NBSIR 75-722

Closure Testing Equipment Instruction Manual

Malcolm S. Morse

Product Engineering Division
Center for Consumer Product Technology
Institute for Applied Technology

October 1975

Final Report

Prepared for
Consumer Product Safety Commission
Washington, D. C. 20016

NBSIR 75-722

CLOSURE TESTING EQUIPMENT INSTRUCTION MANUAL

Malcolm S. Morse

Product Engineering Division
Center for Consumer Product Technology
Institute for Applied Technology

October 1975

Final Report

Prepared for
Consumer Product Safety Commission
Washington, D. C. 20016

U.S. DEPARTMENT OF COMMERCE, Rogers C.B. Morton, *Secretary*
James A. Baker, III, *Under Secretary*
Dr. Betsy Ancker-Johnson, *Assistant Secretary for Science and Technology*

NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Acting Director*

TABLE OF CONTENTS

APPENDIX

FIGURES

1.0 INTRODUCTION

The NBS Closure Testing Equipment is designed to make accurate measurements of the critical characteristics of the "Childproof" closures required by the Poisoning Prevention Packaging Act of 1971. In general, these characteristics are defined as the forces necessary to open these closures, either in the manner by which the closure was designed to be opened, or in an undesired manner.

The general design philosophy for this equipment is to use normal manual manipulation of the closure and container to the greatest extent consistent with accurate measurement. This philosophy originated when an investigation of the problem indicated that this approach would give results consistent with actual field use and would tend to show up deficiencies not apparent if the closure were tested with automated equipment.

Because it is not possible to define all possible types of childproof closures by a set of physical requirements, the assumption is made that all childproof closures which have passed the "Protocol" test* are satisfactory if they conform in all critical respects to the samples originally tested. The "Protocol" test, however, does not provide any physically measurable dimensions, forces, tolerances, or limits which can be used to insure that future closures of the same nominal design conform to those tested. This lack of definitive measurements is due to the fact that at the time the Act was passed these measurable quantities were not known for any closures, and suitable measuring equipment was not available to measure and define these quantities.

Because of the lack of standards, the measurement procedures given here should be regarded only as preliminary and tentative. These procedures have been designed to measure what are assumed to be the critical quantities, but only further and extensive testing can provide assurance of the validity of these assumptions. In addition, the problem of setting limits for the measured quantities is still to be resolved.

*"Protocol" test as defined in section 1700.20 of Chapter II Subchapter E of Title 16 of the regulations of the U.S. Consumer Product Safety Commission.

2.0 OPERATING INSTRUCTIONS

2.0.0 General

The NBS Closure Testing Equipment consists of three main units: the Electronic Unit, the Force-Torque Table, and an X-Y Recorder. An overall view of the equipment is shown as figure 1. In addition two specialized units are provided. The first of these is for making bite and squeeze measurements (Bite and Squeeze Unit) and the second is for making pry measurements (Pry and Shell Unit).

The equipment basically provides three independent force measuring channels which can be used simultaneously or in any combination. The force or torque being measured by each channel is displayed on a calibrated digital panel meter, and may also be simultaneously recorded on the X-Y recorder. However, since the X-Y recorder has only two recording channels, only two quantities may be recorded simultaneously although three may be measured and displayed. The X-Y recorder may also be used to record the output of one force channel continuously against time. To further increase the versatility of the equipment, a peak-reading circuit is provided which may be used to hold the highest reading occurring on a force channel during a given interval.

2.0.1 Units and Conversion Factors

The equipment is calibrated in newtons and in newton-meters as the force and torque units, respectively. The newton is the unit of force used in the International System. In terms of older units, a newton is equivalent to 0.102 kilogram-force and a newton-meter is equivalent to 0.102 meter-kilogram-force or 0.738 foot-pound-force.

2.1.0 Physical and electrical specifications

The detailed physical and electrical characteristics of the equipment are tabulated below.

1. Electronic Unit

   Physical characteristics:
   35 cm long x 25 cm high x 28 cm deep

   Weight: 6.83 kg

   Electrical characteristics:
   Line voltage 117 Vrms ±10% 57-63 Hz

   D C Output voltage to auxiliary force measuring units:
   10.0 volts ±0.2% @ 0.050A

Signal input voltage range: 0 ±100 mV

Signal voltage output to X-Y Recorder: 0 to ±20mV

Sweep voltage output to X-Y Recorder: 0 to +10V

2. Force-Torque Table

Physical characteristics:
25.5 cm long x 21.0 cm high x 25.5 cm deep

Weight: 8.65 kg

Electrical Characteristics: Input voltage: 10 Vdc ±0.2% from Electronic Unit

Output signal voltage: 0 to 100 mV

3. X-Y Recorder

Physical characteristics:
44 cm long x 14 cm high x 27 cm deep

Weight: 9 kg

Electrical Characteristics
Power requirements: 115 Vrms ±10% 50 Hz to 400 Hz, 40W

Signal Input voltage range: Maximum input ±200V peak differential, ±500V peak common mode to ground

Input impedance: greater than 1 megohm
Sensitivity: 0.5 mV/cm to 5000 mV/cm

4. Bite and Squeeze Unit

Physical characteristics:
18 cm long x 6.5 cm high x 2.5 cm deep

Weight: 0.412 kg

Electrical Characteristics: Input voltage: 10.0 Vdc ±2% from Electronic Unit

Output signal 0-±100mV

5. Pry and Shell Unit

Physical characteristics:

30 cm long x 3.1 cm high x 2.5 cm deep

Weight: 0.272 kg

Electrical Characteristic — Input voltage: 10.0 Vdc $\pm 2\%$ Electronic Unit

Output signal: 0 - $\pm$100mV

2.2.0 Initial Setup

2.2.1 Connections

The equipment is prepared for operation by connecting the Electronic Unit and the X-Y Recorder to a suitable ac power source and making the interconnections between the Electronic Unit, X-Y Recorder, Force-Torque Table and the Specialized Units if used (see figure 1). For maximum accuracy an initial warmup time of 30 minutes should be allowed. The equipment may be left on continuously.

2.2.2 Zeroing

Each of the three signal channels of the Electronic Unit as well as the two channels of the X-Y recorder is provided with a separate zeroing control. After initial warmup these controls should be set to their desired initial positions as follows:

a. X-Y Recorder. Each of the three indicators of the Electronic Unit has located directly beneath it an Indicator Range Switch incorporating a zero position. When this switch is set on the zero position the input to the digital indicator is shorted, providing a nominal zero output voltage as indicated on the panel indicators. This also provides a nominal zero output to the X-Y Recorder, since the outputs to the recorder are identical with the voltages indicated by the digital indicator units. Therefore, in order to zero the X-Y Recorder the channel switches on the Electronic Unit should first be set to zero. This will give a nominal zero output to the recorder when the Recorder output switches are set to the appropriate channel. The X-Y Recorder may now be set to the appropriate zero position by means of its individual zero controls. (Before carrying out this procedure, the Operating Instructions section of the manufacturer's Instruction Manual for the X-Y recorder should be read carefully.)

b. Electronic Unit. After initial warm up, and with the Indicator Range Switches set to the Zero position as specified above, the readings on the digital indicators should be close to zero. (Small deviations from zero under these conditions are compensated for in the measurement procedure and need not be corrected.) If the zero readings under these conditions exceed one or two in the last digit, reference should be made to the maintenance section of this manual.

c. Force-Torque Table. After the initial zeroing procedure described above is carried out, the Force and Torque Range Controls on the Electronic Unit should be set to the range to be used in the measurements and the Force-Torque channels should be zeroed, using the individual zeroing controls mounted on the Force-Torque Table. (The Force-Torque Table must be connected to socket 2 of the Electronic Unit for this procedure). During this procedure, as during any procedures where a test result recording is not required, the Recorder Output Switches on the Electronic Unit should be set to the Zero position.

d. Specialized Units (Bite and Squeeze Unit, Pry and Shell Unit). The third or Special signal channel on the Electronic Unit (Socket 1) is for use with either of the Specialized Units. It should be zeroed with the appropriate specialized unit connected to socket 1 on the Electronic Unit and with the Special Channel Range Switch set to the range to be used. Under these conditions this channel is zeroed using the Special Unit zero control mounted on the front panel of the Electronic Unit. Care should be taken to prevent the accidental application of force to the specialized units during the zeroing procedure.

2.3.0 Calibration Procedure

2.3.1 X-Y Recorder Calibration

In operating the Closure Testing Equipment it will normally be desirable to record the outputs of the various force channels, since more information can be obtained from the detailed recording of any test than can be obtained from isolated indicator readings. The flexibility of the equipment is such that the recorder scale can be varied over wide limits and can be readily calibrated for any desired scale factor in either newtons or newton-meters. This is done by the following procedure:

1. Estimate, either by experience or trial, the maximum force or torque which will be encountered in the testing procedure.

2. With the help of the table below chose a suitable range scale for the channels to be recorded.

Table A

Channel	Range	Max. Permissible Loading	Output Voltage (Approximate)
Force	1000 newtons	1200 newtons	0.1 mV/N
Force	200 newtons	1200 newtons	0.1 mV/N
Torque	2.0 newton-meters	3.0 newton-meters	10 mV/Nm
Torque	0.2 newton-meters	3.0 newton-meters	10 mV/Nm
Special	10.0 (x 10)	See rating on Unit	See calibration on Unit
Special	1.0 (x 1.0)	See rating on Unit	See Calibration on Unit

3. From the output in mV/N (mV/Nm if from a torque channel) and the maximum expected force (torque) calculate the maximum expected voltage output from the Electronic Unit.

4. Using the X-Y Recorder on its calibrated range, select the scale factor in mV/cm which will give the maximum usable deflection of the recorder.

   As an alternative procedure a steady force equivalent to the maximum expected during testing may be applied (after zeroing) to the channel which is to be recorded, and its value may be read on the digital indicators. Using the variable calibration controls of the X-Y Recorder, the sensitivity of the X-Y recorder may be set to give the maximum deflection desired, and the calibration factor may be obtained (in N/cm or Nm/cm) by dividing the indicated force by the number of centimeters of deflection produced. For the force channel a convenient method of producing a known force is to use a known weight.

2.3.2 Equipment Calibration

The equipment calibration may be checked conveniently by applying known forces to the channels, most conveniently by means of known weights, and checking the reading of the digital indicators. Any departure of the equipment from calibration by more than 10% calls for maintenance.

2.4.0 Operation of Individual Units

2.4.1 Electronic Unit

The Electronic Unit is always used with either the Force-Torque Table or one of the specialized units or with both together. Operation of the range and zeroing controls has already been covered by the zeroing and calibration instructions given above. The instructions below will cover the operation of two other features of the Electronic Unit, the Sweep Circuit and the Peak Reading Circuit.

2.4.1.1 Sweep Circuit

The Sweep Circuit is controlled by the Sweep Control Switch, located to the right of the Reading Mode Switch on the bottom of the front panel of the Electronic Unit (see figure 1). Te purpose of this circuit is to move the pen of the X-Y recorder slowly along one axis, so that a variable voltage derived from the Force Torque or Special channels and applied to the other axis will be recorded against time. The voltage output of the sweep circuit rises slowly from zero to 10 volts when the sweep control switch is set to the Sweep positions. The Hold position on the Sweep Control Switch interrupts the sweep voltage and maintains it at that value, and the Reset position restores the voltage to zero. The Sweep Circuit gives a comparatively slow sweep from zero to 10 volts. (This slow sweep may be increased over a very wide range by changing the sensitivity setting of the X-Y recorder.) The recorder selection switches on the Electronic Unit are used to apply the sweep voltage to the desired recorder axis.

2.4.1.2 Peak Reading Circuit

The peak reading circuit provides a convenient method of making readings when only a maximum force reading is needed, as for shelling and stripping tests. Peak readings are also useful when the recorder is not being used and the presence of transient peak values is suspected. The peak reading circuit can be switched into any one of the three channels of the Electronic Unit. When it is switched into a channel the digital meter will read and hold the highest force (or torque) encountered between consecutive depressions of the peak reading reset button. The peak reading circuits cannot be used on a channel which is being recorded, since their use will distort the reading. Since there is some "droop" in the peak reading circuits, the highest reading obtained should be noted. In using the peak reading circuit the polarity selector switch should first be set to the expected reading polarity. It should be noted that use of the peak reading circuits causes a reversal of the sign of the readings on the digital indicators.

2.4.2 Force-Torque Table

The Force-Torque Table is designed to measure vertical forces (both upward and downward) exerted on containers mounted on it, and also to measure torques both clockwise and counterclockwise exerted on these containers. A wide range of forces (0-1000N) and torques (0-10Nm) can be accurately measured. Since a force exerted on a closure is equivalent to a force exerted on the container, the practical effect is to measure closure forces.

Operation of the force-torque table involves clamping a container-closure combination into the universal clamp, being careful to insure that it is centered, and exerting force on the closure. These forces will then be displayed on the digital indicators of the Electronic Unit and may be recorded, if desired, on the recorder. Forces necessary to replace the closure may also be displayed and recorded in the same manner. Since most childproof closures require either push, pull, or twist forces, or a combination to remove them, the operation of the closure while clamped in the force-torque table will provide a measurement of the characteristics of the closure from the point of view of its operation.

For example, certain closures will operate only if they are turned with a certain torque while being pulled, or pushed, with a certain force. Such measurements of simultaneous forces are difficult or impossible with other types of equipment, which cannot measure the required quantities simultaneously.

2.4.3 Specialized Units

All of the specialized units plug into socket 1 of the Electronic Unit and their readings are displayed on the "Special" digital indicator. The readings can also be recorded on the X-Y Recorder.

2.4.4 Specialized Units: The Bite and Squeeze Unit

This unit is designed to exert a calibrated squeeze force on a closure, similar to that exerted by a finger squeeze or a bite. After being plugged into the special channel this unit is first zeroed. It is then tightened onto the closure until the desired result is reached (desired torque on the closure as shown on the torque channel, for example, or desired or specified pressure) and is then used to rotate or otherwise manipulate the closure.

2.4.5 Specialized Unit: Pry and Shelling Unit

This unit (see figure 3), is designed to produce a calibrated pry or shelling force. The method of use of the instrument is shown in figure 3. Calibration of this unit is in terms of torque. When it is used for prying, the force involved may be derived from the length of the radius arm.

2.4.6 Specialized Units: Squeeze Unit

The squeeze unit was designed to measure the force exerted by a person between his thumb and opposed fingers. It is not directly applicable to closure measurements but extends the usefulness of the equipment into human factors measurement.

2.4.7 X-Y Recorder

The X-Y recorder is placed in operation by setting the control switch to the "on" position and setting the recorder output switches on the Electronics unit to give the desired display. During actual operation of the recorder the control switch should be in the "pen down" position, and at all other times when the recorder power is on it should be in the "pen up" position. Before making any actual test recordings the X-Y recorder should be calibrated as outlined above.

Further details of the operation of the X-Y recorder are given in the manufacturer's instruction book which is provided with the equipment.

3.0 CLOSURE TEST PROCEDURES

3.1.0 Closure Operating Characteristics

Almost all of the closures which this equipment is designed to test are intended to be opened by hand by normal adults. At the same time, they are designed to be proof against opening by children up to the age of five years. While the "childproof" feature of the closures may not depend directly on the ability of the adult to exert a greater force than a child, it is still true that for almost all closures there is some correlation between the childproof feature and the forces necessary to open the closure.

For example, one commonly used closure must be manually rotated to a specific position, where it can be removed by an upwardly exerted force. The childproof feature is not directly dependent on the inability of the child to rotate the closure, but the force required to make this rotation is important for two reasons.

First, if the force is too great, the normal user will be unable to rotate the cap, and thus it will be ineffective as a reusable closure.

Second, if the force required to make this rotation is too small, the cap will rotate almost at random in response to very small forces, and in this case the security of the cap will be less than normal. Thus, for the closure to function normally, the rotation force must lie between two limits, even though these limits may be widely spaced. In general, such limits can be established for all operating forces for all types of childproof closures.

3.2.0 Measurement Techniques

The closure testing equipment is designed to measure, as closely as practicable, the characteristics of the closures as they are operated by consumers in actual use. While the closures are the items of principal interest, the actual measurements are made on the combination of the closure and its accompanying container. It should be noted that in some cases variations in the container dimensions, finish, etc. may substantially affect the closure operating characteristics. In making tests on the closures, normal operation by the consumer should always be kept in mind, and handling of the closure should reproduce consumer handling whenever this will not interfere with measurement accuracy. Testing should be designed to bring out variables which will be encountered in actual use, rather than to eliminate such variables in the interests of more consistent, but less representative, measurements.

For example, if in measuring the turning torque of a cap type of closure, the cap is held in a holding fixture or jig, the measured results will be considerably more uniform than if the cap is held in the fingers. This is because the jig will eliminate the warming of the cap by the fingers and will modify the unequal pressure distribution of the finger grasp. However, results obtained using the jig will not be representative of the results obtained by the consumer in actual use, while the use of the natural finger grasp will duplicate actual conditions.

3.2.1 Use of the Force-Torque Table

Most closure measurements will be made with a closure-container combination clamped onto the Force-Torque Table. In making these measurements, it should be remembered that here the Force-Torque table is substituting for one of the two hands normally used to open a closure-container combination, so that the forces being measured by the Force-Torque Table are the forces exerted on the closure by the other hand. Care should be taken to see that the hand operating the closure does not exert any force directly on the container itself, since this will result in incorrect readings. The Force-Torque Table is designed to measure vertical force in either the up or down direction (Push or Pull) as well as twisting forces (torque) in either clockwise or counterclockwise directions.

In measuring push or pull forces on the closures with the Force-Torque Table, it will be necessary to compensate for the weight of the container, which can be conveniently done by means of the Force Zero control. Also, if pull forces exceeding the weight of the Force-Torque Table are to be measured, it will be necessary to fasten the Table to a suitable fixed support.

3.2.2 Pry and Shelling Tests

In addition to the operation of the closures in their intended manner, experience has shown that children attempt to open some closures by banging, prying, or biting them in an unorthodox manner. This is especially true of the two-piece overcap type of design, where the child may so distort the cap as to destroy the normal child-proof feature. For this type of cap, and for other caps subject to similar unorthodox opening attempts, it is necessary to measure not only the forces necessary to open the cap in the normal manner, but also to measure any unorthodox forces that may open the cap or distort it so that it is no longer child-proof. Tests to measure such forces are known as pry or shelling tests, since in the common two-piece overcap type of closure the common method of attack is to attempt to pry off or "shell" the overcap.

Tests to measure the prying or shelling force required to destroy the childproof feature are commonly made with the Pry and Shell Unit, which is shown in figure 3.

3.2.3 Bite and Squeeze Tests

Some childproof containers are designed to be opened by utilizing a combination of forces which include applying a squeeze force to some particular point or general region. In this case it is, of course necessary to measure the force required for this operation. For this purpose the Bite and Squeeze Unit shown in figure 5 is provided and may be used to apply and measure squeeze forces.

In addition to the use of a desired squeeze force to operate a childproof closure in its normal manner, it has been found that children may attempt to open containers by biting or squeezing even when such a method of opening is not desired or contemplated by the manufacturer. The ability of a child to so open a closure constitutes a failure. It may therefore be desirable to measure squeeze forces necessary to open (or destroy the childproof feature) of containers not designed for such opening, and this may also be done with the Bite and Squeeze Unit.

3.3.0 Measurement Value Criteria

In measuring the forces necessary to open a childproof closure, and in establishing exact criteria for recording measurement values it will be necessary for the investigator to make a judgement or to establish criteria based on the normal operation of the closure. For example, in measuring the characteristics of a push and turn closure, it is possible to apply and measure a very large range of push forces on the closure. In general, there will be a range of push forces which will be insufficient to operate the closure, and a range of push forces which will be more than sufficient to operate the closure. The desired value, the critical value of force, is the value which is just sufficient to operate the closure. This value will be marked by an abrupt change in the torque necessary to rotate the closure, and it is this change in torque which enables the operator to determine the critical value (minimum operating value) of the push force. In other types of closures other criteria will be necessary to determine the critical forces which are desired. Depending on the types of closures these criteria may be a force change, a torque change, or a change in some visual characteristic. In all cases, the selection of the criterion should be based on the normal operation of the closure.

3.4.0 Environmental Considerations

3.4.1 Temperature

Most closures are temperature sensitive, and for this reason the ambient temperature of the test is quite significant. Closures may also undergo gradual dimensional distortion or "creep", the exact amount depending on time, temperature and pressure conditions. For this reason the temperature of the closures and their containers should be known and reproducible. Also, handling the closure may change its temperature and hence its critical characteristics.

3.4.2 Humidity

Some closures may be sensitive to humidity as well as to temperature. For this reason, tests should be conducted under known humidity conditions. It may be anticipated that if a closure is senitive to humidity there will probably be a lag effect, so that the effect of exposure to a particular humidity will persist for an appreciable time after the humidity is changed.

3.4.3 Operating Interval

Because many of the materials used in closures are subject to the phenomenon of "cold flow" or "memory" the operating characteristics of the closure may depend on the time interval between operations, and this factor itself may well vary with ambient temperature. Where this phenomenon exists it may have a very substantial effect on the operating characteristics of the closure. Conceivably a closure might be acceptable if tested at intervals of an hour and might not be acceptable if tested at operating intervals of five minutes or of a day. Where this phenomenon is encountered a careful evaluation of the way in which it will affect the closure operating characteristics must be made. Test procedures must then be designed to take this into account.

3.5.0 Specific Test Procedures

3.5.1 Test Procedures for Specific Closures

Specific test procedures should be written for each model of closure, based on experience with that model, and keeping in mind the operating principles (with especial emphasis on the factors which are basic to the childproof feature) and the methods, if any, which could be used to defeat the childproof feature. All procedures, in addition to specifying the critical measurements and parameters and the methods of measurement, should call for recording the manufacturer's type, mold number, material, environmental conditions, storage time, and type of contents. Where it is suspected that the contents may influence operation of the closure, testing should be performed on samples which contain materials in the condition and of the type normally found in such container-closure combinations.

3.5.2 Types and Test Methods

While the writing of test procedures for each closure type (closure-container combination) is beyond the scope of this report, general principles applicable to some of the container types which have been studied are discussed below.

3.5.3 Motions and Forces

A number of generalized childproof closure types together with the forces which are applied to operate them, are illustrated in the accompanying sketch (figure 2) and are further defined in figure 4 by type and sub-type. Suggested generalized test procedures are also listed. It should be realized that this list is by no means complete.

As can be seen from the figures, the closures can be classified according to the general type of closure and the childproof feature. Many require two coordinated motions, or the application of two coordinated forces, but others do not. To a large extent, it is this diversity that introduces the major testing problems. Test methods must be directed to the measurements of the normal forces required to operate these closures, as well as the forces necessary to defeat the childproof feature. The three basic forces applicable to the designs illustrated are push or pull, turn, and squeeze.

3.5.4 Two Independent Motion Closures

A widely used class of closures is known as Two Independent Motion closures. These closures may be either thread or lug types, and their operation in general involves an overcap and an inner cap. In the unoperated condition the outer cap spins freely, and the inner cap seals the container. Operation is achieved by either pulling or pushing the outer cap so that it locks into the inner cap and is able to turn it. Critical characteristics are the force necessary to engage the outer cap with the inner cap and the torque necessary to turn the outer cap after engagement in order to open the combination. Recorder plots of vertical force against torque have proven to be very useful in evaluating the characteristics of this type of closure.

3.5.5 Turn and Lift Snap Caps

A common type of closure is the "turn and lift" snap cap. These caps are molded of a flexible material and snap over a projecting lip on the closure. They are operated by turning the cap until some feature is properly aligned, at which time an upward or downward force can be applied to remove the cap. Critical forces are the force required to rotate the cap to its aligned position and the upward force required to remove it. For some styles a critical force might be the force required to remove the cap when it is in its unaligned position, or the force required to remove it in an undesired fashion. The recorder can be used to record the torque and the force in both cases.

3.5.6 Squeeze and Turn Caps

The squeeze and turn type requires squeezing the sides of the cap in order to turn and remove it. Testing requires measuring the squeeze force necessary to turn the cap as well as the torque necessary for a given squeeze. This measurement is made using the Bite and Squeeze unit in connection with the Force-Torque table. The Bite and Squeeze unit is applied to the cap and tightened to apply the squeeze force in the desired place on the cap. The squeeze unit is tightened while squeezing the cap and watching the torque indicator. When the torque reading increases sharply, the squeeze force is becoming effective, and its reading should be noted at the point where the inner cap just begins to rotate, or at the highest point previous to rotation. Recorder plots of squeeze force against torque are useful in this type of measurement.

4.0 MAINTENANCE INSTRUCTIONS

4.1.0 Theory of Operation

4.1.1 General Considerations

The NBS Closure Testing Equipment is an assembly of units for measuring and recording the forces involved in the removal and replacement of closures on containers, specifically child resistant containers. The equipment uses strain gages mounted on cantilever beams to transform the mechanical forces involved into accurately proportional electrical signals, which are then amplified, displayed, and recorded by the remainder of the equipment. Both mechanical and electronic considerations are involved in the maintenance and repair of the equipment.

An overall block diagram of the equipment is shown as figure 9. It should be noted that the equipment can be divided into two groups, one group containing the primarily electronic items, i.e. the Electronic Unit and the X-Y Recorder; and the other group containing the Force-Torque Table, the Squeeze and Bite Unit, and the Pry and Shell Unit and the Squeeze Unit. This second group is primarily electromechanical in nature.

4.1.2 Electronic Unit

The function of the Electronic Unit is to receive, process and display the signals generated by the force transducers of the Force-Torque Table and the specialized units. These signals are amplified and displayed on the digital indicators of the Electronic Unit and made available for recording by the X-Y Recorder. As shown in the block diagram, the Electronic Unit is composed of several sub-units, as follows:

a. Amplifier-Power Supply Units

b. Indicator Units

c. Sweep Unit

d. Peak Reading Unit

e. Power Supply Units

These sub-units, together with their interconnecting wiring, switches, etc. make up the Electronic Unit. The detailed functioning or each of these sub-units is considered below.

a. Amplifier-Power Supply Units. The Amplifier-Power Supply Units, A-1, A-2, and A-3 may be conveniently considered as two separate sections, the power supply section and the amplifier section. The circuit diagram of these units is shown as figure 11. The power supply section is composed of a minaturized, highly isolated power supply operating from the 117-volt line. The output of this supply is regulated at 10.0 volts and is used as the supply voltage to the strain gage bridges. Two highly precise, low temperature coefficient 350 ohm resistors serve as the inactive arms of the strain gage bridge, and connect to the zeroing potentiometer (1.15 ohms) mounted on the front panel of the Electronic Unit. (These resistors are used only in the "Special" channel position). Two filter capacitors are used to bypass the power supply output.

The amplifier section uses an encapsulated instrumentation amplifier to amplify the strain gage output signal to give a calibrated reading on the digital indicators and the recorder output. Details of this instrumentation amplifier are given in the parts list. Supply voltages are derived from an external plus and minus 15-volt power supply. Input protection and output stabilizing resistors and capacitors are incorporated in the circuit. The gain of the amplifier is set by an adjustable gain resistor which is mounted on the front panel of the Electronic Unit and is selected by the range switch for the particular amplifier unit.

b. Indicator Units. The digital indicator units are each 3-1/2 digit panel meters which are fed from the output of the amplifier section through the Peak Reading Unit switch and a range switch which provides for a short position and also selects the appropriate decimal point as well as the gain resistor. Basic sensitivity of the meters is 199.9 mV, full scale. Reading rate is set at approximately 10 readings per second. Details of these indicator units are given in the parts list. The operating power for these units is derived from a 5.0 volt, 3.0 ampere power supply.

c. Sweep Unit. The sweep unit functions to provide a ramp voltage to one axis of the X-Y Recorder when it is desired to move the recorder steadily along one axis while recording a variable on the other axis. Its circuit diagram is shown as figure 13. A panel mounted function control switch provides three settings: (1) Off (reset), (2) Hold, and (3) Sweep. The sweep circuit is a standard operational amplifier linear integrating circuit, using an FET operational amplifier and a polystyrene integrating capacitor. Integrating current is fed from the negative supply through a high resistance. The output voltage is limited to 10 volts.

d. Peak Reading Unit. The Peak Reading Unit may be switched into any of the three signal channels (Force, Torque, or Special) by means of its front panel control switch, and functions to preserve the digital panel meter reading of the highest meter reading occurring during a selected time interval. This circuit is primarily intended for use when making tests where the recorder is not to be used and the main quantity of interest is a peak force or torque. The peak reading circuit is reset after the peak reading is noted and will then function to preserve the next peak reading occurring in the circuit.

The circuit diagram of this unit is shown as figure 12. The circuit consists of two FET operational amplifiers in an overall feedback configuration, with a peak catching diode and reset feature. Power required is supplied by the plus and minus 15 volt power supply unit (see below).

e. Power Supply Units. The dc power required by the Electronic Unit is supplied by two unit power supplies One of these supplies 5 volts at 3 amperes, and the other supplies plus and minus 15 volts at 50 milliamperes. Details of these power supplies are given in the Parts List.

4.1.3 X-Y Recorder

The X-Y Recorder provided as part of this equipment is a commercial item modified to make variable gain settings reproducible (though not linear). Recordings are made with replaceable pens on sheets of 8-1/2 x 11" graph paper. Wide range gain and zero controls provide a high degree of flexibility. However, care must be taken to observe the calibration changes resulting when any of the scale factors are changed. Full details of this unit are given in the accompanying instruction book.

4.1.4 Force-Torque Table

The Force-Torque Table is a table whose motion is restrained by the two cantilever beams which give the force measurements. The electrical circuit of the Force-Torque Table is shown as figure 14. The strain gages are cemented to the cantilever beams and transform the forces exerted on the beams to changes in electrical resistance.

4.1.5 Bite and Squeeze Unit and Pry and Shell Unit

These are force measuring devices using the same cantilever beam method of force measurement as is used in the Force-Torque Table. Their circuit diagram is shown in figure 14, and the circuitry differs from that of the Force-Torque Table only in that the zeroing controls and reference bridge arm resistors are mounted in the Electronic Unit.

4.2.0 Maintenance

4.2.1 Electronic Unit

The Electronic Unit does not require maintenance.

4.2.2 X-Y Recorder

The maintenance of the X-Y Recorder is covered by the separate manual supplied with it.

4.2.3 Force-Torque Table

The electrical portion of the Force-Torque Table should require no maintenance. The bearings which insure free movement of the platform should be kept clean and lubricated. In dusty or adverse environments this unit should be kept covered when not in use. Freedom of movement of the platform should be checked at regular intervals, the length of which will depend on environmental conditions, and if any excessive friction develops the bearings should be cleaned and lubricated.

4.2.4 Bite and Squeeze Unit and Pry and Shell Unit

The remarks made above apply to these units as well.

4.3 Repair and Trouble Shooting

4.3.1 Electronic Unit

Normal electronic trouble shooting procedures apply to this unit. Most problems are likely to be encountered either with socket connections or from the failure of one of the electronic units. The modular construction of the unit should assist in isolating such problems.

APPENDIX

Parts List*

A. Major Units

E-1 Electronic Unit NBS Manufacture (Ref. Fig. 9)
Consists of Chassis Assembly plus sub-units (Ref. Fig. 10) as follows:

A-10, A-11, A-12 Amplifier Sub-Units. NBS Manufacture (Ref. Fig. 11) See parts list below.

I-1, I-2, I-3 Indicator Sub-Units. Newport Laboratories, Inc. Model 253-01 3-1/2 Digit Panel Meter Model 253-02, 199.0 mV full scale, high input impedance, 10 per second read rate, 300 volt overdrive, power supply 5.0V at 2.5 watts.

PR-10 Peak Reading Sub-Unit. NBS Manufacture (Ref. Fig. 12) See parts list below.

PS-1 Power Supply Sub-Unit. Semi-Conductor Circuits, Inc. Model 2.15.50, Regulated plus and minus 15 volts, at 50 mA dc output, input 117V 60 Hz.

PS-2 Power Supply Sub-Unit. Power-Tec Div. of Airtronics, Inc. Model 2B5-3, output 5.0 volts, dc regulated, at 3.0A, input 117V 60 Hz.

SW-10 Sweep Unit. NBS Manufacture (Ref. Fig. 13) See parts list below.

B-1 Bite and Squeeze Unit. NBS Manufacture (Ref. Fig. 14) See parts list below.

F-1 Force-Torque Table. NBS Manufacture (Ref. Fig. 14) See parts list below.

P-1 Pry and Shell Unit. NBS Manufacture (Ref. Fig. 14) See parts list below.

R-1 X-Y Recorder Unit. MFE Corp., Model 715 "Plotamatic" flat bed, 11" x 17" X-Y recorder. Power input 117V 60 Hz. See separate manual.

*Precise identification of some parts as to manufacture has been made in order that an exact replacement can be obtained in the event of failure. Such identification in no way implies superiority to equivalent components nor unique effectiveness over other possible choices.

B. Assembly and Sub-Units

E-1 Chassis Assembly

F-1, F-2 Power line fuses, Type 3AG, 1.5 amperes

PL-1, Pilot light, 5.0V, LED type

R-1 Special Channel Zeroing Resistor, 10 turn potentiometer, 1.15 ohms Amphenol Type 205

R-2 Gain Control Resistor, 16.0k, 1% metal film, T.C. less than 10 ppm/deg C, 1/4 watt

R-3 Gain Control Resistor, Same as R-2 except 2.15k

R-4 Gain Control Resistor, Same as R-2 except 63.5k

R-5 Gain Control Resistor, Same as R-2 except 104k

R-6 Gain Control Resistor, Same as R-2 except 19.5k

R-7 Gain Control Resistor, Same as R-2 except 19.5k

R-8, R-9, R-10, R-11 Decimal Point Resistors, carbon, 5.1k, 10% 1/4 watt

R-12, R-14, R-16 Gain Control Trimmer Resistors, 1k metal film 25 turns, T.C. 10 ppm typical, Vishay Resistor Products Style 1201P

R-13, R-15, R-17 Same as R-12 except 10k

SW-1 Range Selector Switch, Force, three pole, three position rotary, ceramic, miniature

SW-2 Range Selector Switch, Torque, Same as SW-102

SW-3 Range Selector Switch, special, Same as SW-102

SW-4 Power Switch, single pole, single throw, toggle, miniature

SW-5 Recorder Channel Selector Switch, single pole, five position rotary switch

A-10 Amplifier Sub-Unit

A-201 Instrumentation Amplifier, type AM-200C, Datel Systems Incorporated. High input impedance, high CMRR, low drift, power supply plus and minus 14 to 19 V at 7mA.

C-201, C-202 Power Supply filter capacitors. Electrolytic, 25 microfarad at 15 volts, miniature.

C-203 Output filter capacitor. 1.0 microfarad polystyrene or polycarbonate film, 80 volts dc

C-204, C-205 Power Supply filter capacitors for Instrumentation Amplifier. Electrolytic, 25 microfarad at 25 volts, miniature.

PS-201 Bridge Power Supply. Output 10 V at 100 mA, input 117 V 60 Hz, miniaturized, output highly isolated. Acopian Corp. type 10E12

R-201, R-202 Bridge Balancing Resistors. 350.00 ohms 0.01% temp. coefficient less than 1 ppm/deg C. Vishay Resistor Products type S-102

R-203, R-204 Amplifier Input protection resistors. 10k, 1/4 W 10% carbon

R-205 Amplifier Trimming Resistor. 10k, Metal Film, 25 turns, T.C. 10 ppm, Vishay Resistor Products Style 1201P.

R-206 Amplifier Trimming Resistor. Metal film type, temp. coefficient less than 10 ppm/deg C, 1/4 watt, selected with R-205 set to 5000 ohms

R-207 Output stabilizing resistor. 10 ohms, 1/4 watt, 10% carbon

R-208 Output stabilizing resistor 20k, 1/4 watt, 10% carbon

PR-10 Peak Reading Sub-Unit

A-301 Operational Amplifier, general purpose type, FET input. Analog Devices, Inc. type 40J

A-302 Same as A-201

C-301 Integration Capacitor, 2.0 microfarad, 50 volts dc, polycarbonate film, Cornell-Dublier type WCR05WZ or equal

D-301, D-302 Blocking Diodes, Fairchild 1N3333

R-301 Summing Resistor, precision metal film 10k, 1/4 watt, 1%

R-302 Grounding Resistor, 2k, 10% carbon 1/4 watt

R-303 Feedback Resistor, 10k, 1% precision metal film 10k, 1/4 watt

R-304, R-305 Trimmer Resistor, 1k metal film 25-turn, 10 ppm/deg C, Vishay Resistor Products style 1201P

SW-301 Selector switch, rotary, 6 poles, 4 positions

SW-302 Polarity Switch, SPDT, dry circuit type (gold plated contacts)

SW-303 Reset Switch, pushbutton, N.O. dry circuit type (gold plated contacts)

ST-10 Sweep Unit

A-401 Operational Amplifier, Same as A-301

C-401 Integrating Capacitor, 10 microfarad at 200 volts, polystyrene film.

R-401 Integrating Resistor: 50 megohms, 1/2 watt, 5%

R-403 Stabilizing Resistor 2k, 10% 1/4 watt, carbon

R-404 Output Divider Resistor, 1.2 k 10% 1/4 watt, carbon

R-406 Trimming Resistor, same as R304

SW-401 Sweep Selector Switch, DPDT, center off, dry circuit (gold contacts) miniature, Alcoswitch model MTA-106F

F-1 Force-Torque Table

R-501 Force Zeroing Potentiometer. Same as R-1

R-502 Torque Zeroing Potentiometer. Same as R-501

R-503 Bridge Balancing Resistor, 350.00 ohms, 0.01% Same as R-201

R-504 Bridge Balancing Resistor. Same as R-503

R-505 Bridge Balancing Resistor. Same as R-503

R-506 Bridge Balancing Resistor. Same as R-503

SR-501 Strain Gage, 350 ohms, 1/16" temp. coefficient 13 ppm/deg C. Gage factor 2.1, Micro-Measurements type CEA-13-062 VW-350

SR-502 SR-503, SR-504. Strain gage, same as SR-501

B-1 Bite and Squeeze Unit

SR-601, SR-602 Strain Gage, same as SR-501

P-1 Pry and Shell Unit

SR-701, SR-702 Strain Gage, same as SR-501

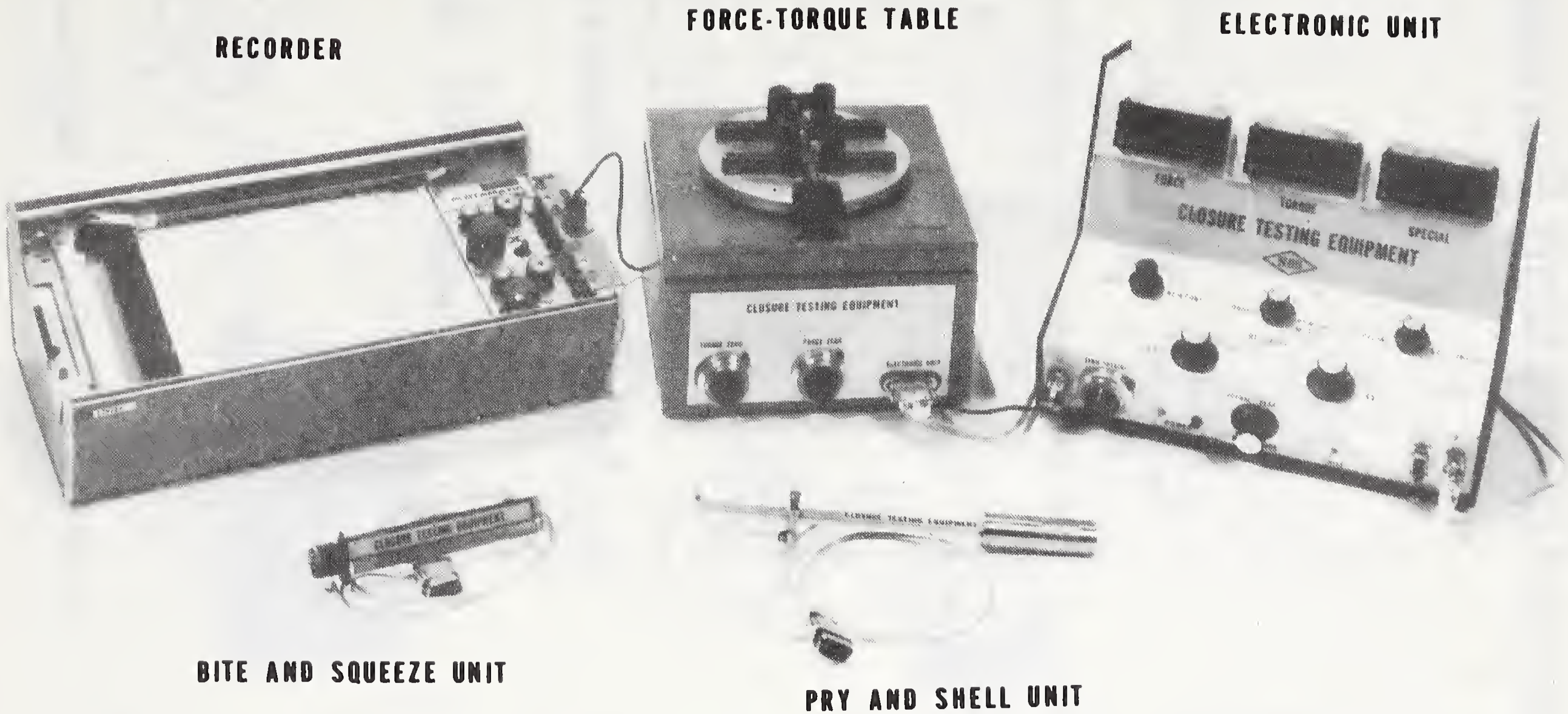
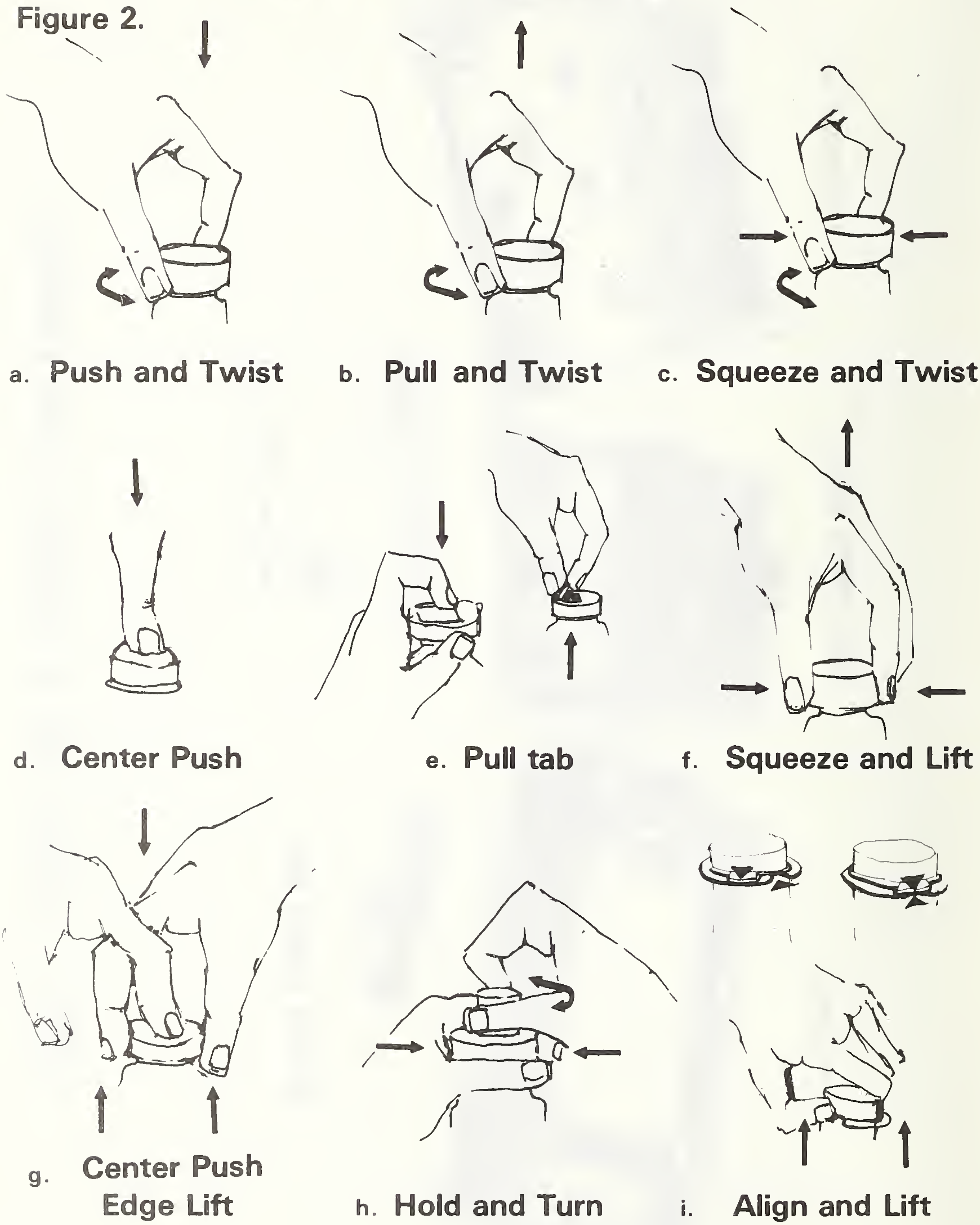


FIGURE 1. OVERALL VIEW OF CLOSURE TESTING EQUIPMENT

Closure Operating Forces

Figure 2.



Pry and Shell Forces

Figure 3.

Figure 4. List of Safety Closure Types

Type	Subtype	Symbol
Threaded cap	Random push and twist	A-1
Threaded cap	Random pull and twist	A-2
Threaded cap	Localized push and twist	A-3
Threaded cap	Localized pull and twist	A-4
Threaded cap	Random squeeze and twist	A-5
Threaded cap	Localized squeeze and twist	A-6
Threaded cap	Key device	A-7
Threaded cap	Two hand twist	A-8
Lug cap	Random push and twist	B-1
Lug cap	Random pull and twist	B-2
Lug cap	Localized push and twist	B-3
Lug cap	Localized pull and twist	B-4
Lug cap	Random squeeze and twist	B-5
Lug cap	Localized squeeze and twist	B-6
Lug cap	Ring position	B-7
Snap cap	Alignment and pull	C-1
Snap cap	Alignment and push	C-2
Snap cap	Center push	C-3
Snap cap	Spot push	C-4
Snap cap	Center push and edge lift	C-5
Snap cap	Hinged tap and lift	C-6
Snap cap	Squeeze and lift	C-7
Aerosol overcap	Squeeze and lift	D-1
Aerosol overcap	Hold and lift	D-2
Aerosol overcap	Hold and turn	D-3
Aerosol cap	Turn and orient	D-4
Aerosol cap	Sequential push	D-5
Aerosol cap	Finger insert	D-6

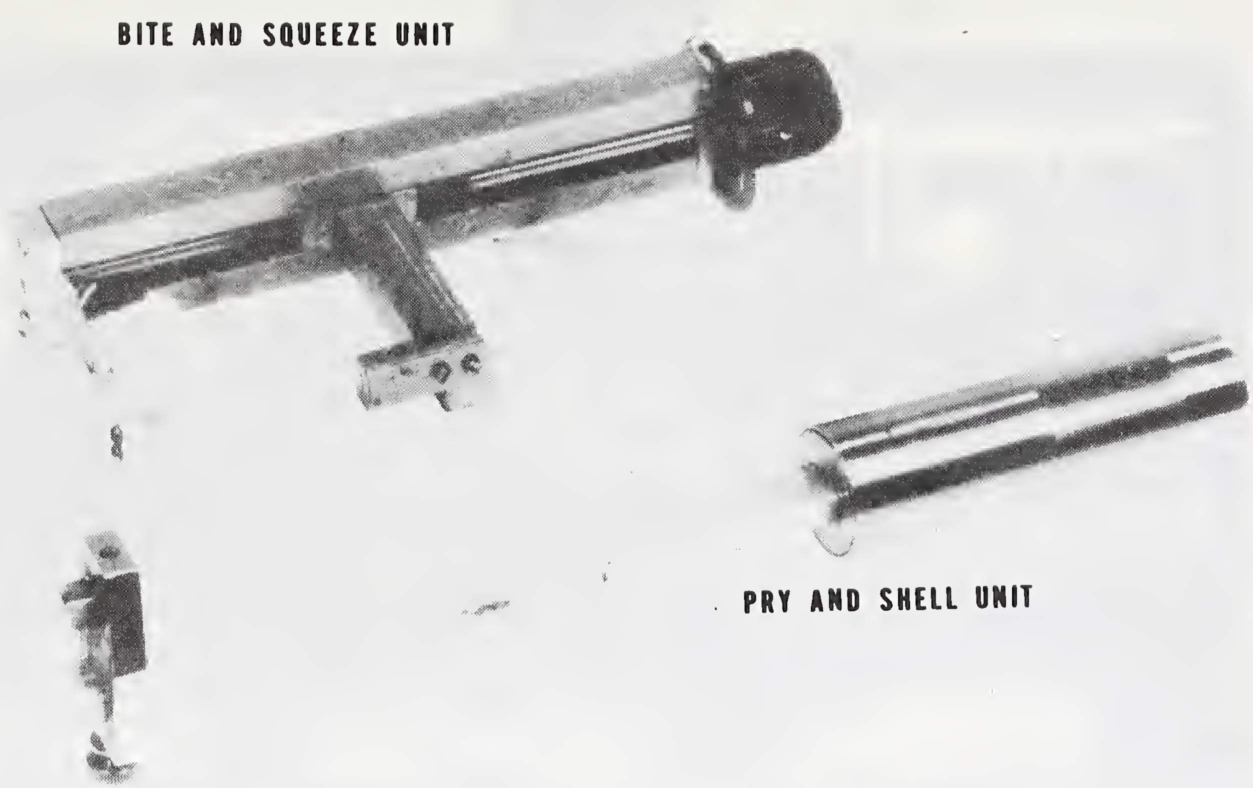


FIGURE 5. OVERALL VIEW OF SPECIAL UNITS

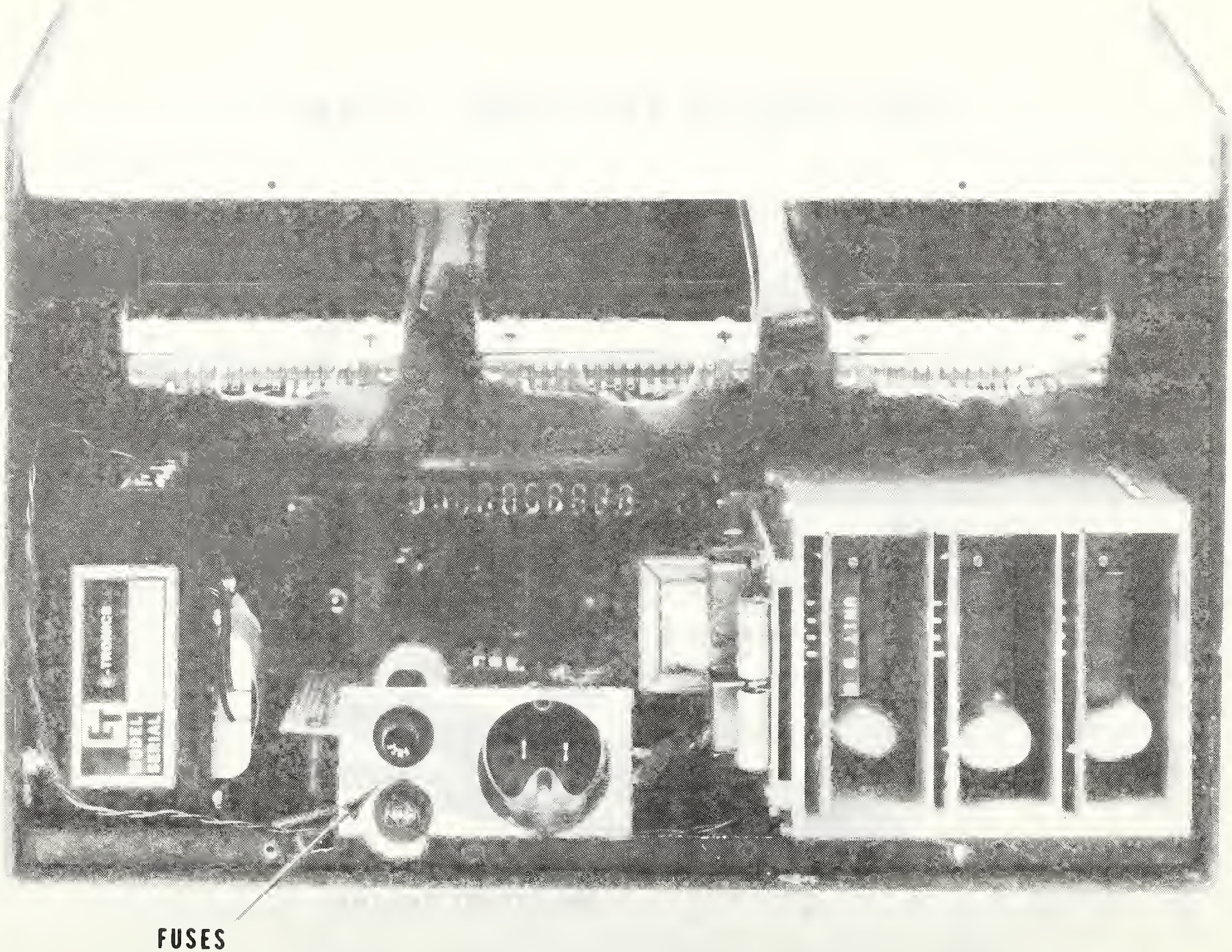


FIGURE 6. ELECTRONIC UNIT-REAR VIEW

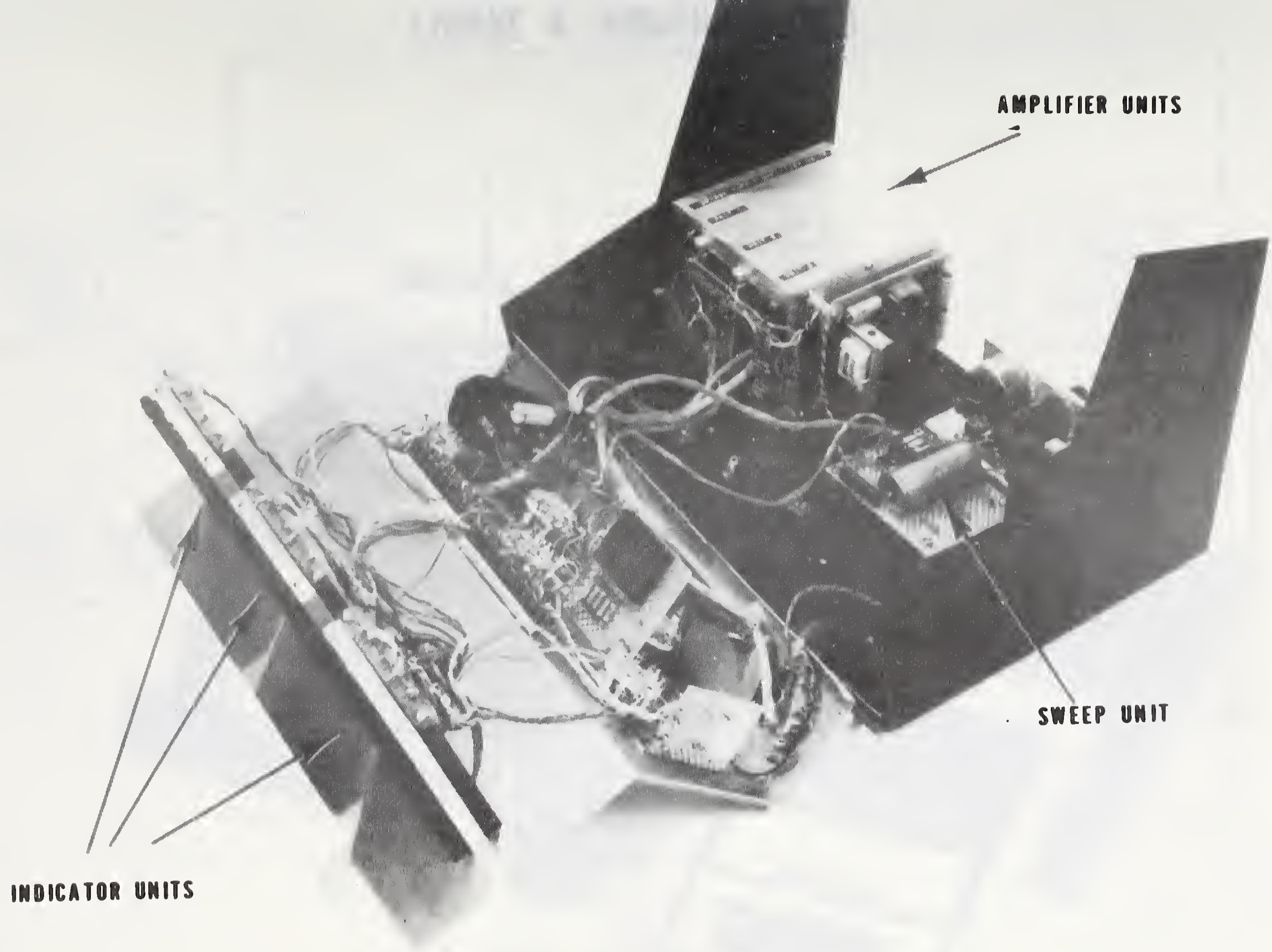


FIGURE 7. ELECTRONIC UNIT - INTERIOR VIEW

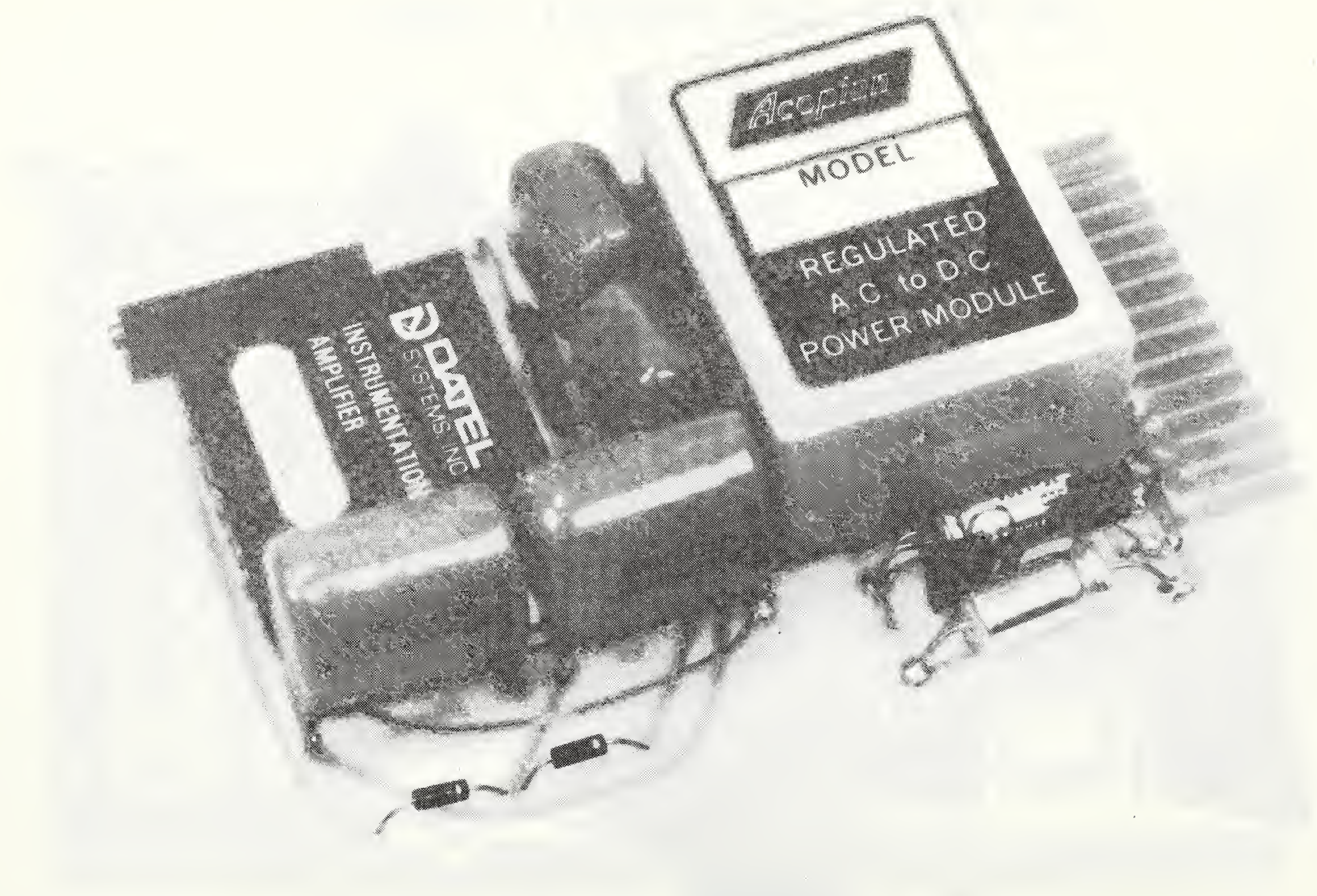


FIGURE 8. AMPLIFIER UNIT

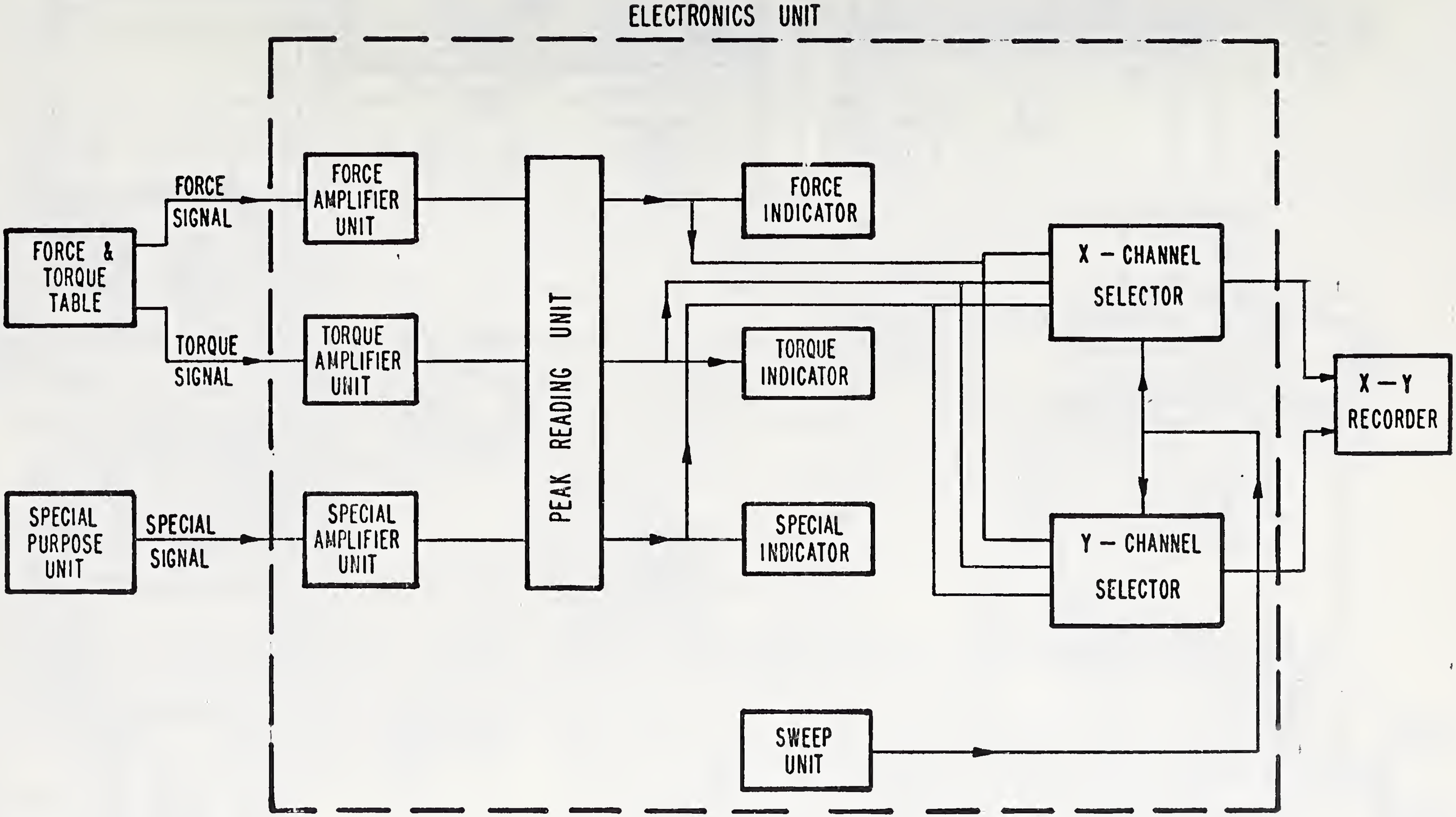


FIG. 9 BLOCK DIAGRAM OF EQUIPMENT

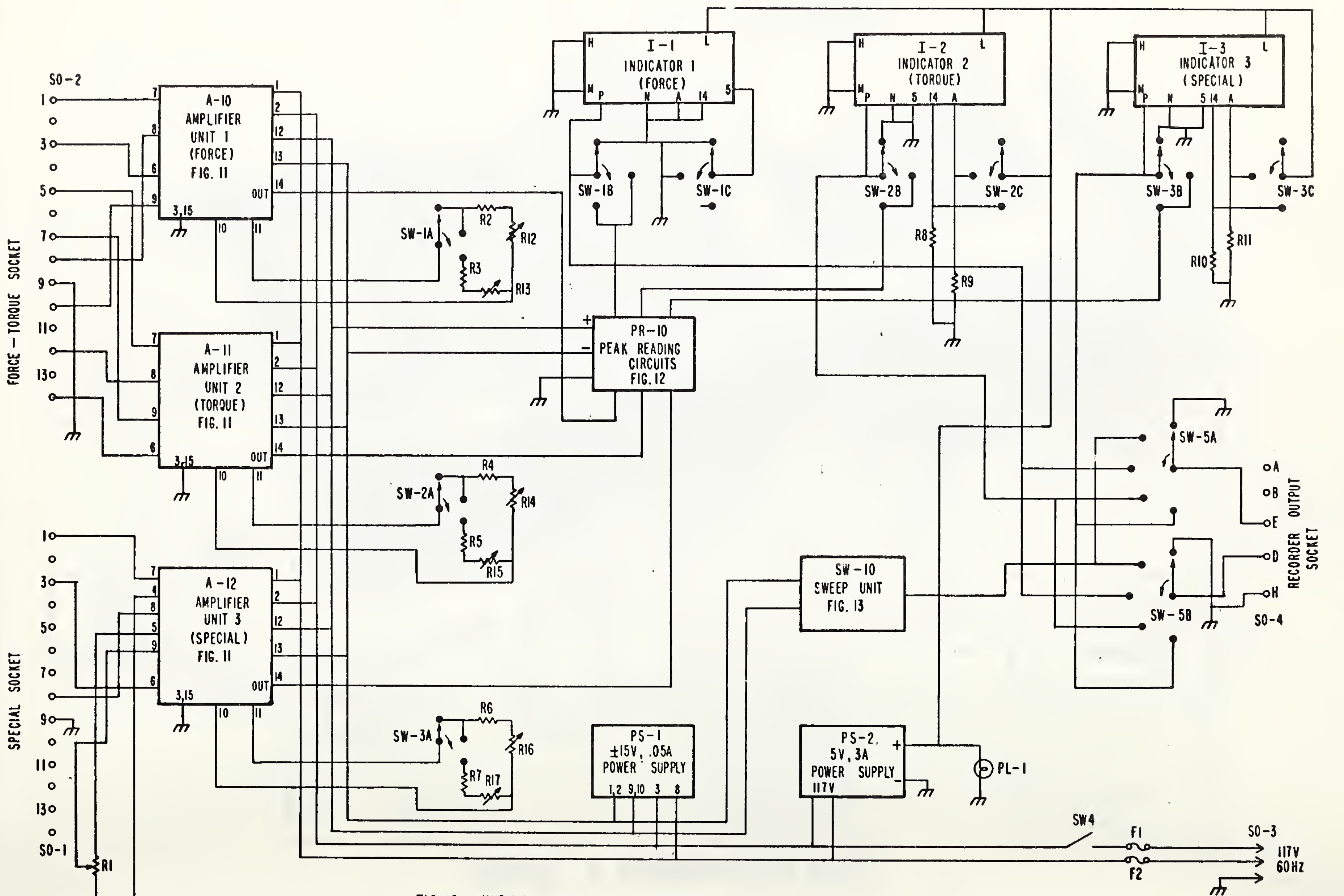


FIG. 10 WIRING DIAGRAM - ELECTRONICS UNIT

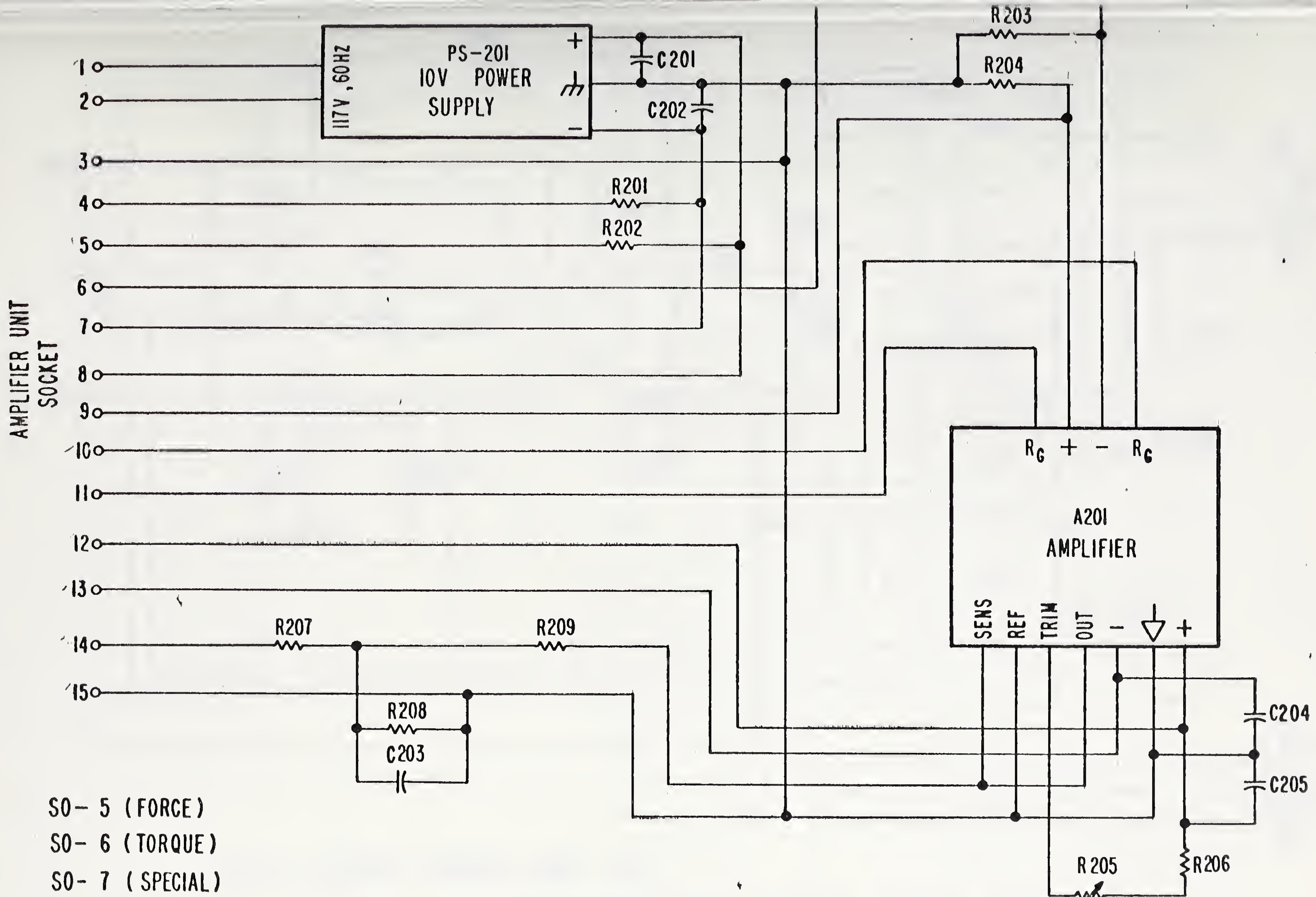


FIG. 11 CIRCUIT DIAGRAM – AMPLIFIER UNIT

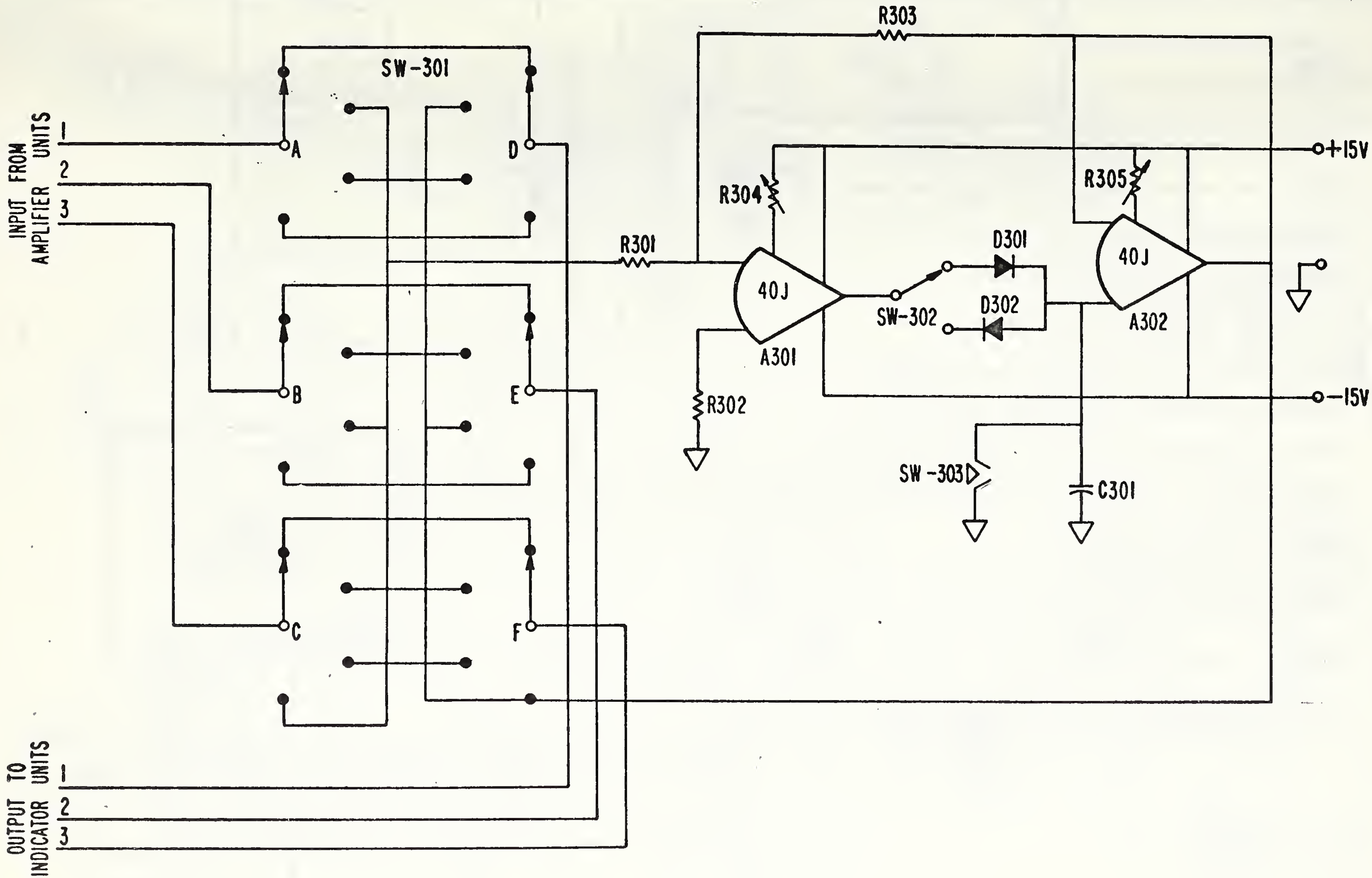


FIG. 12 CIRCUIT DIAGRAM - PEAK READING UNIT

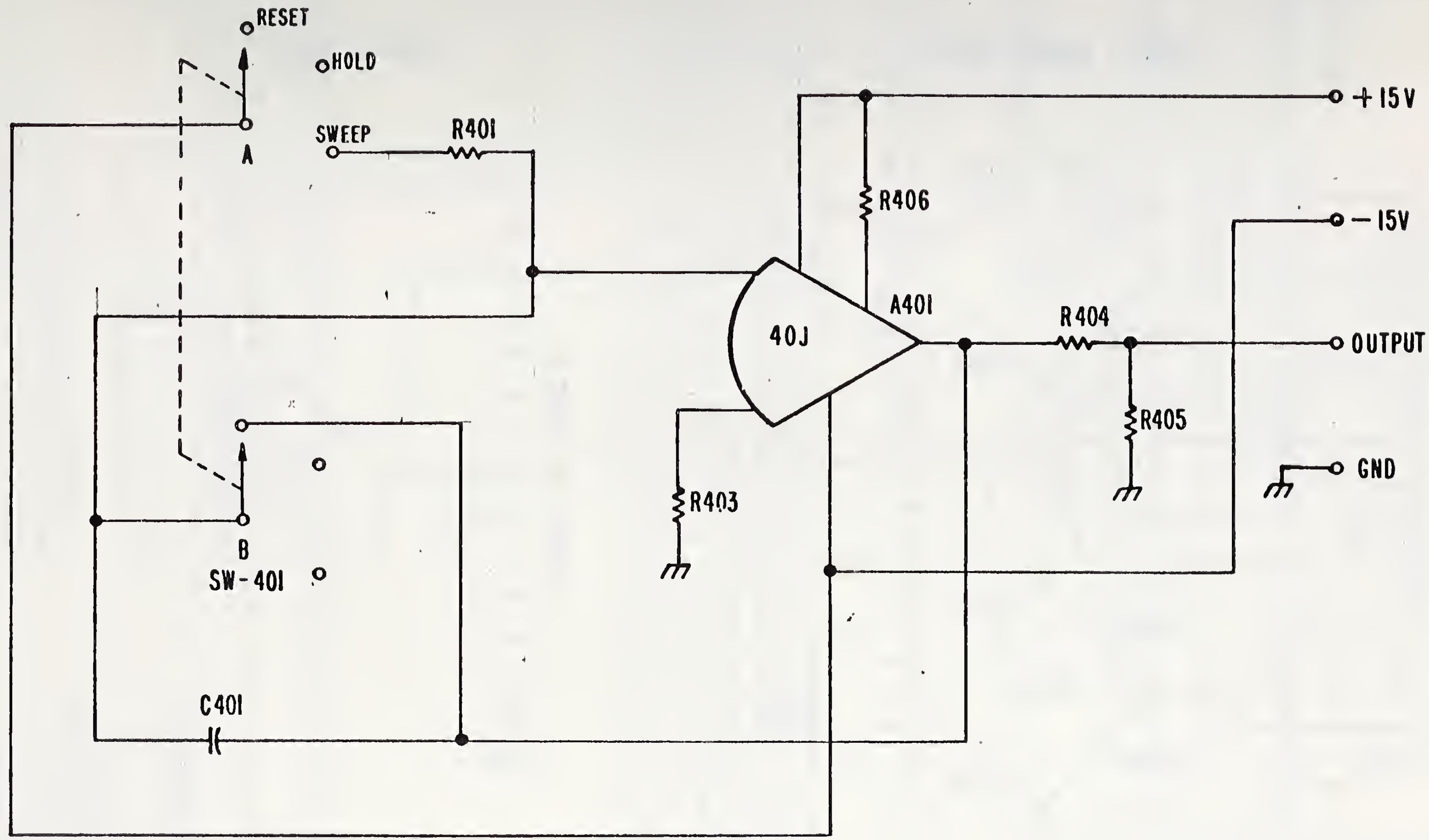


FIG. 13 CIRCUIT DIAGRAM — SWEEP UNIT

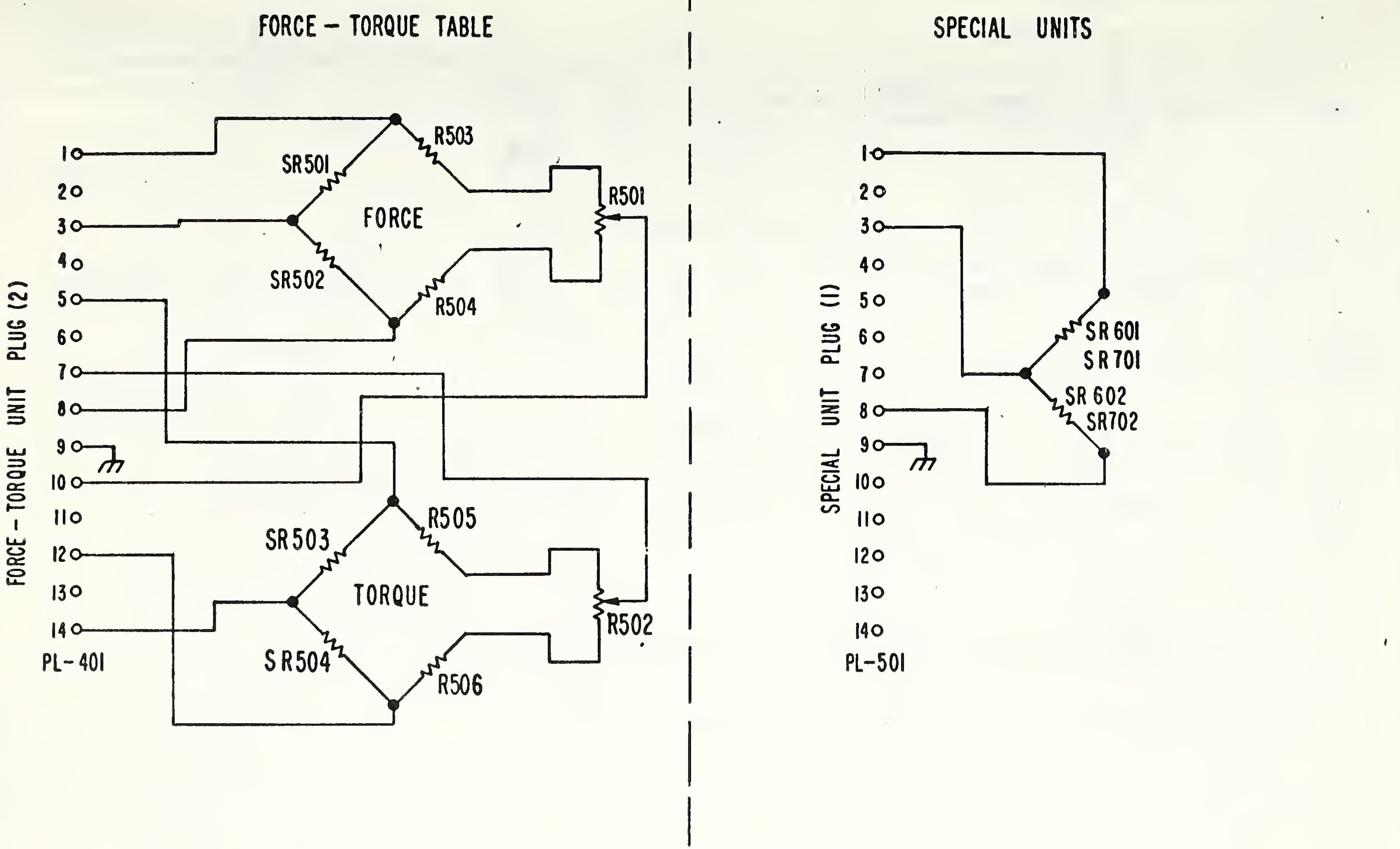


FIG. 14 CIRCUIT DIAGRAMS – FORCE-TORQUE TABLE AND SPECIAL UNITS

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET	1. PUBLICATION OR REPORT NO. NBSIR 75-722	2. Gov't Accession No. -	3. Recipient's Accession No.

4. TITLE AND SUBTITLE

Closure Testing Equipment Instruction Manual

5. Publication Date

October 1975

6. Performing Organization Code

7. AUTHOR(S)

Malcolm S. Morse

8. Performing Organ. Report No.

9. PERFORMING ORGANIZATION NAME AND ADDRESS

NATIONAL BUREAU OF STANDARDS
DEPARTMENT OF COMMERCE
WASHINGTON, D.C. 20234

10. Project/Task/Work Unit No.

11. Contract/Grant No.

12. Sponsoring Organization Name and Complete Address *(Street, City, State, ZIP)*

Consumer Product Safety Commission
5401 Westbard Ave.
Bethesda, Maryland 20016

13. Type of Report & Period Covered

Final

14. Sponsoring Agency Code

15. SUPPLEMENTARY NOTES

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

The NBS Closure Testing Equipment is designed to make accurate measurements of the critical parameters of the "childproof" closures required by the Poisoning Prevention Packaging Act of 1971. In general, these parameters are defined as the forces necessary to open these closures, either in the manner by which the closure was designed to be opened, or in an undesired manner. This manual discusses the design and construction of the testing instrument and gives detailed instructions for its operation.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Bottle caps; child protection; closure testing;containers; medicine bottles; poison packaging

18. AVAILABILITY [X] Unlimited

[ ] For Official Distribution. Do Not Release to NTIS

[ ] Order From Sup. of Doc., U.S. Government Printing Office Washington, D.C. 20402, SD Cat. No. C13

[X] Order From National Technical Information Service (NTIS) Springfield, Virginia 22151

19. SECURITY CLASS (THIS REPORT) UNCLASSIFIED

21. NO. OF PAGES 42

20. SECURITY CLASS (THIS PAGE) UNCLASSIFIED

22. Price $ 4.00