors, windows and other building products
Electronic assemblies for the communications industry
Specialty refractories and refractory products for the steel, aluminum, glass and other industries
Wire cloth and screening for general industrial applications and for paper mills
Industrial minerals mined and processed by the Company for itself and others
Foundry chemicals, washes and supplies

Process Equipment Group—

Erection, retrofit and general contracting in oil and gas field production and processing plants
Specialty chemicals for use in oil and gas production processing
Carbon, alloy and stainless steel forgings
Coating, inspection and other services primarily for the oil and gas industry

C-E Glass—

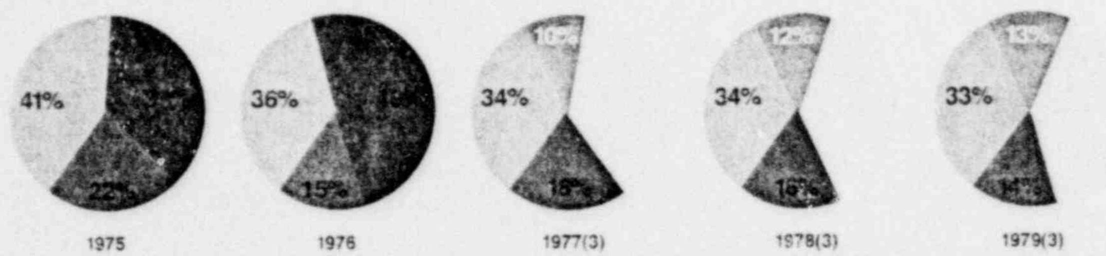
Automotive and architectural glass

Lines of Business and Brief Description of the Business

The Company's products and servicns are classif ed in the following categories according to general markets served: (a) design, manufacture, installation and service of steam generating systems and equipment for the electric utility industry, including nuclear steam supply systems; (b) design, engineering and construction services (principally through its subsidiary, The Lummus Company), primarily for the chemical, petrochemical and petroleum industries; and (c) equipment, products and services supplied to industrial markets. The relative contributions to consolidated net sales and to income from operations before income taxes and extraordinary items by lines of business for the years 1975 through 1979 are shown in the following charts:

Relative Contribution to Net Sales

Relative Contribution to Earnings from Operations(1)



Steam generating systems, equipment and services for the electric utility industry supplied by the Power Systems Group.

Design, engineering and construction services provided by the Engineering Group.

Equipment, products and services supplied to industrial markets by the Industrial Products, Process Equipment and Power Systems Groups and C-E Glass (see Notes 2 and 3).

(1) Before taking into consideration the following: interest expense; interest earned on marketable securities; equity in earnings (losses) of associated and other companies; minority interests in earnings (losses) of subsidiaries; Corporate unallocated expenses and other income and (deductions); and income taxes.

(2) None of the Company's equipment, products or services supplied to industrial markets contributed 10% or more to the Company's consolidated net sales.

(3) See Note 15 of the Notes to Financial Statements. For 1977, 1978 and 1979, the equipment, products and services category is shown as:

Equipment for industrial markets, and
Products and services for industrial markets.

Market Price Range Per Share

	1979		1978	
Common Stock (1)	High	Low	High	Low
First Quarter	$39½	$32⅜	$37¼	$31
Second Quarter	45½	35¼	43¾	33½
Third Quarter	54	44⅝	44⅞	37⅞
Fourth Quarter	59½	43⅛	39¼	31⅞
Preferred Stock (1,2)	High	Low	High	Low
First Quarter	$ —	$ —	$46½	$42½
Second Quarter	—	—	56½	51
Third Quarter	—	—	—	—
Fourth Quarter	—	—	—	—

Quarterly Dividends Declared Per Share

	1979	1978
Common Stock		
First Quarter	$.50	$.40
Second Quarter	.55	.45
Third Quarter	.55	.45
Fourth Quarter	.60	.50
Preferred Stock (2)		
First Quarter	$ —	$.425
Second Quarter	—	.425
Third Quarter	—	—
Fourth Quarter	—	—

1. Traded on the New York Stock Exchange.
2. Redeemed on July 24, 1978.

1978 Compared to 1977

On a consolidated basis, net sales increased 14% over those in 1977. Sales increases by business segment were as follows: Products and services for industrial markets by 33%; equipment for industrial markets by 14%; steam generating systems, equipment and services for the electric utility industry by 9% and design, engineering and construction services by 3%.

Comments on the principal factors affecting sales in 1978 follow:

Sales were adversely affected in the year 1978 by work interruptions at several major plants due to strikes related to contract negotiations. The segments most significantly affected by the strikes were steam generating systems, equipment and services for the electric utility industry and equipment for industrial markets. Other comments by business segment follow:

(a) Products and services for industrial markets—
The increase in this segment was attributable primarily to including for a full year the oil field pipe inspection and coating services and other services provided by Vetco Inc. which was acquired in December, 1977, and to increased shipments of wood doors, windows and other building products, refractory and mineral products, foundry materials and supplies and architectural glass.

(b) Equipment for industrial markets—
The increase in this segment was due mainly to shipments of oil field exploration and production equipment (including those of Vetco Inc.) and increased shipments of equipment for the pulp and paper industry. These favorable trends were offset in part by lower shipments of equipment for the metal casting industry and steam generating equipment for industrial use.

(c) Steam generating systems, equipment and services for the electric utility industry—
The increase in this segment was due mainly to higher shipments of fossil fueled steam generating equipment and increased construction services on boiler erection work and maintenance projects. Activity on contracts for nuclear steam supply systems and fuel was approximately the same in both years.

(d) Design, engineering and construction services—
The moderate increase in this segment was primarily attributable to higher activity in domestic offices on process plants, including petrochemical, pharmaceutical and energy-related projects; offset by a general decline in sales of heat transfer equipment. While engineering and procurement services furnished in connection with the Lummus Joint Venture with Thyssen Rheinstahl Technik, G.m.b.H. for the supply of a petrochemical complex to the Government of Iraq were at a lower level in 1978, material deliveries and construction activities increased during the year. It should be noted that engineering and other services furnished in connection with the Lummus Joint Venture are not included in sales as the 50% interest in the Joint Venture will be accounted for by means of the equity method of accounting (see Note 3 to the Financial Statements).

Cost of Sales increased by 13% over that in 1977 primarily as a result of the increase in sales volume, higher costs of material, labor and services and the effect of work stoppages related to contract negotiations. Other significant factors affecting cost of sales and profitability in 1978 were as follows:

(a) Amortization of the adjustment of Vetco Inc. and Gray Tool Company assets to reflect fair market value at the dates of acquisition (Vetco Inc., November, 1977 and Gray Tool Company, October, 1976), particularly the upward valuation of inventories and intangible assets, adversely affected operating results in 1977 and 1978. Amortization of these adjustments in future years will be at a reduced rate.

(b) Profits from the manufacture and distribution of architectural glass, wood doors, windows and other building products improved in 1978 as a result of the increase in housing starts and a strong home improvement market.

(c) Losses on overall nuclear activities decreased in 1978. This was due primarily to provisions in 1977 for cost adjustments and repairs on certain nuclear steam supply system contracts.

Selling, General and Administrative Expenses increased 22% over those in 1977 due primarily to (a) the inclusion of Vetco Inc. expenses for a full year in 1978, (b) higher selling expenses in all business segments and (c) in general, higher staffing, payroll related expenses and occupancy expenses.

Interest Expense increased 59% over that in 1977 due mainly to interest on proposed federal income tax assessments and interest on the indebtedness of Vetco Inc.

Miscellaneous, net increased in 1978 due mainly to higher interest earned as a result of a higher average level of investable funds and higher interest rates.

Taxes on Income increased 20% over those in 1977 due to the increase in income before taxes.

(b) Profits from steam generating systems, equipment and services for the electric utility industry were higher in 1979 than in 1978 due mainly to reduced losses on overall nuclear activities resulting from an increase in work on nuclear fuel and a decline in provisions for cost and other adjustments to nuclear steam supply system contracts. Adjustments were made in 1979 to recognize the declining level of production in certain nuclear facilities. Profits from fossil steam generating equipment, including construction services, were moderately below the 1978 level due to higher operating expenses.

(c) Profits from products and services for industrial markets increased in 1979 over those in 1978 due principally to the increased shipments of refractory and mineral products, forgings and other products and increased services to the oil and gas industry.

Amortization of the upward adjustment of Basic Incorporated assets to reflect fair market value at the date of acquisition adversely affected the profits of this business segment in 1979. Acquisition adjustments with respect to Vetco coating and inspection services in 1979 were at a lower rate than in 1978.

Profit in 1979 from the distribution of wood building products was below the level of 1978 due in part to competitive market conditions.

(d) Profit on design, engineering and construction services increased slightly over the year 1978. Higher profits on engineering and construction services, primarily on work performed by domestic offices for overseas projects, were offset substantially by unfavorable cost and other adjustments including acquisition adjustments with respect to a company acquired in January, 1979.

Selling, General and Administrative Expenses increased 20% over those in 1978 due primarily to expenses of companies acquired in the latter part of 1978 and the begi[illegible]ing of 1979, and in general, higher staffing, payroll related expenses and other expenses.

Interest Expense declined 9[illegible] from that in 1978 due mainly to a reduction in the provision for interest on proposed federal income tax assessments, offset in part by interest on the indebtedness of Basic Incorporated.

Miscellaneous, net increased $2,527,000 in 1979 due mainly to the increase of $2,944,000 in the equity in earnings of associated and other companies. This increase was due largely to the equity interest in Yara Engineering Corporation acquired in 1978 and 1979.

Taxes on Income increased 13% over those in 1978 due to the increase in income before taxes, offset in part by a decline in the statutory United States Federal income tax rate from 48% to 46%.

Unfilled Orders

A summary showing the backlog of unfilled orders by business segment is set forth below:

December 31,	1979	1978	1977
Steam generating systems, equipment and services for the electric utility industry	$2,113,591,000	$2,143,242,000	$2,247,8[illegible]7,000
Design, engineering and construction services	270,938,000*	200,329,000*	237,529,000*
Equipment for industrial markets	528,261,000	457,331,000	413,160,000
Products and services for industrial markets	73,675,000	79,027,000	69,980,000
	$2,986,465,000*	$2,879,929,000*	$2,968,556,000*

*The backlog at December 31, 1979, 1978 and 1977, does not include the supply of a $1.1 billion petrochemical complex for the Government of Iraq, being performed by the Joint Venture comprised of The Lummus Company and Thyssen Rheinstahl Technik, G.m.b.H.

Management Discussion and Analysis of the Summary of Operations

The following comments are intended to present an overview of the more important matters affecting operating results for the years 1977, 1978 and 1979 as shown on pages 14 and 15, and to provide a comparative summary of the backlog for each of the last three years. Other statistics on Business Segments are contained in Note 15 to the December 31, 1979, Financial Statements and under the caption Lines of Business and Brief Description of the Business on page 20.

1979 Compared to 1978

On a consolidated basis, net sales increased 18% over those in 1978. Sales increases by business segment were as follows: Products and services for industrial markets by 28%; equipment for industrial markets by 18%; steam generating systems, equipment and services for the electric utility industry by 14% and design, engineering and construction services by 14%.

Comments on the principal factors affecting sales in 1979 follow:

(a) Products and services for industrial markets—
The increase in this segment was attributable primarily to increased shipments of refractory and mineral products (including those of Basic Incorporated, which was acquired early in 1979), increased shipments of forgings and other products and services to the oil and gas industry including those furnished by companies acquired in the final quarter of 1978, and increased shipments of automotive and architectural glass. These favorable factors were offset in part by a decline in sales and services caused by the disposition of several companies previously included in this segment.

(b) Equipment for industrial markets—
The increase in this segment was due mainly to increased shipments of oil field equipment (primarily wellhead assemblies, subsea drilling and production equipment, and field production processing equipment), gas-to-gas heat exchangers and pulverizing equipment for general industrial applications, and a higher level of field construction work on industrial steam generating equipment. Sales in 1978 were adversely affected by work interruptions at several major plants due to contract negotiations.

(c) Steam generating systems, equipment and services for the electric utility industry—
The increase in this segment was due mainly to a higher level of activity on nuclear steam supply systems and fuel, higher shipments of air quality control equipment and maintenance parts and increased field construction work on fossil steam generating equipment. Sales in 1978 were adversely affected by work interruptions at several major plants due to contract negotiations.

(d) Design, engineering and construction services—
The increase in this segment was primarily attributable to sales of natural gas processing and conditioning equipment by a company acquired early in 1979. It should be noted that engineering, construction and other services being performed by The Lummus Company in connection with the Joint Venture with Thyssen Rheinstahl Technik, G.m.b.H. for the supply of a petrochemical complex to the Government of Iran are not included in sales (see Note 3 to the Financial Statements).

Cost of sales increased by 18% over that in 1978 primarily as a result of the increase in sales volume and higher costs of material, labor and services. Other significant factors affecting cost of sales and profitability in 1979 were as follows:

(a) Profits from equipment for industrial markets increased over the year 1978 due primarily to increased shipments of oil field production and processing equipment and the lesser effect of acquisition adjustments (primarily with respect to Vetco Inc.) in 1979. These favorable trends were offset in part by lower profits realized in 1979 from shipments of steam generating equipment and equipment for the pulp and paper industry and the metal casting industry caused by various factors in each case, including higher research and development costs, lower profit margins and work interruptions caused by contract negotiations.

1977(5)	[illegible]976(5)	1975	1974	1973	1972	19[illegible]1	1970
[illegible]2,044,764	$1,8[illegible]25	$1,711,151	$1,428,028	$1,168,578	$1,054,532	$ 960,[illegible]10	$ 879,204
$1,776,518	$1,601,773	$1,513,297	$1,253,616	$ 998,987	$ 902,596	$ 819,794	$ 747,439
145,742	122,117	109,317	94,336	87,484	77,181	69,857	65,984
$1,922,260	$1,723,890	$1,622,614	$1,347,952	$1,086,471	$ 979,777	$ 889,651	$ 813,423
$ 122,504	$ 107,035	$ 88,537	$ 80,076	$ 82,107	$ 74,755	$ 71,259	$ 65,781
(11,563)	(9,989)	(10,119)	(11,704)	(9,561)	(8,643)	(6,273)	(5,964)
22,068	8,147	5,024	5,472	6,885	6,387	3,845	3,135
$ 133,009	$ 105,193	$ 83,442	$ 73,844	$ 79,431	$ 72,499	$ 68,831	$ 62,952
65,820	50,990	38,850	33,660	36,340	32,980	32,100	30,630
$ 67,189	$ 54,203	$ 44,592	$ 40,184	$ 43,091	$ 39,519	$ 36,731	$ 32,322
—	—	—	(2,700)	—	(16,000)	—	—
$ 67,189	$ 54,203	$ 44,592	$ 37,484(1)	$ 43,091	$ 23,519	$ 36,731	$ 32,322
$ 4.17	$ 3.36	$ 2.77	$ 2.50	$ 2.70	$ 2.48	$ 2.34	$ 2.09
—	—	—	(.17)	—	(1.00)	—	—
$ 4.17	$ 3.36	$ 2.77	$ 2.33(1)	$ 2.70	$ 1.48	$ 2.34	$ 2.09
16,117,125	16,12[illegible],660	16,083,514	16,080,781	15,952,219	15,930,967	15,722,697	15,467,769
$ 24,098	$ 21,188	$ 20,137	$ 18,617	$ 16,320	$ 15,160	$ 14,195	$ 13,237
1.50	1.316	1.25	1.152	.997	.958	.917	.85
1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70
[illegible],086,841	$ 876,259	$ 717,029	$ 662,049	$ 523,588	$ 484,278	$ 458,427	$ 388,275
894,123	663,412	529,623	494,088	373,170	329,435	315,[illegible]77	281,544
192,718	212,847	187,406	167,961	150,418	154,843	142,4[illegible]	106,731
437,145	358,741	315,850	297,339	266,536	219,096	203,145	182,731
128,948	54,643	35,977	38,111	40,622	39,976	64,82[illegible]	65,215
169,960	99,638	57,802	41,669	14,946	9,557	20,931	19,104
147,270	128,176	116,497	121,242	121,490	107,116	103,193	75,348
441,581	398,417	364,934	340,500	321,140	297,242	28[illegible],291	260,225
27.30	24.31	22.12	20.49	19.15	17.64	17.15	15.47
$ 122,055	$ 81,446	$ 50,621	$ 61,796	$ 57,330	$ 38,747	$ 42,336	$ 35,370
39,630	33,030	29,653	27,744	23,868	19,765	17,972	15,723
$2,111,246	$1,738,626	$1,527,288	$2,515,965	$1,99[illegible]2	[illegible]20,497	$ 979,133	$1,130,262
2,968,556	2,980,098	3,132,481	3,347,114	2,288,[illegible]11	1,477,500	1,350,050	1,337,121
44,770	42,843	45,938	40,765	35,316	34,950	33,374	32,645
26,596	25,536	25,212	24,758	21,305	21,549	21,39[illegible]	19,252

3. Represents, in 1972 and 1974, a provision for loss on the disposition of the holding in United Nuclear Corporation, less in each case the effect of applicable income taxes ($15,000,000 in 1972 and $2,500,000 in 1974).

4. Based on net as[illegible]ets and common shares outstanding at year-end.

5. Includes Gray Tool Company for periods subsequent to October, 1976, Vetco Inc. for the periods subsequent to November, 1977, and Basic Incorporated for the period subsequent to January, 1979.

Comparative Financial Statistics 1970-1979

(Dollars in Thousands, Except per Share Amounts)		1979(5)	1[illegible](5)
Summary of Operations	Net Sales	$2,757,504	$2,331,[illegible]
	Costs and Expenses—		
	Cost of sales	$2,373,357	$2,006,266
	Selling, general and administrative expenses	213,402	178,041
		$2,586,759	$2,184,307
	Operating Income	$ 170,745	$ 147,444
	Other Income and (Deductions)—		
	Interest expense	(16,663)	(18,400)
	Miscellaneous, net	32,499	29,972
	Income Before Income Taxes and Extraordinary Items	$ 186,581	$ 159,016
	Taxes on Income	88,940	78,700
	Income Before Extraordinary Items	$ 97,641	$ 80,316
	Extraordinary Items (3)	—	—
	Net income	$ 97,641	$ 80,316
	Net Income per Share (2)—		
	Income before extraordinary items	$ 5.96	$ 4.97
	Extraordinary items (3)	—	—
	Net income	$ 5.96	$ 4.97
	Average Shares Outstanding (2)	16,371,638	16,171,116
	Cash Dividends Declared—		
	Total	$ 35,892	$ 29,105
	Per share—		
	Common	2.20	1.80
	Preferred	—	.85
Other Financial Statistics	Current Assets	$1,428,639	$1,252,[illegible]
	Current Liabilities	1,144,337	978,948
	Working Capital	284,302	273,594
	Property, Plant and Equipment, net	515,983	450,866
	Investments and Other Assets	136,756	132,171
	Deferred Income Taxes and Investment Tax Credit	232,981	222,999
	Long-term Debt	144,386	139,639
	Shareholders' Equity		
	Amount	559,674	493,993
	Per share (4)	34.26	30.58
	Capital Expenditures	$ 146,741	$ 74,901
	Depreciation and Amortization	66,138	52,567
	Orders Received	$2,897,763	$2,298,490
	Unfilled Orders	2,986,465	2,879,929
	Employees	43,286	45,729
	Shareholders of Record	26,742	26,451

See pages 16-18 for Management Discussion and Analysis of the Summary of Operations for the years 1979 and 1978.

1. In 1974, the Company changed to the last-in, first-out (LIFO) method of inventory valuation with respect to certain domestic inventories (generally inventories other than those involved in long-term contract work). The LIFO method was adopted because the rapid increase in prices would have resulted in an overstatement of profits if use of the average, or first-in, first-out (FIFO) method were continued, since inventories sold were replaced at substantially higher prices. The effect of this change was to reduce net income for the year 1974 by $5,887,919 equal to $.37 per share.

2. Net income per share was based on the average number of shares outstanding. Average shares outstanding include (a) the average number of common shares outstanding, (b) common shares issuable on the conversion of the Series A Convertible Preferred Stock, prior to redemption in July, 1978, (c) in the years 1970 through 1974, estimated shares to be released from escrow based on earnings of certain companies subsequent to acquisition and (d) in the years 1971, 1972, 1973 and 1979, the assumed exercise of all outstanding stock options. The average number of shares outstanding in each period has been adjusted where necessary to give effect retroacti[illegible] to a 2-for-1 stock split in 1970, a 3-for-2 stock split in 1977, and shares issued in connection with significant poolings of interest.

SIGNATURES

Pursuant to the requirements of Section 13 or 15(d) of the Securit[illegible] Exchange Act of 1934, the registrant has d[illegible] caused this report to be signed on its beh[illegible] by the undersigned, thereunto duly auth[illegible]ized.

COMBUSTION ENGINEERING, INC.

By M. Kiamie

Vice President and Controller

Date: March 28, 1980

Mr. Orr was elected a Vice President of the Company in September, 1973. During the past five years he has been a senior operating officer of the Engineering Group.

Mr. Parkin was elected a Vice President of the Company in September, 1973. During the past five years he has been responsible for corporate planning and development.

Mr. Slack was elected a Vice President of the Company in September, 1973. During the past five years he has been a senior operating officer of the Process Equipment Group.

Mr. Winterson was elected a Vice President of the Company in December, 1966. During the past five years he has been a senior operating officer of the Power Systems Group. He has been a Director since 1968.

PART II

ITEMS 13. THROUGH 15.

The Company's proxy statement dated March 21, 1980, in connection with its Annual Meeting of stockholders to be held on April 22, 1980, has been filed with the Securities and Exchange Commission.

A brief account of each officer's business experience during the past five years is set forth below:

Mr. Santry was elected President in April, 1963. During the past five years he has been the chief executive officer of the Company. He has been a Director since 1957.

Mr. Calvert was elected a Vice President of the Company in August, 1974 and as of March 15, 1975, was appointed Vice President-Operations. He was elected a Director in February, 1975.

Mr. Condon was elected a Vice President of the Company in January, 1978 and is responsible for coordinating the Company's international manufacturing and licensing activities, sales and market services, and project financing outside the United States. Before assuming his present position, he was Vice President-International Finance for The Lummus Company, a subsidiary of the Company. Before joining the Company he was a Senior Vice President of Wheelabrator Frye, Inc. and Chairman of Wheelabrator International.

Mr. Connolly was elected a Vice President of the Company in April, 1976 and is responsible for corporate marketing and communications. Prior to joining the Company he was a Vice President of International Paper Company.

Mr. Ennis was elected a Vice President of the Company in January, 1960. During the past five years he has been responsible for the Company's legal and administrative functions. He has been a Director since 1960.

Mr. Gross was elected a Vice President of the Company in June, 1960. During the past five years he has been the chief financial officer of the Company. He has been a Director since 1963.

Mr. Hallinan was elected a Vice President of the Company in November, 1976 and Secretary in April, 1973. He became General Counsel in 1973 and since that time has been in charge of the legal department of the Company.

Mr. Kelly was elected a Vice President of the Company in April, 1967. During the past five years he has been a senior operating officer of the Industrial Products Group.

Mr. Kiamie was elected a Vice President of the Company in August, 1967. During the past five years he has been the principal accounting officer of the Company.

Mr. Kimmel was elected a Vice President of the Company in April, 1979. Prior to joining the Company, he was Vice President-Finance and a member of the Board of Directors of Lykes Corporation.

Mr. Leeper was elected a Vice President of the Company in December, 1978 and is responsible for directing corporate-level technology programs, and for coordination of the Company's engineering and technological development. Before assuming his present position, he was Vice President-Engineering at The Air Preheater Company, Inc., a subsidiary of the Company. Prior to joining the Company, he was President and General Manager of Aerojet Nuclear Company, a subsidiary of Aerojet General Corporation.

SUPPLEMENT TO PART I

OFFICERS OF THE REGISTRANT

Listed below are the officers of the Company as of December 31, 1979:

Name	Age	Position Presently Held
Arthur J. Santry, Jr.	61	President
James F. Calvert	59	Vice President - Operations
Joseph F. Condon	54	Vice President - International
William J. Connolly	50	Vice President - Marketing and Communications
Thomas A. Ennis	59	Vice President - Administration
Lambert J. Gross	64	Vice President - Finance
Richard J. Hallinan	57	Vice President, Secretary and General Counsel
James B. Kelly	52	Vice President in charge of Industrial Products Group
Mitchell Kiamie	58	Vice President and Controller
George S. Kimmel	45	Vice President and Treasurer
Charles K. Leeper	56	Vice President - Corporate Technology
William P. Orr	62	Vice President in charge of Engineering Group
George R. Parkin	64	Vice President - Development and Planning
John H. Slack	57	Vice President in charge of Process Equipment Group
Howard M. Winterson	63	Vice President in charge of Power Systems Group

There are no family relationships among the foregoing officers.

There are no arrangements or any understandings between the above persons and any other persons pursuant to which such persons were elected to the offices indicated.

Election to the offices indicated is for a term of one year.

ITEM 10. SUBMISSION OF MATTERS TO A VOTE OF SECURITY HOLDERS

Reference is made to the information in response to Item 7 on Form 10-Q for the quarter ended June 30, 1979. Reference is also made to Note 5 of the Notes to Financial Statements regarding amendments to the Indenture for the 5 7/8% Sinking Fund Debentures due 1992.

ITEM 11. INDEMNIFICATION OF DIRECTORS AND OFFICERS

Reference is made to the information included in response to Item 9 in the Company's annual reports on Form 10-K filed for the fiscal years ended December 31, 1970, 1971 and 1974 and in response to Item 11 on Form 10-K filed for the fiscal year ended December 31, 1978.

ITEM 12. FINANCIAL STATEMENTS, EXHIBITS AND REPORTS ON FORM 8-K

Item 12(a) 1 - Financial Statements - See accompanying Index to Financial Statements.

2 - Schedules and Exhibits - See accompanying Index.

Common Stock - $1 Par Value

Date and Brief Description	Increase (Decrease) in Number of Shares Outstanding
January 9, 1979, shares issued in connection with an acquisition in 1979	199,995
July 13, 1979, shares returned to the Company in connection with an acquisition in 1979	(33,498)
July 19, thru December 27, 1979, exercise of stock options	13,866

ITEM 8. DEFAULTS UPON SENIOR SECURITIES

No defaults upon senior securities occurred during the year ended December 31, 1979.

ITEM 9. APPROXIMATE NUMBER OF EQUITY SECURITY HOLDERS

The following table discloses, as of December 31, 1979, the approximate number of holders of record of each class of equity securities of the registrant.

Title of Class	Number of Holders of Record
Common Stock -- $1 par value	26,742

In addition to the foregoing, the registrant has 47 domestic subsidiaries and 42 foreign subsidiaries which considered in the aggregate as a single subsidiary, would not constitute a significant subsidiary.

Other Active Subsidiaries Not Included in Consolidated Financial Statements - At December 31, 1979, the registrant has investments in 26 companies accounted for on the equity method which, considered in the aggregate as a single subsidiary, would not constitute a signficant subsidiary.

ITEM 5. PENDING LEGAL PROCEEDINGS

Reference is made to Note 12 of the Notes to Financial Statements shown on page 35.

With respect to Federal, state and local provisions relating to the discharge of materials into the environment and protection of the environment, the Company is engaged from time to time in administrative procedures and/or proceedings with various governmental authorities with a view to establishing appropriate criteria and ensuring the compliance of the Company therewith. To the best of the Company's information, there is not presently pending any legal proceedings commenced by any government authority seeking damages, fines or penalties with respect to an alleged violation of such provisions, except that a division of the Company is conducting negotiations with the Commonwealth of Pennsylvania, Department of Environmental Resources, with respect to a Consent Order and Agreement which would obligate the Company to undertake certain corrective action in response to the alleged improper deposit and dumping of wastes and related discharges at Muse, Pennsylvania. Such corrective action would not be material to the Company. Also, during the fourth quarter, a facility of the Company in Fullerton, California was fined $130 for a smoke emission violation, which fine has been paid.

ITEM 6. INCREASES AND DECREASES IN OUTSTANDING SECURITIES AND INDEBTEDNESS; AND

ITEM 7. CHANGES IN SECURITIES AND CHANGES IN SECURITY FOR REGISTERED SECURITIES

Reference is made to Note 8 of the Notes to Financial Statements shown on page 34.

ITEM 4. PARENTS AND SUBSIDIARIES

There are no parents of the registrant. Information with respect to subsidiaries of the registrant, as of December 31, 1979, follows:

Active Domestic and Wholly-Owned Foreign Subsidiaries included in the Consolidated Financial Statements -

	Incorporated Under Laws of	Percentage of Voting Securities Owned by Immediate Parent
Basic Incorporated	Ohio	100%
C-E Morgan, Inc.	Delaware	100%
C-E Minerals, Inc.	Pennsylvania	100%
C-E Walther, Inc.	Delaware	100%
Combustion Engineering - Superheater, Ltd.	Canada	100%
Crest Engineering, Inc.	Oklahoma	100%
Globe Refractories, Inc.	Delaware	100%
Gray Tool Company (Europe), Ltd.	England	100%
Mullite Company of America	Georgia	100%
C-E Natco Limited	Canada	100%
The Air Preheater Company, Inc.	Delaware	100%
The Bauer Bros. Co.	Ohio	100%
The Bauer Bros. Co. (Canada) Ltd.	Canada	100%
The Ehrsam Company	Delaware	100%
The Lummus Company	Delaware	100%
The Lummus Company Canada Limited	Canada	100%
The Lummus Company Limited	England	100%
Lummus G.m.b.H.	West Germany	100%
Lummus Nederland, B.V.	Netherlands	100%
Societe Francaise des Techniques Lummus	France	100%
Vetco Offshore, Inc.	Delaware	100%
Vetco Inc.	California	100%
Vetco-Disc, Inc.	California	100%
Vetco International, A.G.	Switzerland	100%
Vetco Offshore Limited	United Kingdom	100%
Vetco Singapore (Private) Ltd.	Singapore	100%
W.S. Tyler, Incorporated	Ohio	100%

ITEM 3. PROPERTIES

The principal manufacturing and processing plants and other important physical properties are set forth below. The industry segment(s) which used the property is also identified. Unless noted, the property is owned by the Company or a subsidiary.

Aberdeen, Scotland (3)
Andersonville, Georgia (4)*
Birmingham, Alabama (1)(3)
Bloomfield, New Jersey (2)
Calgary, Alberta (3)
Chattanooga, Tennessee (1)(3)(4)
Cinnaminson, New Jersey (4)
Cleveland, Ohio (4)*
Douglas, Scotland (3)*
East Chicago, Indiana (1)(3)
Enterprise, Kansas (3)
Gabbs, Nevada (4)*
Gulfport, Mississippi (3)*
Houston, Texas (2)(3)*
Mansfield, Texas (3)
Maple Grove, Ohio (4)*
Marion, North Carolina (1)(3)
Mentor, Ohio (3)(4)
Monongahela, Pennsylvania (1)(3)
Newington, New Hampshire (1)
Newell, West Virginia (4)
Oshkosh, Wisconsin (4)
Sherbrooke, Quebec (1)(3)
Springfield, Ohio (3)*
Stamford, Connecticut
St. Catharines, Ontario (3)(4)
St. Louis, Missouri (1)(3)
Tulsa, Oklahoma (3)*
Ventura, California (3)
Waterford, Pennsylvania (4)
Wellsville, New York (1)(3)
Wilmington, Delaware (4)*
Windsor, Connecticut (1)(3)

(1) Steam generating systems, equipment and services for the electric utility industry.
(2) Design, engineering and construction services.
(3) Equipment for industrial markets.
(4) Products and services for industrial markets.

*Includes leased facilities. Expiration dates of such leases are as follows:

Andersonville, Georgia	March 30, 1988
Cleveland, Ohio	March 15, 1996
Douglas, Scotland	November 11, 1988
Gabbs, Nevada	February 1, 1990
Gulfport, Mississippi	August 1, 1994
Houston, Texas	February 28, 1988
Maple Grove, Ohio	July 1, 1990
Springfield, Ohio	February 1, 1992
Tulsa, Oklahoma	July 29, 2001
Wilmington, Delaware	July 1, 1989

The Company's manufacturing facilities are of varying ages and are well maintained, in good operating condition and suitable for the purposes for which they are being used. All of the principal manufacturing and processing plants are utilized on the basis of at least one shift and some operate with more than one shift. Management regards these facilities as having adequate capacity to meet current production requirements.

With respect to equipment and products and services for industrial markets, the Company is one of numerous manufacturers or suppliers and in certain cases is one of the leading manufacturers or suppliers. In general, the Company conducts this portion of its operations under highly competitive conditions.

Research and Development

The estimated amount spent during 1979 and 1978 on material research activities relating to the development of new products or services or the improvement of existing products or services which was Company sponsored was $37,700,000 and $32,000,000, respectively, and on that which was customer sponsored was $24,500,000 and $20,000,000, respectively.

Work on the Company sponsored research and development projects as well as engineering work in connection with the sale of the Company's products and services are carried out by several research laboratories and engineering centers at various locations. For this reason, it is not practicable to state the approximate number of professional employees engaged on a full time basis in Company or customer sponsored research and development.

Compliance With Environmental Protection Laws

Compliance by the Company with Federal, state and local environmental protection laws required capital expenditures of $2,547,000 in 1979 and $677,000 in 1978. It is estimated that capital expenditures in 1980 for such purpose will be at approximately the same level as in 1979.

Employees

At December 31, 1979 the Company employed 43,286 persons.

Item 1(d) Financial Information about Foreign and Domestic Operations and Export Sales

Reference is made to Note 15 of the Notes to Financial Statements shown on pages 36 and 37 which is reproduced from the 1979 annual report to stockholders.

ITEM 2. SUMMARY OF OPERATIONS

Reference is made to the information shown for the five years ended December 31, 1979, on pages 14 and 15 under the caption "Comparative Financial Statistics 1970-1979 - Summary of Operations". Reference is also made to pages 16-18 under the captions "Management Discussion and Analysis of the Summary of Operations", "1979 Compared to 1978" and "1978 Compared to 1977". All of such referred to information is reproduced from the 1979 annual report to stockholders.

the conduct of the business. The Company does not believe that any single patent is of material importance in relation to any business segment or the Company as a whole.

Backlog

Reference is made to "Management Discussion and Analysis of the Summary of Operations - Unfilled Orders" on page 17 which is reproduced from the 1979 annual report to stockholders. Approximately 55% of the consolidated December 31, 1979 backlog of unfilled orders is expected to be recorded as sales (principally on the percentage of completion method) in 1980 and the remainder in subsequent years.

The backlog of unfilled orders cannot be projected into an annual rate of net sales for a variety of reasons, including the length of time required for the completion of contracts and changes in customer requirements.

Competitive Conditions

With respect to the steam generating systems, equipment and services for the electric utility industry, the Company is one of the largest domestic manufacturers of fossil fueled steam generating systems and equipment and is one of four domestic manufacturers of nuclear steam supply systems. The competitors for fossil fueled steam generating systems include The Babcock & Wilcox Company, a wholly-owned subsidiary of J. Ray McDermott & Co. and Foster Wheeler Corporation. The competitors for nuclear steam supply systems are The Babcock & Wilcox Company, Westinghouse Electric Corporation and General Electric Company. All of the competitors for nuclear steam supply systems are substantially larger in size than the Company.

The Lummus Company, the principal component of the design, engineering and construction services segment of the Company, is one of the ten largest domestic firms engaged in designing, engineering and constructing chemical process plants, petroleum refineries and other industrial facilities for the petrochemical, matallurgical, pulp and paper and other process industries. The principal competitors for this business include Bechtel Corporation, Brown and Root, Inc., a subsidiary of Haliburton Company, Stone and Webster Engineering Corporation, Fluor Corporation, Foster Wheeler Corporation and Pullman Kellogg Division, Pullman, Inc.

Usually, the Company competes for new orders for fossil fueled steam generating systems and equipment and for nuclear steam supply systems by responding to specific invitations to bid. This same process is usually involved in securing orders for the design, engineering and construction of chemical process plants and other plants sold by The Lummus Company. The principal methods of competition would include the following factors, but not necessarily in the order of importance: design of the equipment or process to be furnished in response to the customer's specifications, technical support and service, ability to meet the customer's delivery schedule and price.

Profits on long-term contracts for financial reporting purposes are recorded principally on the basis of the estimated stage of completion. However, no profits are recorded on contracts for equipment manufactured in the Company's plants prior to billing the customer and, in most cases, prior to shipment of the equipment. These contracts extend over a period of from several months to four or more years. Revisions in cost estimates during the progress of the work under long-term contracts have the effect of including in subsequent accounting periods adjustments necessary to reflect the results indicated by the revised estimates of final cost. Projected or realized losses under long-term contracts, if any, are provided for in the period when first determined. See Note 1(d) of Notes to Financial Statements on page 28.

Cost estimates for long-term contracts take into account all anticipated costs, including, among others, engineering, manufacturing, subcontracting and field construction costs which are required to meet the specifications, including warranties, of the contracts. In addition, when a long-term contract for steam generating equipment is completed for accounting purposes (usually after payment by the customer of amounts retained under terms of the contract and satisfactory operating performance of the equipment), provision is made for future warranty costs, generally on the basis of past experience.

Item 1(c) Narrative Description of the Business

Reference is made to "Lines of Business and Brief Description of the Business" shown on pages 20 and 21, and to Note 15 of the Notes to Financial Statements regarding a narrative description of the Company's business segments. All of such information is reproduced from the 1979 annual report to stockholders.

Raw Materials

The principal raw material for each of the Company's business segments is steel, principally sheet, plate, bar, structurals, tubing, rod, forgings, castings and wire. However, many other materials are also required. Raw materials are purchased by the Company as needed for individual contracts or to maintain proper inventory levels. The Company normally does not encounter difficulties in procuring adequate supplies of raw materials.

The uncertain availability of natural gas in past years required the Company to develop alternative sources of energy for certain of its operations. Substitute forms of energy, while available, are more costly than natural gas.

Patents and Licenses

The Company and its consolidated subsidiaries have numerous United States and foreign patents and patent applications which relate to many different products and processes, and are deemed by the Company to be adequate for

PART I

ITEM 1. DESCRIPTION OF THE BUSINESS

References to the Company contained herein shall be deemed to refer to the Company and its consolidated subsidiaries. Reference is made to the "Comparative Financial Statistics 1970-1979 - Summary of Operations" on pages 14 and 15, and to "Management Discussion and Analysis of the Summary of Operations" on pages 16-18. All of such information is reproduced from the 1979 annual report to stockholders.

Item 1(a) General Development of Business

Reference is made to Note 2 of the Notes to Financial Statements regarding acquisitions during 1979.

The Company intends to comply with the federal wage and price standards, as issued by the President's Council on Wage and Price Stability. Although the Company cannot predict with certainty at this time, it does not believe that compliance will have any material impact on its operations.

Item 1(b) Financial Information About Industry Segments

Reference is made to "Lines of Business and Brief Description of the Business" shown on pages 20 and 21, and to Note 15 of the Notes to Financial Statements regarding financial reporting by business segment. All of such information is reproduced from the 1979 annual report to stockholders.

Much of the Company's business, especially that relating to steam generating systems, equipment and services for the electric utility industry and design, engineering and construction services for the chemical, petrochemical and petroleum industries, involves long-term contracts of various types, including fixed price and cost plus fee type contracts with some contracts including variations of both types. Certain contracts include incentive provisions whereby the profit is adjusted depending on performance. The largest proportion of sales under long-term contracts is derived from fixed price contracts. Most contracts provide for progress or scheduled payments over the life of the contracts. The contract price in fixed price contracts either includes an amount for the estimated increase in the cost of labor, materials and services over the period required for performance of the contract, or is subject to adjustment based on a price escalation clause.

(This report contains 54 pages).

SECURITIES AND EX MISSION

Washington, D. C. 20549

FORM 10-K

ANNUAL REPORT PURSUANT TO SECTION 13 OR 15(d)
OF THE SECURITIES EXCHANGE ACT OF 1934

For the fiscal year ended December 31, 1979 Commission File number 1-117-2

COMBUSTION ENGINEERING, INC.
(Exact Name of Registrant As Specified In Its Charter)

Delaware	13-1587569
(State Or Other Jurisdiction of Incorporation or Organization)	(I.R.S. Employer Identification No.)
900 Long Ridge Road, Stamford, Connecticut	06902
(Address of Principal Executive Offices)	(Zip Code)

Registrant's telephone number, including area code (203) 329-8771

Securities registered pursuant to Section 12(b) of the Act:

Title of Each Class	Name of Each Exchange On Which Registered
Common Stock -- $1 Par Value	New York Stock Exchange
7.45% Sinking Fund Debentures Due 1996	New York Stock Exchange

Securities registered pursuant to Section 12(g) of the Act:

(Title of Class)

(Title of Class)

Indicate by check mark whether the registrant (1) has filed all reports required to be filed by Section 13 or 15(d) of the Securities Exchange Act of 1934 during the preceding 12 months (or for such shorter period that the registrant was required to file such reports), and (2) has been subject to such filing requirements for the past 90 days.

Yes X No ___

Indicate the number of shares outstanding of each of the issuer's classes of common stock, as of the close of the period covered by this report.

Class	Outstanding at December 31, 1979
Common Stock, $1 par value	16,337,119

FORM 10-K

ANNUAL REPORT
Pursuant to Section 13 of the
Securities Exchange Act of 1934

For the year ended
December 31, 1979

APPENDIX A

License No. SNM-1067, Docket 70-1100

receipt, use and storage of enriched uranium. In the history of the low-enriched fuel fabrication industry, there never has been a criticality accident associated with fuel preparation or fabrication. There have been four criticality accidents in high enriched scrap recovery operations, but all of these involved wet chemical processing. The operations performed on the Windsor site do not involve wet chemical processing.

Fortunately, criticality accidents have occurred so rarely that no statistical analysis of the probability of such an accident has been attempted. Criticality events that have occurred have had no significant environmental impact. Radiation injuries were restricted to individuals directly involved. Fission products were effectively confined to the processing building in which the event occurred. Prompt evacuation of employees upon a criticality alarm would assure no more than minor radiation doses to all except those in the immediate vicinity of the accident.

In estimating the intensity of a criticality accident, it has been assumed that 10^{18} fissions occur producing approximately 6×10^{6} calories of heat. The following type of accident conditions would be necessary to cause a nuclear excursion:

9.2.1.1 Moderated Uranium Oxide - Encapsulated

A sufficient quantity of production assemblies, to sustain a nuclear chain reaction when covered with water, could theoretically, but inadvertently be accumulated.

In the above case, the first spike of the nuclear chain reaction could exceed 10^{16} fissions, ejecting the moderating water as steam in a sufficient quantity to render the system subcritical. The release of fission products is not expected because the enriched uranium is encapsulated in zirconium tubing which is designed to withstand a reactor environment.

9.2.1.2 Moderated Uranium Oxide - Unencapsulated

Unencapsulated enriched uranium such as fuel powder, fuel pellets or fuel sludges could be accumulated, through inadequate administrative controls, in sufficient quantities for a criticality accident. Similar accidents have occurred in the past with high enriched uranium solutions as previously noted. From 10^{15} fissions could be expected from a single burst releasing fission products.

The fission products which could be released would combine to yield maximum off-site doses of:

Whole Body Dose	0.216 RAD
Thyroid Dose	1.32 RAD

(Calculated in accordance with NRC Regulatory Guide 3.34)

9.2.2 Major Airborne Particulate Release

A major airborne radioactive particulate release is again highly improbable because of the High Efficiency Particulate Air (HEPA) Filters utilized at C-E NFM-Windsor (99.97% Efficient). All air released to the environs is sampled continuously by in-line stack samples which are analyzed daily to determine any release. Any release that would result in a concentration of airborne UO_2, greater than 50% of MPC_a for insoluble U^{235} in a 24 hour period at the site boundary will be considered significant and the State of Connecticut, Office of Civil Preparedness shall then be notified. A person standing at the site boundary continuously (24 hr/day in a concentration equal to 1.0 MPC_a (General Population) after 1 year will receive a dose of approximately 0.50 rem. This notification level used by C-E NFM-Windsor is a factor of 1000 less than the NRC notification level required by 10 CFR Part 20. However, because of C-E NFM-Windsor's continued low annual airborne effluent release rates, airborne levels exceeding 50% of MPC_a at the site boundary would indicate a significant increase above normal operating conditions and notification of state agencies is viewed to be appropriate. A release of this magnitude is insignificant from a radiological safety standpoint, but is used to mitigate the consequences of a potentially large release.

9.3 Worst Case Scenario

The emergency plan scenario chosen was an accidental criticality excursion. This scenario was chosen because it is the only accident that could occur at C-E NFM-Windsor that has a potential for any significant off-site impact.

The emergency plan scenario is based on the following: The postulated accident occurs in the powder processing area of the nuclear fuel manufacturing facility, the area in which low enriched UO_2 in powder form is pressed into pellets (UO_2 in powder form has the greatest potential of being brought to the conditions required for an accidental criticality to occur). The following conditions would have to occur simultaneously:

1) A violation of criticality mass limits by a factor of 3 (A safety factor of 3 is incorporated in all mass limits).

2) The accidental introduction of a large quantity of water to the above mass of UO_2 powder to bring it to optimum moderation conditions.

3) The assembly of the powder and water mixture into an optimum geometrical configuration. A burst of 10^{18} fissions is then assumed to occur.

This is equivalent to a release of about 32 megawatt seconds, which is a much larger excursion than could be expected in any system in a low enriched fuel fabrication facility. To cause an excursion of this magnitude, a very rapid increase in reactivity would be required, which is not credible in the systems in this facility.

Radiation injuries would be restricted to individuals directly involved and personnel within a 10-20 foot radius of the accident. Prompt evacuation of employees by an automatic criticality alarm system would result in minor radiation doses to all except those in the immediate vicinity of the accident.

9.3.1 Whole Body Cloud Dose

The fission product isotopic release and the average energy used in this postulated accident are shown in Table 9.1. The distance to the nearest resident bordering the C-E Windsor site is 640 meters. The atmospheric conditions assumed for this accident were very conservatively chosen to be Pasquill Type F with a windspeed of 1 meter per second blowing directly toward the home of the nearest resident. If 50% atmospheric condition information was available for the site, the calculated dose would be decreased by at least an order of magnitude.

The dose was calculated assuming a semi-infinite cloud surrounding the individual with a radioisotope concentration equivalent to the center line of the plume. Since the Pasquill Type F atmospheric stability condition produces a very small plume, the dose is overestimated by about a factor of 8 as a result of the semi-infinite cloud assumption.

The delay time (the time between the criticality and the arrival of the cloud at the nearest residence) was calculated to be 18.2 minutes. This delay was composed of two components: One is the delay in the fuel fabrication building (7.5 minutes) and the other is the transit time from the building to the nearest resident (10.7 minutes). The only other credit taken was for the wake effect of the building which is only 1.5 based on the minimum external area of the building which is 334 square meters.

OFF-SITE DOSES FROM WORST CASE CRITICALITY ACCIDENT

Type of Dose	
Whole Body Cloud	0.212 RAD
Prompt Gamma Beam	0.063 RAD
Prompt Neutron Beam	0.006 REM
*Thyroid	1.32 REM

* Calculated using a breathing rate of $3.47 \times 10^{-4} m^3$/sec.

The methods utilized in the assessment of this accident are consistent with those used by the U. S. Nuclear Regulatory Commission.

9.3.2 Conclusion

The emergency plan scenario evaluated here indicates that evacuation as a protective action need not be considered. Even with the extreme conservatism described above, the off-site doses calculated are below all recommended action guidelines.

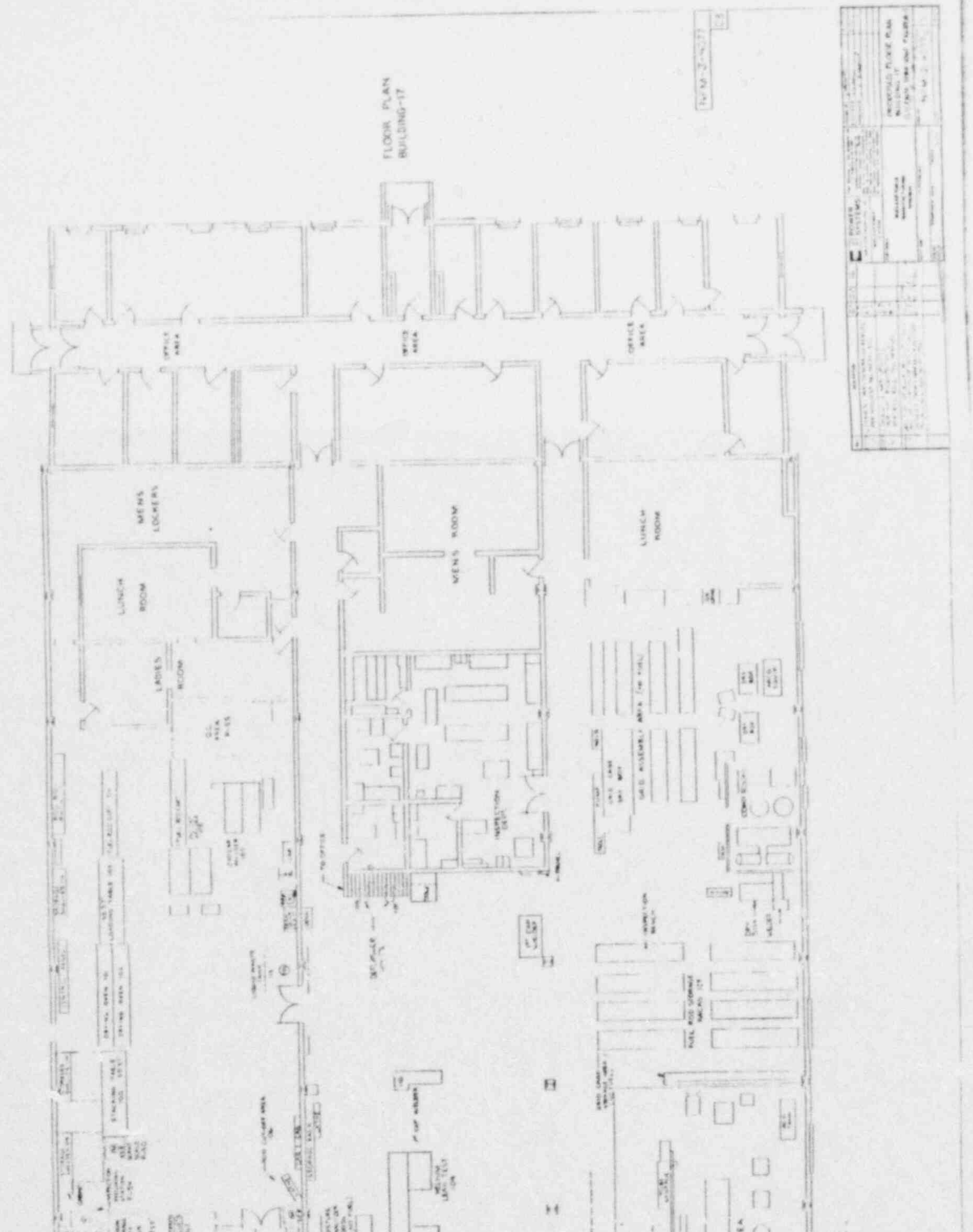
Combustion Engineering's Windor site has its own effluent and environmental measurement and monitoring program. Environmental samples have been taken on a regular basis over the past 10 years and their results are available for comparison in an emergency situation.

TABLE 9.1

Radioactivity of Important Nuclides Released From the Postulated Criticality Accident

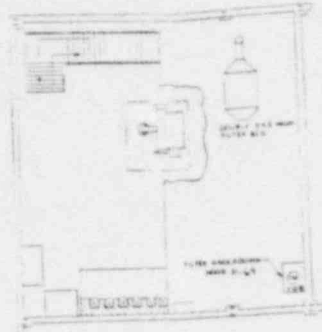
Nuclide	Curies	Average Gamma Energy (Mev)
Kr-83m	3.7E+0	2.6E-3*
Kr-85m	1.6E+1	1.6E-1
Kr-85	1.5E-4	2.2E-3
Kr-87	1.0E+2	7.8E-1
Kr-88	6.5E+1	2.0E 0
Kr-89	4.1E + 3	1.6E 0
Xe-131m	3.8E-4	2.0E-2
Xe-133m	5.5E-2	4.1E-2
Xe-133	1.3E 0	4.6E-2
Xe-135m	1.1E+1	4.3E-2
Xe-135	1.6E+1	2.5E-1
Xe-137	3.8E+3	1.6E-1
Xe-138	1.2E+3	1.1E 0
1.129	4.2E-11	
1-131	1.8E-1	3.8E-1
1-132	6.7E-1	2.2E 0
1-133	3.5E 0	6.1E-1
1-134	4.8E+1	2.6E 0
1-135	1.2E+1	1.5E 0

*E-3 ≡ 10^{-3}

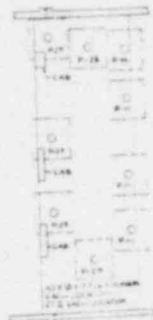


POOR ORIGINAL

WORK STATION	STATION NAME	CRITICALITY LIMIT
[illegible]	[illegible]	[illegible]
[illegible]	CENTRIFUGE	[illegible]
[illegible]	CONCRETE BLOCK STORAGE AREA	[illegible]
[illegible]	[illegible]	SAFE VOLUME
[illegible]	OXIDATION-REDUCTION FURNACE	[illegible]
[illegible]	MICRONIZER SYSTEM	[illegible]
[illegible]	FILTER KNOCKDOWN HOOD	[illegible]
[illegible]	CONCRETE BLOCK STORAGE AREA (ANNEX)	[illegible]
[illegible]	AUTOCLAVE	[illegible]
[illegible]	CLEANING TANK	SAFE VOLUME
[illegible]	[illegible]	[illegible]

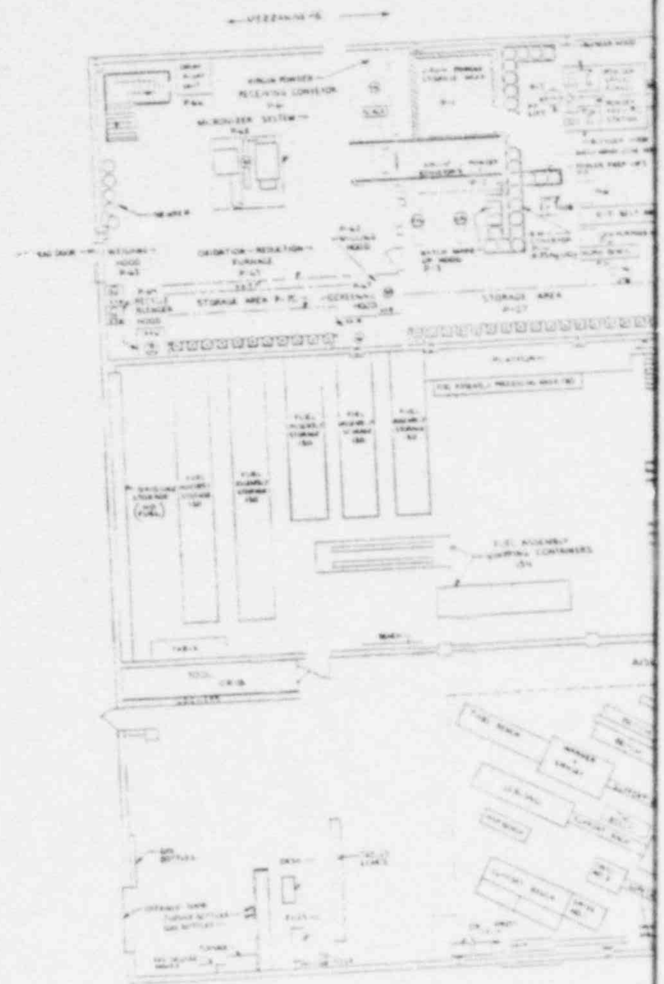


MEZZANINE-B



MEZZANINE-A

LEGEND:
M SAFE MASS
V SAFE VOLUME
CYL SAFE CYLINDER
E SAFE SLAB



POOR ORIGINAL

70-1151

MAP-81-002

PDR

Westinghouse Electric Corporation Power Systems

Nuclear Fuel Division

Box 355
Pittsburgh Pennsylvania 15230

January 9, 1981

DOCKETED
NMSS
MAIL SECTION
DOCKET CLERK

RECEIVED
JAN 14 PM 2 35

U.S. NUCLEAR REGULATORY COMMISSION
Attention: Mr. W. T. Crow
Uranium Process Licensing Section
Uranium Process Licensing Branch
Office of Nuclear Material Safety
and Safeguards
Division of Fuel Cycle & Material Safety
Washington, D.C. 20555

Dear Mr. Crow:

Enclosed is one (1) copy of a request to amend License SNM-1107 as necessary to authorize operations with special nuclear material in an upgraded dry conversion line in our Columbia plant. [Ten (10) additional copies of this request have also been submitted, this date, by the Westinghouse NES License Administration Manager - see attached transmittal letter.]

Included with this transmittal are environmental information and enabling license conditions relating to the proposed Manufacturing Automation Project (MAP) upgrading. A detailed operations safety evaluation for the proposed production line system, which utilizes the Integrated Dry Route (IDR) Conversion Process planned for future applications by the Westinghouse Nuclear Fuel Division, will be transmitted as detailed design progresses.

If you have any questions concerning this transmittal, please call me at (412)-256-5760.

Very truly yours,

WESTINGHOUSE ELECTRIC CORPORATION

F. Cellier

F. Cellier
MAP Project Manager

ACCT-1151
Applicant ....
Check No. 903.76 ....
$34,600.
major safety
1.14.81
Jan 11-1

18934

WRD-LA-276

Westinghouse Electric Corporation
Water Reactor Divisions
Box 355
Pittsburgh Pennsylvania 15230

January 9, 1981

U. S. Nuclear Regulatory Commission
Office of Nuclear Material Safety & Safeguards
Division of Fuel Cycle & Material Safety
Washington, D.C. 20555

Attn: Mr. R. G. Page, Chief
Uranium Process Licensing Branch

Subject: Transmittal of Application for Amendment to Upgrade Facility, License SNM-1107, Docket 70-1151

Gentlemen:

The Westinghouse Electric Corporation hereby requests an amendment to License SNM-1107 to authorize operations with special nuclear material in an upgraded section of our Columbia Facility, in accordance with the attached application.

The information included with this transmittal consists of ten (10) copies of environmental information and altered license conditions (submitted as changed pages, in accordance with applicable license specifications). We will appreciate your timely review of this information such that the installation schedule for the proposed line can be maintained.

Please find enclosed a check payable to the U. S. Nuclear Regulatory Commission, in the amount of $34,600, in accordance with the amendment fee schedule of 10 CFR 170.31.

If you have any questions regarding this matter, please write me at the above address or telephone me on 412/373-4652.

Very truly yours,

Andy Sabo

A. T. Sabo, Director
Licensing, Safeguards & Safety

ATS/dc

LICENSE CONDITIONS

Proposal For Improvement And Upgrading Of Operations

at the

Westinghouse Columbia Nuclear Fuel Fabrication Plant

SNM-1107

Docket 70-1151

January 9, 1981

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Minimum Specifications and Capabilities

2.1 Scope of Licensed Activities

2.1.1 Definitions

Clean Area - an area where radioactive material, if present, is completely contained and there is negligible contamination on the floors or accessible surfaces. (e.g. Machining Area, Grid Assembly Area, Final Assembly Area, Office Areas, Cafeteria, etc.)

Component - when used administratively, an organization unit, distinguishable by its assigned responsibilities, e.g., the line management component, the radiation protection component, etc.

Controlled Area - an area where uncontained radioactive materials are processed and probability of contamination on floors and accessible surfaces is high. Protective clothing is required. (e.g., Conversion Area, Pelleting Area, Rod Loading Area, UF_6 Bay, etc.)

Dry - When used to describe special nuclear material (SNM), having a moderation ratio (H/U = hydrogen to uranium atomic ratio) less than, or equal to, 0.5 for uranium enriched up to 4.15 weight percent in U-235, and less than or equal to 0.3 for uranium enriched between 4.15 and 5.0 weight percent.

Equivalent Diameter - when evaluating the adequacy, for purposes of nuclear criticality safety, of the geometry control of a subcrit unit having a non-circular cross section, the diameter of that circle that has the same area as the area of the cross section of the subcrit unit. $d_{equiv.} = 2\sqrt{\frac{Area}{\pi}}$, where Area is the cross sectional area of the subcrit unit under review.

2.1.2 Summary Description

The objective of the licensed activity will be the ADU or IDR process conversion of uranium hexafluoride to uranium dioxide and the manufacture of fuel-bearing components for nuclear reactor cores. The licensed material will be composed of unirradiated special nuclear materials received principally as uranium hexafluoride containing uranium enriched up to 5.0 w/o in the isotope ^{235}U.

2.1.2 (continued)

Other chemical forms that may be received are uranium oxides and uranyl nitrate. Operations may include the fabrication of fuel assemblies that contain uranium enriched from 4.15 to 5 w/o in the ^{235}U isotope. The material for such assemblies will be processed through IDR conversion or will be received as uranium dioxide powder (only), and, will not be subject to ADU conversion, scrap preparation, or other wet chemical processes (unless properly approved and documented evaluations demonstrate the nuclear criticality safety of the utilized wet processing systems.) Another similar, limited activity will involve the fabrication of fuel assemblies containing mixed oxide fuel material. This material will be a mixture of PuO_2 in natural or depleted UO_2. It will be received and handled only as sealed fuel rods that have been fabricated by another Westinghouse NFD facility. Such rods will be surveyed on receipt on a sample basis to the limits specified for sealed Pu sources. No authorization to possess or use exposed plutonium is intended.

Scrap or waste licensed material ($\leq$ 4.15 w/o ^{235}U) resulting from site operations may be processed for concentration, recovery and/or reuse. These operations may involve chemical separation (e.g., acid treatment and dissolution or acid leaching, followed by chemical precipitation), mechanical separation and thermal decomposition.

Scrap and wastes resulting from processing operations that involve uranium enriched >4.15 w/o will be collected and segregated to assure that no materials at such higher enrichment are introduced into any area unless properly approved and documented evaluations demonstrate the nuclear criticality safety of the subject area at the higher enrichments.

2.1.2 (continued)

The licensed activity will perform work for other Westinghouse Divisions or outside customers which is adapted to the capabilities of the facility. The work may consist of uranium oxide fuel fabrication and quality assurance testing operations and laboratory analyses of uranium or byproduct material.

2.1.3 Material

Special Nuclear Material

Listed below are the maximum quantities of special nuclear materials which will be possessed by the licensed activity at any one time.

Material	Form	Quantity
^{235}U	Unirradiated, any chemical or or physical form at any enrichment	350 grams
^{235}U	Unirradiated, any chemical or physical form at any enrichment $\leq$ 5.00 w/o	50,000 kilograms
^{233}U	Any chemical or physical form, for laboratory uses only	5 grams
^{238}Pu	Sealed Sources	1.5 grams
Mixed Oxides	Unirradiated plutonium oxides, mixed with oxides of natural or depleted uranium, as sealed fuel rods. The fissile PuO2 $[(^{239}Pu + ^{241}Pu)O_2]$ will constitute a maximum of 6.6 w/o of the total oxide weight.	750 kilograms contained Pu. Natural or depleted U to suit.

2.2.11 Chemical Equipment

The equipment specified below will be provided as part of the UF_6 vaporization system.

A UF_6 detection method in the steam condensate system, with an alarm to alert operating personnel to a leak in steam-type vaporizers, and with an interlock and an alarm to alert operating personnel to a leak in hot-water-type vaporizers.

A pressure relief valve and a liquid level detector in the steam-type UF_6 vaporizers; or, with favorable geometry/overflow-type sumps in the hot-water-type UF_6 vaporizers.

Provisions to permit the leak testing of the UF_6-cylinder-to-conversion-system connections prior to heating each time a cylinder is connected.

A means for cooling the UF_6 cylinder.

A means to prevent the backflow of water from the hydrolysis tank to the UF_6 cylinder, in ADU process systems.

2.2.12 Incinerator Equipment

The equipment, controls and safety interlocks specified below will be provided as part of the incinerator system:

Temperature sensor/controllers in the primary combustion chamber, breech and scrubber exhaust.

Safety interlocks to inhibit feeding additional wastes if an overtemperature occurs in the primary combustion chamber.

A means for automatic shut - down of the incinerator in case of overtemperature in the scrubber exhaust.

An auxiliary means for cooling the incinerator exhaust gases.

2.2.12 (continued)

Cooling water flow monitoring devices.

Pressure monitoring devices in the breech and scrubber exhaust

A means for automatic shutdown of the incinerator in case of insufficient negative pressure in the breech and scrubber exhaust.

Continuous, representative gaseous effluent sampler.

HEPA filtered exhaust and ash removal systems.

A means for monitoring and adjustment of the pH of scrubber solutions.

Maintenance of a log indicating the mass of ^{235}U charged and removed for each burn cycle, and the cumulative total of the net, assumed to remain in the incinerator.

2.2.13 Moderation Control Areas

Fire control in areas of the SNM Building where uranium is processed, handled, or stored under hydrogeneous material criticality control criteria shall receive particular attention, as follows:

- Special consideration shall be given to use of fire-resistive or noncombustible building components, equipment, and materials.
- Special consideration shall be given to the prompt disposal of combustible waste. Such waste that is collected during work activities shall be stored in metal containers having fire protection covers.
- A readily available supply of portable fire extinguishers suitable for use on the specific hazards encountered shall be provided.
- Such areas shall be subject to administrative controls, including specific personnel training, to assure that only permissible firefighting means and materials are used.

2.2.14 Interlocks

IDR and moderation controlled blending and storage equipment, and its associated control instrumentation, shall be evaluated for conditions requiring automatically operating interlocks to safeguard facilities, workers, and environs against failures of equipment and instruments signficant to safety.

Equipment and instruments requiring such interlocks shall be identified and documented by the regulatory compliance component.

Identified interlocks shall be installed, maintained, and operable as a minimum condition of applicable equipment or system operation.

3 Safety Limits

2.3.1 Chemical Reaction Safety

Each anion-type ion exchange column will be equipped with a rupture disc. The concentration of the nitric acid regenerant will be controlled at or below 5.0 normal. The columns will be maintained under routine surveillance during regeneration. When the ion exchange columns are not in routine use, the bottom of the column shall be opened to atmosphere by removing the spool piece.

2.3.2.2 Nuclear Criticality Safety Values

Maximum Permissible Values

a. Maximum Permissible Values for subcrits with a maximum ^{235}U enrichment of 5.0 w/o are established in tabular form as follows:

Figure 2.3.2.1 Batch or Mass Controlled Subcrits
Figure 2.3.2.2 Volume Controlled Subcrits
Figure 2.3.2.3 Cylinder Diameter or Equal Cross Sectional Area Controlled Subcrits
Figure 2.3.2.4 Slab Thickness Controlled Subcrits

b. Subcrits containing uranium enriched to greater than 5.0 w/o will be limited to 350 grams of contained ^{235}U.

c. Moderation Controlled Subcrits - Systems shall be considered under moderation control for nuclear criticality safety when the following conditions are met:
The contained special nuclear material is "dry" under normal operating conditions.
The containment precludes introduction of moderator; or, system controls, procedures, and interlocks preclude introduction of sufficient moderator to compromise the nuclear criticality safety of the system.
Moderation controlled UF_6 in approved shipping cylinders will constitute a specific MPV.

d. Uranium concentration controlled subcrits will be limited to a maximum allowable concentration of 5 grams ^{235}U per liter. This MPV will not be applied unless it can be demonstrated that the precipitation of the SNM and higher concentrations due to process failures are not credible.

2.3.2.2 (continued)

e. Subcrits which are safe by concentration control and which are part of a continuous processing line, will be filled with Raschig rings which are maintained in accordance with the current edition of the standard N16.4, "Use of Borosilicate - Glass Raschig Rings as a Neutron Absorber in Solutions of Fissile Material."

f. Fixed poisons may be used in nonliquid special nuclear material systems when the following restrictions are both met: The poison shall be physically protected from abrasive action by the special nuclear material; and, Nuclear Criticality safety of such poisoned systems shall be verified by validated computer calculations.

g. Subcrits composed of fuel assemblies will be limited by reactivity. The computed k_{eff}, including allowances for computational error, will not exceed 0.95. These computations will be performed by the NFD, Nuclear Design Department using procedures such as MUFT, SOFOCAT, LEOPARD, and/or PDQ-03. The results of these computations will be independently reviewed within the department and approved by the department manager before being transmitted to the NFD Manufacturing Department.

h. Maximum permissible values for subcrits containing plutonium will be those established in Figure 2.3.2.5. Subcrits containing plutonium will be restricted to encapsulated components containing PuO_2 mixed with natural or depleted UO_2.

2.3.2.2 (continued)

d. Moderation controlled subcrits ("dry"*) of 5 w/o or less enriched uranium, when limited as follows will not be considered to contribute to interacting arrays: (1) Maximum Permissible Values, (2) in closed containers or configurations which would not retain water, (3) located outside of areas assigned to interacting subcrits, (4) no sprinkler system in the area, (5) no use of water or other hydrogenous agents for fire fighting purposes and (6) appropriate nuclear criticality safety signs posted in the controlled area.

e. Concentration controlled subcrits (with or without borosilicate glass Raschig rings) are not considered to contribute to nuclear interaction provided that they are outside of areas assigned to interacting subcrits.

f. Notwithstanding other spacing requirements, any subcrit will be separated by at least 12 inches from any other subcrit.

g. All subcrits containing plutonium will be spaced such that the "smeared" slab thickness will not exceed 25% of the minimum critical slab thickness.

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*As defined in paragraph 2.1.1

2.4 Minimum Conditions of Operation

Processing operations involving SNM will be performed routinely only when appropriate equipment having the capabilities specified in paragraphs 2.2.3 through 2.2.14 has been provided and is operative and when qualified line management personnel are present.

Non-routine and emergency operations involving SNM will be performed only after the particular operation has been approved by the appropriate line management function and the radiation protection function. The line manager will be responsible to obtain the evaluation and approval of the operation by the radiation protection function, consistent with the urgency of the situation in the event of an emergency. All equipment specified as necessary to the operation by the line management function and radiation protection function will be provided and operative.

The equipment specified in paragraph 2.2.2 will be maintained available at all times. The necessary trained personnel will be available as specified in the emergency procedures.

A continuing program of surveillance, air sampling and smear sampling which will be adquate to detect ventilation deficiencies and assure compliance with 10 CFR 20 limits, will be conducted.

2.5 Emergency Procedures

Written emergency procedures which comply with the requirements of 10 CFR 70.22(i) will be maintained and communicated to all employees and unescorted personnel working in the affected areas of the licensed activity. Selected personnel will be organized and trained to cope with various credible emergency situations.

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4.7 Transfer of Special Nuclear Material

The licensed activity shall be authorized to sell, or otherwise transfer, hydrofluoric acid containing trace quantities of uranium (enriched up to five weight percent in U-235) to nonlicensed persons, provided that:

- The concentration of uranium in the acid does not exceed 10 parts per million.
- Each such sale or transfer shall be accompanied by a written instruction that the acid is not to be used for any purpose involving human consumption.

ENVIRONMENTAL INFORMATION

Proposal For Improvement And Upgrading Of Operations

at the

Westinghouse Columbia Nuclear Fuel Fabrication Plant

SNM-1107

Docket 70-1151

January 9, 1981

SECTION 1

DESCRIPTION OF PLANT CHANGES

To best meet the established need for increased productivity at the Columbia Plant, a fully developed and proven dry conversion process - the Integrated Dry Route (IDR) method developed and commercially utilized by British Nuclear Fuels Limited (BNFL) - is proposed as a supplement to the plant's existing ADU (wet conversion) process production lines. The planned IDR process line will replace an experimental dry process line - the Direct Conversion Fluidized Bed (DCFB) system - which, although it has been shown to provide some of the desired environmental advantages of the IDR process, it has not provided the superior fuel product anticipated in the new process. The IDR process line will provide opportunity for productivity improvement, while generating much lower quantities of regulated constituents in liquid effluents, and, while also providing enhanced control of regulated airborne constituents (when both are compared to equivalent ADU fuel production capacity). Details of the proposed IDR system, and plant changes to accommodate installation of the total Manufacturing Automation Project (MAP), are described in the following discussion.

1.1 OVERALL PLANT OPERATIONS

The fabrication of nuclear fuel assemblies requires both chemical and mechanical operations; and, as a result, some (low level radioactive) solid, liquid, and gaseous wastes are generated. The plant process equipment and ventilation systems are designed and operated to maintain regulated chemical and radioactivity discharges to the environment well within established limits, and as low as reasonably achievable. Figure 1 presents a general flow diagram of proposed total plant operations, including the new process line. (This figure also schematically identifies the sources, treatment, and anticipated effluent concentrations in releases to the environs, from new system installation). Figure 2 presents a plan view and Figure 3 shows a cross-sectional view of the proposed process area.

1.2 SYSTEM DESCRIPTION

1.2.1 Conversion

The planned conversion process will utilize dry methods to convert solid uranium hexafluoride (UF_6) to uranium dioxide (UO_2) powder. [This process involves UF_6 vaporization, gas phase hydrolysis, and gas-solid phase reduction to produce UO_2. The process is well established, has been commercially utilized in two countries, and provides opportunity for significant environmental advantages over alternate processes (by substanitally reducing liquid waste generation).]

UF_6 feed material, received in type 30A/30B cylinders, is vaporized within the cylinders by heating with hot water spray. The resulting UF_6 vapor is reacted with superheated steam at the head-end of a conversion kiln to form uranyl fluoride (UO_2F_2) powder and hydrogen fluoride (HF) gas. The UO_2F_2 is further contacted within the kiln - with a countercurrent flow of hydrogen, nitrogen, and superheated steam - to strip residual fluoride, and to reduce the uranium powder to uranium dioxide. The UO_2 is discharged from the product end of the kiln into check hoppers, and is then pneumatically conveyed (or otherwise transported) to the powder processing area. Process off-gases [hydrogen (H_2), hydrogen fluoride (HF), nitrogen (N_2), and steam (H_2O)] are removed continuously from the top of the head-end of the kiln, through process filtration (periodically reverse-purged) for retention of uranium-bearing solids prior to recovery of hydrofluoric acid.

The conversion process is shown schematically in Figure 4; details of the conversion process follow:

- Vaporization

UF_6 cylinders are transported from the UF_6 storage area to the Manufacturing Building UF_6 bay via lift truck. The cylinders are then installed in a vaporizer, using an overhead crane. A cylinder is connected to its process header by flexible copper tubing. When the cylinder under hot water spray has reached process operating temperature ($\sim$ 180°F) and pressure (> 5 psig), the UF_6 is delivered to the process (kiln) by remotely opening the cylinder valve.

[Normally (during steady-state operations), two cylinders will be hot simultaneously, but during changeover periods (some 50 percent of the time), three cylinders will be hot simultaneously.]

When a cylinder which is supplying the conversion system is sufficiently depleted of UF_6 (so as to no longer maintain a supply pressure above 5 psig), it is disconnected from the supply line and valved into a cold trap evacuation system for removal of residual UF_6 (to an acceptable final heel of less than 25 pounds). Heel removal is accomplished by evacuating the cylinder (with a vacuum pump) through an exhaust train, consisting of a cold trap system with self-contained (-65°F) refrigeration (to condense UF_6 vapor) and two final series chemical absorber (Al_2O_3) traps (for the capture of any final traces of UF_6). Upon completion of the evacuation process, the cylinder is removed from the vaporizer, and transferred by crane to the cylinder scales for weighing to assure that the residual heel is equal to (or less than) 25 pounds.

In the vaporization area, UF_6 vapor or liquid containing lines and vessels are normally enclosed within a pipe chase (or other containment), maintained at a negative pressure with respect to the operating area and vented through the HF Vent Scrubber.

- UO_2 Powder Production and Handling

UF_6 supplied by vaporization is converted to UO_2 powder product in an IDR kiln. Converted powder product from a kiln is held in discharge check hoppers pending analysis and subsequent processing. Composited UO_2 samples are used to establish the physical composition of the contents of each check hopper. Acceptable product powder is discharged to a pneumatic transfer line which conveys the material directly to powder preparation. (Bulk powder containers are also to be provided as an alternate transport system.) Powder in a check hopper found to be unacceptable (with respect to fluoride and/or moisture) is transferred to a powder rework area for further treatment.

- Powder Rework

Rework is necessary when powder properties (primarily fluoride and moisture content) are out of specification. Powder which does not meet specifications is discharged from the check hoppers into (geometrically-controlled) containers, then is campaign processed through auxiliary drying and fluoride stripping equipment.

Reworked powder, which upon analysis is found to meet specifications, is returned to the regular process stream by one of two methods: When the pneumatic conveying system is used, a pre-wieghed amount of reworked powder will be metered into a transfer line after a receiving blender has been charged with the designated amount of virgin powder. When the bulk transport containers are used, the reworked powder will be accumulated in a (moderation-controlled) container until it is full. The container will then be elevated to the blender charging floor through the container lift and used as needed to supply addback to each blender charge.

- Hydrofluoric Acid Recovery

The conversion kiln off-gas is cooled to recover byproduct hydrofluoric acid by condensation. The recovered acid solution is collected in an HF quarantine tank (Q-Tank) and held for uranium analysis before release (if it meets uranium specification) to a bulk storage tank (for subsequent sale as a byproduct).

Out-of-specification (excess uranium) HF solution is transferred to a safe-geometry precipitator system, located in the acid recovery area, where uranium values are recovered by (advanced treatment) precipitation and filtration. The filtrate is transferred to the liquid waste treatment system.

Based on the current HF condenser design, some 95% of the HF will be recovered as (nominally) 55 w/o hydrofluoric acid. The remainder of the HF will be cleaned by NaOH in the Condenser Off-Gas Scrubber. The annual HF transfer to the scrubber liquor is estimated at some 4400 Kg (approximately 10,000 pounds).

[It is planned that the recovered HF be licensed for recycle (e.g., sale); otherwise, it would have to be neutralized with $Ca(OH)_2$ with the product (CaF_2) dried and buried. Licensing for recycle will allow the reuse of the recovered acid in an economic manner which would also conserve resources - rather than requiring the otherwise unnecessary controlled disposal of the material, as radioactive waste, in valuable space at a licensed burial site.]

- Off-Gas Scrubbing

Caustic scrubbing is provided to remove residual HF and UF_6 from gaseous exhaust streams - from either the normal process (and vent exhausts) of the acid recovery system, or from an inadvertent leak in UF_6 cylinders or transfer lines. Two basic scrubber systems are provided for this purpose:

The Condenser-Off-Gas Scrubber is provided to cleanse condenser effluent from the kiln system (which contains traces of hydrogen in addition to acidic off-gas). Uncondensed HF gas carryover is treated with caustic (NaOH) in this scrubber. The resultant scrubber solution (containing traces of uranium) is quarantined and analyzed prior to release to liquid waste treatment, or to the precipitation tanks (if established uranium levels are exceeded). Residual hydrogen (already below the lower limt of flammability) is further diluted with plant air prior to discharge of the gaseous stream to the outside atmosphere (through the confinement and ventilation system described in paragraph 1.3).

The HF Vent Scrubber is utilized to cleanse the normal off-gas from vents on HF storage vessels. In addition, this scrubber can be made available to cleanse air in the vaporizer room, and vaporizer room process enclosures, which might become necessary due to inadvertent leakage of UF_6 process piping or vessels. HF Vent Scrubber solutions and gaseous streams are routed in a similar manner to that previously described for Condenser Off-Gas Scrubbing, except that there is no need for hydrogen treatment.

- Uranium Recovery from Solutions

Uranium will be recovered from spent scrubber solutions (as well as from uranium-containing by-product HF filtrate) via Columbia's existing Advanced Waste Treatment system.

1.2.2 Fabrication

Details of the fabrication process follow:

- Powder Processing and Pellet Fabrication

UO_2 powder from the dry conversion process is transferred to the powder processing area where it is blended with additives - including uranium oxide (U_3O_8)

recycled from scrap recovery processes. After blending, the homogenized powder is compacted, granulated and pressed into pellets. There are no liquid effluents from these operations; airborne effluents are treated by the confinement and ventilation system described in paragraph 1.3.

- Sintering

Pressed pellets are loaded into boats and charged to electrically heated furnaces for transformation to high-density pellets by sintering in a reducing atmosphere. There are no liquid effluents from this operation; airborne effluents are treated by the described confinement and ventilation system.

- Pellet Grinding and Rod Loading

Sintered pellets are processed through a grinding operation to obtain specified dimensions. Ground pellets are loaded into prepared metal tubes (from the Tube Prep Area) and the tubes are sealed by welding. Finished rods are inspected and tested, then transferred for final assembly. There are no liquid effluents from these operations; airborne effluents are treated by the described confinement and ventilation system.

- Final Assembly

In the IDR portion of the Final Fuel Assembly Area, the fuel rods are loaded into designated positions in a prefabricated support structure consisting of a bottom nozzle, thimble tubes, and structural grids. A top nozzle is then attached to complete the final assembly. There are no liquid or airborne effluents from these operations.

1.3 Confinement and Process Ventilation

As noted in the introduction to this Section (and reiterated in several other paragraphs), the dry process provides the opportunity of enhanced control of airborne effluents, through improvements in containment and processing. The MAP Confinement and Ventilation System (within the controlled area of the Manufacturing Building) functions to enhance limitation of plant personnel exposure potential, and to enhance protection of the general public by strict control of airborne effluents discharged to the environment. A generic ventilation schematic is depicted in Figure 5.

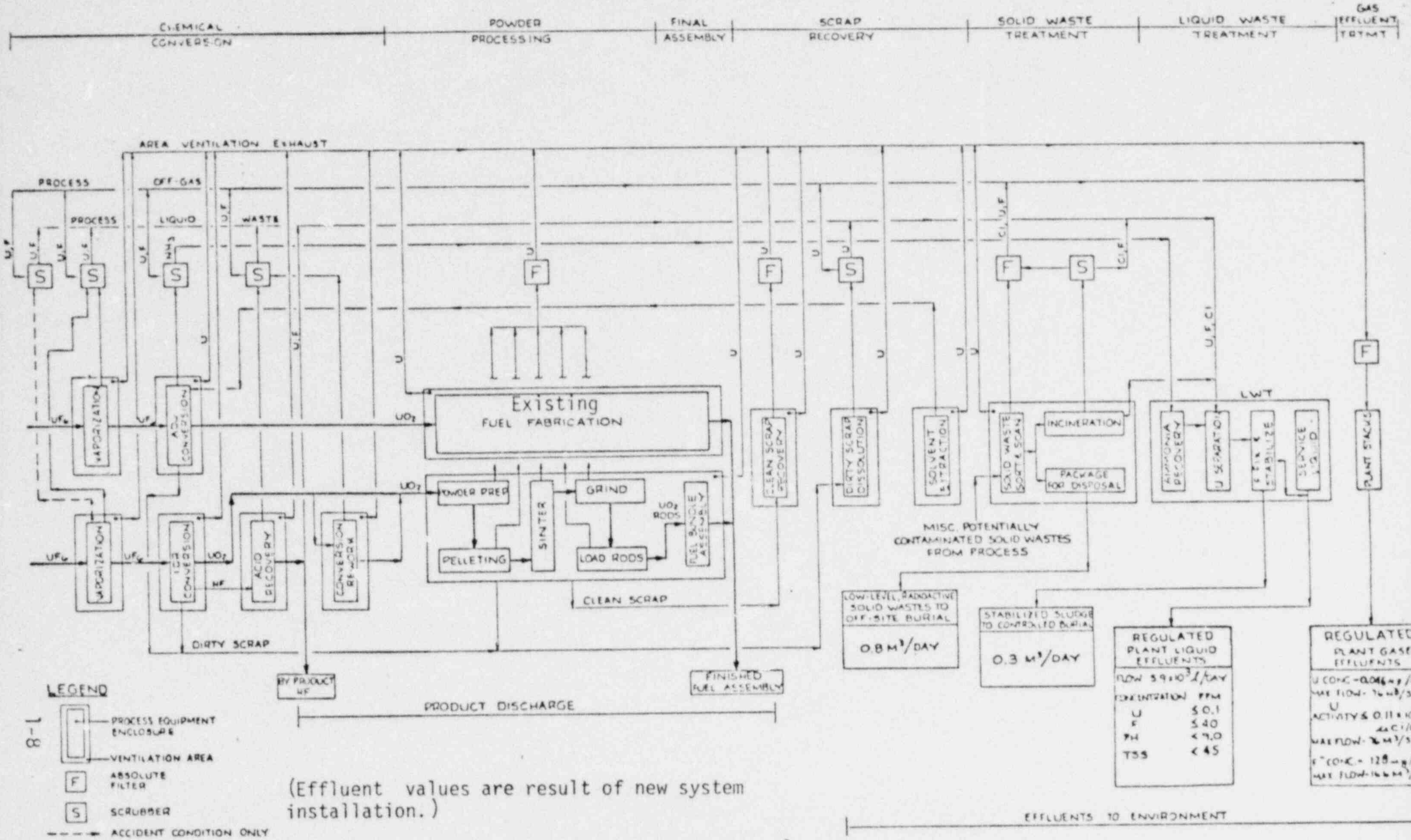
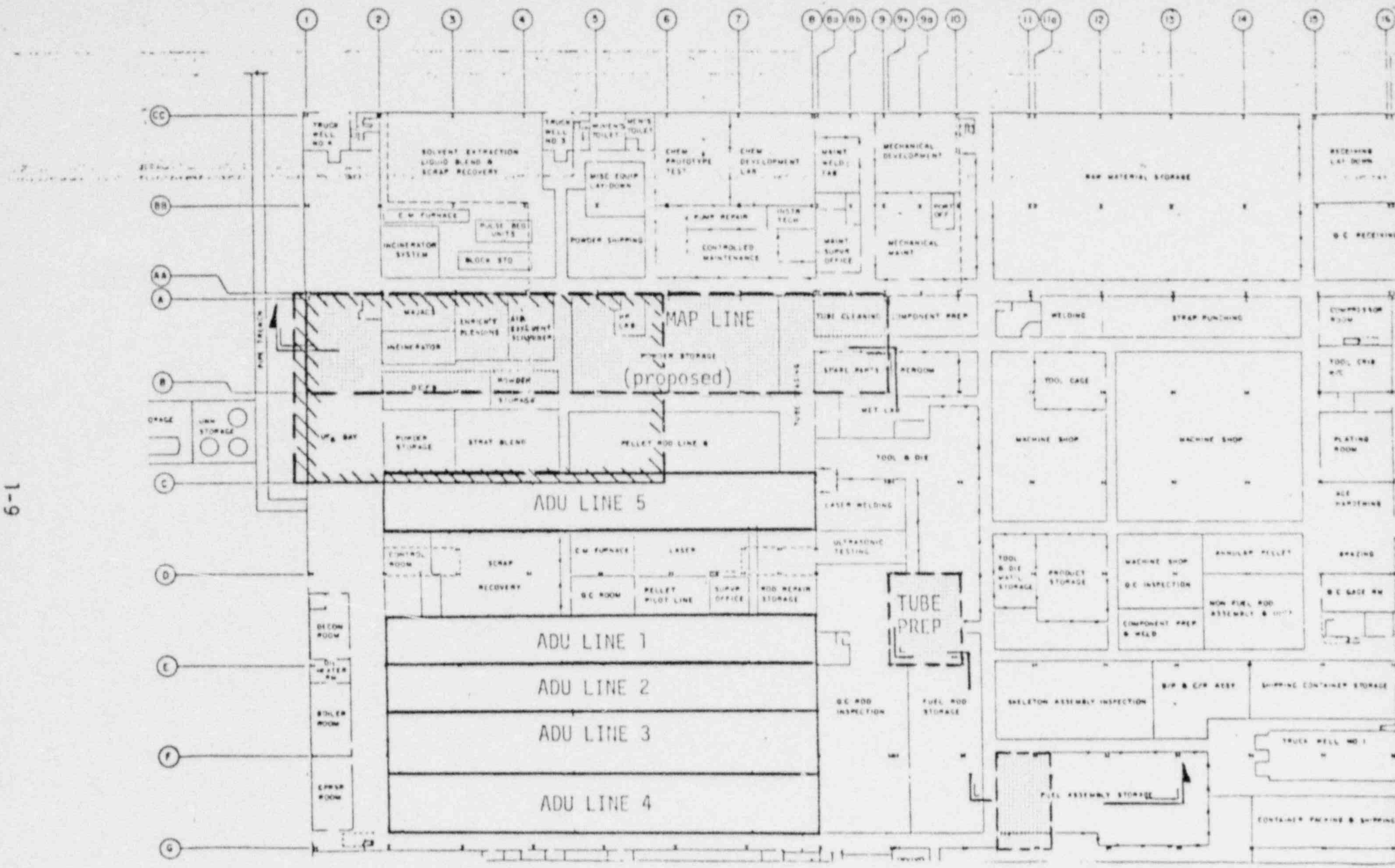


FIGURE 1

GENERAL FLOW DIAGRAM OF PROPOSED COLUMBIA PLANT OPERATIONS INCLUDING MAP LINE



Indicates Area where roof would be elevated.

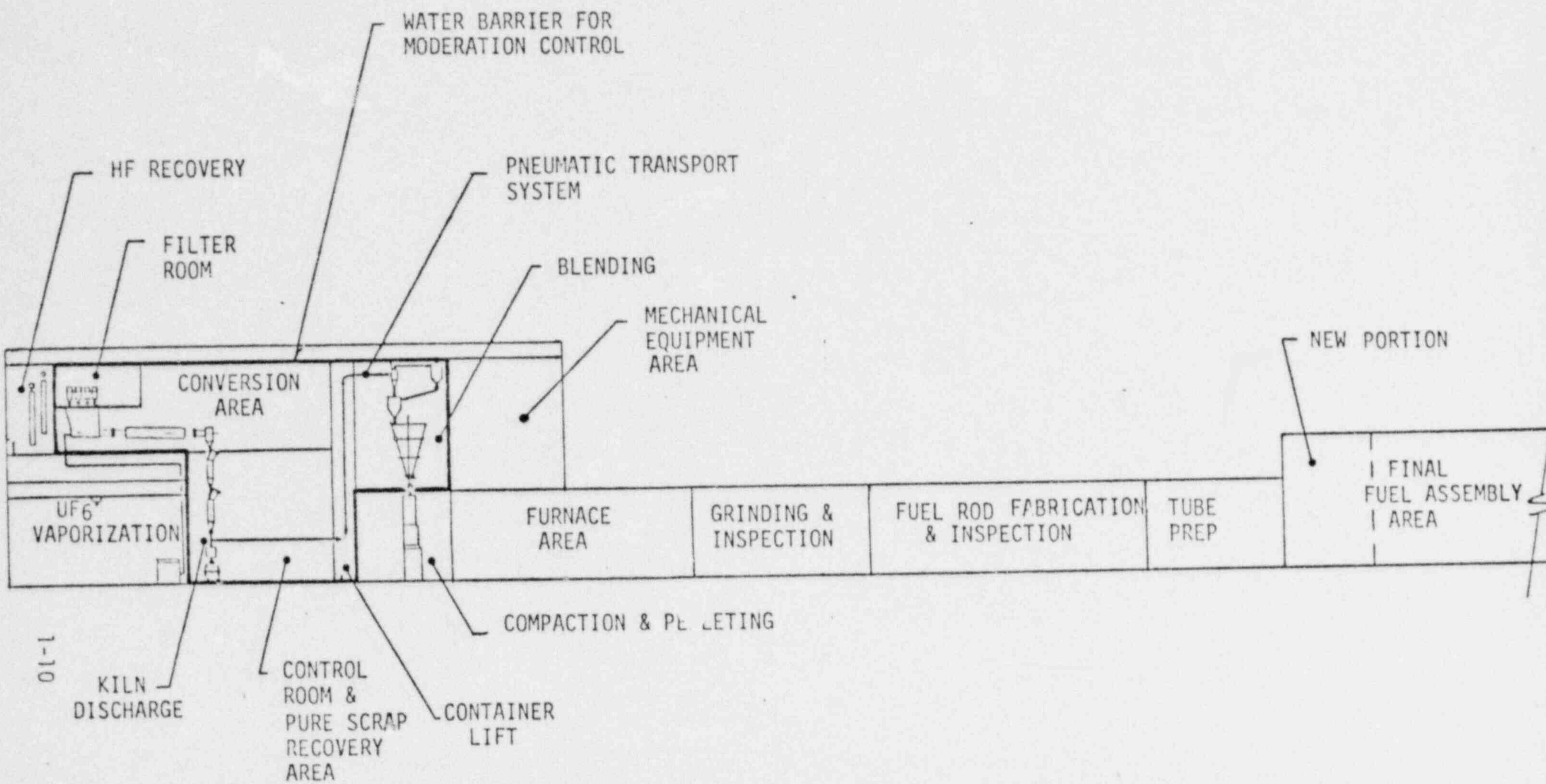
MAP Line Boundary

Figure 2

Manufacturing Building Floor Plan
Showing Changes to Accommodate MAP System

SECTIONAL VIEW

MAP PROCESS AREAS*



* SEE FIGURE 2 FOR SECTION LOCATION

FIGURE 3

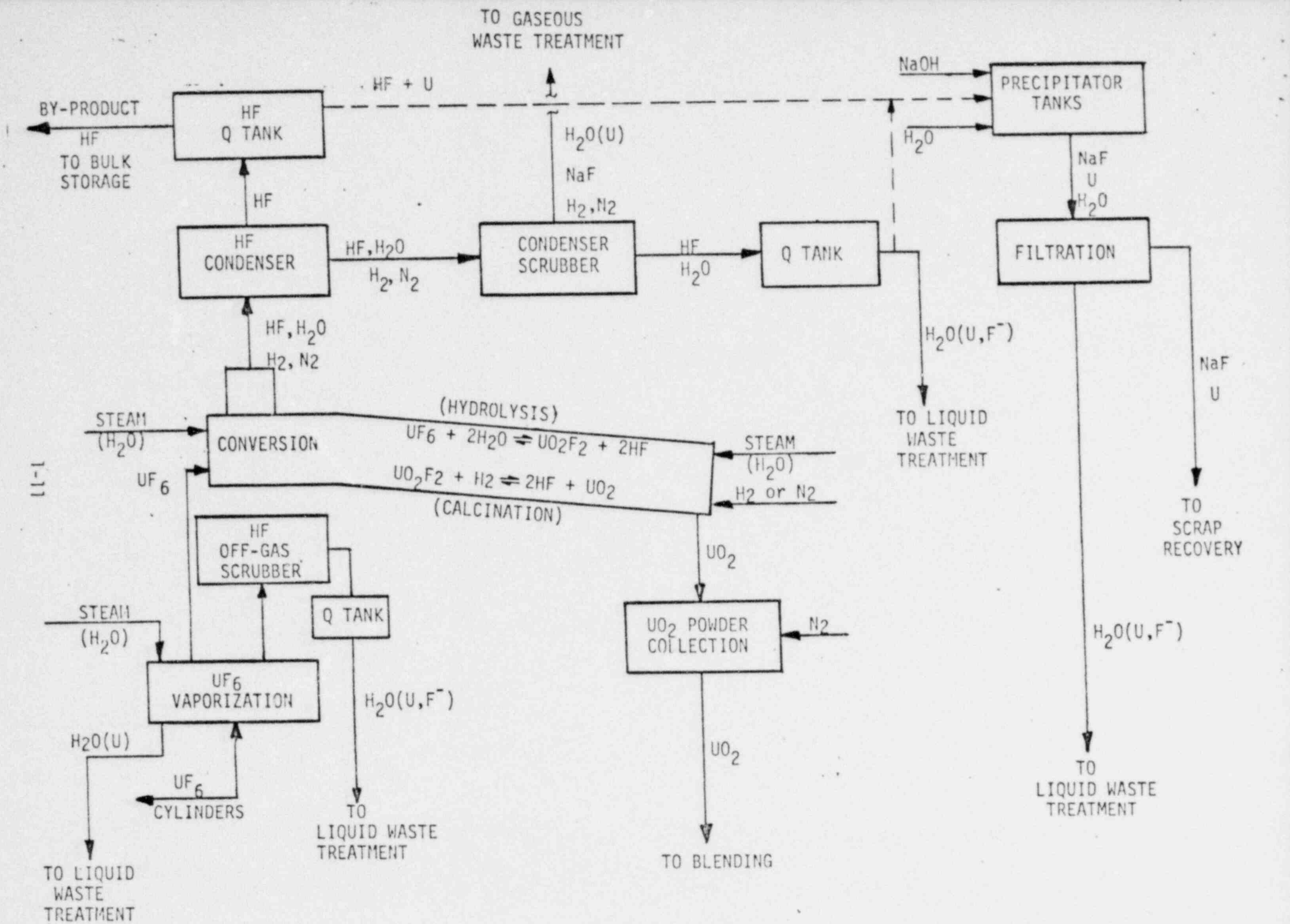


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FIGURE 4 DRY CONVERSION PROCESS FLOW DIAGRAM

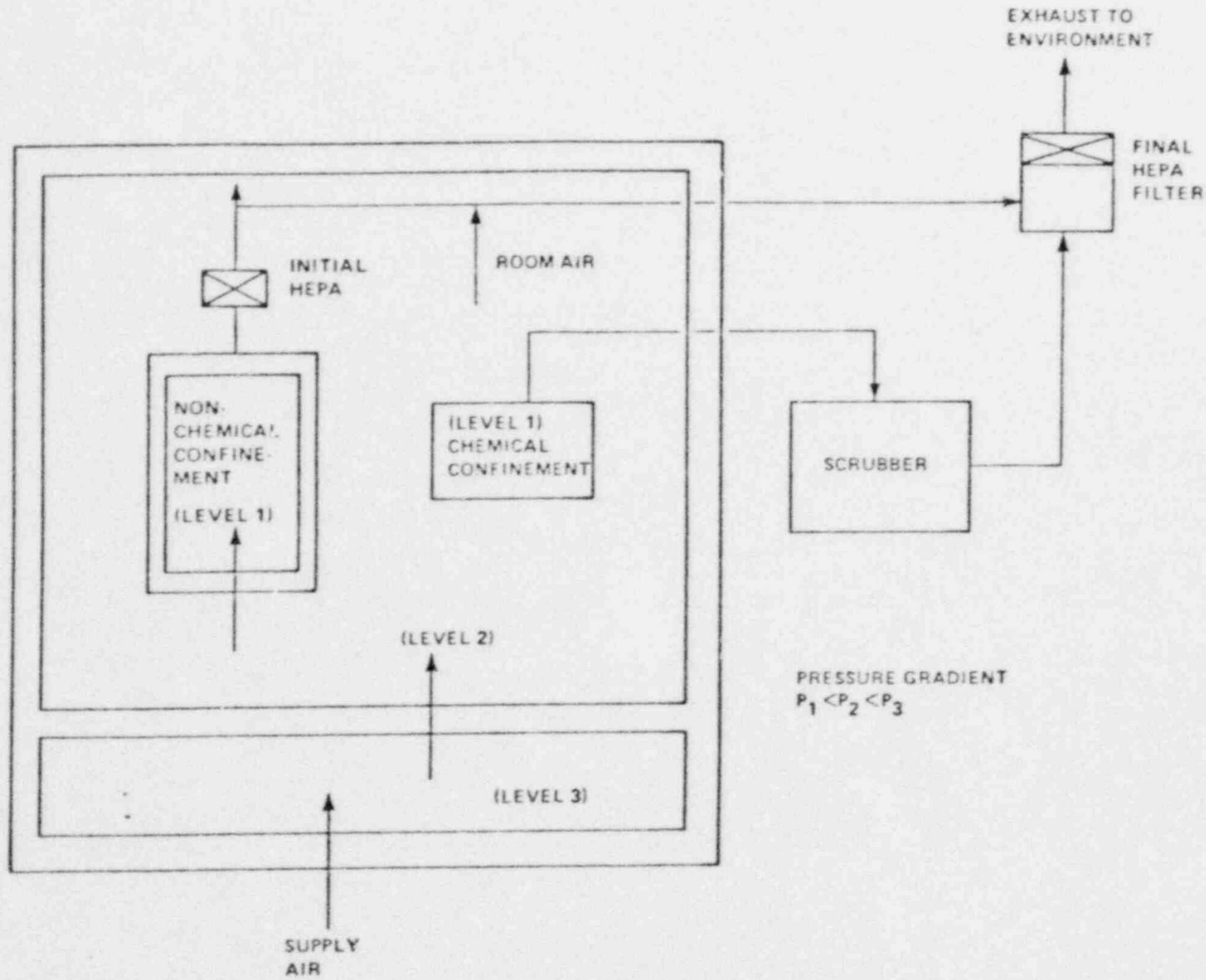

Figure 5 Confinement and Ventilation Schematic for MAP Area

SECTION 2

ENVIRONMENTAL ANALYSIS

The proposed installation of an Integrated Dry Route (IDR) process line at the Nuclear Fuel Division's Columbia Plant requires minor modifications to the existing licensed facility and will result in minor incremental releases of radioactivity and chemicals to the environment. However, expected emissions are much less than those estimated in the 1975 Environmental Evaluation, less than the existing ADU emissions, and less than an equivalent addition of ADU capacity. The purpose of this Environmental Analysis is to compare these effects with those previously approved by the NRC in the 1975 Environmental Evaluation.

A. Area Preparation

1. Existing Equipment Removal

The proposed IDR line will replace the existing Direct Conversion Fluidized Bed (DCFB) line and the obsolescent incinerator which are described in the existing license. The disassembly, decontamination and dispositioning of the DCFB line and obsolescent incinerator are part of an on going program at the Columbia Plant to remove and replace non-productive equipment. Consequently, these plans had been developed and are being implemented independent of the proposed IDR installation. Presently, instrumentation is being removed for possible reuse in other areas of the facility. Future efforts will involve dissassembly and dispositioning of the remaining portions of the DCFB line and obsolescent incinerator.

Dismantling existing equipment to make room for the IDR system is being performed according to existing license conditions. Existing procedures and administrative controls are being used to contain airborne radioactivity and minimize traffic through the affected areas. For example, where necessary, temporary enclosures will be constructed to minimize releases of airborne uranium; and a negative pressure (below atmospheric) ventilation and exhaust system is being maintained in the construction area.

Previous similar experience with equipment removal, decontamination and dispositioning has shown that these activities can be performed with negligible impact on the environment. Examples include: (1) replacement of the pellet line feed ends with improved equipment to facilitate uranium processing and minimize airborne radioactivity, (2) removal of obsolete exhaust ventilation equipment on the facility roof and replacement with state-of-the-art equipment, and (3) construction of an approximately 100,000 square foot addition to the Columbia Plant.

2. Building Modifications

The proposed line will be installed between columns A1-B1 through A9-B9 of the existing Manufacturing Building (as shown in Figure 2). Changes in plant facilities will include elevating the roof in the area between columns A1-C1 to A6-C6 (Figure 2), and modifying existing structures to support the additional load - as required by the equipment and the roof superstructure.

The facility changes required for the installation of the MAP system include: (1) removing part of the concrete floor in the area designated for the IDR line (Figure 2) - as necessary to provide the additional structural support for equipment and the roof superstructure, (2) extending the roof line upward approximately 20-30 feet above existing roof line in the designated area, (3) installing structural steel necessary for IDR equipment and building support, (4) modifying the heating, ventilation and air conditioning (HVAC) system located in the steel trusses in the ceiling above the installation area, (5) replacing filter-exhaust systems located on the piping and conduit systems within the installation area to meet moderation water barrier requirements.

Inside the designated area, some of the concrete floor will be broken up and removed (and some dirt underneath might be removed) to permit installation of support structures.

Exhaust filter systems located on the existing roof of the designated area will be scrapped according to existing licensed procedures. Equipment to be removed will include the DCFB exhaust, the emergency UF_6-DCFB exhaust, and the obsolescent incinerator exhaust. Roof penetrations will be temporarily covered during construction so that there will be no release of airborne constituents, nor leakage of rain or snow into the production areas. The required openings will be promptly covered and sealed in a permanent manner. Continuous air monitoring of existing roof exhaust stacks will be conducted; negative pressure within the manufacturing building will be maintained at all times.

Penetrations through the existing roof will also be required for the new roof superstructure installation, and for new equipment installation. These temporary open penetrations will be handled the same as those required for removal of existing equipment.

3. Relocation of Existing Plant Services

Certain plant services within the planned installation area will have to be relocated. These include the Health Physics Laboratory on the operating floor, and the Machine Shop, which will be moved to another area within the existing building.

4. Summary

For the proposed activity, there will be no significant construction impact. The floor area affected by the IDR system installation will amount to approximately 22,000 square feet, or only about six percent of the existing manufacturing building floor area; and, the roof superstructure will also enclose approximately 22,000 square feet, or only about six percent of the existing plant roof area. Thus the incremental plant area which will be temporarily affected by the dismantling, construction and installation activities is a relatively minor percentage of the total plant area, and planned activities would most certainly be expected to cause much less effect than the approximately 30 percent floor area addition accomplished in 1978 (Amendment #2 to SNM-1107).

B. Effluents

Minor effects on the environment resulting from normal operations might be expected to occur as a result of the addition of the automated IDR process line. There are, however, no changes in the types of effluents from the IDR process when compared to the existing ADU lines. The magnitude of such plant radiological and chemical impacts are evaluated in this section.

The pathways for potential dispersion of radioactive or chemical discharges to the environment are the same for the new IDR line as for the previously evaluated ADU and DCFB processes, differing only in relative magnitude for the respective airborne and liquidborne releases. Thus, there are no unforeseen or unevaluated effects introduced by addition of the IDR line.

The relatively small effects for liquid and air waste discharges are evaluated below.

Table 1 shows the airborne and liquidborne releases from the proposed IDR line and compares them with the 1975 Environmental Evaluation, recent ADU performance and effluents from the existing DCFB line and obsolescent incinerator. This Table shows that: (1) proposed IDR releases are much less than those previously evaluated in the 1975 Environmental Evaluation, (2) except for airborne fluoride releases, IDR effluents are expected to be below the release of the combined DCFB and obsolescent incinerator which are being replaced by the IDR system (the expected airborne fluoride levels are well below the 1975 Environmental Evaluation estimates) and (3) except for airborne fluoride releases, IDR effluents are expected to be below existing ADU performance levels.

All IDR liquid effluents are expected to be well within EPA limits for the existing Columbia Plant National Pollutant Discharge Elimination System Permit (NPDES). Consequently, no changes in this permit will be required.

Estimated stack release rates of uranium and fluoride in micrograms per second are summarized below:

	Fluoride Micrograms/sec	Uranium Micrograms/sec
Previously Estimated (1600 MTU/year)	24,000	75
Existing ADU (700 MTU/year)	660	31
Estimated IDR (500 MTU/year)	2,125	3.5

These data (and Table 1 data) show that fluoride emissions will be considerably less than those previously estimated but somewhat greater than existing ADU emissions. Estimated airborne fluoride concentrations at the site boundary, however, are much less than the most restrictive State limit for fluorides (0.5 micrograms per cubic meter).

During initial operation of the IDR line, representative state-of-the-art stack sampling of fluorides will be performed to verify the expected low effluent concentrations.

Note that the existing ADU fluoride emissions are much less than the 1975 previous estimates. This is attributed to the fact that fluoride scrubbing converts the fluoride to a particulate form which is collected with a high efficiency by the following stage of HEPA filtration. A similar effect is expected with the IDR Scrubber/HEPA filtration system, with actual effluents being less than those estimated.

C. Production Throughput

The 1975 Environmental Evaluation estimated environmental impacts based upon an annual uranium throughput of 1600 MTU. The expected throughput of the Columbia Plant with the addition of the IDR process will continue to be less than 1600 MTU per year.

D. Effects of Accidents

The Westinghouse Columbia Plant License documents have previously evaluated a spectrum of hypothetical plant accidents (ranging in severity of consequences from trivial to significant, and ranging in probability of occurrence from credible to incredible). In considering the addition of an automated IDR process line at the Columbia plant, this spectrum of accidents was reviewed, and an evaluation has been performed for additional postulated accidents which could potentially occur as a result of proposed plant improvements.

Sets of hypothetical accidents for the IDR line shows that (1) the types and severity of postulated accidents are similar to those evaluated in the 1975 Environmental Evaluation, (2) the effects of hypothetical accidents are well within those evaluated in the 1975 Environmental Evaluation, and (3) the probability of occurrence and severity of Category 3 accidents (Maximum Credible Accidents) as defined in the 1975 Environmental Evaluation are not changed with the addition of the IDR line.

E. Conclusion

The proposed installation of the IDR process will result in a significantly improved method of uranium conversion and fabrication, when compated with an equivalent addition of ADU capacity, while guaranteeing minimal environmental impact. The following benefits will be achieved with the IDR process:

1. Increased automation will result in fewer individuals required to operate the lines and thus lower occupational exposures.

2. The IDR process represents an improvement in process control and containment when compared with the ADU process which should result in reduced in-plant airborne radioactivity concentrations and thus reduced personnel exposures.

3. The reduction in the aqueous fluoride emissions will minimize the solid calcium fluoride wastes now generated in the ADU process.

4. Ammonia releases are not a factor as they are in the ADU process since ammonia is not used in the IDR process.

5. The removal of waste fluorides as hydrofluoric acid will result in the potential recycle of this material.

TABLE 1

Comparison of Airborne and Liquidborne Constituent Releases from Proposed IDR Line, with 1979-1980 ADU Performance, and Previously Evaluated Releases

Media	Type of Effluent That May Be Released Offsite	1975 Westinghouse (1600 MTU) Environmental Evaluation	IDR Increment	DCFB + OI Increment (1)	1979-80 ADU Performance	Units
Liquid	Uranium (U)	1.500	0.020	0.023	0.91	Pounds Per Day
Air	U	0.00096	0.00005	0.00005	0.0004	Micrograms Per Cubic Meters(2)
Liquid	Fluoride (F^-)	25.0	0.5	0.1	19.6	Pounds Per Day
Air	F^-	0.3100	0.0275	0.0110 (DCFB only)	0.0084	Micrograms Per Cubic Meters(2)
Liquid	Total Suspended Solids	25.0	0.5	0.2	11.7	Pounds Per Day
Liquid	pH	6.0-9.0	8.5	7.0	8.9	pH Units

(1) DCFB Line plus Obsolescent Incinerator

(2) Calculated concentrations at the site boundary (1800 ft NNW of the plant)