CONF-840996--2

LA-UR-84-2074

LA-UR--84-2074

DE84 015493

TITLE QUALITY ASSURANCE IN THE ANTARES LASER FUSION CONSTRUCTION PROJECT

AUTHOR(S) Walter H. Reichelt

SUBMITTED TO ASQC, Eleventh Annual National Energy Division Conference
September 16-19, 1984
Las Vegas, Nevada

Los Alamos Los Alamos National Laboratory
Los Alamos, New Mexico 87545

ELEVENTH ANNUAL NATIONAL ENERGY DIVISION CONFERENCE

QUALITY ASSURANCE IN OTHER
ENERGY RELATED ACTIVITIES

QUALITY ASSURANCE IN THE ANTARES LASER FUSION CONSTRUCTION PROJECT

Walter H. Reichelt
Antares Operations Manager
Los Alamos National Laboratory
P. O. Box 1663, MS E532
Los Alamos, NM 87545

MASTER

ABSTRACT

The Antares CO_2 laser facility came on line in November 1983 as an experimental physics facility; it is the world's largest CO_2 laser fusion system. Antares is a major component of the Department of Energy's Inertial Confinement Fusion Program.

Antares is a one-of-a-kind laser system that is used in an experimental environment. Given limited project funds and tight schedules, the quality assurance program was tailored to achieve project goals without imposing oppressive constraints. The discussion will review the Antares quality assurance program and the utility of various portions to completion of the project.

INTRODUCTION

The concept of using high energy light pulses from laser systems to drive fusion reactions dates back to the early 1960s. Experimental feasibility of fusion became possible in the late 1960s and early 1970s when the development of large, scalable solid state and gas laser systems demonstrated big machines were a reality. A generic laser system for experimental fusion application is shown in Figure 1. A pulse of light approximately one nanosecond long is created in the short pulse generator. The energy content of this light pulse is amplified many orders of magnitude as it passes through a series of light amplifiers. The main power amplifier, generally, represents the most recent state-of-the-art configuration. After amplification, the pulse is directed into a target chamber where it is focused on the target. The three subsystems, short-pulse generator and preamplifiers, power amplifiers and target system, are stand alone items. These are integrated into the complete laser system by the optical and control subsystems.

In a simplified description, laser-initiated fusion is produced by compressing and heating a tiny pellet containing deuterium and tritium fuel. The pellets are tiny glass microballoons a millimeter in diameter for experiments; larger pellets, about a centimeter in diameter, would be used in commercial power reactors.

In the target chamber, the microballoon targets are struck by focused laser beams, causing the inner shell of the target to implode and compress the fuel. This compression must heat the fuel to at least 50 million degrees and must compress it to densities a thousand times greater than normal, all within trillionths of a second, before the target and its contents fly apart. Because the reaction is contained by the inertia of the target, the process is called inertial confinement fusion.

THE ANTARES SYSTEM

The Antares system represents the fourth generation of large, high energy, carbon dioxide gas lasers developed at the Los Alamos National Laboratory for fusion applications. As with development programs elsewhere, the initial machines were relatively small, simple devices to provide proof-of-principle and served as prototypes for future machines. The Antares facility shown in Figure 2 is the culmination of a fourteen year effort in large CO_2 gas lasers at the Laboratory; it was a Congressional line-item construction project authorized at $62.5M. The laser hall housing the power amplifiers is the high bay to the left rear; the bunker-like building to the right is the target building.

Antares is designed to provide 30-40 terawatts of 10.6 m light on target with twenty-four beams in a one nanosecond pulse. Two power amplifiers (Figure 3) provide the required output energy levels; each amplifier is segmented into twelve channels. The typical output energy from an amplifier consists of an annular array of twelve traposoidal-shaped pulses. A burn pattern on photographic paper from the amplifier output is shown in Figure 4. The power deposited in the photographic paper is 12 terawatts with one terawatt per sector. In the target system (Figure 5), an array of flat and focussing mirrors separate the twenty-four beams into six groups of four beams each to irradiate the target symmetrically.

The earlier laser systems, much smaller and less costly, were primarily R+D efforts and required a minimum of quality assurance (Q.A.) in their construction. However, the funding nature of the Antares project and its complexity dictated that we employ appropriate Q.A. measures to ensure a reasonable end product. The earlier projects did contain critical elements of quality assurance although not in name and formal structure.

Antares is a complex array of technical disciplines, designs and procurements - all requiring different emphasis in Q.A. In Antares, for example, costs for procurements were divided up approximately as follows:

Range	Vendors	Costs
Greater than $1M	8	$31M
Between $100K and $1M	36	10M
Less than $100K	200	10M

These procurements represented a broad spectrum of engineering and scientific disciplines: physics, mechanical engineering, optical and electrical engineering, etc. A formal organization was required in order to ensure that the product, a laser system, would perform to specifications when put together.

THE ANTARES PROJECT ORGANIZATION AND QUALITY ASSURANCE

Successful Q.A. depends on a well established project system, one in which lines of responsibility are clearly defined as well as potential interfaces. The Antares Project format is shown in Figure 6. The format represents the first level of a system work breakdown structure (WBS); elements are those of the system, shown in Figure 1: front end, power amplifier, target system, optical system, etc. The support functions such as scheduling, documentation, and quality assurance are attached directly to the project office. The buildings were constructed by the Department of Energy who was responsible for their Q.A. Our project facility engineer played an important role in ensuring that technical requirements were folded into building construction.

It is generally recognized that the Q.A. function should be independent of project management; the function is that of an independent auditor. The construction of such a specialized one-of-a-kind facility is often closely tied to concurrent development activities as well as constraints of funding and schedule; specialized knowledge in these one-of-a-kind facilities is required even in the Q.A. function. All of these factors dictated that the Q.A. function be performed within the Project and as independent of the various systems and engineering functions as possible. While not optimum, this system worked well when technical personnel understood that their responsiblities were not compromised.

The project format, by WBS, clearly defined system responsibilities, interfaces, and support functions. Various system activities that impacted other systems were clearly visible; control and communications, a vital part of Q.A., were enhanced.

THE ANTARES QUALITY ASSURANCE PLAN

The Los Alamos National Laboratory has established quality assurance programs for high technology projects that have been developed over a number of years . These programs detail Q.A. functions and requirements for the most general projects undertaken by the Laboratory. Antares is without significant exotic operational hazards such as those that might be encountered in experimental or commercial reactor facilities; conventional safety practices are a concern. Development facilities where state-of-the-art changes represents a fluid construction state. Information is constantly upgraded from operating systems; significant changes take place. Consequently, the general Q.A. plan was tailored to fit the perceived needs of the project The Q.A. function resided in the Project office because of the specialized knowledge requirements. The Laboratory groups responsible for the general Q. A. planning process provided the guidance necessary for implementation and continuation of the effort. The Antares Plan index is shown in the Appendix.

CRITICAL ELEMENTS OF THE Q.A. PLAN

Not all elements of a Q.A. plan are created and remain equal in importance; success of the plan, depends on certain elements more than others. In the Antares plan certain elements proved more critical than did others. Of course, teamwork and good communications, although not listed on any Q.A. index, are absolutely necessary for the success of the Q.A. function and to the successful completion of any project.

We observed that the following elements of the Antares plan were essential for the success of the program. The quoted sections denote text from the plan.

1. Establishment of quality control (Q.C.) plan and office:

   "2.2.1 Establishing a Quality Control Representative who reviews inspection requirements, purchase orders, inspection reports, etc., to assure that necessary quality control requirements are met. This is implemented according to Quality Control Plan for Antares, AN-PD-2."

   This function was one of the most critical. In establishing the Q. C. function within Q. A., a formal means was established to assure that specifications were met. This function was closely related to the inspection process; Q. C. was used not only to establish requirements but also to see that they were met.

2. Safety Policy:

   "2.00 The general health and safety policy of the Laboratory is to provide a working environment for its employees in which the standards for health and safety equal or exceed the highest industrial practices. Particular emphasis will be given to the protection of Laboratory employees, the general public, and the environment from any harm which could arise from Laboratory activities as well as to the protection of government property from accidental loss or damage. To meet these objectives, the Laboratory provides a staff of health and safety professionals together with the necessary training and resources to ensure compliance with all applicable policies, codes, standards, and regulations. The Antares Project Office shall be responsible for the establishment, implementation, and maintainence of an effective health, safety,and environment program for all facilties and activities under their control. All Laboratory personnel are responsible for maintaining the risk of their activities at the lowest levels technically and economically achievable, and for observing the Laboratory's health, safety, and environmental requirements in the conduct of all Laboratory operations and programs."

While safety may not generally be included in the Q. A. function, it does appear here. In addition to delivery as a final product we had to assure that safety considerations were a part of the design, fabrication and installation. Standard Operating Procedures coupled with safe handling fixtures permitted assembly of a satisfactory product with minimum safety problems.

3. A formalized method of review and signoffs:

"2.3.2 Drawings

2.3.2.1 Engineering Order Documents (EOD's) shall be used to initiate drawings in Group P-12. EOD's shall be approved by the requester, subsystem manager, system manager, and group leader.

2.3.2.2 Drawings shall be approved by the P-7, P-11, or P-12 Group Leader as appropriate, the concerned Engineer, the appropriate system manager, and any interfacing system' managers. CMB-9 will not review or approve drawings, except as specifically requested.

2.3.2.3 All design changes shall have the same approval as the original design except as limited by Section 2.8. Engineering Change Orders (ECO's) shall be used to initiate design changes within Group P-12 and shall be approved by the P-12 Group Leader, the checker of the drawing(s) involved, and the originating engineer."

2.3.3 Inter-Systems Approvals

The interfacing of designs, tests, operation and maintenance actions affecting more than one system shall be approved by the Systems Integrator, affected System Managers and CMB-9 and shall be documented on Form AN-IF-1.

2.3.4 Design Control

Design control shall be accomplished by keeping the design current, with approvals for design satisfying the requirements of Section 2.3. The same requirements for approvals shall apply to design changes as to the original design."

Drawing and change control were very important from the fabrication process and delivery schedules. We found that requiring approvals, sign-off by affected persons minimized errors. Critical to success of this process is the project attitude (team effort).

4. Source Selection and Acceptance Testing:

"4.2.2 On-Site Survey

Technical, Q.A., and MAT personnel may participate in an on-site survey of prospective suppliers to determine technical, Q.A., and contractual capabilities of the supplier as required. Reports shall be formalized and submitted by each contingent of the survey team to Antares management.

4.3 Acceptance Testing and Inspection

4.3.1 Optical Components

Acceptance testing and inspection of optical components shall be specified on the purchase request draft by the requester and shall be performed and documented by Group P-5 or another specified organization.

4.3.2 Non-optical Components

Acceptance testing and inspection of non-optical components shall be specified in an approved plan or on the purchase request draft by the requester, if necessary. This should be considerably detailed and will be included in the Procurement Procedure. Acceptance testing and inspection shall be accomplished at the inspection shop or another specified facility.

9.1 Inspection

Whenever it is necessary to verify that quality affecting items or services are in compliance with specified requirements, an inspection shall be planned, executed, and documented. Characteristics to be inspected and inspection methods employed shall be specified. When inspection is for the purpose of acceptance of items or services, the inspection shall be performed by individuals who did not perform or directly supervise the work being inspected. Neither will they be responsible to the immediate supervisor who is responsible for doing the work. The personnel performing the inspection shall be qualified to perform the assigned inspection. The qualification of all such personnel shall be documented."

Source selection was done primarily by the cognizant engineer or scientist by competitive bidding. On-site inspection of capabilities served to minimize inadequate sources. Commercially available items generally presented no problems other than delivery times. All commercial items were procured against specification.

Optical components were manufactured to tight specifications with selected vendors. Q.A., in this case, demanded tight specifications, technical monitoring and quality control. We found it advantageous to interface heavily with the vendor. Component inspection and inspection reports were reviewed at the vendor's facility before shipment; such procedures corrected mistakes before delivery. This action saved considerable time and frustration in that on-site nonconforming items were minimized.

Straightforward mechanical and electrical fabrication presented little problem in source selection and acceptance testing. Progress and documentation was generally monitored by the cognizant engineer. However, in a system like Antares there are a great many precision parts: lead screws, gear trains, flex-joints, etc. Satisfactory vendors for such components are limited; here, the cognizant engineer made the source selection and monitored technical progress. Final inspection at the vendor's plant and additional checks at the Laboratory were performed by the project Q.C. group operating independently.

5. Identification and Control of Items:

"6.0 To assure that only acceptable items are used or installed requires that methods be employed for the identification of all items. The individual and distinctive identification of each item will be physically on the item when possible . When this is not possible, documentation shall exist that is directly traceable to the item and which provides it's distinctive identification. This documentation shall include cross-reference between purchase order numbers and part or serial numbers. The items without physical identification will be controlled by physical separation, procedural control other other appropriate means.

Identification markings will be permanent, legible, and cause no detrimental effect to the function or service life of the item. Whenever a marked item is subdivided all resulting portions shall also be marked for identification.

When specified by codes, standards, and specifications that include specific identification or traceability requirements (e.g., to grade of material, heat ,batch, lot, or other) such identification and traceability control shall be provided.

Items having a limited operating or shelf life will be controlled to prevent the inadvertent use of items whose specified life has expired."

Most items coming into stores were gathered into assembly kits. Identification of parts made kit assembly and the consequent assembly a smooth efficient process. Part identification allowed us to place characterized items at specific locations in the system. This was particularly important for components in the optical train; optical performance can be predicted if the surfaces characterization of components is known. We used this to predict faced spot sizes.

6. Control of Processes:

"8.1 Procedures or written instructions, approved as required in Section 2.3, shall be used. These may include checklists, drawings, or travelers to determine that the appropriate steps are performed in the proper sequence and that itmes such as proper environment are specified and documented. Acceptance criteria shall be specified or referenced."

Many components were units assembled in-house from assembly kits containing all neccssary parts. Travelers and check sheets were attached to the units as they went through assembly and checkout phase.

SUMMARY

The Antares Project developed an in-project Q.A. function which was designed to assure a workable product delivered on schedule. Assembly and testing indicated that our Q.A. plan was effective. Drawing and Quality Controls proved to be the most important feature of the Q.A. function. Completion of the Project was planned for the last quarter of calendar year '83; the test shots for Department of Energy acceptance occurred on November 8, 1983. Target experiments commenced on December 22, 1983. No major design faults have surfaced to date. Since December 1983, about 50 target shots were fired. Powers on target range from 3 to 25 terawatts.

APPENDIX

Quality Assurance Program Plan

1. Introduction and Organization
   - 1.1 Purpose and Scope
   - 1.2 General System Description
   - 1.3 Organization
2. Q.A. Program
   - 2.1 General Responsibilities
   - 2.2 Specific Responsibilities
     - 2.2.1 Technical Management
       - 2.2.1.1 Indoctrination and Training of Personnel (Example)
     - 2.2.2 Q.A.
       - 2.2.2.1 Maintenance of Calibration Recall File (Example)
   - 2.3 Method of Review
   - 2.4 Systems Interfacing
   - 2.5 Eng-DO/QA Interface
   - 2.6 Q.A. Manual
   - 2.7 Codes and Standards
   - 2.8 Limits Due to Late Adoption of Q.A. Program
   - 2.9 Policy Statement
   - 2.10 Safety
3. System Designs
   - 3.1 Responsibility
   - 3.2 Design Control
   - 3.3 Format for Design Documentation
     - 3.3.1 System Functions
     - 3.3.2 System Design
     - 3.3.3 Design Requirements
     - 3.3.4 System Limitations
     - 3.3.5 Operations
     - 3.3.6 Maintenance and Modifications
   - 3.4 General Design Description
4. Procurement
   - 4.1 Procurement Package Control
   - 4.2 Source Selection
   - 4.3 Acceptance Testing and Inspection
   - 4.4 Control of Purchased Items and Services
5. Document Control
   - 5.1 Preparation, Approval, and Issue
   - 5.2 Revisions
   - 5.3 Indexing and Storage of Documents

6. Identification and Control of Items

7. Control of Processes
   7.1 Procedures
   7.2 Equipment
   7.3 Personnel, Operating

8. Inspection
   8.1 Personnel Independence and Qualification
   8.2 Planning
   8.3 Records

9. Test Control
   9.1 Requirements
   9.2 Procedures
   9.3 Results
   9.4 Records

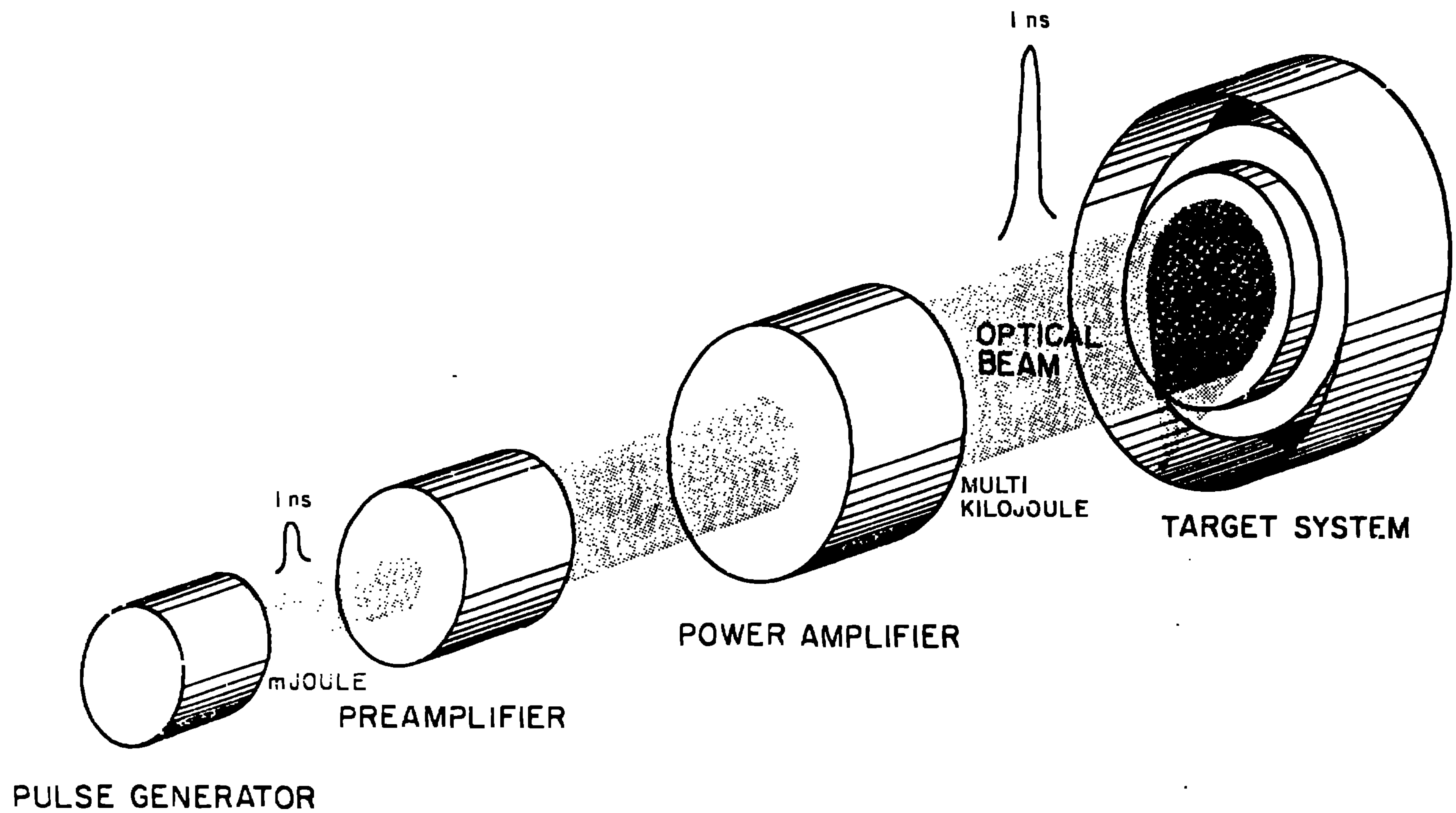
10. Calibration of Measuring and Test Equipment

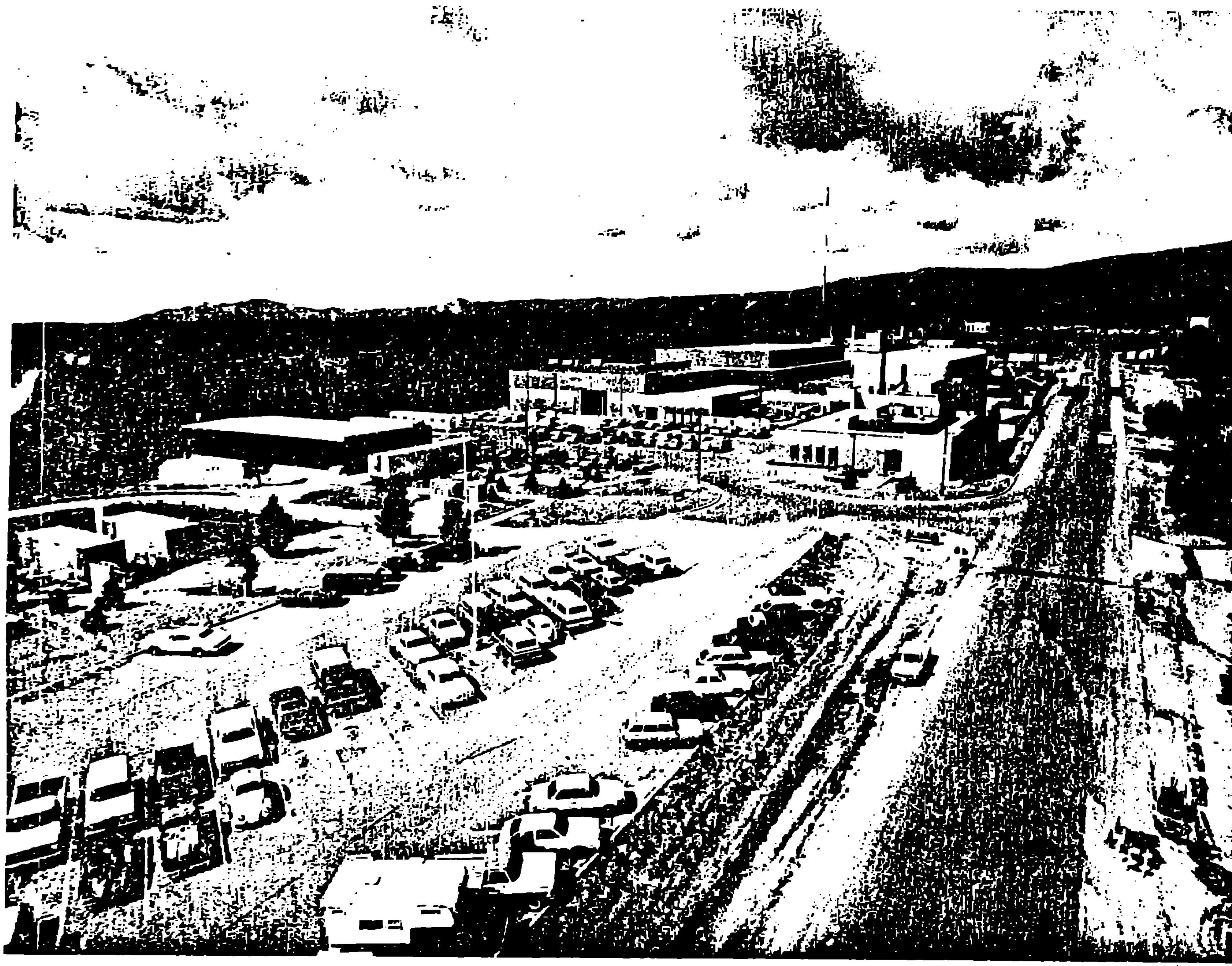
11. Handling, Storage, and Shipping

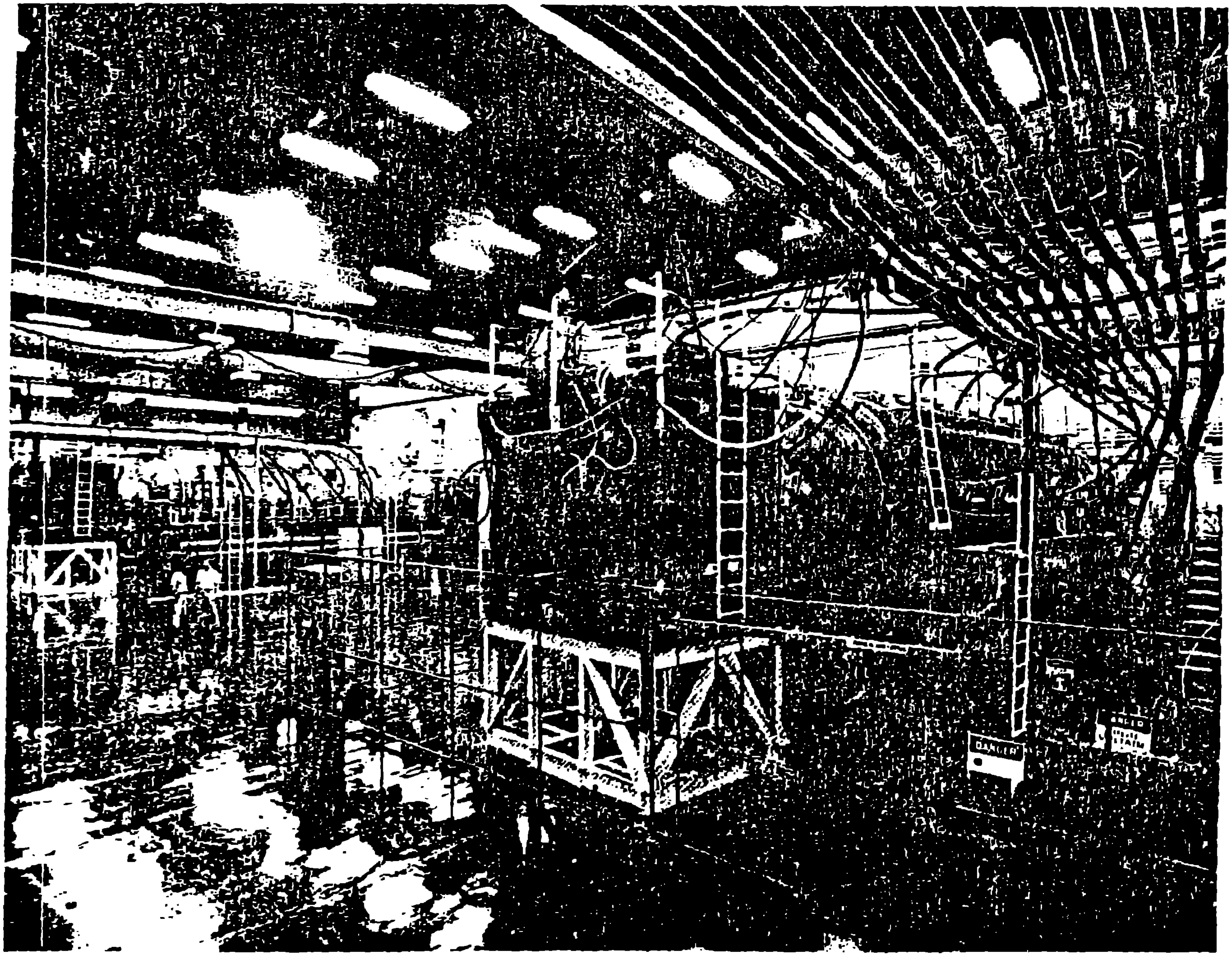
12. Control of Nonconforming Items
   12.1 Identification
   12.2 Segregation
   12.3 Disposition
   12.4 Corrective Action

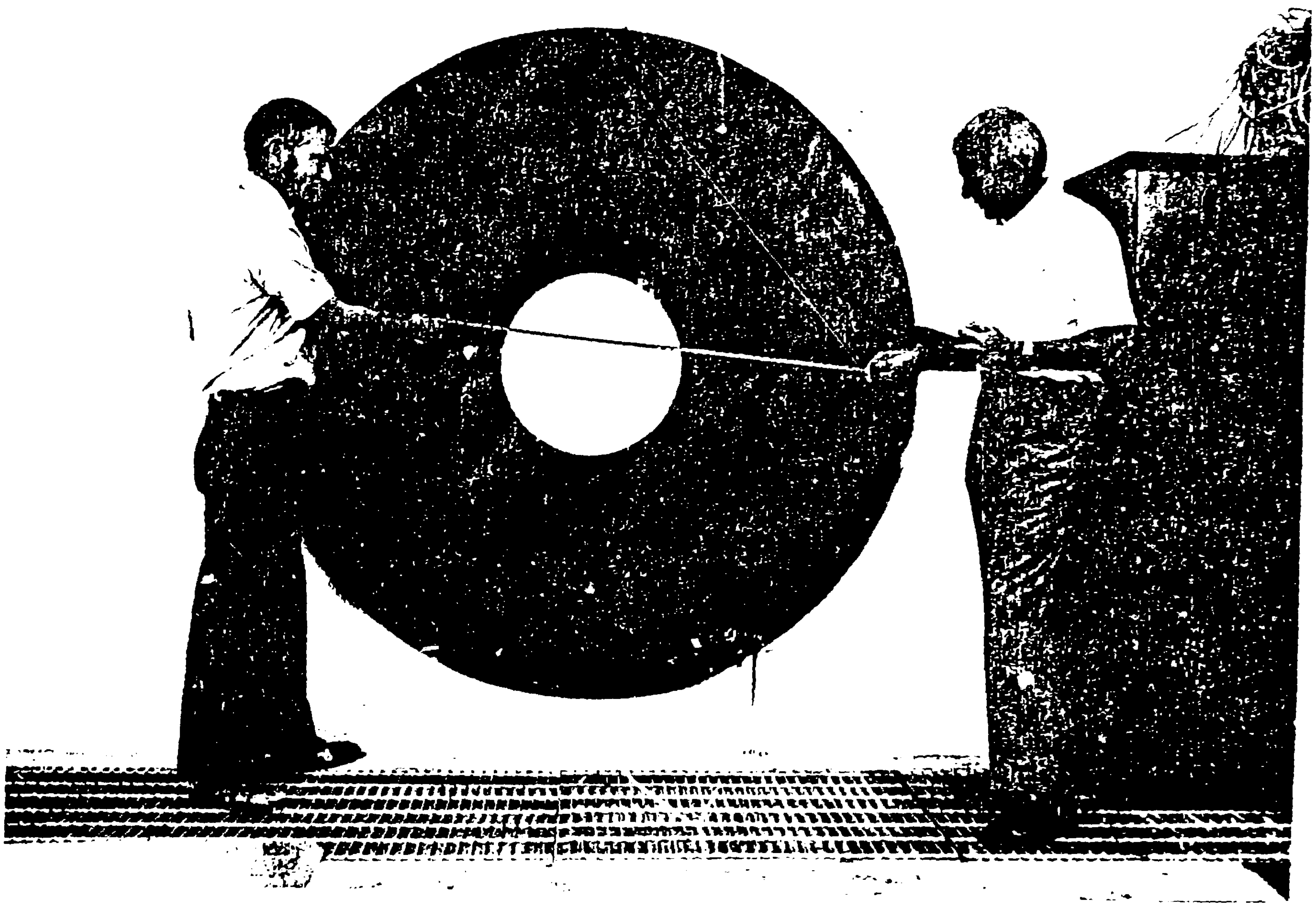
13. Records
   13.1 Storage
   13.2 Retention
   13.3 Indexing

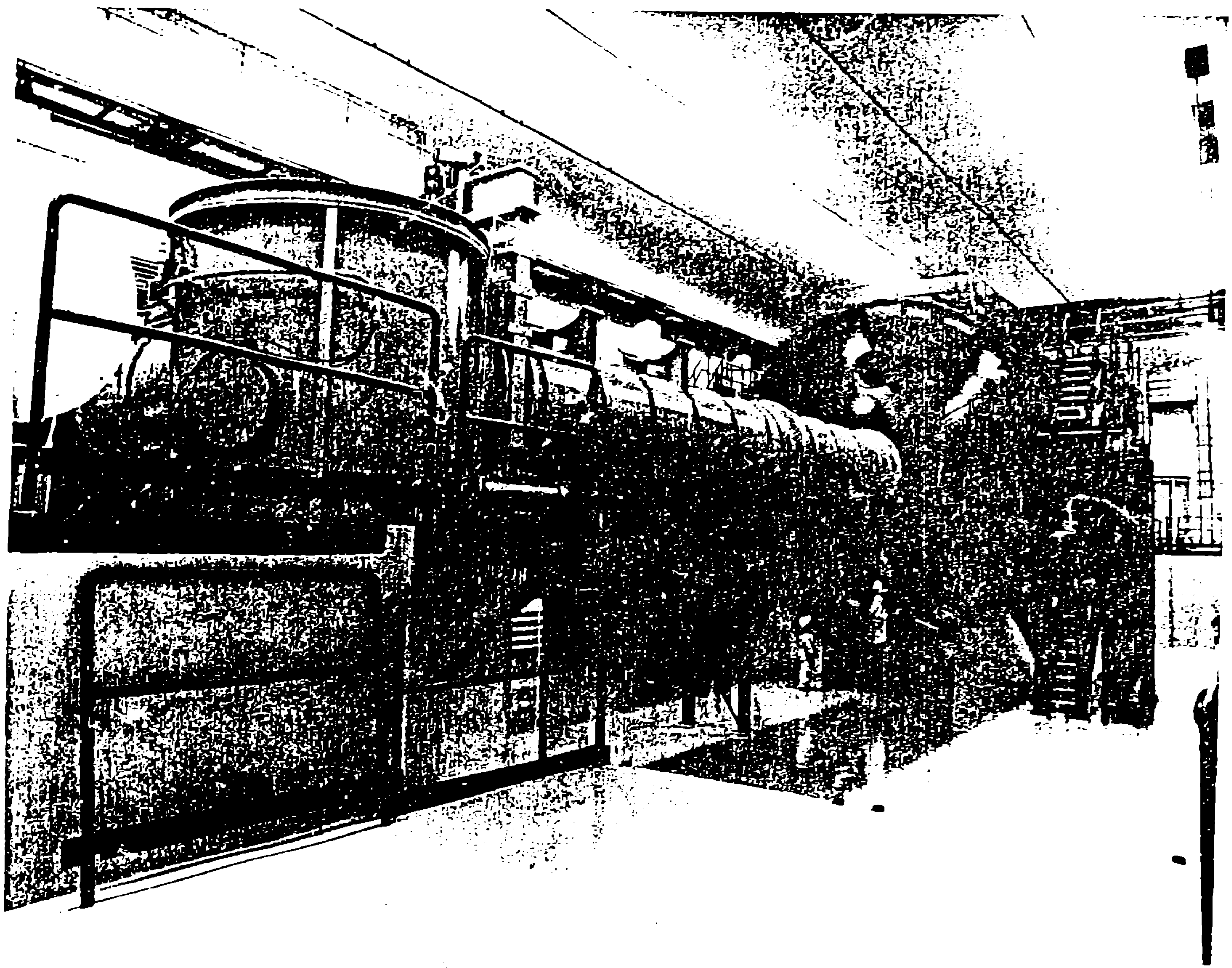
14. Audits
   14.1 Internal
   14.2 External


1 ns
1 ns
OPTICAL BEAM
MULTI KILOJOULE
mJOULE
TARGET SYSTEM
POWER AMPLIFIER
PREAMPLIFIER
PULSE GENERATOR

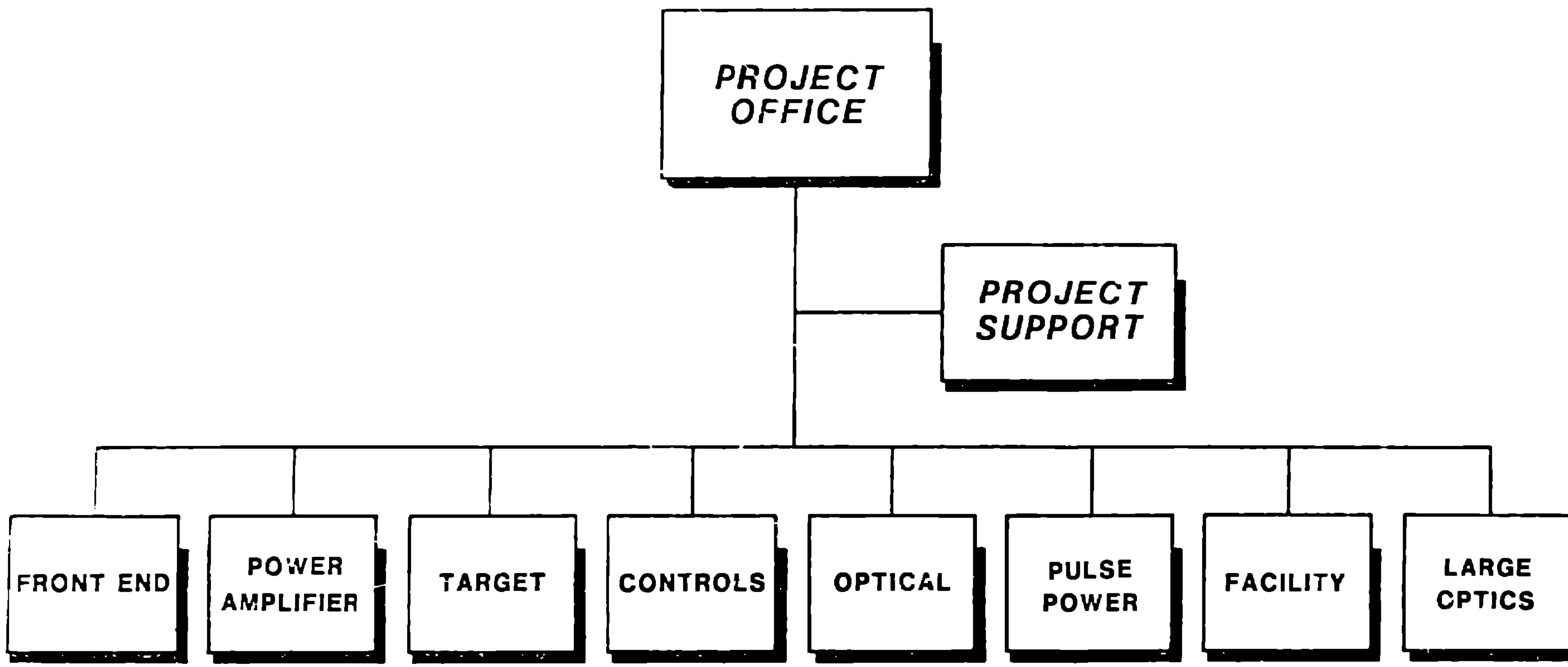








P-73-248


PROJECT OFFICE
PROJECT SUPPORT
FRONT END
POWER AMPLIFIER
TARGET
CONTROLS
OPTICAL
PULSE POWER
FACILITY
LARGE OPTICS