CONTRACT SPECIFICATION
FOR
5,000,000 lb. VERTICAL TESTING MACHINE
FOR
FRITZ ENGINEERING LABORATORY
LEHIGH UNIVERSITY
BETHLEHEM, PENNSYLVANIA, U.S.A.

12 January 1953

Revised 13 May 1953
# TABLE OF CONTENTS

## Part I--Performance

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>101. General</td>
<td>1</td>
</tr>
<tr>
<td>102. Design and Construction</td>
<td>1</td>
</tr>
<tr>
<td>103. Design Information</td>
<td>1</td>
</tr>
<tr>
<td>104. Shop Drawings</td>
<td>1</td>
</tr>
<tr>
<td>105. Inspection</td>
<td>2</td>
</tr>
<tr>
<td>106. Delivery and Site Conditions</td>
<td>2</td>
</tr>
<tr>
<td>107. Permits, Legal Requirements</td>
<td>3</td>
</tr>
<tr>
<td>108. Erection</td>
<td>3</td>
</tr>
<tr>
<td>109. Record Drawings</td>
<td>4</td>
</tr>
<tr>
<td>110. Operating Manual</td>
<td>4</td>
</tr>
<tr>
<td>111. Testing, Clean-up, Acceptance</td>
<td>5</td>
</tr>
<tr>
<td>112. Guarantee</td>
<td>5</td>
</tr>
<tr>
<td>113. Facilities to be Furnished by the Buyer</td>
<td>6</td>
</tr>
</tbody>
</table>

## Part II--Design and Construction

### A. General Requirements

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>114. General</td>
<td>7</td>
</tr>
<tr>
<td>115. Type</td>
<td>7</td>
</tr>
<tr>
<td>116. Capacity</td>
<td>7</td>
</tr>
<tr>
<td>117. Dimensions and Centerlines</td>
<td>7</td>
</tr>
</tbody>
</table>

### B. Operating Systems

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>118. Loading System</td>
<td>9</td>
</tr>
<tr>
<td>119. Weighing System</td>
<td>10</td>
</tr>
<tr>
<td>120. Control System</td>
<td>12</td>
</tr>
</tbody>
</table>

### C. Structural Design

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>121. Foundation</td>
<td>14</td>
</tr>
</tbody>
</table>

### D. Mechanical and Electrical Design

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>122. Main Table</td>
<td>15</td>
</tr>
<tr>
<td>123. Main Columns</td>
<td>15</td>
</tr>
<tr>
<td>124. Screws</td>
<td>17</td>
</tr>
<tr>
<td>125. Sensitive Crosshead</td>
<td>17</td>
</tr>
<tr>
<td>126. Tension Crosshead</td>
<td>18</td>
</tr>
<tr>
<td>127. Upper Horizontal Frame</td>
<td>19</td>
</tr>
<tr>
<td>128. Electric Motors</td>
<td>20</td>
</tr>
<tr>
<td>129. Hydraulic System</td>
<td>20</td>
</tr>
<tr>
<td>130. Lubrication, Bearings and Gears</td>
<td>21</td>
</tr>
<tr>
<td>131. Paint and Finish</td>
<td>21</td>
</tr>
<tr>
<td>132. Safety Devices</td>
<td>22</td>
</tr>
<tr>
<td>133. Shock Absorption</td>
<td>23</td>
</tr>
</tbody>
</table>

### E. Accessories

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>134. Leveling Assembly</td>
<td>24</td>
</tr>
</tbody>
</table>
TABLE OF CONTENTS
(continued)

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>135.</td>
<td>Bearing Plate</td>
<td>25</td>
</tr>
<tr>
<td>136.</td>
<td>Pedestal</td>
<td>26</td>
</tr>
<tr>
<td>137.</td>
<td>Tension Test Fixtures</td>
<td>27</td>
</tr>
<tr>
<td>138.</td>
<td>Tools</td>
<td>28</td>
</tr>
<tr>
<td>139.</td>
<td>Electric Power Outlets</td>
<td>28</td>
</tr>
<tr>
<td>140.</td>
<td>Ladder</td>
<td>28</td>
</tr>
<tr>
<td>141.</td>
<td>Spherically Seated Bearing Blocks</td>
<td>29</td>
</tr>
</tbody>
</table>

F. Tests and Inspection

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>142.</td>
<td>General</td>
<td>30</td>
</tr>
<tr>
<td>143.</td>
<td>Operation Tests</td>
<td>30</td>
</tr>
<tr>
<td>144.</td>
<td>Load Tests</td>
<td>30</td>
</tr>
<tr>
<td>145.</td>
<td>Hysteresis Test</td>
<td>32</td>
</tr>
<tr>
<td>146.</td>
<td>Creep Test</td>
<td>33</td>
</tr>
<tr>
<td>147.</td>
<td>Accuracy Tests</td>
<td>33</td>
</tr>
<tr>
<td>148.</td>
<td>Retests</td>
<td>34</td>
</tr>
<tr>
<td>149.</td>
<td>Inspection</td>
<td>34</td>
</tr>
</tbody>
</table>

Appendix to Part II

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>150.</td>
<td>Appurtenances not the Obligation of the Contractor</td>
<td>35</td>
</tr>
</tbody>
</table>

Figure 1  Testing Machine Arrangement  38
Figure 2  Allowable Lateral Thrust and Leveling Assembly  39
Part I

Performance

101. General.

Under the terms of the contract dated __________________________ between hereinafter referred to as the Contractor, and Lehigh University, hereinafter referred to as the Buyer, of which contract this Specification is made a part, the Contractor shall, excepting insofar as specifically noted in this Specification, design, build, deliver, erect, adjust and test in the laboratory of the Buyer at Bethlehem, Penna., a vertical testing machine of 5,000,000 lb. capacity, hereinafter referred to as the machine, and shall guarantee same for a period of one year from date of acceptance.

102. Design and Construction

102a. The Contractor shall design, build, deliver, erect, adjust and test the machine as specified in Part II, "Design and Construction", of this Specification.

102b. All items of materials to be furnished, or work to be done, which are required for the completion and functioning of the machine, but are excepted from the obligation of the Contractor, are stated at an appropriate place later in this Specification.

103. Design Information

The Contractor shall furnish to the Buyer, to such extent as the latter may request; the design computations for structural and mechanical parts, the motor and pump sizes, etc., and the specifications for materials and appurtenances, to the end that the Buyer shall be assured that the several parts are designed in accordance with first-class practice as regards capacity, strength, wear and susceptibility to fatigue. This requirement shall in no way relieve the Contractor of his responsibilities under the contract.

104. Shop Drawings

The Contractor shall furnish to the Buyer for his consideration, duplicate prints of all shop drawings, before manufacture is commenced. These shall indicate the details of all members and connections, and all prescribed fits and tolerances. Formal approval by the Buyer will not be required. Unless criticism by the Buyer be received by the Contractor within ten days from receipt of a drawing by the Buyer, it will be
assumed that none will be made. The full responsibility for all details shall remain with the Contractor, unless and except in the event that the Buyer shall insist upon a change and shall accept in writing the responsibility for the effects thereof.

105. Inspection

105a. The Buyer shall have the right to place a representative in any mill, foundry, factory or shop where material required for the machine is being produced or finished, and at the erection site, to satisfy the Buyer that all details of the drawings and specifications are being satisfactorily executed.

105b. The Contractor shall not pay any part of the salary or expenses of such representative of the Buyer; but shall afford to him, free of charge, all access, opportunity, and use of gages or instruments there on hand and customarily used for inspection and checking.

105c. The Contractor shall furnish the Buyer with one copy of all mill and foundry analysis records and test reports required by the specifications under which the several materials are ordered.

105d. Insofar as the Buyer shall provide an inspector representative as above authorized, no material shall be shipped from any mill, foundry, factory or shop until the inspector has approved such shipment as complying with the specifications.

105e. Any rejection or hold order by the Buyer's inspector shall be immediately communicated to the Contractor and to the Buyer, who shall at once confer with a view to agreement. Material, which it is agreed does not fully conform, shall be rejected and replaced. The final decision and responsibility, in all cases of doubt as to full compliance, shall remain with the Contractor, but a complete record of the facts shall be supplied to the Buyer.

106. Delivery and Site Conditions

106a. The Contractor shall make all provisions and secure any special permits or assistance required for the transport of machine components from factory to site, including acceptance of access clearances and grades within the property of the Buyer.

106b. The Buyer will keep the Contractor informed as to progress of the Buyer's work at the site.

106c. The Buyer will provide the machine foundation.
106d. The Buyer will provide a building, under roof, including all appurtenances thereto not specifically a part of the machine. Design drawings of the building will be supplied to Contractor for his information.

106e. Electric power available in the building will be 220 volt, 3 phase, 60 cycle. The Buyer shall furnish electrical outlets, conduits and compressed air in the machine pit as required by the Contractor.

106f. The Buyer will provide a firm, metalled access road from the nearest city street to the building entrance, and a firm floor within the building to and beyond the site of the machine.

106g. The machine components shall be adequately protected by the Contractor against damage en route to the site.

107. Permits, Legal Requirements

107a. The Contractor shall observe all State and City requirements as to safety, protection of the public, compensation for injury or death, etc. He shall comply with all Federal Laws and regulations applicable to his work.

107b. The Contractor shall obtain all State and City permits required for the transportation of machine components, and pay any fees or charges in connection therewith.

107c. He shall hold the Buyer free of liability, including liability to defend, in connection with the foregoing.

107d. The Buyer will obtain all State and City permits required for the construction, occupancy and use of the building.

108. Erection

108a. The testing machine will be installed in an enclosed building with a clearance of 70 ft. 0 inches between under side of roof supports and top of floor. There will be available in operable condition a twenty (20) ton capacity overhead bridge crane, the main hook of which will travel from the floor level to a height of not more than 60 ft. 9 inches above top of floor. The roof structure over the machine location will include a beam or beams with a safe lifting capacity of 55 tons.

108b. The machine will be erected by the Contractor in accordance with drawings and procedures approved by the Buyer.

108c. The Buyer shall furnish the prestressing columns and all jacks, pumps and structural steel required by the Contractor for prestressing the main table and adjusting same to its final position on the foundations.
108d. Electric power required during erection and tests shall be furnished by the Buyer.

108e. Complete erection of the testing machine at the Contractor's plant prior to shipment to the University is not required.

108f. All sub-assemblies, including drive units, main cylinder assembly, sensitive crosshead, and all other units which can be assembled in the Contractor's plant shall be test-assembled prior to shipment to the University.

108g. All operational tests which can be reasonably carried out at the Contractor's plant shall be performed prior to shipment of the respective units to the Buyer.

108h. Prior to the commencement of erection at site, the Contractor shall examine the site and declare his acceptance of the conditions there found, subject to the following limitations upon the subsequent operations of the Buyer.

108i. The erection and adjustment of the machine on its foundations shall be executed under the constant surveillance of an experienced and competent representative of the Contractor, and in such sequence and by such methods as the Contractor may elect. If any work by the Buyer or his other contractors be scheduled for the same period, it will be postponed or governed so as not to delay the work of the Contractor, not to create a hazard, and not to subject the Contractor to additional risk of injuring the building or its contents.

109. Record Drawings

Prior to acceptance the Contractor shall furnish one complete set of reproducible tracings on cloth, covering all shop drawings, detail descriptions of purchased accessories, piping and wiring diagrams, etc., revised as required to exhibit the details exactly as supplied and installed.

110. Operating Manual

Prior to acceptance the Contractor shall furnish six bound copies of an operating manual which shall contain the following drawings and descriptive information:

110a. A set of line drawings showing principal cross-sections of machine. These drawings need only be so complete as to acquaint the Buyer's personnel with the operating principles of the different parts, but need not be so complete that they constitute complete shop drawings.

110b. Complete operating and maintenance instructions, including recommended lubricants and lubrication frequency, and spare parts lists for the testing machine proper and for all pumps and auxiliary appliances.
An abbreviated outline of essential operating procedures.

III. Testing, Clean-up, Acceptance

IIIa. The Contractor shall perform the acceptance tests prescribed in Part II of this Specification.

IIIb. Immediately upon satisfactory completion of the acceptance tests, the Contractor shall remove his equipment, remove all debris from the premises, and place the machine and site at the disposal of the Buyer for unimpeded use.

IIIc. Upon the completion and passing of the tests to the satisfaction of the Buyer, and upon the completion by the Contractor of all of his obligations as cited in the contract and in this Specification, the Buyer shall signify his acceptance in writing, and the specified guarantee period of one year shall thereupon commence.

112. Guarantee

112a. The obligation of the Contractor under the guarantee referred to in Articles 101 and 111 shall be as follows:

112b. He shall, at a date between eleven and twelve months after acceptance, cause an inspection of all details of the machine to be made by a competent representative, who shall be accompanied by a representative of the Buyer. Any impairments, defects, or lacks thereupon discovered shall be allocated by agreement to one of three categories as follows:

1. Normal wear appropriate to the actual use of the machine to that date;

2. Wear or breakage due to improper maintenance or improper application, contrary to the instructions contained in the operating manual or outside the intended scope of use of the machine as contained in Part II of this Specification;

3. Impairments, defects, or lacks due to inadequacy of the original design, materials, workmanship or care in installing, or any cause not embraced in (1) or (2) above.

The obligation of the Contractor shall be to replace and/or repair all items allocated to category (3), as promptly as practicable and at his sole expense and subject to the approval and acceptance of the Buyer.

And furthermore: in the event that any deficiencies such as are listed under category (3) shall manifest themselves at
any earlier date than that of the year-end inspection, then the Contractor shall remedy same immediately upon notification by the Buyer; and the guarantee of any part thus repaired or replaced shall extend beyond the general one year term of guarantee to one year from the date of such repair or replacement.

113. Facilities to Be Furnished by the Buyer

The Buyer agrees to:

a. Provide the foundations for the machine (Articles 106 and 121).
b. Provide sump pump and drain connection (Article 121).
c. Provide for the support of flexure specimens outside of the main table (Article 121).
d. Provide a building, under roof, for the machine (Articles 106 and 108).
e. Provide electrical outlets, conduits and compressed air in the pit (Articles 106 and 121).
f. Provide access for delivery of machine parts through the Buyer's property (Article 106).
g. Obtain all State and City permits required for the construction, occupancy and use of the building (Article 107).
h. Install and permit the use of overhead crane (Article 108).
i. Provide columns, jacks, pumps and structural steel for pre-stressing and adjustment of main table (Article 108c).
j. Provide electric power to the Erector (Article 108).
k. Furnish the specimens for the following acceptance tests: (See Article 142)
   1. tension test
   2. compression test
   3. load rate test
   4. tension overload test
   5. compression overload test
   6. eccentric load test

(See paragraph 144a)

(See paragraph 144a)

(See paragraph 144b)

(See paragraph 144c)

(See paragraph 144c)

(See paragraph 144d)
Part II
DESIGN AND CONSTRUCTION

A. General Requirements

114. General

Except as may be hereinafter otherwise provided, the design and details of the testing machine with its control system and accessories shall be prepared by the Contractor and shall be in accord with established successful practices. All of the machine components shall be designed and constructed according to the best practices regarding ability to absorb the dynamic energy resulting from the failure of a specimen, and to withstand repeated loads.

115. Type

The machine shall be of the vertical floor type, hydraulically operated, suitable for tension, compression and flexure testing. It shall consist essentially of three systems, namely a loading system, a weighing system, and a control system. The loading system and weighing system shall be hydraulically and mechanically independent of each other. Figure 1 is a schematic diagram of the machine, indicating the arrangement and function of the parts as will be hereinafter described.

116. Capacity

116 a. Tension and Compression: The testing machine shall have a capacity of 5,000,000 lbs. in tension and 5,000,000 lbs. in compression.

116 b. Flexure: The machine shall be capable of applying a 5,000,000 lb. load to a flexure specimen.

116 c. Lateral Loads: The machine shall be capable of resisting lateral thrusts of magnitude indicated in Figure 2 of this specification applied in any direction to the leveling assembly on the sensitive crosshead, and shall remain operative in all respects under such loads.

116 d. Overload: All loaded parts and accessories shall be capable of carrying a 10 per cent overload without subsequent malfunction.

117. Dimensions and Centerlines

117 a. Principal Centerline: The principal centerline of the machine is defined as the line joining the centers of the two screws at the top of the main table.
117 b. **Transverse Centerline**: The transverse centerline is defined as the centerline in the top surface of the main table, midway between the screws, and at right angles to the principal centerline.

117 c. **Compression Space**: The maximum clear opening between the main table and the leveling assembly on the sensitive crosshead shall be not less than 40 ft. for compression tests.

117 d. **Tension Space**: The maximum clear opening between the sensitive crosshead and tension crosshead shall be not less than 40 ft. (including power stroke) for tension tests.

117 e. **Horizontal Space**: The clear horizontal working space between upright columns shall be 10 feet. There shall be no protrusions into this space without consent of the Buyer. The clear horizontal space between the screws of the testing machine shall be greater than the clear horizontal space between columns.

117 f. **Total Height**: The total height of the machine, from top of main table to top of upper horizontal frame shall not exceed 56 ft. 10 in.
B. Operating Systems

118. Loading System

118 a. Structural Components: The principal structural components of the machine shall consist of two separate frames, arranged and functioning as follows:

1. One frame shall consist of a steel main table or fixed bed, two fixed columns, a fixed upper horizontal frame, and a tension crosshead which can be set at several elevations.

   (a) The main table shall be anchored to a concrete foundation, with the top face of the main table at finished floor level. It shall not be a part of the weighing system.

   (b) The two main columns shall be erected on the main table, and the fixed upper horizontal frame and the tension crosshead shall be connected to the two columns.

2. The second frame shall be movable, and shall consist of an hydraulic jack casting, two main screws, and a sensitive crosshead; which latter carries on its under side the weighing capsule of the load measuring system.

   (a) The hydraulic jack casting shall be positioned in a pit below the main table, and shall fit around a fixed piston to be attached to the bottom of the main table.

   (b) The main screws shall pass through the main table and be fastened to the two ends of the hydraulic jack casting. The portion of each screw that passes through the main table shall not be threaded, and shall be guided by bushings but not otherwise restrained.

   (c) The sensitive crosshead shall be threaded onto the screws, completing the second frame.

3. This movable frame shall be supported from the fixed frame by hydraulic pull-back jacks.

118 b. Operation: The operations involved in loading a test specimen are as follows (compare Figure 1). Prior to test the sensitive crosshead shall be raised or lowered to desired position by the simultaneous rotation of the two main screws through motor-driven gearing. Loading of the specimen shall be accomplished by an increase of hydraulic pressure between the fixed piston and the jack casting which shall lower the latter, pulling the main screws downward and with them the sensitive crosshead. This motion is in the same direction for testing in tension, compression or flexure. The main screws shall not rotate during application of load to the specimen.
118 c. Unloading and Return: After removal of jack pressure the jack casting shall be raised by the pair of pull-back jacks, restoring the loading system to normal pre-test position.

118 d. Stroke: The jack shall have a power stroke of at least 36 inches.

118 e. Loading Speed: The system shall be capable of applying loads up to full capacity of the testing machine at any desired rate of travel of the sensitive crosshead from 0 to 3 inches per minute.

118 f. Return Speed: The pull-back jacks shall have a variable return speed of up to approximately 15 inches per minute.

118 g. Reversal of Load: Controls for the hydraulic jacks and the construction of the jacks shall be such as to permit rapid removal of the load, and reversal of direction of the sensitive crosshead.

118 h. Pump and Pump Motor: The hydraulic pump and pump motor shall be capable of operating indefinitely under the most severe operating conditions without overheating.

118 i. Impulses: Impulses in the hydraulic pump shall overlap so as not to create perceptible or measurable pulsations during application of the load.

118 j. Safety Devices: The loading system shall be provided with limit switches and safety devices as called for in Article 132 of this Specification.

118 k. Shock Absorbers: The loading system shall be provided with suitable springs or other dynamic-energy absorbing appliances as specified in Article 133.

118 l. Overload Capacity: The loading system shall be capable of applying 110 per cent of the rated capacity load of the machine.

118 m. Eccentric Loads: The loading system shall be capable of applying eccentric loads described in paragraph 144d.

119. Weighing System

119 a. General Arrangement

1. Pressure from the loading system shall be transmitted to the weighing system by means of an hydraulic pressure cell or weighing capsule affixed beneath the sensitive crosshead; but there shall be no hydraulic connection between the two systems.
2. The weighing system shall indicate the true load of the loading system on one of two dials conveniently located in the control cabinet. The pressure cell or weighing capsule shall operate so as to eliminate from the measured load any frictional load developed in any part of the machine.

3. The load indicating dials shall operate on the Null or Zero method in combination with an external source of energy.

4. Neoprene tubing or its equivalent shall be used to enclose flexible pressure lines from the pressure cell or weighing capsule to the control cabinet.

119 b. Loading Ranges

1. There shall be six distinct loading ranges as follows:

<table>
<thead>
<tr>
<th>Range</th>
<th>Dial A</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 20,000</td>
<td>lbs. by 20 lb. divisions</td>
</tr>
<tr>
<td>0 to 50,000</td>
<td></td>
</tr>
<tr>
<td>0 to 200,000</td>
<td></td>
</tr>
<tr>
<td>0 to 500,000</td>
<td></td>
</tr>
<tr>
<td>0 to 2,000,000</td>
<td></td>
</tr>
<tr>
<td>0 to 5,000,000</td>
<td></td>
</tr>
</tbody>
</table>

2. The dial ranges shall be grouped as follows:

<table>
<thead>
<tr>
<th>Dial A</th>
<th>Dial B</th>
</tr>
</thead>
<tbody>
<tr>
<td>20,000 lbs.</td>
<td>50,000 lbs.</td>
</tr>
<tr>
<td>200,000</td>
<td>500,000</td>
</tr>
<tr>
<td>2,000,000</td>
<td>5,000,000</td>
</tr>
</tbody>
</table>

119 c. Overload Protection: Overload protection devices shall be provided for the 20,000 and 50,000 lb. dial ranges. A shut-off valve for the 200,000 lb. range also shall be provided.

119 d. Indicating Dials

1. Each dial shall be provided with a sensitive maximum hand, and a convenient means for obtaining zero adjustment.

2. It shall be possible to zero all ranges individually and to switch ranges during a test.

3. Each dial shall be approximately 24 inches in diameter, shall have a scale length of approximately 66 inches, and shall be internally lighted. Scale divisions shall be not less than fifty-five thousandths of an inch center-to-center of graduations, and the width of each graduation shall be not more than one-fifth of the scale division width. The width of the pointers, abreast the scale, shall be not more than one-fifth of a scale division.
119 e. Allowable Errors: The allowable errors for each range shall not exceed the following limits:

<table>
<thead>
<tr>
<th>Range</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>20,000 lb.</td>
<td>1% of actual load or 0.20% of scale range, whichever is greater.</td>
</tr>
<tr>
<td>50,000 lb.</td>
<td>.75% of actual load or 0.15% of scale range, whichever is greater.</td>
</tr>
<tr>
<td>200,000 lb.</td>
<td>.50% of actual load or 0.10% of scale range, whichever is greater.</td>
</tr>
<tr>
<td>500,000 lb.</td>
<td></td>
</tr>
<tr>
<td>2,000,000 lb.</td>
<td></td>
</tr>
<tr>
<td>5,000,000 lb.</td>
<td></td>
</tr>
</tbody>
</table>

119 f. Eccentric Load: The weighing system shall be capable of measuring within the prescribed accuracy of paragraph 119e a vertical load of 2,500,000 lbs. applied to the weighing cell at two inches from the center thereof.

119 g. Hysteresis: The load indicating system shall be as free as possible from hysteresis lag. The measured hysteresis shall not exceed 3 scale divisions at mid-load of any range under the conditions defined in paragraph 145d.

119 h. Creep: The weighing system shall be designed so that it is practically free from creep due to application of heavy loads for long periods of time. The measured creep shall not exceed six tenths (0.6) of one percent under the conditions defined in paragraph 146b.

120. Control System

120 a. General

1. The dials and all electric and hydraulic controls for operating the machine shall be mounted in one control cabinet. The cabinet shall be located not more than thirty (30) feet from the center of the testing machine, and outside of the adjacent wall of the main pit. The Contractor shall furnish and install all required lines to the control cabinet.

2. Controls for varying the speed and reversing the direction of the loading system shall be convenient handwheels or levers.

3. Control of the sensitive crosshead adjusting motor, including variable speed control, shall be by spring-loaded push buttons.

4. Name plates shall identify and sufficiently define the function of the control equipment.
120 b. Control Cabinet

1. The indicating dials shall be mounted at the rear of and above the table of the control cabinet, and at a convenient height and distance to be easily readable by the operator in a standing position.

2. Control devices shall be mounted on the front of the cabinet in a vertical plane and below the top of the cabinet table.

3. No apparatus shall be mounted on the end of the cabinet adjacent to the testing machine.

4. Warning signals as specified in Article 132 shall be mounted in the control cabinet in full view of the operator.

5. The back of the cabinet shall be hinged for ready access to valves and mechanism for maintenance and repair. The back panel shall be of lucite or similar material mounted in hinged metal frames. Internal fluorescent lights and a lock for the back panel shall be provided.

6. The elements of the loading and weighing systems in the control cabinet shall be painted different colors for identification and for educational value.

7. Space shall be provided on the control cabinet for later installation of an autographic recording system, a load rate control system, an automatic load maintainer, and a jack position indicator—none of which devices shall however be provided as a part of this contract. The space provided shall not interfere with the requirements of paragraph 3 above.
121. Foundation

121 a. Design: The foundation design will be prepared by the buyer and approved by the Contractor. The Contractor shall furnish sketches showing all support points and necessary areas for the installation of the testing machine and its auxiliaries. The erection plan prepared by the Contractor shall dimension the locations of machine parts and auxiliaries with respect to the foundation.

121 b. Pit

1. The foundation will include a single rectangular pit with unbroken side and end walls, within which all portions of the machine and its appurtenances required to be beneath the floor shall be installed.

2. The floor of this pit will be 17 ft. below the level of main table. The pit floor will be not less than 16 ft. wide on the principal center line of the machine, and 32 ft. long on the transverse center line of the machine (lengthwise of the building).

3. The top width between pit walls where they support the main table, on the principal center line of the machine, will be approximately 19 ft. 2 in.

4. If electric power outlets, conduits or air lines are required in the pit, the Contractor shall indicate on the foundation drawings the location and intended use of such outlets, conduits or air lines.

5. A pipeway will be provided through one side wall, as directed by the contractor, for the passage of wires or tubes from the pit to the control cabinet.

6. It is proposed to build a sump in the floor of the pit, and to install an automatic pump to remove seepage water. The Contractor shall indicate on the foundation drawings the preferred location of the sump so as to cause least interference with equipment to be installed in the pit. The pump shall be furnished and installed by the Buyer. Connection to sewer or drain will be included in the foundation supplied by the Buyer.

121 c. Special Provisions for Flexural Tests: The foundation will be designed to utilize the full capacity of the machine in testing flexural specimens supported outside the main table. To this end there will be provided in the foundation, long bolts having the required anchorage capacity, which bolts will be extended upward through the main table.

121 d. Foundation Material: The above mentioned bolts, and all other structural steel embedded in the foundation or required for the support of flexural specimens outside of the main table, will be included as foundation material by the Buyer.
122. Main Table

122 a. Design: The main table shall be designed by the Contractor, subject to approval by the Buyer, to include special provisions for the intended use of the machine for flexural testing of long specimens to full machine capacity, involving reactions on either or both edges of the table not exceeding two million five hundred thousand (2,500,000) lb.

After it is erected and adjusted to position, the main table shall be pre-stressed by jacking it upward against the reaction of the anchor bolts, and secured under the prescribed pre-stress by releasing it onto the four permanent pre-stressing columns. The pre-stressing force shall be agreed upon between Contractor and Buyer but shall not exceed 5,000,000 lbs. After erection and adjustment of the machine shall have been completed, the pre-stress in the columns shall be checked and, if necessary, adjusted to the prescribed load before commencement of the acceptance tests. The pre-stressing equipment shall then be removed from the pit and delivered to the Buyer.

122 b. Machining: The main table shall be machined by the Contractor so as to completely satisfy its intended operational function.

122 c. Scribed Lines

1. Lines coinciding with the principal and transverse centerlines of the testing machine shall be scribed on the main table.

2. Additional lines parallel to the principal and transverse centerlines shall be spaced at six (6) inch intervals so that the surface of the main table is marked off in six (6) inch squares.

3. The two lines most distant from and parallel to the principal centerline shall each be sixty (60) inches distant from the principal centerline.

4. The two lines most distant from and parallel to the transverse centerline shall each be sixty (60) inches distant from the transverse centerline.

5. Lines shall be approximately same as markings on Lufkin Company steel scale No. 2404 Heavy.

6. The principal and transverse centerlines shall be easily identified.

122 d. Tapped Holes

1. Holes for one and one-half (1 1/2) inch NF 12-3 bolts shall be drilled and tapped in the main table on each of the pairs of imaginary lines parallel to and nine (9), twenty-seven (27), and forty-five (45) inches from the transverse centerline, at perpendicular distances of nine (9), twenty-seven (27), and forty-five (45) inches in both directions from the principal centerline.

2. All holes shall be bottom tapped to a depth of at least two (2) inches. Plugs shall be supplied for the holes by the Contractor; the top faces of the plugs shall be machined flat with the surface of the main table, and convenient means of removing the plugs shall be provided.
3. Twenty-four (24) one and one-half (1 1/2) inch
NF 12-3 bolts to fit the above holes shall be furnished by the
Contractor. These bolts shall be approximately 8 inches long.

123. Main Columns

123 a. Proportions: The proportions, weight, and strength
of the main columns shall be such as will provide stability for
all possible load conditions well above the limits set by the
overload capacity of the loading unit.

123 b. Guide Ways: Guide ways on the main columns shall
be used to guide the motion of the sensitive crosshead. The
guide ways shall be of the raised "V" type (similar to those
used on precision machine lathes), and need not be hardened.

123 c. Utility Holes: Holes, approximately four (4) inches
in diameter and spaced about twenty-four (24) inches apart ver­
tically, shall be provided through each column. Corresponding
holes in the two columns shall be in the same horizontal plane.
The holes are for the insertion of rods on which a temporary
scaffolding can be erected around the machine.

123 d. T-Slots: Two T-slots shall be provided in each
column and shall extend the full height of the column.

1. The T-slots in each column shall be located on
the face of the main column which faces the transverse centerline.

2. The two T-slots in each column shall be located
symmetrically one on each side of the principal centerline, and
a straight edge between the two slots shall not touch the screw
at any point throughout the height of the column

3. The throats of the T-slots shall be such as to re­
cieve 3/4-inch diameter bolts with special heads. The design of
these bolts shall be submitted by the Buyer, and twenty-four
(24) such bolts with matching nuts shall be furnished by the
Contractor.

4. The T-slots shall be of balanced design to exceed
the strength of the bolts in order that the bolts will fail be­
fore any part of the T-slots will perceptibly distort.

5. There shall be not less than three-fourths of an
inch of flat face on each side of the T-slot throats.

6. At each T-slot on that side of the face which is
more distant from the principal axis of the testing machine
there shall be accurately scribed graduations one (1) foot a­
part. Each foot mark shall be numbered, beginning with zero
at the main table.
7. At the top and bottom ends of each T-slot, the lips of the T-slot shall be removed for a distance which will permit the insertion of the square head of a standard 3/4-inch bolt.

123 e. Connection to Main Table: The connection between the main columns and main table shall conform to the requirements for the accommodation of flexure tests. (See Articles 121c and d).

124. Screws

124 a. Operation: The main screws shall not rotate during application of load to the specimens but shall be rotated only to position the sensitive crosshead.

124 b. Finish: The screws and screw assemblies shall be machined and finished so as to insure uniform bearing between all surfaces to be in contact with other metal surfaces.

124 c. Bearing and Clearances: Bronze or other equally effective bearing material approved by the Buyer shall be used between nuts and the main cylinder brackets to prevent seizing when the screws are rotated. In order to minimize pause in loading, the clearances between the nuts and brackets shall be adjustable to approximately four-thousandths of an inch.

124 d. Rotation: The screws shall be capable of being rotated regardless of the stroke position of the main hydraulic jack, except as provided in Article 132a 7.

125. Sensitive Crosshead

125 a. Positioning: The sensitive crosshead shall be raised or lowered at a maximum speed of not less than 24 inches per minute by rotation of the main screws.

125 b. Lateral Clearance: The crosshead shall be constrained to move vertically in a straight line by means of guide ways on the main columns. The maximum working clearance in any direction in the horizontal plane shall be not greater than twenty-thousandths (.020) of an inch over the full length of adjustment.

125 c. Wear Plates: The crosshead shall be provided with wear plates to match the column guide ways. The wear plates shall be of softer material than the guide ways, replaceable, and adjustable to compensate for wear between the plates and guide ways.

125 d. Lateral Adjustment: Convenient means shall be provided for fixing the crosshead in place laterally at any given position on the screws, so that the relative horizontal motion between the crosshead and guide columns is eliminated.

125 e. Horizontal Forces: The sensitive crosshead shall be designed to resist horizontal forces resulting from loads as specified in paragraphs 116 c and 144 d.
125 f. Vertical Backlash Eliminator: Means shall be provided for taking up the vertical backlash or clearance between the column screws and bronze nuts on the crosshead. Any device provided shall not require manual adjustment for the various positions of the crosshead, but shall be continuously functioning in its intended purpose.

125 g. Power: The power provided for lifting the sensitive crosshead shall be sufficient to lift the tension head or an equivalent external load.

125 h. Lifting Lugs: Two lifting lugs, each of five thousand (5,000) pounds capacity, shall be provided on each side of the sensitive crosshead for lifting models, specimens and appliances.

125 i. Tension Test Fixtures

1. The sensitive crosshead shall be designed to accommodate tension test fixtures as follows:

   (a) Tension grips for flat specimens up to twelve (12) inches wide and six (6) inches thick.

   (b) Tension grips for round specimens up to ten (10) inches in diameter.

   (c) Spherically seated tension rods as described in paragraph 137 b.

2. Slots wider than the grip pockets shall be provided to make it possible to test flat specimens up to twenty (20) inches wide by four (4) inches thick.

3. The sensitive crosshead shall be fitted with suitable equipment so that the grips shall be remotely operated by air pressure.

4. A means shall be provided to prevent the test fixtures from leaving the grip pockets when a specimen fails suddenly.

125 j. Leveling Assembly: The sensitive crosshead shall be fitted with the leveling assembly described in Article 134.

125 k. Safety Devices: Limit switches shall be provided on the sensitive crosshead as specified in Article 132.

126. Tension Crosshead

126 a. Positions: The tension crosshead shall be adjustable to several positions vertically to enable the testing of tension specimens of various lengths at a convenient working level
above the main table. In each such position convenient means shall be provided for positioning and for freeing reaction devices between tension crosshead and columns.

1. The highest position shall be at the maximum possible height of the crosshead.

2. The lowest position shall be such that the bottom of the compression leveling assembly is above the main table a distance equal to the power stroke of the hydraulic jack plus 1 inch.

3. The remaining positions shall be spaced between the highest and lowest positions at approximately equal intervals of about 5 feet.

126 b. Means of Adjustment: The tension crosshead shall be positioned by allowing it to rest upon the sensitive crosshead and raising or lowering the sensitive crosshead.

126 c. Clearances: The working clearances of the tension crosshead in the column guide ways shall be not more than one thirty-second of an inch.

126 d. Tension Test Fixtures: The tension crosshead shall be designed to accommodate the same tension test fixtures and specimens as the sensitive crosshead and shall be fitted with similar operational equipment.

127. Upper Horizontal Frame

127 a. Arrangement: The upper horizontal frame shall consist of two pieces which connect the main columns of the testing machine, and shall be so designed that this frame does not unnecessarily limit the highest position of the tension crosshead.

127 b. Rigidity: The attachment of the frame members to main columns shall be by bolts, and shall be as rigid as practicable. Rigidity shall be obtained in both the vertical plane of the main columns and in the horizontal plane of the frame itself.

127 c. Access: A central opening in the upper horizontal frame shall be large enough to permit removing or adjusting the test fixtures in the tension crosshead when the crosshead is in its highest position. Openings in the frame above the main screws shall be large enough to permit passage of the sensitive crosshead retainer nuts.

127 d. Accommodation of Movable Platform: The upper horizontal frame shall be designed to accommodate installation of a movable platform (see paragraph 151 c).
127 e. Lifting Lugs: Four lifting lugs, two on each side and each having a capacity of 5,000 pounds, shall be provided on the upper horizontal frame of the testing machine for the attachment of blocks to lift models, specimens, and appliances.

127 f. Alternate Design: The Buyer reserves the right to substitute a revised structural design for the Contractor's standard design of the upper horizontal frame; at such time as not to delay the work. In the event of such substitution the Contractor shall review the design of the frame, and accept full responsibility for its proper functioning as a part of the testing machine.

128. Electric Motors

128 a. Ratings: Motors one-half horsepower and larger shall be designed for operation on a 220/440-volt, 60 cycle, 3-phase circuit. Motors smaller than one-half horsepower shall be designed for operation on a 110-volt, 60-cycle, single-phase circuit.

128 b. Protection and Control: Each motor shall be individually controlled by an automatic starter having overload and low voltage protection with push-button control. All motors shall have inverse time, thermal overload protection. Motor and control wiring shall be enclosed in a rigid conduit or flexible Neoprene tubing with suitable terminal enclosing boxes at the motors.

128 c. Crosshead Adjusting Motor: The sensitive crosshead adjusting motor shall be of the wound-rotor type with sufficient steps of resistance to insure starting and switching surges not exceeding 150 per cent of full-load motor current. Primary control for the sensitive crosshead adjusting motor shall be of the push-button operated reversing-type suitably interlocked with the secondary control to insure starting with maximum secondary resistance in the circuit. Secondary control for the sensitive crosshead adjusting motor shall have six or more control points in either direction of operation.

128 d. Bearings: The sensitive crosshead adjusting motor and the hydraulic pump motor shall have anti-friction bearings.

128 e. Standards: The motors shall be rugged and suitable for the purpose for which they are to be used, and shall conform to standards of the American Institute of Electrical Engineers, and the National Electrical Manufacturers Association.

129. Hydraulic System

129 a. Design: The design of the hydraulic loading system shall be such that the system may be kept as clean as possible at all times.
129 b. Cleaning Plugs: Cleaning plugs shall be installed at the bottom of the main cylinder, at the pull back jack, at the bottom of the storage cylinder, and at any other desirable location.

129 c. Pressure: The operating pressure of the system shall not be excessive.

129 d. Storage Cylinder: If possible, the oil storage cylinder shall be slightly above the hydraulic working parts of the testing machine, to reduce the possibility of air getting into the system.

129 e. Air Bleeds: The hydraulic system shall have as few high points as practicable and each high point shall have an air bleed valve.

129 f. Leakage: Hydraulic leakage is to be kept at a minimum. Garlock Chevron or equivalent packing approved by the Buyer shall be used.

129 g. Other Requirements: The hydraulic system shall conform to the requirements of Article 118.

130. Lubrication, Bearings and Gears

130 a. Lubrication: Means for adequate lubrication shall be provided for all moving parts. Leads to lubrication points shall be conveniently located and grouped.

130 b. Guards and Covers: Such guards and covers as may be necessary to keep all bearings, gears and working surfaces clean and in good order shall be provided.

130 c. Bushings: All bushings shall be bronze or other material approved by the Buyer.

130 d. Bearings and Gears: All bearings and gears shall be adequately designed for frequent and long term use of the respective components at rated capacity load.

131. Paint and Finish

131 a. Painted Surfaces: All external parts of the testing machine except lubricated surfaces, bearing surfaces of main table, etc., and other parts where a paint coat is not desirable, shall be given one coat of basic lead chromate primer and two coats of flat gray paint of good photographic quality, similar to that used on the similar testing machine at the Aluminum Research Laboratories.
131 b. Lubricated Surfaces: Surfaces not required to be painted shall be coated prior to shipment with an easily removable protective coating having an oil or grease base.

132. Safety Devices

132 a. The following safety devices shall be furnished and installed:

1. Limit switches or other devices to prevent over-travel of moving parts of the loading system:
   
   (a) Limit switch to shut off sensitive crosshead motor when tension crosshead reaches its top position.
   
   (b) Limit switch to shut off sensitive crosshead motor when sensitive crosshead reaches its lowest position.
   
   (c) Limit switch to prevent sensitive crosshead from running off top of screws. (This limit switch shall not prevent rotation of screws because of the jack position.)
   
   (d) Limit switch to operate when sensitive crosshead comes within two (2) inches of tension crosshead, putting circuit in jog position. The jog position shall be operative at the two slowest screw speeds only.
   
   (e) Hydraulic valve to prevent over travel of main jack.

2. Automatic release valves to prevent building up of excessive pressure in the hydraulic system.

3. Overload protection devices on the 20,000, 50,000, and 200,000 lb. dial ranges.

4. Thermal overload protection for all electric motors.

5. Interlock between sensitive crosshead motor and backlash eliminators to prevent operation of the motor when the backlash eliminators are on.

6. A device to prevent dropping of the movable frame of the testing machine in case of failure of the pull back jacks.

7. A device to prevent downward motion of the sensitive crosshead by rotation of the screws unless the hydraulic jack casting has been lowered about one-half inch through its power stroke. This is to enable the sensitive crosshead to be raised hydraulically if it were accidentally jammed against a compression specimen by rotation of the screws.
8. Warning signals on the control cabinet to indicate that operating electrical circuits are turned on, that the pit is occupied, or for such other warnings as are advisable.

132 b. Overload devices shall operate at about 110 per cent of rated capacity of the protected component.

132 c. All limit switches and other safety devices shall be of rugged construction to insure proper operation and shall be designed and located in such a manner that they do not interfere with the test area.

132 d. Power Switches

1. Contractor shall provide a key locking power panel near the control cabinet, with a separate fuse switch for all motors used with the machine.

2. Contractor shall also provide at the foot of the ladder in the pit beneath the machine another switch for each piece of power driven equipment within the pit. These switches shall have no by-passes, and shall be of the lever operated type to insure positive control of the electrical circuits.

133. Shock Absorption

The testing machine shall be equipped with suitable springs or other dynamic energy absorbing appliances to absorb the shock when tension, compression and flexure specimens are broken at full load capacity of the machine. The machine shall also be capable of absorbing energy resulting from the application of dynamic loads.
E. Accessories

134. Leveling Assembly

134 a. Components: The sensitive crosshead shall be fitted with a leveling assembly which shall consist of three principal parts; namely, two leveling disks, and one bearing plate. In addition, minor parts such as one center pin, a number of supporting springs, and other miscellaneous items required for satisfactory operation of the leveling assembly shall be furnished.

134 b. Function: At any position of the sensitive head, after bringing the bearing plate parallel to the main table of the machine, it shall be possible to further adjust the bearing plate seven thirty-seconds (7/32) inch out of parallel in either direction.

134 c. Leveling Disks: Each leveling disk shall vary linearly in thickness from 1-3/8 inches at one edge to 1-1/8 inches at the edge diametrically opposite, except that disks having greater thickness may be furnished if such thicker disks are considered necessary, and if the differential of one-fourth of an inch is maintained between diametrically opposite edges. This will permit a total adjustment of one-half of an inch when the leveling disks are turned 180 degrees with respect to each other. Each face of each leveling disk shall be finished flat to a tolerance of plus or minus four-thousandths of an inch.

134 d. Bearing Plate: The bearing plate of the leveling assembly shall be 7/2 inches square and not less than 4 inches thick. The plate shall have its two faces parallel within four-thousandths of an inch, and each face shall be finished flat to a tolerance of plus or minus four-thousandths of an inch. The tolerance on parallelism includes the tolerance of flatness.

134 e. Yoke: The yoke to which the leveling assembly is attached shall be constructed with the bottom face having the same area as the bearing plate of the leveling assembly. The lower plate of the yoke which bears against the leveling disks shall be designated as the yoke plate. The yoke plate shall be integral with the yoke. In addition it shall be adequately stiffened with the ribs which extend from the yoke plate to the yoke proper. That face of the yoke plate which bears against the top leveling disk shall be finished flat to a tolerance of plus or minus four-thousandths of an inch.

134 f. Bearing Plate Support: The bearing plate shall be supported from the yoke plate on springs and a pin at the center. The center pin shall support the bearing plate so as to prevent sag at the plate center. The number of springs shall be the minimum necessary, and their location shall be such as to cause a minimum of interference with the operation of rotating the leveling disks and reading the graduations. The springs shall be capable of holding the bearing plate and the two leveling disks snugly against the yoke plate over the entire area at all times with such pressure that the leveling disks can be adjusted by a single force of not more than 50 pounds at a distance of 48 inches from the center of the disks without adjustment of the spring tension. These springs shall pass through the yoke plate and be
supported by a nut or other mechanism above the yoke plate which permits varying the tension on the support springs. The springs shall be capable of holding the bearing plate and leveling disks against the yoke plate with a force equal to 140 per cent of the dead weight of those parts.

134 g. **Spring Adjustment:** The nut or tension adjusting mechanism on the support springs shall have such travel that the bearing plate and leveling disks can be lowered such a distance that there is one-half inch clear space between the yoke plate and top leveling disk.

134 h. **Relative Rotation:** The bearing plate shall be prevented from rotating with respect to the yoke plate.

134 i. **Bearing Block Supports:** There shall be provided on the bearing plate suitable means for supporting auxiliary spherically seated bearing blocks for testing small-sized specimens in compression.

134 j. **Scribed Lines**

1. Lines shall be scribed on the bottom face of the bearing plate similar to those on the main table, as described in paragraph 122c.

2. The edge of each leveling disk shall be graduated from 0 to 360 degrees in one-degree divisions. Each ten degree division line shall be stamped with the number of degrees from zero. The markings on each disk shall be such that when the zero marks coincide the leveling disks will be complementary to each other; that is, the thickest portion of one disk shall coincide with the thinnest portion of the other.

134 k. **Centering:** The geometric center of the bearing plate shall be plumb over the center of the main table.

134 l. **Finish:** The finish of the flat faces of the yoke plate, leveling disks, and bearing plate shall be either ground or highly polished, and shall be of the highest quality with regard to flatness and smoothness. Edges of plates and disks shall have a high-grade machine-finish. On the yoke plate and bearing plate a one-sixteenth chamfer or radius shall be machined on each edge.

134 m. **Method of Adjustment:** The leveling disks shall be rotated under zero test load by electric motors with push-button control. The slack in the system shall be kept to a minimum.

135. **Bearing Plate**

135 a. **Dimensions:** There shall be provided for the main table a hardened bearing plate approximately seventy-two (72) inches long, forty-eight (48) inches wide, and six (6) inches thick.
135 b. Tolerances and Finish: The bearing plate shall conform to the requirements for the bearing plate of the leveling assembly as regards flatness, parallelism, finish, edge chamfer, and scribed lines. To aid in positioning, vertical lines shall be scribed on the four (4) faces at the centerlines.

135 c. Attachment to Main Table: The bearing plate shall be provided with a convenient means for fastening it to the main table, utilizing the tapped holes in the main table.

135 d. Tapped Holes: The bearing plate shall contain the following tapped holes in the four (4) faces:

1. On the two faces which are forty-eight (48) inches long there shall be three (3) tapped holes at twelve (12) inch centers to receive three-quarter (3/4) inch bolts, two (2) inches long. The middle tapped hole shall be on the centerline of the plate.

2. On the two faces which are seventy-two (72) inches long there shall be five (5) tapped holes at twelve (12) inch centers. The three (3) interior holes shall be as described above, and the two (2) end holes shall be tapped to receive eye bolts of such capacity that any one eye bolt will lift the plate.

135 e. Bolts: Machined bolts two (2) inches long shall be provided for all three-quarter (3/4) inch holes, and four (4) eye bolts shall be provided for the eye bolt holes.

136. Pedestal

136 a. General: A movable steel pedestal with hardened top surface and with capacity of five million (5,000,000) pounds shall be provided for use on the main table in compression tests. The top surface of the pedestal shall be an integral part of the pedestal, shall be thirty (30) inches above the main table, and shall be seventy-two (72) inches long and forty-eight (48) inches wide.

136 b. Mobility: The mobility of the pedestal shall be obtained by having retractable wheels, one at each corner.

136 c. Attachment to Main Table: The pedestal shall be provided with a convenient means for fastening it to the main table, utilizing the tapped holes in the main table.

136 d. Tolerances and Finish: The top and bottom surface of the pedestal shall conform to the requirements for the bearing plate of the leveling assembly as regards flatness, parallelism, finish, and edge chamfer. Lines similar to those on the bearing plate of the leveling assembly shall be scribed on the top surface of the pedestal. At the base of the pedestal vertical lines shall be scribed at the centerlines to aid in positioning.

136 e. Tapped Holes: The pedestal shall contain the following tapped holes in the vertical sides at a distance of about three (3) inches from the top surface.
1. On the two (2) sides which are seventy-two (72) inches long there shall be five (5) tapped holes at twelve (12) inch centers to receive three-quarter (3/4") inch bolts two (2) inches long. The middle tapped holes shall be on the centerline of the pedestal.

2. On the other two (2) sides there shall be three (3) similar tapped holes at twelve (12) inch centers, with the middle hole on the centerline of the pedestal.

136 f. Bolts: Machined bolts two (2) inches long shall be provided for all the tapped holes.

137. Tension Test Fixtures

137 a. Tension Grips

1. The following types of tension grips are to be provided:

   (a) Flat grips to accommodate specimens up to twelve (12) inches wide and six (6) inches thick.

   (b) Vee grips to accommodate round specimens one and one-half (1-1/2) to three (3) inches in diameter.

   (c) Vee grips to accommodate round specimens three (3) to six (6) inches in diameter.

   (d) Vee grips to accommodate round specimens five (5) to ten (10) inches in diameter.

2. All required filler plates are to be furnished.

3. All grips and filler plates shall be capable of use at the full capacity of the testing machine without damage.

4. Where the thickness of the piece permits, eye bolt holes of uniform size shall be provided in both ends of all tension test fixtures.

137 b. Spherically Seated Tension Rods

1. There shall be provided with the testing machine two (2) spherically seated tension rods. One of these rods shall fit in the tension crosshead and the other shall fit in the tension side of the sensitive crosshead. Each tension rod shall be designed to transmit one hundred and ten (110) per cent of the testing machine capacity (5,500,000 lbs.) in direct tension.

2. Each tension rod assembly shall consist of four (4) principal parts; as follows:

   (a) A wedge block which fits into the tension grip pockets. This block shall have a concave seat to receive the spherical surface of the tension rod bolt.
(b) A tension rod bolt, threaded on one end, and headed with a spherical seat on the other end.

(c) A clevis type nut, one end of which is a socket threaded to fit the tension rod bolt, and the other end of which is a fork. The fork arms shall be drilled to receive a pin.

(d) A tension rod pin of circular cross section. The pin shall be a medium fit in the fork, and shall be provided with a locking device to prevent it from slipping out of the fork.

3. The quality and appearance of the machine work on the tension rods shall be consistent with the highest standards of machining practice.

4. All required filler plates are to be furnished.

138. Tools

A complete set of all wrenches and other tools necessary for the normal operation and adjustment of the machine shall be furnished. Tools shall be of first quality and suitable for their intended purpose. They shall be individually marked with the serial number of the testing machine, and fitted in racks in a portable steel or hardwood case. The case shall be fitted with a cylinder lock of good grade.

139. Electrical Power Outlets

Electrical power outlets shall be provided at 6 ft. intervals on each column throughout the height of the testing machine. These outlets are to be duplex units, 110 volts, and are to be located so as not to decrease the clearance between columns.

140. Ladder

One ladder, extending beyond the full height of the columns, shall be furnished. The ladder shall have round uprights. Provision shall be made for convenient access from the ladder to the movable platform and to the top of the testing machine. The ladder shall be located at the main column corner nearest the control cabinet.

141. Spherically Seated Bearing Blocks

141 a. Number and Size: Two spherically seated hardened bearing blocks for testing compression specimens shall be supplied. One block shall have a bearing-face diameter of 8 inches, the other block shall have a bearing-face diameter of 14 inches. A spherical seat block shall be supplied for each of the bearing blocks.
141 b. Fasteners: Each bearing block shall be provided with means for fastening to the main bearing plate on the leveling assembly. The fasteners shall be especially designed to absorb energy loads resulting from sudden failures of specimens and to prevent dropping of the fixture.

141 c. Scribed Lines: A circle, having a diameter of 6 inches shall be accurately scribed on the bearing face of the 8-inch bearing block. Concentric circles, having diameters of 6 inches, 8 inches, 10 inches, and 12 inches shall be accurately scribed on the bearing face of the 14-inch bearing block.

141 d. Workmanship: The same high-grade requirements of workmanship and accuracy with regard to flatness, smoothness, and general appearance applying to the main bearing plates of the testing machine shall also apply to the spherical bearing blocks.
F. Tests and Inspection

142. General

After installation, adjustment, and calibration, the testing machine shall be subjected to the following tests. The tests shall be made by the Contractor. The test specimens shall be furnished by the Buyer, but all other equipment shall be furnished by the Contractor. The tests shall be made in the order hereinafter given, unless changed by agreement between Contractor and Buyer.

143. Operation Tests

143 a. Attachments: All attachments and accessories required to be furnished with the machine shall be tried in place to demonstrate their satisfactory construction and operation.

143 b. Sensitive Crosshead: The sensitive crosshead shall be raised and lowered by power throughout its full limit of travel at a rate not less than 24 inches per minute by rotation of the screws.

143 c. Tension Crosshead: The sensitive crosshead shall be used to raise the tension crosshead, which shall in turn be mounted and secured in each of its positions.

143 d. Power Stroke: The sensitive crosshead shall be raised and lowered for a vertical distance of at least 36 inches by the hydraulic jack. This test shall be carried out with the sensitive crosshead at any position on the screws as selected by the Buyer.

143 e. Pump and Pump Motor Test: A suitable test shall be performed to demonstrate that the pump and pump motor satisfy the requirements of paragraph 118h. This test shall be continued until the pump and pump motor have reached an equilibrium temperature.

143 f. Leveling Assembly: With the sensitive crosshead in any position on the screws as selected by the Buyer, a suitable test shall be performed to demonstrate that the leveling assembly meets the requirements of Article 134b.

143 g. Safety Devices: The adequacy of all limit switches, control and safety devices shall be demonstrated.

144. Load Tests

144 a. Tension and Compression Tests: The machine shall be used to rupture a tension and a compression specimen designed to break at a load between 75 per cent and full capacity of the machine. As a result of these tests there shall be no disarrangement or damage whatsoever to the machine.

144 b. Load Rate Test: If the Buyer elects to supply the required specimen, the loading system shall demonstrate its ability to apply full capacity loads at a rate of movement of the sensitive crosshead of 3 inches per minute. The movement of the crosshead during this test shall be at least one-half inch. The indicated load during this test shall not fall below 75 per cent of full-rated capacity of the machine. The speed of 3 inches per minute is to be guaranteed whether or not a special test is carried out.
144 c. Overload Tests

1. The machine shall pull a tensile specimen to at least 110 per cent of full-load tension capacity.

2. The machine shall compress a block specimen to at least 110 per cent of full-load capacity.

3. It is not required that the specimens be broken in the overload tests.

Note: A special pressure gage to be furnished by the Contractor will measure the load through the complete overload tests with the regular dial operating simultaneously up to its limit of 5,000,000 lbs. The pressure gage shall remain the property of the Contractor.

144 d. Rigidity Test

1. The machine shall be tested for its ability to withstand eccentric loads by compressing a column, 10 feet long and so inclined that a horizontal component of 10 per cent of the end load will be applied to the sensitive crosshead.

2. Under capacity load, the main columns, screws, and other parts shall not deflect from their initial position (zero load) more than 1 inch as indicated at the floor level by the movement of at least two plumb bobs suspended from tops of the main column members.

3. This test shall be conducted in four directions, two with the horizontal thrust in the vertical plane of the columns, and two with the horizontal thrust normal to the vertical plane of columns.

4. During this test there shall be no indication of unsatisfactory operation of any part of the machine.

144 e. Clearance Tests

1. These tests shall be conducted simultaneously with the rigidity test under (d).

2. With the wear plates on the sensitive crosshead previously set so that the machine satisfies the requirements of paragraph 143 b, it shall be demonstrated that the relative horizontal motion between the sensitive crosshead and main columns is not more than twenty-thousandths (.020) of an inch under a horizontal load of 100,000 pounds. The relative horizontal motion shall be measured by two (2) gages mounted on the sensitive crosshead, one bearing on each column. The average of the dial changes shall be taken as the relative horizontal motion.
3. Suitable tests shall also be made to demonstrate that the mechanism employed to prevent relative vertical motion between the sensitive crosshead and screws restricts such motion to less than fifteen-thousandths (.015) of an inch under capacity load.

4. During the tests described above, the Buyer may take such other measurements as may be desired for his own information.

145. Hysteresis Test

145 a. Number and Purpose: The following tests shall be performed on the 2,000,000 lb. dial. The purpose of this test is to ascertain the accuracy with which a dial indicator will repeat its readings under the following loading cycle:

1. Compression load to one-half full capacity of dial.

2. Compression load increased to within five (5) per cent of full capacity of dial.

3. Compression load maintained at a given figure within five (5) per cent of dial capacity for approximately one (1) hour.

4. Compression load decreased to one-half dial capacity. Hysteresis readings on the dial indicator will be taken between 1 and 4.

145 b. Proving Rings: This test shall be conducted by using for the half-load indication a group of proving rings, not fewer than 2, whose combined capacity is greater than one million five hundred thousand (1,500,000) pounds but not more than three million (3,000,000) pounds.

145 c. Compression Jack: The full compression load shall be exerted by a hydraulic jack of about three million (3,000,000) pound capacity, placed on the main table at its center, and the proving rings spaced concentrically about it.

145 d. Method of Test: The manner of conducting the test shall be as follows:

1. Compression load will be applied to the proving rings, with the ram of the jack clear of the compression plate, until a load of one million (1,000,000) pounds (plus or minus one (1) per cent) is reached. The dial indicator scale will be adjusted so that the pointer reads one million (1,000,000) pounds (or the sum of the loads on all the rings).

2. The hydraulic jack will then be pumped up until the dial indicator reads between one million nine hundred thousand (1,900,000) and two million one hundred thousand (2,100,000) pounds, relieving the proving rings of some of their load. The apparatus will be held in this position for a period of one hour. The combined load of the proving rings shall be recorded during this interval.
3. The jack will then be slowly lowered until the proving rings have again taken the entire compression load and the ram of the jack is clear of the compression plate.

4. The proving rings and the dial indicator shall be read again.

5. Necessary manipulation of load applying mechanism will be permitted during this test, except that the indicated load shall not be increased at any time during the operation described in (3) until after the final reading of the proving rings in (4).

145 e. Required Accuracy: The difference between the two readings shall be less than three scale divisions on the indicator (3,000 lbs.), plus or minus.

145 f. Optional Test: If the Buyer requests, a test similar to that described in 145d above shall be repeated on one other dial indicator (not the 5,000,000 lb. dial) selected at time of test.

145 g. Test Equipment: The Contractor shall supply the proving rings and the three million (3,000,000) pound (or other) hydraulic jack for the test, but these and other special test equipment shall remain the property of the Contractor.

146. Creep Test

146 a. Number of Tests: This test shall be performed on any one dial indicator which the Buyer may select at the time of the test, except the 5,000,000 lb. range.

146 b. Method of Test

1. A compression load of not less than ninety (90) percent of full rated capacity of the loading range selected shall be applied through proving rings.

2. The proving rings shall be read, and the dial indicator set to the combined load.

3. This load shall then be held as nearly constant as possible (variations shall be recorded) for a period of six (6) hours, at which time the proving rings and dial indicator shall again be read.

146 c. Required Accuracy: The difference between the latter two readings shall not exceed six-tenths (0.6) of one per cent of dial reading.

147. Accuracy Tests

147 a. Number of Tests: Accuracy tests shall be made on each of the six dial ranges, and an additional test for accuracy under eccentric loads shall be made on one of the ranges.

147 b. Proving Rings: The Contractor shall supply for these tests the necessary proving rings for testing up to loads of
2,500,000 lbs. Each proving ring shall conform to specifications of letter circular L.C. 822 dated April 15, 1946, (or the latest succeeding circular) of the U.S. Bureau of Standards and shall have been primarily calibrated by the Bureau of Standards within twelve months prior to test of the machine described herein. A certificate of such calibration from the Bureau of Standards shall be submitted for examination at the time of test.

147 c. Gage Tester: For tests at loads between 2,500,000 and 5,000,000 lbs, the Contractor shall provide a gage tester which shall be guaranteed by the Contractor to be accurate within three-tenths \((0.3)\) of one \((1)\) per cent.

147 d. Selection of Proving Rings: The proving rings shall be selected for tests in such a manner that the capacity of any proving ring, or the combined capacity of any group of rings, will not exceed two times the maximum load capacity of the particular dial indicator being tested. Readings shall not be taken from the proving rings at loads below one-tenth of their rated capacity.

147 e. Eccentric Load Test: The test for accuracy under eccentric loads shall be performed on the five million \((5,000,000)\) pound dial. With the proving rings in position on the main table, a vertical load of two million five hundred thousand \((2,500,000)\) pounds shall be applied at an eccentricity of two \((2)\) inches.

For the purposes of information only, and not as an acceptance test, a similar test shall be performed on the five hundred thousand \((500,000)\) pound dial. For this test a load of five hundred thousand pounds shall be applied at an eccentricity of ten \((10)\) inches.

147 f. Required Accuracy: For all acceptance tests prescribed above, the machine shall meet the accuracy requirements defined in paragraph 119e with or without special fixtures.

In the event that the dial indicators or any other parts of the weighing mechanism are tapped to obtain the best reading, a record shall also be preserved of the reading prior to tapping.

148. Retests

After the above tests are completed, the operations tests listed in Article 143 shall be repeated. Any of the other tests listed in Articles 144 through 147 shall be repeated if the Buyer so requests.

149. Inspection

During and after each test, the testing machine will be checked and inspected by the Contractor and the Buyer to ascertain if any damage has been done to the machine, and whether the machine has performed in accordance with the specifications.
APPENDIX TO PART II

150. Appurtenances not the Obligation of the Contractor

150 a. Control Cabinet Equipment: The following appurtenances will not be designed or furnished under this contract, but space for their installation will be provided in the control cabinet, as noted in Article 120:

1. Jack Position Indicator
2. Load Rate Control System
   (a) Load rate pacer
   (b) Jack motion pacer
3. Automatic Load Maintainer
4. Autographic Recording System

150 b. Auxiliary Appliances: The following appliances may and presumably will be supplied by the Buyer. The obligation of the Contractor shall be only to ensure that the installation as proposed by the Buyer is feasible and in no way will interfere with the performance and accuracy of the machine:

1. Screw Protection Curtains
2. Protective Screen
3. Intercommunication System
4. Auxiliary Hoists on Upper Horizontal Frame
5. Two large and two small End Supports for Flexure Tests
6. Dynamic Loading Equipment
7. Auxiliary (Flat) Bearing Block for Leveling Assembly
8. Lateral Support Fixtures
9. Roller Nests for Flexure Specimen Support
10. Multiple Stress-Strain Recorder
150 c. Movable Platform: The Buyer expects to contract with another vendor for the furnishing and installing of a movable platform which can be raised by power from the laboratory floor to as close as practicable to the top of the machine. For the information of the Contractor for the machine, the general specifications for this platform are quoted hereafter in this paragraph 151 c.

The obligation of the Contractor for the machine, in connection therewith, is limited to the following: he will cooperate with the vendor of the platform, when and as requested by the Buyer, in exchange and cross-checking of detail drawings; and he will for reasonable compensation provide such drilled, or drilled and tapped, holes in the shop before shipment of parts of the testing machine, as the delivery of detail drawings for the said holes shall render feasible.

Specifications:

1. Travel: The testing machine is to be equipped with a movable platform which can be raised by power at a lifting speed of about 12 feet per minute, from the floor to the maximum practicable height.

2. Stops: It shall be possible to stop the platform at any position for indefinite periods.

3. Control: Rise and drop of the platform shall be controllable from either the working deck of the platform or from the testing machine control cabinet by spring loaded push-button control. A control on the platform shall make it possible to render the platform control at the cabinet inoperative.

4. Removable Units: Removable light-weight floor units shall be supplied with the platform to vary the size and shape of the space enclosed by the platform. The number and size of the units shall be such that the size of opening enclosed by the platform can be reduced to about 2 ft. by 2 ft. The removable units shall be so arranged that if the platform were accidentally lowered into an object which obstructed the motion of the removable units, the units would lift upward without damage to the remainder of the platform.

5. Capacity: The platform shall have a lifting capacity of not less than 4,000 lbs. in addition to the dead weight of the platform.

6. Railing: A railing 3-1/2 ft. high shall be provided on all sides of the working platform, including the open sides nearest to the machine. Railing opposite the clear space between testing machine columns shall be removable. Railing which would limit the highest position of the platform also shall be removable. The railing shall consist of a structural pipe handrail at the top with wire screening from the rail down to 6 inches above
the platform floor. The last 6 inches shall be formed with 1/8-inch thick plate.

7. Construction: The movable platform shall be as light as is consistent with other requirements, and shall be constructed to the same standards of appearance, workmanship, and reliability as the testing machine.

8. Motor Location: The motors and drums for the movable platform shall be located on the under side of the movable platform.

9. Access to Ladder: Convenient access shall be provided at all times from the platform to the ladder on the main column.

10. Entrance: A convenient entrance to the platform from the floor level shall also be provided.

11. Guide Rails: The movable platform guide rails shall be located so as not to interfere with continued use of electrical power outlets on the main columns.

12. Safety Devices: The platform shall be furnished with all protection and safety devices consistent with the best practice in movable platform installation, including limit switches at the top and bottom of the machine to prevent over-travel of the platform.
DURING TEST, SENSITIVE CROSS-HEAD IS PULLED DOWN BY HYDRAULIC JACK. VERTICAL SCREWS TURN ONLY TO POSITION HEAD BEFORE TEST BEGINS.

ANY SPECIMEN HELD IN THIS SPACE IS PULLED.

ANY SPECIMEN IN THIS SPACE IS COMPRESSED.
Fig. 2

ALLOWABLE LATERAL THRUST ON LEVELING ASSEMBLY

HEIGHT ABOVE TABLE, ft.

0 5 10 15 20 25 30 35 40

LATERAL THRUST 1000 lbs.
<table>
<thead>
<tr>
<th>Subject</th>
<th>Article No.</th>
<th>Subject</th>
<th>Article No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acceptance</td>
<td>111</td>
<td>Eccentric Load</td>
<td>119f</td>
</tr>
<tr>
<td>Acceptance Tests</td>
<td>142,148</td>
<td>Electric Motors</td>
<td>128</td>
</tr>
<tr>
<td>Accessories</td>
<td>134-141</td>
<td>Electric Power</td>
<td>139</td>
</tr>
<tr>
<td>Accuracy Tests</td>
<td>147,146c,</td>
<td>Outlets</td>
<td>108</td>
</tr>
<tr>
<td></td>
<td>145e</td>
<td>Erection</td>
<td></td>
</tr>
<tr>
<td>Air Bleeds</td>
<td>129e</td>
<td>Facilities to Be</td>
<td>113,150</td>
</tr>
<tr>
<td>Allowable Errors</td>
<td>119e</td>
<td>Furnished by the Buyer</td>
<td></td>
</tr>
<tr>
<td>Allowable Lateral Thrust</td>
<td>Fig.2</td>
<td>Flexure Capacity</td>
<td>116b</td>
</tr>
<tr>
<td>Appurtenances not the Obligation of the</td>
<td>150</td>
<td>Foundation</td>
<td>121</td>
</tr>
<tr>
<td>Contractor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arrangement</td>
<td>Fig.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Auxiliary Appliances</td>
<td>150b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Backlash Eliminator</td>
<td>125f</td>
<td>Gage Tester</td>
<td>147c</td>
</tr>
<tr>
<td>Bearing Block</td>
<td>1341</td>
<td>Gears</td>
<td>130</td>
</tr>
<tr>
<td>Support</td>
<td></td>
<td>General</td>
<td>101</td>
</tr>
<tr>
<td>Bearing Blocks</td>
<td>141</td>
<td>General Requirements</td>
<td>101,114-117</td>
</tr>
<tr>
<td>Bearing Plate</td>
<td>135</td>
<td>Grips (see Tension Test</td>
<td>1251</td>
</tr>
<tr>
<td>Bearings</td>
<td>130,128d</td>
<td>Fixtures)</td>
<td></td>
</tr>
<tr>
<td>Bed Plate (Main table)</td>
<td>122</td>
<td>Guarantee</td>
<td>112</td>
</tr>
<tr>
<td>Bushings</td>
<td>130c</td>
<td>Guards and Covers</td>
<td>130b</td>
</tr>
<tr>
<td>Capacity</td>
<td>116</td>
<td>Height</td>
<td>117f</td>
</tr>
<tr>
<td>Centerlines</td>
<td>117</td>
<td>Horizontal Space</td>
<td>117e</td>
</tr>
<tr>
<td>Clean-up</td>
<td>111</td>
<td>Hydraulic System</td>
<td>129</td>
</tr>
<tr>
<td>Clearance Tests</td>
<td>144e</td>
<td>Hysteresis</td>
<td>119g</td>
</tr>
<tr>
<td>Compression Capacity</td>
<td>116a</td>
<td>Hysteresis Test</td>
<td>145</td>
</tr>
<tr>
<td>Compression Jack</td>
<td>145c</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compression Space</td>
<td>117c</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Construction</td>
<td>102</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control Cabinet</td>
<td>120b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control System</td>
<td>120</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Creep</td>
<td>119h</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Creep Test</td>
<td>146</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delivery</td>
<td>106</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design</td>
<td>102</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design Information</td>
<td>103</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dimensions</td>
<td>117</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drawings</td>
<td>104,109</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# INDEX  
(Continued)

<table>
<thead>
<tr>
<th>Subject</th>
<th>Article No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Columns</td>
<td>123</td>
</tr>
<tr>
<td>Main Table</td>
<td>122</td>
</tr>
<tr>
<td>Mechanical and Electrical Design</td>
<td>122-133</td>
</tr>
<tr>
<td>Movable Platform</td>
<td>150, 127d</td>
</tr>
<tr>
<td>Operating Manual</td>
<td>110</td>
</tr>
<tr>
<td>Operating Systems</td>
<td>118-120</td>
</tr>
<tr>
<td>Operation Tests</td>
<td>143</td>
</tr>
<tr>
<td>Overload Capacity</td>
<td>116d, 116L</td>
</tr>
<tr>
<td>Overload Protection</td>
<td>119c, 132</td>
</tr>
<tr>
<td>Overload Tests</td>
<td>144c</td>
</tr>
<tr>
<td>Paint and Finish</td>
<td>131</td>
</tr>
<tr>
<td>Pedestal</td>
<td>136</td>
</tr>
<tr>
<td>Permits, Legal Requirements</td>
<td>107</td>
</tr>
<tr>
<td>Power Stroke</td>
<td>118d, 143d</td>
</tr>
<tr>
<td>Power Switches</td>
<td>132d</td>
</tr>
<tr>
<td>Proving Rings</td>
<td>145b, 147b, 147d</td>
</tr>
<tr>
<td>Pump and Pump Motor</td>
<td>118h</td>
</tr>
<tr>
<td>Record Drawings</td>
<td>109</td>
</tr>
<tr>
<td>(See also &quot;Drawings&quot;)</td>
<td></td>
</tr>
<tr>
<td>Retests</td>
<td>148</td>
</tr>
<tr>
<td>Rigidity Tests</td>
<td>144d</td>
</tr>
<tr>
<td>Safety Devices</td>
<td>132, 118j, 125k, 143g</td>
</tr>
<tr>
<td>Screws</td>
<td>124</td>
</tr>
<tr>
<td>Sensitive Crosshead</td>
<td>125, 143b</td>
</tr>
<tr>
<td>Shock Absorption</td>
<td>133, 118k</td>
</tr>
<tr>
<td>Shop Drawings (see also &quot;Drawings&quot;)</td>
<td>104</td>
</tr>
<tr>
<td>Site Conditions</td>
<td>106</td>
</tr>
<tr>
<td>Spherically Seated Bearing Blocks (See also &quot;Bearing Blocks&quot;)</td>
<td>141</td>
</tr>
<tr>
<td>Structural Design</td>
<td>121</td>
</tr>
<tr>
<td>Tension Capacity</td>
<td>116a</td>
</tr>
<tr>
<td>Tension Crosshead</td>
<td>126, 143c</td>
</tr>
<tr>
<td>Tension Space</td>
<td>117d</td>
</tr>
<tr>
<td>Tension Test</td>
<td></td>
</tr>
<tr>
<td>Fixtures</td>
<td>137, 1251, 126d</td>
</tr>
<tr>
<td>Testing, Clean-up, Acceptance</td>
<td>111</td>
</tr>
<tr>
<td>Testing Machine Arrangement</td>
<td>Fig. 1</td>
</tr>
<tr>
<td>Tests and Inspection</td>
<td>142-149</td>
</tr>
<tr>
<td>Tools</td>
<td>138</td>
</tr>
<tr>
<td>Upper Horizontal Frame</td>
<td>127</td>
</tr>
<tr>
<td>Weighing System</td>
<td>119</td>
</tr>
</tbody>
</table>