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ENVIRONMENTAL CONTROL REQUIREMENTS FOR THE WEAPONS PRODUCTION PRIMARY STANDARDS LABORATORY (WPPSL)

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BACKGROUND

Sandia National Laboratories operates the Weapons Production Primary Standards Laboratory (WPPSL) for the Department of Energy Nuclear Weapons Complex. The present facility is housed principally in a three story building shared with other organizations but has some functions located in other buildings. The building has been occupied for 30 years and the environmental control equipment, while functional, shows the ravages of time. This facility was quite advanced for its time but does not meet current needs. The general characteristics were described by H. H. Baxter, Jr., of Sandia National Laboratories in a document which is in the source-file for ISA RP52.1, "Recommended Environments for Standards Laboratories." A paper was also presented at an ISA meeting in 1963 by J. C. O'Neal.

Replacement of obsolete measuring equipment, extension of measurement capability to additional disciplines and to higher precision levels have made the facility inadequate for current and future needs. Accordingly, plans have been under way for a new updated facility which is planned to meet today's requirements and to be sufficiently flexible to cover changes in the near future. Where practical in this set of requirements, reference has been made to existing documents on standards laboratory environments.

Because of the history of the facility and because of the advanced features, interest has been expressed in the requirements developed for the new facility. Accordingly, this document has been prepared so that these requirements are published.

INTRODUCTION TO REQUIREMENTS

The WPPSL is composed of a number of laboratory units each of which houses the measurements and standards of a particular discipline. A high degree of environmental control is required in the WPPSL laboratories. Accordingly, temperature, humidity, air flow pattern, vibration, electromagnetic interference (electrical noise) and particulate matter limits are specified for each laboratory. These factors are listed in general form in Table I and are more completely described below. Isolation between laboratories is required to preclude environmental interaction that would degrade the WPPSL function.

TEMPERATURE

Temperature control is one of the more critical elements. The degree of control depends on the specific calibration to be performed and the accuracy required. A temperature set point of either 20°C (68°F) or 23°C (73.4°F) is required for each laboratory of the WPPSL. The choice is dictated primarily by the prevailing practice in the applicable standards discipline assigned to that laboratory. 20°C is required for Length, Mass and Force laboratory; 23°C is required for all other laboratories.

The limits on temperature variation are set to meet measurement requirements in each laboratory. The Interferometer and Coordinate Measuring Machine (CMM) Rooms in the 20°C Length, Mass and Force Laboratory require a temperature control limit of ±0.01°C. The Mass, Force and General Dimensional Rooms of the 20°C Length, Mass and Force Laboratory require a temperature control limit of ±0.1°C. Because it is impractical to maintain such tight temperature control limits in large rooms, it is required that separate rooms be provided and sized to the specific measuring function they house. All 23°C laboratories require temperature control limits of ±1°C except for the dc electrical laboratory which requires a temperature control limit of ±0.25°C.

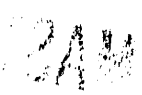
The requirements for temperature are generally similar to those in ISA-RP52.1 but the limits are more stringent to fit the specific calibration requirements of the WPPSL. Temperatures are required to be controlled in the measuring space in each laboratory (a practical realization of ISA-RP52.1 "at the gaging point"). The measuring space is that portion of the laboratory in which measurements are actually made. To meet the requirement for temperature limits of ±0.01°C, adaptive control will be required to compensate bulk heat output from measurement personnel and offset of the temperature set point will be required to compensate their radiant heat output.

HUMIDITY

Humidity control is very important to the WPPSL. Low humidity leads to electrostatic effects which are troublesome in all precision measurements. High humidity produces electrical leakage which degrades precision instrument performance and is active in promoting corrosion of precision dimensional standards. A humidity level of 40±5% is required for the 23°C laboratories and 35±5% is required for the 20°C laboratories (the requirements are similar to but more stringent than the requirements of ISA-RP52.1).

Humidity level, temperature set point and air flow rates through each laboratory are highly interdependent. This interdependence is a consequence of natural physical laws, the required temperature level and the design heat load expected (equipment, lights and personnel). Humidity levels and their limits are an important design consideration in development of the HVAC (Heating, Ventilation and Air Conditioning) systems.

AIR FLOW PATTERN



The normal ceiling-down air flow pattern is specified for the 23°C laboratories. This air flow pattern produces turbulent layer mixing between the cooled air flowing down from the ceiling and heated air rising from instruments in the laboratory. Near the ceiling, the air is somewhat cooler and near the floor the air is somewhat warmer but the turbulent zone has a more uniform temperature and corresponds to the normal measuring space in the laboratory. This air flow pattern is common in practice and well understood.

The inverse air flow pattern, from floor up, is specified for the 20°C laboratories in which a more uniform and more tightly controlled temperature is required. In concept, a perforated floor might seem ideal but it cannot support the traveling loads required in the laboratory without unacceptable deflection. An alternative approach, developed by Moore Special Tool Company uses floor level inlets and mid-height correcting vents and is, therefore, specified. To help optimize air temperature uniformity in the critical CMM room, heat generated in the electronics cabinets associated with the CMM is to be vented directly to the ceiling air return.

The layout of the Length, Mass and Force laboratory rooms was chosen to isolate critical laboratory space from the environments of less critical space. The CMM and Interferometer rooms are buffered by surrounding them with other laboratory spaces under very good temperature control.

VIBRATION

Vibration control is another of the more critical elements and is of major concern in all laboratories. Expected sensitivities are listed in the table as high, moderate or low depending on an analysis of each discipline. Because of the necessity for extrapolating vibration measurements to frequencies lower than can be practically measured, specifications can only be estimates (in accord with the intent of available standards such as ISA-RP52.1). Following studies of the present and proposed WPPSL sites, the vibration consultant selected by the WPPSL Architect/Engineer determined that his (Frank Hubach Associates or FHA) "AA" criterion is achievable providing the specification is applied to all laboratories and an as-large-as-possible floor slab construction is used for the two laboratory sections. The FHA "AA" criterion is defined as 0.8 RMS microns/sec., 5-50 Hz. It is unfortunate that no definitive, accepted standard or measurement technique exists which is applicable to the WPPSL requirement.

Control of vibration level after occupancy is very difficult and can yield only limited results. Available vibration measuring equipment can measure only down to about 5 Hz. It is necessary to extrapolate vibration measurement results carefully to obtain reasonable estimates of vibration levels in the optimum frequency range. Accordingly, the equipment itself is often the most reliable indicator of vibration problems.

Precision laboratory equipment designed for interface with personnel is optimized for response in the range from 0.1 Hz to 1 Hz. The 0.1 Hz to 1 Hz range has been observed at the Sandia Primary Standards Laboratory 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.

ELECTROMAGNETIC INTERFERENCE (EMI)

The level of EMI, sometimes referred to as electrical noise, is of critical importance in the WPPSL. The term EMI includes interference from signals such as Radio, TV and Radar installations, from interference signals carried into the facility on power and signal feeds, and from those signals inadvertently generated in the facility (such as from fluorescent lights).

Two significantly different levels of EMI suppression are required:

First is the need for a moderate reduction in the level of electromagnetic signals for all laboratories to prevent interference with sensitive measurements. Of the 15 laboratories/rooms, 3 are listed on the table as having low sensitivity to EMI as based on an analysis of standards and equipment at the present time; however, new equipment trends make moderate signal reduction highly desirable. The requirement is for signal levels no greater than 100 μV/meter over the frequency range from 1 kHz to 2 GHz. This requirement is that of ISA-RP52.1 which was established from susceptibility measurements on precision measuring instruments (designs since the standard was written are known not to respond with significant differences). From the 9,000 to 26,000 μV/meter level measured for TV signals in the area and estimates of signal levels from other nearby radiating sources (radio and radar), the 100 μV/meter signal level translates into the requirement for 40db of shielding.

A second level of EMI suppression is required for three specific metrology subdisciplines; one in the microwave laboratory and two in the dc laboratory. The requirement is for 100db attenuation. This requirement can be met by additional small dedicated shielded enclosures in the appropriate laboratories. These enclosures can be designed and constructed as part of occupancy.

Fluorescent light fixtures inside the laboratory require treatment which includes absorbing lenses to minimize generated radio frequency.

PARTICULATES

The level of airborne particulates is of concern throughout the laboratory. Particulates (dust particles) interfere directly with a number of the precision measurements such as Mass where direct errors accrue. Care in making measurements can readily overcome some particulate problems and this level of care is required for all precision measurements. Particulate specification is made according to the ISA-RP52.1 recommendation. This specification is essentially identical to the Class 100,000 Clean Room specification and is not overly stringent.

REFERENCES

1. "Recommended Environments for Standards Laboratories," Recommended Practice, ISA-RP52.1, 1975. Although the information contained in this Recommended Practice was published 15 years ago, it is still current. EMI susceptibility was based on vacuum tube and early solid state precision measuring equipment, but modern equipment shows the same sensitivity pattern.

2. "Laboratory Environments," SAND90-1962J (based on PSLM-3B), Primary Standards Laboratory of Sandia National Laboratories. This document is developed from ISA-RP52.1, updates and extends the contents and sets the Recommended Practice for the Weapons Production Complex.

3. "Where Moore Builds Its Measuring Machines," Moore Special Tool Co., Inc., Bridgeport, CN 06607, 5/73. This brochure describes the techniques pioneered by Moore in innovative temperature control in moderate volume laboratories.

4. Untitled Document from Frank Hubach Associates (FHA) describing Building Vibration Criteria, Methodology for analysis and measurement etc., copyrighted but not dated. FHA is the Vibration Consultant selected by Lendrum, the Architect designing the WPPSL.

5. "60 kV Power Line Effects on Microwave Measurements," Memo from C. J. Still, 7242, to B. E. Barnaby, 7242, May 4, 1987. This memo describes measurements of power line induced interference on available microwave equipment (150 kHz to 1,300 MHz).

6. "Magnetic and Electromagnetic Field Measurements," Memo from S. L. Kupferman and J. A. Foesch, 7242, to S. R. Booker, 7242, June 30, 1987. This memo describes measurements of the field strength from Channel 13 (TV) at the roof of Building 805, 9,000 to 26,000 μ V/meter, which are representative of signal levels throughout the area.

	LABORATORY	TEMPERATURE		HUMIDITY	AIR FLOW (a)	VIBRATION (b)	EMI	PARTICULATES
		SET POINT	CONTROL LIMITS					
LMF LAB	MASS	20°C	±0.1°C	35±5%	UP	H	40db	(d)
	FORCE	20°C	±0.1°C	35±5%	UP	H	40db	(d)
	GENERAL	20°C	±0.1°C	35±5%	UP	H	40db	(d)
	CMM	20°C	±0.01°C	35±5%	UP	H	40db	(d)
	INTERF	20°C	±0.01°C	35±5%	UP	H	40db	(d)
	dc	23°C	±0.25°C	40±5%	DOWN	H	40db 100db(c)	(d)
	μ WAVE	23°C	±1°C	40±5%	DOWN	L	40db 100db(c)	(d)
	RAD/OPT	23°C	±1°C	40±5%	DOWN	L	NONE	(d)
	ac	23°C	±1°C	40±5%	DOWN	L	40db	(d)
	VACUUM	23°C	±1°C	40±5%	DOWN	L	40db	(d)
	PRESSURE	23°C	±1°C	40±5%	DOWN	H	NONE	(d)
	LEAK	23°C	±1°C	40±5%	DOWN	L	40db	(d)
	FLOW	23°C	±1°C	40±5%	DOWN	L	NONE	(d)
	TEMP	23°C	±1°C	40±5%	DOWN	M	40db	(d)
	SSL	23°C	±1°C	40±5%	DOWN	M	40db	(d)

Table I. Environmental requirements for the Weapons Production Primary Standards Laboratory

Notes: Abbreviations:

LMF = Length, Mass and Force
CMM = Coordinate Measuring Machine
INTERF = Interferometer
uWave = Microwave
RAD/OPT = Radiation and Optics
TEMP = Temperature
SSL = Sandia Standards Laboratory

(a) Air Flow: UP = upwards air flow from floor to ceiling.
DOWN = downwards air flow from ceiling to floor.

(b) Vibration: H, M and L refer to relative sensitivity to vibration of High Medium and Low. The specification in the text relates to the High requirement.

(c) EMI: The 100 db attentuation specification is for small shielded enclosures within the specified laboratories. The three laboratories listed NONE have low sensitivity to EMI with present equiplment and levels of EMI. However, potential new equipment makes shielding to 40db highly desirable.

(d) Particulates: ISA-RP52.1 Particulate specification which is essentially identical to Class 100,000 Clean Room specification.

END

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