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SUBJECT: TECHNICAL FUNCTION AND OPERATION OF THE HIGH RADIATION LEVEL EXAMINATION LABORATORY, BUILDING 3525

TO: Distribution

FROM: Staff of the Metallurgy Division

Abstract

This report is concerned with the nature and scope of the technical services to be rendered and the general plan proposed for operation of Building 3525, High Radiation Level Examination Laboratory (HRLEL). The role of postirradiation examination in implementing the over-all task of irradiation testing for various programs under way at the Oak Ridge National Laboratory (ORNL) and the importance of this effort to the United States reactor development program are stressed. The shielded-cell complex with provisions for remote decontamination, hot-equipment storage, and maintenance is described, as well as other supporting activities which are incorporated into the facility. The proposed technical functions include general observation, mensuration, nondestructive testing, burnup and induced-activity measurements, fission-gas sampling and analysis, corrosion evaluation and related measurements, disassembly and cutup, metallographic examination, mechanical-property determinations, and x-ray diffraction analyses. Equipment design and operational features to improve detection and measurement of selected properties in radioactive materials are described, also. The current status on design, procurement, construction, and preoperational testing of in-cell equipment in the mockup is presented along with a forecast of future needs. The mode of operation, manpower requirements, and management of the facility are discussed.

I. INTRODUCTION

After an initial period of rapid growth, the nuclear power industry has tapered off and entered into a natural period of retrenchment to evaluate more fully the technological and fiscal aspects of doing business. A similar transition period was experienced by the aircraft venture some thirty years ago; and, if one continues to trace the analogy, he finds that the aircraft business grew into a world-wide and profitable industry after reaching adulthood. Since we have every reason to assume that the underlying principles or basis of nuclear technology are valid, there should be no doubt about the ultimate outcome of the nuclear venture other than the question on timing to reach maturity. Is it not a foregone conclusion, therefore, that growing up and successful harnessing of nuclear power will become a reality only when we know how to truly live with our environment? In other words, we must gather sufficient phenomenological and base-line engineering data not only to define key problem areas in less obscure terms, but to understand clearly all critical aspects or pertinent ramifications as well before we can hope to achieve a worthwhile solution.

A key problem area that has been recognized since the inception of nuclear science and technology is that of radiation damage. Yet, we are currently at a loss to bridge the gap and apply existing radiation damage theory to the solution of practical problems, particularly where side effects are involved. Secondary effects, such as the role of radiolytic decomposition on corrosion, mechanism of release and coalescence of gas which causes swelling in certain materials, and the effect of radiation-induced space charge on crud deposition are not clearly understood. Even in the field of metals, where much attention has been focused, the influence of radiation on impact strength, creep, fatigue, and other service-life-determining parameters appears to elude rigorous explanation. We must acquire a better understanding of the role radiation is playing on the instability problem often observed in a two-component system involving a fluid and a solid, if we intend to predict with any degree of assurance the long-range performance capability of various coolants like water, organics, and salts in contact with container materials.

Practically every major technological setback encountered in the reactor field is traceable directly to the presence of radiation or is greatly aggravated by its presence; viz., abnormal dimensional growth in metallic uranium, holes in the HRT core tank, the Windscale incident, and the meltdown in the SRE. One must know more about the influence of nuclear radiation on different substances under various environmental conditions if he intends to develop improved structural, moderator, control, fuel, and shielding materials for reactor application. Hence, there is a pressing need to investigate radiation effects from both an applied and basic approach. The Commission has adequately endowed the industry with a large number of research reactors in which to conduct experiments, but there is an acute shortage of suitable facilities to implement the postirradiation examination phase. Part I of the HRLEL will fulfill this need in part. It has been designed and will be equipped primarily to satisfy the pressing needs of the reactor project effort, and within this framework will offer valuable assistance to the basic research effort. It is expected from anticipated reactor project demand, however, that only a very limited amount of cell space will be available for rental on a long-term assignment basis. Part II of the facility will be designed to handle larger and more active components and, thus, free some of the cells in Part I to satisfy more fully the requirements of the basic research programs.

Part I of the HRLEL was an outgrowth of a much larger hot-cell and laboratory complex designed to provide rather complete facilities for handling essentially all aspects of postirradiation work at the laboratory, including equipment for dismantling full-scale reactor components. One of the unique features that distinguishes the HRLEL from existing facilities in the field is that of operation under the philosophy of complete containment. This philosophy was conceived by the Solid State Division during establishment of the initial design criteria to prevent the spread of contamination. The dual requirements of particulate containment and gamma shielding have been met by integration of the containment liner and biological shield into the cell-wall structure. Thus, all equipment will be installed and removed remotely, decontaminated remotely, and, as much as possible, maintained within the basic containment shell. The present design of the so-called alpha-gamma hot cell fulfills these criteria.

This report was prepared to acquaint interested parties with the various technical services that will be rendered and the method of operation in Part I of HRLEL. The over-all facility, technical functions, and associated in-cell equipment are described in detail. The mode of operation, manpower requirements, and management of the facility are presented.

II. DESCRIPTION OF FACILITY

The High Radiation Level Examination Laboratory currently under construction at the Southeast corner of Fourth Street and Central Avenue consists essentially of a two-story brick building with a partial basement for housing some of the essential ventilation equipment. Upon completion at the end of 1961, the structure will provide a gross floor area of approx 26 500 ft^2, exclusive of the floor area occupied by the shielded-cell complex which has an internal working area of 950 ft^2.

A. Structure and General Arrangement

The building structure and general layout of internal facilities of the laboratory are illustrated in perspective view in Figs. 1 and 2. These illustrations are actual photographs of a reduced-scale model that was prepared to assist in the final stages of design and during construction of the laboratory. The model shows that the building is divided into two functional sections with an enclosed stairwell appended at the rear. The front section, facing Central Avenue, is a single-story office and laboratory area, while the two-story structure to the immediate rear houses the cell complex, operating areas, and other supporting activities. The detailed arrangement of the various activities located on each floor level is shown in Figs. 3, 4, 5, and 6.

Besides exercising primary control of radiological hazards at the cell complex, the laboratory is designed to provide additional safety by the physical arrangement of barriers and ventilation control. The office section, for instance, is separated from the operating area by a wall, and routine traffic between these areas is routed through a change room. This barrier wall has observation windows for direct-access viewing of the cell face from the office corridor. Similar restrictions on personnel access and the selective use of air locks, to prevent

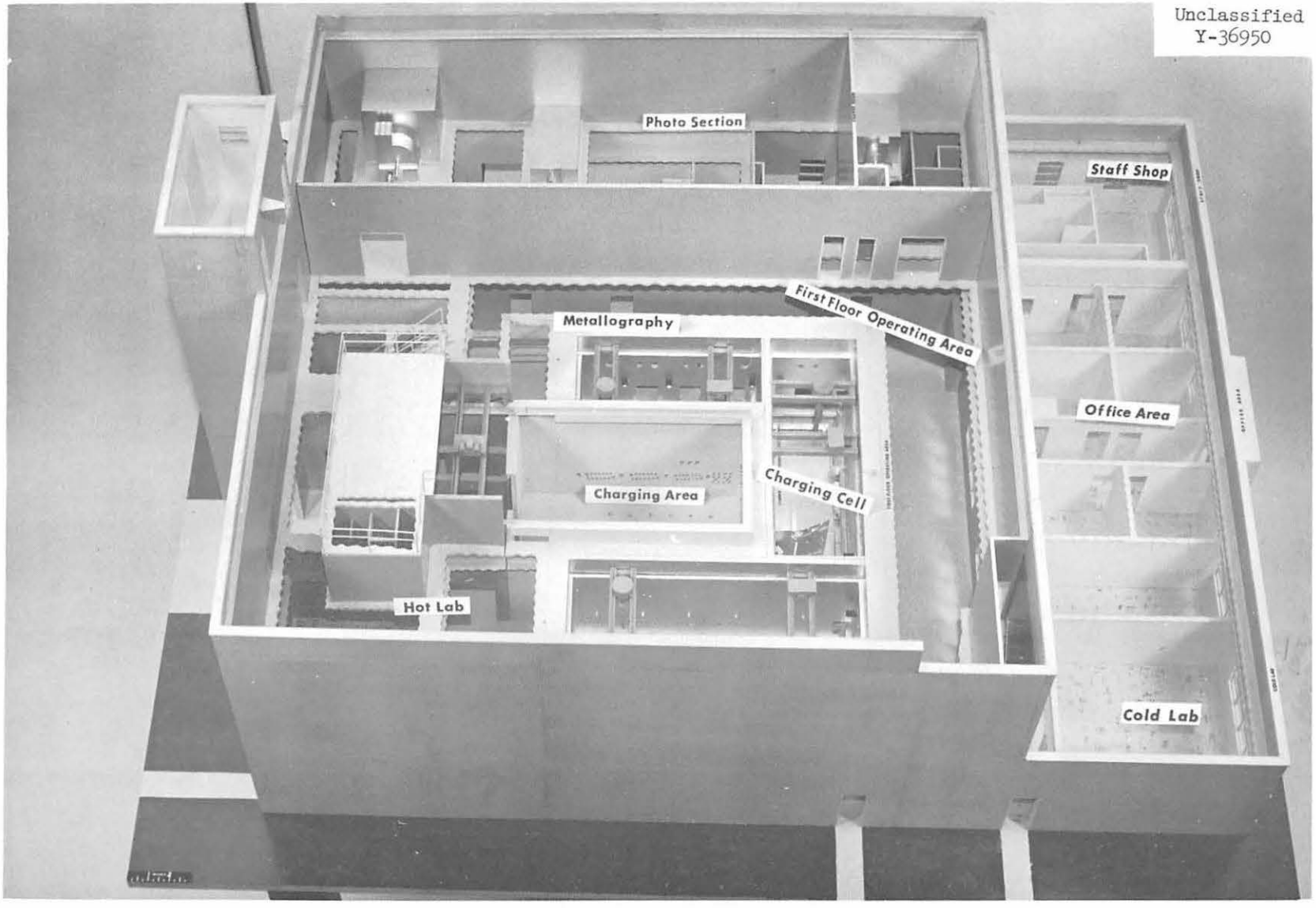

Fig. 1. Building Structure and General Layout of Internal Facilities at Ground Level of the HRLEL, Building 3525.

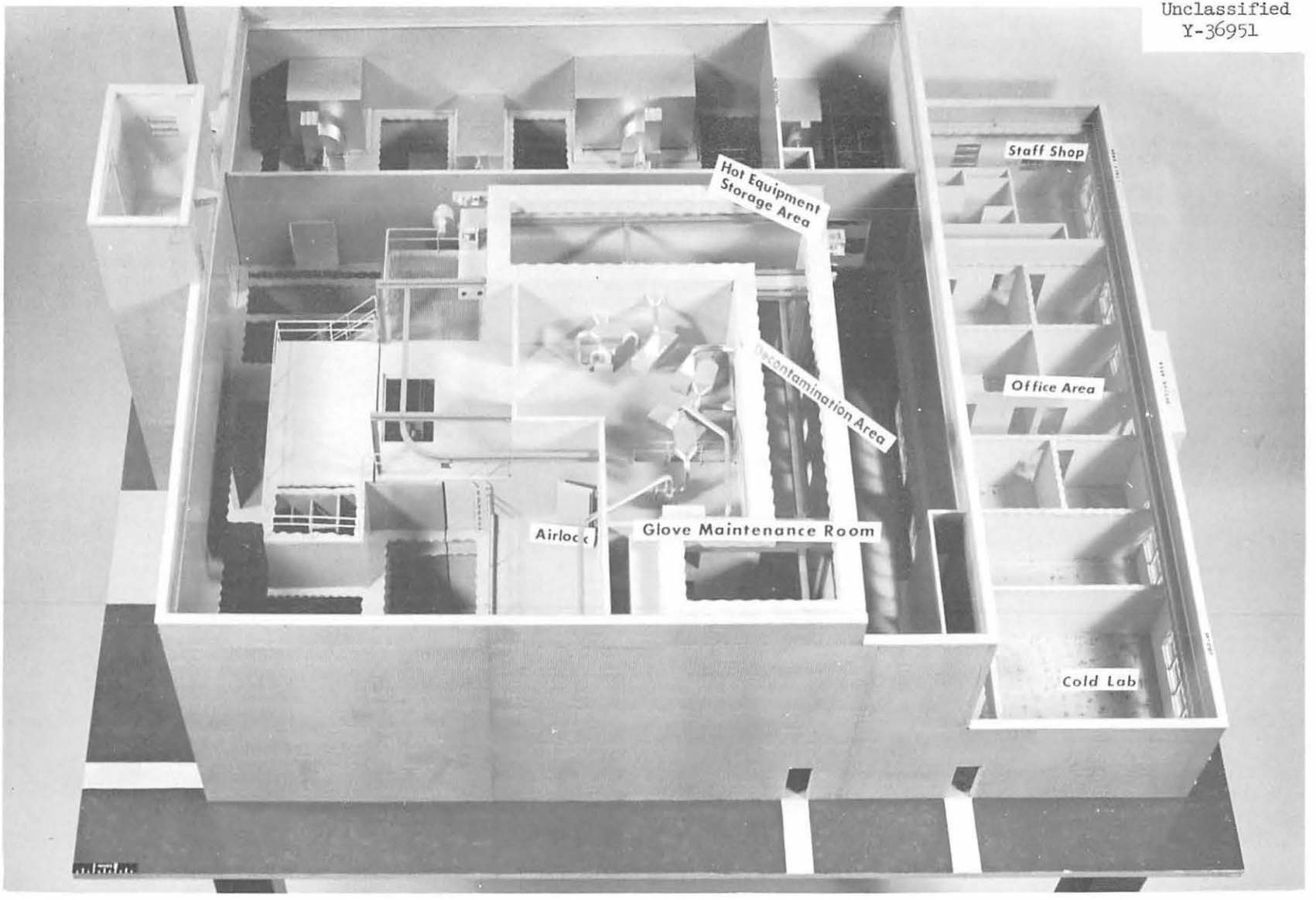

Fig. 2. General Arrangement at Second-Floor Level of the HRLEL, Building 3525.

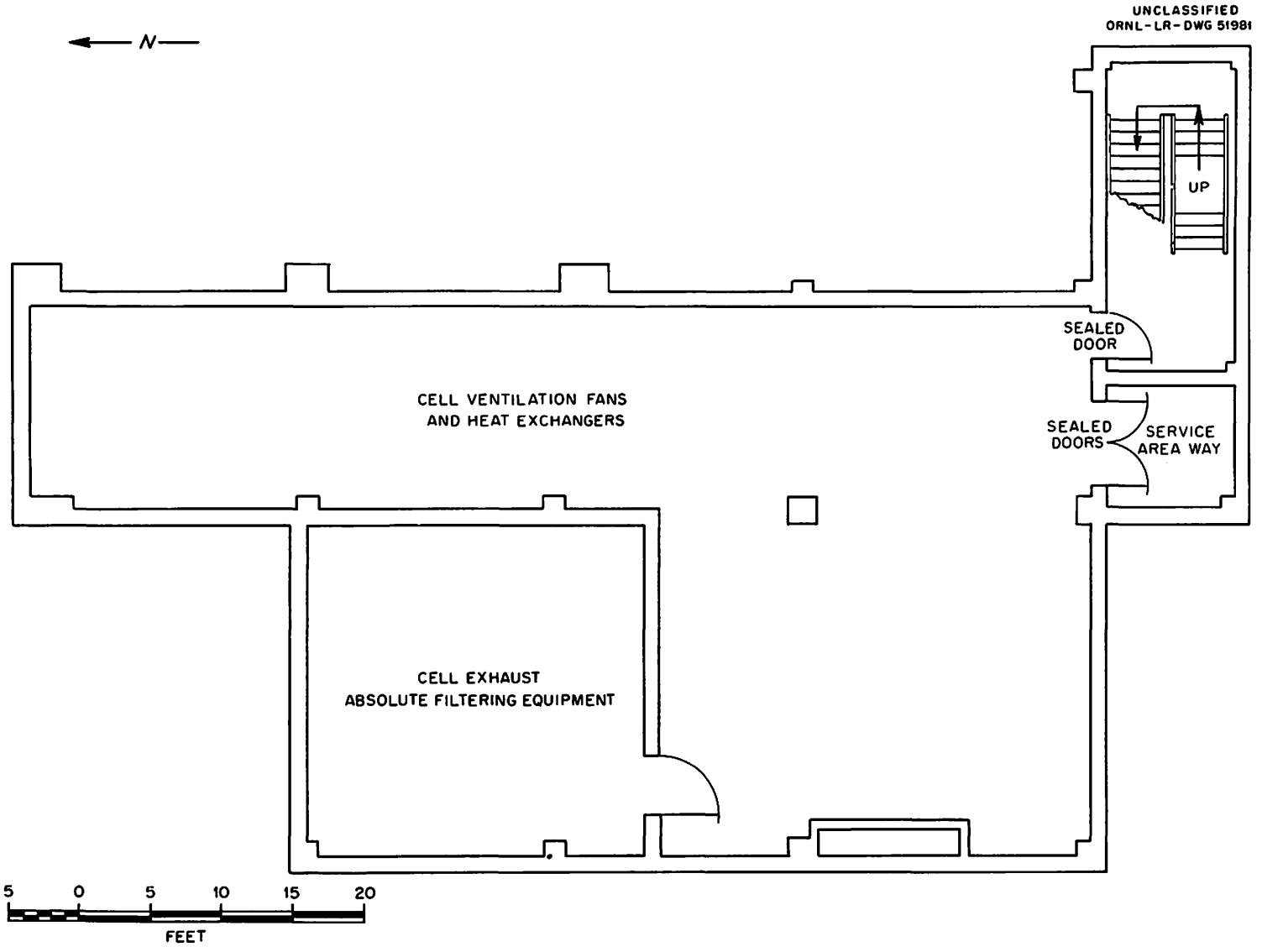

Fig. 3. Detailed Arrangement of the Various Activities Located on the Basement Level of the HRLEL, Building 3525.

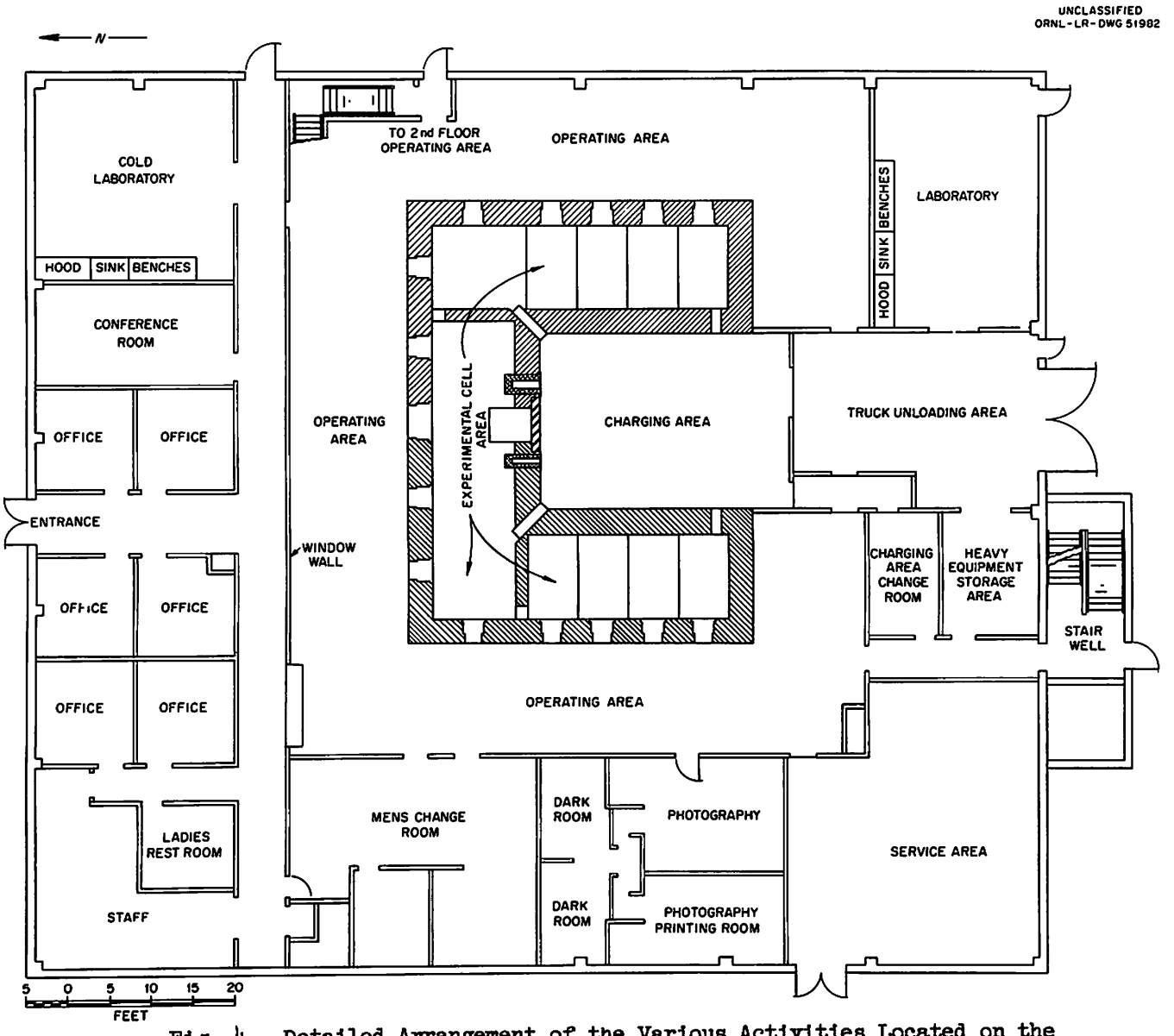

Fig. 4. Detailed Arrangement of the Various Activities Located on the First-Floor Level of the HRLEL, Building 3525.

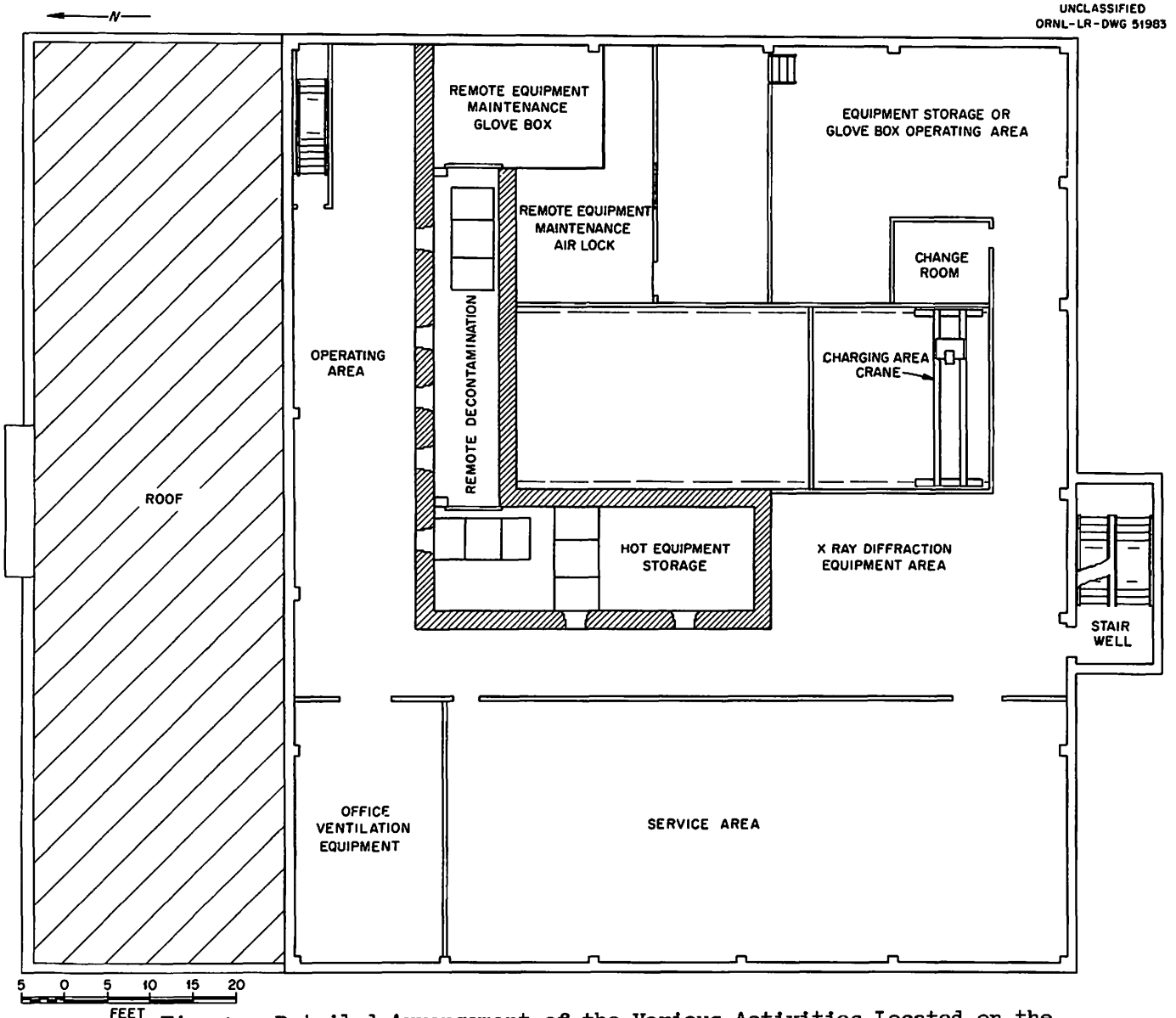

Fig. 5. Detailed Arrangement of the Various Activities Located on the Second-Floor Level of the HRLEL, Building 3525.

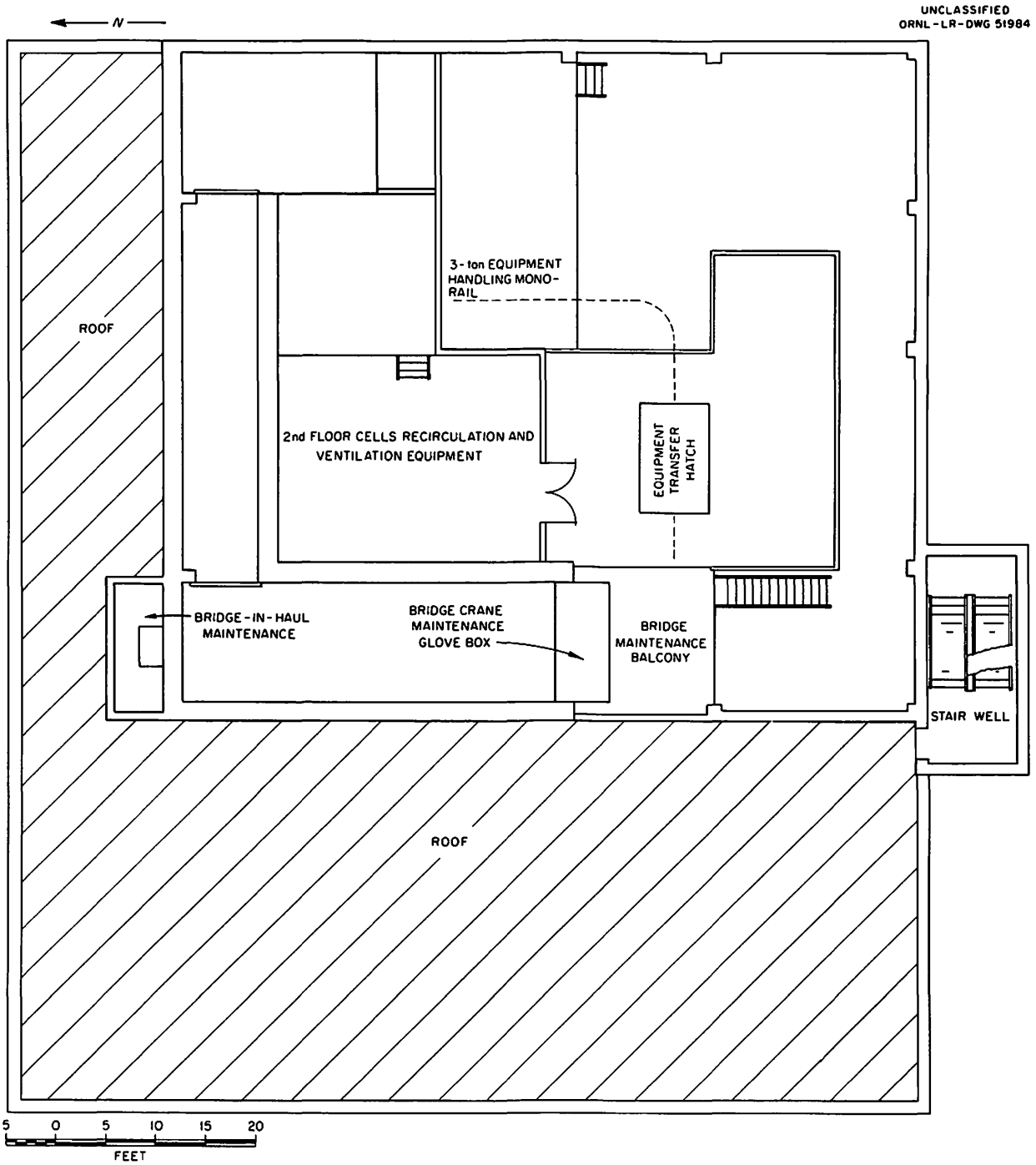

Fig. 6. Detailed Arrangement of the Various Activities Located on the Second-Floor Upper Level of the HRLEL, Building 3525.

the spread of contamination between various operating areas, appear throughout the laboratory. The office and cold-laboratory section has its own filtered air supply and exhaust system. The main section of the laboratory is subdivided outside the cell complex into: (1) the charging area; (2) the equipment maintenance and air lock areas; (3) the operating area; (4) the truck unloading area, the photographic rooms, and main change room; and (5) the supporting mechanical equipment rooms. Thus, the various operational areas are listed in order of decreasing contamination potential. Preset air balances and some automatic control establish an air migration pattern from the least to the most probable contamination zone. All air exhausted from the facility must first pass through CWS filters.

B. Shielded-Cell Complex

The shielded-cell complex, which is the very heart of the facility, is centrally located and occupies the full building height. The main cells, which are designed to handle a large variety of primary operations, are located on the first floor, while direct supporting functions that require shielding are located above on the second-floor level. The arrangement of the integrated shielded areas is shown in Figs. 7 and 8.

The primary cell structure consists of three straight-line banks which are arranged in the form of a "U" for functional purposes. Each completely enclosed bank can be further subdivided by the remote insertion of "splash" barriers, should additional control be required to prevent the internal spread of particulate matter to adjacent work areas. In the subdivided form, each operating cell is 6 ft wide by 10 ft deep and 14 ft high, except for the two corner cells with right-angle viewing and the charging cell which are somewhat wider. The 13 cells on this level are served by 15 viewing windows (each corner cell has two) and a pair of master-slave manipulators located at each window station. The shielding windows are the oil-filled, lead-glass variety of proper thickness and density to match the shielding provided by the cell wall. The 3-ft-thick walls of high-density concrete have sufficient shielding capacity to attenuate gamma-radiation in the kilocurie range to a safe level for operating personnel. A point source of 80,000 curies of Co-60 at the cell midpoint, for example, gives a calculated dose rate of 0.75 mr/hr at the cell face. Depending on cooling time, source geometry and personnel exposure factors, the facility can accommodate irradiated fuel elements containing 2-200 grams of

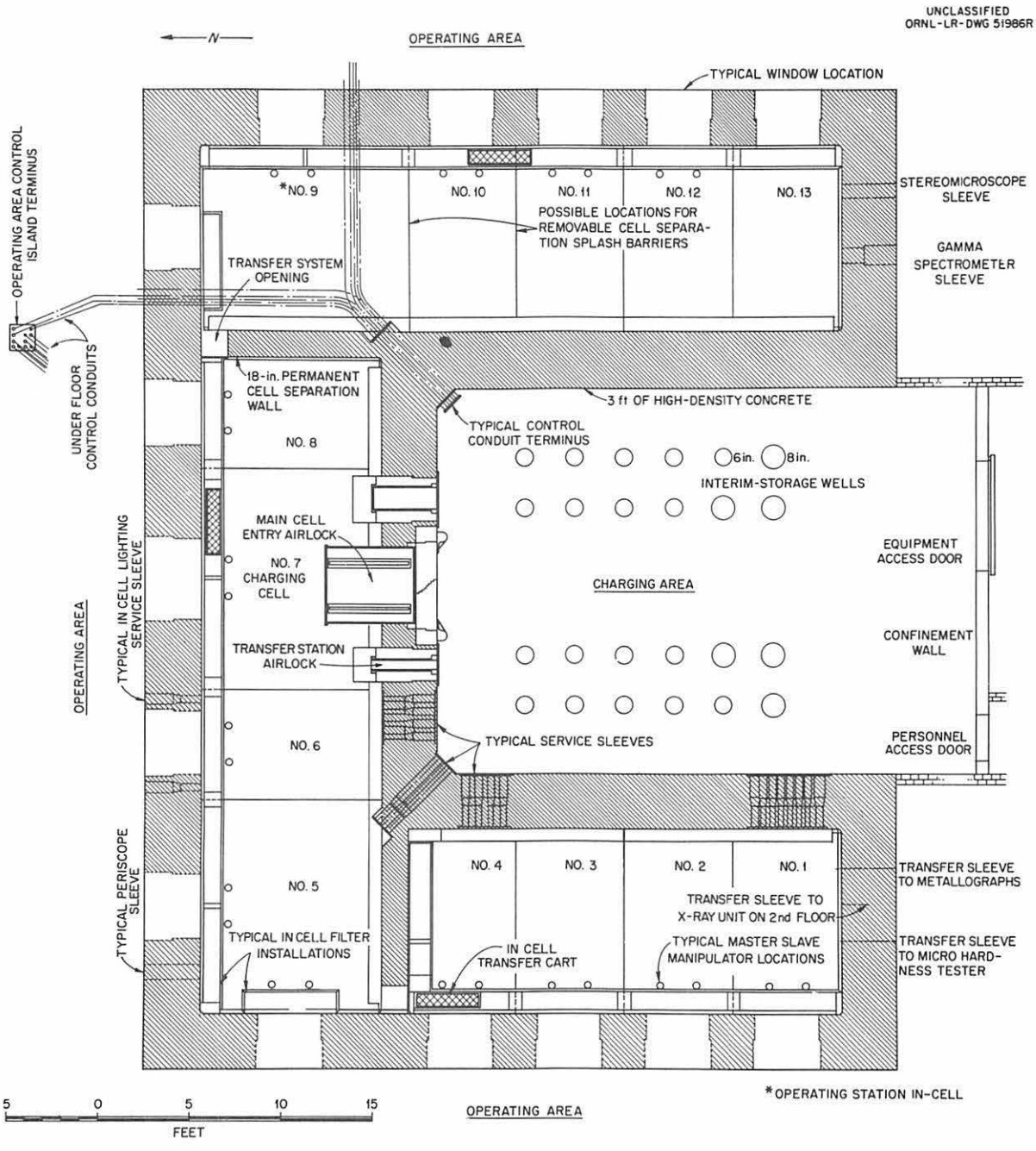

Fig. 7. Experimental Cell Bank on First-Floor Level of the HRLEL, Buidling 3525.

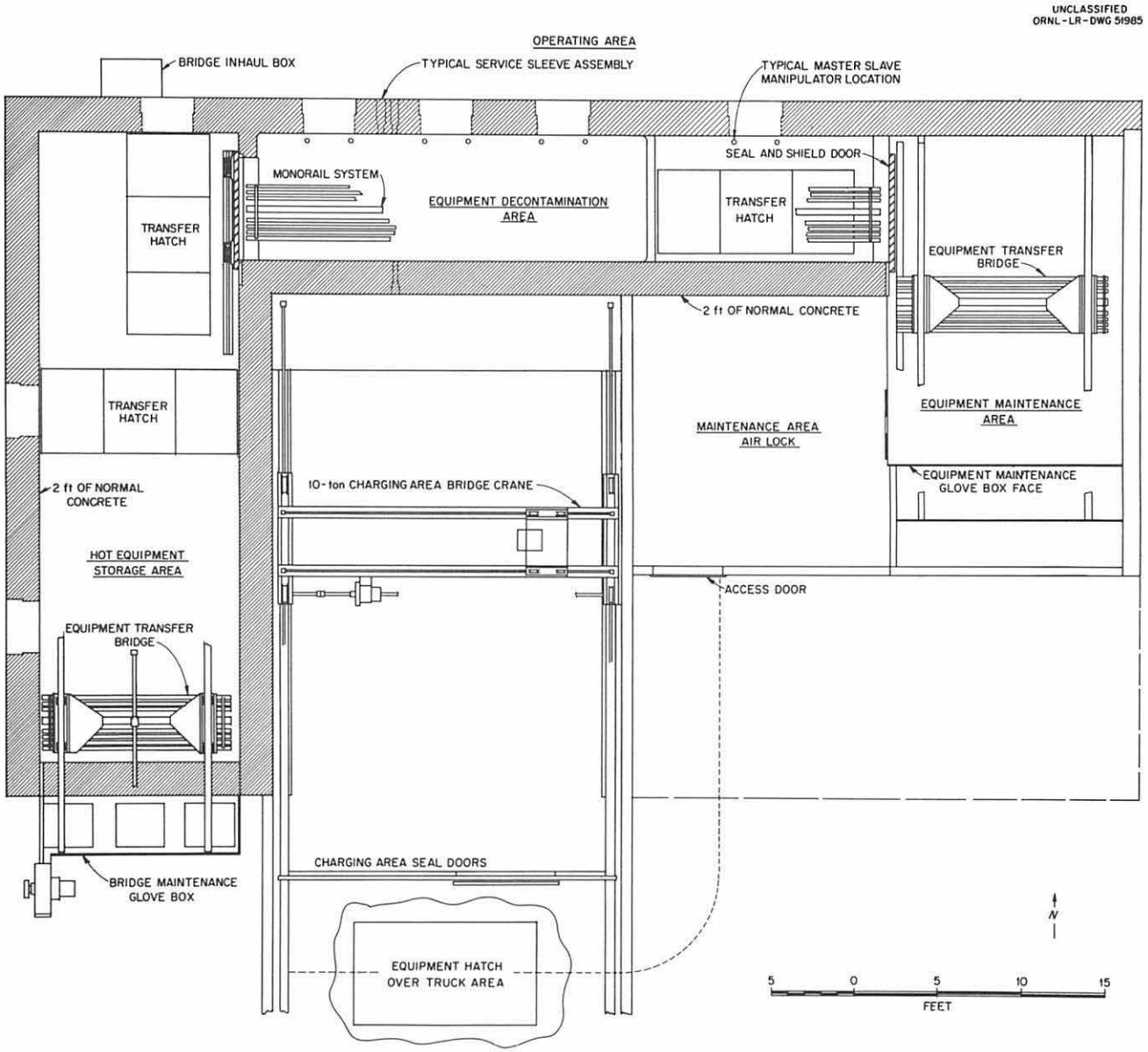

Fig. 8. Shielded Area for Equipment Storage and Maintenance, HRLEL, Building 3525.

mixed fission products.

The inside surfaces of the cell banks are lined with stainless steel sheet to provide containment of particulate matter. Sealed entry of services, such as instrument lines, water or gas, is accomplished by the use of special plugs. Air-tight seals are provided also at all ports which penetrate the wall to accommodate supporting cell equipment such as windows, master-slave manipulators, etc. All contaminated parts are replaced by forcing them inward into the cell as the replacement object is moved forward into place; thus, the philosophy of complete containment is maintained.

Movement of heavy objects within each cell bank is managed by the General Mills, Model 303, electromechanical manipulators and a companion 3-ton bridge crane. These motorized units are designed for remote removal and repair by transfer through ceiling hatches into the second-floor portion of the cell complex. Movement of experimental equipment for installation, removal, or transfer to another section within the complex also will be handled through these hatches. Small pieces and test samples under examination will be transferred to various stations within the cell complex with the aid of a trolley that runs on tracks mounted to the wall under the windows. Pass-through doors have been provided in the separating walls between cell banks to accommodate this trolley. Replaceable mercury-vapor lamps located around each window will be utilized for cell illumination.

Special penetrations have been made in the cell wall to accommodate some basic experimental equipment and for the installation of shielded and sealed transfer mechanisms. Included in this group are the sleeve ports for the periscope, stereomicroscope, collimator for the gamma spectrometer, as well as openings for the transfer of samples to shielded appendages for x-ray diffraction and metallographic work.

The supporting functions located on the second-floor level are hot-equipment storage, decontamination, and maintenance. The areas designed for the first two activities are shielded with 2 ft of normal concrete, while the glove-box area for equipment maintenance is essentially unshielded. In-cell equipment not in current demand will be stored in the hot-equipment storage area after removal of

gross contamination. Equipment in need of repair will be routed through decontamination to the maintenance area. If the equipment cannot be maintained in the glove-box area, it will be bagged and forwarded to the Operations Division for further decontamination or sent to the burial grounds.

Handling equipment located on the second-floor level includes an integrated bridge, monorail, and trolley system for transfer of objects from one area to another through the shielded doors located at either end of the decontamination area. Ports for installing master-slave manipulators are provided at each window in the decontamination area and structural provisions have been made for installation of heavy-duty manipulation equipment in this area should it prove necessary.

Ventilation of the various cell banks is accomplished by a system of individual recirculation units and a single-exhaust system. Each bank is cooled by a high-flow recirculation system which is filtered through both roughing and CWS filters located in the cells. The system has certain inherent limitations which will be discussed in a subsequent section dealing with operation of in-cell equipment. The exhaust system is rough filtered within the cells and air passes through two stages of CWS filtering in the basement. This exhaust is normally routed up the local stack, but under emergency conditions is automatically routed to the isotope stack. The cells will operate at a negative pressure of one inch of water, with respect to the charging area, which in turn is maintained at a negative pressure with respect to the balance of the building and thus to the outside. An in-cell hood (or house vacuum) system and radioactive off-gas system also have been provided.

C. Supporting Features

The enclosure formed on the first floor by the "U"-shaped cell structure and the curtain wall at the truck-unloading area in the rear constitutes the charging area, and is designed as an air lock to prevent contamination spread in the event of a mishap during hazardous charging and discharging operations. Deep dry wells buried in the floor of the charging area provide spaces for interim storage of experimental samples and test components. These wells are sealed

and shielded by plugs to give proper radiation protection. Both the truck unloading area and the charging area are serviced by a 10-ton bridge crane. Heavy carriers in the 10- to 20-ton capacity range will be transported to the charging face with the aid of a heavy-duty dolly.

Cell entry and exit of radioactive materials are accomplished through the use of the three shielded transfer stations provided at the rear face of the charging cell. The 6-1/2-in.-diam and 14-1/2-in.-diam air locks are capable of handling objects up to 40 in. in length, while items up to 4 ft x 4 ft x 6 ft in size and weighing up to 10 tons are transferred through a shielded air lock door system. Solid wastes generated within the cell complex are disposed of through these transfer stations after proper canning and decontamination of the external surfaces of the container. Liquid wastes are removed by direct discharge to the holdup tank in the hot-drainage system.

The laboratory also contains photographic darkrooms, change rooms, and other supporting functions required in an integrated operation of this nature. The building is replete with emergency showers, preaction sprinkler, and fire alarm systems and will be equipped with radiation monitors for detection of alpha and gamma radiation as well as with associated warning devices to safeguard personnel.

All services to the experimental equipment within the cell complex are provided through sealed service ports which terminate in the charging area. The associated instrumentation and control panels will be located in the operating area and connected through buried conduits which pass under the cell to the charging area. By this flexible method of providing all types of services and the versatility allowed in shifting portable equipment, operations may be converted to new experiments in any one area without seriously interfering with adjacent operations.

III. TECHNICAL FUNCTIONS AND EQUIPMENT

The main purpose of the facility is to obtain technical information needed in support of the various irradiation test programs under way at the Laboratory. Consequently, the building and cell structure have been designed to permit safe

examination, testing, and evaluation of a wide variety of materials, assemblies, component parts, and equipment that have been subjected to high-level radiation. It is contemplated that both nondestructive and destructive means of testing and measurement will be required to accomplish this objective.

In regard to the nature of technical services to be rendered, it was absolutely essential that criteria be established at an early date for several reasons: (1) to permit these requirements to be properly factored into the final building design; (2) to allow sufficient lead time for equipment design, procurement, and renovation for remote operation as well as for preoperational testing; and (3) to expedite operation of the facilities as soon as possible after the completion of construction. Many contributed to the difficult task of selecting and equipping the facility for technical operation. Initially, a survey was made among the Laboratory personnel responsible for various irradiation test programs to ascertain the type of detection and measurement work required in support of their program; viz., density, microstructure, hardness, fission-gas analysis, thermal conductivity, etc. All requirements were analyzed subsequently to establish the frequency of need, equipment requirements, state of the art, and knowledge required as well as the prospects for new developments in the field during the ensuing period between initial design and actual operation. By means of this evaluation and adding certain stabilizing and projection factors, a firm list of equipment required was compiled. Equipment items that were highly specialized and of low-demand frequency, as well as items that were subject to possible change in the immediate future, were deleted from the compilation.

The various technical functions that will be performed in HRLEL-I and the specialized equipment associated with each function are described in this section. It should be noted that the bulk of equipment is portable in nature so as to gain greater flexibility for the attainment of better operating efficiency. The permanently fixed items of equipment, such as the remote milling machine and the appendages for the x-ray diffraction unit, the microhardness tester, and research metallographs are exceptions to the above. In some instances, the capacities of

various operations are given, but these estimates may be exceeded or gradually attained only under conditions of actual remote operation. The cross support between various functions may not be stated always, but operating an integrated cell complex to provide as complete a postirradiation picture as possible will clearly require at least the same degree of cooperation as has been shown in developing the equipment. The order of presentation is significant only in that it represents the general order of material flow for technical observation, but many deviations from this order will certainly ensue during actual operation.

A. General Observation

Visual examination remains the foremost among the wide variety of procedures utilized for inspecting exposed or accessible surfaces of opaque materials and the interior of transparent objects. Examinations of this nature are so commonplace, it is rather easy to overlook their importance. The general method serves to determine number, size, finish, reflectivity, color characteristics, cracks or flaws, fit, and other performance characteristics.

This functional activity, therefore, is concerned with the broad field of general observations, both with and without optical aids. Another important aspect of this function is that of macrophotography for the purpose of obtaining permanent and accurate records of pertinent observations for future reference. Because of widespread demand, provision has been made to perform general observation-type work in all cells.

1.0 Optical Equipment

In order to improve both the coverage and resolution of observation within the cell bank, it is necessary to employ visual aids to complement direct viewing through the lead-glass windows. The more important optical aids of this nature planned for installation are described below.

1.1 Periscope and Camera

The original 300 Model periscope developed by the Kollmorgen Optical Company has proved in prior application to be a valuable piece of equipment for general scanning work at apparent magnification in the range of 2 to 10 diameters.

Four Model 301-type units, incorporating the new seal and dome feature for alpha containment, have been purchased for general utility work. The general appearance of the equipment as viewed from the operating floor is illustrated in Fig. 9. Figure 10 shows a close-up of the seal and dome feature as viewed from inside the cell.

One sleeve and dome assembly for accommodating the periscope will be installed in the cell wall at the operating face adjacent to each window. Hence, the general utility scopes can be moved at random from one sleeve position to another without disturbing cell containment. To facilitate the transfer of the periscopes, a small brake shoe is being installed on each unit after delivery to ORNL. This brake will eliminate the need for the standard counterweight and at the same time permit one to lock securely the unit in any given position in order to obtain steadiness for detailed examination or photography. The need for the development of the brake was an outcome of preoperational testing of a unit of the new design in the mockup.

The periscope is equipped with a photographic eyepiece and a mounting fixture to accommodate a standard 4 x 5 Crown Graphic camera.

1.2 Stereomicroscope and Camera

Another essential optical instrument for hot-cell work with solid materials is the stereomicroscope. The main feature of this instrument is that it provides a true sense of depth so that by proper manipulation the object may be located and identified in three-dimensional space. The microscope has binocular vision which makes possible prolonged use for visual inspection and measurement tasks.

Several years ago the Bausch & Lomb Optical Company developed such a unit for hot-cell operations. Unfortunately, this unit was shaped in the form of an inverted "U" and, for maintenance reasons, this configuration was not applicable to the philosophy of total containment. Three units of a new design which do fulfill the containment philosophy are now on order; one unit is scheduled for location in each of the three cell banks. The new units are L-shaped and fit

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Fig. 9. Appearance of Periscope at Operating Face.

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Fig. 10. In-Cell Appearance of Seal and Dome Features for Periscope.

into seal sleeves at the cell wall as illustrated in Fig. 11. The optics are of nonbrowning glass and will incorporate the zoom-objective lens, recently developed for the standard stereomicroscopes. When coupled with the proper eyepieces and an auxiliary objective lens, this lens will provide continuous magnification in the range of 1 to 60 diameters. Field coverage varies roughly as the inverse of the power. A precision camera can be attached to the optical system for direct reproduction of stereonegatives of 35-mm size.

An in-cell stage or table for the purpose of positioning the object in the focal plane is an important accessory required to utilize the full potential of the stereomicroscope. Such a stage has been designed and constructed on the basis of limitations encountered in working with the older model stereomicroscope. The resulting unit shown in Fig. 12 utilizes Bodine motors to provide two-speed rectilinear motion, slow-speed rotation and slow-speed tilt motions. The base will occupy a 23-in. x 23-in. floor area and the table will support a 50-lb object when in the cantilevered position, some 18 in. off center.

1.3 Questar Telescope

A more recent innovation in the field of hot-cell work is that of employing an astronomical telescope, such as the Questar telescope which currently is being employed by the Metallurgy Division for a variety of remote examinations. The Questar telescope employs the relatively new caladioptric, or mixed lens mirror system, which permits a full-size 3-to-5-in. telescope of 7-ft focal length to be compressed by optical folding into a closed tube only 8 in. long. The complete optical package is mounted on a tripod in a manner similar to a surveyor's transit to give altitude and azimuth control. The over-all unit weighs but 6.7 lb and occupies less than one cubic foot of space.

A telescope normally brings an object closer without magnification and is physically limited from focusing closer than a few hundred feet. The Questar telescope, however, can be focused continuously from infinity to approx 8 ft, allowing the object to be magnified and thus, the instrument to be employed as a long-distance microscope. As purchased, optic variations will give powers of

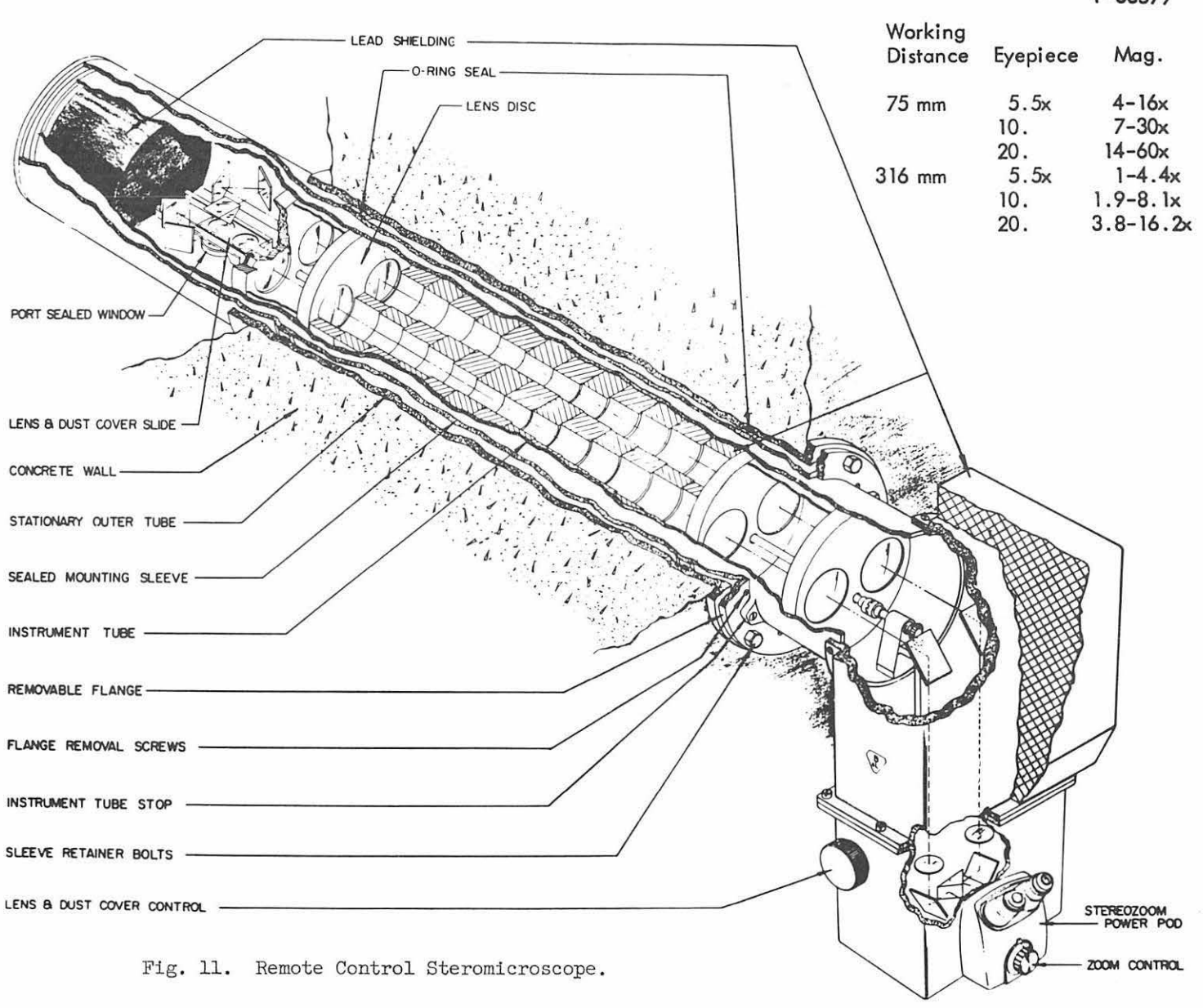

Fig. 11. Remote Control Steromicroscope.

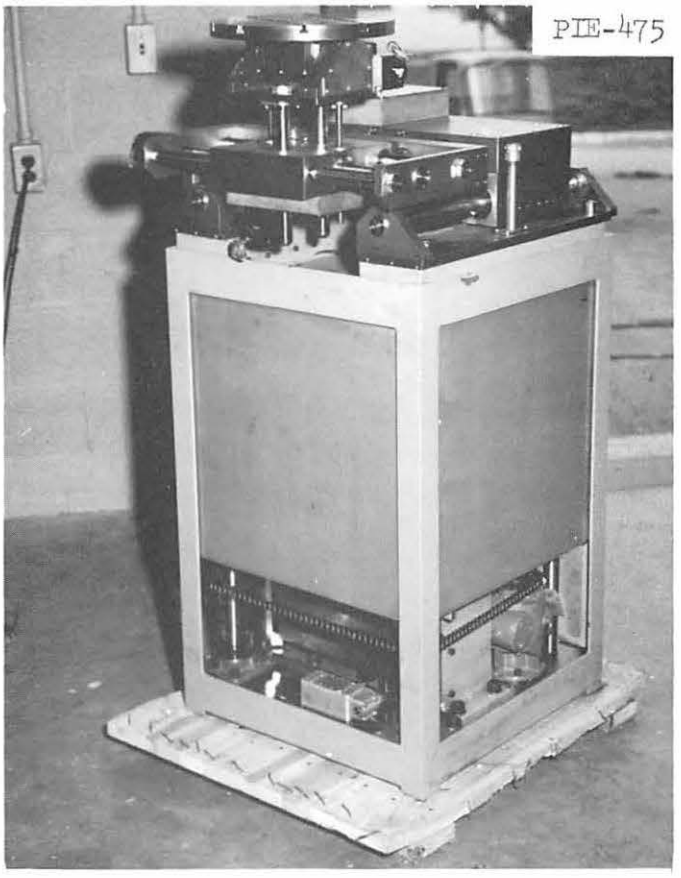

Fig. 12. Mechanical Stage for Steromicroscope.

4.4X, 8.8X, 80X, or 160X; but higher magnifications with good resolution are possible by coupling extension tubes to the eyepiece.

The instrument lends itself to a variety of applications, but time and effort will be required to develop the full potential of the Questar telescope. It can be used, for example, for spot work on test objects or tools located within the cell, such as for reading gages, micrometers, thermometers, and burettes with a high degree of accuracy. It has proved helpful also in the examination of internal surfaces of autoclaves, loop sections, and as an aid in viewing and photographing the interior surface of the HRT core vessel. It has extreme versatility and promises to be a most useful tool.

A 35-mm single-lens reflex camera with the lens removed can be coupled to the Questar. By employing a series of tubes with the 80X-eyepiece forward of the camera, a 6X-magnification of an object can be recorded on the film which, in turn, can be enlarged easily to give greater magnification.

2.0 Television Equipment

There are several areas within the cell complex where television can be employed advantageously. It would be helpful, for instance, in the equipment storage, decontamination, and remote maintenance areas. Services have been provided but no equipment has been ordered as of yet; this will be done only after the cells are in operation and the precise needs are known. Also, delaying procurement of this equipment is not considered serious, for one can get better industrial equipment in this rapidly changing field and on a rather short delivery schedule by waiting.

B. Mensuration

No advanced preparations have been made on tooling for dimensional analysis except for the procurement of a precision set of standard gage blocks for calibration work. Deferral of this task is not considered serious at this time for several reasons: (1) conventional tools will serve to meet the majority of the measurement requirements; (2) such tools can be obtained either directly from stores or procured on a rather short-time basis; and (3) modification for remote

manipulation should be a relatively simple task. When additional manpower is available, a study of proposed work to be handled in the new hot cells will be made to determine whether or not the anticipated needs can be met by either nondestructive tooling or mechanical means.

C. Nondestructive Testing

One of the activities that will be included in the new High Radiation Level Examination Laboratory is that of nondestructive testing. By definition, the science of nondestructive testing embraces all the methods of detection and measurement where the character of the test object is not destroyed. Hence, in a broad sense, it would include weighing, optical examination, and x-ray testing, because these tests are nondestructive in nature. However, this section will deal only with those more stereotyped nondestructive tests, viz., eddy-current and ultrasonic testing.

1.0 Basic Test Methods and Application

Both eddy-current and ultrasonic testing encompass a number of different techniques which may be utilized to gain much information concerning the quality or integrity of the test object. Several of these techniques will be described briefly along with an example of their applicability to specific problems.

1.1 Ultrasonic Resonance Technique

In very general terms this involves the application of a continuous electrical signal of varying frequency in the ultrasonic range to a piezoelectric crystal which converts the electrical signal into a mechanical vibration having the same varying frequency range as the driving signal. This mechanical vibration or ultrasonic beam is transmitted into the specimen through a suitable couplant. When the thickness, ultrasonic velocity, and frequency are such that a standing wave or resonant condition (at multiples of one-half wave length) can be established, this is detected and the signal can be processed in such a fashion so as to present a thickness measurement. Thus, this technique can be applied to thickness measurement of a specimen with access to only one side. The accuracy of such measurements is usually one percent or better in most common metals.

Other applications include the detection of certain nonbond conditions in clad structures. Commercial instrumentation can be used for this technique with most of the equipment being outside the hot cell. The only portion of the instrumentation which must be near the test piece is the small canned oscillator, the coaxial cable, and the piezoelectric transducer. It may be necessary to provide simple handling jigs for the transducers and quick-disconnect coaxial cable couplings.

1.2 Ultrasonic-Pulsed Technique

This system uses a piezoelectric crystal to convert electrical energy to ultrasonic energy as does the resonance technique. However, only a short burst of energy is applied to the crystal with a comparatively long waiting time between pulses. The nominal frequency is determined by the sinusoidal character in the electrical energy or by the resonant frequency of the transducer. This system can be used with a single transducer as both transmitter and receiver or with separate transducers for sending and detecting the ultrasonic pulses. Thus, the utilization can be obtained by the detection of reflections of sound energy from flaws, interfaces, boundaries, etc., or by the attenuation or scattering of sound from such areas offering acoustic anomalies. This technique can be applied to the inspection of most common structural shapes for cracks, laminations, nonbond, and other common defects which offer sufficient reflecting or scattering area to the ultrasound beam.

As with the resonance technique, commercial equipment can be procured to generate, transmit, detect, and display the electrical and ultrasonic signals. The electronic equipment can be retained outside the hot cell with only the transducers, transducer holders, and coaxial cables being exposed to the high-radiation levels. More will be said concerning the handling of the transducers in the discussion on the mechanical facility for nondestructive testing.

1.3 Ultrasonic Measurement of Elastic Constants

With the current technology, this is actually an extension of application of the pulse technique. The speed of propagation of ultrasound through a medium is a function of the elastic properties of that medium. Therefore, by

measurement of the velocity of the longitudinal and transverse modes in a material, and the utilization of appropriate calculations, Young's modulus, Poisson's ratio, and the "Lame" constants may be determined. The same ultrasonic equipment which is used for the pulse technique will be adequate for the determination of the elastic constants; however, it will require auxiliary equipment such as gating and counting circuitry.

Samples for this determination must have at least one pair of parallel faces. A long cylindrical shape would be the most advantageous for the determination of both longitudinal and transverse wave velocities with a single setup.

1.4 Eddy-Current Techniques

The basic eddy-current technique requires the energizing of a coil of wire by means of an electrical signal, usually with a frequency in the kilocycle range. This coil will induce eddy currents in a metal specimen in proximity to the coil. The conductivity, permeability, geometry, and flaws in the specimen will affect the eddy-current flow and thus the impedance of the driving coil or of a separate detector coil. Thus, with the proper instrumentation and coil system, it may be possible to measure electrical conductivity, determine specimen or clad thickness, detect discontinuities, or measure other properties of the specimen which may affect the eddy-current flow.

Commercial equipment may be procured to accomplish many of these inspections or measurements, but, is generally not amenable to operation with the extremely long cable lengths which would be necessary for hot-cell operation. Therefore, modification will be necessary if the instruments are to be retained in the uncontaminated zone. If this is successful, it still may be necessary to have oscillators and/or preamplifiers in the hot cell with the necessary test coils and cables. Simple handling jigs will be needed similar to those for the ultrasonic resonance techniques.

2.0 Mechanical Equipment

An immersion tank with remote operating capabilities has been designed for use in the hot-cell facility. Although it was designed primarily for performing the necessary mechanical scanning in conjunction with the ultrasonic

pulse technique, it is anticipated that it will be flexible enough for use with each of the other techniques. A top view of this tank is illustrated in Fig. 13. The immersion tank is 60 in. long x 26 in. wide x 16 in. deep and can accommodate parts up to 48 in. in length. Clamping and rotating features make possible the inspection of cylindrical and tubular specimens with diameters up to 2-1/8 in. Position control on the scanning head (transducer) is available in the X, Y, and Z directions as well as angular motion from the vertical in both the X and Y directions. Automatic scanning can be accomplished in the X-Y plane. The motor drives for the transducer adjustment and the rotation of cylindrical parts are all remotely controlled.

An auxiliary dump tank and pump system is available for rapidly removing or replacing the water in the inspection tank. Thus, it can be used for ultrasonic immersion techniques, or the water may be removed and the scanning equipment used to perform contact ultrasonic or eddy-current tests.

3.0 Space Requirements

In addition to the space required for the immersion tank and auxiliary dump tank, it will be necessary to provide racks for the search tubes and transducers for the pulse ultrasonic technique, for the resonance ultrasonic oscillators, cable and transducers, and for the eddy-current test probes and oscillator and/or preamplifiers.

4.0 Care and Maintenance

The mechanical equipment is the only portion of the nondestructive testing facility which will need to be considered for maintenance. The relatively low cost of the test components in the hot-cell proper and the difficulty of repair even in an accessible area, would make maintenance of damaged or worn-out components unfeasible. The water of the tank system will be changed at some periodic interval depending upon the accumulation of sediment. Those components which are most subject to breakdown have been designed for remote removal and replacement. Thus, it is hoped that maintenance will not be a critical problem within the hot cell.

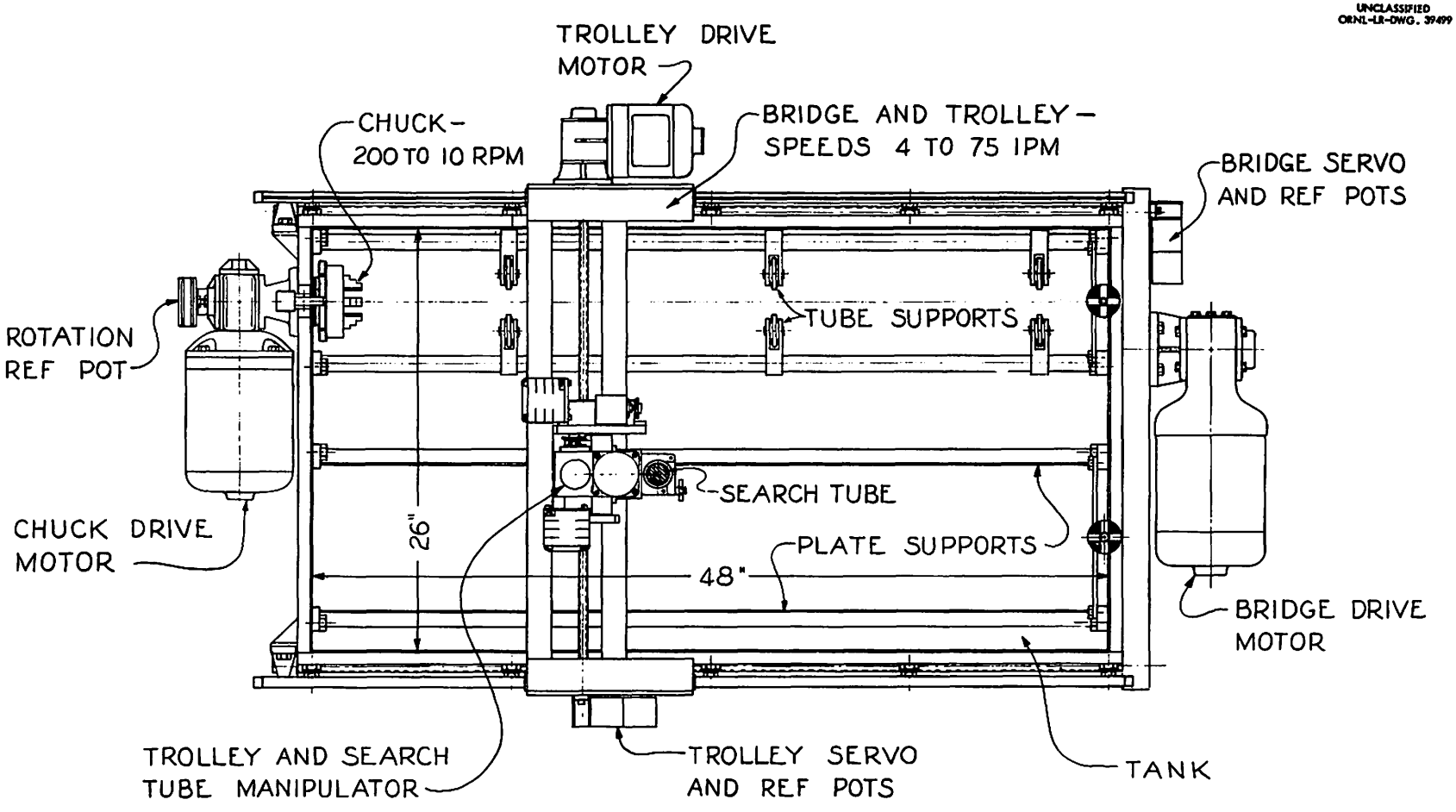

Fig. 13. Top View of Immersion Tank for Nondestructive Testing, HLREL, Building 3525.

5.0 Knowledge of Operation

It is anticipated that most of the common ultrasonic and probe-coil eddy-current tests can be accomplished by remote means in the hot-cell facility. Because of the rather specialized knowledge and training which are required for the accomplishment and interpretation of such tests in the open laboratory, it is evident that these same skills must be employed for the hot-cell application. In order to gain maximum utilization of the nondestructive testing equipment, it will be necessary to have personnel who are thoroughly familiar with nondestructive testing techniques.

D. Fuel Burnup and Induced-Activity Measurements

One of the parameters to be considered in evaluating the potential of various materials for reactor construction is that of behavior under intense radiation and performance of this nature is measured as a function of radiation exposure. The ability of nuclear fuels to perform without functional impairment under a given set of conditions is normally discussed in terms of fuel consumption or the percentage of uranium fissioned, and this is referred to as "burnup." The performance capability of structural materials, on the other hand, is often related to the accumulated neutron flux or integrated flux. A convenient means often is required to identify various radioisotopes in studies of corrosion and other reaction products. Hence, in the evaluation of various reactor materials, it becomes necessary to detect and measure radiation dosage.

More often than not, measurements of this nature involve total dissolution of the sample for quantitative analysis by wet chemical means and/or analysis by gamma-ray spectrometry after further dilution. An alternate method is to make a direct comparison with a solid sample exposed under known conditions by gamma-ray spectrometry, the solid sample thus serving as a reference standard. Recently, BMI and others have extended the nondestructive technique to permit scanning of an entire fuel plate or pin in order to obtain burnup profiles.[1]

[1] R. J. Burion and J. E. Gates, Post-Irradiation Examination and Evaluation of an OMRE Fuel Assembly, BMI-1319 (February 11, 1959).

This technique involves the point by point quantitative analysis of specific fission products, such as Ba-La or Zr-Nb, by gamma-spectrometry using a collimator to limit the area and define the point of analysis. Results are correlated with the chemical analysis of a few selected samples and thus provide a more complete picture at less operating cost.

A gamma-ray spectrometer has been designed with special provision for collimation and operation through the shielded-cell wall. The degree of collimation can be varied by orientation and replacement of component parts. The general arrangement will permit one to perform either comparative activation or burnup profile analyses under fully shielded conditions.

1.0 Measuring Equipment

The gamma-scanning device consists of three essential parts; viz., a mechanical positioner, a collimator, and a scintillation counter equipped with detector and shield. The positioner will be located inside the shielded-cell structure and aligned with the spectrometer outside via a special penetration through the cell wall. A thin-walled stainless steel can will provide the needed seal for containment. A stepped, shielded-collimator plug will be inserted from the operating face, and attached to this plug will be a shielded crystal detector. The degree of collimation or absorption can be varied by replacement or orientation of the center section of the plug.

1.1 Mechanical Stage

The positioning device located inside the cell will expose the sample to the collimation port. The device will have a special shield to eliminate background activity from other cell operations. Samples will be loaded and unloaded by the master-slave manipulators. Detailed design of the in-cell portion of this unit has not been started.

1.2 Spectrometer and Recorder

The spectrometer purchased for burnup and induced-activity measurements is a fully transistorized 256-channel analyzer manufactured by Nuclear Data, Inc., complete with a readout typewriter, oscilloscope, and X-Y point recorder. The display scope will be utilized for quick examination of the gamma-ray spectrum.

In addition, the analyzer can be connected to a typewriter for automatic recording of digital information or to the point recorder for plotting gamma-ray spectrum data. This particular multichannel analyzer has been loaned to the Analytical Chemistry Division for use with a standard detector shield, and has given excellent service with essentially no maintenance. Recently, at the expense of the manufacturer, it was returned to the factory where all of the circuitry was revised to incorporate recent advancements and to provide certain additional features. When not required for cell use, this spectrometer can be employed with other detectors for low-level analytical spectrometry.

1.3 Collimator

The collimator section has been designed to cover two distinct ranges of specimen activity to give proper coverage for burnup analysis. The unit is made up of three sections of tungsten. One section is 7 in. long with an 0.200-in.-diam hole in the center, while the other two are each 7 in. long and have a slit at their center which is 0.200 in. wide and 0.002 in. thick. When aligned in parallel these slots will provide collimation suitable for accurate analysis of specimens with activities of about 1×10^{8} disintegrations/sec-in.^{2}. When aligned at right angles, the collimation will be suitable for high-level samples in the range of 1.2×10^{10} disintegrations/sec-in.^{2}. This flexible arrangement will permit the scanning of most fuel elements and plates after moderate burnup and approx 120 days cooling. Design of the detector shield-collimation plug assembly is complete, and fabrication of some parts has been initiated. The shield is adequate to reduce the background and unwanted radiation to a low level; a 500-photon source will be attenuated to a level of less than 1 photon. The shield also will reduce the penetration exposure to less than permissible laboratory tolerance.

1.4 Detector

A 3 in. x 3 in. scintillation crystal of thallium-activated sodium iodide is used for the detection of gamma rays. It will be mounted on a 3 in. photomultiplier tube according to standard Oak Ridge National Laboratory practice.

2.0 Operation and Maintenance

Comparative activation analyses probably can be made on 1 to 4 samples per hour depending largely on the spectrum detail desired. Since there is no experience in nondestructive burnup analysis, and the number of scans required will vary with the element, no reasonable estimate of productivity can be made at this time.

E. Fission-Gas Sampling and Analysis

Gas-pressure buildup to the point of rupture in metal clad fuel elements is a potential hazard to (1) fuel element life, (2) operation of the reactor, and (3) personnel safety. Various fuels are being irradiated under a variety of conditions for the investigation of this problem. Hot-cell equipment for the evaluation of these experiments must be sufficiently versatile to pierce various sized capsules of steel, nickel alloys, and beryllium, and to obtain aliquots of fission gases suitable for analysis by gamma spectrometry from a wide range of gas activities and volumes. Additional facilities are necessary for the purification and concentration of the fission gases if mass spectrometric analyses of the stable nuclides are desired.

1.0 ORNL Equipment

The piercing valve presently used for room-temperature sampling of irradiated capsules is a modification of a commercial valve used in the refrigeration industry.[2] Stock valves were suitable for copper tubing but would not pierce stainless steel tubes. The points then were changed to tempered Vega steel.[3] These points have pierced up to 1/16-in.-wall stainless steel tubing. The body of the valve also was modified. The split screw was extended for easier installation of the capsule, and the split screw nut was replaced with a threaded tube having a "T" handle for remote operation with the manipulators.

[2]Madden Tube Piercing Valve made by Madden Brass Products Co., Aurora, Illinois.

[3]Vega steel is manufactured by the Carpenter Steel Co., Reading, Pennsylvania.

Accurate sampling is accomplished by taking volumetric proportions of the gas. Samples of less than 0.020 r/hr have been taken from a total gas activity of 1000 r/hr at one foot with the system now used. The system consists of a rack fitted with tanks, valves, sampling bulbs, and connecting lines (Fig. 14). The tanks vary in size up to two liters and are used to take most of the gas from the manifold to reduce the amount of gas collected in the sample bulbs. Bellows sealed, vacuum-type valves are fitted with crank handles for remote operation. The manifold system is arranged to have a minimum volume so that a maximum tank-to-manifold volumetric ratio may be obtained. Removable tubing clamps act as valves for the glass bulbs and fit a slot provided with swivel locks on the rack. For remote operation, "T" handles are added. Part of the gas is collected in a small thin-walled, shielded tank connected to an ion chamber. The activity measured by the ion chamber multiplied by a known volumetric ratio will give the total gaseous activity. This enables the operator to select a proportional sample suitable for gamma-ray-spectrometer analysis.

After filling, the glass bulbs containing an activity of 10 to 20 mr/hr at contact are removed with the closed tubing clamps and tubing attached and taken out of the hot cell. A gas torch is used to draw out and seal the glass stems in a laboratory hood. The glass sample bulbs are sent to the gamma-ray-spectrometer laboratory for analysis. One of the sample containers is a tank having a volume equal to that of the manifold system so that it will contain one half of the total gas. This sample is saved in a shielded container until it has decayed to an activity safe for handling, and is analyzed on the mass spectrometer. Mass spectrometer analysis of very small amounts of inert fission-product gases is more accurate when all chemically active gases, which endanger the filament, are removed. The sample of fission gases is passed through a tube containing two sections of calcium at 720 and 350°C, respectively. This has been effective in removing most of the oxygen, nitrogen, and water vapor. A Toepler pump is used to pump the prepared sample into a 20-cc bulb for later use on the mass spectrometer.

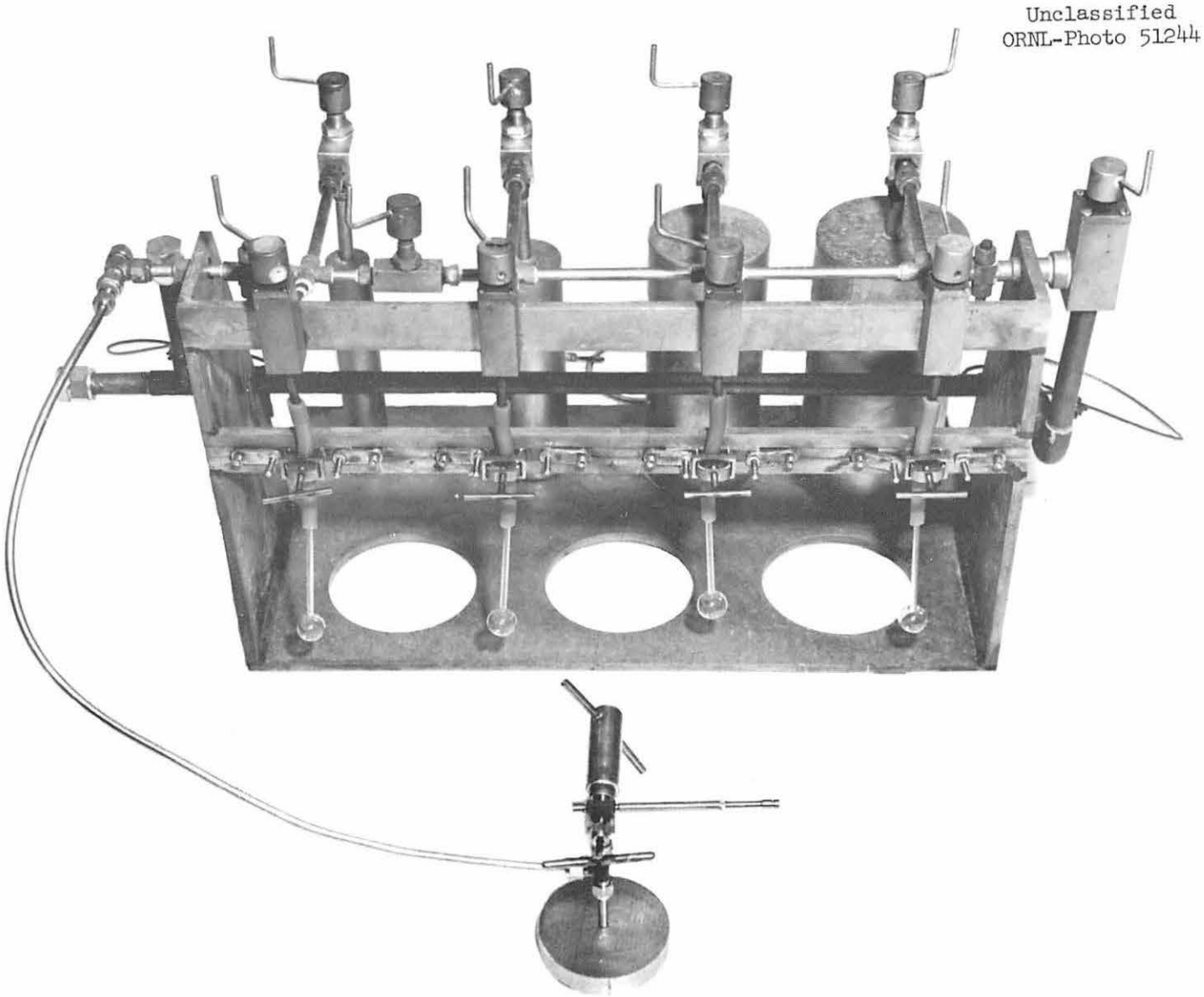

Fig. 14. Apparatus for Collection and Accurate Proportioning of Fission-Gas Sample for Measurement.

2.0 General Electric Equipment

An alternate method for capsule piercing is employed at the General Electric-Vallecitos Atomic Laboratory (GE-VAL). The puncture head is practically universal, accepting capsules up to 3 in. in diameter for side puncturing, and up to 24 in. long for end puncturing (Fig. 15). The seal mechanism and puncture pin drive are hydraulically operated by pumps and control valves located outside the cell. Thermocouple vacuum gages are used to ensure a good seal to the capsule before puncturing. Since the bulk of the gas collection system is located outside the cell, a lamb's wool particle-filter and a - 35°F copper-coil iodine trap are used to prevent transfer of any fuel particles or radioiodine from the cell (Fig. 16). The iodine may be driven from the trap by gentle heating at some later time. Additional in-cell equipment is used to evolve and collect fission gases from capsules heated to a maximum of 1900°F.

All of the in-cell equipment at GE-VAL is semipermanently mounted, and can be removed and replaced remotely. The vacuum system consists mainly of copper tubing with brazed joints for maximum sturdiness. Modified UCRL vacuum connectors and ball and socket connectors sealed with Apiezon "W" wax are used where semipermanent metal-to-metal and metal-to-glass connections are necessary. The equipment outside the cell consists of a conventional vacuum system exhausted to the cell, a Bendix-Westinghouse BRH-25 refrigeration unit, and two 3000-psi, hand-operated hydraulic pumps. Stable krypton carrier gas is used to transfer the radiokrypton through the system to the calibrated burettes.

3.0 Drilling Brittle Materials

Equipment and techniques for drilling beryllium capsules are being developed at ORNL. It is felt that the present method of piercing with a tool-steel needle would be unsuccessful for this brittle metal. One end of the capsule will be clamped in the drilling chamber with a circular seal around the capsule (Fig. 17). A modified No. 12 lathe center drill passes through a Wilson-type seal, and the capsule is positioned so that the drill will penetrate the capsule wall at the edge of a fuel pellet. The drill is driven by a variable speed electric motor through a flexible shaft. The gas-collection system will be similar to that used with the piercing apparatus.

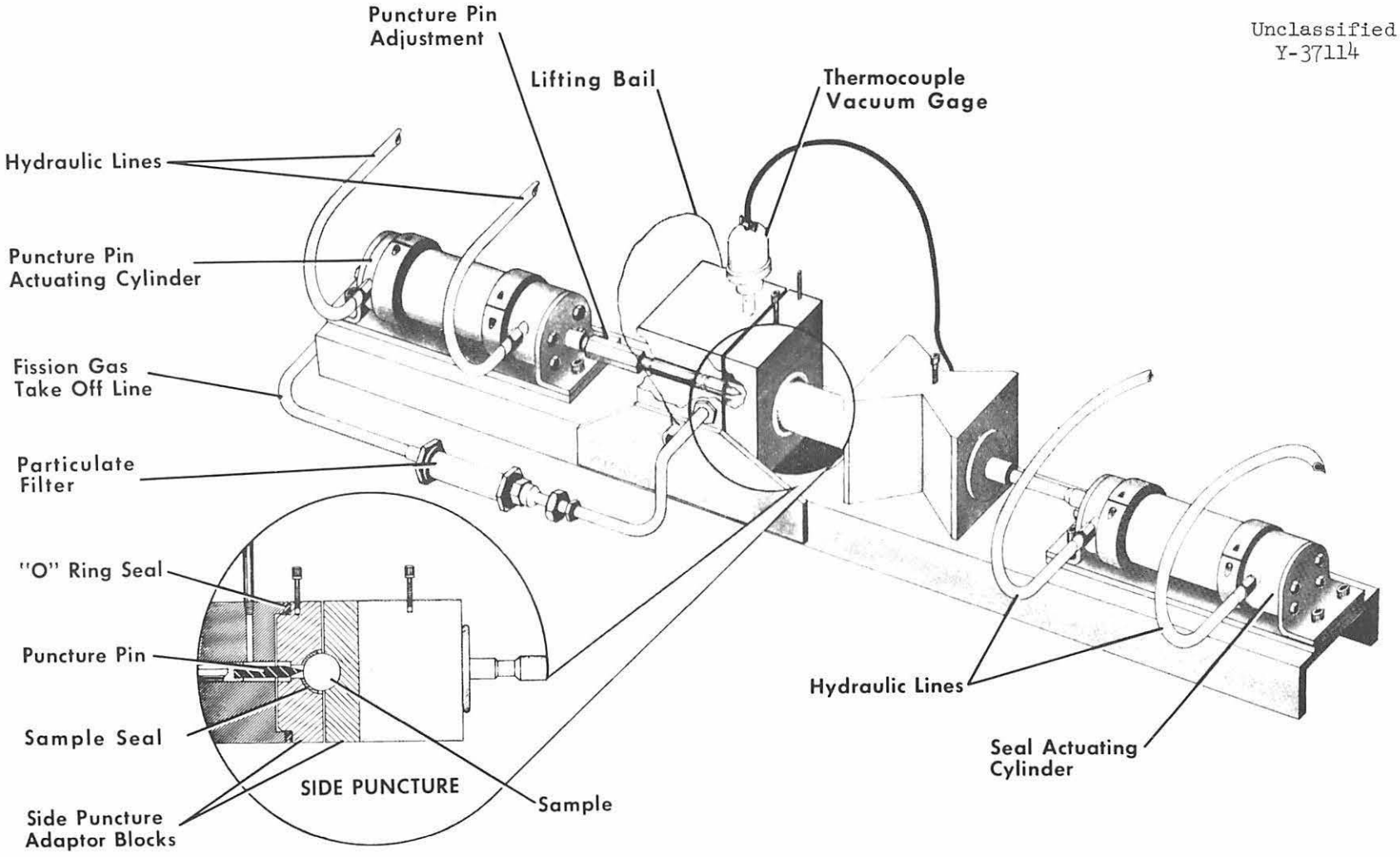

Fig. 15. Mechanism Employed at GE-Val to Puncture Fuel Tubes for Sampling Fission Gas.

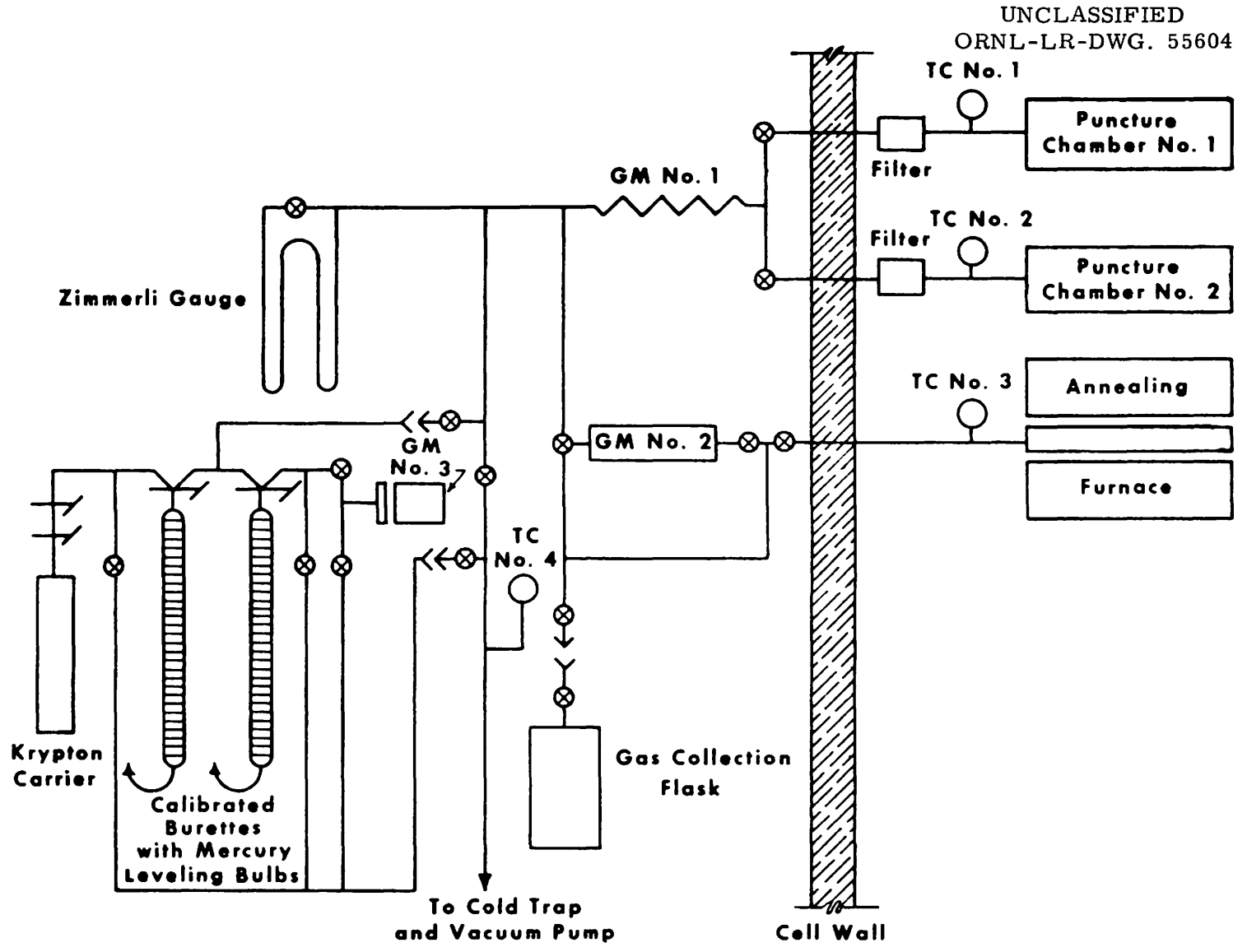

Fig. 16. Arrangement of Tube-Puncture and Gas-Collection Equipment for Fission-Gas Analyses at GE-Val.

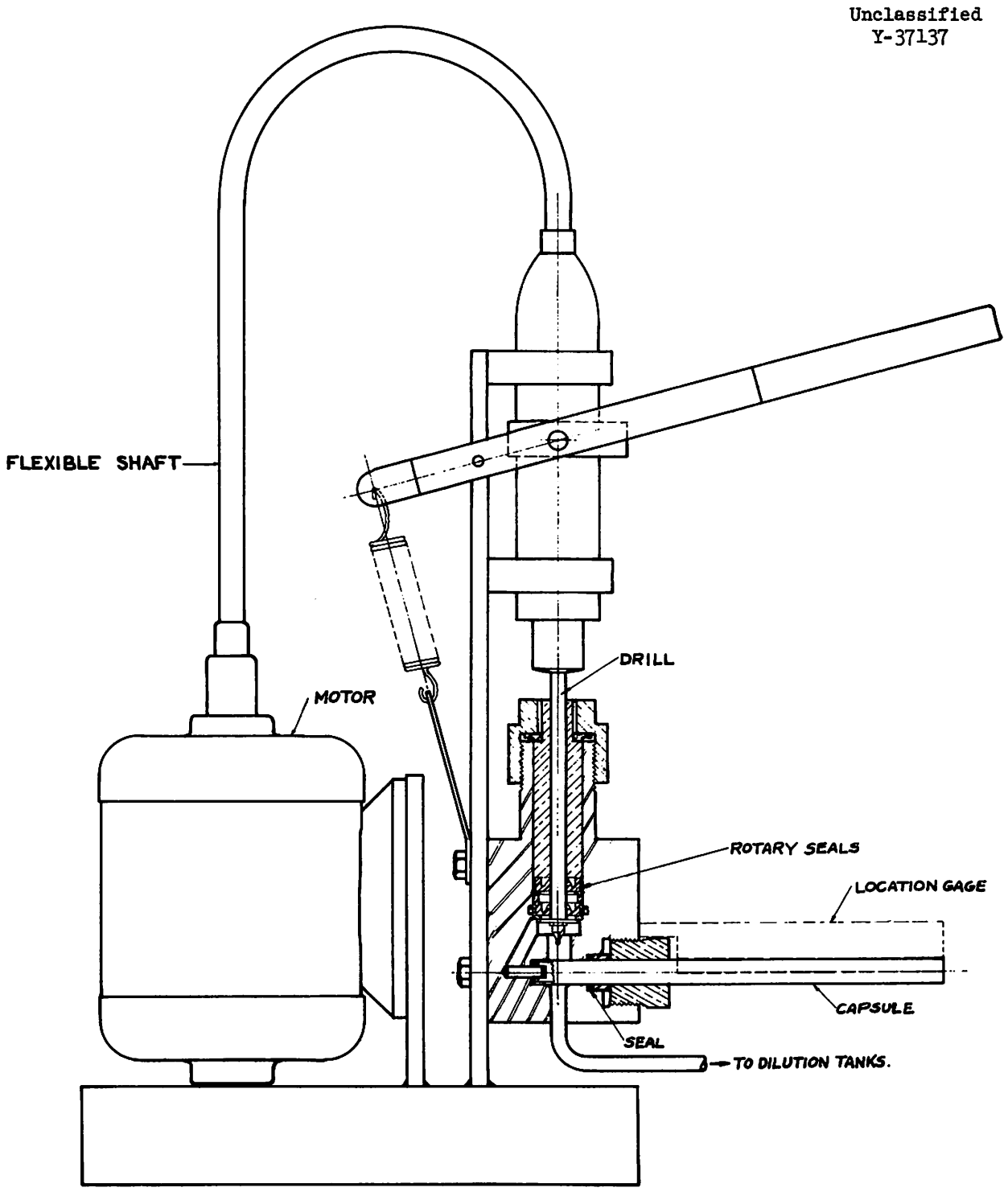

Fig. 17. Apparatus Used for Drilling Beryllium Capsules.

No significant difference in space requirements for the different systems is apparent. A minimum of 15–20 ft^2 of cell floor space is required, depending on location of the vacuum and gas-collection systems. Location of these systems outside the cell saves space and simplifies operation and maintenance. However, there is also an increase in the possibility of contamination of the working area outside the cell.

4.0 Analytical Techniques

Analytical techniques useful in evaluating fission-gas release include gamma spectrometry, mass spectrometry, pressure-volume measurements, and gas chromatography. The first three techniques are used at both ORNL and GE-VAL. Gamma spectrometry has the highest sensitivity of the above methods, expecially for short-lived gases. Three gas isotopes, Kr^{85m}, Kr^{88}, and Xe^{135} have half-lives of a few hours, while Xe^{133} and Kr^{85} have half-lives of 5.3 days and 10.3 yr, respectively. Where there is much delay between irradiation and gas analysis, only the latter are measured. Mass-spectrometric analysis yields only relative data; absolute measurements of Kr^{85} content are necessary for correlation of the stable isotope ratios. About 10^{16} atoms of a given isotope are necessary to permit mass-spectrometer analysis with a precision of ± 5%(ref 4) but only about 10^{12} atoms of Kr^{85} are necessary for a gamma-spectrometric determination of similar precision. Both analyses are recommended for fission-gas-release determinations. Gas chromatographic analyses could be substituted for mass-spectrometer analysis.

Fission-gas-pressure measurements in a known volume have been used as a means of estimating total pressure buildup in a capsule due to both radioactive and stable gases. This technique may be even more valuable for measuring pressure buildup in capsules containing beryllium oxide or beryllium, since the helium created by neutron-beryllium reactions will contribute to the total gas pressure. The prime requisites for making these measurements are a collection system of accurately known volume and a very sensitive gage to measure pressures in the 100–800 mm Hg range.

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[4] T. J. Slosek and B. Widenbaum, Fission Gases, Their Measurement and Evaluation GEAP-3440 (August 15, 1960).

The development of the fission-gas sampling and analytical equipment is being carried out in the Solid State Division, which has an active group working in this specialized field.

F. Disassembly and Cutup

In general, the technical functions discussed up to this point have been nondestructive in nature. Disassembly and cutup imply destruction, and extreme care must be exercised in performing these operations to ensure that the integrity of key features of the test article remains intact. One must be certain, for example, that critical evidence resulting from the in-reactor test is not disturbed, and that the resulting component parts are not affected by cross contamination during various cutting operations.

Operations to be performed can be classified into two broad categories: (1) those concerned with disassembly or dissection of relatively large and complex units into smaller component parts such as in the removal of fuel plates from a parallel plate assembly, the dissection of individual tubes from a tube bundle, as in the case of a heat exchanger, radiator or tubular fuel bundle, and the disassembly of an in-reactor fluid test loop; and (2) selective cutup to obtain samples or test coupons for chemical analyses, mechanical property determinations, induced-activity measurements, microstructural analyses, burnup analyses, density determinations, etc. In some instances, surface samples will be required for corrosion, crud deposition, diffusion, x-ray diffraction, and surface contamination studies.

The only two pieces of equipment planned for installation in Cell 5, which is designated for this function, are the versatile milling machine and the modified pipe cutter. These will be augmented, however, by an abrasive cut-off machine in Metallography and by the equipment available in the dismantling cell in Building 3026D for handling extremely large components.

1.0 Milling Machine

The general-purpose milling machine planned specifically for service in the HRLEL is an adaptation of a standard Cincinnati Milling Machine Company production mill. It will have a stationary rather than a movable table; hence, all motions will be transmitted via the moving head of the machine. The X motion will

be accomplished by moving the saddle on ways which are mounted permanently to the table and base. The Y motion is provided by a vertical counterweighted column attached to ways on the saddle. The Z motion comes from a ram attached by ways to the vertical column. All these motions (X, Y, and Z) are remotely operable through an electrohydraulic system. In addition to the X, Y, and Z motions, the head has a universal swivel for angle cutting. The motions of the universal swivel are not remotely operable and will be accomplished by using the master slaves and the General Mills overhead manipulators. With the exception of the base and table, this machine is designed so that it may be taken apart and removed from the cell or repaired. These component parts are mounted permanently in the cell structure to obtain machine rigidity for accuracy. The disassembly of the machine, machine repair, indexing of the head, changing of head speed, mounting tools in the head, and mounting material on the table will require special tooling. The special tooling will be done by the Laboratory and should ideally be done before the milling machine is installed in the cell.

The milling machine will be essentially the only unit installed in Cell 5. The machine will be complete and remoted as received from Cincinnati Milling Machine Company. All necessary modifications have been made to the Cell 5 design to install the machine. The machine is electromechanically controlled from a console outside the cell. The operation of the machine should be no more complex than the operation of a standard machine except for distance and remote tool usage. These two factors are enough to restrict the use of this machine to a small group of operators especially trained for this type of machine operation. It would be desirable to train these operators in a mockup. This could be accomplished after the machine is delivered to the Laboratory and before it is installed in the cell. This also would be a proper time to design, manufacture, and test the special tooling necessary for good machine operation.

The machine is designed to have the same accuracy as a standard milling machine of comparable size as described in Table I. It will occupy a space 100 in. x 118 in. x 88-7/8 in. high. Cutting tool travel of the machine is 46 in. x 20 in. x 17-3/8 in. vertical travel. The machine has its own cooling and lubrication systems and is electrically interlocked to prevent its operation

TABLE I

TESTS AND TOLERANCES FOR MILLING MACHINE

Test No.	Test	Tolerance (in.)
1	Table Flatness - Longitudinally	± 0.001/ft ± 0.0025 max over full length
2	Table Flatness - Transversely	± 0.0005/ft ± 0.001 max over full width
3	Alignment of arbor support with arbor (horizontal machine)	± 0.001/ft check at 90 deg
4	Spindle Face Axial Runout	0.0004 max
5	Spindle Face Radial Runout	0.0004 max
6	Spindle Runout - 1-1/4 in. from face 12 in. from face	0.0005 max 0.001 max
7	Table top parallel with spindle horizontal machine, or right angle to spindle (check at 90 deg), vertical machine	0.001 max in 12 in.
8	Cross movement parallel with spindle (horizontal machine)	0.001 max in 12 in.
9	Table top square with vertical movement	0.001 max in 18 in.
10	Rise and fall of table in longitudinal movement	0.001 max in 20 in.
11	T slots parallel with table movement	0.001 max in 18 in.
12	Displacement of any slide during locking	0.001 max 12 in. from spindle nose
13	Back lash in all screws	0.005 max
14	Lead error in all screws	± 0.001 in 12 in. ± 0.002 accum total

unless both the cooling system and the lubrication system are in working order. The lubrication system, the hydraulic system, and the cooling system are so designed that they may be serviced remotely through controls located outside the cell.

2.0 Pipe Cutter

There are many instances when the slow and noncontaminating action of a pipe cutter is preferred over other forms of cutting tools. A nonmechanized pipe cutter has been in service in the Postirradiation Examination Cells for some time, and has proved to be a valuable tool where close control on the depth of cut is required or where preservation of the tube surfaces is mandatory. While the abrasive cutoff wheel is an effective tool, it oftentimes impairs the integrity of the surface condition in the immediate vicinity of the cut due to the release of abrasive particles during the cutting operation. Another area where the slow-speed pipe cutter is beneficial is in the disassembly of tubular fuel elements containing refractory oxide, such as uranium monocarbide, which is pyrophoric and hygroscopic in nature. Here, again, a high-speed rotating cutter with or without water cooling is harmful due to the fact that it generates considerable heat and scatters fine material, as well as the fact that it may impair seriously the condition of the ceramic-fuel body.

A motorized pipe cutter assembly has been built for service in the HRLEL. The basic unit shown in Fig. 18 is patterned after the design successfully employed in the hot cells at the Westinghouse Test Reactor station. The new assembly contains an Oster Power Unit with appropriate renovation for remote operation. Initial testing in the mockup, however, reveals further modifications will be necessary in the positioning mechanism to improve serviceability. Upon completion of these modifications, the unit will be pressed into service to facilitate postirradiation-examination operations in Building 4501. It is expected to be extremely useful for cutting HRT piping, loop tubing, and capsule experiments.

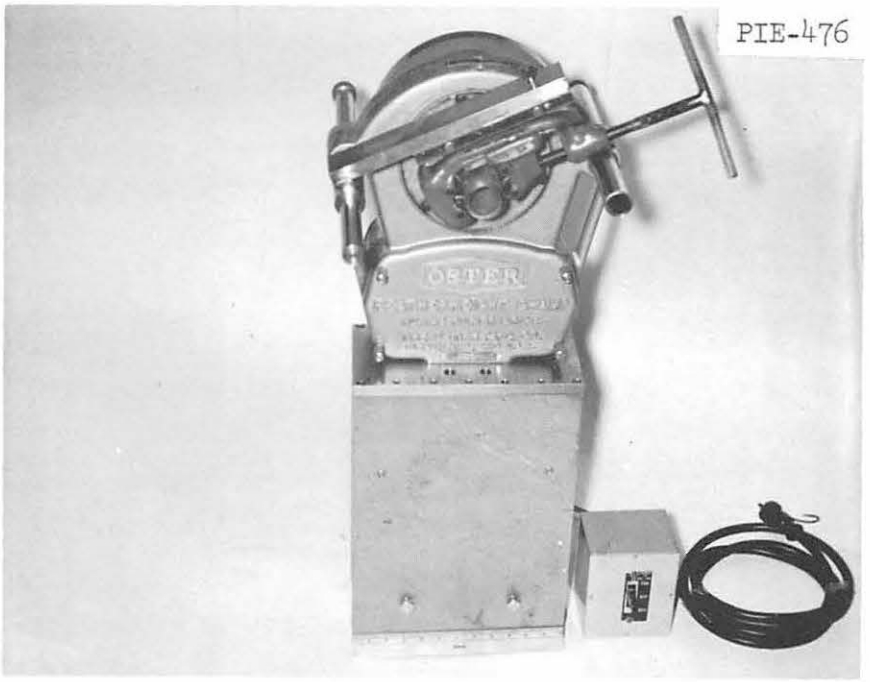

Fig. 18. Component Parts of Motorized Pipe Cutter Design for Hot-Cell Operation.

G. Corrosion Evaluation and Related Measurements

This function will be concerned primarily with chemical corrosion, mechanical erosion, crud deposition, and other surface degradation phenomena encountered in reactor service on vital reactor components, such as heat exchangers, primary vessels, fuel cladding and coolant tubes. The major objective of the evaluation will be to obtain supporting data that will give one an insight as to the possible mechanism and nature of attack: (1) uniform, due to direct chemical solution or reaction; (2) selective, due to preferential attack on specific constituents; (3) two-stage, due to sequential reaction; and (4) mass transfer, due to thermal or concentration gradients. Specific areas of work will include the identification of reaction products, measurement of the total amount of material reacted, and the determination of the rate of reaction. In addition, measurements will be made of the bulk and specific density of various products as well as an evaluation of surface topography by replication and direct observation.

The equipment in this section will be general purpose in nature, and its use for failure analyses, radiation-induced property changes, corrosion studies, and chemical analyses will be obvious. Perhaps not so obvious, but of equal importance, will be the role of the equipment in the preparation of samples for induced-activity measurements, x-ray diffraction analyses, and metallographic examination.

1.0 Weighing Equipment

This equipment is basic to the implementation of a wide variety of experimental work, such as density determinations, weight change data for corrosion evaluations, induced-activity measurements, and weighing samples for chemical and other supporting analyses. Equipment with different characteristics is required in order to obtain the proper coverage and accuracy.

1.1 Standard Analytical Balance

Wolland speedigram balances modified for remote operation will be employed for accurate weighings in the 0.5-mg to 200-g range. These balances are identical with the units now in service in Building 4501 and have a sensitivity

of ± 0.5 mg at full load. The balances occupy a space of 20 in. x 12 in. x 21 in. high and are actuated by the master-slave manipulators. Specimens can be remotely weighed at the rate of 10–15/hr by skilled technicians, and this compares favorably with a rate of 15–20/hr for cold operation. Reproducibility and accuracy are equivalent to what can be achieved in the cold state.

New electronic balances with greater sensitivity (± 0.1 mg) in the same capacity range are being investigated. In this installation a remote-control panel is located outside the shielded-cell structure and all controls, such as weight-shifting knobs, zero adjustments, and beam locks, are designed to operate by means of motors and electronically controlled circuitry. Until the reliability of operation of these units is demonstrated in the cold state, the electronically controlled balances will not be considered as replacement items.

1.2 High Capacity Balance

Higher capacity weighings and density determinations will be performed on a commercial balance built by the Lederer-Kohlbusch Company. This balance with a specially designed mounting is a revised version of a similar unit in operation at the Argonne National Laboratory. The remotized balance will have a 5-kg capacity and sensitivity of ± 0.5 mg. The unit is equipped with a chain for working in the range of less than 1 g, and will have a keyboard arrangement for applying weights up to 12 g. The principal use for this unit will be to measure density accurately by the liquid-immersion technique. A thermally insulated container that can be elevated electrically to immerse the sample for a wet weight determination is provided. The solution temperature will be monitored by means of an unimmersed thermocouple. The high capacity balance will occupy a cell area of 26 in. x 52 in. with the 48-in. portion above and 14-in. mechanism below the operating table. At present it is planned to operate the unit with the master-slave manipulators. Density determinations of 2–4/hr appear attainable with this equipment. Specimen handling time and temperature drift in the immersion bath probably will be limiting features.

2.0 Sample Defilming

At present, the degree of surface reaction of a given material with its environment is best determined by measuring the amount of unreacted material. To do this reliably, one must remove the retained scale or product of reaction. Experience has shown that in cases where the chemical reaction at the oxide-metal interface is under the influence of a cathodic potential, scale can be removed by electrochemical stripping. The temperature of the chemical bath must be controlled carefully and the current adjusted to the conditions of the surface area and specific material involved.

2.1 Electrochemical Unit

The defilming apparatus consists of an electrically heated bath into which lead anodes are inserted. Sample manipulation is accomplished by the use of an air-operated tong device which holds the sample and serves as the cathode lead. The tongs are loaded and positioned with the aid of the master-slave manipulators.

2.2 Supplementary Equipment

Two additional operations usually are required to assist in defilming specimens. Formal design of the brushing apparatus has not yet been started, although the criterion has been established and some preliminary layout work has been done. The unit is expected to occupy a cell area approx 12 in. x 12 in. and stand approx 18 in. high. The capacity will be equivalent to that obtainable with the cathodic defilming apparatus. The second additional operation is that of drying, which involves heating in a low-temperature laboratory drying oven for 30 min after immersion of the sample in a small acetone or alcohol bath. Essentially, no modification of the standard ovens which are available from stores is required.

Since the corrosive fumes from the cathodic defilming bath and the potentially explosive fumes from the solvents should not be allowed to enter the recirculated ventilation system, these items will be installed in a small hood and exhausted through the in-cell hood system. This same hood also will be used for the chemical work required in preparing specimens for induced-activity measurements.

3.0 Replication

For various reasons it has long been desirable to replicate the surface topography of critical areas, particularly in the evaluation of corrosion and erosion phenomena.

3.1 External Surfaces

Surface replication using cellulose acetate film is a well-established process, and with this as a starting point, a program was initiated to develop remote techniques. The standard Fax film was found to be too thin for both handling and decontamination reasons; therefore, a nominal 0.040-in. sheet, static- and lint-free, was substituted. The standard solvent of acetone plus a small trace of cellulose acetate was found to set too rapidly, and the acetone was replaced by methyl ethyl ketone (MEK). Methyl ethyl ketone delays the setting time sufficiently to allow for remote handling. Contact time usually varies from 1 to 5 min depending upon the sample size and geometry. A specimen 1/4 in. x 1/4 in., for instance, would require approximately one minute, while a 1 in. x 5-in. specimen would require about five minutes. Pressures in the order of 10 psi are required to obtain good replication.

Stripping the replica from the specimen has posed no problem, and with the proper contact time little or no distortion is encountered.

In order to find an effective means for decontaminating the surface of the replicas and thus lower the activity for direct viewing at a bench microscope, specimens reading a few hundred mr/hr were replicated in a shielded dry box. As was expected, repeated replication does an effective decontamination of the specimen surface. In many cases, the first few replicas are discarded and the subsequent ones are cleaner. The replica is ultrasonically cleaned in an Electrosol solution, rinsed, and checked. If further cleaning is necessary, acid etches are used in the ultrasonic tanks until the replicas are smear clean. To date, replica surfaces have been decontaminated so that they are smear clean and read less than 20 mr/hr on probing.

With the above criterion established a rig was designed and a working model was built to replicate the entire exposed surface of a metallographic

sample cut from the HRT Core Vessel. Using an air clamp to supply the required pressures, 3-in. x 3-in. x 0.040-in. cellulose acetate blanks with the MEK solvent and a 3-min contact time gave good results on the first attempt. Stripping on this rig is done by sliding the supporting plate from under the specimen and allowing the piston to push specimens through the plate, thus deflecting the cellulose acetate enough to break it free. Fine structure detail has been obtained on 95% of a surface of a specimen of 0.5 $in.^2$ in size, and this is suitable for observations under the microscope at magnifications up to 1000X.

Further refinements will be required. A dial gage must be attached to determine the depth of the replication. This is important because the depth required for good replication is limited, and an excess of this amount usually results in curling of the replica. A simple means of raising and lowering the specimen to obtain the optimum height must be added, also. With the addition of these refinements, it is anticipated that remote surface replication of "hot" specimens can be done at a rate of 3 to 4 an hour.

It has been noted that all cellulose acetate sheet does not respond in the same manner for replication work. Best results to date have been obtained with sheet material processed with the lowest degree of polymerization during manufacture. Hence, it will be necessary to qualify the specification for procurement of cellulose acetate sheet for replication work in order to assure high-quality reproduction.

3.2 Internal Surface Replication

Very preliminary development has shown that the internal surfaces of capsules, autoclaves, or pipes may be remotely replicated. Although the technique has not been firmly established, several excellent replicas have been obtained by centrifugally casting a thin coating of RTV silicone material on the inside of experimental autoclaves. The composition normally used has been modified to improve the castability for remote operations. The resulting replica is flexible and may be removed with tweezers by the master-slave manipulators. Decontamination of these replicas has not been attempted as yet but this should not be too difficult as the material does not adhere to foreign materials.

H. Metallographic Examination

Metallography usually is defined as the study of the internal structure of metals and alloys and its relation to their composition and their physical and mechanical properties. More recently, however, utilization of the basic techniques has been extended to study the internal structure of plastics, ceramics, and other solid materials. Since it investigates the spatial arrangement, it is intimately related to crystallography. Usually, the examination requires complementary information or data from such sources as x-ray diffraction, density measurements, resistivity determinations, nondestructive testing, chemical analyses, and mechanical property determinations. In performing metallographic service, the metallographer assists a materials engineer in much the same manner that the pathologist assists a medical doctor. Hence, it can be seen that metallography is one of the more potent research tools at our command to study the internal structure of materials.

The exact nature of the examination varies a great deal with the purpose and scope of the investigation. It may, for instance, take on the character of a failure analysis where the detection of evidence like abnormal strain, cracks, voids, flaws, and other forms of discontinuities are of prime importance. The objective may require a microstructural analysis where phenomena like segregation, preferred orientation, grain or crystallite size, second-phase precipitation, identification of microstructure, or change in hardness are of interest. Then, again, changes wrought by environment like surface diffusion, intergranular attack, or subsurface void formations might be of prime concern.

In general, metallographic examination involves first the selection of a sample which is representative of both the character of the material and the object of the investigation. Then, by a variety of sequential operations, such as cutting, mounting, grinding, polishing, and etching, the sample is prepared for microscopical examination and/or microhardness testing.

Metallographic techniques have been altered greatly by specialized mechanization, and as such have reduced much of the art previously required for each of the sequential operations. The artistic touch remaining, however, plus the requirement of remote operation make certain metallographic operations difficult to perform. This is particularly true in polishing and etching due to the fact

that most metals respond differently and require individual handling. In addition, radiation alters the etching characteristics of many materials and complicates the task of revealing the true structure for evidence needed in making a valid analysis.

The following section describes various pieces of metallographic equipment planned for service in the facility. Where possible, an attempt has been made to include information on the principle of operation, special remoting features, maintenance, and limitations and skill of operation required.

1.0 Abrasive Cutoff Machine

Abrasive cutting generally is employed as a secondary operation in the preparation of small samples for metallographic, chemical, and physical properties studies. The unit designed for service in Cell 4 will be capable of handling materials up to 2 in. in diameter and 12 in. in length. It will occupy a floor area of approx 22 x 42 in.

The machine assembly consists of the following component parts: (1) a motorized spindle with an arbor-mounted abrasive wheel; (2) a double-jaw vise for holding the workpiece; (3) a Plexiglass enclosure to contain the abrasive wheel and vise mechanism; (4) a hydraulic system to remotely operate the vise and enclosure shield; and (5) a recirculating coolant system to flood the cutting wheel and workpiece with coolant.

The power source is a two-speed motor of 2-hp capacity with radiation-resistant insulation and of explosion-proof design to prevent ignition of vapor. Spindle speeds of 1800 and 3600 rpm are provided to permit operation with either diamond or standard abrasive wheels. The rigidity of the system is improved by the use of super-precision ball bearings which are lubricated by oil from the hydraulic system. The assembly is designed to mount abrasive wheels up to 12 in. in diameter and 1/8 in. in thickness. A quick-change-lock mechanism to facilitate wheel replacement has been developed and satisfactorily tested in the cold metallographic laboratory.

The hydraulic system which actuates the Plexiglass enclosure shield, vise, and feed mechanisms is self-contained in the machine base to conserve

valuable cell space and minimize penetrations through the cell wall. Provision has been made also to replace remotely the hydraulic-fluid filter as well as to drain and replenish the fluid with the aid of the master-slave manipulators.

The Plexiglas box serves to contain the coolant and particulate matter dispersed during the cutting operation. Stainless steel shields are mounted inside the box to protect the Plexiglas from damage in the event of wheel breakage. The enclosure is designed so that, upon opening, the work area is exposed to permit easy access for loading and unloading operations as well as for changing abrasive wheels and general cleanup.

The liquid coolant is recirculated to conserve hot-liquid storage space. The system has a removable settling basket for trapping and removing particulate matter created by the cutting action. This system also is connected to the hot-drain system for periodic draining and flushing of the liquid-coolant sump.

Normal operating controls will be actuated from a console located at the front face of the cell. All controls are electrical and enter the cell through sealed service plugs. Primary settings for hydraulic control of the vise grip and feed-indexing speed are located at the cutting machine inside the cell and adjustments must be made with the master-slave manipulators.

2.0 Ultrasonic Cleaning Unit

Good metallographic practice requires high standards of cleanliness and previous work by Feldman[5] shows that this can be accomplished in hot-cell operation by applying power in the ultrasonic-frequency range to serve as a cleansing aid. The technique is still not fully developed, but shows considerable promise. The cavitation action formed by transmission of sonic energy through a liquid medium facilitates cleaning by removal of tightly adherent particles from both hidden and exposed surfaces of immersed objects. Besides thoroughness of cleaning, the technique offers the advantage of fast action when compared to mechanical means of cleaning.

Despite these advantages, the method has certain innate limitations. Ceramic transducers of barium titanate, which are best suited for light-duty cleaning, are subject to heat depolarization at temperatures slightly above 200°F

[5] M. I. Feldman, "New Solid State Remote Metallographic Facilities," Fourth Annual Symposium on Hot Laboratories and Equipment, Washington, D. C., September 29–30, 1955, TID 5208, p. 208.

as well as to cracking due to poor resistance to shock. Another disadvantage often encountered is that of surface deformation of soft materials like aluminum or the dislodgement of friable inclusions from the matrix. The only practical solution known for this problem is to reduce peak power which also reduces cleaning efficiency. The presence of gas in the solution impairs cleaning action. In addition, the surface of the specimen may be damaged due to bombardment by particulate matter suspended in the cleaning solution. When properly used, however, the technique is nondestructive in nature.

The equipment setup planned for service in the HRLEL is designed for continuous degassing and fluid cleanup. It is based on experimental work performed at the Bell Laboratories. The technical feasibility of the system has been demonstrated already by mockup testing in Building 4501. In fact, the initial results have been so encouraging that the unit has been pressed into service in Cell 6 of Building 3025.

Two adjacent ultrasonic transducer tanks within the cell and one ultrasonic generator located at the cell face constitute each cleaning station. The matched barium titanate transducers are operated at 40 kc with an average power level of 125 w. The tanks will be so arranged as to have a fresh supply of water fed into one tank, which will overflow into the second tank. The second tank will overflow into a hot drain.

The water flow will be controlled at the cell face and will flow continually during cleaning operations at a maximum rate of 1% of the tank volume per minute. Fresh tap water requires a degassing period of 15–20 min and, therefore, the 1% volume change per minute will not sufficiently dilute the degassed water in the first tank or grossly affect the cleaning efficiency. The degassed water from the first tank will overflow into the second tank to which a small amount of detergent will be added. It is of interest to note that although plain water requires a degassing period of 15–20 min, water to which a detergent has been added may require 60–90 min to degas. It is for this reason that the detergent is added to the second tank only.

The parts to be cleaned will be immersed in the two tanks consecutively countercurrent to the water flow. The tank which contains the detergent-water

solution will remove the bulk of the contamination while the tank containing only water will act as a final rinse. If the load on a station should become so great as to overload the tanks with contamination, a third tank with an independently controlled water supply and drain will have to be placed in line. The third tank then would become the first step in the cleaning procedure and would eliminate overloading of the other tanks in the cleaning station. The cleaning time required will vary depending on the degree of contamination, but will require usually 2 to 5 min per tank.

Each cleaning station will require a cell floor area of approx 10-1/2 x 13 in. If an additional tank is added to the station, an additional area 6-1/2 x 10-1/2 in. will be required. A total of three ultrasonic cleaning stations will be required for full scale operation. The transducers and generators for all three units have been purchased, but only one station has been fabricated to date. The remaining stations will be fabricated pending results on the operating experience with the first unit, presently located in Cell 6, Building 3025.

The care and maintenance required will be negligible except for maintaining the prescribed water volume change (which will be controlled outside of cell with the aid of a rotometer) and adding a small amount of detergent to the second tank perhaps twice every eight-hour working period. No special skill or knowledge will be required.

3.0 Electroplating Bath

One problem that always confronts the metallographer in either hot or cold work is that of edge-rounding of the specimen during the various polishing operations. This problem is of little or no consequence, if general microstructure is the objective of the investigation. However, in instances where information is required on corrosion penetration, oxide films, surface diffusion studies, failure analyses, or similar investigations that require edge examination, it is of paramount importance to keep the sample and mounting material as level as possible.

One of the best known ways to minimize rounding of the edges of metallographic specimens during polishing is to electroplate prior to mounting.

Edge rounding occurs because of a differential rate of polishing between the specimen and the mounting material. A relatively heavy electroplate shifts the location of the large differential polishing rate to the plate-mount interface, and thereby, protects the critical edge of the sample. Excellent results have been obtained in the cold-laboratory work with a nickel electroplate of an average thickness of 0.05 to 0.1 in. Nickel was selected for its hardness, ease of plating, pH of the electrolyte, position in the electrochemical series, and its relative corrosion resistance to the most frequently used chemical etchants.

An electroplating tank has been designed and fabricated for remote operation. Up to a dozen specimens can be plated simultaneously. The sample will be suspended in the electrolyte by an 0.020-in. nickel wire. The wire will be attached to the specimen by welding or using a conducting epoxy cement. The wire also serves as the electrical contact as well as a means of suspending the specimen in the electrolyte. Each sample is suspended inside a perforated polyethylene cup which, in turn, is immersed in the bath. In the event that the sample should become disconnected from the suspending wire, the polyethylene cup can be removed from the bath and the sample retrieved without disturbing the other samples being plated.

To produce a nonporous plate, it is imperative that proper agitation, current density, temperature, and pH of the bath be maintained. The bath will be agitated by a short, periodic burst of air bubbles from an air line in the bottom of the tank. Air agitation is more efficient than mechanical agitation since not only is the bath stirred to keep any chemical gradients to a minimum but the rising air bubbles sweep the samples and remove small hydrogen bubbles that form during plating and would otherwise not be removed by mechanical agitation. If the small hydrogen bubbles remained on the samples a porous plate would result. Vapors generated during operation of this unit will be exhausted through the in-cell hood system to protect the recirculated atmosphere.

Proper current density settings and the duration of the air burst will be set at the control panel. Also, proper plating temperature and electrolyte level will be maintained through automatic control. The control panel has been designed, but construction has not yet begun.

It is anticipated that the unit will require a minimum amount of care and maintenance. After a properly buffered electrolyte has been added (which already has been tried and proved in the cold laboratory) to the electroplating tank and the tank conditioned, no additional care should be required for a 6- to 12-month period.

No special skill or knowledge should be required for operation after the variables have been established.

4.0 Mounting Press

After sectioning to a desirable size, it is conventional practice to mount metallographic specimens in a suitable material to standardize the overall dimensions which serves as an aid in handling throughout the entire metallographic operation. A large variety of mounting materials is commercially available but the thermosetting, thermoplastic, and epoxy resin plastics are employed in the bulk of the work.

Requirements for hot-cell metallographic mounts are that the material must be relatively hard, resist softening below 200°F, and be chemically resistant to strong acids, alkalies, and solvents. In addition, the material must be resistant to deterioration from radiation. A preliminary study at ORNL on the stability of various mounting materials that have given excellent service in cold metallography indicates that red Bakelite and an epoxy resin can withstand a total gamma radiation dosage of 5×10^8 r without impairment.

A commercial mounting press is being renovated for remote operation. The resulting mounts will be standard right cylinders 1-1/4 in. in diameter by 3/4 in. max height. The mounting press is designed for mounting materials that require heat and pressure and has a self-contained hydraulic system that operates two opposing rams for molding. The mold is heated by a built-in resistance-type furnace and the temperature is automatically controlled. The unit will occupy a floor area no larger than 23 in. x 23 in.

The control panel that will be located at the cell face has been completed. All controls for the press, except hydraulic pressure adjustment which is on the press, are located in the control panel. The only maintenance anticipated in the unit will be to periodically check the condition of the hydraulic

oil for possible deterioration from radiation. Should either of the rams or the mold become damaged or excessively worn, remote replacement is possible.

Samples that will not withstand the heat and pressure required in the mounting press will be mounted in a liquid epoxy that cures at room temperature and reaches full hardness in 24 hr. The technique has been utilized for many years in the cold laboratory and currently is being employed remotely in Cell 6, Building 3025.

5.0 Grinding Equipment

Following mounting and preceding polishing, specimens must be ground for two reasons: (1) to remove all deleterious effects from the cutting operation, such as burring, overheating, and deformation, and (2) to produce a flat finely ground surface for polishing. An investigation is currently under way to evaluate potential methods and to select optimum equipment. It is unlikely, however, that a single method will be found to process a wide variety of materials in a time period equivalent to that required in the mounting step. The average mounting time will be approx 20 min per specimen. The following equipment is being considered for service in the facility.

5.1 Tool Grinder

Preliminary specifications covering a modified shop tool for remote grinding of standard 1-1/4-in. mounted specimens have been prepared. The grinder would employ abrasive cup wheels rather than a loose abrasive, abrasive papers, or cloths. The specimen would be fed into the wheel at a controlled rate and pressure and would be rotated while grinding to minimize smearing effects. A self-contained recirculating cooling system would be located in the base of the grinder. A floor space of approx 23 in. x 23 in. would be required; all controls would be electrical and contained in a control panel at the cell face.

This method offers the advantage of a reliable means for controlling the amount of material removed as well as that of producing an extremely flat surface which is perpendicular to the wheel axis. The wheel must be capable of producing a surface finish which would permit the specimen to advance to a polishing operation. In addition, various types and grades of wheels can be changed remotely in order to accommodate a wide variety of materials, such as

hard and soft metals, cermets, and ceramic compounds. The equipment is limited to handling one specimen at a time but this is offset somewhat by its fast grinding action.

Bids were solicited last fall and of the several proposals received only one was within the desired price range.

5.2 Automet Grinder[6]

The Automet grinders are designed as a standard metallographic unit for grinding and polishing and have been in service at this laboratory for some time. However, the grinding is confined to a batch operation, and, if for no other reason, was not considered suitable for polishing the variety of materials anticipated. This grinder has been used with moderate satisfaction in other hot metallographic installations in the United States.

The Automets employ abrasive paper discs placed on an 8-in.-diam wheel to grind five standard 1-1/4-in.-diam specimens per load. The pressure on the specimen carrier is adjustable from 5 to 60 lb or, in effect, 1 to 12 lb per sample.

After a relatively short investigation it was decided that, although the grinder produced the desired finish on the specimens, too much time was consumed in changing abrasive papers, charging and discharging operations, and maintenance. To avoid the time and effort that would be involved in redesigning the equipment, alternate grinding equipment was sought.

5.3 Polymatic Grinder[7]

As in the case of the Automet grinder, the Polymatic grinder is designed for both grinding and polishing operations. In addition, the mechanical functions appear to be more adaptable to hot-cell work. One such grinder has been modified and is shown in Fig. 19.

While the unit originally was designed to grind up to a dozen specimens at a time, a new holder has been fabricated for handling three specimens. The

[6]Marketed by Buehler, Ltd., Evanston, Illinois.

[7]Marketed by Precision Scientific Company, Chicago, Illinois.

Fig. 19. Polymatic Grinding Machine and Specimen Holder.

grinder employs abrasive paper discs, but the wheel size is 12 in. in diameter which, in effect, increases the grinding surface area by a factor of more than two over that of an 8-in.-diam wheel, thus reducing the frequency of disc changing.

Preliminary tests indicate that each grinding stage can be completed with only one abrasive disc. Also, no disassembly is required in changing abrasive discs which are held in place by a pressure-sensitive adhesive. The pressure on the samples during grinding can be adjusted by regulating the pressure to an air cylinder located on the top of the grinder. If the grinder performs satisfactorily and is accepted for the grinding operation in the metallography cells in the HRLEL the air cylinder would have to be replaced with a hydraulic system. The floor area required is approx 16 in. x 18 in.

6.0 Polishing Equipment

Polishing of a metallographic specimen carries the same objective in a hot cell as in a standard cold laboratory, i.e., the removal of the fine scratches induced during the final grinding operation and ultimate intent of producing a highly polished and scratch-free surface.

In general, several methods are necessary to accomplish this task and the over-all success is dependent upon being properly equipped to utilize a particular method to reveal a particular bit of information. Basically, the methods involve uniform metal removal from the specimen by employing: (1) very fine abrasives, (2) a chemical-polishing solution, and (3) electrolysis.

6.1 Vibratory Polisher

During the last four years, a study has been under way in the Metallographic Laboratory to find a suitable abrasive polishing procedure that removes still more of the art from this tedious operation. The bulk of the effort has centered on vibratory polishing because this technique offers the greatest potential for achieving the objective. A great deal of information has been developed, and the results have been so encouraging that at least six other laboratories have adopted the practice or are in process of converting

over to vibratory polishing. The results have been reported for both cold-laboratory and hot-cell application.[8,9,10]

A total of six vibratory polishers will be installed in Cell 3 of the HRLEL. Four will be used for standard metallographic polishing operations; these will be charged with alumina-water slurries. Two of the four polishers will be used for first-stage polishing, one for intermediate polishing, and one for final polishing. The two remaining polishers will be reserved for special polishing techniques where abrasives and vehicles other than alumina and water would be more suitable or compatible with the specimens. Vibratory polishing also is being considered for final grinding to be performed in Cell 4. At the present time, nine commercially available polishers have been purchased and modified for remote manipulation. The accompanying control panel to be located at the cell face has been completed.

The entire polishing operation has been checked in the mockup cell in Building 4501, which includes remote installation, maintenance, and polishing sequences. A typical arrangement of the polishers in the mockup cell is shown in Fig. 20. To test the equipment in a radiation environment, two units have been installed in Cell 6, Building 3025. In addition, one unit has been sent to the General Electric-Vallecitos Laboratory in Pleasanton, California, to aid in preparing ORNL specimens there.

Experience in metallography is a must in the polishing operations, because prescribed polishing times and conditions cannot be predetermined for the variety of materials expected to be processed in the HRLEL. In addition, it is impossible for inexperienced personnel to recognize the proper termination point

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[8] E. L. Long, Jr., and R. J. Gray, Preparation of Metallographic Specimens Through Vibratory Polishing, ORNL-2494 (September, 1958).

[9] E. L. Long, Jr., and R. J. Gray, "Better Metallographic Techniques - Polishing by Vibration," Metal Progress, 74(4), 145 (October, 1958).

[10] E. L. Long, Jr., J. T. Meador, and R. J. Gray, "Experience with Vibratory Polishers for Hot-Cell Application," Paper presented at the Symposium on Metallographic Specimen Preparation 63rd Annual Meeting of ASTM, July, 1960 (to be published).

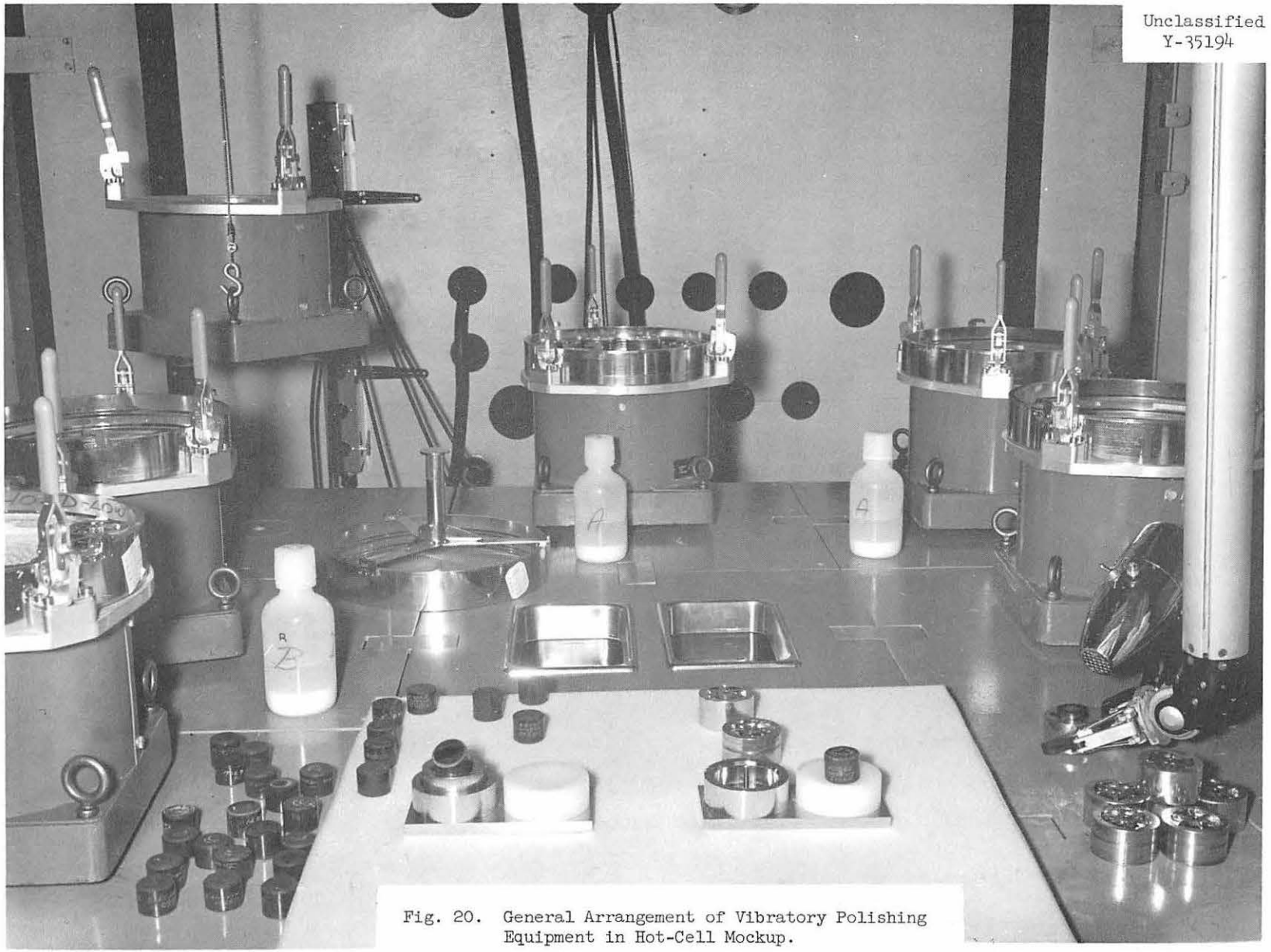

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Fig. 20. General Arrangement of Vibratory Polishing Equipment in Hot-Cell Mockup.

in all of the polishing stages. Moreover, only experienced personnel can recognize from the appearance of the specimens the need and time for maintenance of the polishing equipment, such as replacing the polishing cloths or addition of abrasive. So, even though much of the art in metallographic preparation has been mechanized through automation, a definite amount of skill will always be required to maintain quality in the finished product. To expect otherwise would be a mistake.

6.2 Electrolytic Polishing

Although electrolytic polishing is a very powerful tool in a standard metallography laboratory, it is not widely used for hot-cell work. With a proper amount of development, there is no doubt that considerable work could be accomplished by this procedure. Many types of specimens can be polished by closely controlled conditions to obtain a specimen surface free of cold-worked metal. Equally important is the fact that many specimens can be electrolytically polished in a fraction of the time consumed when conventional techniques are employed.

It must be emphasized that electropolishing has limitations. For example, it is not always possible to polish the entire microstructure in the desired uniform manner, particularly if the specimen is a multiphase alloy. In addition, electropolishing is useless where an edge or fracture examination is required due to voltage concentrations at points and edges.

A commercial electrolytic etch polisher with a separate control unit has been purchased and renovated for remote operation. The electrolyte tank and specimen table require a floor space of approx 9 in. x 14 in. The tank holds up to one liter of electrolyte and is removed easily from the table. The table contains a centrifical pump and control valve for flooding the specimen with the electrolyte at various rates. The table also contains the cathode and anode electrodes. The control console houses the power unit and allows the operator to preselect conditions, such as voltages, current densities, and polishing and/or etching cycles.

To date some modifications have been made on one electropolishing unit and this has been used successfully to polish several low-radiation level

Zircaloy specimens. Additional improvements will be required before the units are ready for in-cell use.

6.3 Chemical Polishing

This technique involves the removal of minute ridges of metal by chemical dissolution to a degree that a flat surface free of cold working results. A chemical polishing bath is placed in the cell and a mounted metallographic specimen which previously has been ground to a flat surface is immersed in the bath.

Some special equipment will be required, such as a specimen mount holder which can be attached to a cell manipulator. Chemical polishing is limited to a comparatively few metals and alloys.

7.0 Etching Equipment

Etching is the process of revealing the microstructure of metals and alloys by subjecting a highly polished surface to a reagent that produces a controlled rate of attack. To be effective, the reagent must have a differential effect on different crystals or constituents. This is ordinarily accomplished by straight chemical or electrochemical means. Vacuum cathodic etching is an exception and will be described in a subsequent section.

Etching of specimens in hot-cell work is a difficult task for several reasons: (1) the etching characteristics of a given sample vary markedly with radiation exposure; (2) most of the more frequently used reagents are unstable and must be used immediately after mixing; and (3) special provision must be made to properly remove the resulting corrosive vapors and prevent their entry into the in-cell recirculation system. Some effort to alleviate these problems has been made by various hot-cell groups throughout the country, but no satisfactory solution has been reported – at least not where a variety of materials requiring etching is involved. Some hot-cell personnel either bring the samples out of the cell with little or no shielding and employ long tongs to immerse the specimen in the etchant; while in other instances, the etchants are prepared outside and subsequently transferred into the cell. While the first case usually produces a good etch, it is a definite hazard to the operating personnel and would

be a violation of the operating philosophy planned for the facility. The second procedure would be permissible but its usefulness is limited to cases where stable etchants are involved.

7.1 Electrolytic Etching

A partial solution to the problem of etching in cell would be electrolytic etching. The majority of electrolytes for etching are stable and of a low-corrosive nature. In addition, it is often possible to electroetch with the same electrolyte employed for polishing and in a sequential procedure by adjusting voltages and current densities. Not only could many types of specimens be etched under controlled conditions but duplication of etching in a series of specimens could be achieved. Equally important is the fact that many specimens could be electrolytically etched in a fraction of the time required by conventional chemical techniques.

7.2 Vacuum Cathodic Etcher

A small remote vacuum cathodic etching unit with associated control panel has been designed and fabricated. The equipment is illustrated in Fig. 21. The in-cell table which supports the etcher and houses the vacuum pump, gages, etc., will fit into a 23-in.-square module. The panel is designed with dual controls so that two units can be operated simultaneously. Check-out tests in the mockup will begin as soon as the high-voltage connections between the etching unit and control panel are completed.

The vacuum cathodic etcher is a unit of equipment designed to bombard polished surfaces of the metallographic specimens with positively charged inert gas ions, viz., argon, krypton, at low pressures (approx 50–70 μ) and high voltages (3–10 kv). This results in an etched surface, the severity of which is proportional to the sputtering rate of the specimen. The method offers several advantages: (1) true microstructure can be determined whenever there is any question concerning the validity of microstructures obtained by direct chemical or electrochemical means; (2) dissimilar metals can be etched simultaneously at a uniform rate which is difficult to achieve by other techniques; (3) the time-consuming effort required to develop new procedures for etching new materials is

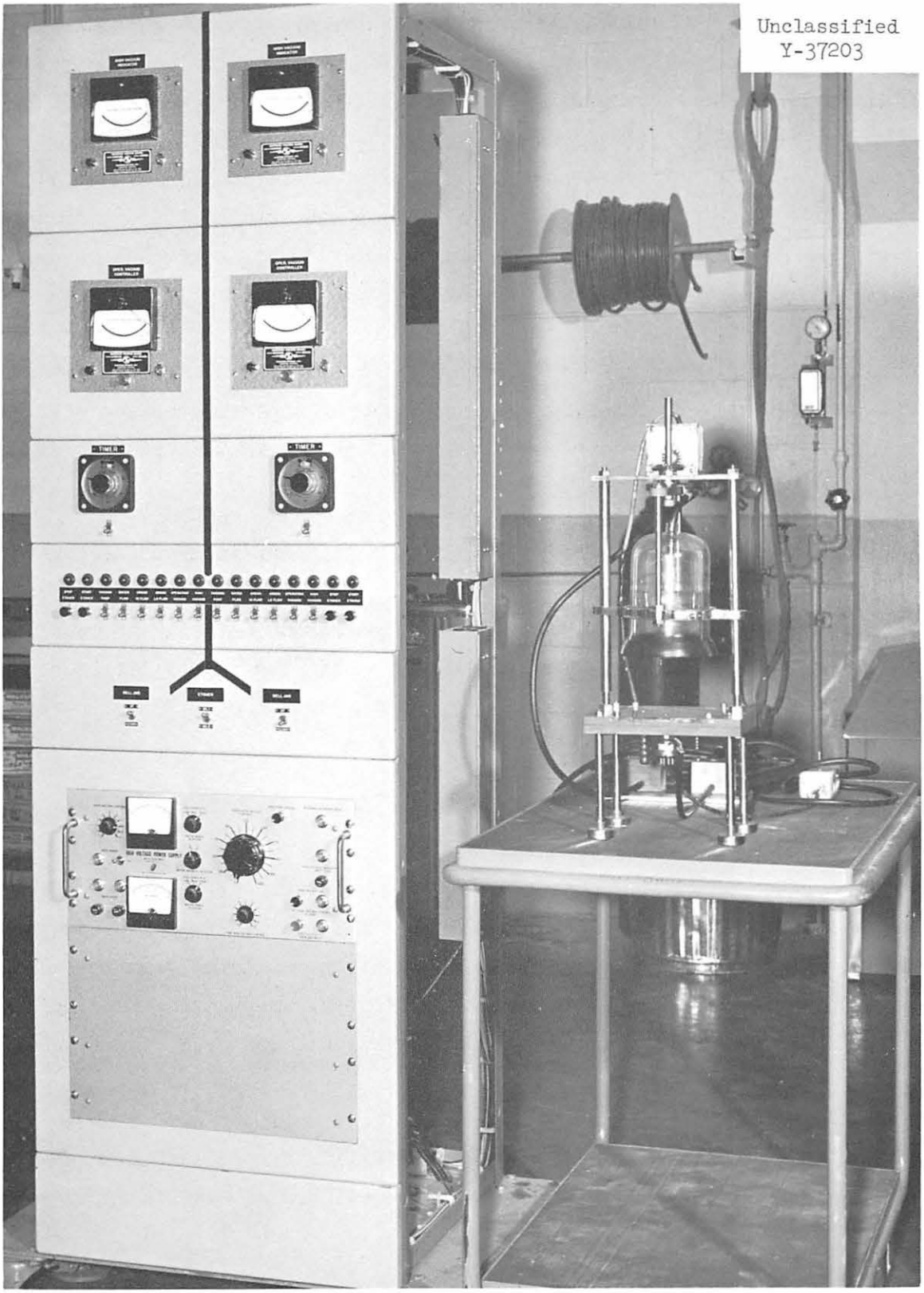

Fig. 21. Vacuum Cathodic Etcher and Control Panel.

avoided; and (4) cathodically etched surfaces are more resistant to oxidation and, hence, have longer life for examination than do surfaces etched by electrochemical means.

The major disadvantage of the technique at this time is that the specimens will have to be removed from the mount prior to etching. This removal requires the specimen to be remounted for subsequent examination on the metallographs. Some equipment development work to overcome this disadvantage will be necessary after the instrument is operable.

No special care and maintenance will be necessary except for occasionally replacing an inner glass cylinder when it becomes contaminated. Only personnel experienced in metallography and aware of the caution necessary when working with high-voltage equipment should operate the vacuum cathodic etcher.

7.3 Chemical Etching

Although it is the process most frequently used in a standard metallography laboratory, chemical etching is the least desirable method for hot-cell operations. Close observation by an experienced person normally is required and this is difficult to achieve under remote conditions. Very little equipment can be designed in advance.

8.0 Injection Molding Device

An injection molding device has been conceived to assist in the examination of ceramic fuel bodies which are subject to fracture and movement during sectioning. The design will be based on the idea of injecting a suitable plastic in liquid form into the component and allowing the plastic to solidify prior to cutting in order to preserve the internal condition resulting from in-pile service. It is anticipated that the technique will be helpful in studying "coring" due to center melting and similar in-service effects encountered with tubular fuel elements containing ceramic bodies.

An injection hardening apparatus has been built to explore the feasibility of the technique. The equipment is illustrated in Fig. 22 and consists of a tube holding and piercing mechanism along with associated ware for injecting the plastic.

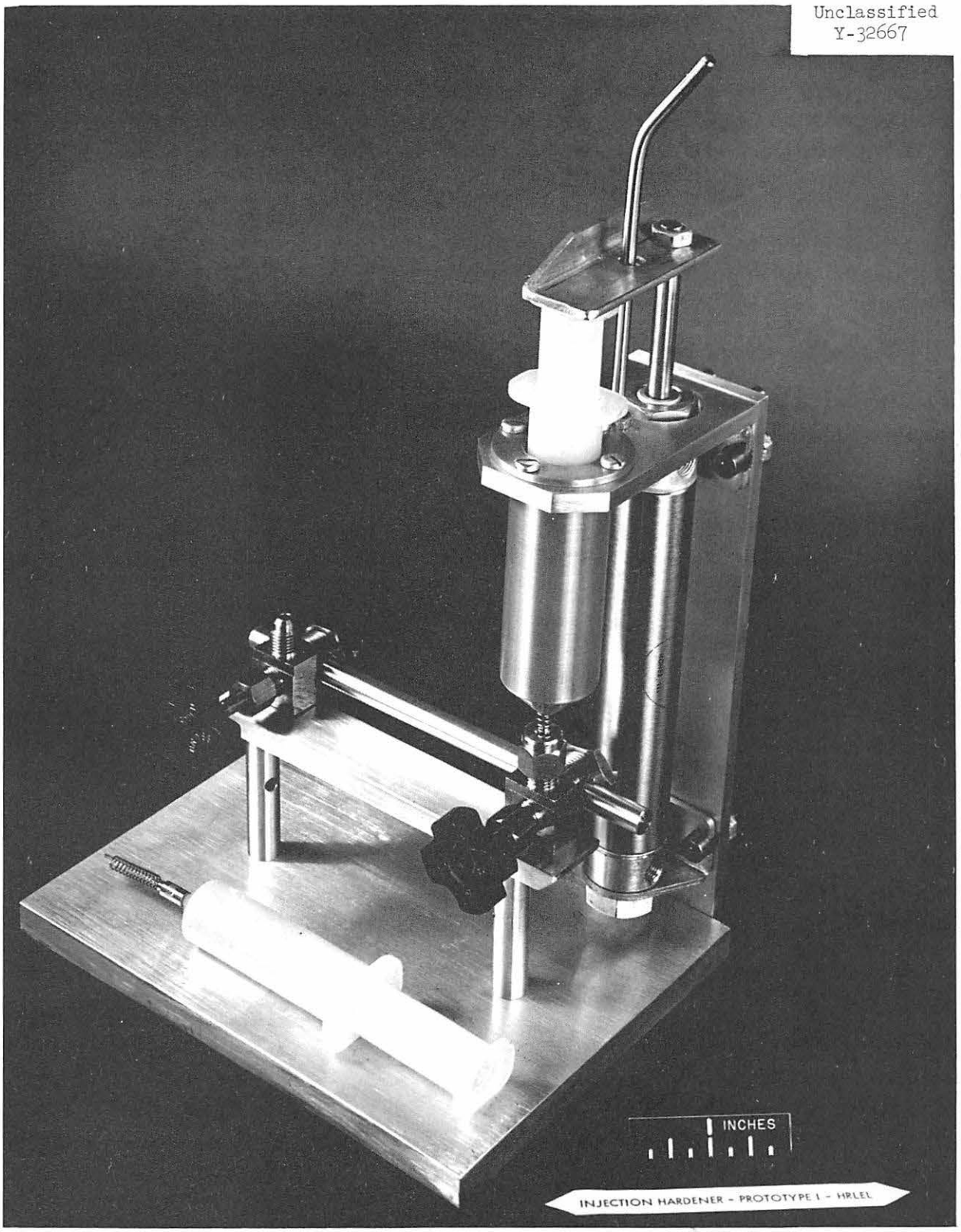

Fig. 22. Device for Piercing and Injecting Plastic into Tubular Fuel Components.

Preliminary experiments have been completed using an epoxy resin for a retaining agent. The specimen was pierced by using a standard refrigeration piercing valve at each end. One valve exit was sealed with a rubber diaphragm and a vacuum pulled through the other valve. When a vacuum of 20 μ was reached, a syringe filled with epoxy was placed in the apparatus. An air cylinder was used to force the syringe needle through the diaphragm on the valve and forced the epoxy into the specimen. Results were encouraging, but indicate that additional work must be performed before the device is ready for application in the hot cell.

9.0 Research Metallographs

A metallograph is similar to a metallurgical bench microscope in the sense that it is designed for viewing opaque materials at various levels of magnification. The incorporation of a built-in camera and other additional features, however, complicates its design far beyond that of a simple microscope. The other features vary somewhat among instruments supplied by different manufacturers, but usually are of the following nature: (1) a special mounting stand with concealed shock absorbers, (2) an inverted microscope, (3) an automatic carbon arc or mercury vapor lamp for illumination, (4) a large viewing screen for prolonged examination, and (5) provisions for bright field, dark field, phase contrast, and polarized light examinations in diverse applications.

In view of the anticipated work load and the utter dependence of the entire metallographic operation on the metallograph, several key decisions were made concerning this instrument for operation in the HRLEL: (1) that two instruments would be required, (2) that the operating characteristics and performance capabilities of these instruments would be equivalent to the standard commercial units, and (3) that both units would be designed to handle 1/2-in.-cubed specimens mounted in 1-1/4-in.-diam by 15/16-in.-high cylinders of red Bakelite or epoxy resin.

9.1 Method of Installation

Previous experience shows that there are two separate approaches to the installation of equipment for metallographic examination of radioactive materials, viz., (1) the basic unit can be placed within the cell and remotely operated by means of optical relays and electrical controls, or (2) the instrument can be annexed to the cell wall in the form of a shielded blister and essentially becomes a separate entity. The latter method of installation is preferred, for it permits one to maintain the high degree of cleanliness required as well as to physically locate certain parts of the instrument external to the shield for greater ease of operation. Consequently, this method has been adopted for installation of the metallographs.

9.2 Selection of Basic Units

Contrary to the popular belief, the purchase and modification of standard equipment is not the best solution to the problem of providing microscopic equipment for hot-cell work. Most laboratories have followed this practice and, to their regret, have found it to be extremely expensive. In most cases, the basic unit had to be altered to such an extent that it no longer functioned as intended. Consequently, metallographic units will be built according to ORNL specifications for service in the facility.

Considerable care was exercised in the establishment of the basic criteria as well as in the selection of reputable firms for construction of the instruments. Potential suppliers were furnished with a detailed specification, covering a shielded metallograph with camera and light source located external to the shield, and requested to bid. A review of the proposals indicated that more versatility could be attained by purchasing separate units from different manufacturers rather than buying two identical units. Hence, purchase orders were awarded to the Bausch & Lomb Optical Company of Rochester, New York, and the W. J. Hacker Company of East Caldwell, New Jersey, representing the Reichart Company of Austria, for construction of the desired units.

A schematic view of the new model metallograph to be supplied by Bausch & Lomb is illustrated in Fig. 23. This metallograph features very high light transmission characteristics with excellent provision for examination under polarized light. All objective lenses are turret mounted to facilitate remote

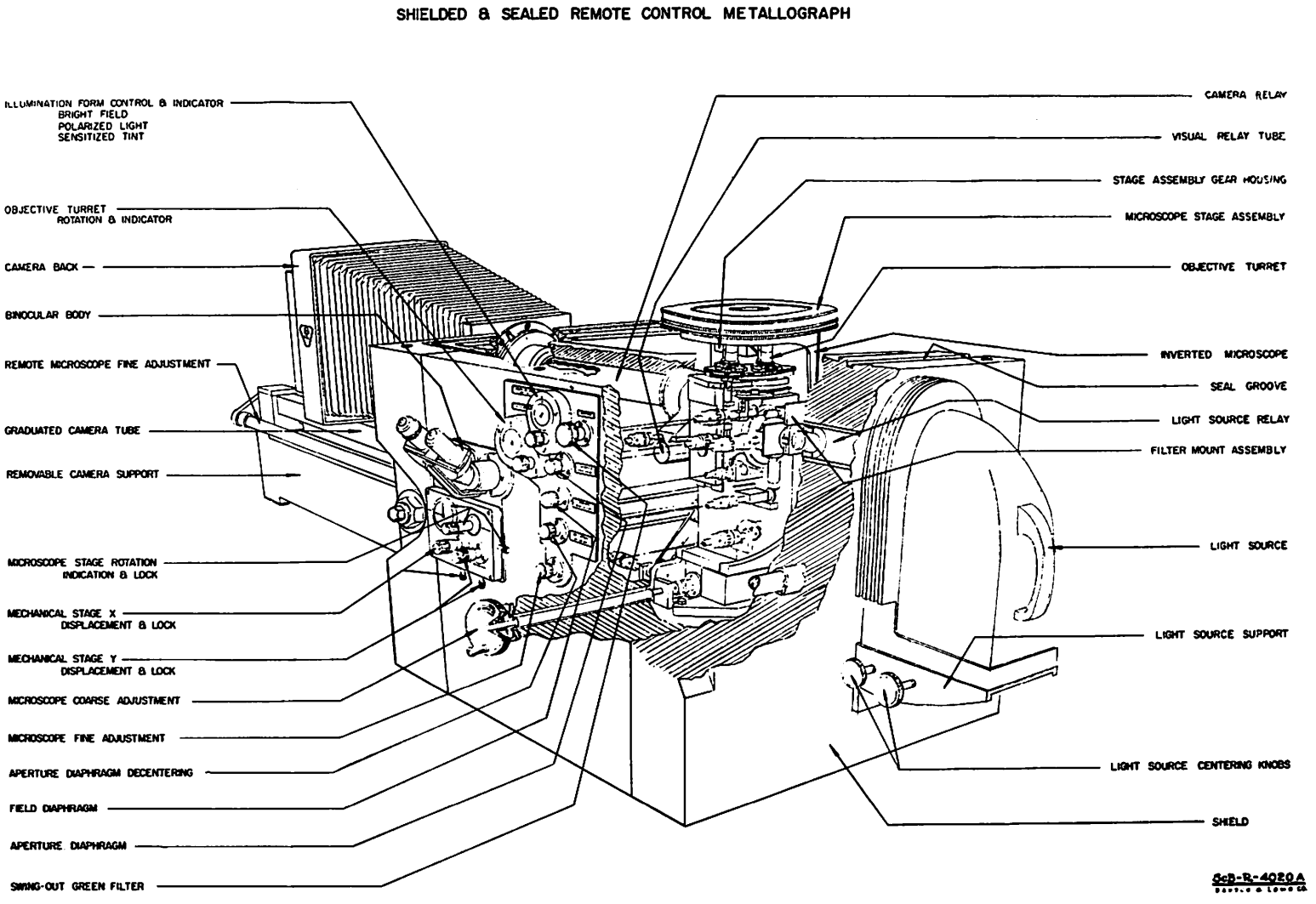

Fig. 23. Shielded and Sealed Remote Control Metallograph by Bausch & Lomb Company.

changing. As mentioned earlier, the entire unit will be mounted as a shielded appendage to the cell wall and requires a floor space of 21-5/8 in. by 90 in. outside of the operating cell, with the longer dimension being adjacent to the cell wall. A port through the cell wall is provided for the transfer of specimens.

A line drawing showing the general design of the Reichart Telatom instrument is given in Fig. 24. The over-all arrangement of installation will be similar to that of the Bausch & Lomb unit. One of the accessories on this unit is phase contrast which is not available on the Bausch & Lomb unit.

9.3 Shielding

The mechanical stage, inverted microscope, and associated gear will be completely contained in a shielded box to protect the observer. The box will be constructed of 8-in.-thick steel plate which has been subjected to 100% ultrasonic inspection. It will be securely attached and sealed to a steel plate mounted at the cell wall containing the transfer port.[11] A small lead-glass window has been provided in the steel cover plate for access viewing of the mechanical stage and specimen positioner. The interior of the box at this location will be illuminated by an incandescent lamp.

9.4 Transfer Mechanism

The cylindrical specimens will be moved through the cell penetration and positioned on the mechanical stage for optical examination by means of a transfer mechanism. The motor drive and associated mechanism will be supported from the sleeve in the cell wall.

9.5 Control

There is a total of some 14 different motions or adjustments that must be remotely controlled in the operation of the metallograph. These are concerned

[11] The cell wall then becomes the back shield for the box. An 8-in.-thick steel cover plate forms the lid of the shield box. Current plans call for fabrication of the cover plate at the same facility scheduled to fabricate the balance of the shield in order to obtain better matching of shield components as well as to realize some financial savings.

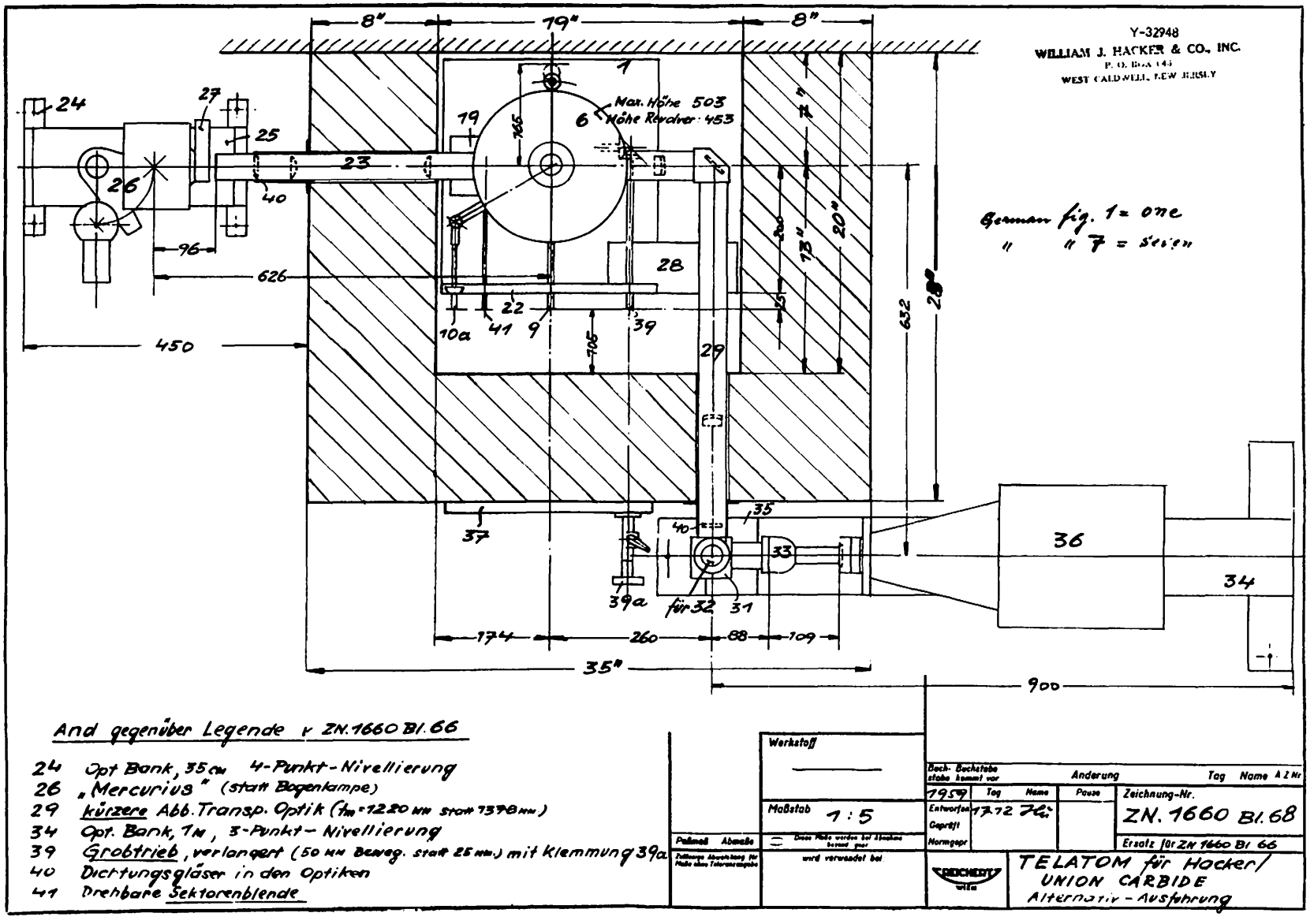

Fig. 24. Plan of the Reichart Telatom Unit Designed for Hot-Cell Service.

with specimen rotation and translation, fine- and coarse-focusing adjustment, changing of objectives, aperture diaphragm focusing and adjustment, field diaphragm adjustment, changing filters, and altering the form of illumination for bright field, polarized light, and sensitive tint.

The control system is designed so that all controls are centrally located for the convenience of the operator. All control motions are translated via sealed rotary motions rather than by reciprocal means to assure containment of cell atmosphere. The shielded system is designed to withstand a negative pressure of one inch of water, and air leakage inward at the rotary seals must not exceed 0.2 cc per day per shaft under ambient conditions of STP.

9.6 Preoperational Testing

Preoperational testing on the integrity of the shield and seal mechanism will be made at the site selected by the manufacturer. The specimen transfer mechanism will be transported to the site where the completely shielded microscope will be tested for operating and performance characteristics. If unforeseen alterations are required, arrangements can best be made at the test site.

9.7 Maintenance

Although both microscopes have been designed for a minimum of upkeep, adequate provisions have been made for maintenance. Because the unit is located externally to the operating cell, the background level of radiation should be very low in the absence of a mounted specimen; and minor changes, such as replacing objective lenses, can be accomplished by converting the viewing window in the cover to a glove port. If more extensive maintenance is required, the entire cover could be removed. In each instance plastic bags would be utilized to prevent any spreading of particulate matter.

Maintenance for the specimen transfer mechanism can be accomplished by withdrawing the entire mechanism into the cell for repair or replacement.

9.8 Operation

Personnel especially trained for remote metallographic work will be required in the operation of these units. Observations can be made by other

personnel, of course, but most setups and manipulations should be made by trained workers so as to prevent unnecessary damage to the delicate and valuable equipment.

9.9 Status of Metallographs

The Bausch & Lomb Company and W. J. Hacker Company (agent for the Austrian Reichart Company) have progressed to the extent that preoperational tests can be made in April or May, 1961. Following a satisfactory demonstration of performance and acceptance, the units will be stored until they can be installed in the facility.

10.0 Hardness Testing Equipment

The ability of a material to resist indentation under static load is one measure of hardness, and measurement of this property affords a simple and rapid means for control and inspection in the processing of various materials as well as to provide a general indication of the structural character of some materials. The technique of hardness testing is often employed in the metallurgical shop to control the degree of cold work or heat treatment in the manufacture of products. The resulting data also can be correlated with mechanical property data, but interpretations of this nature are risky unless properly correlated with other supporting information from compositional and microstructural analyses.

A microhardness tester will be installed as a separate appendage for service in the HRLEL in a manner similar to the installation of the metallographs. In addition, an extended range macrohardness unit which is capable of operation with the master-slave manipulators will be located in cell.

10.1 Microhardness Tester

In contrast to the purchase arrangements for the metallographs, an unshielded, partially remoted microhardness tester was purchased under the trade name of Kentron Remote Microhardness Tester. Shielding and completion of the remotization were performed at ORNL. A physical arrangement of the basic equipment with remote control is shown mocked up in a simulated cell wall in

Fig. 25. The unit is completely shielded with 8-in.-thick steel plate and is located contiguously to the same cell as the metallographs but on the mezzanine. The unit requires a floor space of 27-1/2 in. by 46 in. with the longer dimension being along the cell wall. A wall-penetration port and space have been provided adjacent to the unit for installation of similar equipment in the future. In a fashion similar to the metallograph, the 1-1/4 in. by 15/16 in. cylindrically mounted metallographic specimen is transported from the cell interior and positioned on the hardness tester via a transfer train.

Minor maintenance can be accomplished by removing one of two viewing windows and converting the opening to a glove port. Major maintenance requires the removal of an end shield plate within a large plastic bag. Maintenance of the specimen transfer train is accomplished by removal of the train into the cell for established repair procedures.

Due to the remotized features of the microhardness tester, only thoroughly trained personnel would be permitted to operate this unit.

The unit is complete except for the electrical control panel for the weight load, microscope illumination, and stage elevation. Preoperational tests have been made with the unit positioned in the steel shield.

10.2 Extended Range Hardness Tester

A macrohardness tester capable of performing superficial and standard Rockwell hardness testing work is shown in Fig. 26. The unit requires a space of 16 in. by 18 in. in Cell 4. The as-purchased unit is adaptable to remote operation with a minimum of alteration. Operation of the unit will be limited to experienced manipulator operators. Major care and maintenance will require complete removal of the unit.

I. X-Ray Diffraction Analysis

X rays have become an important tool for the analysis and study of matter. By diffraction a large variety of crystalline substances can be identified. X-ray diffraction also can be used to reveal crystallite size, orientation, and strain.

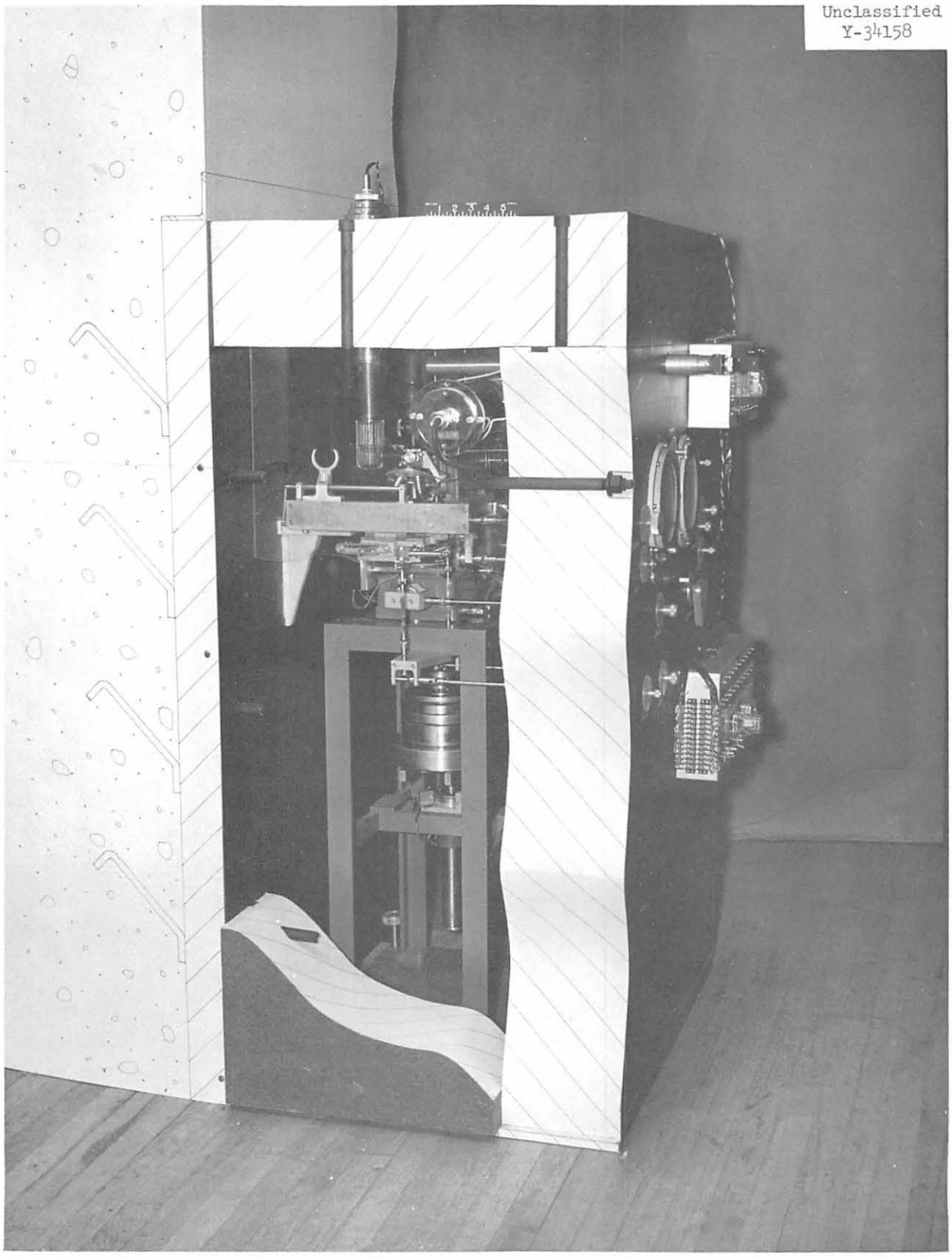

Fig. 25. Appended Remote Kentron Hardness Tester and Shield.

Fig. 26. Extended Range Hardness Tester for In-Cell Service.

It is our general contention that the potential of this basic research tool has not been fully exploited in hot-cell work, and it is our specific intention that this be done. In general terms, therefore, the purpose of the x-ray diffraction system scheduled for installation in the facility will be to record and interpret useful x-ray diffraction patterns of polycrystalline radioactive materials.

1.0 Definition of Terms

To indicate the manner in which this purpose will be accomplished, a definition of terms is necessary.

1.1 Materials

The HRLEL X-Ray Diffraction Facility has been designed to examine only solid or powdered polycrystalline materials which can be contained in standard 1.250-in. diam, 0.75 to 1.00-in.-high cylindrical Hysol or red Bakelite mounts, such as are to be employed in metallography.

1.2 Radioactivity

It has been assumed that the mounted diffraction samples may emit alpha, beta, and/or gamma radiation in a broad energy spectrum. Maximum gamma activity equivalent to 20 curies of Co^{60} (E = 1 Mev, approximate dose = 120 r/hr at 1 ft) has been anticipated.

1.3 Recording of Useful X-Ray Diffraction Patterns

Existing facilities for x-ray diffraction examination of highly radioactive materials have simply placed commercially available x-ray tubes, goniometers, and primary detectors inside shielded cells where operation and maintenance of all components must be accomplished through manipulators. Since the operating philosophy of the HRLEL is one of complete containment with rigidly limited cell access and, since existing diffraction facilities invariably have been plagued by the necessity to physically enter cells for maintenance or alignment procedures too intricate for manipulators, a departure from the precedent was indicated.

This departure has centered on the design of a special x-ray diffraction goniometer specifically for the HRLEL. The North American Philips Company is completing the detailed design and will construct the goniometer.

The basic concept is one of a shielded cell projection in which diffraction specimens will be positioned by a remote transfer mechanism. The position of the diffraction specimen in the projection will coincide with the geometric center of an external goniometer which will simultaneously rotate an x-ray tube and a primary detector so as to record the diffraction pattern of the specimen. A double advantage is thereby gained in (1) conservation of cell space and (2) ease of maintenance of external components.

1.4 Interpretation of Patterns

In this area the function of the HRLEL X-Ray Diffraction Facility will be exactly analogous to any other x-ray diffraction laboratory. It is expected that the operator will have sufficient technical training to perform any desired analyses of the recorded diffraction patterns. Such analyses may include phase identification, lattice parameter measurements, and estimates of particle size, strain, or faulting from peak profile and displacement measurements. One technically competent operator should be sufficient for the facility. With reasonably efficient programing, it seems likely that four to six diffraction examinations per day might be performed.

1.5 Space Requirement

The equipment will occupy virtually no cell space, but will require a 20 to 30 ft^2 area on the second-floor elevation above and to the side of Cell 1.

2.0 X-Ray Diffraction Equipment

While these basic definitions serve to indicate the manner in which the purpose of the HRLEL X-Ray Diffraction Facility will be accomplished, several points connected with the equipment itself may be discussed in greater detail.

2.1 Transfer Mechanism

This system will bring mounted diffraction specimens from Cell 1 to a second-floor elevation where the diffraction examination will be performed. It

will be capable of fully remote operation. Disassembly of the transfer mechanism, its housing, and its shielding will be effected so that complete containment will always be possible. At the upper limit of travel of the transfer mechanism, there will be a locating device to align the specimen face with the center of the goniometer.

2.2 The Goniometer

The diffraction specimen and its holder will be positioned inside an alpha-tight beryllium-windowed projection which is sealed against leakage of particulate matter. The interior of this projection, while in the environment of the high-level cells by virtue of the transfer mechanism coupling, will be isolated from the environment of the rest of the goniometer insofar as exchange of particulate matter is concerned. The diffraction specimen will be stationary inside the projection while, outside the projection, the x-ray tube and primary detector will execute equal and opposite angular rotational movements at either of two optional scanning speeds (1 or 0.1 deg of 2θ/min).

2.3 Shielding

To avoid the necessity of a bulky, expensive biological shield surrounding the entire goniometer, a method has been devised whereby the biological shield may be concentrated around the specimen-containing projection at the center of the goniometer. This is, in reality, a movable double shield which protects all areas except for strictly defined solid angles in which the primary and diffracted x-ray beams are contained. The shielding concept leaves the x-ray tube and primary detector completely accessible for maintenance and alignment. It requires additional shielding about the x-ray tube head and the primary detector unit, of course, but shielding about the latter would be necessary regardless of the location of the biological shield. In fact, placement of the biological shield at the center of the goniometer actually reduces the local detector shielding needed.

Since such a central biological shield must be accommodated within reasonable goniometer dimensions, it is proposed that plated depleted uranium be used as the shielding material at critical sites.

2.4 Primary Detector

While the sensitivity and accuracy of the goniometer should be equal to, or better than, that of any commercially available cold-laboratory instrument, the ultimate utility of the hot-laboratory apparatus will rest in its ability to discriminate the desired diffracted x-ray photons from the background radioactivity of the specimen itself. Such discrimination may be accomplished either by diverting the desired x-ray photons into a shielded primary detector through a monochromating crystal, or by using the discriminating characteristics of special detectors (e.g., scintillation or proportional counters). In existing hot-cell x-ray diffraction facilities, the former solution, together with its attendant 90% loss in intensity of the diffracted x-ray beam, has been adopted universally.

To yield a versatile, yet compact primary detector unit, both methods of discrimination should be available for selection based on the nature of the specimen activity. A simple design for such a detector unit has been formulated. It may use either scintillation or proportional counters with or without monochromation of the diffracted x-ray beam. A change in the mode of operation from one combination to any other desired combination may be achieved in minutes and without any loss in accuracy or sensitivity. Design and construction of the primary detectors and their associated scaling and recording circuits are being carried out by the Instruments and Controls Division at ORNL.

Since the detection unit is readily available for service and maintenance, it is anticipated that many examinations, particularly of specimens containing only small amounts of the material of interest, will be made without monochromation of the diffracted x-ray beam. This should result in greatly improved sensitivity of the apparatus for specimens of this kind.

J. Mechanical Property Determinations

As the title infers, this function is concerned with mechanical property measurements. The activity is largely confined to the planning stage at the present moment. No firm plans for equipment purchases will be made until firmer commitments from the various in-pile experimental programs are available and

it is known whether or not these demands can be handled in the existing in-cell equipment located in Building 3025.

Two major pieces of equipment have been considered in the general plans. These are the tension-compression machine and the impact tester which are described briefly below. In order to properly interpret data resulting from testing radioactive specimens, it will be absolutely necessary that cold tests be run on the same lot of material for the purpose of direct comparison.

1.0 Tension-Compression Machine

This will be a universal-type machine designed for performing tensile tests, bend and compression tests, strain and load cycling (fatigue), and other tests that may require load and/or strain measurements. The only machine known to have the necessary versatility in this application is the Instron machine. The capabilities of this equipment are discussed in the literature by J. C. Wilson et al.[12]

The Instron Engineering Corporation has developed an adaptation of the machine for hot-cell use that is sold commercially. Initial criteria for the equipment and accessories have been established. The in-cell portion of the machine requires a space 3 ft x 5 ft and is mounted on casters or wheels so that it may be readily moved about if necessary. The capacity of such a machine in terms of output data is difficult to estimate; however, it is probable that several simple tensile tests (less than ten) could be performed per day. More complicated tests would require more time.

2.0 Impact Tester

An impact tester is used to study the properties of materials in bending under high rates of loading. The machine consists of a calibrated pendulum that is caused to swing through a prescribed arc striking a small

[12] J. C. Wilson, R. G. Berggren, and W. W. Davis, "Tension Testing of Radioactive Specimens," Fourth Annual Symposium on Hot Laboratories and Equipment, Supplement 1, Washington, D. C., (September, 1955).

specimen. The energy absorbed by the specimen is measured. The machine requires a space of approx 2 ft x 3 ft when not in operation. Because of the pendulum swing, a space 2 ft x 7 ft is required during operation of the machine.

A full-size Charpy and a subsize Izod machine, both having remotized features, are on hand and available for HRLEL use. The Izod machine will require a space approx 2 ft x 4 ft during operation.

K. Charging and Discharging

As indicated in the facility description, special provisions have been made for charging and discharging the cell complex with irradiated articles, equipment, tools, and various waste products. Associated with these provisions are certain pieces of equipment to permit the safe handling and transportation of these various products. Equipment of this nature includes the in-cell canning device and a decontamination station as well as transport carriers.

Experience in performing hot-cell work has shown that the generation of solid waste as a by-product of various experimental operations presents a serious disposal problem. Approximately 15 gal/day of intermediate activity-level waste are handled in the operation of a seven-cell complex at Savannah River. At Hanford, the Metallurgy Cell complex produces from 16 to 20 ft^3 of waste per week. Most of this waste will have a gamma activity of less than 20 r/hr at one foot. Packaging of this waste and safely transporting it to the disposal area is almost a continuous operation.

Bulk waste of this nature will be removed from the Cell complex via the 14.5-in. transfer station. Cans, 14 in. in diameter and up to 39 in. long, will collect the waste in individual operating areas. These cans with lids in place will be transferred by the cell transfer system to the charging cell. At this point the cans will be sealed, decontaminated by ultrasonic cleaning, and placed in the transfer station. The mechanism is designed so that the final rinsing operation is performed in the station air lock. The cans will then be moved directly into a preplaced carrier which will provide 3 in. of lead shielding. This carrier should weigh approx 6 tons. Approximately 4 cans per day are expected to be passed through this station.

High-level waste and sections from experiments to be stored or transferred to other operations will be handled through the 6.5-in.-transfer station. The cans will be 6 in. in diameter and up to 40 in. long. A carrier is being designed with 10-1/2 in. of lead shielding, or a mass equivalent to the cell walls. Approximately two cans per day are expected to pass through this station.

Both carriers will be usable in either a horizontal or vertical orientation. The smaller carrier may be designed with doors at both ends to increase its flexibility and thus permit easier movement of irradiated products to and from the interim storage wells.

The majority of work items being introduced into the cell will flow directly from the carriers into the transfer stations. As has been outlined[13] larger items can be loaded through the shielding door and air-lock system located between the above-described stations.

Design of the canning equipment, decontamination bath, and waste carriers is in the preliminary stage at this time. A single decontamination bath is proposed. Inquiries are being sent to manufacturers in the hope that a single can-sealing station can be developed to accommodate closures of either diameter.

L. In-Cell Equipment Summary

A summary of all major pieces of in-cell equipment required in the initial operation of the facility is presented in Table II. The equipment items are listed according to function. Information also is presented on the quantity required, status of design, procurement, fabrication, and instrumentation as of December 1, 1960. The current status of funding is given also.

IV. BUILDING SUPPORT EQUIPMENT

A. Radiation Safety Equipment

Various measures have been taken in the design of the facility to safeguard operating personnel against radiological hazards. Yet these measures, which form the initial lines of defense against the insidious danger, must be coupled with a well-designed detection and alarm system in order to be effective and

[13] Part II, "Description of Facility," p. 4 of this report.

Table II
BUILDING 3525 EXPERIMENTAL EQUIPMENT STATUS AS OF 12-1-60

Equipment Items by Function	Quantity	Design	Procurement	Fabrication	Instrumentation	Mockup Testing	Funding			Remarks
							Estimated	Authorized	Expended	
A. General Observation										
Kollmorgen periscope	4	Complete	On hand	In process	Not required	Complete		37,750	37,750	
Seal sleeve for above	16	Complete	On hand	Complete	Not required			22,000		
Shield plugs for above	11	Complete			Not required	Not required	3,230	None		
Bausch and Lomb stereomicroscope	3	In process	On order	In process	Not required			82,600	31,008	
Seal sleeve for above	3	Complete	On order	In process	Not required					
Mechanical stage for above	2	Complete	Complete	Complete	In process					
Questar telescope	1		On hand			In process			1,300	Under development testing by PIE Group
Television camera and receiver		Pending					7,000	None		Requirement to be established after building occupancy
B. Mensuration										
Standard gage blocks	1 set	Not required	Complete	Not required	Not required	Not required		1,200	1,200	
Additional tooling		Preliminary		Not authorized	Not authorized			None		
C. Nondestructive Testing										
Immersion tank and scanner	1	Complete	Complete	In process	In process	No progress	38,550	33,550	32,125	
Ultrasonic resonance	1						18,000	None		
Ultrasonic pulse echo	1						24,000	None		
Ultrasonic elastic constant	1						21,900	None		
Eddy current (thickness)	1	In process	Partial				10,200	3,150	3,150	Design development
Eddy current (electrical cond)	1	In process	Partial				14,500	3,965	3,965	Design development
D. Fuel Burnup and Induced Activity Analysis										
Positioning device	1	In process						None		
Gamma-ray spectrometer	1	In process	On hand	In process	In process			41,000	36,074	Instrumentation and design
Collimator for above	1	In process						None		
E. Fission Gas Sampling and Analysis										
Piercing device	1							None		Responsibility for this equipment has been transferred to EGCR Program
Gas collection system	1							None		
Heat treating furnaces		Not authorized		Not authorized	Not authorized			None		
F. Disassembly and Cutup										
Milling machine	1	Complete	On order	In process	In process		102,000	97,750	1,198	By Cincinnati Milling Machine Company
Oil tank for above	1	Complete		Not authorized	Not authorized		7,100	None		Safe storage of coolant
Milling machine accessories							1,600	None		Tooling estimated, no fixtures included
Pipe cutter	1	In process	On hand	In process	In process					Being constructed for current PIE operations
G. Corrosion Evaluation, Etc.										
Welland balance	2	In process	On hand		Not started		5,000	3,300	3,300	
Density balance (high capacity)	1	In process	On order	In process	Not started		9,000	9,000	5,915	
Drying oven	1	Not required	Stores item	Not started	Not started			None		

Table II (continued)

Equipment Items by Function	Quantity	Design	Procurement	Fabrication	Instrumentation	Mockup Testing	Funding			Remarks
							Estimated	Authorized	Expended	
G. Corrosion Evaluation, Etc.										
Refilming pot	1 unit	Complete	On hand	Complete	In process		4,300	4,300	3,579	
Ultrasonic cleaner	2	In process						None		Development testing in current PIE operation
Replication press	1	In process	On hand	In process	In process			None		Under development testing by PIE Group
H. Metallographic Examination										
Cutoff machine	1	Complete	On hand	In process	In process	Not started	28,400	27,400	24,442	
Ultrasonic cleaner	6	Complete	On hand	Complete	In process		6,000	2,950	2,950	Development testing in Building 3025, cell 6
Electroplating bath	1	Complete	On hand	Complete	In process		8,550	8,550	6,882	
Powermet mounting press	1	Complete	On hand	Complete	In process	Not started	11,600	9,570	10,759	
Rough grinder	1	Not started					7,000	None		Preliminary inquiries in process
Automet polisher	2	Pending	On hand					700	700	
Syntron polisher	10	Complete	On hand	Complete	Complete	In process		12,500	12,901	Development testing in Building 3025, cell 6
Specimen holder		In process		Complete	Not required	In process	2,000	2,000	2,008	Development testing in Building 3025, cell 6
Cathodic etcher	1	In process		In process	Complete		14,150	14,150	11,393	Being tested in Building 2000
Electrolytic etch and polish	1	Preliminary		In process	Not started			None		
Injection molding device	1	Pending		Pending	Pending			None		Pending
Balphot metallograph	1		On hand					4,500	4,500	Pending
Bausch and Lomb metallograph	1	In process	On order	In process	In process	Not required				By Bausch and Lomb and ORNL
Reichert metallograph	1	In process	On order	In process	In process	Not required	95,500	90,000	23,671	By Reichert and ORNL
Transfer mechanisms for above	2	In process	On order	In process	In process	Not required				
Transfer tubes for above	2	Complete	On hand	Complete	Not required	Not required				ORNL supplied, contractor installed
Mounting plates for above	2	Complete	On hand	Complete	Not required	Not required				ORNL supplied, contractor installed
Kentron microhardness tester	1	Complete	On hand	In process	In process	In process	47,000	44,600	42,831	
Transfer tubes for above	2	Complete	On hand	Complete	In process					ORNL supplied, contractor installed
Mounting plates for above	2	Complete	On hand	Complete						ORNL supplied, contractor installed
Extended range hardness tester	1	In process	On hand					1,003	1,003	
Carbon replication apparatus	1	In process		In process	In process		12,000	None		
Specimen holder storage		Complete		Complete	Not required	In process	600	None		
Specimen storage		In process			Not required			None		
Specimen driers		In process						None		
Research metallograph	1	Complete	On hand					12,000	12,000	For comparative cold examinations
Spot welder		In process						None		
Microscope relay	2						2,000	None		For use with periscopes
I. X-Ray Diffraction Analysis										
Spectrometer	1	In process	On order	In process	In process		97,000	97,000	15,953	By Philips Electronic and ORNL
Transfer tube	1	Complete	Complete	Complete		Not required				ORNL supplied, contractor installed
Transfer mechanism	1	In process	On order	In process	In process					ORNL supplied, contractor installed

Table II (continued)

Equipment Items by Function	Quantity	Design	Procurement	Fabrication	Instrumentation	Mockup Testing	Funding			Remarks
							Estimated	Authorized	Expended	
J. Mechanical Property determination										
Instron tensile machine	1						37,000	None		
Impact tester	2							None		May be available from Solid State Division
K. Charging and Discharging										
General Mills cranes and manipulators	3 sets	Complete	Partial (2)	Partial (2)	Not required	In process				One additional unit required by construction project
General Mills accessories		Not authorized						None		For maintenance operation only
Master slave manipulators	32	In process	On order			In process				Construction project funds
In cell lighting		In process				In process				Construction project funds
Cell ventilation duct tie-in		In process								Construction project funds
Transfer tube shield plug	1	Complete		In process	Not required	Not required		None		
Decontamination equipment		In process		In process	In process	In process		None		Decontamination studies by PIE Group
Can sealer	1 or 2	In process						None		
Plastic bag sealer	1	Not required						None		
Service sleeve shield plugs		Complete	In process			In process				Construction project funds
Master slave manipulator guard	1	In process					110	None		For prototype testing only
In-cell microphone								None		
14½-inch-ID carriers	2	In process						None		
6½-inch-ID carriers	1	In process						None		
Miscellaneous cell maintenance equipment		In process						None		
Cell work tables	90	In process						None		As required by mockup operation
Ion chambers (in cell)	2						4,000	None		

give proper warning to personnel in the event of a failure or mishap. The personnel warning system will include high-level gamma alarm and constant air monitoring equipment as well as contamination detectors such as hand and foot counters. The needs for these types of equipment have been discussed with qualified Health Physics and Instrument Division personnel.

At present, the preliminary design criteria have been established and are being reviewed by the recently established committee on Radiation Safety Instrumentation. The plans call for a network of instruments to provide local alarms and, in some instances, remote indications of unusual radiation conditions at a central panel. A few of these instruments will be connected with the ventilation control panel in order to actuate the controls and place the building in a state of emergency containment.

The identity and location of various pieces of equipment in the monitoring system are shown in Fig. 27. A summary of needed equipment along with their function and scope of coverage is presented in Table III.

B. Intercommunication System

Experience has shown that an intercommunication system between various operating stations is an invaluable aid in the discharging of certain duties in a safe and efficient manner. This is particularly true in the execution of tasks where team members are isolated from one another by a barrier, such as in-cell work requiring members to be stationed at both the front and back of the cell bank. The necessary conduit and junction boxes for installation of such a system have been included in the construction contract.

Specifications for the necessary equipment and the distribution pattern have been developed in cooperation with the Instrument Division. Only those units known to be absolutely necessary will be included in the original installation, but provisions will be made in the wiring for installation of additional units as the need develops with operational experience.

C. In-Cell Microphones

Experience in remote operations has shown that operator fatigue can be reduced and efficiency improved in a number of operations if provisions are made

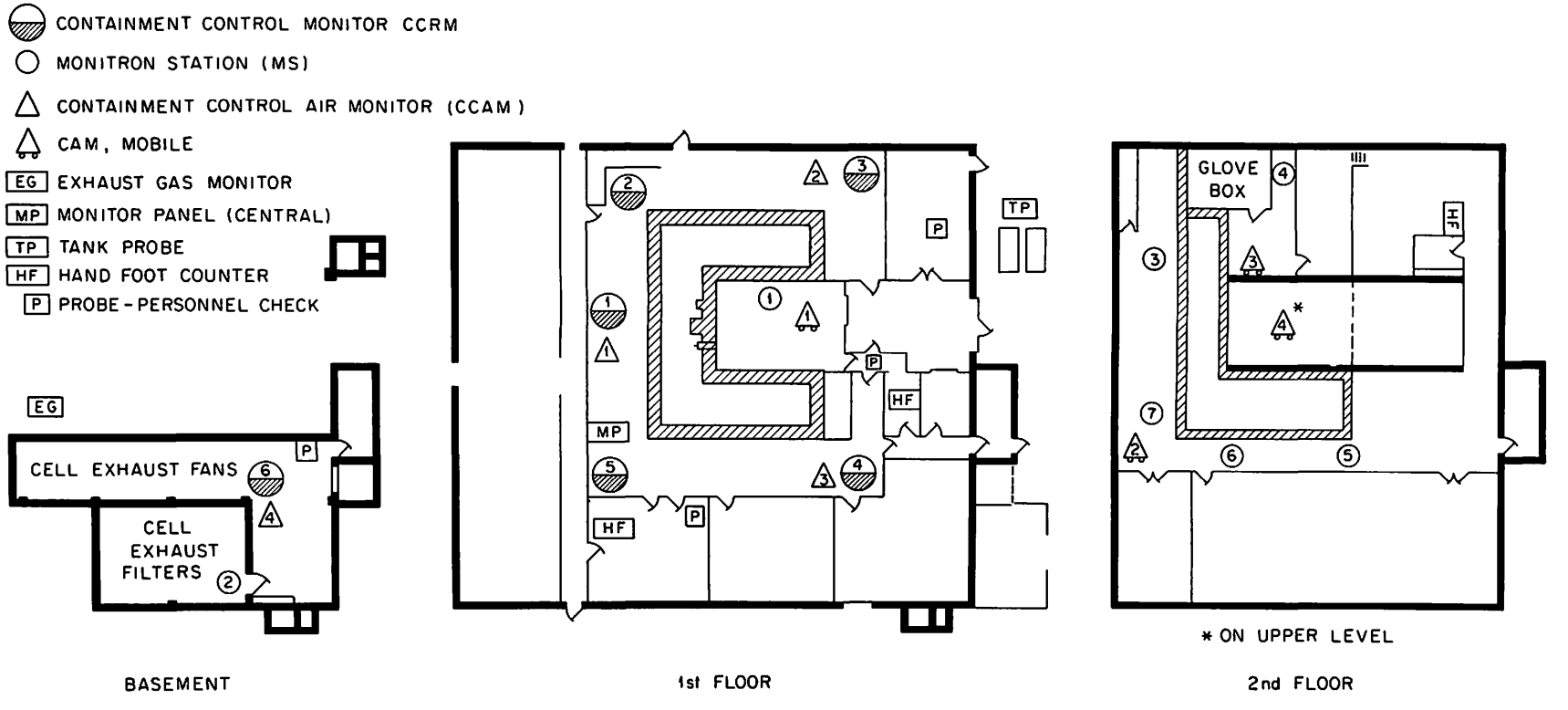

Fig. 27. Radiation Monitoring System, Building 3525.

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TABLE III. RADIATION MONITORING SYSTEM – BUILDING 3525

Symbol	Name	Function	Instrument Failure		Intermediate Radiation Level		High Radiation Level		Containment Control	Quantity				
			Light Indicator	Audible Alarm	Light Indicator	Audible Alarm	Light Indicator	Audible Alarm		Basement	1st Floor	2nd Floor	Upper Level	Total
⊘	CCRM	β-γ Containment Control Radiation Monitor	L P	L	L P	L	L P	L P B	Yes	1	5	0	0	6
△	CCAM	β-γ Containment Control Air Monitor	L P	L	L P	L	L P	L P B	Yes	1	3	0	0	4
○	MS	β-γ Radiation Monitor Station	L P	L	L P	L	P		No	1	1	5	0	7
⚠	CAM	Continuous Air Monitor Mobile	L	L	L	L	L	L	No	0	1	2	1	4
MP	MP	Monitor Panel with Alarm Indicators and Recorders								0	1	0	0	1
EG	EGM	Exhaust Gas Monitor	P	P	P	P	P	P	Yes	1	0	0	0	1
TP	TP	β-γ Probe in Hot Waste Tank			P		P		No	0	1	0	0	1
P	PSP	Personnel Survey Probe	L		L		L	L	No	1	3	0	0	4
HF	HFC	Hand and Foot Counter	L		L		L	L	No	0	2	1	0	3

L = at local detector, P = on monitor panel, B = throughout building.
All monitors which indicate at the monitor panel also record there

for in-cell listening. No provision has been made for this requirement as yet because of the short lead time required to obtain and install necessary equipment. The service sleeves and conduit, for instance, are available for running leads from an in-cell microphone to the operating face of the cell bank.

D. Status of Building Support Equipment

The current status and funding for various items needed in support of operating the over-all facility are presented in Table IV.

V. OPERATION AND MANAGEMENT

While the topic of operational management has not been discussed up to this point, one could hardly have designed and equipped a facility of this nature with only rudimentary thoughts on the subject. In fact, considerable time and effort have been devoted to the critical problem of providing a sound plan of operation for the facility. The experience accumulated in the Post-irradiation Examination Laboratory and the Solid State hot cells, for instance, was reviewed carefully. In addition, practices utilized in the operation of hot cells located at other installations were examined. Under close scrutiny, it soon became evident that the facilities with the best reputation had one thing in common – a similar policy on operational management that was evolved through experience.[14,15]

The general plan proposed for operation of the High Radiation Level Examination Laboratory is described below. It is based primarily on Laboratory needs, facility design, metallurgical nature of work, level of technical competence desired, and hot-cell experience gained at various laboratories.

A. Operating Philosophy

The main goal or mission of the facility will be to provide technical assistance in a safe, efficient, and competent manner. Hence, the facility will

[14] J. M. Davis and E. D. Grazzini, "Operational Experience in the Components Development Hot Cells at Atomics International," TID-7599, Proceedings of the Eighth Conference on Hot Laboratories and Equipment, San Francisco, California, December 13–15, 1960, p. 316.

[15] J. H. Saling, E. C. Lush, R. N. Eddy, and J. E. Gates, "Changes in the Design and Operational Management of Battelle's Hot Cell Facility," Ibid, p. 324.

TABLE IV

BUILDING 3525 SUPPORT EQUIPMENT
STATUS AS OF 12-1-60

Item	Design	Funding ($)			Remarks
		Estimated	Authorized	Expended	
Radiation Monitoring System	In Process	99 000	none		Being reviewed by committee
Intercommunication	In Process	36 500	none		Preliminary bids will be requested
Hot Drain Continuation	In Process	65 000	65 000	4 620	
Furniture	Not Required		none		
Darkroom Equipment	Complete	13 800	7 300	7 300	Additional funds of 6500 required

be run as a service-type function to obtain the postirradiation data needed in support of the various research and development programs under way at the Laboratory. The general direction and scope of the work to be performed will come from the program sponsor or an affiliated representative assigned the responsibility to coordinate the over-all experimental effort. The responsibility for actual implementation of the hot-cell work, however, will rest primarily with the regular staff at the facility. In areas of examination involving highly specialized technique or equipment developed by the experimenter, space will be made available and the required assistance provided.

In general, the program coordinator would not be a member of the facility staff, but his presence would be expected during the implementation of important phases of work so that he could observe results and alter technical direction, if necessary. In this manner, he fulfills his duty and maintains technical control.

The facility will be manned with technically oriented people, and close ties with similar functions in the cold laboratories of the Metallurgy Division will be maintained to ensure a high degree of technical competence. Since the bulk of the operations will be performed by technicians, a close cooperative arrangement is deemed advisable to avoid stagnation and guarantee that the latest techniques and equipment are employed as well as to assist in the interpretation of data. In addition, an integrated operation under direct technical management is planned to assure the attainment of sound and accurate data.

In many respects, the facility will operate as a separate entity. For the most part, it will provide its own equipment, manpower, operational procedure for detection and measurement, and handle supporting operations such as maintenance, decontamination, and waste disposal with very little outside assistance. Operating personnel will be welded into a team to gain high morale and improve performance. In other words, the facility assumes the responsibility for safe and efficient operation with its main charter in life being to provide technical service of a high quality with a minimum of cost and effort.

B. Organization and Management

The organization planned for operation of the HRLEL is rather simple and straightforward. It embodies a line operating force and a technical staff reporting to a single head. The lines of authority and responsibility will be as clear-cut as possible, in order to avoid duplication of effort, improper coverage, and split responsibility.

The manpower requirements for the operation of the facility are listed in Table V. It is estimated that a total of 36 people will be required to operate the facility on a one-shift basis. In addition, seven craft people and one person from Health Physics Division on loan to the facility will be required in the over-all operation. It is more likely, however, that the facility will be operated on a three-shift basis, i.e., two regular shifts with a small crew for maintenance and renovation on the third shift. The number of people required for full-fledged operation on this basis is estimated to be approx 48. Actual startup operation will commence with a reduced force, however, in order to feel the way and add people as the situation demands.

The technical staff of three people will be composed of professional people trained in metallurgy, physical chemistry, mechanical engineering, or related fields. Their function will be: (1) to perform hazard analyses, criticality, and shielding calculations; (2) design and development of special equipment; and (3) compilation of experimental data for reporting. Another important aspect of their work will be to coordinate the requirements of postirradiation examinations with preirradiation design to ensure that the needed data can be obtained in a reliable and economical manner. They will also serve in an advisory capacity on various matters concerned with planning, scheduling, operating procedures, and safety.

The operational force will be composed mostly of technicians and a few professional people for guidance. This staff will be responsible for remote manipulations, and all hot-cell operations requiring the service of the facility. This includes decontamination activities, remote maintenance, waste disposal, and the surveillance of the examinations and evaluations. The nucleus for this

TABLE V

MANPOWER REQUIREMENTS FOR OPERATION OF BUILDING 3525

A. Technical and Administrative Staff		Professional	Nonprofessional
Supervision		2	
Technical Review and Planning		3	
Secretarial			1
Accountability			1
B. Operational Force			
Function	**Location**		
Metallography	Cell 1 Right Bank	1	5
Metallography	Cell 2 Right Bank		
Metallography	Cell 3 Right Bank		
Metallography	Cell 4 Right Bank		
Disassembly and Cutup	Cell 5 Center Bank	2	7
Mechanical Properties Determination	Cell 6 Center Bank		
Charging and Discharging	Cell 7 Center Bank		
Fission Gas Analysis	Cell 8 Center Bank		
Nondestructive Testing	Cell 9 Center Bank		
Physical Property Determination	Cell 10 Left Bank	1	5
Descaling and Chemical Operations	Cell 11 Left Bank		
Weighing and Density Determinations	Cell 12 Left Bank		
Mensuration and Gamma Spectrometry	Cell 13 Left Bank		
Decontamination and Maintenance	2nd Floor	1	7
X-Ray Diffraction Analysis	2nd Floor		
Photographic Support Service	1st Floor		
	Total	10	26

C. Supporting Personnel	
Function	**Number**
Health Physics Monitor Survey	1
Machinists	2
Electricians	1
Instrument Mechanic	1
Pipe Fitter	1
Millwrights	2

force will be drawn from current operations under way in the PIE Laboratory and Building 3025. It will be supplemented with additional personnel carefully screened for mechanical aptitude, dexterity, versatility, and keen perception to search for the unusual.

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