A SYSTEMATIC PROCEDURE
FOR
PREPARING SPECIFICATIONS
ON ELECTRONIC INSTRUMENTATION AND CONTROL SYSTEMS

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ABSTRACT

A systematic procedure for preparing purchase specifications on
electronic instrumentation or control systems has been developed. This
procedure results in preparation of specifications which: 1) make it
possible to find any particular specification requirement quickly; and
2) insure that no important requirement has been omitted. Details of
this systematic specification preparing procedure are presented.
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INTRODUCTION

The Electronics Engineering Department of the University of California Radiation Laboratory at Livermore is a support organization which functions to design, develop, fabricate and install the instrumentation and control facilities required for the research programs carried on at this Laboratory. These programs include testing and analysis of the effects of atomic weapons, development of controlled nuclear fusion power sources, industrial applications of nuclear explosions, and high temperature nuclear propulsion reactors. Hence the instrumentation and control facilities created and put into operation by this department are of great variety, and are often of very unusual design and complex nature.

To save development time and costs these facilities are evolved, whenever possible, by utilizing appropriate units, subsystems; or even whole systems that can be obtained commercially. Hence the preparation
of equipment purchase specifications is an extensive activity of the Electronics Engineering Department.

It is the policy of this Department that such specifications be prepared by the engineer or coordinator responsible for design and construction of the particular instrumentation or control facility, since the Department believes that the best person to specify equipment is the one responsible for its sound design and construction.

We therefore do not have any writers who prepare the specifications for the engineers. However, to assist the engineers in the preparation of their specifications, we have a technical writing consultant in the Department. To insure that they are well written, all specifications must be reviewed by him before a specification is given a number and thereby made an official EE Department document. This expert's experience in reviewing all our specifications has led to the evolution of a standard procedure for preparing equipment purchase specifications which serves as a guide to all our instrumentation and control design personnel.

As a result of this standard procedure, we find that our designers are preparing better equipment specifications and are accomplishing this preparation with much less expenditure of time than before this procedure was adopted.

STANDARD SPECIFICATION PROCEDURE

The philosophy on which this standard specification procedure was based is that the information in the specification must be organized
so as to meet these two basic requirements:

1) It must be easy to find any particular requirement desired.

2) It must provide an almost automatic check to insure that all important requirements have been included.

This standard specification procedure was developed by starting with an already existing guide for preparing specifications which the NE Department had previously developed and which is shown in Appendix I. This guide was brief and covered most of the major requirements. However, it had these limitations: 1) It omitted some important areas that should be covered; and 2) it was inherently suited for application to a single-chassis unit or instrument only; it was not basically suited for framing the specifications for a whole system, which often involved a considerable number of such units together with complex interconnecting facilities for forming functional combinations of them.

To meet the need for a system specifications procedure, a list of the important requirement areas to be covered by the specification was developed (design features, operating characteristics, construction, performance, tests). In addition, these major areas were included in the procedure: a) Purpose of the whole system; b) over-all system functions; c) a list of equipment units included in the system. The entire standard procedure then called for coverage of the nine major areas, as stipulated in Appendix II.

A significant aspect of this procedure is that, for those major areas where appropriate (i.e. - for design features, performance, construction, tests), it calls for the requirements of each of these areas to be tabulated separately for each major unit or functional assembly of
the system mentioned in the list of equipment units. When such a simplification approach is followed, it is very easy to detect when some important requirement for a particular unit has been left out. In other words, one has almost an automatic check against omission of important individual stipulations that may be overlooked if one follows the conventional procedure of grouping all the stipulations for the entire system in one list, instead of grouping them separately for each major unit of the system.

Using this same approach, a simplified specification procedure was developed for single-unit electronic instruments such as frequency meters, counters, or pulse generators (Appendix III). For both the simple instrument specification procedure and the more comprehensive system specification procedure, an example of a specification prepared by that procedure is included in each engineer's and coordinators "standard practices" manual. (See Appendices IV and V.) Thus it is easy for the engineer or coordinator to apply the procedure by following an example of its use.

**ADVANTAGES OF THIS SPECIFICATION PROCEDURE**

One valuable by-product of this standard system specification procedure that has evolved is the fact that the engineer or coordinator responsible for design of the instrumentation or control facility can use this procedure (list of primary areas to be covered, Appendix II) as a guide or check-off list in discussing the facility to be built with the research scientist requesting it. By reviewing this list, both the
engineer and the scientist gain a clear and complete picture of just what has to be provided. In the past these discussions had commonly centered on a few aspects of the facility on which the scientist or engineer was particularly well informed, and many other important aspects of the facility that should be specified were lost sight of. With this list of important areas of requirements to be covered in front of both the engineer and his scientist customer, they both tend generally to devote a balanced amount of time to each major area, and to cover all the important areas to an equal extent instead of overdoing some and omitting or slighting others.

To illustrate how this new specification preparation procedure improves the specifications and the work of preparing them, consider these examples:

One engineer was responsible for purchase of an environmental test chamber. Following the conventional specification writing practice, he listed all the requirements he could think of in pretty much the order in which they occurred to him. This resulted in the list of specifications shown in Appendix VI.

When this specification was reviewed by the Department's writing specialist, the engineer was told to break the desired unit down into these major functional equipments - the test chamber, the heating system, the cooling system, the instrumentation, and the structure; then, in each major area, to list the requirements of that major area in a separate tabulation for each of these functional units. The result was the improved specification shown in Appendix VII.
From the breakdown of the requirements into a tabulation for each major unit it became apparent that a few very important requirements (item ____ and _____, Appendix VII) had been overlooked. Thus, not only was a specification achieved in which it is easy to find any individual requirement, but the format has served as an automatic check which prevented omission of some important requirements. Another good example of the comprehensive coverage of all the major requirement areas affected by this specification procedure is afforded by the specification for an electron microscope system in Appendix VIII.

One other significant aspect of this systematic specification preparation procedure should be noted. That is, the specification defines only one system design, all the way through to the last section on "Special Requirements." Any variations of the system design or optional system arrangements are defined here, at the end of the specification. They are not mentioned at all in any earlier parts of the specification. They are not mentioned at all in any earlier parts of the specification as is ordinarily often done. This has the effect of concentrating the supplier's attention entirely on the system which is primarily required. He is not distracted from this basically wanted design until he reaches the end of the specification. By the time he reaches this point the basic system design desired is well established in his mind, and any variations which the purchaser will consider are regarded as variations only. The vendor does not go off on tangents or sidelines when first forming a concept of what the purchaser wants.

In the stipulation of these options it is often not clear, even to the scientist who wants the facility or to the engineer working with
him to produce it, exactly what the optional variations from the main design should be. This difficulty can be quickly and fully resolved by evolving a diagramatic representation of the modifications that the purchaser will consider. This happened in the case of the specification for a 100-channel data logging system used as the sample specification in our system specification procedure (Appendix II). The diagramatic representation of this system's variations which were evolved (Page 26, Appendix II) show how clear and precise a definition of them is achieved by the diagramatic representation evolved for them.
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The following is an outline of the procedure to be used in writing specifications for electronic instruments.

**PERFORMANCE SPECIFICATIONS**

1.0 Purpose or Use.

Make a concise general description of the instrument, including any proposed designs. Use block diagrams, if pertinent.

(Use sub-numbering 1.1, 1.2, 1.3, etc. as needed.)

2.0 Tabulation of Electrical Specifications.

This section will tabulate the requirements for signals in and out, pulse configurations, A.C. and D.C. power, metering, frequency centers, etc. (Remember general specification for outside fabrication #1020 will also be included.)

(Use sub-numbering 2.1, 2.2, 2.3, etc. as needed.)

3.0 Physical Characteristics.

Indicate all physical and mechanical considerations pertaining to panels, notching, chassis, cabinet, dustproofing, layout, finish, hardware, size and weight limitations, etc. Include chassis and panel layout sketches, if needed.

(Use sub-numbering 3.1, 3.2, 3.3, etc. as needed.)

4.0 Special Instructions to Fabricator.

Include in this section any special references, standards, or special techniques to be used by the manufacturer. Requests for drawings and Description and Instruction books or special parts should be made in this section.

(Use sub-numbering 4.1, 4.2, 4.3, etc. as needed.)

5.0 Outline all tests to be made by the manufacturer and test data required from him. Describe any acceptance tests you will make and indicate the manufacturer's participation in these tests, if any.

(Use sub-numbering 5.1, 5.2, 5.3, etc. as needed.)
The purpose of a specification is to help the designer to produce the best possible equipment for the job at the lowest possible cost. Performance and test requirements are added to insure that the equipment bought will do exactly what it is intended to do.

To do a good design job, the designer must know:

2.1 Nature and Purpose

What basic type of system is it (logging, data reduction, reactor or accelerator control); and what general research, test, or control function will it be used for? (Example: See Specification L 1384, paragraph 1.0).

2.2 Functions

What specific functions will the system as a whole have to perform? (Example: Specification L 1384, paragraphs 1.1 to 1.1.4.5). Use block diagrams, if pertinent.

2.3 Equipment Units (System Components)

What major equipment units or assemblies will be required to accomplish these system functions? What specific functions will each of these units or assemblies have to perform? Tabulate functions separately for each unit. (Example: Paragraphs 2.0 to 2.6.5, Specification L 1384).

2.4 Design Features and Operating Characteristics

What general design considerations and operational requirements must these equipment units meet to perform their functions properly? Also, describe specific electrical and operating characteristics required and tabulate them separately for each unit or assembly. (See items 3.0 to 3.5.4.6, Specification L 1384).

This section shall also specify (where applicable) the modes of operation, how the different modes are selected, and what monitoring or protective arrangements are required. (Example: Specification L 1384, paragraphs 3.3 to 3.3.4).

2.5 Construction and Physical Requirements

What layout or location of equipment must be met? What construction practices are to be followed? What construction considerations (accessibility, enclosure, etc.) must be met so the equipment will best do the job? Are there any physical limits as to weight, height, or shape that must be conformed to? (See Specification L 1384, paragraphs 4.1 to 4.4).
2.6 **Operational Requirements**

What are the critical environmental conditions (of temperature, moisture, atmospheric pressure, radiation) that will affect the equipment's operation and should be taken account of in its design? Off what power supply, air supply, water supply or other feed source will the system have to work? (See Specification L 1384, paragraphs 5.0 to 5.2.4).

2.7 **Performance Requirements**

What ranges of measurement, output, etc. will be required? What limits of accuracy, sensitivity, linearity, pulse shape, shall be maintained in these outputs and measurements? Within what limits shall voltage or frequency regulation, temperature variation, hum, etc. be kept? (Example: Specification L 1384, paragraphs 3.1, 3.1.1, 3.2.2, 3.4.2, and 6.0 to 6.3).

2.8 **Tests**

Outline all tests to be made by the manufacturer and test data required from him. Describe any acceptance tests you will make and indicate the manufacturer's participation, if any. Specify location and facilities to be used if tests are required outside manufacturer's plant. Stipulate industry or professional society standard test procedures to be followed, when applicable. (Example: Specification L 1384, paragraphs 7.0 to 7.2.1).

2.9 **Special Requirements**

Are there any special, unconventional requirements in design, construction or test that will have to be met? For example, must units be small enough to be shipped by flat car? Also, will any special modifications of the firm requirements stated in the preceding parts of the specification be considered? (See Specification L 1384, paragraphs 8.0 to 8.3.3).
The following is an outline of a procedure to be used in writing specifications for electronic instruments such as frequency meters, counters, and pulse generators, or for related electronic equipment such as amplifiers, discriminators and power supplies. This procedure applies mainly to instruments or equipment comprising standard, single-unit (single-chassis) assemblies. For multi-chassis assemblies or for instrumentation systems, use the specification procedure of Procedures and Drafting #17 (LE 1387).

An example of a specification prepared by use of this procedure is given in Appendix I. (Spec L 1387).

1.0 Purpose or Use

Make a concise general description of the instrument, including any proposed designs. Use block diagrams, if pertinent.

(Use sub-numbering 1.1, 1.2, 1.3, etc. as needed.)

2.0 Functional Characteristics

2.1 Tabulation of Electrical Specifications

This section shall tabulate the requirements for signals in and out, pulse configurations, AC and DC power, metering, frequency center, etc.

(Use sub-numbering 2.1.1, 2.1.2, etc. as needed.)

2.2 Operating Characteristics

This section shall specify the modes of operation, how the different modes are selected, and what monitoring or protective arrangements are required.

(Use sub-numbering 2.2.1, 2.2.2, etc. as needed.)

3.0 Performance Requirements

What ranges of measurement, output, etc. will be required? What limits of accuracy, sensitivity, linearity, pulse shape, shall be maintained in these outputs and measurements? Within what limits shall voltage or frequency regulation, temperature variation, hum, etc. be kept?

(Use sub-numbering 3.1, 3.2, etc. as required.)

4.0 Construction and Physical Characteristics

Indicate all physical and mechanical considerations pertaining to panels, notching, chassis, cabinet, dustproofing, layout, finish, hardware, size and weight limitations, etc. Include chassis and panel layout sketches, if required. Specify any unusual environmental operating conditions (heat, pressure, radiation) and special construction measures required to
meet them. (Remember LRL general specification for outside fabrication #1020 will also be included.)

(Use sub-numbering 2.1, 4.2, etc. as required.)

5.0 Tests

Outline all tests to be made by the manufacturer and test data required from him. Describe any acceptance tests you will make and indicate the manufacturer's participation, if any. Specify location and facilities to be used if tests are required outside manufacturer's plant. Stipulate industry or professional society standard test procedures to be followed, when applicable.

6.0 Special Instructions to Fabricator

Include in this section any special references, standards, or special techniques to be used by the manufacturer. Requests for drawings and Description and Instruction books or special parts shall also be made in this section.

(Use sub-numbering 6.1, 6.2, etc. as needed.)
1.0 PURPOSE

The instrument defined in this Specification shall be an infra-red recording Spectrophotometer which is available as a bench type, standard commercial product, and which can be used for: 1) qualitative and quantitative examination of the infra-red spectra of molecules; and 2) as a general analytical instrument.

2.0 GENERAL

Over-all functional characteristics of the instrument shall be as follows:

2.1 The instrument shall be a double beam, optical, null recording Spectrophotometer with appropriate source and optics to make the instrument capable of recording infra-red spectra in the range from 0.2 to 35 microns.

2.2 The instrument shall be readily convertible to single beam operation.

2.3 The instrument shall have a variable scan drive feature which permits selecting scanning speed ranging from a few minutes to several hours for the entire spectral range.

2.4 Operation of the instrument shall be automatic after starting a scan and the instrument shall automatically come to a stop at the end of a scan.

2.5 Recycling shall be available as an accessory if it is not an integral functional element of the Spectrophotometer.

2.6 The instrument shall include an automatic slit programming system with a variable slit programming changer.

2.7 Data presentation by the instrument shall be linear in wave numbers.

3.0 EQUIPMENT

The instrument shall comprise a light source, sample holding assembly, optical system, and an automatic measurement and recording system. Design particulars and operating characteristics of these major functional
divisions of the instrument shall be as follows:

3.1 Light Source

3.1.1 The instrument shall be equipped with an appropriate radiation source to cover the range from 0.2 to 35 microns.

3.2 Optical System

3.2.1 The instrument shall have interchangeable optics to permit recording of spectra in the range from 0.2 to 35 microns.

3.2.2 The prism interchange optics shall be on mountings such that exact optical alignment in the Spectrophotometer will be insured when prisms are interchanged.

3.2.3 A sodium chloride (NaCl) and a potassium bromide (KBr) prism interchange unit shall be supplied.

3.2.4 The instrument shall be easily and quickly accessible for prism interchange.

3.2.5 The instrument shall be flushable or readily modified for gas flush operation.

3.3 Detector

Detector supplied shall cover the minimum range of 0.2 to 26 microns and shall be easily accessible for replacement with detectors to extend this range to 35 microns.

3.4 Automatic Measurement and Recording System

3.4.1 The recorder shall permit making written entries on the record.

4.0 CONSTRUCTION AND PHYSICAL REQUIREMENTS

4.1 The instrument shall be contained in a single housing or module suitable for mounting on a table or bench.

4.2 The electronic equipment of the instrument shall be of high quality construction as exemplified by LAL Specification L-1020-D.

5.0 OPERATIONAL REQUIREMENTS

5.1 The instrument shall operate on standard 115-volt 60-cycle AC supply.

6.0 PERFORMANCE

6.1 Minimum resolution is 0.02 microns at 10 microns with minimum accuracy at 10 microns of ± 0.015 microns in wavelength.
6.2 Minimum % transmission accuracy ± 1.0%.
6.3 Minimum % transmission reproducibility ± 0.05%.

7.0 TESTS

7.1 The instrument shall be tested at vendor's plant to verify that it fulfills design requirements stipulated in section 3.0, and performance levels stated in section 6.0.

8.0 SPECIAL REQUIREMENTS

8.1 The vendor shall supply 3 sets of instruction manuals and complete wiring diagrams.
100-CHANNEL DIGITIZER
SITE 300

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1.0 GENERAL

The purpose of this specification is to detail the requirements for a digital data logging system which will automatically select and record a number of channels of strain gage and thermocouple information. The general nature of the system, shown on the functional schematic of figure 1, is as follows:

1.1 Functional Characteristics:

1.1.1 The system shall be able to record automatically, in any sequence in which they may be connected, 50 thermocouple channels and 50 strain gage channels.

1.1.2 The system shall digitize the analog data outputs of thermocouple and strain gage channels and produce readout of the data in printed form by typewriter, and in encoded form on punched paper tape.

1.1.3 The system shall produce continuous repetition of the preselected sequence or shall repeat the preselected sequence at periodic intervals selected by the operator.

1.1.4 In addition to the data readout, the system shall also provide the following monitoring arrangements to insure that the high accuracy required is being maintained.

1.1.4.1 The system shall include a "demand readout" control which will permit the operator to select a single channel and produce visual readout of the data from that one channel.
50 COPPER CONSTANTAN THERMOCOUPLES

50 CHANNELS STRAIN GAGES
+ 50 OR LESS COMPENSATING STRAIN GAGES

100 INPUT SELECTOR SWITCHES

POWER SUPPLY

DIGITIZE

SWITCH

PAPER PUNCH

NUMBER DISPLAY TUBES

PATCH PANEL OR PINEBOARD

100 PRECISION BALANCE RESISTORS

50 CHANNEL TERMINAL STRIP

50 CHANNEL TERMINAL STRIP

FIG. 1
1.1.4.2 The system shall include a "self-check channel" provision which will provide a known, precise, voltage input to a selected channel or to all channels, thus provide a readout from those channels that will check their accuracy. It shall be possible for the operator to include a check channel in the automatic logging sequence.

1.1.4.3 The data readout for all strain gage channels shall be in millivolts and for thermocouple channels shall be in degrees Fahrenheit.

1.1.4.4 The system shall also include provisions so that the readout for each channel will, at preselected intervals, include, besides the data from the thermocouples and/or strain gages, the channel identification and the time of day and the date when the readout was made.

1.1.4.5 It is expected that the system will produce readout at such a slow rate that the data can be processed by the paper punch and printer as fast as it is received. However, the Lawrence Radiation Laboratory will consider vendor's suggestions for much faster logging operation which may require memory storage of the output data to permit its readout, without loss, by the specified tape punch or printer. (See item 8.1.4.1.)
2.0 **EQUIPMENT**

The system shall include the following major equipment groups. Functions, design features and operating characteristics of these major equipment divisions are detailed in section 3.0.

2.1 **Thermocouple Channels**

The system shall digitize and record the output of a number of thermocouples (TC) located at several stations. For design features and characteristics of thermocouple channels see items 3.1 to 3.1.3.

2.2 **Strain Gage Channels**

The system shall also measure strain at a number of locations, with each strain gage connected in a bridge circuit. The bridge circuit electrical parameters, balancing arrangement, and power supply shall be as stipulated in items 3.2 to 3.2.4.

2.3 **Readout Devices**

The equipment shall include:

- **2.3.1 A digital millivoltmeter**, which will convert the analogue millivolt inputs from the thermocouple and strain gage channels into corresponding digital values. Range, sensitivity, accuracy and other design features of the millivoltmeter shall be as stipulated in items 3.5.1 to 3.5.1.4.

  - **2.3.1.1 Visual Indicator.** In addition to the digital millivoltmeter, there shall be a visual display device to provide visual indication of the digital readout from a selected channel. Design details of the indicator shall be as stipulated in items 3.5.2 to 3.5.2.2.

- **2.3.2 Paper Tape Punch**

  Punched paper tape readout shall be provided by a motor driven paper tape punch such as Friden model 2 or equivalent, suitable for 6-channel punched tape code. Format of the paper punch readout shall be as detailed in items 3.5.4, 3.5.4.1, 3.5.4.6.

- **2.3.3 Printer**

  The printed readout shall be provided by an automatic typewriter such as IBM parallel typewriter printer. Printed readout format shall be as stipulated in items 3.5.3 to 3.5.3.2.3.
2.4 **Clock and Timing Mechanism**

The system shall permit automatic logging of strain gage and thermocouple channels in a preselected sequence (logging cycle), and automatic repetition of this cycle at preselected intervals. (See items 3.3.1 to 3.3.3.1.3) Control of the logging cycle and its repetition periods shall be performed by a clock and timing mechanism which derives its timing action from the 60-cycle power supply to the system. (See item 3.3.5.1.6.)

This clock and timing mechanism shall also provide the digital outputs for identifying the time and date when the logging operation was performed. (See items 3.3.5 to 3.3.5.1.6.)

2.5 **Selection and Sequencing Mechanism**

The system shall include the patch boards, selector switches, or other devices required to:

2.5.1 Preselect the order in which different channels are read out during automatic logging cycle, in groups of 10 channels.

2.5.2 Preselect the period at which the logging cycle shall be repeated.

2.5.3 Select the channel for visual "command readout".

2.5.4 Select the channels to be checked by the self-check operations and their positions in the logging cycle sequence.

2.5.5 Select the voltage to be applied to the strain gage bridges; also the voltages to be used in the self-checking operation.

2.6 **Auxiliary Equipment**

The system shall also include these auxiliary equipments:

2.6.1 Thermocouple temperature compensating oven. (See item 3.1.1.)

2.6.2 Bridge balance network for strain gage channels. (See item 3.2.3.)

2.6.3 Power supplies

2.6.3.1 Bridge pulsed power supplies. (See items 3.2.1, 3.2.2.)

2.6.3.2 Reference signal voltages for self-checking the system. (See items 3.4.2, 3.4.2.1.)
2.6.3.3 Power system (oven, AC input, etc., items 3.4.2, 5.1).

2.6.4 Cooling equipment

The room in which the system's equipment is installed shall be airconditioned. (See items 5.2, 5.2.2, 5.2.3.)

2.6.5 Housings

All equipment shall be housed in standard rack type enclosures which mount standard 19-inch panel supported chassis (see item 4.1).
3.0 DESIGN FEATURES AND OPERATING CHARACTERISTICS

The electrical and mechanical design parameters, and the operating characteristics of the system equipment shall be as follows:

3.1 Thermocouple Channels

The system shall handle inputs from 50 type T copper-constantan thermocouples (50 thermocouple channel capacity). Each thermocouple shall be cold-junctioned compensated and measuring circuits shall be linearized over the entire useable range of the thermocouple, which shall be from -100°F to +700°F. Thermocouple input voltages shall be digitized and recorded to an accuracy of 0.1°F, 10 microvolts, or 0.1% reading, whichever is greater. The readout of all thermocouple channels, on all readout devices, shall be in degrees Fahrenheit.

3.1.1 Compensation Cubicle

Cold junction compensation shall include a temperature controlled thermocouple reference junction compensation oven, operating at 200°F, and stable to ±1°F. Maximum variation in temperature between thermocouples in the cubicle shall be ±1°F. Since the oven is part of the low signal level data acquisition system, the use of 50-cycle AC heating shall be preferably avoided. If AC is used, a rejection figure (dB) below maximum reading of the digital meter shall be made known to LRL.

3.1.2 Thermocouple Circuit

Sketch of the thermocouple circuit is depicted below (Fig. 2) as an explanatory aid. Broken line section is the responsibility of LRL.

![Thermocouple Circuit Diagram](image-url)
3.1.3 Thermocouple Channel Switching Mechanism. Switching devices shall be provided, as stipulated in Item 3.3.1 to 3.3.3.1, to produce any desired readout action (visual, paper tape, and print of each thermocouple channel.

3.2 Strain Gage Channels

All strain gage channels (50) shall be similar and each strain gage shall be connected in a bridge circuit. The bridge shall be manually balanced for initial condition. Millivolts of bridge unbalance output shall correspond to units of change of strain from the initial condition.

Each strain gage shall be connected as the active leg of a bridge circuit, and each bridge shall have a temperature compensator (the same temperature compensator may be used with several strain gages) as the inactive leg of the gaseous bridge. The other two legs of the individual bridge shall be composed of a balancing leg and a fixed leg. This bridge arrangement is shown in figure 3. The nominal impedance of the bridge is 120 ohms. Each bridge shall have three terminals brought to a patchboard (Fig. 3). Maximum DC voltage applied to the bridge shall be 20 volts. Resistances between adjacent bridge channels, and to ground, shall be greater than 100 megohms. The broken line-section in figure 3 is the responsibility LRL. The two bridge arms to be supplied by the vendor shall each consist of a copper-constantan strain gage mounted on a common metallic strip, plus the parallel resistors and potentiometers. We require modular fabrication of the bridge, so that field changes can be readily accomplished.

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**FIG. 3 Strain Gage Bridge Circuit**
3.2.1 Pulsed Energizing of Strain Gage Channels. Strain gages will be located in environmental areas where heat dissipation is difficult. Therefore, it is imperative that the bridge power for the strain gage be pulsed. The pulse length should be as short as will be compatible with the circuitry involved.

3.2.1.1 Vendors shall state the pulse length.

3.2.2 Bridge Power Supplies. Pulsed power for the strain gage bridge circuits shall be provided by regulated 250-miliampere power supplies, and the pulsed power shall be available in manually selectable steps of 5, 10, 15, and 20 volts, accurate to \( \pm 0.01\% \).

3.2.3 Bridge Components. The bridge balance potentiometers shall be arranged to provide accurate, fast, and complete bridge balance, with consideration for ease of operation, maintenance and servicing. The potentiometers shall be in a panel-mounted drawer; or, if front panel-mounted, shall provide protection against unintentional movement of the potentiometer (cover plates or equivalent). Ten-turn potentiometers, of sufficient wattage rating, shall be used, each with a position locking device.

3.2.3.1 The resistive elements shall be of sufficient wattage rating to cause negligible unbalance due to heat dissipation; the fixed resistors shall be of \( \pm 0.1\% \) tolerance and of a design and construction to insure long term stability.

3.2.4 Strain Gage Channel Switching Mechanism. The system shall include appropriate switching mechanism, as detailed in item 3.2.2, to select the bridge input voltage level; and as detailed in items 3.3.1 to 3.3.2, to select the readout action for each strain gage channel.

3.3 Selection and Sequencing Mechanism. The system shall include appropriate circuit changing arrangements to produce the following modes of system operation.

3.3.1 Logging Cycle. A logging cycle shall consist of the automatic digitizing and readout of the channels of the transducer system, in groups of 10, up to a maximum of 100 channels. Vendor shall supply means so that operator can select logging cycles of 10, 20, 30, 40, 50, 60, 70, 80, 90, or 100 channels. This may be effected with pin boards if desired. See Design Option, item 3.1.2.

3.3.2 Logging Sequence (Programming). In order that sampling may be effected in the order desired, this selection mechanism shall permit the thermocouple channels, strain gage channels and the self-check channels to be intermixed in any desired time relation in the automatic log cycle.

3.3.3 Normal Logging Repetition Period. The system shall repeat the
automatic-sequence logging cycle at preselected periodic time intervals.

3.3.3.1 By positioning a single control, the operator shall be able to select continuous repetition of the logging cycle, or repetition of 2, 5, 10, 15, 30, or 60 minutes. All readout devices shall record in coordination with these repetition periods, unless operator removes a readout device from the system. (Removal shall be effected manually, with means provided by vendor.)

3.3.3.1.1 In both continuous and periodically repeated log cycles, the complete logging operation for each channel shall take place in not more than one second. This interval shall be called the "logging rate".

3.3.3.1.2 The logging repetition periods (continuous, 2, 5, 10, 15, 30, and 60 minutes) shall be established by the clock mechanism which shall be timed by the 60-cycle power supply frequency. (See item 3.3.4.1.6.)

3.3.3.1.3 Paper punch and IBM typewriter shall stop paper feed and recording in the intervals between logging cycles.
3.3.4 Demand Readout. To enable fast and accurate balance and checking of bridge circuits, and checking of thermocouple channels, the vendor shall provide means for digitized visual readout of any selected individual channel by a "demand readout" feature. In no way shall this feature cause a loss of data during a periodic log cycle.

3.3.4.1 Selection of the analog input to be read out during "demand readout" shall be affected by means of rotary dial switches or by means of push buttons set to the number of the selected channel, and the pressing of a "point select" button. The "point select" button shall, except during a periodic cycle or a continuous log, enable the selected input to be continuously digitized at 2-second intervals, and the reading to be digitally displayed on a lighted digital display panel (red light digits preferred), for 1.9 seconds. (See visual readout mechanism, item 3.5.2.)

3.3.4.2 Demand readout readings shall be displayed on the digital voltmeter and on the visual light indicator, but shall not be recorded on the paper punch or printer.

3.3.5 Clock and Timer Assembly

The system shall be clock-controlled so that data can be recorded at the logging repetition periods stated in items 3.3.3.1 and 3.3.3.2.

3.3.5.1 In addition, the clock shall provide the following digital outputs:

3.3.5.1.1 Two-digit output, from 01 to 12 inclusive, signifying the month of the year.

3.3.5.1.2 Two-digit output, from 01 to 31 inclusive, signifying the day of the month.

3.3.5.1.3 Two-digit output, from 00 to 23 inclusive, signifying the hour of the day.

3.3.5.1.4 Two-digit output, from 00 to 59 inclusive, signifying minutes of the hour.

3.3.5.1.5 The clock shall operate automatically, but shall have facilities for individual manual reset of any of the digital outputs stated above.

3.3.5.1.6 Vendor may assume that a synchronous motor running from the available 60-cycle power supply will provide sufficiently accurate
time for time recording and for programming. Any errors from cumulative frequency drift will be compensated for by resetting digital clock where necessary.

3.3.5.2 Additional clock functions:

The clock shall start automatically and function normally after AC power is restored following a power failure. Correcting the digital value of time elapsed shall be a manual function to be performed by the operator. When the operator makes this correction, the light which goes on, to indicate when AC power failure has occurred, shall be extinguished. (See item 3.4.5.1.)

3.4 Checking and Monitoring Equipment

3.4.1 Vacuum Tube Voltmeter

A drawer-mounted AC/DC volt-ohm-milliammeter shall be included as part of the system to permit checking individual channels for open, shorted, high or low resistance, or AC ripple between leads or to ground. Appropriate terminals and function switches shall be mounted in the drawer.

3.4.2 Self-Checking Unit

3.4.2.1 The system shall include means for self-checking analog to digital conversion. These means will include the ability to check any channel (selected by operator) with any of 8 available voltages. These 8 voltages shall cover the millivolt range of the digital voltmeter. For example, ±1, ±10, and ±90 millivolts DC and shall be accurate to ±0.01%. In normal logging operation, one channel will ordinarily be used for a system self-check and should be recorded in the same manner as the regular channels.

It is recommended that the above self-checking voltages be available as the function of a single power supply unit, with ease of programming as prime requisite.

3.4.3 Monitoring Devices

On a readily readable location, that will not interfere with normal digitizing operations, and in as small a rack space as is possible, front panel indications of the following shall be installed as part of the system:
3.4.3.1 A light, amber in color and 1" diameter, indicating 117-volt AC power is "on", plus a 3" diameter voltmeter (accurate to ± 1%) located directly above or below the light and suitable to read the AC power input. Meters to read 0-125 volts AC, and have a 1-milliamp full scale movement.

3.4.3.2 A light and meter grouped as stated in 3.4.3.1, indicating the reading and "power on" condition of each strain gage bridge power supply individually. Meters to have ranges of 0 to 10, 0 to 20, 0 to 30, 0 to 40-volts DC, with 1-milliamp full scale movement.

3.4.3.3 Suitable light and meter, such as stipulated in 3.4.3.1, to indicate the reading and the "power on" condition of the power supply for self-checking. It is necessary to monitor only the maximum voltage available.

3.4.3.4 A thermometer indicating the internal ambient temperature of the thermocouple oven, readable from 195° to 205°. In addition, one light, when "on" to indicate the oven is within ± 1° of the operating temperature of the oven (200°F). Another light, different in color, shall indicate when the oven temperature is outside ± 1° of the normal operating temperature (200°F) of the oven.

3.4.3.5 Operational monitoring devices

Vendor will supply suitable monitoring devices or indicators, such as are normally used with digitizing equipment, to inform operator as to readout devices being used; logging cycle repetition period, manual or automatic positions, logging cycle in progress, etc. These devices shall be mounted so that they can be easily observed by the operator.

3.4.4 Protective Devices

Vendor shall supply full protective devices and indicators, wherever deemed necessary for complete equipment protection. In addition, fuses, under- and over-current or voltage relays, under- and over-temperature relays, and other standard protective devices normally provided with such equipment, shall be supplied as part of the system.

3.4.5 Power Failure Indication

3.4.5.1 A light shall be provided to indicate visually if an AC power failure has occurred. This light shall stay lit until turned off by manually resetting the digital clock. The light shall be located so that it will be immediately noticed by operator.
3.4.5.2 When a DC power failure has occurred in any strain gage power supply, or in the reference thermocouple oven (if DC is used), a light shall go on to indicate the unit in which power has failed. The light shall stay on until manually reset to "off" by operator, through a switching system provided by vendor. In addition, the power failure symbol shall be printed, as stipulated in items 3.5.3.2.1 and 3.5.4 to indicate a power failure, and shall continue to be printed until a manual reset has been made.

3.5 Readout Equipment

3.5.1 Digital Millivoltmeter

3.5.1.1 Components. The digital millivoltmeter shall include:

1) A device to provide analog-to-digital conversion of the outputs from the thermocouple and strain gage channels.

2) A visual readout device to indicate the digital value of the channel output being processed.

3.5.1.2 Analog-to-Digital Conversion. The digital millivoltmeter shall perform the conversion and read out for any channel selected, regardless of the sequence of channels in the log cycle (item 3.3.2) and the log cycle repetition period selected (items 3.3.3.1 and 3.3.3.2).

It shall also perform the analog-to-digital conversion at the time the channel is processed (no delay in reading).

3.5.1.3 The digital value shall be indicated by a four-figure decimal number (up to 9999) plus a sign (+ or -) to indicate polarity of the input.

3.5.1.4 Strain gage channel analog-to-digital conversion shall produce readout in millivolts, normally from -99.99 to +99.99. Thermocouple channel analog-to-digital conversion shall produce readout which shall represent temperature in degrees Fahrenheit from -999.9 to +999.9.

3.5.2 Visual Readout Mechanism

A visual indicator, in addition to that in the digital voltmeter is required. This indicator shall display the digital voltmeter readings as each channel is sampled or shall permit...
selecting any one channel for continuous display 
as the logging cycle is repeated). On such single 
channel (continuous display) operation, the visual 
readout shall indicate the new channel output data 
each time the selected channel is sampled. Selection 
for continuous visual display shall be easily made 
and shall indicate which channel is being displayed. 
The visual display for any particular channel may be 
selected, stopped or started at any time without 
affecting normal operation of the system.

3.5.2.1 The visual display indicator shall display 
the digital voltmeter readings of the strain 
gages in millivolts, and thermocouples in 
degrees F.

3.5.2.2 The visual display shall also be used for de-
mand readout in balancing bridge channels and 
for spot checking during test runs, as 
stipulated in item 3.3.3.

3.5.3 Printed Readout - Typewriter (IBM)

The digital voltmeter readings, channel decade number, 
time and date information, and power supply symbol 
shall be typed on a 24-inch carriage IBM typewriter 
or equivalent.

3.5.3.1 Typed analog variable shall be logged in 4 
decimal digits, plus a sign signifying 
polarity, each channel readout thus comprising 
one 5-digit blockette.

3.5.3.2 It is desired that the format of the printed 
record be flexible. Some of the desired 
arrangements are as follows:

3.5.3.2.1 Example 1. At the start of each 
log cycle only, print the log cycle 
identification data, the time, the 
date, decade number and the power 
supply symbol (Fig. 4); then in the 
channel readout sequence, print the 
strain gage and thermocouple in-
formation in blocks of 10 1-channel 
blockettes each, with the channel 
readouts arranged in the order in 
which the channels are logged. If 
the information for the log cycle 
requires more than one line, start 
the second line in from the margin,
3.5.3.2.2 Example 2. Same as Option 1, but one log cycle follows immediately after the end of the preceding cycle.

3.5.3.2.3 Example 3. Time, date, channel identification and power failure information shall be printed at start of each log cycle and then a decade identifying number included in every ten-channel block. Start new line at beginning of each log cycle, with run-over onto indented second line as stipulated in item 3.5.3.2.1.

3.5.4 Paper Tape Readout

The system shall provide a motor driven paper punch machine (Friden Model 2 or equivalent) which, with proper code, shall record the digital voltmeter readings, the time, the date, the channel decade number, and the power failure indication. The time, date, power failure and channel identification number (Fig. 4) shall occur periodically following 10 channels of digit logging (Fig. 6).

Start Log Cycle
Channel 1 and 2
through
Channel 9 and 10

2nd. decade channels and decades through

to

Channels 99 and 100
9th. decade
channel 91 and 92

through
channel 99 and 100

FIG. 6 Format, paper tape readout
3.5.4.1 Format for punched tape is attached (refer to IRL LE 2983-8A for 8-channel punched tape code). Seven of the channels shall be used and punched by the system. The eighth channel shall be manually initiated to signify end of test, etc. Basic word shall have 12 serial characters (one line of punched holes per character), and one word shall be used to record the time, date, decade number and power indication symbol or two channel data readouts.

3.5.4.2 Vendor shall supply manually initiated means for signifying "end of test", as stipulated in item 3.5.3.1.

3.5.4.3 The paper punch machine shall become inoperative during the interval between logging cycles.

3.5.4.4 The paper punch machine shall automatically become inoperative during the demand readout operation.

3.5.4.5 It shall be impossible to print a channel out of its proper place in the format.

3.5.4.6 Analog channels that are shorted or open shall be recorded at their proper place in the format as a 4-digit entry of zero (0000).
4.0 CONSTRUCTION

4.1 Racks

The system shall be housed in standard, rack-type enclosures or cabinets which mount standard 19-inch, panel-supported chassis. These racks shall be equivalent in ruggedness, accuracy of alignment, and accessibility to the standard LRL type racks, and shall be deep enough to accommodate chassis of up to 24 inches in depth.

4.2 Fabrications

Fabricated units, (chassis, panel assemblies, etc.) shall be of the highest custom electronic construction as stipulated in LRL specification L 1020 D, a copy of which is attached.

4.2.1 Fabrication inspection shall be made by LRL representatives while the equipment is being built, to check workmanship and construction practices for compliance with this specification.

4.3 Serviceability

The system shall be constructed so that preventive maintenance can be accomplished with a minimum of effort. The equipment shall be constructed so that it can be inspected and serviced while system is in operation.

4.3.1 LRL shall be informed of recommended maintenance principals by the vendor, with respect to any abnormal feature of the vendor's equipment, and general information on the easiest and best way to keep system "breakdown" to a minimum. System capabilities with equipment breakdown shall be stated in a general manner, i.e., a power failure will completely take the system "off the air", but if one channel reading fails due to some reason, the rest of the system shall operate in the normal manner, etc. In addition, equipment must be able to be inspected, and serviced (within reason) while equipment is in operation.

4.3.2 Terminals, plugs and circuit wiring shall be numbered both on the drawings and on the equipment so that a point on the wiring diagram can be readily located on the equipment.

4.4 Assembly

The bridge balance potentiometers for the strain gage channels shall be mounted, and physically installed so that changing position of the balance potentiometer chassis will not affect system operation.

The optional pinboards (or equivalent), if they are part of the system, shall likewise be mounted as stated above.
4.4.1 Vendor shall state explicitly the recommended maintenance procedure, availability of parts, and general cost of replacement parts (such as relays, etc.) that are an integral part of the system. Time of trouble free operation with respect to relays, contact resistance of switching circuits, type of contact (whether mercury vetted, gold plated, or other,) and medium within which these contacts are enclosed (whether oil, air, gas, etc.) shall be stated by vendor.
5.0 OPERATIONAL REQUIREMENTS

5.1 Power Supply (System)

The system shall operate completely from a single-phase, 117-volt, 60-cycle AC power line which has a voltage tolerance of 117 ± 8 to 117 -12 volts and a frequency tolerance of 60 ± 3 cycles per second.

5.1.1 Power Consumption

AC power consumption will be stated by the vendor.

5.2 Environmental requirements

The system shall meet operations specifications for an ambient room temperature range of 60°F to 120°F.

5.2.1 The building where system will be installed will be exposed to air ambient temperature from 30°F to 110°F, with no abnormal radiant heat conditions.

5.2.2 The room where system will be installed will be air-conditioned.

5.2.3 Manufacturer will determine and incorporate equipment cooling system from the above, and from the acceptance testing requirements in 7.1.2.

5.2.4 Dust, humidity, etc.

All relays, switches, and other low-signal-level circuit switching components shall be enclosed with dustproof or other protective enclosures, which enclosures shall be filled with a suitable medium (air, oil, gas), as required to provide long term trouble-free operation of the system regardless of prevailing climatic or peculiar local conditions.
6.0 PERFORMANCE

The primary concern of the data acquisition, digitizing, and recording system is accuracy, repeatability, and reliability.

6.1 Accuracy

The over-all error of the system - from input terminals through the complete digitizing system - with respect to an accurate test voltage input on any or all channels, shall be less than 1 digit, or 0.1% of the readout, whichever is greater.

This error shall include inaccuracies that may result from input termination; thermocouple reference junction; thermocouple linearization; punched, typed, and voltmeter readings; reference voltages; system noise; transient pulses due to switching; contact resistance; and strain gage power supplies. This over-all error limit shall apply for any logging cycle repetition period of which the system is capable.

6.2 System Noise

It is desired that this system shall operate with noise levels as low as possible, (10 microvolts maximum). All inputs, bridges, dc amplifiers, etc., shall be isolated to a minimum of -70 db of full scale digitizing voltmeter reading on any or all channels with respect to 50 cycle power including 60 cycle harmonics.

6.3 Repeatability and Reliability

The system will be operated continuously (up to 30 days) in some instances. Errors introduced by the system (i.e., change of contact resistance, due to heating, switching, etc.) shall be completely minimized.

Expected changes, after a number of operations, for all system components relative to system accuracy and reliability, shall be made known to LRL representatives by the vendor. Components that will give trouble-free and accurate, long term operation, shall be used in the system.

For example, if gold plated contacts on a terminal or relay contact will provide maximum reliability for long periods of time, then vendor's quotations shall include such items.
7.0 Tests

7.1 Testing at Manufacturer's Plant

The functional subdivisions of the system (listed in section 2) shall be tested by the manufacturer, at his plant, to insure that the design and functional requirements stipulated in section 3.0 are fulfilled.

7.1.1 Inspection See section 3.1

7.1.2 Complete System Test

The vendor shall supply 10 different test voltages, (0.01% regulated minimum) which will be connected to 100 channels as input to the system. Each power supply necessary to supply the 10 test voltages shall be monitored by suitable paper recorder, accurate to 0.01% or better. The operating times and temperatures are as follows: (internal temperatures shall be achieved by blowing heated or cooled air into the racks, etc., via the ventilating ducts.)

Day #1 - 2 hours, with a 105-volt, AC, 60-cycle input, at 90°F.

2 hours, with a 105-volt, 60-cycle, AC input at 180°F.

Day #2 - Repeat of day #1, except for an input of 125-volt 60-cycle AC.

Day #3, #4, #5 - 24 hours at 70°F with 117-volt, 60-cycle AC input.

All above readings will be checked at the fastest sampling rate (shortest log cycle repetition period). LRL representatives will work with the factory personnel a maximum of 5 days for the above tests. Associated readout (paper punch, channel identification, etc.) as part of this equipment, shall be operated for a reasonable length of time to enable readings and comparison checks as to the consistency of the over-all system.

7.2 Testing at LRL

The final acceptance will be complete after the system is installed and properly operating at LRL in Livermore, with the final test specified below (item 7.2.2).

7.2.1 The vendor shall include the services of a field engineer to supervise installation of the system, and to instruct operating personnel. The period of the field engineer's
services shall be 10 working days maximum, unless additional time is required due to faulty equipment, for which LNL is not responsible.

7.2.2 After installation and proper operation of the equipment is obtained, the tests specified in section 7.1.2 for days 3, 4 and 5 will be repeated as a complete system check.
8.0 SPECIAL REQUIREMENTS

8.1 Design Options

Listed are functions which are desirable but not essential to the logging system. If some of these options are included in the vendor's design for the system, he should so state. For those that are not included in his design, the vendor should quote the cost of adding them to his system.

8.1.1 Optional Dual Log Cycle Repetition Frequencies

Due to the nature of some tests, it may be desirable to split the entire transducer system into two groups of channels, one group to be scanned frequently, at short log cycle repetition periods, the other group to be scanned infrequently, at a long log cycle repetition period.

It shall be possible for the operator to select:

1. The repetition periods for the long and short cycle sequences.

2. The ratio of the number of channels in the short cycle sequence to the number of channels in the long cycle sequence.

3. The ratio of short cycles to long cycles in the alternating long and short scan cycle groups.

4. The overlap between the short and long cycle groups.

This will make possible a number of different combinations of: 1) channel groupings in the slow and fast cycle; 2) the ratio of the number of fast to the number of slow cycle periods; and 3) overlap between the alternating fast and slow cycle groups. Practical examples of such combinations are the modes of operation 1, 2, and 3, illustrated in figure 7.

8.1.1.1 Another mode of operation under this option would allow full scan of the sampling switch each cycle but would automatically stop printout at the desired times.

8.1.2 Faster Logging Repetition period. It is recommended that vendors quote on arrangements that will provide more frequent logging cycle repetition (with consequently faster logging rates), if their respective systems have that capability without requiring extensive electronic additions or changes. For example, in addition to the logging cycle repetition periods stipulated in 3.3.3.1, logging cycle repetition periods of 0.5, 0.6, and 1 minute are highly desirable.
EXAMPLES USE RATIO OF 5 SHORT CYCLES TO 1 LONG CYCLE

MODE 1 - Dual Log Cycle (Fast every 2 min. - slow every 10 min.)

- 2 Min. - 2 Min. - 2 Min. - 2 Min. - 2 Min. - etc.
- 50 sec Decade 1-5
- 50 sec Decade 6-10

MODE 1 - Dual Log Cycle (Fast every 100 sec. - slow every 500 sec.)

- (Fastest uniform rate)

- 100 sec - 100 sec - 100 sec - 100 sec - 100 sec - 100 sec - etc
- 20 sec Decade 1 & 2
- 80 sec Decade 1 & 2
- Dual Log Rate (Fast every 3 min. - slow every 15 min.)

- 3 Min. - 3 Min. - 3 Min. - 3 Min. - 3 Min. - etc.

20 sec Decade 1 & 2
80 sec Decade 3 - 10

MODE 2 - Continuous Log (Fast every 50 sec. but skip every 6th cycle to make room for decades 6-10 - slow every 5 min.)

- 5 Min. - 5 Min. - etc.
- 50 sec Decade 1 - 5
- 50 sec Decade 1 - 5
- 50 sec Decade 6 - 10

Continuous Log (Fast every 20 sec. but after 100 sec. (5 cycles) stops for 80 sec. to allow for decades 3-10 - slow every 3 min.)

- 3 Min. - 3 Min. - etc.

20 sec Decade 1 & 2
80 sec Decade 3-10

MODE 3 - Dual Log Cycle - Constant Interval

- 1 Minute - 1 Minute - 1 Minute - 1 Minute - 1 Minute - 1 Minute - etc.

- 50 sec Decade 1 - 5
- 50 sec Decade 1 - 5
- 50 sec Decade 1 - 5
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3.1.2.2 The faster logging (shorter log cycle repetition periods) shall allow no deviation from the accuracy of the system as specified in section 3.3.1.2.

3.1.3 Optional Pin Boards or Equivalent

Pin boards may be added to facilitate programming and operation, as for example:

8.1.3.1 Arrangement of transducer channel readout sequence in the logging cycle should be possible on the pinboard.

8.1.3.2 The pinboard may permit connecting the bridge power voltages available to different bridges in a desired bridge-energizing program.

8.1.3.3 The programming of self-check voltages (item 3.4.2).

8.1.3.4 The programming of dual log rates (item 8.1.1).

8.1.4 An optional feature would be to provide for the use of two IBM typewriters, so as to achieve a system capable of:

8.1.4.1 Operation in a manner to double writing speed of one machine.

8.1.4.2 Operating in parallel to produce two copies.

8.1.4.3 Operating with either machine in standby for emergency use.

8.2 Service Manuals

System shall be supplied with a minimum of eight bound copies of a complete descriptive operating and service manual.

8.3 Vendors Exceptions and Alternatives

To permit a fair and adequate evaluation of received proposals, it is necessary that vendors submit a list correlated with the sections of this specification and containing itemized descriptions and thorough explanations of:

8.3.1 All exceptions or alternatives to each specified section of specifications.

8.3.2 Degree of exceeding specification in all cases.

8.3.3 All cases where desired specifications are not listed.
APPENDIX VI

TEMPERATURE AND HUMIDITY TEST CHAMBER

February 4, 1960

Purpose: To test components and electronic assemblies at different temperature and humidity conditions.

Performance:

1. Temperature range: minus 100°F to plus 350°F
2. Cooling rate: ambient to minus 100°F in less than 90 minutes.
3. Heating rate: ambient to plus 350°F in less than 30 minutes.
4. Live load: 150 watts at minus 65°F, 100 watts at minus 85°F.
5. Temperature control tolerance: plus or minus 3°F
6. Relative humidity range: 20% to 95% RH from 35°F dew point to 185°F dry bulb.
7. Humidity control tolerance: Less than plus or minus 3% RH.

2.0 Physical requirements:

1. Complete test chamber should be on casters for portability.
   - Inside work space: Minimum 20" x 18" x 13"
2. Viewing window with minimum 10" x 10" in door. Internally mounted incandescent lamp to illuminate the work space.
3. The inner-liner shall be stainless steel with welded seams for a permanent vapor seal. It shall be suitably braced.
4. The exterior casing shall be 1/16 ga. cold rolled steel with arc welded seams. It shall be suitably braced.
5. There shall be an average of 6" of fiberglass insulation.
6. The door shall be fabricated similar to the chamber, and shall be an overlap type giving full access to the work space. It shall be front opening and will have a vapor sealing gasket to minimize moisture infiltration. It shall have soft gaskets that will make an efficient seal over thermocouple wires.
7. The door and door opening shall be constructed in such a way as to prevent moisture from getting into the insulation.
8. A support shall be provided on the side of the unit for an inverted 5-gal. bottle of distilled water for the humidifying system supply.

3.0 Mechanical equipment:

2.0.10 Two 3 kW motors shall be provided in units of 60-cycle, 3 KVA, approximate

3.2 The chamber shall be heated by rapid response air heaters arranged so that different heat levels may be preset manually to give close control at moderate temperatures and high heating rates when required.
3.3 The air within the working space shall be circulated by an internally mounted blower which will be driven by means of an externally mounted motor and stainless steel vapor-sealed shaft assembly running through the insulated wall.
3.4 For humidity control, the blower shall be used for air recirculation and the heaters will be used for raising the dry bulb temperature. For increases in the wet bulb temperature, a vapor generator shall be supplied. It shall have electric heater and shall operate at atmospheric pressure. The wet and dry bulb temperatures shall be reduced by a separate refrigeration circuit incorporating a separate evaporator, and other items necessary to make a complete system.
3.5 The water level in the vapor generator and wet bulb trough shall be automatically maintained and will not be damaged by freezing; it shall not require
Draining when operating below 32°F in the chamber.

	Controls and electrical equipment:

1. The instruments for controlling wet and dry bulb temperature shall be a Brown Model 6020-A100-24-384-74. This instrument is a 2-peg 12" circular chart recording thermometer. The chart range shall be -100°F to 300°F with a 24-hour drive.

2. Manual switches shall be provided for turning on heating or cooling, selecting heat level, and for turning on wet bulb heaters, fan, and light. All necessary relays, magnetic starters, wiring, pilot lights, etc., shall be furnished to make a complete, functional, and serviceable unit.

3. The individual branch circuits shall be protected against overload and short circuits.

4. Panels shall be used to enclose the equipment. Openings provided for air circulation where necessary.

The unit will be completely fabricated at the factory and tested for proper performance. When delivered, it will be complete and ready to operate when connected to proper utilities.
ENVIRONMENTAL TEST CHAMBER

1.0 EQUIPMENT - Unit to consist of:

1.1 Test chamber
1.2 Cooling equipment
1.3 Heating equipment
1.4 Humidifying equipment
1.5 Instrumentation
1.6 Support

2.0 PERFORMANCE

2.1 Temperature range, minus 100°F to plus 350°F.
2.2 Cooling rate, ambient to minus 100°F in less than 90 minutes.
2.3 Heating rate, ambient to plus 350°F in less than 30 minutes.
2.4 Live load, to minus 65°F with 150 watts, to minus 85°F with 100 watts.
2.5 Temperature control tolerance, plus or minus 3°F for any 24-hour period.
2.6 Relative humidity range, 20% to 95% relative humidity (RH) from 35°F dew point to 185°F dry bulb.
2.7 Humidity control tolerance, less than plus or minus 5% RH for any 24-hour period.

3.0 DESIGN AND CONSTRUCTION FEATURES

3.1 Test chamber

3.1.1 Minimum inside work space shall be 20" x 18" x 18".

3.1.2 A viewing window shall be mounted in the door. It shall have a minimum size of 10" x 10" and shall be a multi-pane hermatically sealed type.

3.1.3 It shall have an internally mounted, recessed, incandescent lamp to illuminate the work space and the lamp shall be turned on or off by an external switch.

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3.1.4  The inner liner shall be stainless steel with welded seams for a permanent vapor seal and shall be suitably braced.

3.1.5  The exterior casing shall be #16 gage cold rolled steel with arc welded seams and be suitably braced.

3.1.6  The work space shall have an average of 6-inch of fiberglass insulation around it.

3.1.7  The door shall be fabricated similar to the chamber, be an overlap type giving full access to the work space. It shall be front opening and shall have a vapor sealing gasket to minimize moisture infiltration. It shall have soft gaskets that will make an efficient seal over thermocouple wires.

3.1.8  The door and door opening shall be constructed in such a way as to prevent moisture from getting into the insulation.

3.1.9  Two (2) 3-inch I.D. sleeves with appropriate seal-off plugs shall be provided in the side of the chamber as access ports for cables.

3.1.10  The air within the working space shall be circulated by an internally mounted blower which shall be driven by means of an externally mounted motor and stainless steel vapor-sealed shaft assembly running through the insulated wall.

3.1.11  An external coupling shall be included in this shaft assembly to permit convenient replacement of motor or fan.

3.2  Refrigerating equipment

3.2.1  For low temperature cooling, the test space shall be cooled by a cascade type mechanical refrigeration system.

3.2.2  The system shall be designed to meet the requirements of this specification (L 1409) without running to full capacity.

3.3  Heating equipment

3.3.1  The chamber shall be heated by rapid-response electric air heaters arranged so that different heat levels may be preset manually to give close control at moderate temperatures and high heating rates when required.

3.4  Humidifying equipment

3.4.1  For humidity control, the blower shall be used for air recirculation and the heaters will be used for raising the dry bulb temperature.

3.4.2  For increases in the wet bulb temperature, a vapor generator shall be supplied. It shall have electric heaters and shall operate at atmospheric pressure.
3.4.3 The wet- and dry-bulb temperatures shall be reduced by a separate refrigeration circuit incorporating a separate evaporator, and other items necessary to make a complete and independent system.

3.4.4 The water level in the vapor generator and wet bulb trough shall be automatically maintained and shall not be damaged by freezing; it shall not require draining when operating below 32°F in the chamber.

3.4.5 Distilled water shall be used for the humidifying system and an inverted 5-gallon reservoir for it with suitable piping shall be provided on the side of the unit.

3.5 Instrumentation and controls

3.5.1 The instruments for controlling wet and dry bulb temperature shall be a Brown Model 6000A10C-04-III-74. This instrument is a two-pan 12-inch circular chart recording thermometer. The chart range shall be minus 100°F to plus 300°F with a 24-hour drive.

3.5.2 Manual switches shall be provided for turning on heating or cooling, selecting heat level, and for turning on wet bulb heaters, fan, and light. All necessary relays, magnetic starter windings, pilot lights, etc., shall be furnished to make a complete, functional, and serviceable unit.

3.5.3 The individual branch circuits shall be protected against overload and short circuits.

3.6 Support

3.6.1 There shall be a structural steel frame upon which the chamber shall be supported. It shall also be used for mounting the mechanical equipment. Sheet steel panels shall be used to enclose the equipment and shall have vents for air-circulation where necessary.

3.6.2 The whole unit shall be mounted on large, strong casters for ease of movement.

3.6.3 The unit shall be painted in a standard gray or a gray hammer-tone finish.

4.0 SPECIAL REQUIREMENTS

4.1 Electrical power

4.1.1 The entire unit shall operate from a 105- to 125-volt AC, or 210- to 250-volt AC, single-phase, 60-cycle line.

4.2 The unit shall be completely fabricated and tested at the factory for proper performance. Test results shall be sent with the unit. Test shall be made in accordance with standard industry test procedures for such equipment.

4.3 When delivered, the chamber shall be complete and ready to operate when connected to the proper utilities and shall meet the requirements specified here-in.
ELECTRON MICROSCOPE

1.0 PURPOSE

This electron microscope is to be used primarily for research in metallurgy, solid state physics, and various fields of inorganic chemistry.

2.0 FUNCTIONAL CHARACTERISTICS

The microscope shall be capable of the following functions.

2.1 Provide direct visual magnification from about 400 x to at least 200,000 x:

   2.1.1 With magnification continuously adjustable throughout whole range without breaking vacuum

   2.1.2 With sufficient intensity at highest magnification to permit easy, accurate, visual focusing

   2.1.3 With provision for photographing images without decrease in magnification.

2.2 Display and photograph selected area diffraction patterns easily and accurately.

2.3 Provide dark-field as well as bright-field images.

2.4 Be capable of taking stereoscopic photographs.

2.5 Be capable of accommodating the following accessories without major changes or inconvenience:

   2.5.1 High resolution diffraction stage for transmission and reflection diffraction, with specimen heating device and charge neutralizer

   2.5.2 Specimen heating stage for microscopy

   2.5.3 Specimen cooling stage for microscopy

   2.5.4 Accessories for reflection microscopy (see Design Options Item 8.4.1).
2.6 Be as versatile as is compatible with highest performance in electron microscopy.

3.0 EQUIPMENT

The microscope shall include these major equipment units or assemblies.

3.1 Power Supply

3.2 Electron gun

3.3 Electron optics - electro-magnetic lens system to consist of five (5) lenses as follows:

3.3.1 condenser lens system

3.3.2 objective lens

3.3.3 intermediate lens

3.3.4 projector lens

3.4 Specimen chambers

3.5 Viewing system

3.6 Photographic system

3.7 Vacuum system

3.8 Accessories

4.0 DESIGN FEATURES AND OPERATING CHARACTERISTICS

Design features and operating characteristics of the major equipment units shall be:

4.1 Power Supply

4.1.1 shall provide accelerating voltages for beam of 30, 50, 75, and 100 kv (see Design Options Item 8.1.1.1)

4.1.2 shall be fed from single-phase, 110-volt, 60-cycle AC main (see Design Options Item 8.1.1.2)

4.1.3 power consumption shall not exceed 3.0 to 3.5 kva

4.1.4 shall provide 500- or 1,000-volt AC voltage which can be superimposed on high voltage for voltage-centering the beam.

4.1.5 shall include meters for monitoring the lens currents, beam current, and beam voltage. These meters shall be mounted on the control console.
4.2 Electron gun

4.2.1 accelerating voltages - see 4.1.1 and 8.1.1.1

4.2.2 bias shall be controlled externally as well as by position of bias cap

4.2.3 beam current for normal use shall be 0 to 60 microamps

4.2.4 maximum beam current shall be at least 150 microamps

4.3 Electron optics

4.3.1 Condenser lens system

4.3.1.1 double condenser lens system (2 condenser lenses) shall be built in as standard equipment

4.3.1.2 current for each lens shall be controlled independently of other lenses

4.3.1.3 shall have aperture diaphragm with several apertures interchangeable during operation (without breaking vacuum)

4.3.1.4 aperture diaphragm shall be removable from beam during operation

4.3.1.5 aperture diaphragm shall be removable from column without removing pole piece.

4.3.2 Objective lens

4.3.2.1 shall have current controlled independently of other lenses

4.3.2.2 shall include a magnetic stigmator, which shall consist of a pair of rings mechanically adjustable around the objective axis and in the direction of that axis

4.3.2.3 shall include an aperture diaphragm for objective lens, with several apertures interchangeable during operation

4.3.2.4 aperture diaphragm shall be removable from beam during operation

4.3.2.5 aperture diaphragm shall be removable from column without removing pole piece.

4.3.3 Intermediate lens

4.3.3.1 shall have current controlled independently of other lenses
4.3.3.2 shall include a field limiting aperture for intermediate lens - same requirements as for objective aperture (4.3.2.3, 4.3.2.4, 4.3.2.5).

4.3.4 Projector lens

4.3.4.1 shall include four different pole pieces that any one can be rotated into position without breaking vacuum

4.3.4.2 shall have current adjustable independently of other lenses.

4.4 Specimen chambers

4.4.1 The microscope shall include one specimen chamber for microscopy and selected area diffraction; one for high resolution diffraction.

4.4.2 The specimen chamber for microscopy shall:

4.4.2.1 be provided with air lock

4.4.2.2 accommodate standard 1/8-inch specimen screens

4.4.2.3 be movable + 0.8 mm in two orthogonal directions in the horizontal plane

4.4.2.4 have movement controlled from convenient position

4.4.2.5 have the stage motion calibrated, over its entire range of movement, to 1 micron

4.4.2.6 have movement smooth even as seen at high magnification, free from backlash and drift

4.4.2.7 be provided with stereo specimen holder as well as regular holder - or one holder for both plain and stereo microscopy. In both cases stereo angle shall be not less than 5°.

4.4.3 The specimen chamber for diffraction - see accessories, Item 4.5.1.

4.5 Viewing system

4.5.1 shall have a fluorescent screen 9 cm or more in diameter

4.5.2 shall have a tiltable section in screen to permit use of optical microscope outside front window

4.5.3 shall include a binocular magnifying viewer, giving 10 x magnification, which can be swung into position in front of front window

4.5.4 shall provide 3 windows
4.6 Photographic system

4.6.1 shall include an air lock for camera.

4.6.2 Plate camera shall have a capacity of 18 plates, each 3\(\frac{1}{8}\)" x 4\(\frac{1}{4}\)", giving 36 exposures, each 3\(\frac{1}{8}\)" x 2" (see Design Options, Item 8.1.2.1).

4.6.3 Shall include means of determining number of exposures in any one camera load.

4.7 Vacuum system

4.7.1 Shall comprise two mechanical pumps, two oil diffusion pumps, (see Design Options 8.1.3.1)

4.7.2 shall have vapor traps between oil diffusion pumps and microscope column

4.7.3 shall include inlet air filter-drier

4.7.4 shall include a plate pre-evacuation chamber

4.7.5 shall include air lock for camera chamber and specimen chamber

4.7.6 shall have an interlocking valve system to prevent mishandling

4.7.7 shall include a vacuum gage.

4.8 Accessories

4.8.1 Specimen holder for high resolution diffraction by transmission and reflection, which shall:

4.8.1.1 have provision for simultaneous Riedmiller diffraction

4.8.1.2 have charge neutralizer for non-conducting specimens

4.8.1.3 have heater for studying samples to 1000°C or more

4.8.1.4 require minimum of realignment of electron optics between modes of operation

4.8.1.5 permit the following movements of the sample (approx.);

4.8.1.5.1 in the direction of the normal to the specimen at least 3 mm

4.8.1.5.2 tilt with respect to the beam at least 8\(^\circ\) total

4.8.1.5.3 rotation around the normal to the specimen 179\(^\circ\)
4.8.1.6 accommodate samples of the following dimensions.

4.8.1.6.1 cold specimens – up to 30 mm diam and 10 mm thick

4.8.1.6.2 specimens to be heated – 8 mm diam and 2 mm thick

4.8.1.6.3 specimens for transmission diffraction – 2.4 mm

4.8.1.6.4 specimen for Holdmiller diffraction – 2.4 mm

4.8.2 Specimen heating stage for microscopy and diffraction (see 4.8.1.3)

4.8.3 Specimen cooling stage for microscopy

4.8.4 Adaptor for reflection microscopy, with charge neutralizer and device for lifting electron gun (see design options 8.1.4.1)

4.9 Construction.

4.9.1 The electron microscope equipment shall be grouped (assembled) in three units (see design option 6.1.5.1) as follows:

4.9.1.1 Power supply cabinet

4.9.1.2 Microscope column and panel unit

4.9.1.3 Pump unit (see design option 8.1.5.1)

4.9.2 The cable (s) between power cabinets and microscope column unit shall be long enough to permit the power cabinet to be in a different room from the microscope column unit

4.9.3 The components of the power supply and lens circuits shall be grouped in such a way as to provide easy access for inspection and servicing. All access doors to high voltage power supply shall be interlocked in such a manner as to prevent personnel injury in event access door is opened while power supply is on.

4.9.4 The electrical and electronic parts shall be of highest quality, as exemplified by IRL Specification L 1020-B.

5.0 OPERATION REQUIREMENTS

5.1 Environment:

the electron microscope shall operate, as specified, under the following conditions:
5.1.1 ambient room temperature of 60°F to 110°F
5.1.2 normal room air (requiring protection of sensitive relays, etc., from dust and humidity)
5.1.3 normal laboratory vibrations (from pumps, air circulating systems, etc., and other laboratory equipment in adjacent rooms)

6.0 PERFORMANCE

6.1 System as a whole
6.1.1 resolving power for microscopy: 8 Angstroms, guaranteed
6.1.2 resolving index for selected area diffraction: $5 \times 10^{-5}$

6.2 Power Supply
6.2.1 accelerating voltage shall be stabilized to 0.001% for 2-minute span
6.2.2 lens currents shall be stabilized as specified below (6.3.3.3, 6.3.4.2, 6.3.5.1)
6.2.3 filament current shall stabilized to 0.1% or better

6.3 Electron optics
6.3.1 overall astigmatism < 0.1 μ
6.3.2 reproducibility of magnification 2%
6.3.3 condenser lens system
6.3.3.1 shall be able to produce beam at specimen (for microscopy) down to 2 micron diameter
6.3.3.2 shall be able to produce beam at specimen (for diffraction) down to 5 micron diameter
6.3.3.3 shall have current stabilized to 0.003% for 2 minutes
6.3.3.4 temperature of coils shall not vary during 3 hours continuous operation, more than 3°C

6.3.4 objective lens system
6.3.4.1 astigmatism shall be such as to comply with 6.3.1
6.3.4.2 current shall be stabilized to 0.001% for 2 minutes
6.3.4.3 temperature rise of coils, during 3-hour continuous operation, shall not be more than 3°C
6.3.5 projector lens

6.3.5.1 current shall be stabilized to 0.003% for 2 minutes

6.3.5.2 temperature of coils shall not vary more than 3°C

6.4 Specimen Chambers

6.4.1 both must be free from drift, back-lash, jerkiness

6.5 Viewing System

6.5.1 fluorescent screen must be of fine grain, high intensity material with minimum of after-image

6.5.2 binocular viewer must be free from distortion and aberration

6.6 Photographic System

6.6.1 shortest time needed between successive exposures shall be not more than 5 seconds

6.7 Vacuum System

6.7.1 normal operating vacuum shall be $10^{-4}$ mm Hg

6.7.2 pump-down times shall be:

- starting cold: 15 minutes
- after loading plates: 3 minutes
- after changing specimen: 5 - 10 seconds

6.8 Accessories

6.8.1 diffraction resolving index for high resolution diffraction unit: $5 \times 10^{-6}$

7.0 TESTS

7.1 Such tests as shall be necessary to prove compliance with specifications shall be made before the electron microscope leaves the factory.

7.2 final acceptance shall be based on tests made after the electron microscope has been installed in the electron microscope laboratory of the Lawrence Radiation Laboratory.

7.2.1 these tests shall be made by the vendor’s installing engineer together with the LRL personnel who will be operating the instrument in the laboratory.
7.2.2 these tests shall be such as to prove that the instrument complies with these specifications. Particular attention will be paid to:

7.2.2.1 resolution
7.2.2.2 intensity of beam at highest magnification
7.2.2.3 vacuum performance
7.2.2.4 voltage and current stabilities

8.0 SPECIAL REQUIREMENTS

8.1 Design Options

8.1.1 power supply

- instead of features listed in 4.1.1 and 4.1.2; the supply:
  - 8.1.1.1 may provide accelerating voltages of 40, 60, 80, 100 kv
  - 8.1.1.2 may be fed from 208-volt, 60-cycle ac line (single or 3-phase)

8.1.2 photographic system

- 8.1.2.1 instead of 4.6.2, it may have plate camera for 12 exposures on 12 separate plates, each 6 1/4 x 9 cm, plus a 35 mm film camera with 35 or 36 exposures, 2.4 x 3.6 cm each; the arrangement must be such that photographs can be taken either on film or on plates at will during operation of the microscope

8.1.3 vacuum system

- 8.1.3.1 instead of 4.7.1, may have one mechanical pump, one mercury diffusion pump and one oil diffusion pump

8.1.4 accessories

- 8.1.4.1 an adaptor for reflection microscopy, with charge neutralizer and device for lifting electron gun shall be included, but only if currently available
- 8.1.4.2 instead of the assembly arrangement specified in 4.9.1 and 4.9.1.3, the microscope may consist of two units, with pumps included in microscope column panel unit.

8.2 Service Manuals to be Supplied

8.2.1 five copies of the complete instruction manual
8.2.2 five complete sets of circuit diagrams.
8.2.3 five complete sets of drawings or pictures of parts

8.3 Service

8.3.1 electron microscope and accessories shall be installed by vendor's engineer, who shall

8.3.1.1 remain at LRL until instrument and accessories have been tested and found to comply with specifications

8.3.1.2 instruct LRL personnel who will use the instrument on how to operate it and its accessories

8.3.2 the vendor shall provide

8.3.2.1 at least two maintenance service calls during the 1st year

8.3.2.2 emergency service

8.3.2.3 replacement parts during the first year

8.4 Vendors exceptions and alternatives

8.4.1 list all exceptions or alternatives

8.4.2 list specifications exceeded, and degree to which exceeded

8.4.3 list specifications not met

END