DEPARTMENTAL RESEARCH

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DEVELOPMENT OF A SKID TEST TRAILER

by

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and
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Research Project 1-8-63-45

HIGHWAY DESIGN DIVISION
TEXAS HIGHWAY DEPARTMENT

DEVELOPMENT OF A SKID TEST TRAILER

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Research Report 45-1

Determining and Evaluating Skid
Characteristics of Texas Pavements
Research Project 1-8-63-45

Conducted by

Highway Design Division, Research Section
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ABSTRACT

Early in 1963, the Texas Highway Department in cooperation with the Bureau of Public Roads initiated a research project to study skid characteristics of Texas highways. The first prerequisite for this project was to design and construct a device to measure skid resistance. After a detailed literature survey and considerable personal contact with other representatives working in this field, a two-wheel trailer was selected which obtains a locked wheel skid resistance with the pavement in a wet condition. The system was designed so that either a standard test could be run automatically or the operator could control the various operations (time of skid, amount of water, number of wheels, etc.) through manual control.

The development of the various measuring systems and component parts are discussed in detail to provide accessible information for others desiring to construct a skid trailer. In addition the static and dynamic calibration of the trailer and its component systems are discussed.

Approximately 12,000 individual tire skids have been performed with the trailer through February, 1965, with good performance and only minor repairs. Tests were made in each highway district in the State encompassing some 500 different projects.

I. INTRODUCTION

Background

The earliest correspondence of the Texas Highway Department discussed slick sections of pavement and prescribed methods of signing these sections. Other correspondence suggested that these sections receive a deslicking treatment as soon as possible. No attempt was made to determine to what extent the pavement was slick, nor was a feasible method available to measure skid characteristics. This process continued for many years until early in 1961, when one particularly high volume concrete roadway was brought into focus. Accident data collected on this roadway showed that eight fatalities had occurred in ten months, and furthermore, the damages ranging from $500 to $10,000 per month could be attributed to slick pavement.

These facts resulted in the use of a stopping distance vehicle, the first method of determining a numerical value for skid resistance ever to be used in the State for which any record could be found. Skid resistance values were found with the vehicle before and after the pavement was "deslicked" by sawing the concrete.[1] A desire to prevent such "phenomenon" from recurring coupled with the fact that other Districts reported slick pavements resulted in a study to obtain an instrument which would measure the skid characteristics of pavement.

Feasibility Study

A literary study found numerous publications involving skid characteristics of pavements and many individuals who were interested in the problem. As many as eight State Highway Departments, three universities, General Motors, NASA, and the Bureau of Public Roads are engaged in measuring skid resistance or obtaining equipment necessary to make the measurements.

After contacting numerous authorities, it was found that work in this field was progressing toward standardization under the ASTM Committee E-17.[2] A standard test method was emphasized rather than a standard trailer, and the Committee was submitting a standard for adoption. A copy of the tentative standard was secured in which the equipment, calibration, and test procedure were outlined.

II. SELECTION OF EQUIPMENT

An extensive literature survey was made, and at its conclusion all agencies--both governmental and private--conducting some form of skid resistance were consulted for self evaluation and recommendations. This information was then considered in conjunction with Texas Highway Department needs to make the final selection of equipment.

Modes of Testing

In an attempt to classify and evaluate various equipment, all of the skid measuring techniques used by the various agencies were broken down into three basic categories.[3] These were the steady state-slip method, the steady state sliding method, and the non-steady state sliding method. Since the mode of test has a profound influence on the value of skid resistance, the first decision was to select the test method. This decision automatically eliminated two of the groups and allowed a relative evaluation of the equipment in the selected mode of testing.

Comments From Authorities

One noted authority suggested the use of both a portable tester and a truck trailer type tester equipped with a self-watering system. The individual's comments on the stopping distance method correlated with the Departmental experience. His observations indicated that the stopping distance method required an operation which was too elaborate, could be hazardous, and was not well adapted to performance on high-volume roadways.

The New York State Department of Public Works[4] selected the towed trailer and a design similar to the PCA trailer (steady state sliding) because of the trailer's ability to correlate well with the stopping distance method as determined by Virginia and Purdue skid cars. In addition, the ability of the trailer to perform many tests without major repairs or modifications was a strong factor in the selection.

One State Highway Department sent a complete set of costs for fabrication and operating expenses. This agency stated that a cost per test including salaries, equipment rental, and analysis based on 5,200 tests was $0.50 per test. This method of test was with the two wheeled trailer (steady state sliding).

Final Selection

In the early stages of this research program the decision was made to reproduce the trailer of another agency insofar as possible. By going this route full advantage could be taken of other agencies' experience in this field. Furthermore, cost of development would be avoided, which would allow immediate initiation of the research phase in the program.

The next decision was the selection of the mode of testing. In line with the tentative ASTM test procedure and the excellent correlations obtained at the Tappahannock study,[5] the decision was made to use the steady state sliding mode of testing. Another supporting factor for this decision was the fact that the wheel locking condition more closely simulated the actual stopping of a moving vehicle. After a detailed analysis of correspondence from other agencies and the available literature, it was decided that the Texas Highway Department's Shops would construct a trailer similar to that presently being used by the New York State Highway Department, the U. S. Bureau of Public Roads, and the Portland Cement Association (Figure 1).

Figure 1. Texas Highway Department Skid Trailer

The selected equipment provides a method which is mobile, obtains measurements rapidly, can be operated in heavy traffic, is free from hazards to the operating personnel and to the traveling public, gives reproducible data, is of rugged design, and corresponds to the tentative ASTM standards. Even though the initial cost is high, the annual cost per test would be low. The decision to construct the trailer in the Departmental Shops resulted from two facts: (1) lower fabrication costs and (2) a personal knowledge of the equipment would lead to less time loss in the event that repairs were necessary.

III. DESCRIPTION OF EQUIPMENT

In this chapter, the various pieces of equipment comprising the skid trailer-truck combination will be described and their functions will be enumerated. For the purpose of discussion, the equipment is broken into two divisions; these being major equipment and minor equipment. The major equipment comprises the two basic elements of the equipment, the towing vehicle and the trailer; whereas the minor equipment is considered as the components of each individual part of the system.

Major Equipment

Towing Vehicle. Many kinds of towing vehicles are being used by other agencies ranging from simple equipment installation on light vehicles to elaborate installations on heavy trucks. After considering the various possibilities, it was decided to use a two-ton truck powered by a V-8 engine and equipped with a flat bed (Figure 2). This decision was based on two considerations. The first was a comment from the correspondence with Mr. E. A. Whitehurst, Director, Tennessee Highway Research Program in which he suggested that the prime mover should be a large vehicle in order that its momentum during tests would be great; hence, its speed would not be affected by the drag of the sliding wheel of the test trailer. The second reason for this selection is closely associated with the first and resulted from a study of the films taken during the correlation study at Tappahannock, Virginia.[6]

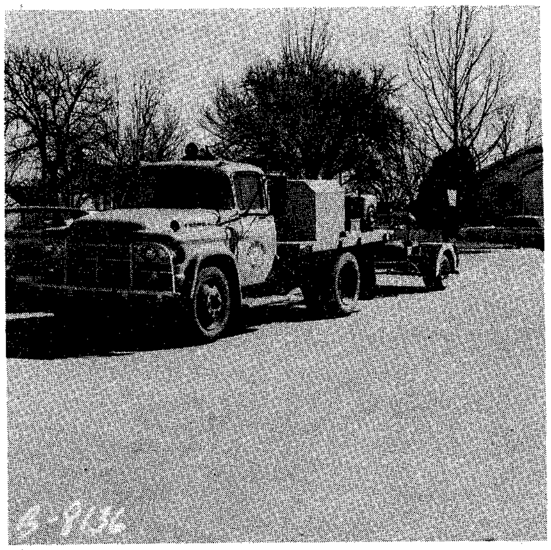


Figure 2. Towing Vehicle

It was noted that the larger towing vehicles were superior in that the towed trailer performed with less side-sway than the equipment using a lighter towing vehicle. The flat bed was selected for easy access to equipment.

Trailer. Plans of the selected two wheel trailer design were obtained from the Bureau of Public Roads and the Portland Cement Association. The original plans called for an axle from the rear end of a passenger vehicle. A change was made from the original plans in which a commercial running gear equipped with square steel tubing as an axle was used. This commercial running gear is equipped with wheel hubs affixed with a 12-volt braking system (Figure 3).

Minor Equipment

The minor equipment consists of the various components of the trailer-truck combination: the water pump, water tank, generator, recorder, etc. Table A.1 in the Appendix is a description of each piece of equipment, the specifications, and refers to its location on Figure A.1. In addition a photograph of the individual pieces of equipment is also presented in the Appendix.

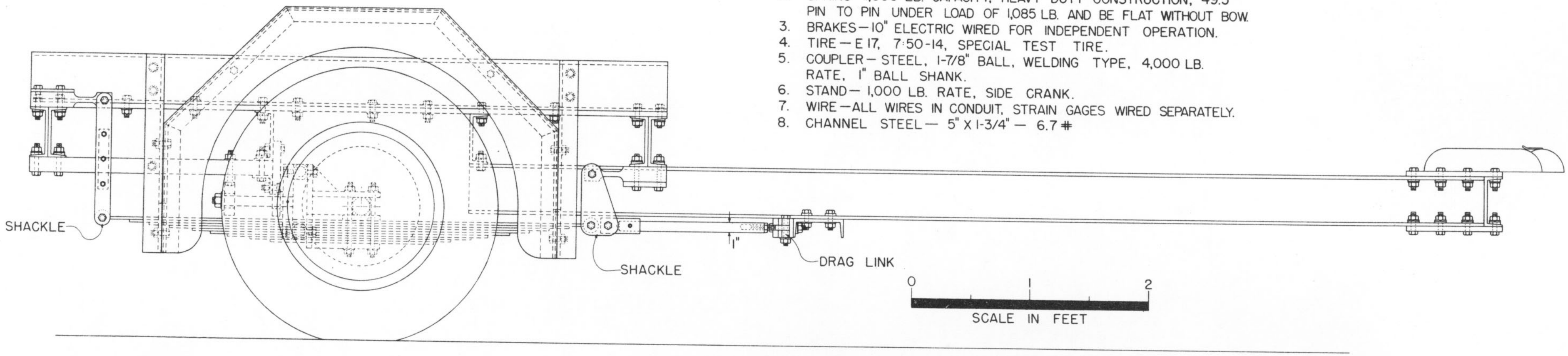
Functions of Equipment Systems

Electrical. The electrical components basically obtain power from two voltages: 12 volts D. C. and a 120 volts A.C. The brakes and warning lights use 12 volt D. C. power, and the strain gages are supplied from a regulated source from within the recorder. The water pump, recorder and solenoid valves are supplied with power from the 120 volt A.C. output from a gasoline motor driven electric generator (Figure 4).

There are three control panels in this system. Two control panels are located in the cab of the truck, and another which is the timer control box is located on the truck bed. One of the control panels is located to the left of the

GENERAL NOTES

1. AXLE - 3,000 LB. CAPACITY, 58" TRACK, 42" C-C SPRING WIDTH.
2. SPRING - 1,500 LB. CAPACITY, HEAVY DUTY CONSTRUCTION, 49.5" PIN TO PIN UNDER LOAD OF 1,085 LB. AND BE FLAT WITHOUT BOW.
3. BRAKES - 10" ELECTRIC WIRED FOR INDEPENDENT OPERATION.
4. TIRE - E 17, 7.50-14, SPECIAL TEST TIRE.
5. COUPLER - STEEL, 1-7/8" BALL, WELDING TYPE, 4,000 LB. RATE, 1" BALL SHANK.
6. STAND - 1,000 LB. RATE, SIDE CRANK.
7. WIRE - ALL WIRES IN CONDUIT, STRAIN GAGES WIRED SEPARATELY.
8. CHANNEL STEEL - 5" X 1-3/4" - 6.7 #



TRAILER PLANS
FIGURE 3

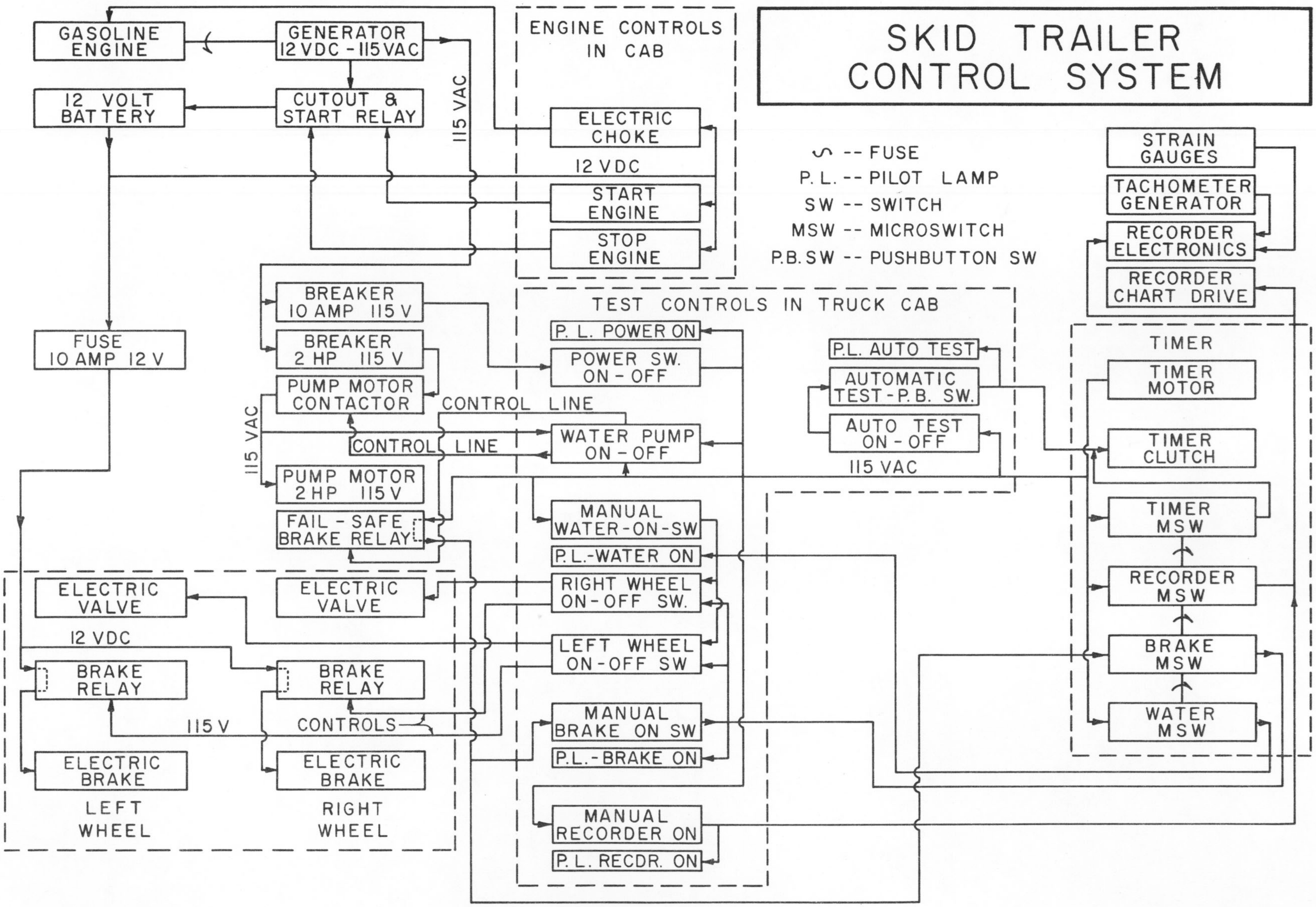

SKID TRAILER CONTROL SYSTEM
GASOLINE ENGINE
GENERATOR 12 VDC - 115 VAC
12 VOLT BATTERY
CUTOUT & START RELAY
115 VAC
ENGINE CONTROLS IN CAB
ELECTRIC CHOKE
12 VDC
START ENGINE
STOP ENGINE
∽ -- FUSE
P. L. -- PILOT LAMP
SW -- SWITCH
MSW -- MICROSWITCH
P.B. SW -- PUSHBUTTON SW
STRAIN GAUGES
TACHOMETER GENERATOR
RECORDER ELECTRONICS
RECORDER CHART DRIVE
FUSE 10 AMP 12 V
BREAKER 10 AMP 115 V
BREAKER 2 HP 115 V
PUMP MOTOR CONTACTOR
PUMP MOTOR 2 HP 115 V
FAIL - SAFE BRAKE RELAY
TEST CONTROLS IN TRUCK CAB
P. L. POWER ON
POWER SW. ON - OFF
CONTROL LINE
WATER PUMP ON - OFF
CONTROL LINE
MANUAL WATER-ON-SW
P.L.-WATER ON
RIGHT WHEEL ON-OFF SW.
LEFT WHEEL ON-OFF SW
MANUAL BRAKE ON SW
P.L.-BRAKE ON
MANUAL RECORDER ON
P.L. RECDR. ON
P.L. AUTO TEST
AUTOMATIC TEST-P.B. SW.
AUTO TEST ON - OFF
115 VAC
TIMER
TIMER MOTOR
TIMER CLUTCH
TIMER MSW
RECORDER MSW
BRAKE MSW
WATER MSW
ELECTRIC VALVE
ELECTRIC VALVE
12 VDC
BRAKE RELAY
BRAKE RELAY
115 V
CONTROLS
ELECTRIC BRAKE
ELECTRIC BRAKE
LEFT WHEEL
RIGHT WHEEL

FIGURE 4

operator (Figure 5). Through start-stop buttons, the electric generator can be started or stopped from the cab. The second control panel located in the cab is the "test control panel", and it is mounted on the center of the dash in the cab (Figure 6). This panel enables the operator to control the test equipment. The "test control panel" controls are: power on/off, pump on/off, left wheel test, right wheel test, automatic manual test, automatic test start and a manual control for the recorder chart drive, brake operations, and electric valves.

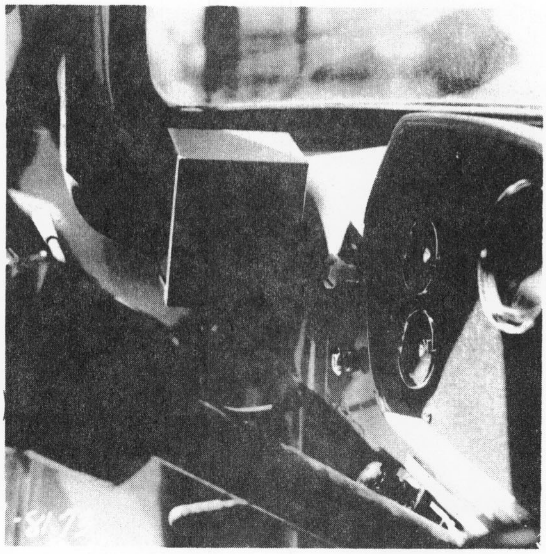


Figure 5. Generator Control Panel

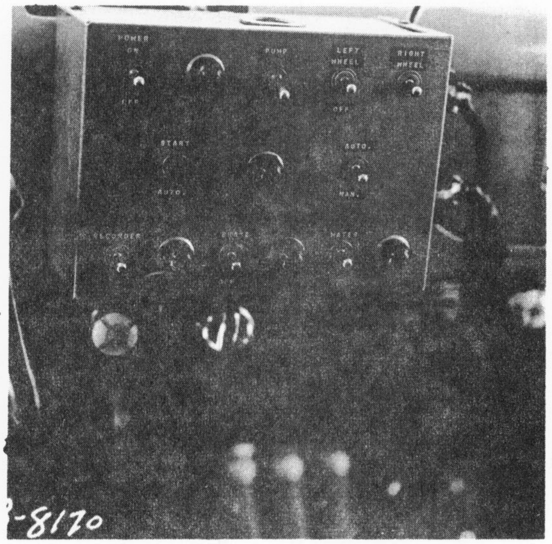


Figure 6. Test Control Panel

The "timer control box" located on the truck bed contains four relays and a synchronous motor driven timer with four cams (Figure 7 and Figure 8). All four relays in the box operate on 115 volts A.C. One is used to turn the water pump power on and off, and two are used to control the 12 volt power to each individual brake, and the fourth is a safety switch to release the brakes, should power to the pump motor fail. The timer consists of a synchronous motor, magnetic clutch and brake, drive shaft, four cams and four switches. The drive shaft is connected to the synchronous motor and the magnetic clutch and brake controls the shaft rotation. Four cams are connected to the shaft and four switches are actuated individually by a cam when the synchronous motor shaft is actuated. The shaft makes one complete revolution in 10 seconds, turning on and off each switch, so as to automatically control the test cycle.

The "test control panel" is equipped with an automatic-manual toggle switch. If this toggle switch is in manual position, the recorder, the pump, and the brakes on either wheel may be actuated separately from each other by selection of the proper toggle switch. If the switch is in automatic position, the systems may be actuated and standard tests made by pressing the automatic test start button. This engages the automatic timer control circuits, and the results of the test

Figure 7

TIMER-CONTROL BOX LAYOUT

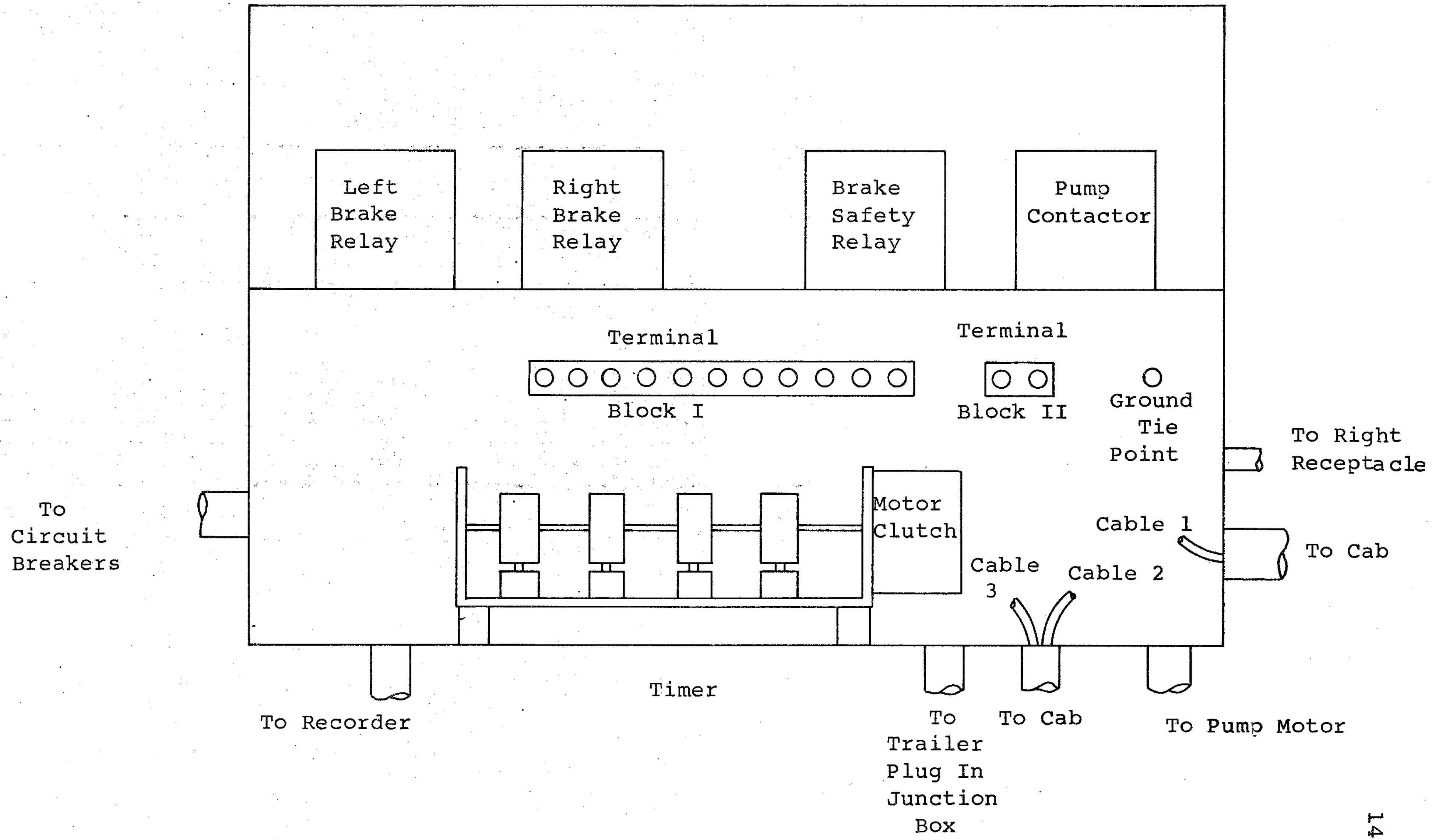
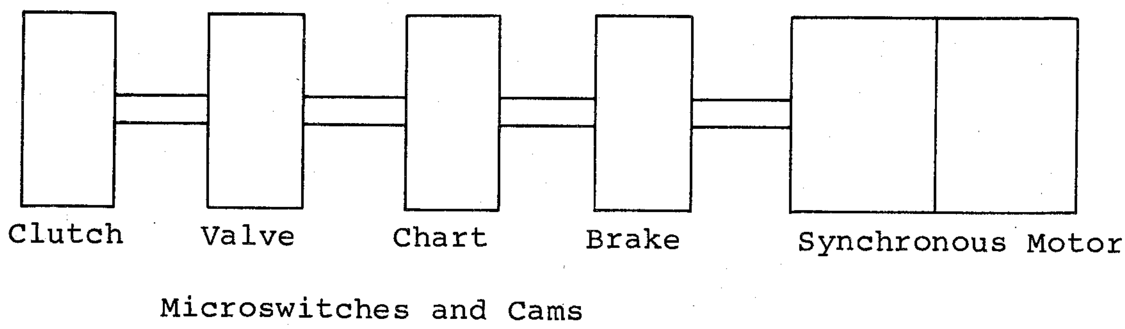
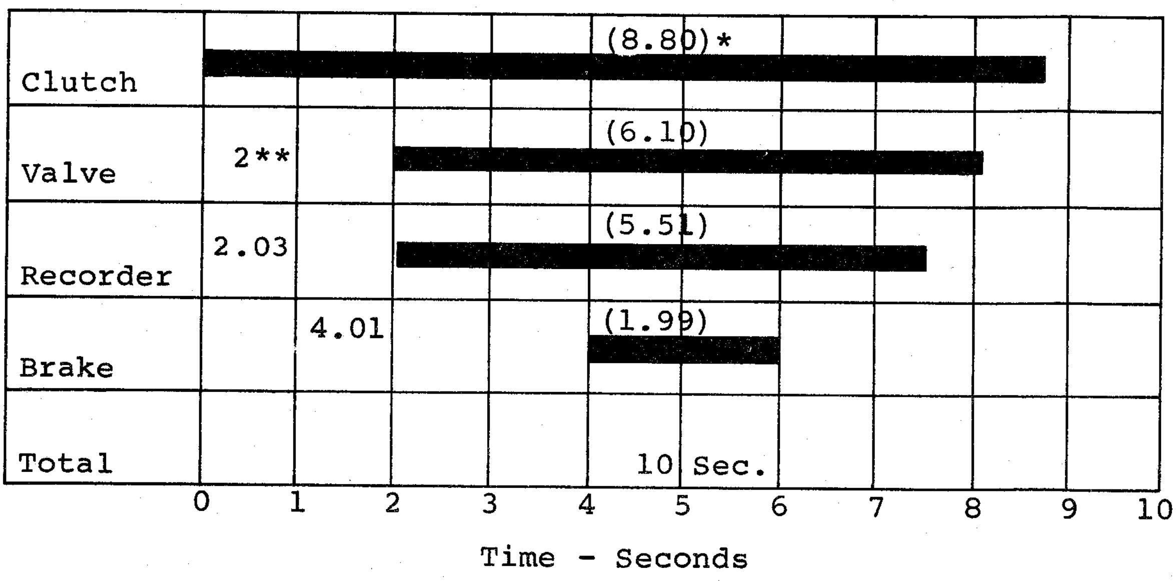


Figure 8

TIMING MECHANISM



TIME CHART FOR AUTOMATIC OPERATION



* Numbers in parentheses refer to operation time in seconds.

** Numbers not in parentheses refer to the elasped time in seconds between pressing automatic switch until operation in question starts.

are recorded on the continuous roll emitted from the recorder. This dual arrangement allows the trailer to be used for standard testing or as a "research" vehicle to investigate various testing procedures.

A distribution cabinet, located on the truck bed against the water tank, contains three 115 volt A.C. breakers and a fuse for the 12 volt supply. One 15 ampere breaker controls the instrument power, the other supplies a weatherproof outlet on the right side of the water tank. A 30 ampere breaker supplies the water pump motor and an outlet on the left side of the water tank. Twelve volts D.C. for the trailer brakes is available through a 10 ampere fuse. The outlets on either side of the water tank were placed for a power supply which will be available for maintenance uses.

<u>Hydraulic</u>. The hydraulic system consists of a water tank, a two horsepower water pump, solenoid valves, and an orifice system. This operation was designed as a variable orifice size system with a constant pressure. The water in the tank is actuated by the pump and is forced from the tank to the pressure relief valve. If the solenoid valves are closed, the pressure is such that all water circulates back into the tank through the pressure relief valve. When the solenoid valves are open, the pressure relief valve allows the water to flow through the system at some predetermined

pressure. The water then passes through the solenoid valves and continues to the orifice. The desired volume of water is obtained by combining the proper orifice size with the known pressure (Figure 9). Changing the orifice size is manual, and this is the only operation which causes the operator to get out of the truck. If the selected speed changes, the operator must manually remove the orifice being used and replace it with a new orifice.

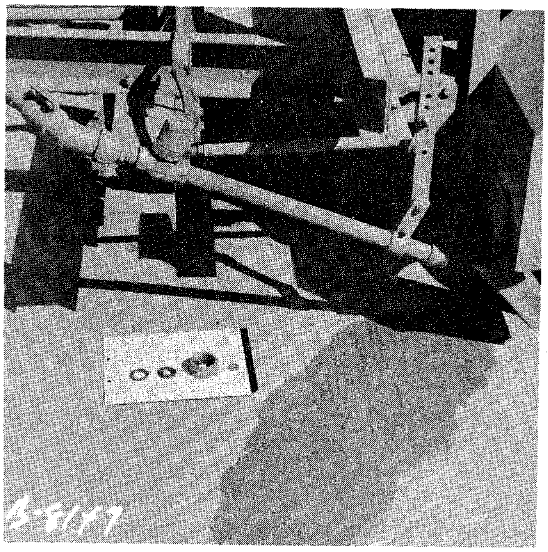


Figure 9. Valve and Orifice System

Measuring Systems. There are two measuring systems: (1) A velocity System which measures the vehicle speed by use of the tachometer generator. (2) A Force Measuring System utilizing SR-4 strain gages and a two channel recorder.

The speed equipment which is standard equipment on the truck is used in the velocity recording. The flexible speedometer cable actuated by the truck differential was separated from the odometer, and a one to one Tee was inserted between the differential and the odometer. One side of the Tee was reconnected to the odometer. The third or new side was attached with a short flexible cable. The opposite end of this short cable was connected to the tachometer generator. The electrical output from the tachometer generator is fed to the recorder to be recorded as velocity.

The Force Measuring System consists of four SR-4 strain gages. These gages are mounted one on either side of two drag links arranged so as to measure the horizontal force between the wheels and towing arm. Electrically, they are in a Wheatstone Bridge connected to the recorder by a special four conductor cable. The drag links operate in a cantilever fashion with the gages mounted in approximately the center of the bending area.

IV. COSTS

During the initial stages of this project it was difficult to obtain information of the costs of equipment needed in measuring skid resistance. In an effort to supply this information for the test trailer described in this report a list of equipment and approximate costs as of the last months of 1963 is listed below:

<u>Minor Equipment</u>

1.	Water Pump	$364.00	
2.	Solenoid Valves (Globe Type) 2 @ $35.00	70.00	
3.	Pressure Relief Valve	68.00	
4.	Tachometer Generator	160.00	
5.	Two Channel Recorder	2,349.00	
6.	Gasoline Engine Electric Generator	595.00	
7.	E-17 Standard Test Tire--2 each	80.00	
			$3,686.00

<u>Major Equipment</u>

Construction of Trailer	3,878.00	
Truck Modification and Water Tank	1,295.00	
TOTAL		$8,859.00

The truck operating cost for nine months of operation is approximately $1,200.00 and trailer operating costs for the same period is approximately $250.00. It is interesting to note the cost of the skid measuring equipment is less than the accident damages for just one month on only one of the three sections discussed previously in this report

V. CALIBRATION

Hydraulic

The water was calibrated by pumping water at a known temperature for a known length of time, and then measuring the quantity of water. For this application, the water was pumped from the tank as if in actual application through the system and out the orifice and caught in a container. The previously tared container was then weighed and the volume of water determined from this weight. This operation was performed on the left and right sides individually and then simultaneously. Orifice sizes were previously fabricated to conform with the rate of water application as specified in the tentative ASTM E-17 Standards. The quantity of water designed at 20 mph was 40 gallons per minute ± one gallon per minute, and the quantity of water at 40 mph was 60 gallons per minute ± one gallon per minute. If the desired quantity of water was not existant the pressure was increased by means of the pressure relief valve or the orifice was refabricated to the proper size.

Velocity

The velocity of the truck was calibrated using a radar unit. This calibration consisted of operating the truck at predetermined speeds and correlating these speeds with those obtained by the radar unit as the truck passed. Additional calibration was also performed with the tachometer generator. The flexible tachometer generator drive shaft was turned at a known rpm and the measured generated voltage was compared with the manufacturer's rated voltage output. The reading on the recorder was then correlated with the truck speed.

Force Measuring System-Static

The static calibration of the force measuring system was similar to that being done by others[4] and consisted of separating the trailer from the truck and placing a force measuring device and a hydraulic pump between the truck and the trailer. The trailer wheels were locked and the truck brakes were set. The pressure or force was applied with the hydraulic jack. The force was measured between truck and trailer and correlated with the force obtained with the recorder and strain gages. Fifty pound increments of force were used for calibration purposes. The system was calibrated using forces ranging from 100 pounds to 900 pounds.

Force Measuring System-Dynamic

The dynamic calibration procedures were changed somewhat from those suggested in the tentative ASTM Standard. After consulting with the Bureau of Public Roads personnel involved in measuring skid resistance by a similar manner, the usual method of dragging the locked trailer wheel over a standard canvas was omitted. It was felt that the standard canvas was subject to rapid wear; hence, this method would not give results with accuracy sufficient to determine a malfunction in equipment. To replace this method, eight sections of roadway were selected, five of which contain low traffic volumes. These eight sections include two concrete sections, three hot mix asphaltic concrete sections, and three bituminous surface treatments. These sections are tested at periodic intervals and the results are judged on a statistical basis to determine if there is significant difference in each new calibration as compared with the older calibration results.

A thorough study of these calibration procedures is not complete at this time; however, some doubt exists as to the results obtained by this method. Even though static calibration results show excellent correlation between applied force and force measured with the strain gages, completely random results are being experienced with the dynamic calibration. A slight trend toward a higher coefficient of friction is developing when dynamic calibrations are made after a rain. Further study should be and will be made using these dynamic calibration procedures.

VI. DISCUSSION

Problems were experienced in two areas during early operations of the trailer. The first was with the electric brake in that apparently, considerable time is needed to "break in" the new electric brake. It was found during initial static calibration and at low speeds the brakes would not lock. After considerable applications, the brakes did lock, but were considered in the doubtful range. An additional source of power was connected in series with the existing power, and eventually considerable experimentation was done with various types of brake shoes. It was found that if a soft material were used, such as a pressed asbestos fiber with steel insets, the brake shoe would lock the wheels under all conditions, and the additional power could be removed. It is felt that possibly a larger contact area between brake shoe and brake drum would also be helpful.

The second source of trouble was obtaining the rate of water application enumerated in the ASTM Standard. The problem was traced to the solenoid valves which had two sharp changes in water direction fabricated into the valves. The directional changes were causing high turbulence, and a resulting pressure loss greater than anticipated. However, it was found that 120 gallons per minute could be achieved on one side if the valve and orifice system were removed. After some discussion, two motor operated valves were purchased. These valves are a gate type valve in which a motor actuates the gate and the gate slides into a shallow slot. These valves have a straight through type flow and are used in the fuel systems of jet aircraft. This valve has not been installed, but it is believed that the system will operate as designed with this correction.

BIBLIOGRAPHY

1. Hilgers, H. F. and McCullough, B. F., "Slick When Wet", Texas Highways, January, 1963.

2. ASTM E-17 Committee, Tentative ASTM Standard.

3. Kummer, Hartwig W. and Meyer, Wolfgang E., "The Penn State Road Friction Tester as Adapted to Routine Measurement of Pavement Skid Resistance", Highway Research Record Number 28.

4. "Skid Characteristics of Bituminous Surfaces", Skid Test Trailer Development and Evaluation, Physical Research Project Number 16, Research Report RR 61-7.

5. Dillard, J. H., and Mahone, D. C., "Comparison of Several Methods of Measuring Road Surface Slipperiness-Tappahannook, Virginia, 1962," May 1963.

6. 16 mm Movie File "1962 Skid Correlation Study", by Bureau of Public Roads, Department of Commerce.

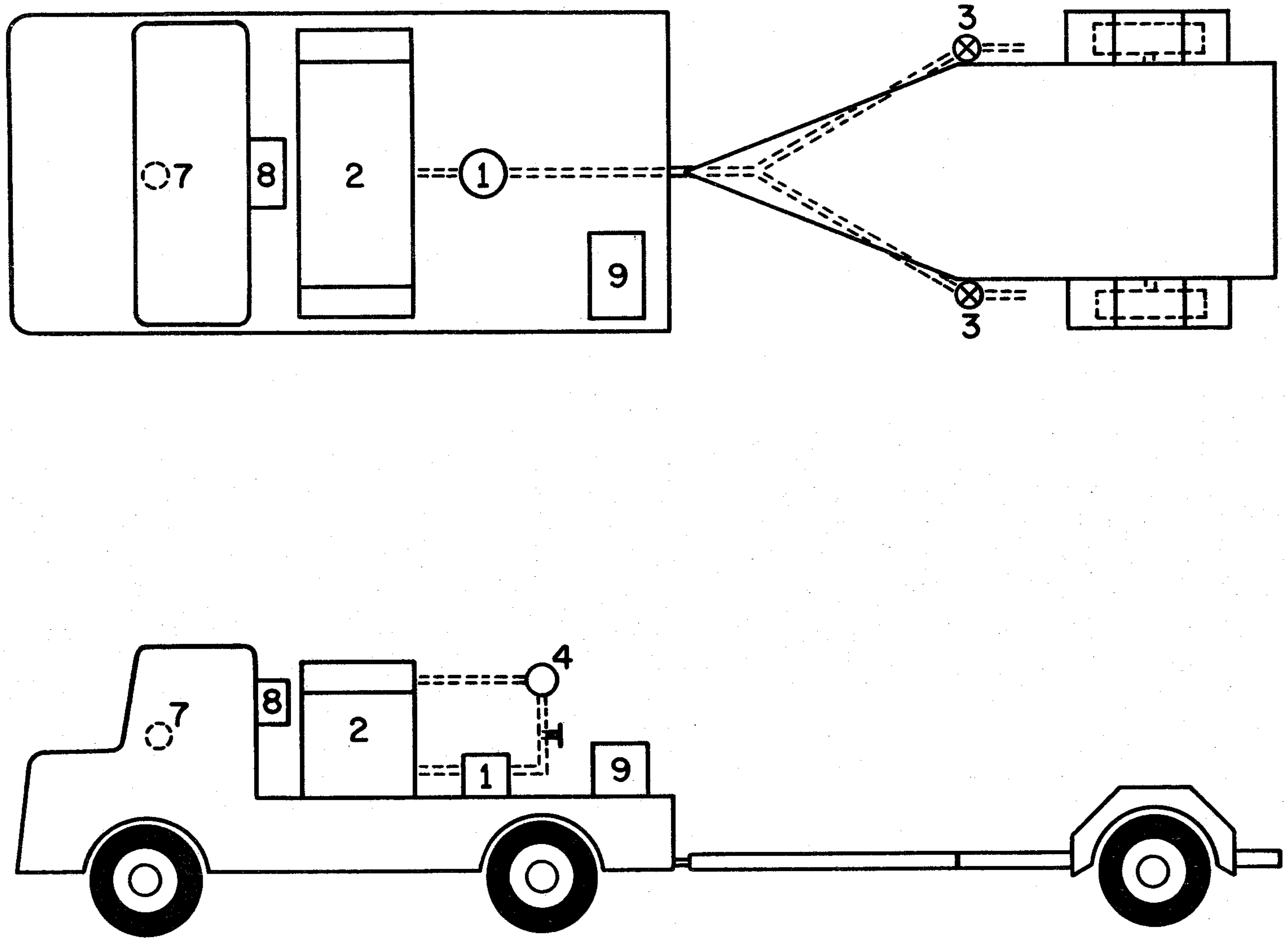
A P P E N D I X   A

Equipment

Table A.1

Component Parts of
Skid Truck-Trailer Combination

Ref. No.	Description	Specs.	Photograph In Fig.
1	Electric Motor Driven Centrifugal Water Pump	1. Capacity-160 gpm at 40 foot head 2. 2 horsepower driven motor, 115 volt, 60 cycle, single phase 3. Single stage end suction with 1½ inch outlet and 2 inch inlet	A-2
2	Water Tank	Capacity-410 gallons with baffles to reduce water movement	A-3
3	Globe Type Sclenoid Water Valve	115 volt, 60 cycle, single phase with 100 psi pressure range.	A-4
4	1½" Bronze Relief Valve	Capacity 160 gpm with pressure range up to 100 psi.	A-5
5	Red Blinker Lights used as a precautionary warning system	- - -	A-6
6	SR4 Foil Strain Gages	½" gage length	A-7
7	DC Tachometer Generator	Output 3 volts per 1000 rpm	A-8
8	2 Channel Hot-Wire Recorder	1. Paper width-6 centimeters per channel 2. 120 volt, 60 cycle, AC power	A-9
9	Gasoline Engine-Driven Electric Generator	1. 5000 watt, AC, 120 volt, 60 cycle single phase 2. Gasoline engine-10 horsepower, 2 cylinder-4 cycle	A-10



EQUIPMENT SCHEMATIC

FIGURE A-1

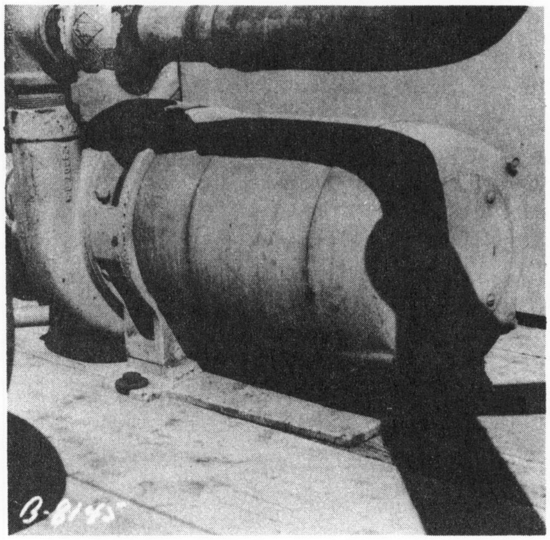


Figure A-2. Electric Motor Driven Centrifugal Water Pump

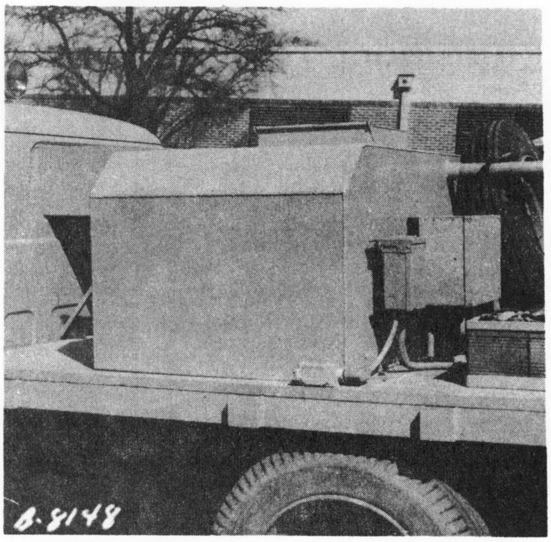


Figure A-3. Water Tank

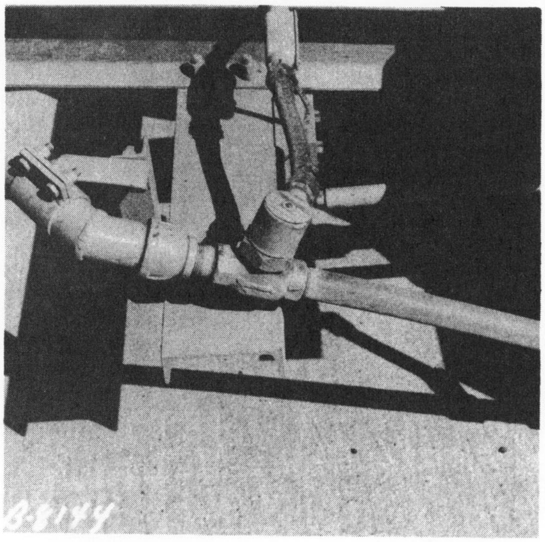


Figure A-4. Globe Type Solenoid Water Valve

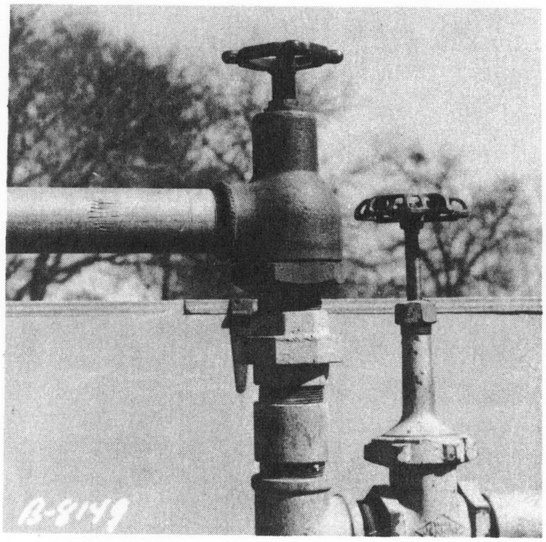


Figure A-5. 1½" Bronze Relief Valve

Figure A-6. Red Blinker Lights Used As A Precautionary Warning System

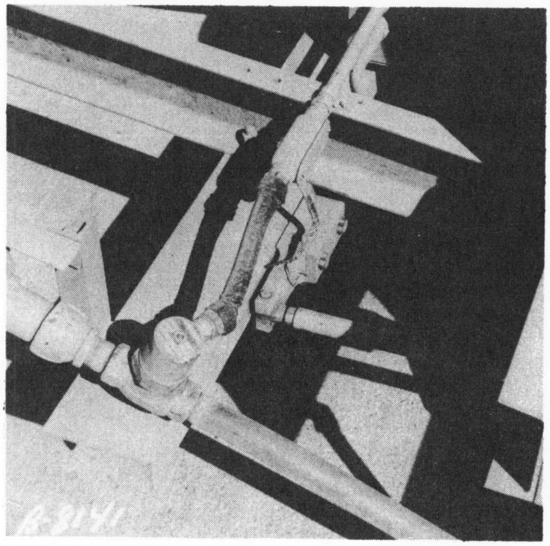


Figure A-7. SR4 Foil-Strain Gages

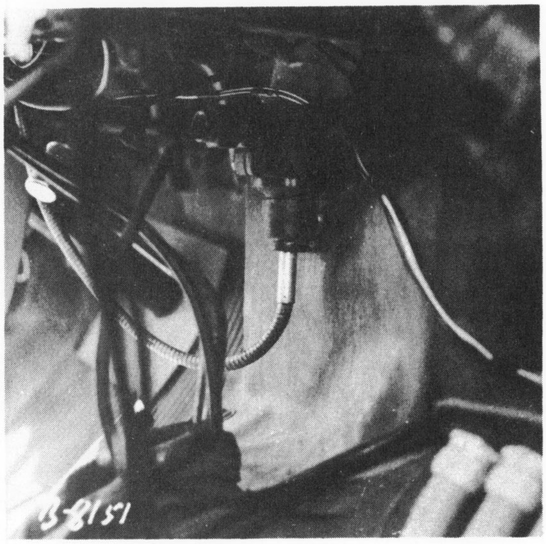


Figure A-8. DC Tachometer Generator

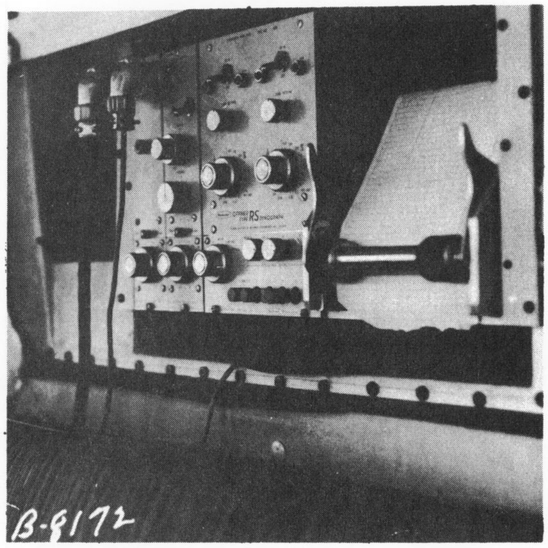


Figure A-9. 2 Channel Hot-Wire Recorder

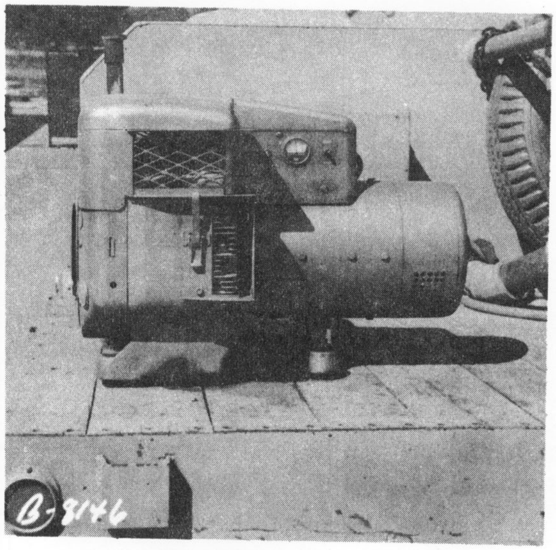


Figure A-10. Gasoline Engine-Driven
Electric Generator