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The New Sandia Primary Standards Facility

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THE NEW SANDIA PRIMARY STANDARDS FACILITY

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ABSTRACT

A new facility is being constructed for the Primary Standards Laboratory (PSL) at Sandia National Laboratories in Albuquerque, New Mexico. Features of the final design are at the state of the art and were developed over a number of years of study and design effort. Based on experience and evaluation of anticipated needs, a philosophy was established for the design and followed through the effort. A temperature control limit of ±0.01°C is required for some of the dimensional measuring spaces; isolation from vibration and electromagnetic interference (EMI) are required for all measurement spaces. The requirements for the facility and the principal design features are presented.

INTRODUCTION

Sandia National Laboratories operates the Primary Standards Laboratory (PSL) for the Department of Energy Nuclear Weapons Complex. The present facility is principally housed in a three story building which was occupied, with other organizations, in 1960. Since that time, expansion of need has necessitated locating some calibration functions in other, less capable facilities. The principal facility, which was described by Baxter[1] and O'Neal[2], was quite advanced for its time but does not meet current or future needs. Replacement of obsolete measuring equipment, extension of measurement capability to additional disciplines and to higher precision levels, and deterioration of environmental control equipment have made this facility marginal in meeting today's demanding requirements.

For some years, plans have been under way for a new facility to meet today's requirements and to be sufficiently flexible to cover changes in the foreseeable future. The design philosophy and features established in a 1982-1984 conceptual design study[3] have been the mainstays of the actual

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design effort. The contract for construction was awarded September, 1990, and building has been under way since then. As this paper is offered, a few months remain before completion of the basic facility and the process of occupancy can begin. Accordingly, this paper covers the facility requirements, the design philosophy, and the basic features designed to meet these requirements.

THE DESIGN PHILOSOPHY

Early in the conceptual study, a philosophy was developed to guide the design effort. The principal features of the design philosophy are:

1. Establishment of the environmental requirements and review of the nature and effects of the various environmental factors,
2. A review of the status of current technology and the experience in overcoming environmental problems, and
3. Applying the maximum design effort to those factors for which correction is most difficult as an add-on.

In brief, the philosophy was based on a graded risk approach with maximum design effort to be placed on those requirements most difficult to achieve. Electrical power supply, temperature set point and degree of control, and air flow pattern and rate are relatively easy to change providing only moderate changes are required. Inadequacy of space and problems from EMI are somewhat more difficult to correct. Change of humidity level and isolation from vibration are most difficult to address as an afterthought.

Humidity level is established by design of the heating, ventilating and air conditioning (HVAC) equipment and the basic operation of the HVAC was established early on. A considerable early effort was invested in checking vibration levels and designing laboratory floor pads for high vibration isolation. A considerable effort was also invested to insure adequate environmental control and to minimize possible interaction between environments of individual laboratory spaces.

THE NEW FACILITY

The design for the new facility is of a single story, sloped roof building with about 2,118 m^2 (22,800 ft^2) of laboratory space plus space for offices, computer, lunchroom, shipping and receiving, storage and the complex mechanical equipment rooms necessary for the environmental control equipment (the total floor space is over 4180 m^2 (45,000 ft^2)). In addition to the PSL laboratory spaces, space was included for the electrical calibration operation of the Sandia Standards Laboratory (SSL), which provides general calibration for Sandia organizations.

An artists view of the building is shown in Fig. 1. General construction of the basic building is of reinforced concrete and steel. The outside wall sections are of tilt-up design, welded into place after erection, and were cast on site. A sloped standing-seam metal roof was selected to present minimum reaction to wind and low water leak probability. A mezzanine over the central corridor contains the environmental equipment for the laboratory spaces. To achieve the environmental control required, the environment surrounding the laboratory spaces is also controlled. Fig. 2. is a

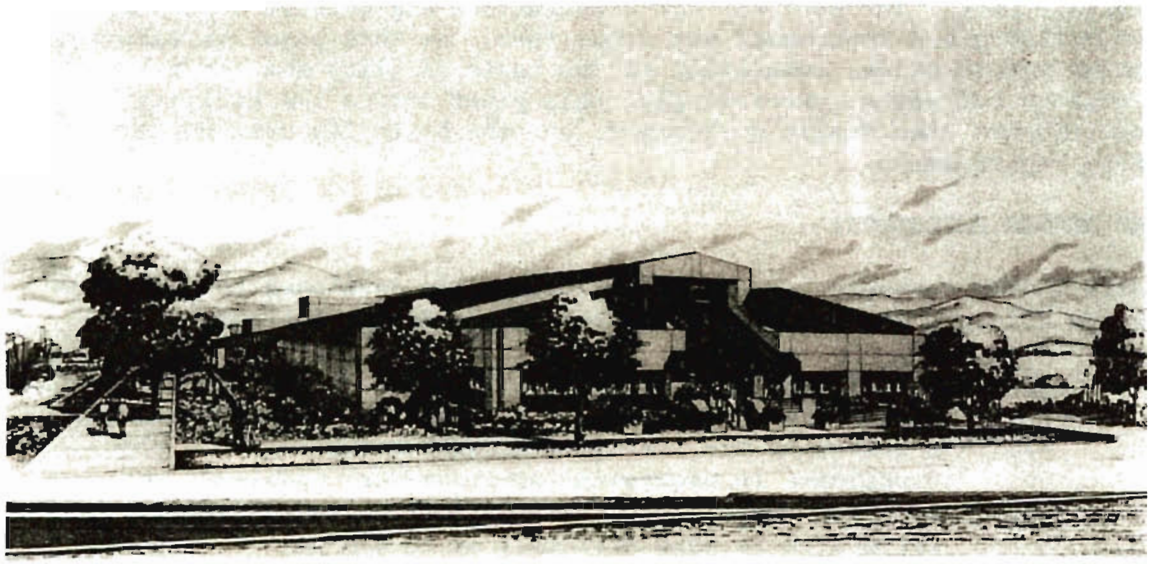
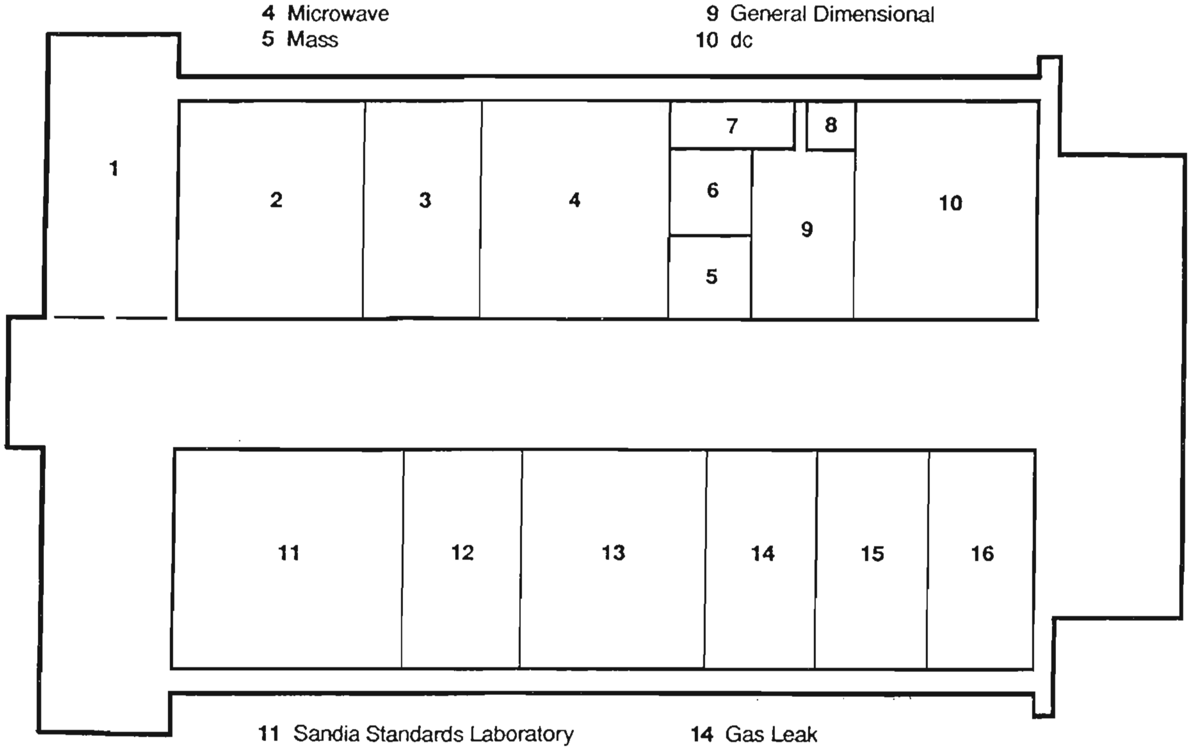


Fig. 1 The New PSL Facility

1 Building Equipment
2 ac
3 Radiation & Optical
4 Microwave
5 Mass
6 CMM
7 Force
8 Interferometer
9 General Dimensional
10 dc



11 Sandia Standards Laboratory
12 Temperature
13 Humidity Flow, Shock & Acceleration
14 Gas Leak
15 Pressure
16 Vacuum

Fig. 2. The Basic Floor Layout

simplified drawing of the building floor plan which shows the basic layout. The central corridor provides a 2.4 m (8 ft) wide aisle and two 3.7 m (12 ft) wide spaces along the laboratory blocks for personnel offices and laboratory air locks.

GENERAL ENVIRONMENTAL REQUIREMENTS

The facility consists of a number of individual laboratory spaces, each of which houses the measurements and standards for a particular discipline. A high degree of environmental control is required in each laboratory space. Accordingly, temperature, humidity, air flow pattern, vibration, electromagnetic interference (electrical noise) and particulate matter limits are specified for each laboratory space. These factors are listed in general form in the Table and are covered in more detail in the text description below. Isolation between laboratories is required to preclude environmental interaction that would degrade the PSL function. A more complete description of the environmental specifications is given in Reference[4].

TABLE
Environmental Requirements

	LABORATORY	TEMPERATURE SET POINT	TEMPERATURE CONTROL LIMITS	HUMIDITY	AIR FLOW	VIBRATION	EMI	PARTICULATES
LMF LAB	MASS	20°C	±0.1°C	35±5%	UP	H	40db	RP52.1, 4.21 (CLASS 100,000 CLEAN ROOM)
	FORCE	20°C	±0.1°C	35±5%	UP	H	40db	
	GENERAL	20°C	±0.1°C	35±5%	UP	H	40db	
	CMM	20°C	±0.01°C	35±5%	UP	H	40db	
	INTERFEROMETER	20°C	±0.01°C	35±5%	UP	H	40db	
	dc	23°C	±0.25°C	40±5%	DOWN	H	40db and 100db	
	MICROWAVE	23°C	±1°C	40±5%	DOWN	L	40db and 100db	
	RADIATION & OPTICAL	23°C	±1°C	40±5%	DOWN	L	NONE	
	ac	23°C	±1°C	40±5%	DOWN	L	40db	
	VACUUM	23°C	±1°C	40±5%	DOWN	L	40db	
	PRESSURE	23°C	±1°C	40±5%	DOWN	H	NONE	
	GAS LEAK	23°C	±1°C	40±5%	DOWN	L	40db	
	HUMIDITY, FLOW, SHOCK & ACCELERATION	23°C	±1°C	40±5%	DOWN	L	NONE	
	TEMPERATURE	23°C	±1°C	40±5%	DOWN	M	40db	
	SSL	23°C	±1°C	40±5%	DOWN	M	40db	

TEMPERATURE

The degree of temperature control is one of the more critical elements and depends on the specific calibration to be performed and the accuracy required. Most of the laboratory spaces require a 23°C temperature set point and a conventional ceiling to floor air flow pattern is used (DOWN in the Table). All 23°C laboratory spaces are controlled to ±1°C except for the dc laboratory which requires control to ±0.25°C. Three shielded rooms will be employed in the dc laboratory and the goal is to control the temperature in each to the ±0.25°C specified for the general dc laboratory space. A temperature set point of 20°C is specified for the Length, Mass and Force laboratory (LMF) and floor to ceiling air flow (UP in the Table) is employed to minimize gradients in the rooms. The Interferometer room and the Coordinate Measuring Machine (CMM) room require a temperature control to ±0.01°C but ±0.1°C is sufficient for the other LMF areas. Because it is impractical to maintain such tight temperature control limits in large rooms, separate rooms are provided and sized to the specific measuring function they house.

The requirements for temperature are generally similar to those in ISA-RP52.1[5] but the limits are more stringent to fit the specific calibration requirements of the PSL. The PSL specification is that the temperature control be met in the measuring space of each laboratory (that space in which measurements are actually made, a practical realization of ISA-RP52.1 "at the gaging point"). To meet the requirement for temperature limits of ±0.01°C, adaptive control is used to compensate bulk heat output from the metrologist and a small offset of the temperature set point is used to compensate for metrologist radiant heat output. These techniques are used in the interferometer room of the present facility and have been successful.

Problems are not expected in achieving temperature control limits through ±0.25°C using normal control tuning techniques. However, development of the control parameters for the rooms requiring ±0.1°C and ±0.01°C can be a time consuming and difficult task. An experimental, analytical technique for obtaining control parameters is being applied to these rooms in an attempt to achieve the intended degree of control quickly. The technique employs optimal control theory and requires both modeling the thermal response of each room and establishing the transfer functions of the associated control equipment. Combination of the mathematical expressions yields a nonlinear system equation which is solved to obtain the reachable sets of control parameters, rather than to yield a unique solution. The technique was developed by the author some years ago and has been applied to the control of precision temperature baths with excellent results. Measurements are being made on the control equipment to characterize the performance and to establish the necessary transfer functions. These measurements have disclosed some performance shortfall and have led to selection of alternate control equipment for the most tightly controlled temperatures.

VIBRATION CONTROL

Vibration control is of concern in all of the PSL laboratory areas but is most needed in mass measurements. Precision laboratory equipment designed for interface with personnel is optimized for response in the range from 0.1 Hz to 1 Hz. This range has been observed at the PSL by the author and at the National Physical Laboratory in the UK by J. J. Hill (now retired) to produce optimum equipment/personnel interface; however, these observations have not been published. Sensitivity to vibration is listed in the Table as high (H), moderate (M) or low (L) depending on an analysis of each discipline.

The 0.1 Hz to 1 Hz range requires extrapolation below the range that can practically be measured and sensitive metrology instruments are often the best indicator of vibration problems. Following studies of the present and selected sites, the vibration consultant to the Architect/Engineer determined that his "AA" criterion[6] is achievable providing the specification is applied to all laboratories and an as large and as rigid as possible floor slab is used for each the two laboratory blocks. The "AA" criterion is defined as 0.8 RMS μm/s, 5-50 Hz. The two laboratory block floor slabs are formed of 0.61 m (2 ft) thick post-tensioned concrete resting on an engineered fill and isolated from the ground and other parts of the building by an air column around the periphery of each slab.

To effectively isolate 0.1 Hz, a slab dimension of over 500 ft is required. The laboratory floor slabs in the new facility have half this length in one of their two dimensions and an eighth this length in the other dimension. To minimize vibration input from the building equipment, each piece of equipment is mounted on a moment frame which is isolated from the building structure using supports which are sprung and dampened. This isolation technique, applied to a massive block made in the form of a bench or table, has been useful in reducing the vibration reaching sensitive instruments. A number of such designs are described in the literature (see, for example, Reference[2]).

ELECTROMAGNETIC SHIELDING AND GROUNDING

Both of the laboratory blocks are electromagnetically shielded to provide 40 db of attenuation from low frequency to 2 GHz. To accomplish this, each block and its associated utility chase are enclosed in a shield cage through which all penetrations are filtered. The laboratory and utility chase floor slabs include wire mesh to accomplish this part of the cage; steel sheet coated walls, metal doors and the roof structure complete the cage. A relatively stiff mesh is used on the floor surface, but a more flexible mesh with an expansion loop bridges the air gap vibration isolation which separates the slabs from the rest of the building. To finish the floor, a final 2.5 cm (1 inch) high-strength self-leveling toping layer is poured to encapsulate the mesh and provide a smooth surface. Shielding is expected to provide EMI levels below those known to impact measurements with normal equipment. As noted in the Table, additional shielding is required in the dc and Microwave laboratories and this is achieved by shielded rooms in these laboratories. To meet this tighter requirement, three shielded rooms will be used in the dc laboratory and one will be used in the microwave laboratory. Although not shielded rooms exactly, protective isolation cages are used in the dc laboratory and the SSL to insure safety with high voltage.

The practice at the PSL has been not to use an extensive grounding system within the laboratories. In major part, this approach is dictated by the fact that the soil on the site does not have high conductivity and the grounding system relied on in many calibration laboratories appears, on the surface, to be not achievable. A building code required grounding grid is emplaced to assure electrical common and safety grounds are as near the ideal earth potential as possible. Also, it must be recognized that inside a shield cage, the potential of the cage determines the effective ground potential. Bonding of the cage to the ground system insures that this common potential is that intended.

OTHER ENVIRONMENTAL FACTORS

A humidity level of 40±5% is specified for the 23°C laboratories and 35±5% is specified for the 20°C laboratories. The lower humidity level in the 20°C laboratories was chosen to minimize potential corrosion, especially noted during failure of environmental control systems. The specified humidity levels are sufficiently high to minimize possible electrostatic effects and low enough to minimize possible electrical leakage currents. They are also in an acceptable range for precise correction of interferometry data for the speed of light and mass data for air buoyancy.

Particulate control in the laboratories, as noted in the Table, is to the highest level specified in ISA-RP52.1. This requirement is substantially the same as the specification for Class 100,000 Clean Rooms and is not overly restrictive. Traditionally, tight control has been specified for dimensional, optical and mass measurement spaces. For the PSL, the same requirement is specified for all measurement spaces. The tighter control has been found helpful in all measurement disciplines and especially helpful where open oil and water baths are used. Modern filters in the HVAC system are sufficient to achieve the result; protective clothing is not required.

SUMMARY AND CONCLUSIONS

The specifications established for the new facility for the PSL are tight but are needed to support maintenance of standards and calibration measurements in the several disciplines. The design has benefitted from experience with the present facility and the conceptual studies. The design utilizes advanced concepts necessary to produce a state of the art facility. Those of us at the PSL await completion of the facility with eager anticipation.

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[4] Braudaway, D. W., "Environmental Control Requirements for the Weapons Production Primary Standards Laboratory (WPPSL)," Sandia

Report SAND90-1961 • UC-706, Sandia National Laboratories, November, 1990 (copies are available from the author).

5 Recommended Practice ISA-RP52.1, "Recommended Environments for Standards Laboratories," ISA, 1975.
NOTE: Although published 15 years ago, much of the information in this document is still current.

6 Untitled Document from Frank Hubach Associates (FHA) describing Building Vibration Criteria, Methodology for analysis and measurement etc., copyrighted but not dated.

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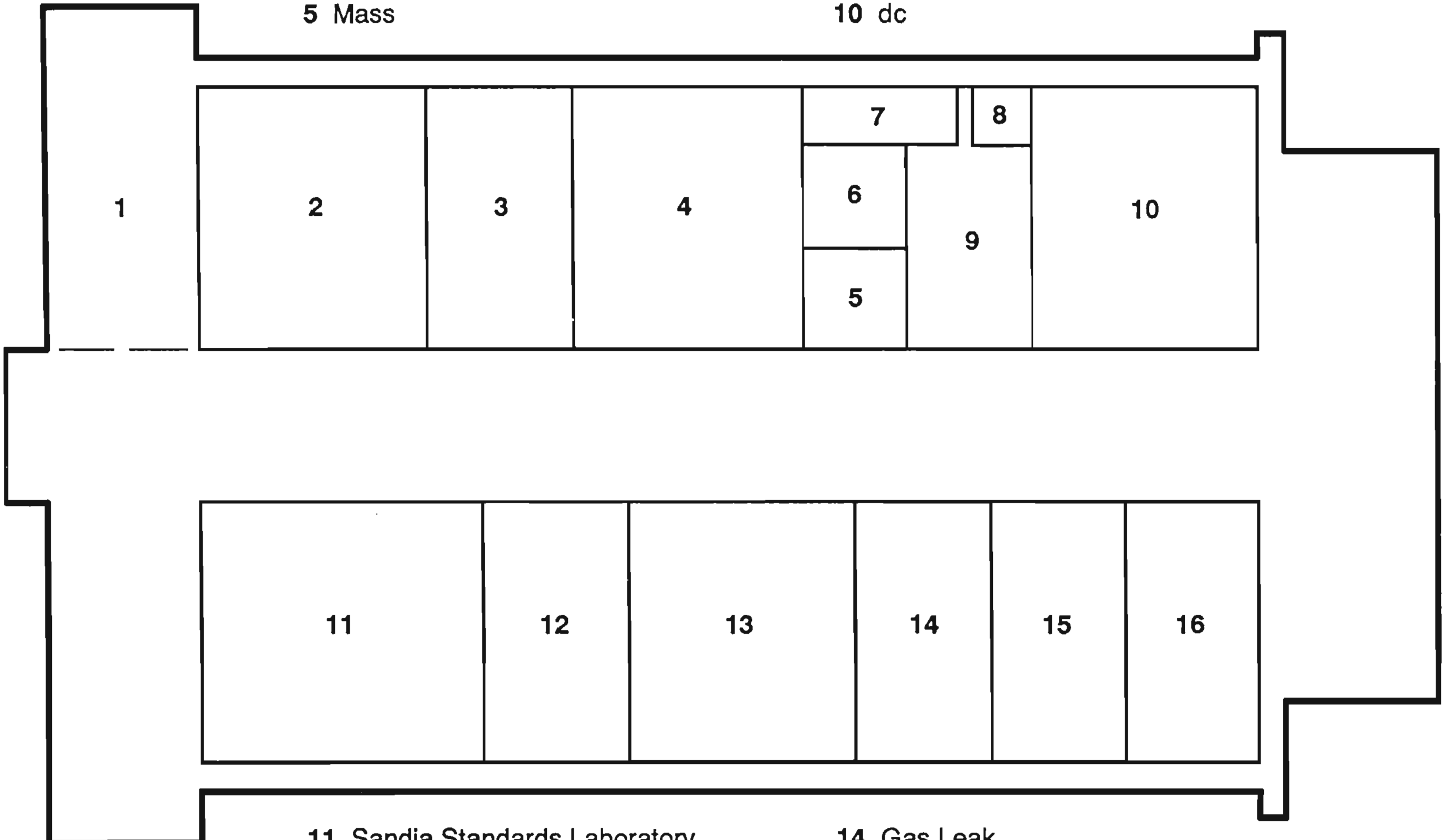

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