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DESIGN AND OPERATION
OF THE
TRAFFIC SIMULATOR

by

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Iowa State University
Ames, Iowa

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Heavy traffic volumes frequently cause distress in asphalt pavements which were designed under accepted design methods and criteria. The distress appears in the form of rutting in the wheel tracks and rippling or shoving in areas where traffic accelerates or decelerates. Apparently accepted stability test methods alone do not always assure the desired service performance of asphaltic pavements under heavy traffic.

The Bituminous Research Laboratory, Engineering Research Institute of Iowa State University undertook the development of a laboratory device by which the resistance of an asphalt paving mix to displacement under traffic might be evaluated, and also be used as a supplemental test to determine adequacy of design of the mix by stability procedures.

To perform these functions the instrument must meet certain basic requirements:

1. That it be of such size that it may be used in a field laboratory.
2. That it simulate, as closely as possible, the effects of traffic travelling in one direction.
3. That the asphaltic mix under test may be subjected to various temperatures and weather conditions.
4. That the character and extent of displacement of the mix under various traffic loadings and volumes may be measured fairly accurately.

5. That the behavior of several mixes under identical test conditions be compared simultaneously.

6. That the results of tests by this instrument be of such character so they may be compared with results of stability tests.

A variety of concepts and theories of operation, controls and tentative designs of the instrument were studied and tested.

The relation of the resistance of a mix to displacement under traffic to its stability as measured by accepted stability tests is of prime importance. Therefore, it was decided that test specimens should be identical to specimens used in the Marshall and Hveem Stability tests. In this manner the compaction variable could be eliminated.

To achieve one-way traffic action, the means of imposing a moving load upon the test specimen was resolved in favor of an oscillating carriage. Thus in its forward travel the carriage is driven by the wheel imposing the load on the test specimen; in its reverse travel the loading wheel is retracted and the carriage is driven by an auxiliary drive.

Based upon these fundamental aspects of design, a traffic simulator instrument was constructed in 1958. During the next several years the instrument was modified, adjusted and tested under a variety of conditions, including width of loading wheel, wheel loading, carriage speed, specimen temperature and operation controls.

Upon completion of the basic design and operation of the instrument, named a Traffic Simulator, there followed a series of tests in which test procedures, test specimen temperatures, and test criteria were established and field correlation of test results were made[1,2].

Design

The Traffic Simulator consists primarily of the main frame upon which the carriage travels and in which the specimen box is installed; the carriage containing the loading wheel and drive mechanism; the specimen retainer box; and a control panel where operation of the instrument and specimen temperatures are controlled. The detailed dimensional design of each of the parts and their composite assembly are shown in Figures 1-11.

Main Frame:

The main frame of the Traffic Simulator serves as a base for the guidance and limitation of the carriage travel and as a mounting for the test specimen retainer box.

The main frame, Figures 1 and 2, consists of the following assembled parts: the carriage support tracks (1)* mounted on four legs bolted to the floor or laboratory truck, which carries and guides the carriage (2) and within which the specimen retainer box (3) is mounted; the retarder springs (4), the limit switches (8), and reversing switch actuators (9) limit carriage travel; carriage drive tracks, forward (5a), reverse (5b) and automatic carriage travel counter (10).

Carriage:

The carriage, Figures 3-5, consists of the following assembled parts: The frame of the carriage (2) upon which all other parts of

* Numbers in parentheses refer to parts numbers in the figures.

the unit are mounted, and the vertical (15) and horizontal (16) guide wheels which carry the carriage on the carriage support tracks of the main frame (these wheels are 4 inches in diameter, 1½ inches wide and are solid rubber tired).

Electrical power (110 volt, A.C.) is conveyed from the control panel, Figure 11, to the carriage by means of an overhead swinging cable (6) to a plug-in power distribution box (23). Compressed air is furnished to the carriage by overhead hose (7) leading from the control panel to a quick connection air distribution system (24).

The carriage is driven by a ½ H.P., 1750 R.P.M. electric motor (19) equipped with a 10:1 reduction gear (20) and ½ inch V belt drive 4 inches in diameter (22), connected to a drive mechanism (Figures 6 and 7) which actuates the forward drive wheel (11) and the reverse drive wheels (12). The forward drive wheel (11) is 8 inches in diameter, 1½ inches wide, solid rubber tired. The reverse drive wheels (12) are 5 inches in diameter, 1½ inches wide and also are solid rubber tired. The drive wheels are mounted on the ends of the rocker arm (14) which is actuated by a double acting air ram (13), 2 inches in diameter with a 3 inch stroke, through a connecting yoke (30).

As the carriage travels back and forth on the frames it strikes the retarder springs at each end of the frame. These springs, in compressing, stop the carriage and in expanding start it forward in the opposite direction. Simultaneously the reversing switch actuators operate the reversing switch (17) which activates the respective electric solenoid air valves (25) admitting air to the ram (13) which in turn tips the rocker arm (14) to either engage or disengage the forward (11) or reverse drive wheels (12), depending on direction of travel.

The carriage is equipped with a speed indicator (21) connected to the forward drive wheel by a friction take off (31) drive. Compressed air gauges (18) are also provided to check air pressure at the ram and the water spray tank (29). Water from the spray tank is conveyed to a nozzle mounted in front of the forward drive wheel to simulate various rates of rainfall upon the test specimens.

Carriage Drive Mechanism:

The details of the carriage drive mechanism are shown in Figures 6 and 7. The electric drive motor (19), Figures 3-5, operating continuously in one direction is connected to the drive pulley (32) (5 inches in diameter) by a ½ inch V belt. The drive pulley shaft operates the forward drive wheel by a 4 inch diameter, ½ inch V belt pulley (33) and a 2 inch diameter idler (34) connected to a 4 inch pulley on the drive wheel (35). This shaft also operates a forward drive, 4 inch diameter, 64 teeth pinion gear (26). This gear meshes with a 2½ inch diameter, 40 teeth reverse drive pinion gear (34), the shaft of which drives the reverse drive wheels (12) by means of two 4 inch diameter, ½ inch V belt pulleys (36). All shaftings are mounted in self aligning pillow block (37).

Specimen Holder Box:

The details of the specimen holder box, specimen holder rings, heating tapes, specimen temperature thermocouples and their connections are shown in Figures 8-10.

The specimen holder box (3) shown in Figure 1 is mounted in the main frame of the simulator in such manner that it is level with the main forward drive wheel track, and that this wheel tracks over the center of the test specimens inserted in the box.

The specimen holder box is equipped with a cover (38) bored to hold the specimen holding rings (39) in proper position; specimen leveling screws are located (47) in the bottom of the box to raise or lower specimen level with surface of the cover. Other features include the following: electrical conduit with plug-in junction boxes (48) for 110 volt, 194 watt, 1½ inch wide, 24 inch long specimen heating tape connections (41), and binding post connections (49) for specimen thermocouples; a specimen box air temperature thermal regulator (42) and a main junction box (43) for connection of electrical and thermocouple circuits to control the panel (Figure 11).

The specimen holding rings (39) are beveled at the top, as shown, for insertion and positioning in the specimen holder box cover. They are also fitted with a specimen supporting base plate (46), specimen positioning and holding screws (45) to prevent the specimen from rotating during test, and thermocouple plugs (40) for insertion and retention of thermocouples.

Control Panel:

The assembly of the control panel is shown in Figure 11.

Electrical power (220 volt, 3 phase, 60 cycle, A.C.) enters the system at a main electric power, 30 ampere switch (50) from which it is distributed to the carriage drive motor, air valve solenoid and heater circuits. The drive motor circuit (110 volts) consists of a motor start-stop switch (53), a line thermal overload relay (51) and a plug-in junction box for the power cable (6) leading to the carriage. The air valve solenoid circuit (110 volts) is controlled by an off-on switch (56). Voltage of the heater circuit is controlled by a 230 volt, 8 ampere Variac (57) with individual cut-off switches (58) for each of the specimen heater tapes through a multiple jack junction box (61). A specimen box heater, when used, is controlled by an off-on switch (60). Voltage of the heater circuits is regulated by a 150 volt meter (59).

Thermocouple leads from the individual specimens are connected to a multi-contact selector switch (62), which in turn is connected to a direct reading pyrometer (63). The temperature of each test specimen may thus be kept under surveillance at all times during the test.

Air pressure to the air ram is controlled by an air pressure regulator (54). Main line air pressure is indicated by a gage on the regulator (55). System air pressure is indicated by a gage at the air ram.

Displacement of the material in the test specimens during test is measured by an Ames dial (64), reading in .001 inch, placed in a bridge spanning the specimens and set on bench marks on the main frame of the instrument.

Operation

Materials to be tested in the Traffic Simulator are molded into cylinders 4 inches in diameter and 2½ inches in height. If the Simulator results are to be related to Marshall or Hveem Stability results, the specimens should be compacted in accordance with the requirements of the respective stability tests.

The test specimen is placed upon the base plate (46) within the holding ring (39) and its surface leveled with the upper beveled edge of the ring and locked into this position by the holding screws (45). A small hole is drilled into the specimen through the thermocouple plug (40) and the thermocouple is inserted and locked in position. The rings containing the specimens are then placed into the specimen holder box (3) on top of the several sets of leveling screws (47) and thermocouple and heating connections made. After the holder box cover (38) has been placed in position and the several rings inserted into their respective holes the cover is bolted down and the surfaces of the specimens adjusted level and flush with the surface of the cover by the leveling screws.

Initially full voltage is applied to the heating tapes to raise the temperature of the specimens to $140^{\circ}F$, or other test temperature, as rapidly as possible. As the temperature of the specimens approaches test temperature the voltage is reduced, by the Variac, to hold the specimen constantly at test temperature.

While the specimens are being heated, Ames dial readings are taken at three points, front, center and rear, on the surface of each specimen along the center line of travel of the forward drive wheel across the specimen. The elevations of these points are related to the bench marks on the main frame of the instrument. Also during this period the air pressure at the air ram is adjusted to the desired tire pressure. According to the design of the forward drive wheel, a 45 psi air pressure applies an equivalent tire pressure of 80 psi.

As soon as the specimen temperatures have steadied at test temperature the test may be started. The pass counter is set at predetermined passes at which displacement readings will be taken and the power turned on.

During the test, periodic checks are made of specimen temperature, and controls adjusted to maintain desired temperature.

Displacement readings should be taken after 100 to 300 passes, depending on characteristics of the mix, to ascertain initial traffic compaction. Subsequently, readings may be taken at the 500 or 1000 pass intervals to plot progressive displacement. The test is usually terminated either when a displacement of 0.100 inch has occurred or at 5000 passes, whichever occurs first.

Test results are reported as the amount of displacement for a given number of passes at a given test temperature.

References

1. Traffic Simulator for Checking Mix Behavior
L. H. Csanyi, H. P. Fung, Highway Research Record No. 51, H.R.B., 1964.

2. Service Correlation of the Traffic Simulator
L. H. Csanyi, Final Report, Engineering Research Institute, Iowa State University, March, 1967.

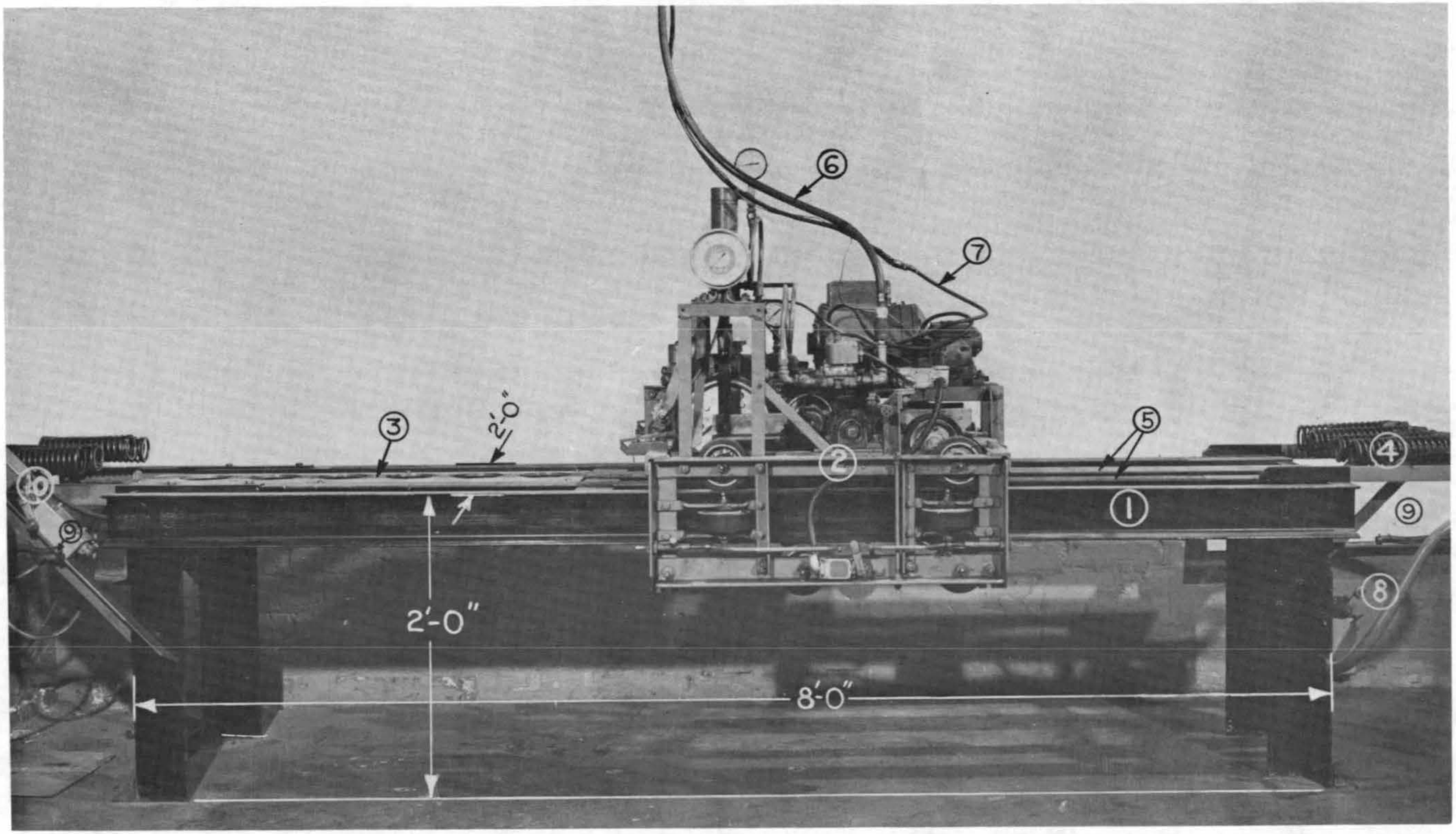


Fig. 1. Frame

1. Frame, 4" x 1½" Channel
2. Carriage
3. Specimen Holder Box
4. Retarder Springs, 7½" x 2½" dia.
5. Drive tracks: a-Forward
   b-Reverse
6. Power Connection
7. Air Connection
8. Limit Switches
9. Reversing switch activator
10. Automatic travel counter

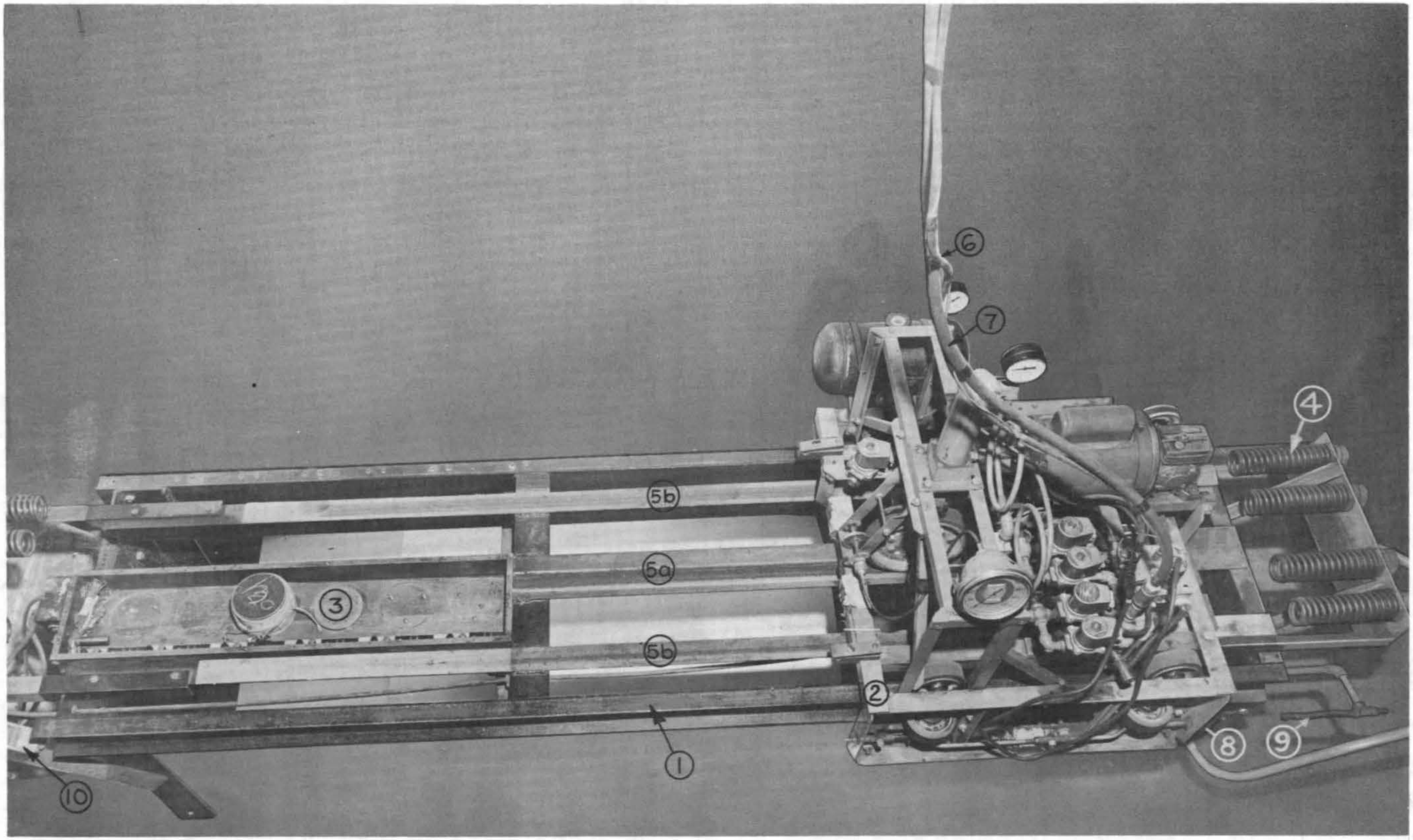


Fig. 2.

1. Frame, 4" x 1½" Channel
2. Carriage
3. Specimen Holder Box
4. Retarder Springs, 7½" x 2½" dia.
5. Drive tracks: a-Forward
   b-Reverse
6. Power Connection
7. Air Connection
8. Limit Switches
9. Reversing switch activator
10. Automatic travel counter

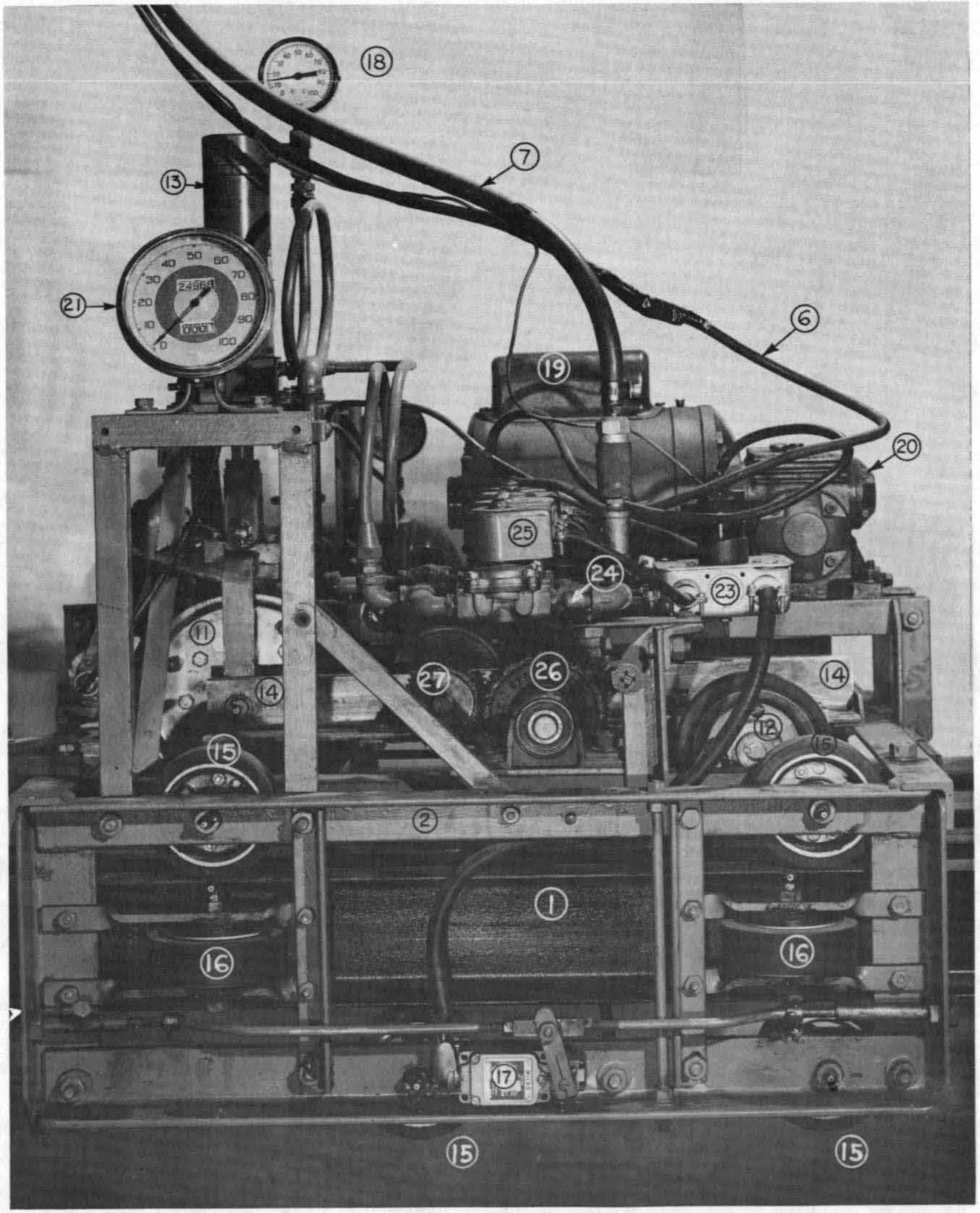


Fig. 3. Carriage

1. Frame
2. Carriage
6. Power Connection
7. Air Connection
11. Forward Drive Wheel, 8" dia., $1\frac{1}{4}$ inch wide, solid rubber tired
12. Reverse Drive Wheel, 5" dia., $1\frac{1}{4}$ inch wide, solid rubber tired
13. Double Acting Air Ram, 2" dia., 3" stroke
14. Reversing rocker arm
15. Vertical guide wheels, 4" dia., $1\frac{1}{4}$ inch wide, solid rubber tired
16. Horizontal guide wheels, 4" dia., $1\frac{1}{4}$ inch wide, solid rubber tired
17. Reversing switch
18. Air pressure gage
19. Carriage maindrive motor, $\frac{1}{2}$H.P.-1750 R.P.M.
20. Gear reducer, 10:1
21. Carriage Speed indicator
22. Main Drive pulley, 4" dia-$\frac{1}{2}$" V belt
23. Power distribution box
24. Air distribution system
25. Electric solenoid air valves
26. Forward drive gear, 4" dia-64 teeth
27. Reverse drive gear, $2\frac{1}{2}$" dia-40 teeth
28. Electric Counter connector
29. Water Spray Tank
30. Reversing rocker arm yoke to air ram
31. Carriage speed drive

Fig. 4. Carriage

1. Frame
2. Carriage
6. Power Connection
7. Air Connection
11. Forward Drive Wheel, 8" dia., 1¼ inch wide, solid rubber tired
12. Reverse Drive Wheel, 5" dia., 1¼ inch wide, solid rubber tired
13. Double Acting Air Ram, 2" dia., 3" stroke
14. Reversing rocker arm
15. Vertical guide wheels, 4" dia., 1¼ inch wide, solid rubber tired
16. Horizontal guide wheels, 4" dia., 1¼ inch wide, solid rubber tired
17. Reversing switch
18. Air pressure gage
19. Carriage maindrive motor, ½H.P.-1750 R.P.M.
20. Gear reducer, 10:1
21. Carriage Speed indicator
22. Main Drive pulley, 4" dia-½" V belt
23. Power distribution box
24. Air distribution system
25. Electric solenoid air valves
26. Forward drive gear, 4" dia-64 teeth
27. Reverse drive gear, 2½" dia-40 teeth
28. Electric Counter connector
29. Water Spray Tank
30. Reversing rocker arm yoke to air ram
31. Carriage speed drive

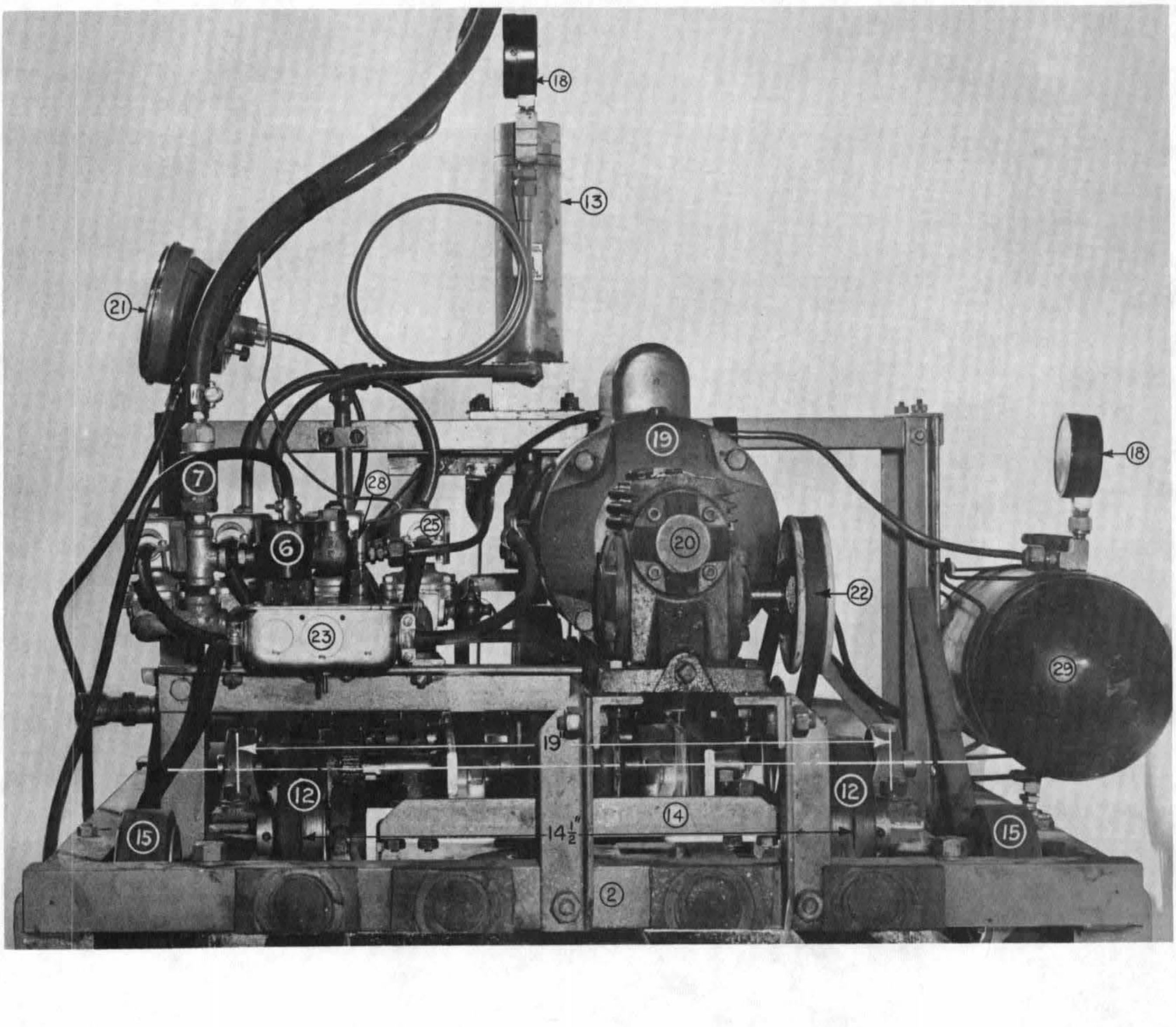
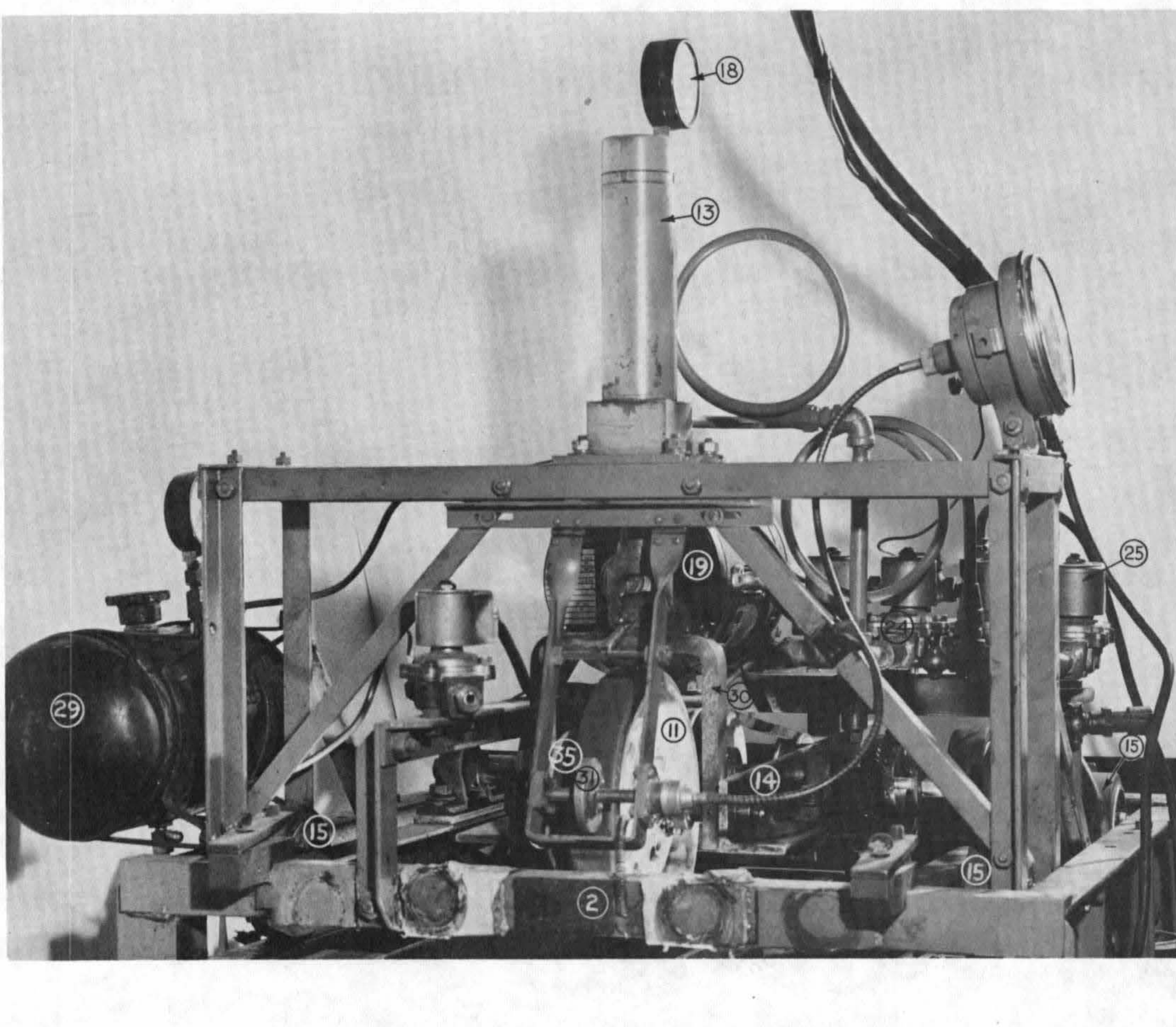


Fig. 5. Carriage

1. Frame
2. Carriage
6. Power Connection
7. Air Connection
11. Forward Drive Wheel, 8" dia. $1\frac{1}{4}$ inch wide, solid rubber tired
12. Reverse Drive Wheel, 5" dia. $1\frac{1}{4}$ inch wide, solid rubber tired
13. Double Acting Air Ram, 2" dia., 3" stroke
14. Reversing rocker arm
15. Vertical guide wheels, 4" dia., $1\frac{1}{4}$ inch wide, solid rubber tired
16. Horizontal guide wheels, 4" dia., $1\frac{1}{4}$ inch wide, solid rubber tired
17. Reversing switch
18. Air pressure gage
19. Carriage maindrive motor, $\frac{1}{2}$H.P.-1750 R.P.M.
20. Gear reducer, 10:1
21. Carriage Speed indicator
22. Main Drive pulley, 4" dia-$\frac{1}{2}$" V belt
23. Power distribution box
24. Air distribution system
25. Electric solenoid air valves
26. Forward drive gear, 4" dia-64 teeth
27. Reverse drive gear, $2\frac{1}{2}$" dia-40 teeth
28. Electric Counter connector
29. Water Spray Tank
30. Reversing rocker arm yoke to air ram
31. Carriage speed drive



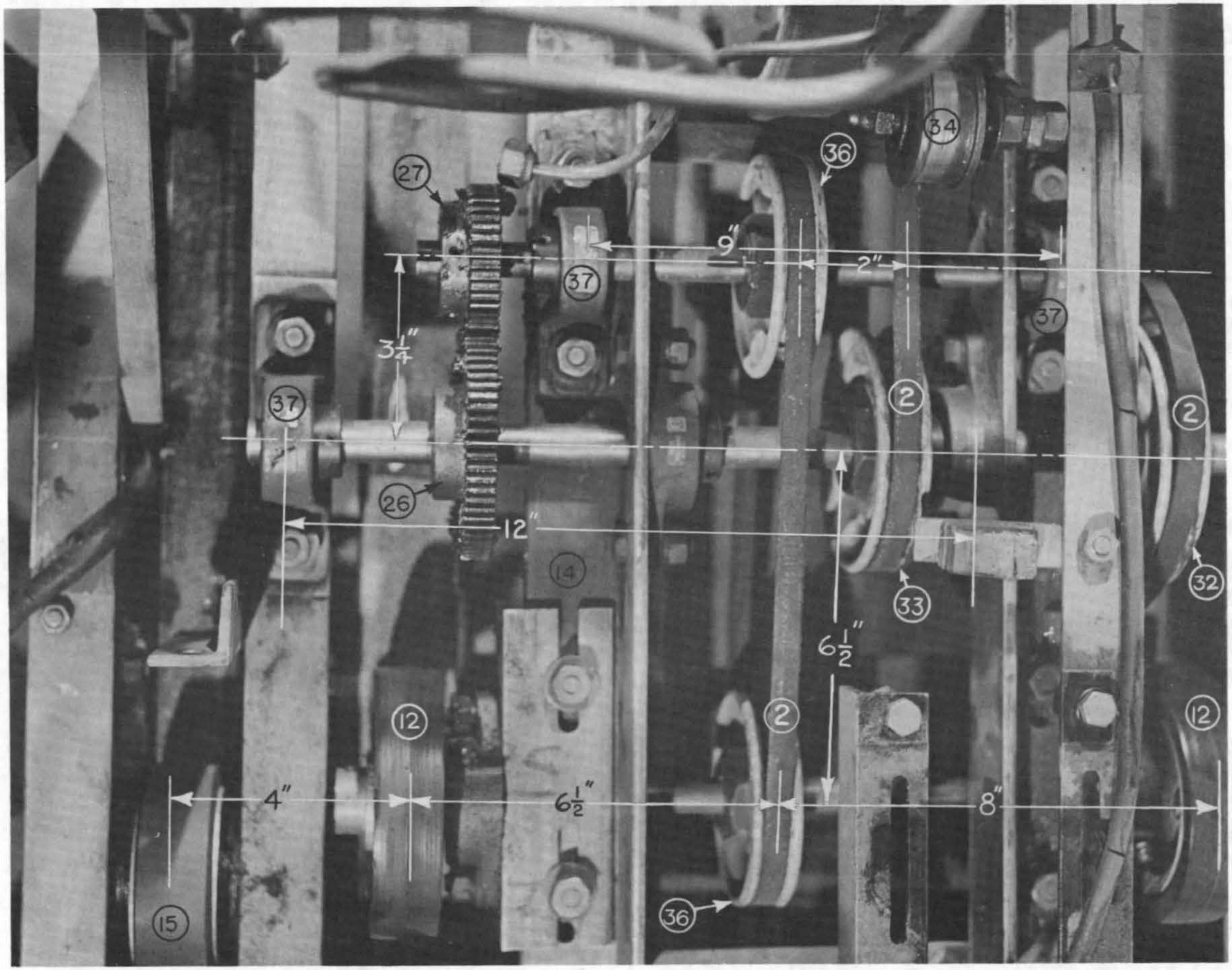


Fig. 6. Drive Mechanism

32. Main drive pulley, 5" dia, ½" V. belt
33. Forward drive pulley, 4" dia, ½" V. belt
34. Forward drive idler, 2" dia, ½" V. belt
35. Forward drive pulley on drive wheel, 4" dia, ½" V belt
36. Reverse drive pulleys, 4" dia, ½" V. belt
37. Pillow blocks

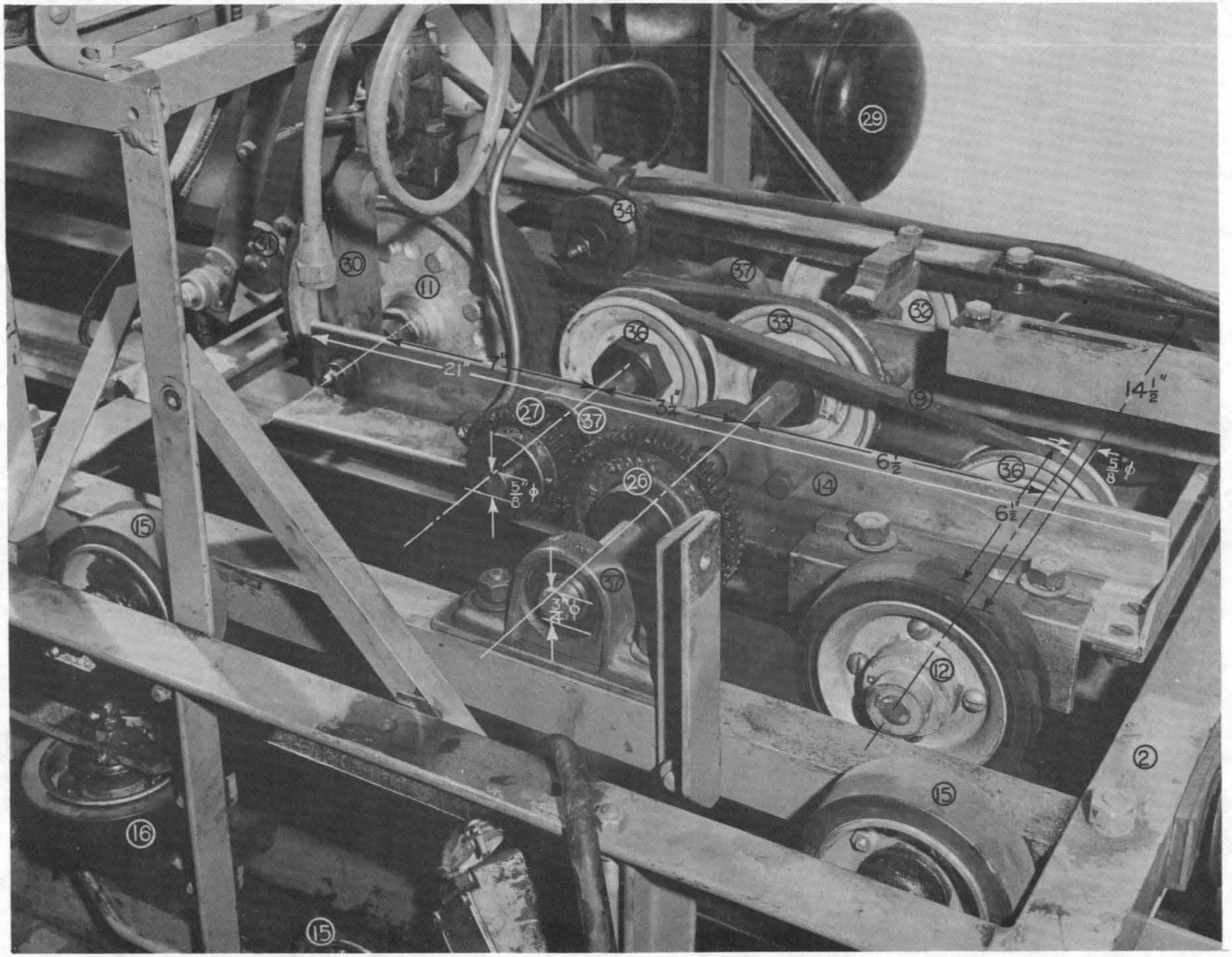


Fig. 7. Drive Mechanism

32. Main drive pulley, 5" dia, ½" V. belt
33. Forward drive pulley, 4" dia, ½" V. belt
34. Forward drive idler, 2" dia, ½" V. belt
35. Forward drive pulley on drive wheel, 4" dia, ½" V belt
36. Reverse drive pulleys, 4" dia, ½" V. belt
37. Pillow blocks

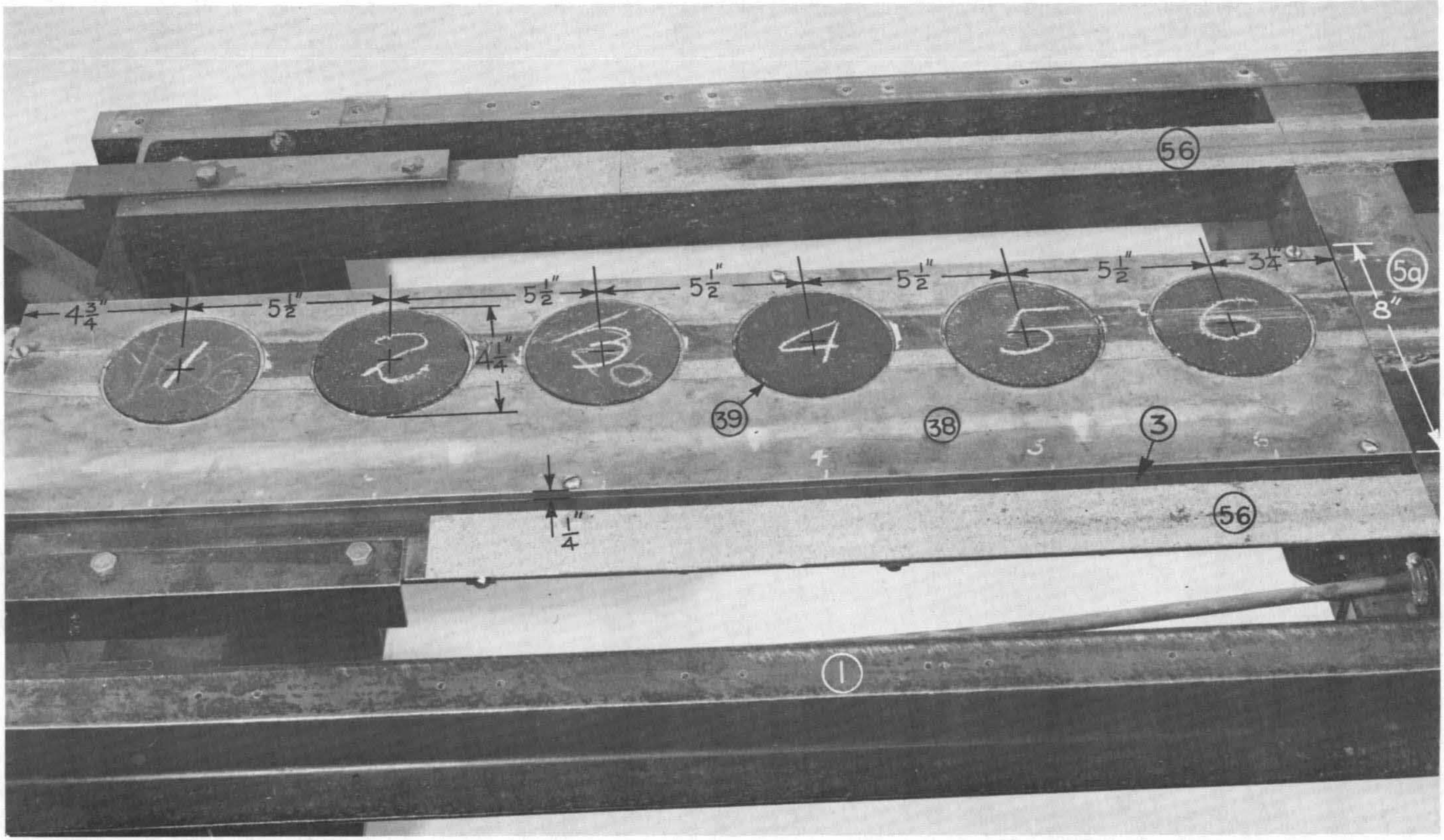


Fig. 8. Specimen Holder Box

38. Specimen Holder Box Cover
39. Specimen holding ring, 4" ID
40. Thermocouple
41. Flexible Heating tape, 1" wide, 24" long, 110v-194 watts
42. Thermal switch
43. Junction Box for heating and controls
44. Abrasion tape on drive tracks
45. Specimen positioning and holding screw
46. Specimen holding ring base plate
47. Specimen height adjustment and leveling screws
48. Heater tape plug in socket
49. Thermocouple connection

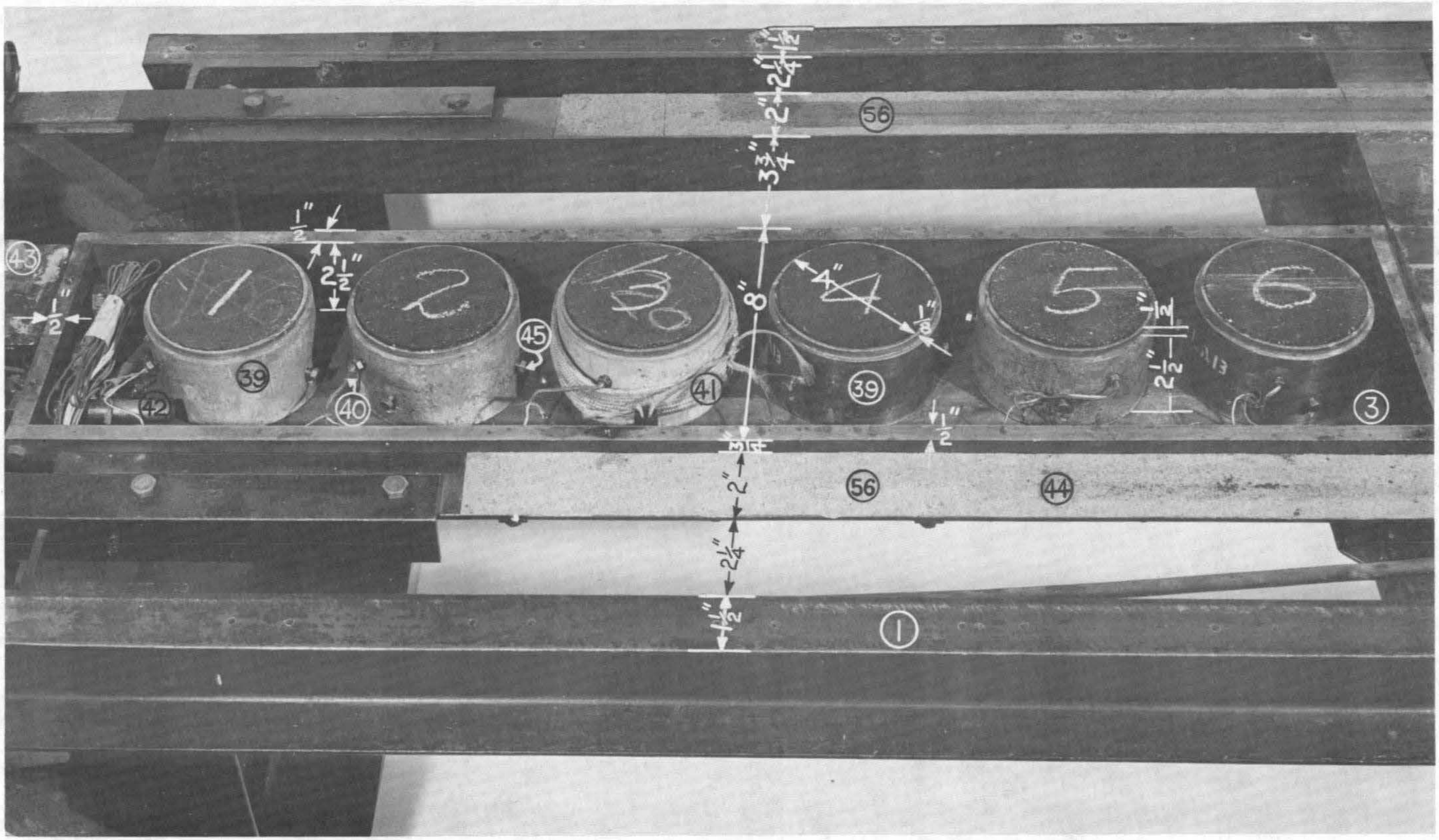


Fig. 9. Specimen Holder Box

38. Specimen Holder Box Cover
39. Specimen holding ring, 4" ID
40. Thermocouple
41. Flexible Heating tape, 1" wide, 24" long
    110v-194 watts
42. Thermal switch
43. Junction Box for heating and controls
44. Abrasion tape on drive tracks
45. Specimen positioning and holding screw
46. Specimen holding ring base plate
47. Specimen height adjustment and leveling screws
48. Heater tape plug in socket
49. Thermocouple connection

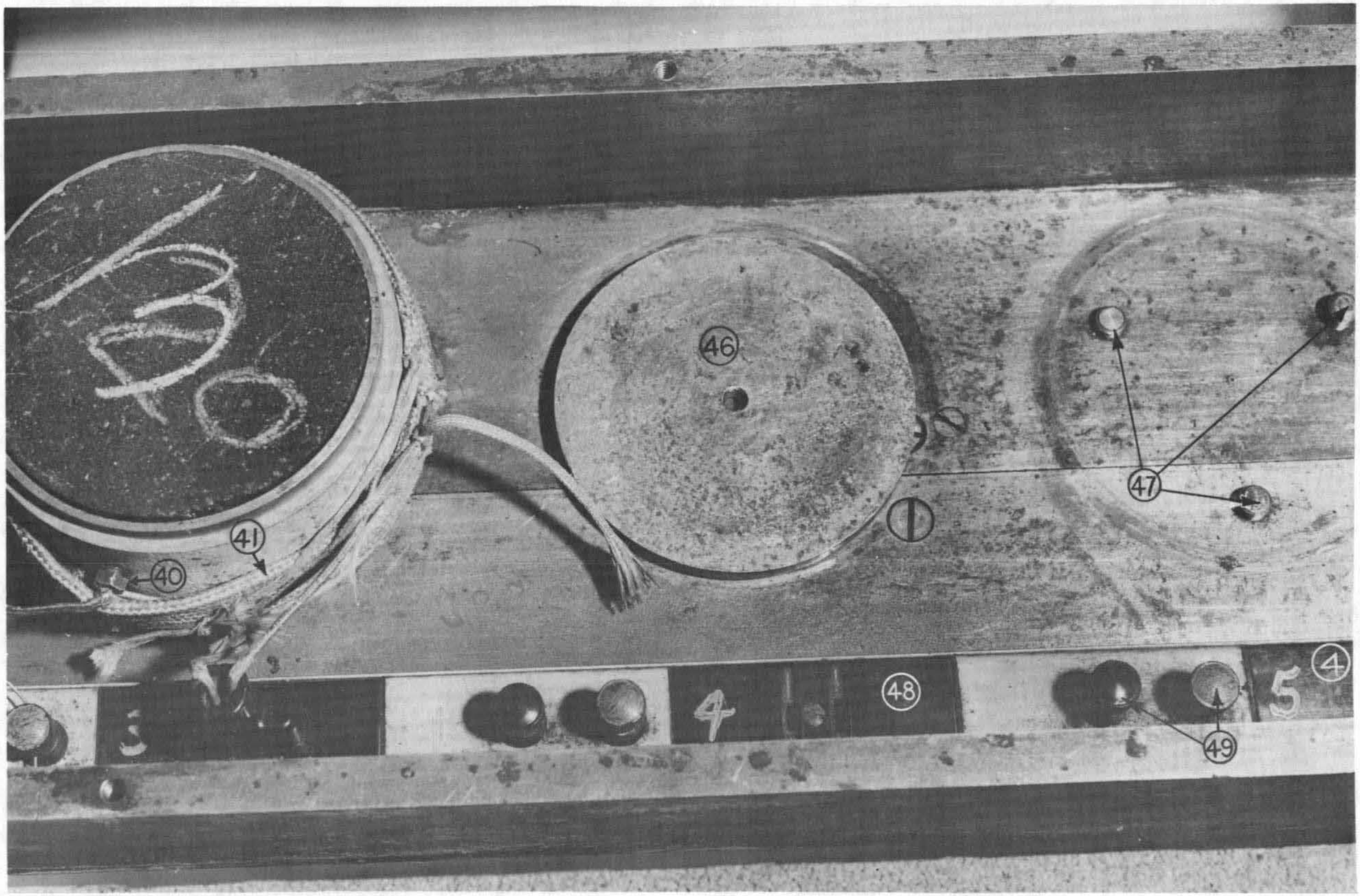


Fig. 10. Specimen Holder Box

38. Specimen Holder Box Cover
39. Specimen holding ring, 4" ID
40. Thermocouple
41. Flexible Heating tape, 1" wide, 24" long, 110v-194 watts
42. Thermal switch
43. Junction Box for heating and controls
44. Abrasion tape on drive tracks
45. Specimen positioning and holding screw
46. Specimen holding ring base plate
47. Specimen height adjustment and leveling screws
48. Heater tape plug in socket
49. Thermocouple connection

Fig. 11. Control Panel

50. Main Electric Power Switch
51. Thermal overload relay
52. Plug in connection box for power to carriage
53. Drive motor start-stop switch
54. Air pressure regulator
55. Air pressure gage
56. Electric solenoid air control switch
57. Variac for heating control 15 amp., 0-240r
58. Individual heating tape switches
59. Volt meter reading voltage of heating tapes
60. Specimen box heater control switch and plug in connector
61. Plug in connector power distribution to heating tapes
62. Thermocouple selector switch
63. Pyrometer
64. Ames dial for measuring displacement