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**Small Arms Components Motion-Simulator
for Lubricant Development
II. Use in Lubricant Friction Testing**

Rock Island Arsenal III General Thomas J Rodman Lab

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SMALL ARMS COMPONENTS MOTION-SIMULATOR FOR LUBRICANT DEVELOPMENT: II. USE IN LUBRICANT FRICTION TESTING.

by

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AUGUST 1975

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) A Small Arms Components Motion-Simulator was designed and constructed to establish the performance characteristics of current and future lubricants under extremes of environment. The machine is installed in the Research Directorate, GEN Thomas J. Rodman Laboratory, and has been subjected to tests to determine its capabilities. This report describes the results of these tests. Primarily, the simulator imparts linear motions on the basis of time-displacement characteristics of the XM19 Bolt, M85 Machine Gun Bolt, M219		

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Machine Gun Barrel Extension and Rammer, and the M129 Grenade Launcher Barrel to a test specimen through which contact is made with a stationary specimen. The motions are obtained from an adjustable constant speed drive and cam system. Friction forces generated by the rubbing surfaces are transferred to a load cell and recorded on an oscillograph. Lubricant tests can be conducted at temperatures ranging from -65° to +165°F (-54° to +74°C), and relative humidities from 20 to 95% from +35° to +165°F (2° to 74°C). Friction tests were conducted at ambient (74°F or 23°C) conditions on four weapon lubricants: MIL-L-46000A, MYL-L-46150, VV-L-800A, MIL-L-14107B, and a hydraulic fluid MIL-H-6083C that contains an antiwear additive. These materials behaved as expected for fluid and semifluid lubricants under thin film and boundary lubrication conditions. The simulator enabled detection of subtle differences due to lubricant, load, speed, and condition of the test specimen surface.

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OBJECTIVE:

This task was conducted to develop a laboratory type of small arms components motion-simulator that could reliably establish the performance characteristics of current and future lubricants under extremes of environment.

BACKGROUND:

The background study and the selection of parameters to be included in the design of the Small Arms Components Motion-Simulator are described in an earlier report.¹ In that report, the significant weapon lubrication parameters, the estimation of their ranges, and the preparation of the scope of work for the development of the simulator are discussed. The basic principle of the machine was that of reproducing the motions of selected small arms weapon components by means of cams. Means were to be provided to control the test environment, in the laboratory, over the range of conditions expected for field use of the weapons. Test specimens could then be used in this apparatus to evaluate the friction and wear performance of lubricants and metals used, or proposed for use in small arms. Five cams manufactured on the basis of the time-displacement characteristics of small arms weapons components were to be initially supplied. These components were:

- Cam 1. XM19 Bolt
- Cam 2. M219 Machine Gun Barrel Extension
- Cam 3. M219 Machine Gun Rammer
- Cam 4. M85 Machine Gun Bolt Slide
- Cam 5. M129 Grenade Launcher Barrel
(modified to a sine curve)

The machine described in this report was designed and fabricated by Applied Devices Corporation, Long Island, N.Y., under Contract Number DAAF03-71-C-0307. This motion-simulator is installed in the Research Directorate, CEN Thomas J. Rodman Laboratory, and has been tested to determine its capabilities.

1. Bornong, B.J., AWC Technical Report RE-70-182, Small Arms Components Motion-Simulator for Lubricant Development: I. Selection of Parameters, November 1970.

APPROACH:

All electrical and mechanical systems of the simulator were operated and checked according to procedures outlined in the Technical Manual² and in test procedures formulated by the contractor and the Research Directorate. When the checkout procedures were completed, friction tests were conducted on five current fluid and semifluid lubricating materials with well-known friction-and-wear properties. The use of these materials could help to establish the characteristics of the motion-simulator in comparison with other friction-and-wear testers.

PROCEDURE:

A. Description and Function of the Small Arms Components Motion-Simulator.

Detailed descriptions of the machine, and procedures for operation and maintenance are given in the technical manual, sketches, and drawings that are on file in the Research Directorate. Photographs of various units of the simulator will be presented in this report along with brief descriptions of their functions to aid future operators and to aid the reader in understanding the test procedures presented here.

In brief, the Small Arms Components Motion-Simulator imparts predetermined linear motions to a metallic or nonmetallic test specimen that is in contact with a stationary specimen. The linear motions are obtained from an adjustable constant speed drive and cam system. Friction forces generated by the rubbing surfaces of the test specimens are transferred to a load cell and recorded on a oscillographic recorder.

The overall appearance of the simulator is illustrated in Figure 1, in which the six principal units of the machine are shown. These units are numbered and described briefly as follows:

Unit 1- Control Console. This unit contains electronic controls and power supplies, and computing, amplifying and recording equipment for the simulator.

Unit 2- Motor and Cam Drive. An adjustable constant speed D.C. motor and belt-driven cam are housed in a sound-absorbing inclosure, and impart the predetermined linear motions to the test specimen.

2. Applied Devices Corporation, "Technical Manual for Small Arms Components Motion Simulator," DAAr03-71-C-0507, March 1973.

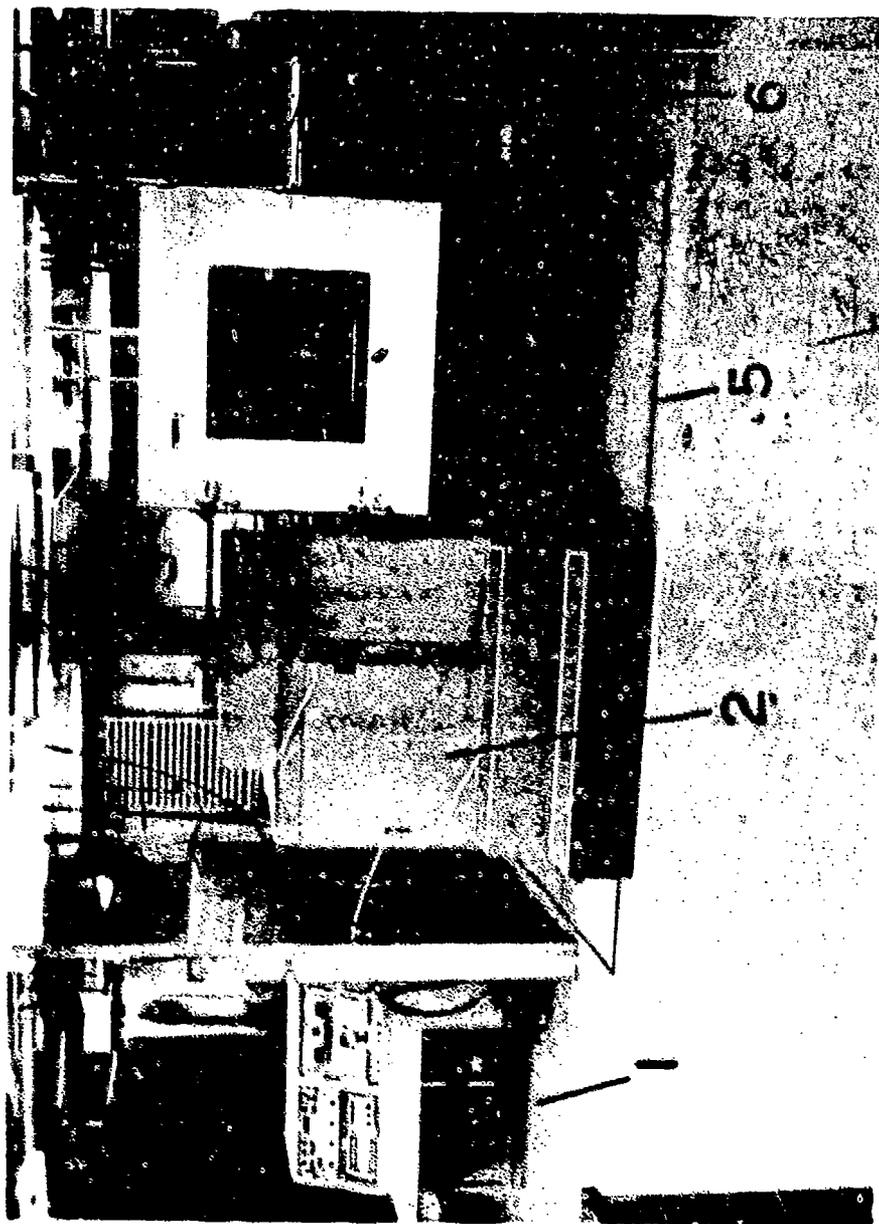


Figure 1 Small Arms Components Motion-Simulator

- Unit 1 Control Console
- Unit 2 Motor and Cam Drive
- Unit 3 Environmental Chamber and Test Specimen Assembly
- Unit 4 Induction Heater
- Unit 5 Reaction Mass
- Unit 6 Load Cell Pedestal

Unit 3- Environmental Chamber. This chamber controls the test temperature and relative humidity, and houses the test specimen assembly. A shaft passing through a port in the side of Unit 3 connects the cam follower and test specimen.

Unit 4- Induction Heater. This unit is intended to supply heat to the test specimens, in addition to that provided by the frictional effect, to simulate the thermal input from propellant combustion to the operating mechanism of a weapon.

Unit 5- Reaction Mass. The concrete reaction mass, weighing approximately 17,000 pounds, is supported on Neoprene-rubber cross-ribbed pads designed to isolate the vibrations of the motor and cam drive system from the load cell. The theoretical isolation efficiency is 90 percent or better for vibrations over 2400 Cpm.

Unit 6- Load Cell Pedestal. This unit, constructed of steel plates and weighing approximately 3,000 pounds, provides a massive support for the load cell and its associated electronics.

Additional photographs that show external details of the various units of the simulator are given in Appendix A. These pictures and further descriptive material provided may help to clarify the relationship between the locations and the functions of the controls and data acquisition equipment.

The functions of the mechanical and electrical systems of the simulator were checked during several phases. The first phase was carried out in an in-plant inspection on 27-30 November 1972. Upon completion of inspection, the machine was shipped to Rock Island. After considerable damage (received in shipping) had been repaired, a second inspection was conducted during November 1973. These tests revealed that excessive noise was generated, and that potential damage to the simulator and inaccurate measurements could be caused by this vibration of the motor and cam drive unit. After the installation of modification kits to move some electronic controls from the reaction mass to the solid laboratory floor and to absorb sound in Unit 2, the machine was again checked for proper functioning during the December 1974 to February 1975 period. Acceptance of the simulator was made on 14 March 1975. An outline of the test procedure that was followed in checking out the operation of the machine is given in Appendix B.

The operation of the cams was given particular attention. Five cams were supplied with the machine, each was mounted in turn and was operated to determine its characteristics. Time-displacement records were obtained on the test specimen by means of a drum camera. Caution was exercised

during these tests because this machine is the first of its kind and the practical upper limits on the reciprocating rates were not known. The designer and the operators decided that to test the simulator to destruction would not be prudent. The noise level in the cam drive and the heating of the cam follower bearings were used to judge when a practical upper limit of cam speed was being approached. These observations, along with calculated acceleration forces, formed the basis for setting the limits on cam speed or reciprocating rate to be reported here.

B. Friction Tests of Weapon Lubricants.

Experiments were conducted to determine the friction characteristics of several current weapon lubricants. These lubricants are listed below:

1. MIL-L-46000A, Lubricating Oil, Semi-Fluid (Automatic Weapons); (LSA).
2. MIL-L-46150, Lubricant, Weapons, Semi-Fluid (High Load-Carrying Capacity), (LSA-T).
3. VV-L-800A, Lubricating Oil, General-Purpose, Preservative (Water-Displacing, Low-Temperature), (PL-S).
4. MIL-L-14107B, Lubricating Oil, Low-Temperature, Weapons, (LAW).

A sample of Hydraulic Fluid MIL-H-6083C was included for comparison purposes. For these tests, the load, speed (cycle rate), and type of lubricant were investigated. The temperature for the lubricant friction tests was ambient (74°F, 23°C).

The metal specimens used in these tests were of AISI 4140 steel, with hardness R_c 40. These specimens had been used in the acceptance testing of the simulator with MIL-G-21164, Grease, Molydenum Disulfide, for Low-Temperatures. Before these specimens were used in the present tests, they were abraded with 240 and 400 grit silicon carbide abrasive paper to remove grease residues and to smooth scratches. The specimens were then cleaned with petroleum solvent for each lubricant application.

The first lubricant tested was MIL-L-46000A; this was applied to the test surfaces by means of a cotton small arms cleaning patch. Initially, an attempt was made to determine the durability of the LSA by running the specimen at 600 cpm for 10,000 cycles to determine if any changes in friction would occur. In subsequent tests on LSA and LSA-T, a 2000-cycle break-in was used by cleaning and relubrication. The specimen was then run for 2000 cycles; at the end of which, the friction measurements were made at 620, 330 and 50 cpm. Loads used were 50, 100, and 150 pounds. The same speed settings and loads were used in all tests. For the remaining lubricants, the break-in period was 500 cycles. After cleaning and relubrication, each of these tests was run for 500 cycles before friction measurements were made.

RESULTS AND DISCUSSION:

A. Results of Function Tests of the Simulator.

All electronic systems of the simulator were found to operate satisfactorily in the tests outlined in Appendix B. Tests performed on the cams resulted in a set of cam-operating specifications shown in Table 1. Cams 1 and 5 have two lobes giving two cycles of reciprocation per revolution, while the remaining cams give one reciprocating cycle per revolution. The time-displacement characteristics of the five cams are shown in Figure 2, plotted on common abscissae. These curves are plotted from measurements of time-displacement curves taken with the high-speed drum camera. Since the cycle rate can be varied up to maximum shown in Table 1 for each cam, the actual time-displacement characteristics are also variable, even though each cam is made on the basis of a particular weapon component. Cams 1 and 5 give similar curves; however, No. 5 is a sine curve, with its maximum displacement at the center of the cycle; whereas No. 1 has its maximum displacement slightly ahead of the center of the cycle. Cam 5 also has a stroke length one-half inch longer than that of Cam 1. The many variations that can be obtained in time-displacement characteristics of the test specimens with these five cams operated over a range of speeds should make this simulator a versatile lubricant research and testing machine.

B. Friction Tests of Weapon Lubricants.

The tracing of a recording of the test specimen velocity, and the instantaneous (INST) and average (AVG) friction force for one cycle of reciprocation obtained in a test conducted on MIL-L-46000A lubricant is shown in Figure 3. Cam 5 was used. The roughness in the velocity curve is a result of gear backlash in the tachometer used to provide the velocity signal, not from variations in test specimen motion. The 120-130 Hz vibration present in the instantaneous friction force is a natural frequency of the interconnected drive, test specimen, and load cell pedestal assemblies. This was proved by tapping of the cam follower with a hammer (while the test specimens were in contact under load) and by recording of the resulting load cell output. These vibrations are filtered out in the recording of the average friction force. The average coefficient of friction obtained from the data in Figure 3 is 0.068. Friction coefficient can be displayed in the same way and gives a trace similar to that shown by the friction force, since it is computed by division of the friction force by the load which is a constant.

Results of the attempted durability test of LSA were inconclusive. The observed friction coefficient varied from 0.043 at 2,000 cycles to 0.037 at 10,000 cycles. At this time, the cam follower bearings were hot to the touch. Therefore, the shortening of the duration of subsequent tests was believed to be prudent. All friction coefficients observed in the remaining tests were higher than those observed in this first run.

Table 1

Cam Specifications

<u>Cam</u>	<u>Cam Shaft Speed, rpm</u>	<u>Cam Cycle Speed, Max., cpm.</u>
No. 1	500	1000
No. 2	612	612
No. 3	400	400
No. 4	800	800
No. 5	500	1000

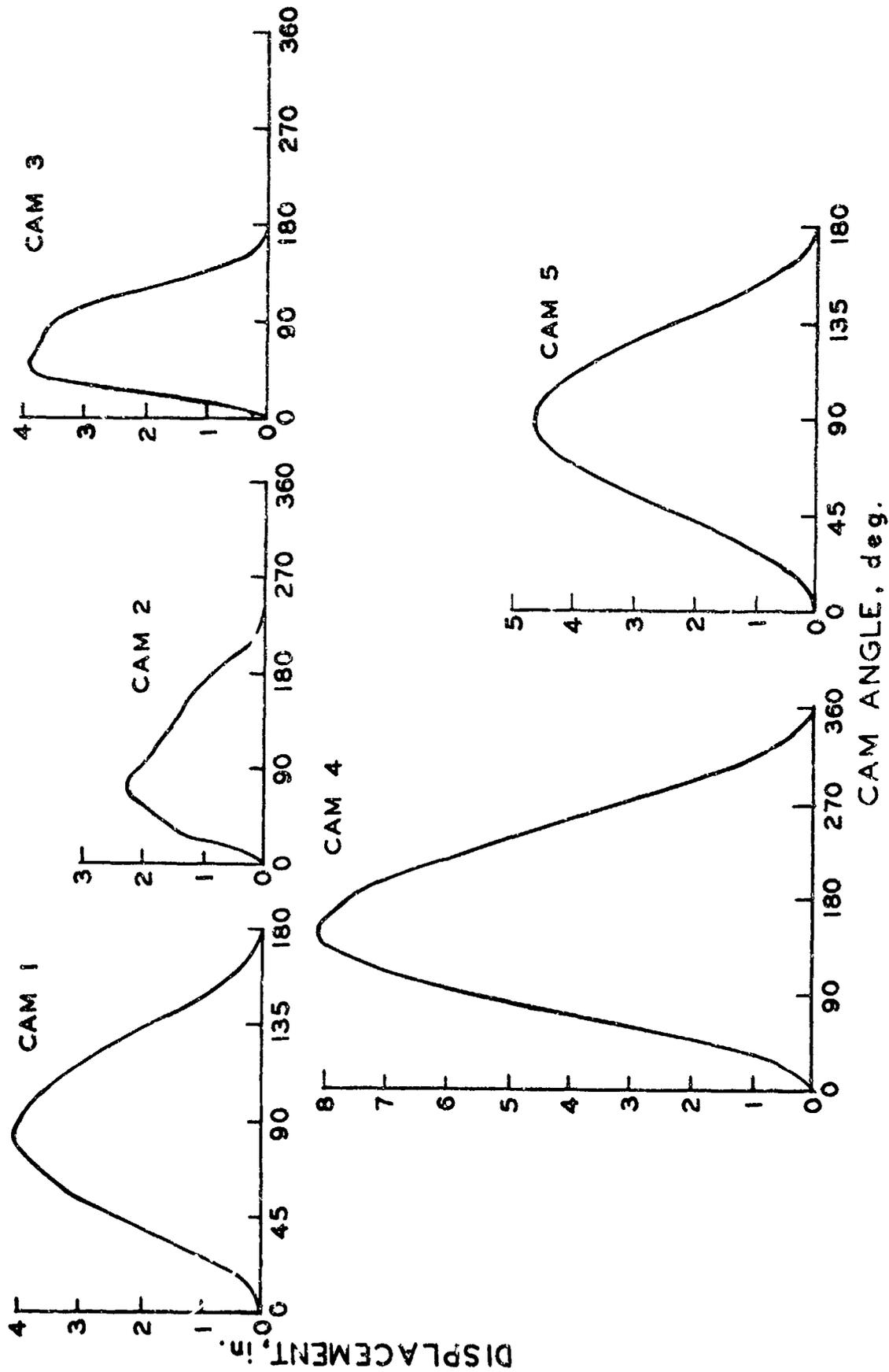


Figure 2 Specimen Displacement Characteristics

LOAD = 50 lb.

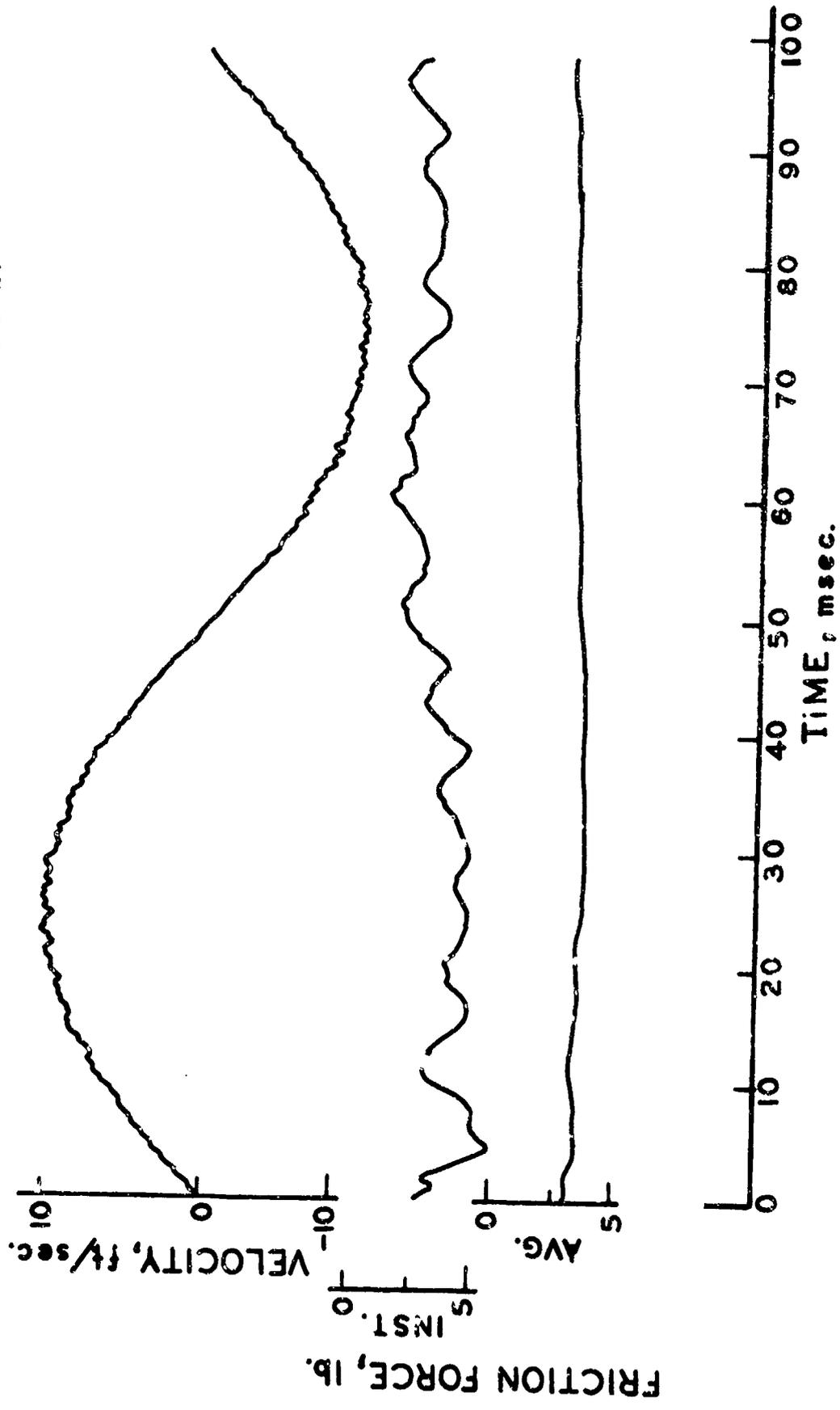


Figure 3 Representative Recorder Data

The results of the friction tests carried out on the three fluid materials and on the two semifluid materials used are shown in Table 2. Results of the first tests conducted showed, surprisingly, that friction was dependent upon the direction of motion of the specimen. The reason or reasons for this effect was not apparent; but, this effect could have been caused by a misalignment of the test specimens. In a first attempt to find the cause of this friction effect, the specimens were reversed in the specimens assembly and the test was repeated. The friction effect was reversed, as shown in Table 2. Therefore, this effect must be caused by the condition of the test specimens, possibly surface roughness. This phenomenon will be further investigated in future experiments. For the LSA lubricant, the friction coefficient varies with both the load and speed; whereas, for the LSA-T, the coefficient is dependent only on the load and shows no significant dependence on speed. These results are given by an analysis of variance (F-test) of the data at the 95 percent confidence level. The hydraulic fluid tested had lower friction coefficients at all speeds tested than the VV-L-800 or MIL-L-14107. The MIL-H-6083C contains tricresyl phosphate, an anti-wear agent, which may contribute to the lower coefficient. All lubricants tested, except for the LSA-T, show an increased friction coefficient at low speeds; the friction usually passes through a minimum and increases again at the highest speed. This behavior is expected for fluid lubricants passing from boundary to hydrodynamic lubrication conditions. The LSA-T did not show a significant change in friction with speed, except possibly at the lowest load used. The behavior of the Teflon additive in LSA-T, as a solid lubricant, is consistent with these results³.

C. Summary of Simulator Capabilities.

The types of data that can be acquired by use of the Small Arms Component Motion-Simulator are summarized in Table 3. The test condition capabilities of the machine are shown in Table 4. Comparison with other laboratory-type lubricant testers^{1,4} shows that the simulator has test capabilities that have not been exhibited by any other machine.

3. Clauss, Francis J., "Solid Lubricants and Self-Lubricating Solids," Academic Press, 1972, p. 202.

4. Benzing, R., et.al., Lubrication Fundamentals Committee, "A Catalog of Friction and Wear Devices," 1972.

Table 2

Friction Tests of Weapon Lubricants

SPEED cpm.	LOAD, lb.	50		100		150					
		Coefficient of Friction (left)	Coefficient of Friction (right)	avg	Coefficient of Friction (left)	Coefficient of Friction (right)	avg	Coefficient of Friction (left)	Coefficient of Friction (right)	avg	
MIL-L-46000, specimens in original alignment; 10,000 cycle break-in.											
620		0.083	0.054	0.068							
330		0.067	0.051	0.059							
50		0.092	0.067	0.080							
MIL-L-46000, specimens reversed for all tests following:											
620		0.093	0.102	0.098							
330		0.082	0.105	0.094							
50		0.110	0.124	0.117							
MIL-L-46000, after 10,000 cycle break-in on reversed specimens:											
620		0.076	0.092	0.084	0.084	0.101	0.083	0.079	0.086	0.084	0.084
330		0.073	0.098	0.085	0.083	0.096	0.079	0.088	0.088	0.084	0.084
50		0.102	0.110	0.106	0.102	0.113	0.101	0.106	0.106	0.104	0.104
MIL-L-46150 (LSA-T)											
620		0.142	0.156	0.149	0.101	0.110	0.099	0.109	0.109	0.104	0.104
330		0.120	0.132	0.126	0.108	0.110	0.100	0.102	0.102	0.101	0.101
50		0.111	0.119	0.115	0.089	0.108	0.095	0.105	0.106	0.100	0.100
VV-L-800											
620		0.114	0.163	0.138							
330		0.099	0.155	0.127							
50		0.099	0.179	0.139							
MIL-L-14107											
620		0.064	0.131	0.098							
330		0.055	0.147	0.101							
50		0.092	0.160	0.126							
MIL-R-6083C											
620		0.065	0.129	0.097							
330		0.055	0.133	0.094							
50		0.068	0.137	0.102							

Table 3 Data Acquisition

Coefficient of friction, instantaneous and average.

Friction force, instantaneous and average.

Velocity of moving test specimen.

Load.

Cycle rate.

Number of cycles.

Test temperature and relative humidity.

Test specimen temperature.

Table 4

Test Conditions, Capabilities

Motion:	Reciprocating, by cams based on XM19 bolt, M35 bolt slide, M73 (M219) barrel extension and rammer, M129 grenade launcher time-displacement data.
Specimen load:	0-150 lb. (0-68.2 Kg.).
Contact configuration:	Flat on flat.
Reciprocating rate:	1000 cpm, max. (see Table 1).
Stroke length:	8 in. max. (Figure 3).
Relative humidity:	20 to 95%, from +35° to +165°F (1.7° to 73.9°C)
Test temperature (environmental chamber):	-65° to + 165°F (-53.9° to + 73.9°C)
Test specimen temperature:	-65° to +500°F (-53.9° to 260°C)
Specimen materials:	Various materials used in weapons
Lubricants:	All types

CONCLUSIONS:

1. The Small Arms Components Motion-Simulator is a versatile laboratory-type friction and wear tester and is capable of carrying out tests under wide ranges of test conditions typical of weapon operation.
2. This simulator can be used to detect subtle differences in friction due to lubricant, load, speed and condition of the test specimen surface.
3. The behavior of the lubricants tested is typical of fluids and semifluids in the transition region between boundary and hydrodynamic lubrication.
4. The solid lubricant additive, Teflon, in the LSA-T also showed the expected improvement in lubricity of the base LSA material at the highest loads and the lowest speed used.
5. The simulator is ready to carry out lubricant research, development and applications testing for weapons.

RECOMMENDATIONS:

Experiments should be conducted to determine friction coefficients for current and experimental lubricants over the ranges of operating parameters of the simulator. A variety of experiments can be carried out. Initially, friction properties should be determined over the ranges of velocities, loads, stroke lengths and test specimen clearances within the design limits of the machine. These tests will provide data for the design engineer to incorporate into new weapon designs or modifications of existing weapons. Tests of dry film lubricants and solid self-lubricating composites should be included along with experiments on fluid lubricants.

The test specimens for the simulator are now designed for flat-on-flat reciprocating motion with variable side clearances. The test specimens and specimen unit assembly may be modified for future experiments to determine the effects of impact forces, locking and unlocking actions, chambering and extraction and similar actions typical for small arms mechanisms.

Another series of experiments should be conducted to determine friction coefficients for current and experimental weapon lubricants over the temperature and humidity ranges of the simulator. These tests would define more accurately the useful temperature ranges for the lubricants. Two series of experiments are recommended: One would cover the range of +30°F to -65°F (-10°C to -54°C). The effects of frost formation on lubricant properties would be determined in addition to the usual effects due to changes in lubricant flow properties with lowering temperature. A second series of experiments would cover the temperature range of +32° to -165°F (0°C to +74°C) ambient temperature and up to 500°F (-260°C) test specimen temperature. The effects of humidity would be determined in addition to the usual changes in lubricating properties with temperature.

APPENDIX A

MACHINE DESCRIPTION

APPENDIX A. MACHINE DESCRIPTION

This Appendix contains photographs of various units and components of the Small Arms Components Motion-Simulator, along with tables and descriptive material giving the nomenclature and functions of the controls, meters, recorders, and related equipment.

Figure 1-A shows the front panel of the control console. These components of the control console provide most of the control and data output for the simulator. Other units located in the lower part of the control console, which appear in Figure 1 but not in 1-A, are a power supply drawer and relay panel which also carries fuses and a test switch and meter to monitor system reference voltages. Several of these units or panels will be discussed in more detail because they are frequently used in experiments. These units are the recorder computer drawer, power control, and temperature control/monitor panels. The recorder will not be discussed further, except that it is a commercial 12-channel oscillographic type recorder with an associated 4-channel amplifier. Currently, the test specimen instantaneous velocity, instantaneous friction force or friction coefficient, and average friction force or friction coefficient can be recorded. The remaining channels are available for recording other data.

A closeup view of the computer drawer is shown in Figure 2-A. The functions of the numbered computer drawer front panel components are described in Table 1-A. This drawer holds electronic circuits to compute the friction coefficient and a potentiometer used to control the speed of the drive motor. The friction feedback (FRICT FDBK) is a device used to control the speed of the drive motor as a function of the friction coefficient. This is to simulate variations in the cyclic rate of weapons as a function of friction.

The power control panel is shown in Figure 3-A. This panel holds five switch-indicators, one indicator (without switch), and two meters. These components are described in Table 2-A.

The temperature control/monitor panel is shown in Figure 4-A. This panel contains two electronic thermometers, a four position-two pole rotary switch, two switch-indicators, an indicator without switch, and eight test jacks. The functions of these components are described in Table 3-A.

Additional control and monitoring devices are located on the control panel shown in Figure 5-A. The functions of these units are described in Table 4-A. Further details of the functions and operation of these control, computing, monitoring, and recording units are given in the Technical

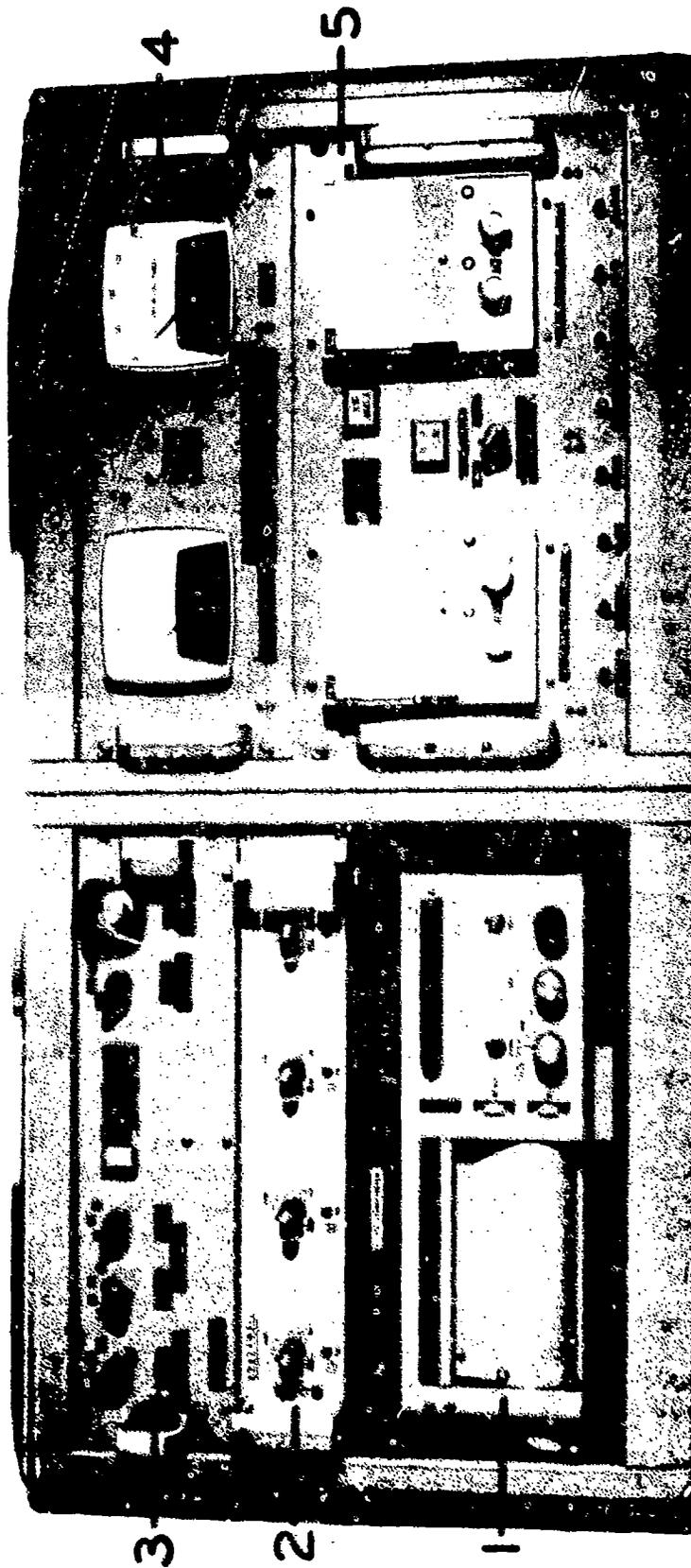


Figure 1-A Photograph of Front Panel of Control Console

- 1. Recorder
- 2. Recorder Amplifier
- 3. Computer Drawer
- 4. Power Control Panel
- 5. Temperature Control/ Monitor Panel

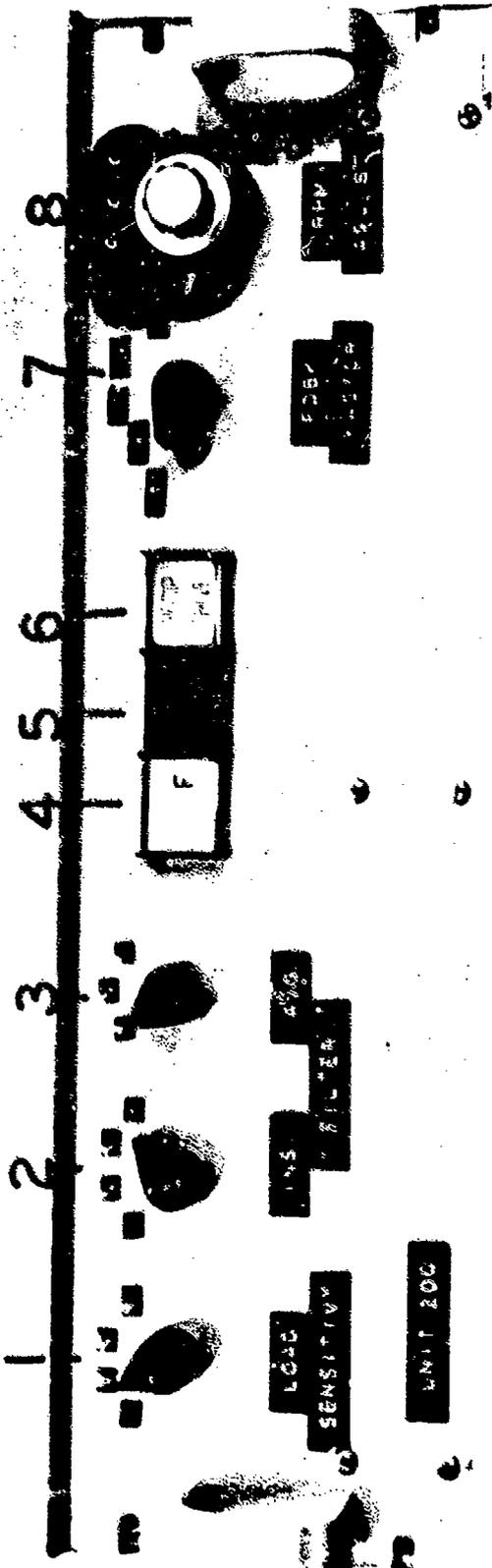


Figure 2-A Computer Drawer Front Panel

Table 1-A

Computer Drawer-Front Panel Components

<u>Designation</u>	<u>Nomenclature</u>	<u>Description and Function</u>
1	LOAD SENSITIVITY	Four position-two pole rotary switch to optimize computer voltage gradients as a function of load between specimens.
2	INST FILTER	Four position-two pole rotary switch used to select filtering for the analog of instantaneous u or f.
3	AVG FILTER	Three position-two pole rotary switch used to select filtering for the analog of average u or f.
4	U-F	Switch-indicator used to select either coefficient of friction (u) or friction (f) to be recorded.
5	FRICT FDBK	Switch-indicator used to introduce friction feedback to the constant speed reciprocating drive.
6	RECIP DRIVE	Switch-indicator used to introduce speed control voltage to the reciprocating drive.
7	FRICT FDBK FACTOR	Five position-single pole rotary switch used to select the value of friction feedback factor for the reciprocating drive.
8	RPM ADJUST	Two gang-ten turn potentiometer used to set in speed control voltage for the reciprocating drive.

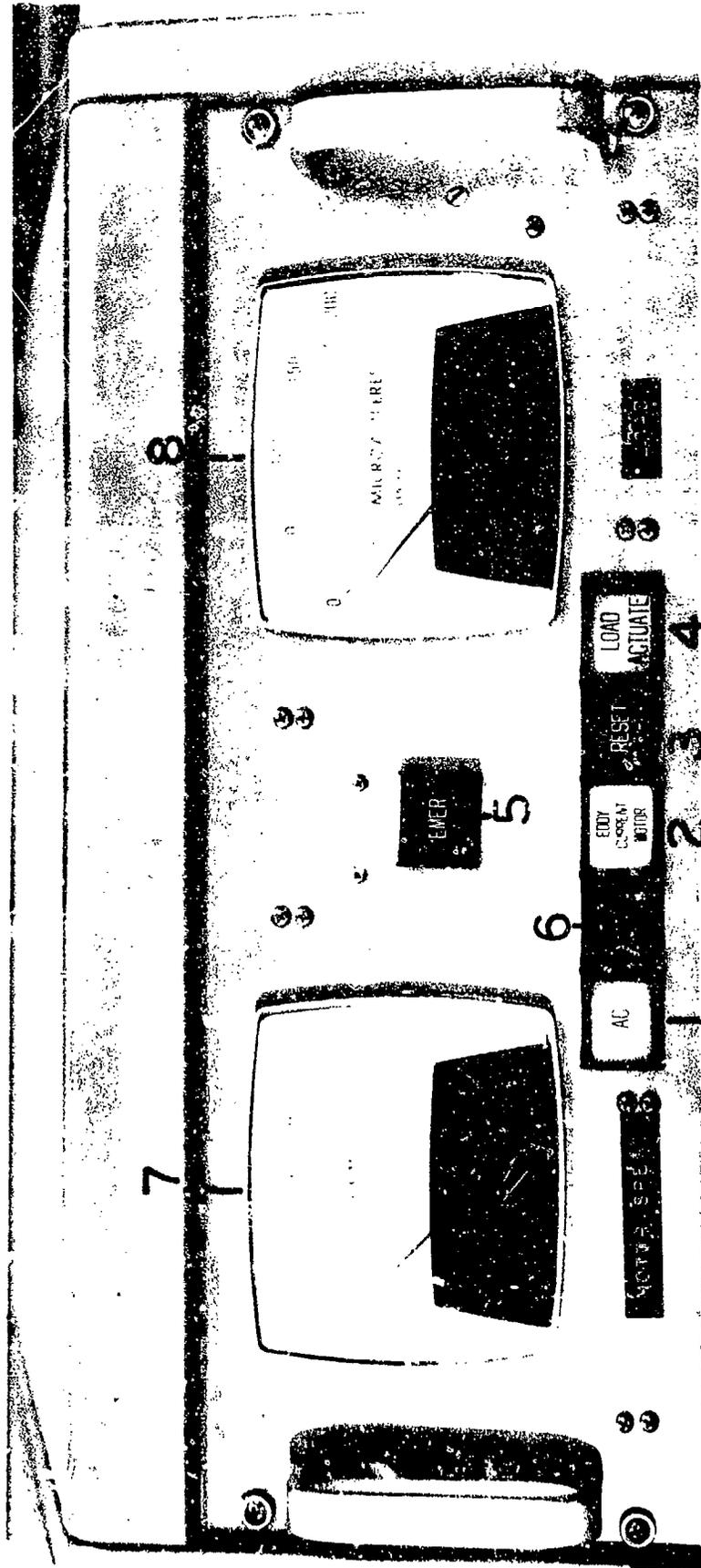


Figure 3-A Power Control Panel

Table 2-A

Power Control Panel-Front Panel Components

<u>Designation</u>	<u>Nomenclature</u>	<u>Description and Function</u>
1	AC	Switch-indicator used to energize system with ac power.
2	EDDY CURRENT MOTOR	Indicator that shows when three phase power is applied to constant speed drive motor.
3	RESET	Switch-indicator used to reset system.
4	LOAD ACTUATE	Switch-indicator used to apply and remove load between specimens.
5	EMER	Switch-indicator used to manually turn off the system in case of emergency.
6	DC	Switch-indicator used to energize the dc power supplies in the system.
7	MOTOR SPEED	Meter that indicates rotational speed of the constant speed drive motor.
8	LOAD	Meter that indicates load between the specimens.

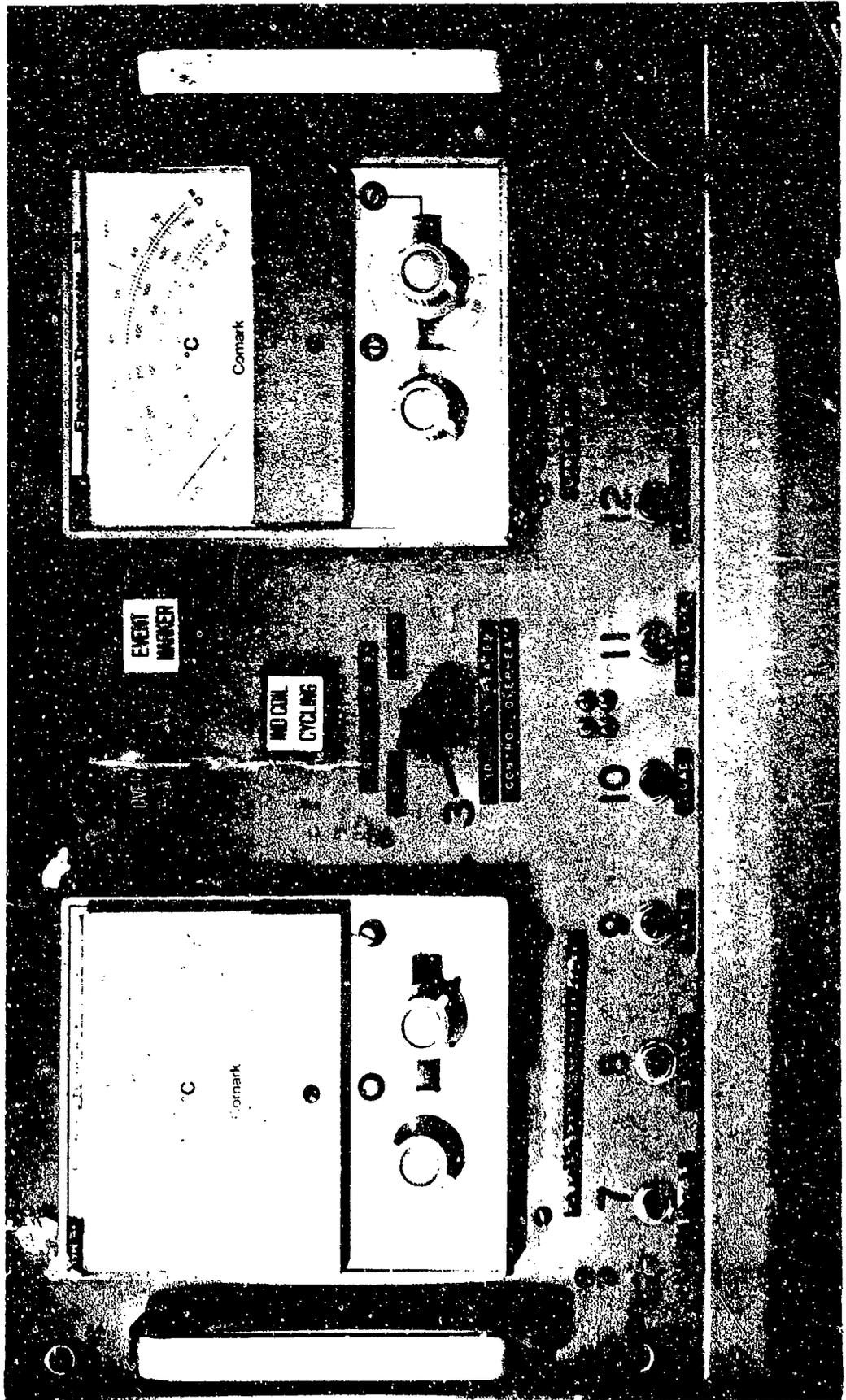


Figure 4-A Temperature Control/Monitor Panel

Table 3-A

Temperature Control/Monitor Panel Front Panel Components

<u>Designation</u>	<u>Nomenclature</u>	<u>Description and Function</u>
1	Lower Specimen Temperature	Electronic Thermometer used to monitor and control lower specimen temperature.
2	Upper Specimen Temperature	Electronic Thermometer used to monitor and control upper specimen temperature.
3	Induction Heater Control/Overheat	Four position-two pole rotary switch used to select the specimen in controlling the Induction Heater
4	IND COLL/CYCLING	Switch-Indicator for the Induction Coil and indicator, showing when Heater in on (cycling).
5	OVERHEAT	Indicator, showing when an overheat condition exists.
6	EVENT MARKER	Momentary switch-indicator used to put event marking on channel 4 of recorder.
7	L.S. TEMP	Test jack for lower specimen temperature analog (from M101).
8	U.S. TEMP	Test jack for upper specimen temperature analog (from M102).
9	RATE	Test jack for reciprocating rate analog.
10	LOAD	Test jack for analog of load between specimens.
11	INST u/f	Test jack for instantaneous u or f.
12	AVG u/f	Test jack for average u or f.
13	VELOCITY	Test jack for the analog of the linear velocity of the upper specimen.
14	INPUT	Jack to provide input to channel 4 of the recorder.

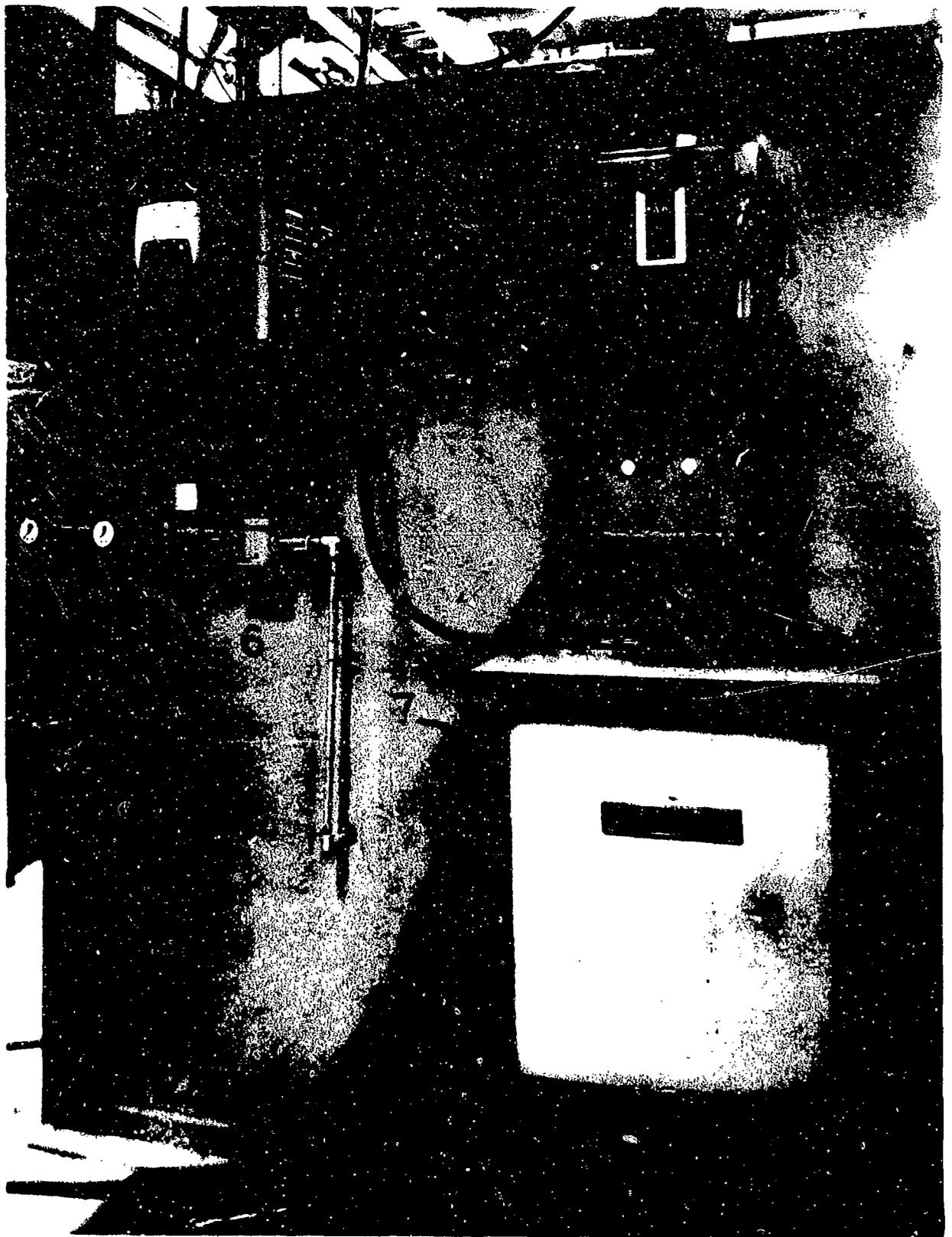


Figure 5-A Control Panel

Table 4-A

Control Panel Components

<u>Designation</u>	<u>Nomenclature</u>	<u>Description and Function</u>
1	MOTOR FUSE BOX AND STARTER	Input line fusing and starter for the Unit 2 motor.
2	MOTOR REVOLUTIONS	Counts revolutions made by motor when load is applied to specimens.
3	LOAD METER	Indicates load between specimens.
4	AIR METER	Indicates incoming air pressure.
5	LOAD TRANSDUCER	Air pressure sensitive potentiometer which monitors load between specimens.
6	AIR SOLENOID VALVE	Transmits load to specimen when energized, or vents air to atmosphere, removing load when de-energized.
7	MOTOR CONTROLLER	Electronics associated with the constant speed drive system.
8	LOAD ADJUST VALVE	Adjustment for setting load between specimens.
9	ARC SUPPRESSOR DIODE	Arc suppressor for counter M22.

Manual,² and drawings and commercial literature are on file in the Research Directorate.

The cam drive unit, located on top of the motor drive unit, is shown in Figure 6-A, in the normal operating position. The cam follower and the guide assembly raised in the position used for changing cams are shown in Figure 7-A. The base circle, or short axis, of the cam shown (cam No. 5) is 13.3 inches in diameter.

Some details of the interior of the environmental chamber are shown in Figure 8-A. In this figure, the test specimen unit assembly is shown with a set of test specimens in place. The environmental chamber is a commercial unit capable of controlling the temperature from -65°F to $+165^{\circ}\text{F}$, (-54° to $+74^{\circ}\text{C}$) and relative humidity from 20 to 95% in the temperature range from $+35^{\circ}$ to $+165^{\circ}\text{F}$ ($+2^{\circ}$ to $+74^{\circ}\text{C}$). An induction heater coil, not shown in Figure 8-A, is wrapped around the test specimens and can be used to supply additional heat to the specimens to test the thermal stability of lubricants. A closeup view of the test specimens is shown in Figure 9-A. The drive shaft (left) is disconnected from the upper specimen. The upper T-shaped specimen, connected to its holder and guide rods, is raised to allow the lower specimens to be removed. The lower specimens are swung out on the gimbaled holder supported by the air piston. The load arm that transmits friction forces to the load cell appears at the right lower center of Figure 9-A, attached to the supporting cradle of the specimen assembly.

Drawings of the test specimens are shown in Figure 10-A, 11-A, and 12-A. The 9-inch-long upper specimen is used for reciprocating stroke lengths up to 4.5 inches and the 12-inch specimen is used for 4.5 to 8 inch strokes. The different size specimens are used for stabilization of the gimbal-mounted loading cylinder.

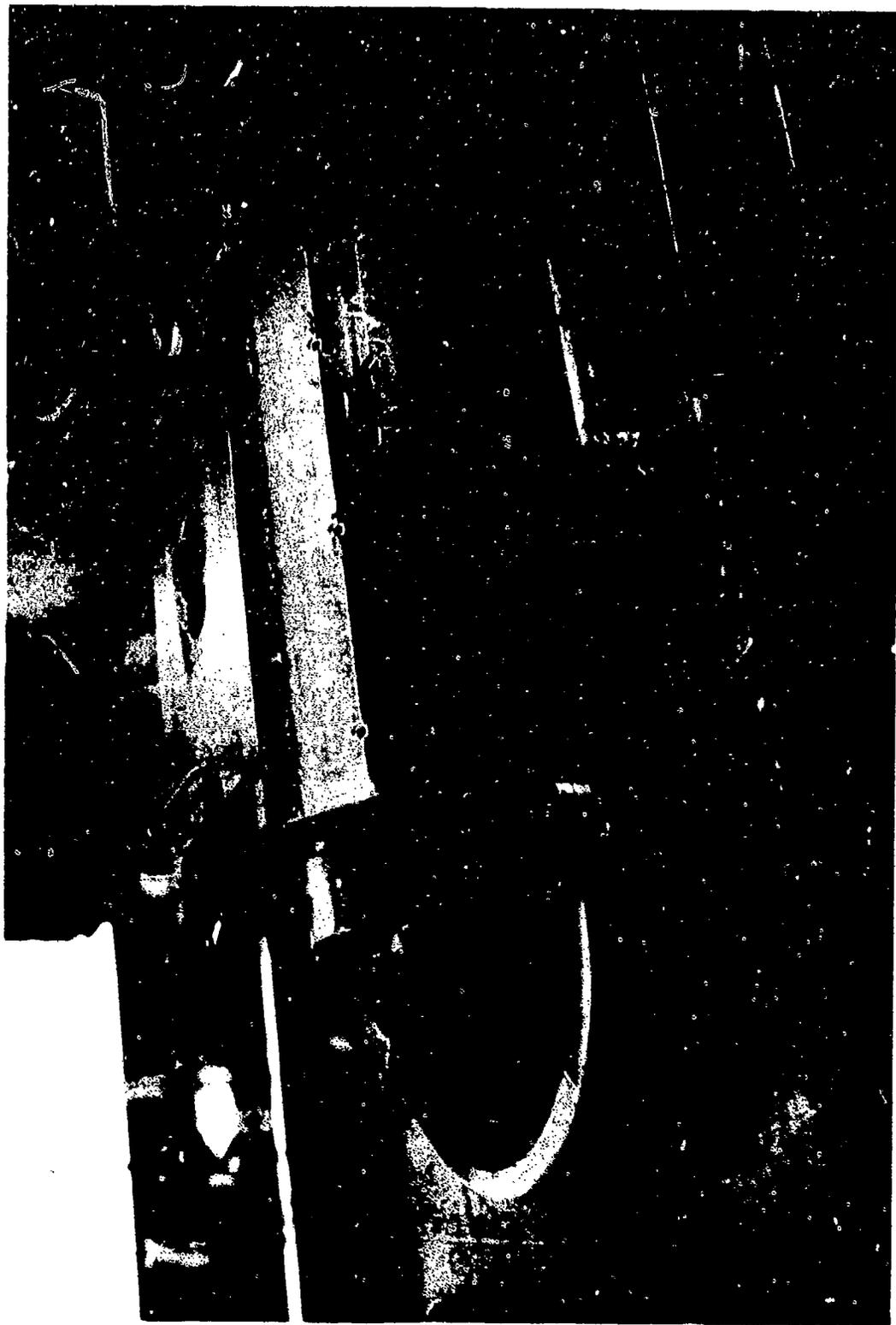


Figure 6-A Cam Drive Unit

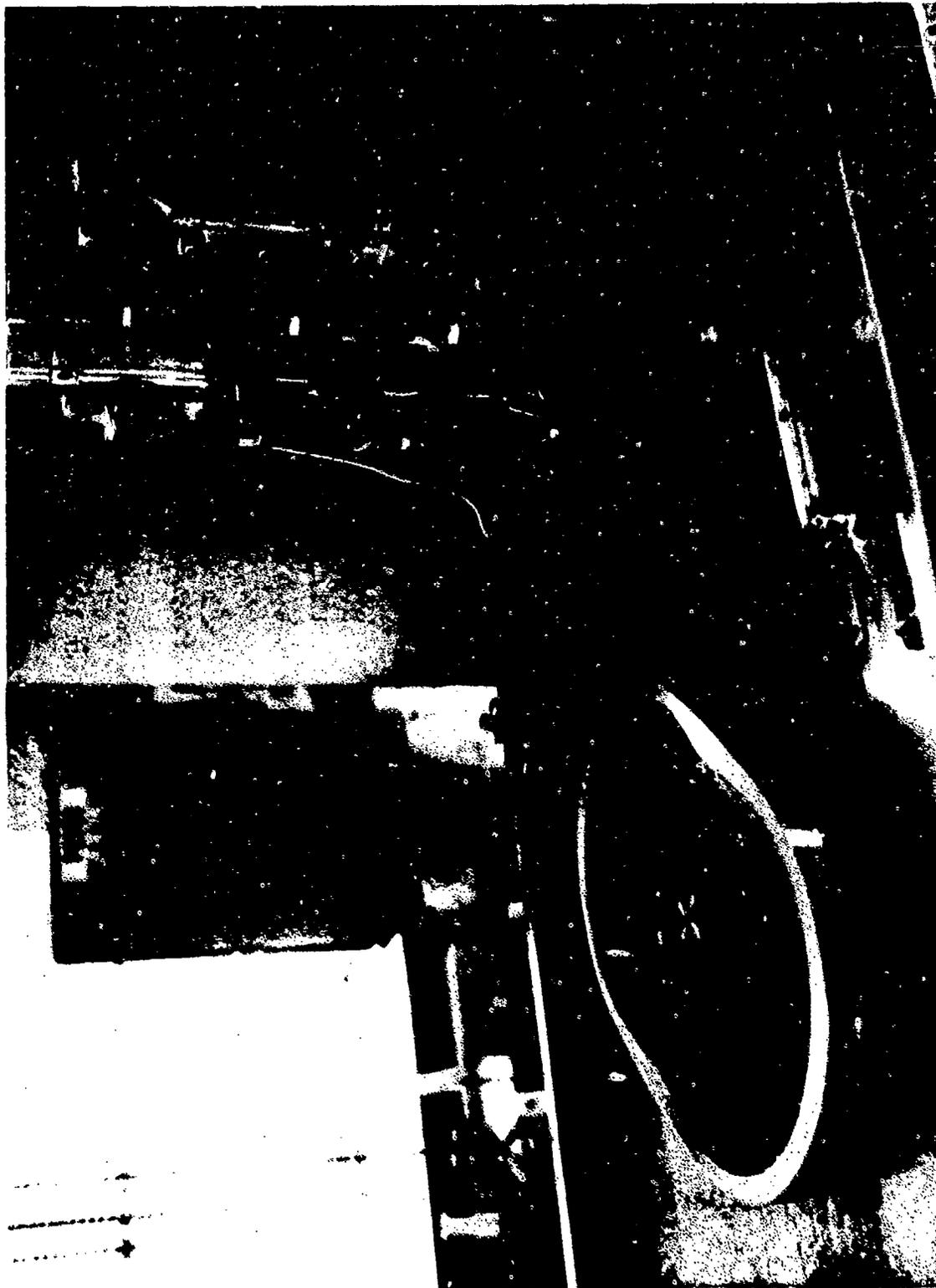


Figure 7-A Cam Drive Unit With Follower
Assembly Raised

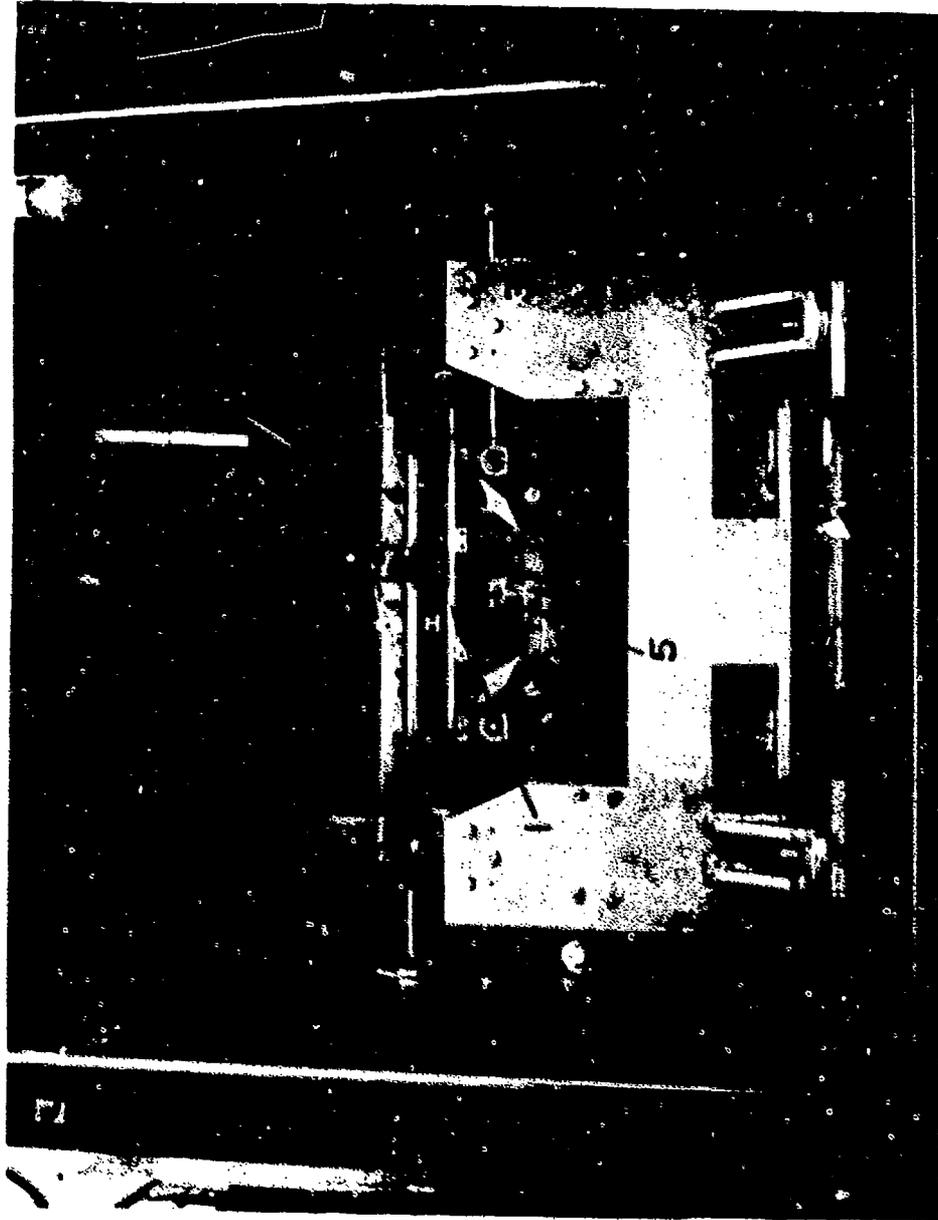


Figure 8-A Environmental Chamber-Test Specimen Unit Assembly

1. Test specimens (Lower specimen length 20 in.)
2. Upper specimen drive shaft
3. Friction force transducer shaft
4. Upper specimen holder and guides
5. Specimen loading piston and cradle

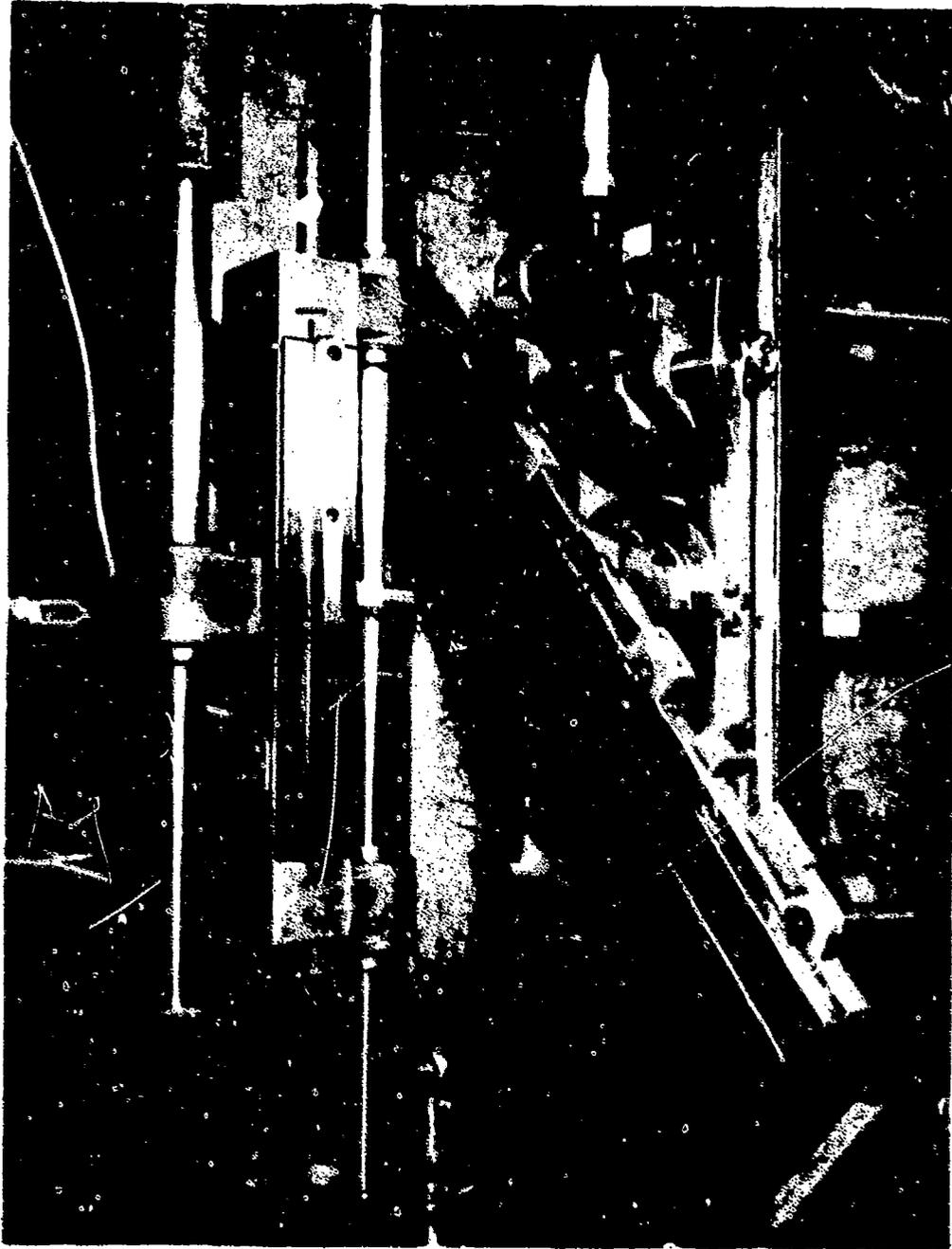
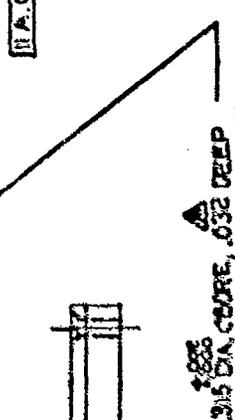
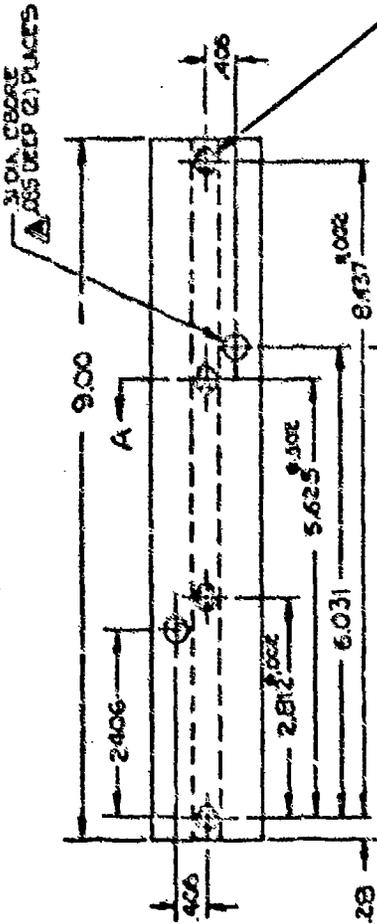


Figure 9-A Test Specimens
1. Upper specimen (Length 9 in.)
2. Lower specimen

721300107

REVISIONS		
REV	DESCRIPTION	DATE APPROVED
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PART NO.	MATERIAL	HARDNESS	FINISH
421C3001	ALUMINUM 7050-T6	120-130	AS SUPPLIED
421C3002	ALUMINUM 7050-T6	120-130	AS SUPPLIED
421C3003	ALUMINUM 7050-T6	120-130	AS SUPPLIED
421C3004	ALUMINUM 7050-T6	120-130	AS SUPPLIED
421C3005	ALUMINUM 7050-T6	120-130	AS SUPPLIED
421C3006	ALUMINUM 7050-T6	120-130	AS SUPPLIED
421C3007	ALUMINUM 7050-T6	120-130	AS SUPPLIED
421C3008	ALUMINUM 7050-T6	120-130	AS SUPPLIED
421C3009	ALUMINUM 7050-T6	120-130	AS SUPPLIED
421C3010	ALUMINUM 7050-T6	120-130	AS SUPPLIED



Applied Devices Corporation

UPPER SPECIMEN

SIZE CODE COUNT NO. C 95036 421C3001 A

SCALE 1:1 UNIT WEIGHT SHEET

DESIGNED	CHECKED	PROGRAM	ENGINEER

SEE TABLE

SCALE 4:1

Figure 10-A

APPENDIX B

TEST PROCEDURE

APPENDIX B. TEST PROCEDURE

The test procedure written for the purpose of checking out the operation of the Small Arms Components Motion-Simulator is outlined in Table 1-B. A load calibration procedure is provided in Paragraph 2.2.1.

Table 1-B

TEST PROCEDURE

- 1.0 Checks of System Input Requirements.
- 1.1 Electrical Inputs. Utilizing an AC Voltmeter ascertain that the following input voltages are present. (These voltages may be measured at the appropriate fuse boxes.)
- 1.1.1 115^V AC VOLTS SINGLE PHASE
- 1.1.2 220^V AC VOLTS THREE PHASE
(each line voltage) Exciting Unit 2. Motor Drive
- 1.1.3 220^V AC VOLTS THREE PHASE
(each line voltage) Exciting Unit 3. Environmental Chamber
- 1.1.4 220^V AC VOLTS THREE PHASE
(each line voltage) Exciting Unit 4. Induction Heater
- 1.2 Water Inputs.
- 1.2.1 Ascertain that the pressure gage on the input water line to the Unit 3 Environmental Chamber indicates a pressure of 40 psi or greater.
- 1.2.2 Ascertain that the pressure gage on the input water line to the Unit 4 Induction Heater indicates a pressure of 40 psi or greater.
- 1.3 Air Input. Ascertain that the air pressure gage on the input air line to Unit 2 Drive indicates a steady pressure of 90 psi or greater.

- 2.0 Preliminary Tests.
- 2.1 Unit 1 Control Console.
- 2.1.1 Prior to applying input power to the system, place all positional switches to their OFF position or full counter-clockwise position.
- 2.1.2 Apply 115^V AC power to the system and press the AC switch-indicator on Unit 300 (These unit numbers and their locations will be found in the Technical Manual.) Power Control panel. The AC indicator shall illuminate. Unit 300 RESET indicator shall illuminate.
- 2.1.3 Press Unit 300 DC switch-indicator. The DC indicator shall illuminate.
- 2.1.4 Monitor System Voltages.
- 2.1.4.1 Ascertain that the RECIP DRIVE switch-indicator on Unit 200 Computer Control panel is not illuminated. (If indicator illuminated, press RECIP DRIVE switch and indicator shall extinguish.)
- 2.1.4.2 Close main switch on Unit 2 Fuse Box F.B. 21.
- 2.1.4.3 Push START button on Unit 2 Fuse Box F.B. 21. Unit 2 Drive motor shall turn (however, no external motion should occur) and the Control Console Unit 300 EDDY CURRENT MOTOR indicator shall illuminate.
- 2.1.4.4 Using the TEST Meter and TEST METER selector switch on the Unit 400 Power Supply panel, make sure that the TEST Meter needle points to the green area when the select switch is in each of the following positions:

2.1.4.4 Continued. . . .

<u>Position</u>	<u>Function</u>
2	115 VAC
3	230 VAC PH 1-2
4	230 VAC PH 1-3
5	230 VAC PH 2-3
6	6.3 VAC
7	24 VAC
8	+15 VAC
9	-15 VAC
10	5 VAC

2.1.4.5 Place the TEST METER selector switch to the OFF position (1 or 11). Meter shall not indicate in the green area.

2.1.4.6 Push the STOP button on Unit 2 Fuse Box F.B. 21. The Drive motor shall stop and the Computer Console Unit 300 EDDY CONTROL MOTOR indicator shall extinguish.

2.1.5 Control Console Indicator Test.

2.1.5.1 Press Unit 300 DC switch-indicator. Indicator shall extinguish.

2.1.5.2 Press Unit 300 AC switch-indicator. Indicator shall extinguish. Unit 300 RESET Indicator shall extinguish.

2.1.5.3 Press Unit 300 AC switch-indicator and Unit 300 DC switch-indicator. Each indicator shall illuminate. Unit 300 RESET indicator shall illuminate.

- 2.1.5.4 Press Unit 300 RESET switch-indicator. Indicator shall extinguish if mechanical overload switches and Unit 300 EMER switch are in normal positions.
- 2.1.5.5 Press Unit 300 EMER switch-indicator. Indicator shall illuminate and Unit 300 RESET indicator shall illuminate. Press EMER switch again, and indicator shall extinguish.
- 2.1.5.6 Press Unit 300 RESET and LOAD ACTUATE switch-indicator. RESET Indicator shall extinguish and LOAD ACTUATE shall illuminate. Press LOAD ACTUATE switch again. Indicator shall extinguish.
- 2.1.5.7 Press the u-f switch-indicator. Only the u portion of the indicator shall illuminate. Press the u-f switch-indicator again. The u indication shall extinguish and the f indication illuminate.
- 2.1.5.8 Press Unit 200 FRICK FDBK switch-indicator. Indicator shall illuminate. Press FRICK FDBK switch again. Indicator shall extinguish.
- 2.1.5.9 Press Unit 200 RECIP DRIVE switch-indicator. Indicator shall illuminate. Press RECIP DRIVE switch again and indicator shall extinguish.
- 2.1.5.10 On Unit 100, set the Electronic Thermometer monitoring the LOWER SPECIMEN TEMP to the °C position. Note the approximate temperature. Without changing temperature scale (A,B, C or D) turn right hand selector to SET TRIP A position. Adjust the center screwdriver adjustment so that pointer indicates a value well above the previously noted temperature. Return selector to °C position.

- 2.1.5.11 Repeat previous step (2.1.5.10) utilizing UPPER SPECIMEN TEMP thermometer.
- 2.1.5.12 Press Unit 100 IND COIL switch-indicator. Indicator shall illuminate.
- 2.1.5.13 Close Unit 3 Environmental Chamber door if open, and press Unit 300 RESET switch-indicator. Unit 100 CYCLING indicator shall illuminate. Unit 100 OVERHEAT indicator shall not be illuminated. Unit 300 RESET indicator shall extinguish.
- 2.1.5.14 Press Unit 100 IND COIL switch-indicator. The IND COIL indicator and CYCLING indicator shall extinguish. Press the IND COIL switch again and both lites shall illuminate.
- 2.1.5.15 Open Unit 3 Environmental Chamber door. The CYCLING indicator shall extinguish. Close door and indicator shall illuminate.
- 2.1.5.16 Press Unit 300 EMER switch-indicator. EMER indicator shall illuminate, Unit 300 RESET indicator shall illuminate and Unit 100 CYCLING indicator shall extinguish.
- 2.1.5.17 Press Unit 300 EMER switch-indicator and Unit 300 RESET switch-indicator. Unit 300 EMER indicator shall extinguish. Unit 300 RESET indicator shall extinguish and Unit 100 CYCLING indicator shall illuminate.
- 2.1.5.18 Place the Unit 100 INDUCTION HEATER selector switch to each of the switch positions and ascertain that the CYCLING indicator is illuminated in all switch position. Return switch to the L.S./NONE position.

- 2.1.5.19 On Unit 100, note the temperature indicated on the UPPER SPECIMEN TEMP thermometer. Set the control to SET TRIP A position and adjust the center screwdriver adjustment so the indicator reads well below the noted temperature. Return the control to the °C position.
- 2.1.5.20 Place the Unit 100 INDUCTION HEATER selector switch to the L.S./U.S. position. The CYCLING indicator shall extinguish and the OVERHEAT indicator shall illuminate.
- 2.1.5.21 Place the Unit 100 INDUCTION HEATER selector switch to the U.S./L.S. position. The OVERHEAT indicator shall extinguish and the CYCLING indicator shall remain out. Place the INDUCTION HEATER selector switch to the U.S./NONE position. There should be no change in any of the indicators.
- 2.1.5.22 On Unit 100, note the temperature indicated on the LOWER SPECIMEN TEMP thermometer. Set the control to SET TRIP A position and adjust the center screwdriver adjustment so the indicator reads well below the noted temperature. Return the control to the °C position.
- 2.1.5.23 Place the Unit 100 INDUCTION HEATER selector switch to the U.S./L.S. position. The Unit 100 OVERHEAT indicator shall illuminate.
- 2.1.5.24 Place the Unit 100 INDUCTION HEATER selector switch to the L.S./U.S. position. The OVERHEAT indicator shall remain illuminated in this position.

- 2.1.5.25 Place the Unit 100 INDUCTION HEATER selector switch to the L.S./NONE position. The OVERHEAT indicator shall extinguish.
- 2.1.5.26 Press the Unit 100 IND COIL switch-indicator. IND COIL indicator shall extinguish.
- 2.1.6 Recorder Test. (Including amplifiers.) Turn on power to recorder and amplifier. Permit warmup of recorder as indicated in manual.
- 2.1.6.1 Utilizing the rear access doors on the Unit 1 Control Console put the Unit 200 COMP TEST switch to the TEST position. (Switch is located on the rear of Unit 200 chassis.) The Unit 300 RESET indicator shall illuminate.
- 2.1.6.2 On Unit 200 Computer Drawer set the LOAD SENSITIVITY selector switch to position No. 2 (load range 30 to 60 lbs.).
- 2.1.6.3 Utilizing front panel jacks measure the voltage of the INST u/f signal with a voltmeter and/or scope. Ascertain that the deflection on the recorder channel 2 agrees with the INST u/f signal.
- 2.1.6.4 Repeat step 2.1.6.3 for the AVG u/f signal. This voltage should be recorded on channel 3 of the recorder.
- 2.1.6.5 Jumper the AVG u/f signal to the input jack and ascertain that the signal is recorded on channel 4 of the recorder.
- 2.1.6.6 Depress the Unit 100 EVENT MARKER. Ascertain that channel 4 of the recorder indicates the marked voltage (approximately 5 VOC) while the EVENT MARKER switch is depressed.

- 2.1.6.7 Set the Unit 200 COMP TEST switch to its normal position. (Switch located on rear of Unit 200 chassis.) Remove jumpers from Unit 100 AVG u/f and INPUT test jacks.
- 2.1.6.8 Channel 1 of the recorder should be tested while the machine is operating. Therefore, steps 2.1.6.9 thru 2.1.6.11 should be conducted during step 2.2.3.3 of this procedure.
- 2.1.6.9 Monitor the Unit 100 VELOCITY test jack with a scope.
- 2.1.6.10 Ascertain that channel 1 of the recorder indicates the same signal as that shown on the scope.
- 2.1.6.11 Remove the test probes, meter and scope from the Unit 100 test jacks.
- 2.1.7 Computer Test.
- 2.1.7.2 On Unit 200 Computer Drawer set the LOAD SENSITIVITY selector switch to position No. 2 (load range 30 to 60 lbs.).
- 2.1.7.2 Utilizing the rear access doors on the Unit 1 Control Console, put the Unit 200 COMP TEST switch to the TEST position (switch is located on the rear of the Unit 200 chassis). The Unit 300 RESET indicator shall illuminate.
- 2.1.7.3 Ascertain that the Control Console recorder indicates, for both the instantaneous and average value of u/f, a voltage of 2.25 volts DC.
- 2.1.7.4 On Unit 200, set the INST FILTER selector switch to each position and ascertain that the voltage indicated on the Control Console

2.1.7.4. . . .

recorder for instantaneous u/f (after allowing for a transient after changing switch positions) is 2.25 volts DC in each position. Return switch to position No. 1.

2.1.7.5 On Unit 200, set the AVG FILTER selector switch to each position and ascertain that the voltage indicated on the Control Console recorder for average u/f (after allowing for a transient after changing switch positions) is 2.25 volts DC in each position. Return switch to Position No. 1.

2.1.7.6 Press the Unit 200 u-f switch-indicator. The f portion of the indicator shall extinguish and the u portion shall illuminate.

2.1.7.7 Ascertain that the Control Console recorder indicates, for both the instantaneous and average value of u/f, a voltage of 3.0 volts.

2.1.7.8 On Unit 200, set the INST FILTER selector switch to each position and ascertain that the voltage, indicated on the recorder for instantaneous u/f (after allowing for a transient after changing switch position) is 3.0 volts DC in each position. Return switch to position No. 1.

2.1.7.9 On Unit 200, set the AVG FILTER selector switch to each position and ascertain that the voltage indicated on the recorder for average u/f (after allowing for a transient after changing switch positions) is 3.0 volts DC in each position. Return switch to position No. 1.

2.1.7.10 Put the Unit 200 COMP TEST switch to its normal position (switch located on rear of Unit 200 chassis).

2.2 Unit 2 (Drive) and Unit 3 (Chamber) Tests.

2.2.1 Load Test (Static Load Calibration).

2.2.1.1 Test Equipment. The following is a list of test equipment necessary to accomplish the load calibration:

Disc, Plate, and Bracket	Shown in Figure B-1.
Force Transducer	Tyco Model JP200 (Figure B-1)
Power Supply	5 volt DC regulated supply. Lambda, LH118 FM or equivalent.
Voltmeter	Digital or vacuum tube.

Note: The simulator is equipped to accommodate the Tyco JP 200 load cell in place of the P.C.B. Piezotronics, Model 206A, load cell initially installed. The Tyco load cell can be connected through the load cell electronics box located on the load cell pedestal, after the P.C.B. load cell is disconnected. The load cell output will then appear on the friction force channel of the recorder on the Control Console.

2.2.1.2 Calibration Procedure. Calibrate the unmounted load cell by applying known standard weights. Read the load cell output by means of the voltmeter or simulator recorder. Prepare a table or a graph of load cell output vs. applied weight up to 150 pounds.

2.2.1.3 Remove the drive shaft from the upper specimen. Lift the upper specimen and remove the induction heater coil from around the lower specimens. (Ascertain that the water supply to the Unit 4 Induction Heater is off prior to removing coil.)

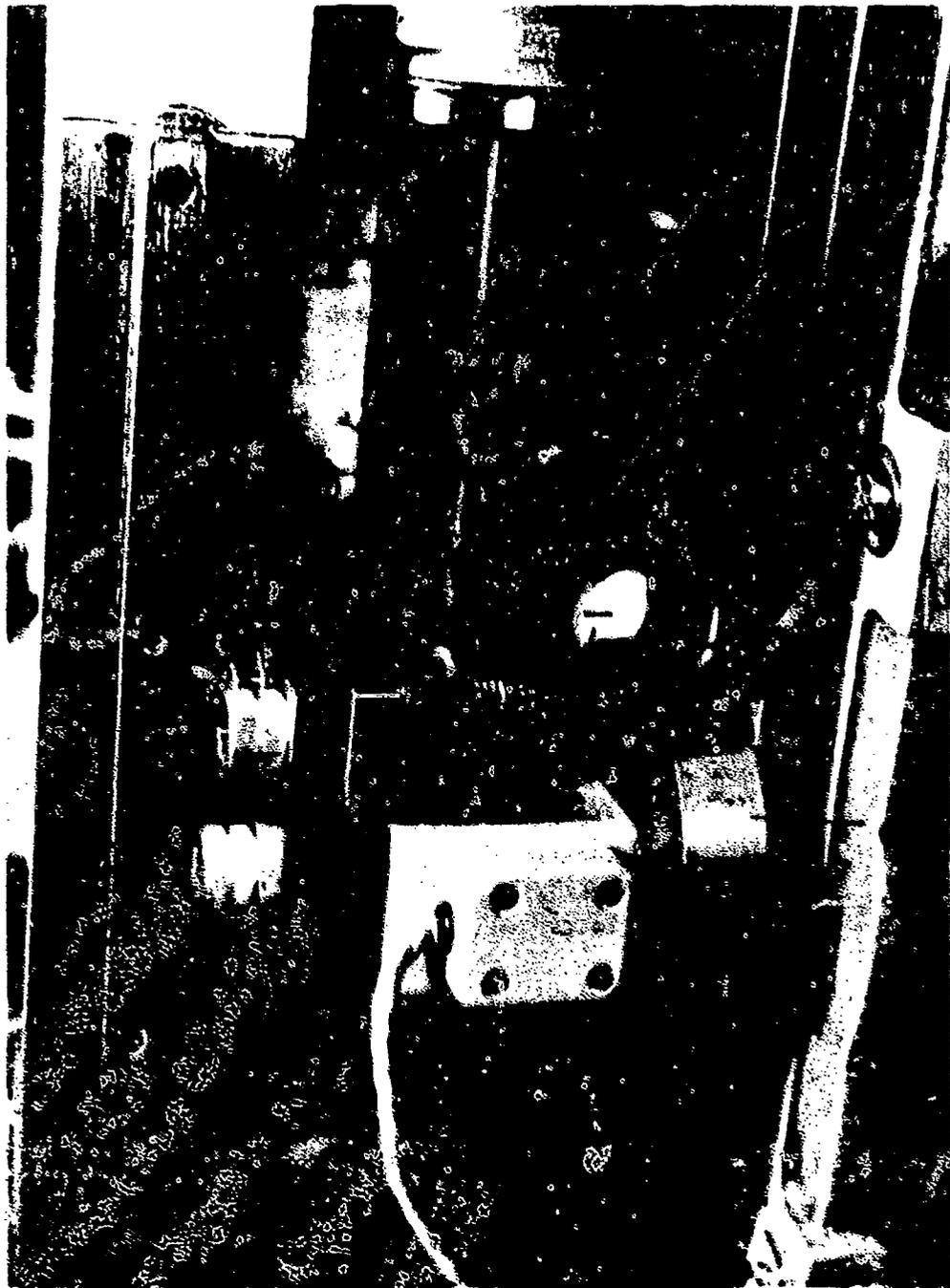


Figure 1-9 Calibration Fixture, Mounted

1. Load Cell (Force Transducer)
2. Dial
3. Plate
4. Bracket

- 2.2.1.4 Attach the load cell and bracket in position on the specimen assembly as shown in Figure B-1. The bracket (4) is bolted to the center support for the upper specimen carriage.
- 2.2.1.5 Energize the simulator by turning on the air, main power switch, AC, DC, RESET and recorder. Do Not energize the drive motor.
- 2.2.1.6 Slowly lift the lower test specimens by pressing the LOAD ACTUATE button on the Control Console and by adjusting the Load Adjust Valve on the Control Panel. When the specimens have been elevated to a position 0.010 inch to 0.005 inch from the disc attached to the load cell, and no contact exists, adjust the LOAD meters on the Control Console and Control Panel to zero. Slowly apply a force to the lower specimen by adjusting the air pressure valve. Compare the load indicated on the meters with the output of the calibrated load cell. Generate a correction table or graph for the various loads up to 150 pounds, if necessary.
- 2.2.1.7 Restore the simulator to its original configuration.
- 2.2.2 Friction transducer Checks.
- 2.2.2.1 On Control Console, press the Unit 200 u-f switch-indicator. The u portion of indicator shall extinguish and f portion shall illuminate.
- 2.2.2.2 Set Unit 200 INST FILTER selector switch to position No. 1 and LOAD SENSITIVITY selector switch to position No. 4 (load 60 to 150 lbs.).
- 2.2.2.3 Attach the calibrating pulley system to the lower specimen and place 100 pound calibration weight on the system. Utilizing the control Console recorder, instantaneous u/f channel, ascertain that the friction analog is 6.45 volts DC.

- 2.2.2.4 Remove the 100 pound calibration weight. Set Unit 200 LOAD SENSITIVITY selector switch to position No. 3 (load 30 to 60 lbs.).
- 2.2.2.5 Repeat paragraph 2.2.2.3 using 50 pound calibration weight. Friction analog shall be 8.06 volts DC.
- 2.2.2.6 Remove 50 pound weight. Set Unit 200 LOAD SENSITIVITY selector switch to position No. 2 (load 10 to 30 lbs.).
- 2.2.2.7 Repeat paragraph 2.2.2.3 using 25 pound calibration weight. Friction analog shall be 8.06 volts DC.
- 2.2.2.8 Remove 25 pound weight. Set Unit 200 LOAD SENSITIVITY selector switch to position No. 1 (load 0 to 10 lbs.).
- 2.2.2.9 Repeat paragraph 2.2.2.3 using 5 pound calibration weight. Friction analog shall be 4.04 volts DC.
- 2.2.2.10 Remove calibrating weight and pulley system from lower specimen. Swing upper specimen into its normal position.
- 2.2.3 Constant Speed Drive. (With Sine Cam Installed)
- 2.2.3.1 On Unit 2, close the fuse-disconnect switch on F.B. 21 and push the START pushbutton. The Control Console Unit 300 ENDY CURRENT MOTOR indicator shall illuminate.
- 2.2.3.2 Ascertain that the Control Console Unit 200 RPM ADJUST control is fully counterclockwise. Push the RECIP DRIVE switch-indicator. The indicator shall illuminate.
- 2.2.3.3.* Turn the Unit 200 RPM ADJUST control clockwise until the Unit 300 RATE meter indicates a speed of 200 RPM (cam output of 400 RPM). Once the speed has stabilized, the drive will run at a

*If desired, test channel 1 of recorder. Refer to step 2.1.6.8 of procedure.

constant speed without further adjustment. Note that REVS counter on Unit 2 is counting.

- 2.2.3.4 Utilizing the Control Console recorder, instantaneous velocity channel, ascertain the velocity output is sinusoidal in shape with a peak to peak amplitude of 14.72 volts.
- 2.2.3.5 Repeat paragraph 2.2.3.3 and 2.2.3.4 at a RATE meter indication of 500 RPM (cam output of 1000 RPM). Velocity output shall be 36.81 volts peak to peak.
- 2.2.3.6 Turn the Control Console Unit 200 RPM ADJUST control to its fully counterclockwise position. Note that REVS counter on Unit 2 stops counting. Push the Unit 200 RECIP DRIVE switch-indicator. The indicator shall extinguish.
- 2.2.3.7 On Unit 2 fuse disconnect box, push the STOP pushbutton. The Control Console Unit 300 EDDY CURRENT MOTOR indicator shall extinguish.
- 2.2.3.8 Open the Unit 2 fuse disconnect switch on F.B. 21.
- 2.2.4 Environmental Chamber Checks.
- 2.2.4.1 Close Unit 3 Environmental Chamber door.
- 2.2.4.2 On Unit 3 Environmental Chamber put CONTROL switch on. Associated lamp shall illuminate.
- 2.2.4.3 Set the Unit 3 Chamber dry bulb temperature pointer to -65°F . Place the Unit 3 MAIN COOLING switch on. Associated lamp will illuminate.
- 2.2.4.4 Ascertain, by utilizing the Unit 3 recorder, that the dry bulb temperature within the chamber reaches -65°F and maintains that temperature.
- 2.2.4.5 Set the Unit 3 dry bulb temperature pointer to 0°F . Place the HIGH HEAT switch and the LOW HEAT switch to on. Associated lamps shall illuminate.

- 2.2.4.6 Ascertain, by utilizing the Unit 3 recorder, that the chamber temperature goes to 0°F and maintains that temperature. It may be necessary to switch off the MAIN COOLING switch and turn on the AMBIENT COOLING switch and/or turn off the HIGH HEAT switch to obtain smooth temperature control.
- 2.2.4.7 Set Unit 3 dry bulb temperature pointer to 80°F and the wet bulb temperature to 79°F (corresponding to a relative humidity of approximately 95%). Put the MAIN COOLING switch off and the AMBIENT COOLING switch on. Put the HIGH HEAT switch on and the LOW HEAT switch off. Place HUMIDITY switch on. Open a small vent port to avoid internal pressure build up.
- 2.2.4.8 Ascertain, by utilizing Unit 3 recorder, that the dry bulb chamber temperature goes to 80°F and maintains that temperature, and that the wet bulb temperature goes to 79°F and maintains that temperature.
- 2.2.4.9 Set the Unit 3 dry bulb temperature pointer to 165°F and the wet bulb temperature pointer to 112°F (corresponding to 20% humidity). Place the HUMIDIFY switch to off and the DEHUMIDIFY switch to on.
- 2.2.4.10 Ascertain, by utilizing Unit 3 recorder, that the dry bulb chamber temperature goes to 165°F and maintains that temperature and that the wet bulb temperature goes to 112°F and maintains that temperature. Leave chamber on and proceed to next test (2.3 Unit 4 INDUCTION HEATER).
- 2.3 Unit 4 (Induction Heater) Tests.
- 2.3.1 Set the Unit 3 Environmental Chamber to a temperature of 70°F by setting the Unit 3 dry bulb temperature setting to 70°F. Turn off the HUMIDIFY and DEHUMIDIFY switches. (If chamber temperature

2.3.1. . . .

is high, to expedite cooling, the MAIN COOLING switch, may be placed on.)

2.3.2 Ascertain that the chamber dry bulb temperature goes to 70°F and maintains that temperature (while waiting for the temperature to stabilize, do paragraph 2.3.3 thru 2.3.7).

2.3.3 On the Control Console Unit 300, Power Control Panel press the LOAD ACTUATE switch-indicator. The LOAD ACTUATE indicator shall illuminate. Set the load to approximately 10 pounds.

2.3.4 On Control Console Unit 100, set the INDUCTION HEATER selector switch to the L.S. /NONE position.

2.3.5 On Unit 100, set the LOWER SPECIMEN TEMP thermometer control to SET TRIP A position and the scale knob to scale D. Adjust the center screwdriver adjustment until the indicator reads 260 (500°F). Return the control to the °C position.

2.3.6 At Unit 4 Induction Heater, turn on the filaments by closing the main power switch located on the side of the unit. The Unit 4 FILAMENT lamp shall illuminate.

2.3.7 After a time delay, the Unit 4 RESET lamp shall illuminate. Push the STOP pushbutton and the lamp shall extinguish.

2.3.8 Ascertain that the chamber temperature has stabilized (refer to paragraph 2.3.2), monitor the UPPER SPECIMEN TEMP thermometer. (Care should be taken not to change the LOWER SPECIMEN TEMP thermometer scale setting from the D scale during the remainder of this section of the test procedure.) When the UPPER SPECIMEN TEMP thermometer indicates a temperature of 24°C (75°F or below,

2.3.8. . . .

press the Control Console Unit 100 IND COIL switch-indicator.

The Unit 100 IND COIL and CYCLING indicators shall illuminate.

On Unit 4 Induction Heater, the HEAT lamp shall illuminate.

2.3.9 Measure the time that the Unit 100 CYCLING indicator is illuminated.

This time shall not exceed 90 seconds. The Unit 4 HEAT lamp shall extinguish at the same time as the CYCLING indicator.

2.3.10 On Unit 4, open the main power switch on the side of the unit. The FILAMENT lamp will extinguish.

2.3.11 Push the Control Console Unit 300 LOAD ACTUATE switch-indicator. The indicator shall extinguish.

2.3.12 Press the Control Console Unit 100 IND COIL switch-indicator. The indicator shall extinguish.

2.3.13 On Unit 3 Environmental Chamber put the CONTROL switch off. Associated lamp shall extinguish.

2.3.14 Press the Control Console Unit 300 DC switch-indicator and AC switch indicator. All Control Console indicators shall extinguish.

3.0 System Test.

3.1 Ascertain that the cam in the machine is the "sine" cam (i.e., will produce a sinusoidal output motion when rotated).

3.2 Select desired test specimen and lubricate with desired lubricant. Place specimen in machine.

3.3 Press the Control Console Unit 300 AC switch-indicator and DC switch-indicator. The AC indicator and DC indicator shall illuminate. The Unit 300 RESET indicator shall also illuminate.

- 3.4 Close Unit 3 Environmental Chamber door and put the CONTROL switch on. Associated lamp shall illuminate.
- 3.5 Set the Unit 3 Chamber dry bulb temperature pointer to 75°F. Put the AMBIENT COOLING switch on the and the LOW HEAT switch on. Chamber dry bulb temperature should stabilize at 75°F.
- 3.6 At Unit 4 Induction Heater, turn on the filament by closing the main power switch located on side of Unit. The Unit 4 FILAMENT lamp shall illuminate.
- 3.7 After a time delay, the Unit 4 RESET lamp shall illuminate. Push the STOP pushbutton and RESET lamp shall extinguish.
- 3.8 On Control Console Unit 100, set the LOWER SPECIMEN TEMP thermometer scale selector to scale D. Set the thermometer control to SET TRIP A. Adjust the right hand screwdriver adjustment until the pointer indicates 160 degrees (320°F). Return the control to the °C position.
- 3.9 On Control Console Unit 100, set the UPPER SPECIMEN TEMP thermometer scale to scale D. Set the thermometer control to SET TRIP A. Adjust the center screwdriver adjustment until the pointer indicates 250 degrees (482°F). Return the control to the °C position.
- 3.10 Set the Control Console Unit 100 INDUCTION HEATER selector switch to the L.S. /U.S. position.
- 3.11 On Control Console Unit 200, set the following selector switches to the indicated positions:
- LOAD SENSITIVITY to position 2
 - INST FILTER to position 2
 - AVG FILTER to position 2
 - FRICT. FDBK FACTOR to position 1

- 3.12 Press the Unit 200 u-f switch-indicator. The u section of the indicator shall illuminate and the f section shall extinguish.
- 3.13 Ascertain that the Unit 200 FRICT FDBK switch-indicator is not illuminated. (If the indicator is illuminated, press switch and indicator will extinguish.)
- 3.14 Adjust Unit 2 air pressure valve until LOAD meter on Unit 2 indicates 20 pound load.
- 3.15 On Unit 2, close power on switch disconnect (F.B. 21). Push START button. Control Console Unit 300 EDDY CURRENT MOTOR indicator shall illuminate.
- 3.16 On Control Console Unit 300, press the RESET switch-indicator. The indicator shall extinguish.
- 3.17 Start the recorder moving at a slow speed and set the amplifiers for each the u instantaneous, u average, and instantaneous velocity channels to a low amplification.
- 3.18 Set the Control Console Unit 200 RPM ADJUST control fully counterclockwise. Press the RECIP DRIVE switch-indicator. Indicator shall illuminate.
- 3.19 Turn the Unit 200 RPM ADJUST clockwise until the Unit 300 RATE meter indicates a speed of 500 RPM (cam output 1000 RPM) and stabilizes at that reading.
- 3.20 Press the Control Console Unit 300 LOAD ACTUATE switch-indicator. The indicator shall illuminate and the specimen, within the chamber, shall contact.
- 3.21 Utilizing the recorder, monitor the velocity of the motion (sinusoidal with a peak to peak amplitude of 36.81 volts) and the u of the specimen.

- 3.22 After approximately 15 seconds, press the Control Console Unit 100 IND COIL switch-indicator. The Unit 100 IND COIL indicator and CYCLING indicator shall illuminate. The Unit 4 Induction Heater HEAT lamp shall illuminate. Utilize the recorder Event Marker to indicate occurrence on recorder.
- 3.23 The Unit 100 CYCLING indicator and Unit 4 HEAT lamp shall remain lighted only while the lower specimen temperature remains below 160°C (320°F). They shall extinguish when the temperature exceeds 160°C (320°F).
- 3.24 At any convenient time during the test, preferably when the value of u is other than zero, press the Control Console Unit 200 FRICT FDBK switch-indicator. The indicator shall illuminate and the reciprocating speed of the drive shall be reduced as evidenced by monitoring the Unit 300 RATE meter. Utilize the recorder Event Marker to indicate occurrence on the recorder.
- 3.25 When test is completed, press the Control Console Unit 300 LOAD ACTUATE switch-indicator and Unit 100 IND COIL switch-indicator. The indicators for each shall extinguish.
- 3.26 On Control Console Unit 200 turn RPM ADJUST fully counter-clockwise. After drive has slowed, press Unit 200 RECIP DRIVE switch-indicator and FRICT FDBK switch-indicator. The indicators for each shall extinguish.
- 3.27 On Unit 2 push STOP pushbutton and open power on switch disconnect (F.B. 21). Control Console Unit 300 EDDY CURRENT MOTOR indicator shall extinguish.

- 3.28 On Unit 3 Environmental Chamber put all switches to the OFF position. All lamps on Unit shall extinguish.
- 3.29 On Unit 4 Induction Heater, open power switch located on side of Unit. Unit 4 FILAMENT lamp shall extinguish.
- 3.30 On Control Console Unit 300, press AC switch-indicator and DC switch-indicator. The indicator for each shall extinguish.