Operator & Service Manual

A.T.S. 500

TOURNIQUET SYSTEM

Aspen Labs
A SUBSIDIARY OF ZIMMER

TABLE OF CONTENTS
& LIST OF ILLUSTRATIONS

A.T.S. 500

SECTION	TITLE	PAGE
1.0	GENERAL INFORMATION	3
1.1	Features	3
1.2	Specifications	4
1.3	Intended Use	5
1.4	Contraindications	5
1.5	Precautions in Use	5
1.6	Adverse Effects	7
2.0	INSTALLATION AND OPERATING INSTRUCTIONS	9
2.1	Initial Inspection	9
2.2	Functional and Calibration Check	9
2.3	Installation	10
2.4	Controls, Indicators and Connectors	11
2.5	Single Cuff Operation	13
2.6	Dual Cuff Operation	14
2.7	Bier Block Operation	14
2.8	Alarm Conditions	15
3.0	THEORY OF OPERATION	19
3.1	Block Diagram	19
3.2	Detailed Circuit Description	19
3.2.1	Power Supply	19
3.2.2	Microprocessor and Memory	21
3.2.3	Control Line Decoder	21
3.2.4	Sound Generator	21
3.2.5	Watch Dog Timer	22
3.2.6	Displays	25
3.2.7	Switches and the Switch Latch	25
3.2.8	Pressure Transducer and Amplifier	25
3.2.9	A/D Converter	26
3.2.10	Valves and Valve Relay	26
4.0	MAINTENANCE	27
4.1	General Maintenance Information	27
4.2	Access to Parts	27
4.3	Periodic Maintenance	27
4.3.1	Cleaning	27
4.3.2	Inspection	33
4.3.3	Functional and Calibration Checks	33
4.3.4	Calibration	33

SECTION	TITLE	PAGE
4.3.4.1	Transducer Zero	33
4.3.4.2	Common Mode	36
4.3.4.3	Span Adjustment	36
4.3.4.4	Iteration of Adjustments	36
4.3.5	Watchdog Timer Test	40
4.3.6	Leak Testing	40
4.4	Unscheduled Maintenance	40
4.4.1	Troubleshooting Guide	41
4.5	Replaceable Parts	43
4.6	Parts Ordering Information	47

LIST OF ILLUSTRATIONS

FIGURE	TITLE	PAGE
2.1	Controls, Indicators & Connectors	12
3.1	Block Diagram	18
3.2	Microprocessor Address/Data Bus Timing	20
3.3	$\overline{\text{WDTSTB}}$ Synchronization Timing Diagram	23
3.4	WDT Timing Diagram	24
4.1	A1 Printed Wiring Board Assembly	28
4.2	Rear Panel Assembly	29
4.3	Front Panel Assembly	30
4.4	Valve Cover Assembly	31
4.5	Front and Rear Assemblies	32
4.6	Calibration Adjustment Locations	34
4.7	Calibration Kit: "T" Hose Assembly	35
4.8	Common-Mode Display Sequence	37
4.9	Schematic Diagram	48

TABLE	TITLE	PAGE
2.1	Alarm Conditions	16
2.2	Hardware Malfunction Codes	17
4.1	Switch Functions & Display Indications in the Calibration Mode	38
4.2	Expected Test Point Readings	39

GENERAL INFORMATION

SECTION 1.0

A.T.S. 500

1.1 FEATURES

The A.T.S. 500 is an automatic, microprocessor-based pneumatic tourniquet system. Its features include:

- The ability to control two cuffs in a Bier Block or Bilateral procedure.
- Microprocessor control prevents loss of occlusion during Bier Block cuff switching.
- Uses standard single port cuffs.
- Precision pressure transducer in conjunction with a microprocessor based control system.
- Built-in inflation time alarm system to alert the operating room staff when the anticipated cuff inflation time has been reached. This system also provides a convenient means to monitor and record total inflation time.
- Large, bright LED displays for easy viewing from a distance.
- Self-testing of alarm tones, displays, system calibration, and certain portions of the hardware and software each time the unit is turned on. In addition, some self-testing occurs continuously during normal operation.
- Automatic zeroing of pressure transducer circuit to compensate for system drift.
- A variety of audible and visual alarms to alert the user to abnormal conditions; including sensed pressure not within acceptable limits, time alarm, pressure supply low, and hardware failure. For certain types of equipment malfunctions, the unit will display error codes that identify the cause of the error, thus reducing fault isolation time.
- An alarm silence switch to permit silencing of most alarm tones for 30 seconds.
- Simple calibration that may be performed without disassembly.
- Modular construction for ease of maintenance and repair.
- Lightweight, portable, and designed to be mounted on existing I.V. poles.

1.2 SPECIFICATIONS

Line Voltage Range:
105-130 VAC, 50/60 Hz
Consult factory for other available voltages.

Line Current:
400 mA Maximum
125 mA Nominal

Input Power:
48 W Maximum
15 W Nominal

Power Cord:
Type SJT, AWG 18, 14 ft. (4.27m)

Power Plug:
Hospital Grade, 3 prong straight blade, 15 A

Line Protection:
0.5 A, 250 V, 5 x 20 mm SLO-BLO Fuse

Cuff Pressure Range:
50-475 mmHg

Pressure Accuracy:
± 5 mmHg (50-475 mmHg, T = 15-25°C)

Pressure Regulation:
± 6 mm of Set Point

Maximum Pressure:
475 mmHg (Normal Operation)
650 mmHg (Unit Failed)

Time Alarm Set Ranges:
0-240 min.; 1 min. increments

Timer Accuracy:
0.25% ± 1 sec.

Internal Diagnostics:
Program, Memory, Watchdog Timer, Transducer Calibration, Improper Valve Actuation.

Supply Pressure:
Requires 30 psi-200 psi Pressurized Nitrogen or Hospital Grade Air. Unit is equipped with a male Schrader connector.

SIZE:

Height:
15.2 in. (38.6 cm)

Width:
4.75 in. (22.5 cm)

Depth:
6.75 in. (17.1 cm) (including 2 in. clamp)

WEIGHT:
13 Lbs (5.9 Kg)

ALARMS:

CONDITION:	VISUAL INDICATION:	AUDIBLE TONE:
Over Pressure	Pressure Display & Cuff LED Flashes	996 Hz
Under Pressure	Pressure Display & Cuff LED Flashes	996 Hz
Exceeded Set Time	Time Display Flashes	488 Hz
Pressure Supply Low	Pressure Supply LED Illuminates	244 Hz (Modulated)
Hardware Failure	Failure Codes Appear On Time & Pressure Displays	996 Hz

CONTROLS:

On/Off Switch:
Control to apply power to unit.

Pressure Switches:
Controls to increase or decrease the pressure setpoint.

Time Switches:
Controls to increase or decrease the time alarm setpoint.

Cuff Switches:
Controls to inflate or deflate the main cuff and/or the second cuff.

Mode Switch:
Control to determine if the unit is capable of controlling only the main cuff or both cuffs.

Alarm Silence Switch:
Control to allow operator to manually silence certain alarm tones for 30 seconds.

DISPLAYS:

Pressure:
Red LED Display for Pressure Setting, Sensed Cuff Pressure, and Hardware Failure Condition codes.

Time:
Red LED Display for Time Alarm Setpoint, Elapsed Time, and Hardware Failure Condition Codes.

Main Cuff LED:
Yellow light bar to indicate inflation of the main cuff or pressure alarm in the main cuff when flashing in conjunction with the Pressure Display.

Second Cuff LED:
Yellow light bar to indicate inflation of the second cuff or pressure alarm in the second cuff when flashing in conjunction with the Pressure Display.

Pressure Supply Low LED:
Red light bar to indicate insufficient supply pressure for normal operation.

SPECIFICATIONS ARE SUBJECT TO CHANGE WITHOUT NOTICE.

1.3 INTENDED USE

The A.T.S. 500 Tourniquet System is intended to be used by qualified medical professionals to temporarily occlude blood flow in a patient's extremities during surgical procedures on those extremities. Tourniquets have been found useful in producing a bloodless operating field in surgical procedures involving the extremities including:

Reduction of certain fractures
Kirschner wire removal
Tumor and cyst excisions
Subcutaneous fasciotomy
Nerve Injuries
Tendon Repair
Bone Grafts
Total wrist joint replacement
Replacement of joints of the fingers
Knee joint replacements
Amputations
Replantations

1.4 CONTRAINDICATIONS

The medical literature lists the following as possible contraindications. However in every case the final decision whether to use a tourniquet rests with the attending physician.

Open fractures of the leg
Post-traumatic lengthy hand reconstruction
Severe crushing injuries
Elbow surgery (where there is concomitant excess swelling)
Severe hypertension
Skin grafts in which all bleeding points must be readily distinguished
Compromised vascular circulation, e.g., peripheral artery disease
Diabetes mellitus
The presence of sickle cell disease is a relative contraindication. (See Precautions in Use)

1.5 PRECAUTIONS IN USE

■ The tourniquet system must be kept well calibrated and in operable condition. Accessories should be checked regularly.

■ The tourniquet cuff should never be punctured; therefore towel clips used near the system must be handled with special care. Cuffs with inner rubber bladders must be completely enclosed by the outer envelope to preclude ballooning and possible rupture of the bladder. Cleaning and assembly instructions of the cuff manufacturer should be followed carefully.

■ Do not use an elastic bandage for exsanguination in cases where this will cause bacteria, exotoxins, or malignant cells to spread to the general circulation, or where it could dislodge thrombi that may have formed in the vessels.

■ The tourniquet cuff must be applied in the proper location on the limb, for a "safe" period of time, and within an appropriate pressure range. Never apply a tourniquet over the area of the peroneal nerve or over the knee or ankle. Do not readjust an already inflated cuff by rotating it because this produces shearing forces which may damage the underlying tissue.

■ Prolonged ischemia may lead to temporary or permanent damage to tissues, blood vessels, and nerves. Tourniquet paralysis may result from either excessive or insufficient pressure. The latter may be more dangerous, resulting in passive congestion with possible irreversible functional loss. Prolonged tourniquet time can also produce changes in the coagulability of the blood with an increase in clotting time.

■ Inflation must be done rapidly to occlude arteries and veins as near simultaneously as possible, and to avoid return of blood into the limb.

■ No known safe limit to the number of aeration intervals during prolonged tourniquet time has been established. Tissue aeration periods should last at least 10 and preferably 15 minutes the first time and 15 to 20 minutes subsequently.

■ During exsanguination with an elastic bandage, a safe zone of uncovered skin about one inch wide should be maintained between cuff and bandage. This is necessary to prevent the cuff from slipping distally. Cuff effectiveness is also reduced if the bandage is wound up to the cuff. Careful and complete exsanguination reportedly prolongs pain-free tourniquet time. However, partial exsanguination may be desirable in certain cases where the residual blood will aid in the visualization and identification of vascular structures. In the presence of infection and painful fractures, after the patient has been in a cast, and in amputations because of malignant tumors, exsanguination before tourniquet application must be done without the use of an elastic bandage by elevating the limb for 3 to 5 minutes.

■ In case of failure, the tourniquet cuff must be fully deflated and the limb exsanguinated again before reinflation. Reinflation over blood-filled vasculature may lead to intravascular thrombosis.

■ Tourniquet users must be familiar with the inflation-deflation sequence when using a dual-cuff tourniquet, or two tourniquet cuffs together, so that the wrong tourniquet will not be released accidentally.

■ Test for hemoglobin type and its level before using a tourniquet on patients with sickle-cell anemia. When the tourniquet is used for these patients, the limb should be carefully exsanguinated and the PO_2 and pH should be closely monitored.

■ Select the proper cuff size to allow for overlap of about 6 inches. Too much overlap may cause rolling and wrinkling and lead to localized excessive pressure build-up. The skin under the tourniquet cuff must be protected from mechanical injury by smooth, wrinkle-free application of the cuff. If the tourniquet cuff is applied over any material that may shed loose fibers (such as Webril) the fibers may become embedded in the contact closures and reduce their effectiveness. In most cases padding has not been found necessary and may cause additional wrinkles. The deflated cuff and any underlying bandages should be completely removed as soon as tourniquet pressure is released. Even the slightest impedance of venous return may lead to congestion and pooling of blood in the operative field.

■ If skin preparations are used preoperatively, they should not be allowed to flow and collect under the cuff where they may cause chemical burns.

■ Whenever the tourniquet cuff pressure is released, the wound should be protected from blood surging back by applying pressure dressings and, if necessary, elevating the limb. Transient pain upon tourniquet pressure release can be lessened by elevation of the limb. If full color does not return within 3 to 4 minutes after release, the limb should be placed in a position slightly below body level.

■ Whenever infiltration anesthesia is used, it is recommended that the tourniquet remain inflated for at least 20 minutes from the time of injection. For a procedure requiring only a few minutes, too rapid release of the anesthetic agent can be prevented by reinflating the tourniquet several times. Deflation periods should last about 15 seconds; reinflation periods about 30 to 45 seconds.

1.6 ADVERSE EFFECTS

A dull aching pain (tourniquet pain) may develop throughout the limb following use.

Pathophysiologic changes due to pressure, hypoxia, hypercarbia, and acidosis of the tissues occur and become significant after about 1-½ hours of tourniquet use. Symptoms of tourniquet paralysis are motor paralysis and loss of sense of touch, pressure, and proprioceptive responses.

Intraoperative bleeding may be caused:

1. By the slight impeding effect exerted by an unpressurized cuff (and its padding, if used), which prevents venous return at the beginning of the operation.
2. By blood remaining in the limb because of insufficient exsanguination.
3. By inadequate tourniquet pressure (between systolic and diastolic blood pressure of the patient), or slow inflation and deflation, all of which allow arterial blood to enter while preventing venous return.
4. By blood entering through the nutrient vessels of the long bones, such as the humerus.

INSTALLATION & OPERATING INSTRUCTIONS

SECTION 2.0

A.T.S. 500

2.1 INITIAL INSPECTION

Unpack the A.T.S. 500 upon receipt and physically inspect the unit for any obvious damage that may have occurred during shipment. We recommend that this inspection be performed by a qualified biomedical engineer or other person thoroughly familiar with electronic medical devices. If the unit is found to be damaged, notify the carrier and your Zimmer representative immediately. If the initial inspection results are satisfactory, a functional and calibration check should be performed.

2.2 FUNCTIONAL AND CALIBRATION CHECK

The unit shall produce the results explained in the following steps, exactly as indicated. Failure to do so indicates that the device is not to be used until necessary repairs are made.

1. Connect the power plug of the unit to a source of power compatible with the ratings listed on the unit's nameplate.
2. Connect a pressure source meeting the requirements listed in Section 1.2 of this manual to the lower right of the unit.
3. Move the ON/OFF switch to the ON position and observe the following sequence:
   a) Four zeros appear on the PRESSURE display; three zeros appear on the TIME display;
   b) Four eights appear on the PRESSURE display; three eights appear on the TIME display; the red PRESSURE SUPPLY LOW indicator illuminates; both yellow cuff indicators illuminate;
   c) The Alarm Silence Switch illuminates;
   d) The unit emits a high pitched (996 Hz) tone; then a medium pitched tone (448 Hz); then a low pitch tone (244 Hz);
   e) The tones are silenced; the Alarm Silence Switch glows more brightly for a moment then is extinguished;
   f) The PRESSURE SUPPLY LOW indicator and both cuff indicators are extinguished; the TIME display reads 0; the PRESSURE display reads sensed pressure (near zero).
4. Test the PRESSURE setpoint system as follows;
   a) Press and hold the pressure increase (or decrease) switch;
   b) The PRESSURE display will blank momentarily;
   c) The PRESSURE display reads "200", the default pressure setpoint, for approximately 1.5 seconds;
   d) The PRESSURE display again blanks momentarily;
   e) The PRESSURE display increases (or decreases) by units of one, until 210 (or 190), thus altering the pressure setpoint in increments of 1 mmHg;
   f) The PRESSURE display again blanks momentarily;
   g) The PRESSURE display increases (or decreases) by units of five to a maximum of 475 (or a minimum of 0) mmHg;
   h) Releasing the switch causes the display to blink twice, then display sensed pressure (near zero);
   i) Once again press the pressure increase (or decrease) switch for approximately 1 second; after momentary blanking, the pressure display should read the last setting from step g) above;
   j) Release the PRESSURE switch.

5. Test the TIME alarm system as follows:
   a) Press and hold the TIME increase (or decrease) switch;
   b) The TIME display will blank momentarily;
   c) The TIME display will read "60", the default alarm setting, for approximately 1.5 seconds;
   d) The TIME display will again blank momentarily;
   e) The TIME display increases (or decreases) by units of one until 70 (or 50), thus altering the time alarm setpoint in increments of 1 minute;
   f) The TIME display again blanks momentarily;
   g) The TIME display increases (or decreases) by units of five to a maximum of 240 (or a minimum of 0) minutes of inflation before the alarm sounds;
   h) Releasing the switch causes the display to blink twice then display elapsed time (zero);
   i) Press the TIME increase (or decrease) switch for approximately one second;
   j) After momentary blanking, the TIME display should read the last setting from step g) above;
   k) Release the TIME switch.

6. **Calibration Check**

NOTE: The fact that the unit successfully completed the power-up diagnostic self-tests in step 3 above indicates the A.T.S. 500 is sufficiently calibrated for use. However, the following quantitative check is recommended at regular intervals.

   a) Connect a manometer, known to be in good working, order to the main cuff connector.
      CAUTION: The A.T.S. 500 is capable of developing pressures greater than some manometers can measure. Select the calibration pressure to be within the range that can be measured by your manometer.
   b) Set the desired test pressure using the PRESSURE increase and/or decrease switches. A test pressure of 250 mmHg is recommended.
   c) Press the MAIN CUFF inflate switch.
      OBSERVE: The manometer reading should increase to within 6 mmHg (plus or minus the accuracy of the manometer) of the pressure setpoint. It is suggested that a record be kept of the results of each calibration check to identify trends.
   d) If the unit does not inflate the manometer to within 6 mmHg of the setpoint, please see Section 4.3.4, Calibration.

7. **Under Pressure Alarm Check**

Create a leak in the main cuff while it is inflated. Make the leak large enough that even though the unit will be attempting to maintain pressure, the pressure still falls more than 15 mmHg below setpoint. Observe:

   a) The PRESSURE display and MAIN CUFF LED begin to flash.
   b) The Alarm Silence Switch illuminates.
   c) After approximately 1 second, an audible tone will sound announcing the pressure-out-of-limits condition. This delay is used to preclude nuisance alarms.
      Stop the leak and observe that the pressure returns to within limits, the audible tone ends, and the Alarm Silence Switch light extinguishes.

8. **Pressure Source Low Check**

While the unit is inflated, disconnect the pressure supply. The red PRESSURE SUPPLY LOW LED should illuminate and a low warbling tone should sound. The pressure display should still be displaying the sensed pressure. Reconnect the pressure supply. The tone should cease, the red LED extinguish, and normal operation should continue.

9. If all of the previous eight checks were successful, the A.T.S. 500 is ready for use.

2.3 INSTALLATION

The A.T.S. 500 is designed to be mounted on any stable I.V. pole. The adjustment range of the pole clamp on the right side of the unit will accommodate pole diameters of 0.5 to 1.5 inches (1.25 to 3.8 cm).

The power cord of each unit is equipped with a restraining strap that should be attached to the bottom of the I.V. pole in use. This is intended to minimize the likelihood of upsetting the pole mounted unit in the event of an inadvertant jerk on the power cord.

Connect the power cord of the unit to a properly polarized and grounded power source whose voltage and frequency characteristics are compatible with those listed on the nameplate of the unit. The A.T.S 500 is now ready for use.

2.4 CONTROLS, INDICATORS, AND CONNECTORS

Refer to Figure 2.1 for the locations of the unit's controls, indicators, and connectors. Their primary functions are described below.

1 POWER SWITCH - With the unit's power cord connected, this switch turns the unit on and off.

2 PRESSURE SETTING SWITCHES - To view current pressure setting, depress either pressure setting touch-switch for up to 1.5 seconds. The pressure display will blank, display the pressure setting for a moment, and then return to displaying the current cuff pressure when the touch-switch is released.

To change pressure setting, depress and hold the increase (+) or decrease (−) touch-switch until the desired setting is reached. The setting will change in increments of 1 mmHg for the first 10 mmHg, and then in increments of 5 mmHg thereafter until the touch-switch is released or the limits of 0 or 475 mmHg are reached.

Other - See Section 4.3.4 of this manual for functions of the switches during Calibration.

3 TIME ALARM SWITCHES - To view a current time alarm setting, depress either time alarm touch-switch for up to 1.5 seconds. The time display will blank, display the time alarm setting for a moment, and then return to displaying the current inflation time when the touch-switch is released.

To change time alarm setting, depress and hold the increase (+) or decrease (−) touch-switch until the desired setting is reached. The setting will change in increments of 1 min. for the first 10 min. and then in increments of 5 minutes thereafter until the touch-switch is released or the limits of 0 or 240 minutes are reached.

Other - See Section 4.3.4 of this manual for functions of these switches during Calibration.

4 MODE SWITCH - This switch determines whether the unit can control the pressure in a single cuff (the main cuff) or both cuffs.

5 INFLATE/DEFLATE SWITCHES - Inflation or deflation of the cuff(s) is accomplished by depressing the appropriate touch-switch. If the mode switch is in the single cuff position, only the main cuff can be inflated or deflated, and the second cuff inflate/deflate touch-switches are ignored. If the mode switch is in the dual cuff position, both cuffs can be inflated or deflated. When the main cuff is inflated, the main cuff light is on, and when the second cuff is inflated, the second cuff light is on.

NOTE: In the dual cuff mode it is not possible to deflate a cuff when the other cuff is inflating, and the deflate touch-switch must be depressed longer than usual to achieve deflation.

Other - See Section 4.3.4 of this manual for functions of these switches during Calibration.

6 ALARM SILENCE SWITCH - This lighted push-button switch will light when any of a number of alarm conditions exist. The audible tone associated with most of these alarms may be silenced for 30 seconds by depressing this switch. The push-button will remain lighted until the alarm conditon is corrected. In general, when an alarm condition is a result of an internal circuit malfunction, the tone cannot be silenced by this switch.

7 PRESSURE DISPLAY - During normal operation, with no touch-switches being depressed, this display will show the pressure sensed in the cuff(s) over the range of 0 to 475 mmHg. If in the dual cuff mode with one cuff inflated and the other deflated, the display will show the pressure in the inflated cuff. The desired pressure setting may be viewed on this display when the pressure setting touch-switches are operated in accordance with item 2 above. When the sensed pressure in the cuff(s) is not within 15 mmHg of the desired pressure setting, this display will flash the sensed pressure.

See Section 2.8 for other possible indications during alarms or abnormal conditions.

See Section 4.3.4 for indications during Calibration.

8 TIME DISPLAY - During normal operation, with no touch-switches being depressed, this display will show the inflation time of the cuff(s) in 1 min. increments up to a maximum of 240 minutes. The time alarm setting may be viewed on this display when the time alarm touch-switches are operated in accordance with item 3 above. If the inflation time has exceeded the time alarm setting, the display will flash the current inflation time.

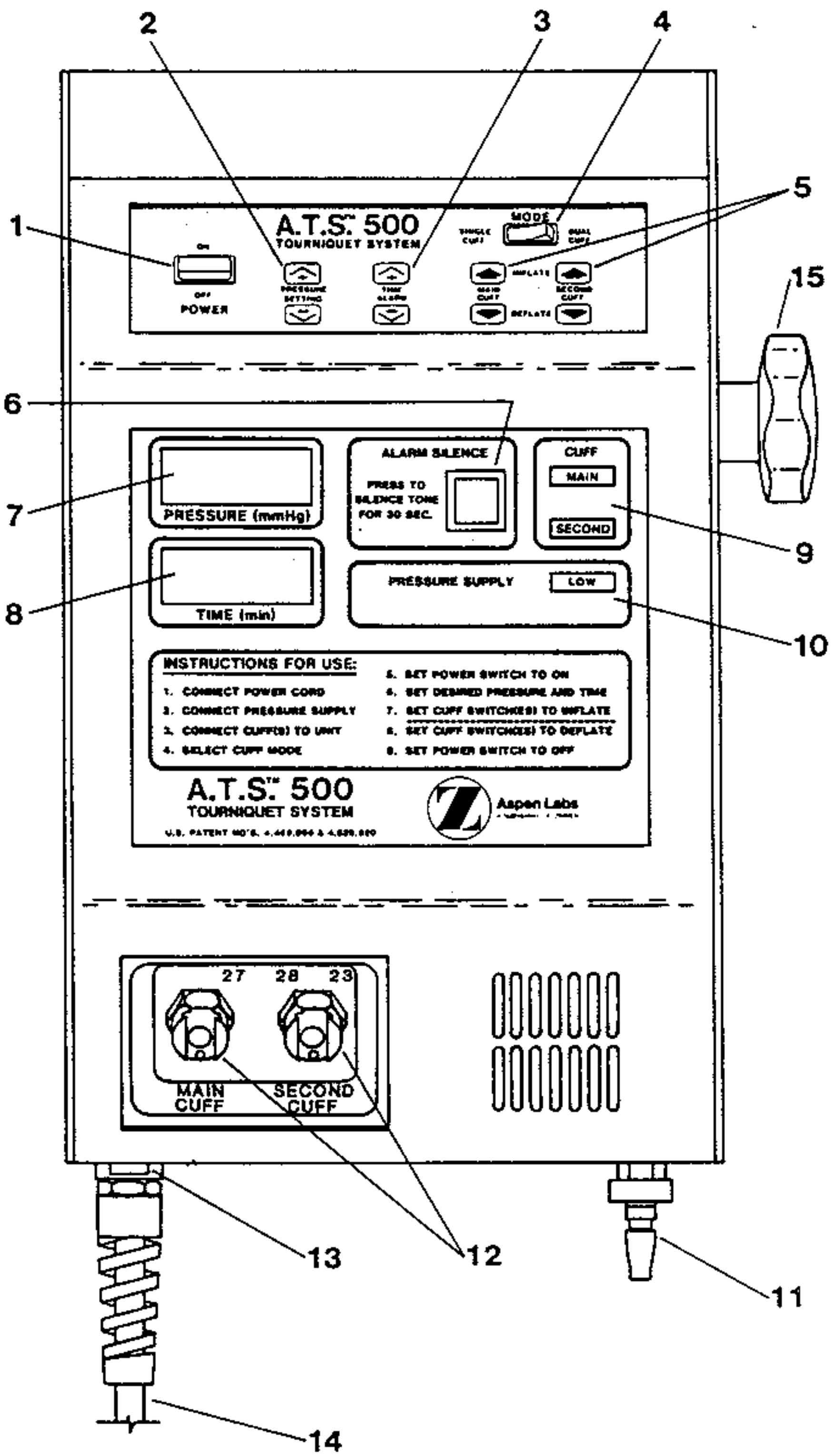
See Section 2.8 for indications during alarms or abnormal conditions.

See Section 4.3.4 for indications during Calibration.

9 CUFF LIGHTS - Indicates which cuff or cuffs are active. Lights flash when a pressure alarm occurs to indicate which cuff to check.

10 PRESSURE SUPPLY LOW LIGHT - Indicates the pressure supply connected to the unit is too low to support adequate operation.

Figure 2.1 Controls, Indicators and Connectors



11 MALE SCHRADER CONNECTOR - Connection point for a source of pressure for the unit. The unit is designed to run on Hospital Air or pressurized Nitrogen only.
12 CUFF CONNECTORS - Ports to connect tubing to cuff(s).
13 PRIMARY LINE FUSE - Protects power line against internal overloads. This fuse should be replaced only with one of the same type and rating.
14 POWER CORD - Supplies primary AC power to unit when connected to appropriate receptacle.
15 POLE CLAMP - Adjustable clamp to mount the unit on an I.V. pole.

2.5 SINGLE CUFF OPERATION

1. With the ON/OFF switch in the OFF position, connect the power cord to an electrical power source that is compatible with the ratings listed on the nameplate of the device. Connect a pressure source meeting the requirements listed in Section 1.2 to the lower right of the unit.
2. Connect a single port cuff to the unit at the main cuff connector.
3. Set the ON/OFF switch to the ON position. The unit will execute a self-check diagnostic test as described in Section 2.2 of this manual. Successful completion of the self-check indicates the unit is ready to use.

CAUTION: Special note should be made of the fact that if either cuff is pressurized to 50 mmHg or more during power-up, the A.T.S. 500 will declare it an abnormal start-up sequence. It will assume that a surgical procedure is in process and will adopt the higher of the pressures sensed in each cuff as the new set point. It will automatically go into the inflation mode and regulate either or both cuffs (depending on whether either or both had pressures in excess of 50 mmHg) to the new set point. To alert the operator of this condition, the unit will sound a high pitched tone and illuminate the Alarm Silence Switch light. The operator should immediately check the pressure set point and readjust it if necessary.

The alarm can be cleared by depressing the Alarm Silence Switch.

4. In the absence of operator action, the unit adopts preset values for desired cuff pressure and inflation time alarm of 200 mmHg and 60 minutes respectively. These values may be observed on the digital displays by pressing the PRESSURE and/or TIME increase or decrease switch for up to 1.5 seconds.

For each patient, tourniquet pressure should be set to the minimum effective pressure. The minimum effective pressure should be determined by taking into account factors such as: whether the cuff is to be applied to an upper or lower limb; whether the limb is normal, hyperthrophied, or obese; the patient's pre-operative systolic pressure; and the maximum anticipated rise in systolic pressure during the procedure.

Set the desired cuff pressure by pressing and holding the PRESSURE INCREASE or DECREASE switch until the desired setting is reached. Similarly set the desired inflation time alarm using the TIME INCREASE or DECREASE switches.

5. Prepare the patient in accordance with your established procedures and cuff manufacturer's instructions. The precautions of Section 1 and the following are offered as a guide to assist in this process.

In most cases a tourniquet cuff should be applied at the widest part of the limb to allow as much tissue as possible to lie between the cuff and any nerves or vascular structures susceptible to damage. The optimum positions are the upper arm and the proximal third of the thigh. In certain cases of fore-foot surgery, the tourniquet cuff can be applied around the calf or to the area proximal to the malleoli. For emergency surgery of the hand, a sufficiently small tourniquet can be inflated around the wrist.

Apply a leak-free tourniquet cuff smoothly without wrinkles. The valve stem and tube connections should be placed so that the tubing will not be kinked when the limb is positioned for surgery (usually with the valve stem pointing proximolaterally, away from the operative field). The limb is then prepared and draped for surgery. The viability of the skin and deeper tissues should be established prior to exsanguination of the limb and tourniquet inflation.

Exsanguinate the limb by elevating it for a minimum of 2 minutes and wrapping it, starting from the distal and progressing to the proximal part, using an Esmarch, Martin, or elastic bandage. The bandage should come up approximately to one inch from the edge of the tourniquet cuff. The elastic bandage is removed following inflation of the cuff. The anesthetic agent for the regional anesthesia or nerve block is then injected.

The tourniquet time depends greatly on the patient's anatomy, age, and absence of vascular disease. The surgeon will determine when the tourniquet is to be inflated, to what pressure, for how long, whether to allow for intermittent aeration of tissue by deflating the cuff for 10 to 15 minutes, and to what point in the operation the tourniquet should be released. In many operating rooms, it is customary to note prominently the time of inflation, and to warn the surgeon after a certain time period so that he can assess the need for further tourniquet time.

There is general agreement that, for reasonably healthy adults, about one and a half hours is "safe" and two hours should not be exceeded without releasing the tourniquet to allow the underlying tissue to "breathe" for about 15 to 20 minutes. During this time, the limb should be elevated about 60 degrees, and steady pressure should be applied to the incision with sterile dressings.

Under optimum conditions, the tourniquet cuff can be kept inflated until the final compression dressings are in place. Postoperative swelling is then kept to a minimum.

6. The cuff is inflated by pressing the red MAIN CUFF INFLATE switch. The unit will pressurize the main cuff to the desired pressure and start the inflation time clock. The main cuff light will illuminate to indicate cuff activation. See Section 2.8 for possible alarm conditions.

7. At the end of the procedure, deflate the cuff by pressing the MAIN CUFF DEFLATE switch. The MAIN CUFF light will go out, the pressure display will show the deflation of the cuff, and the inflation time clock will stop. Record the elapsed inflation time if desired.

It is best to remove the tourniquet cuff and any underlying bandages immediately following final deflation. The time of tourniquet cuff removal should be noted, and the circulation of the limb should be checked.

8. Set the ON/OFF switch to the OFF position only after the pressure display indicates less than 50 mmHg.

2.6 DUAL CUFF OPERATION

Operation of the unit in the Dual Cuff Mode is identical to operation in the Single Cuff Mode except for the following points.

1. Both single port cuffs are connected at the lower left of the unit.

2. The cuff lights indicate the cuff that is active. (ie. If both cuff lights are illuminated then both cuffs are inflated.)

3. During a pressure alarm the flashing cuff light indicates the cuff to check.

4. Deflation of one cuff will not be permitted while the other cuff is inflating.

5. For added safety, the DEFLATE switches must be pressed approximately 0.5 seconds longer than in the Single Cuff Mode.

6. When inflating a cuff with the other cuff already inflated, the unit will periodically check the original cuff to insure that the pressure is within allowable limits. The unit will stop its inflation, and maintain the original cuff to within 5 mm of setpoint before returning to the inflating cuff. This is to insure that at least one cuff maintains occlusion at all times. If there is a significant leak in the original cuff, this feature could cause the inflation rate of the subsequent cuff to be longer, perhaps even causing the 30 second inflation alarm to sound. The display shows the pressure in the inflating cuff so as to allow the operator to view the progress of inflation.

7. When deflating a cuff with the other cuff remaining inflated, the unit will stop the deflation and maintain the inflated cuff within allowable limits if the pressure in the inflated cuff drops more than 5 mmHg. This is to insure that at least one cuff maintains occlusion at all times. If there is a significant leak in the cuff that remains inflated, the deflation of the other cuff could be affected. The display shows the pressure in the cuff that remains inflated.

2.7 BIER BLOCK OPERATION

1. Review Sections 2.5 and 2.6, SINGLE CUFF OPERATION and DUAL CUFF OPERATION.

2. The unit should be used in the DUAL CUFF MODE.

3. The following are suggested cuff connections:
   a) The proximal cuff connected to the MAIN CUFF connector using the white cuff tubing.
   b) The distal cuff connected to the SECOND CUFF connector using the blue cuff tubing.

4. Remember that deflation of a cuff is not possible while the other is inflating and that deflation requires pressing and holding the deflate button longer than usual.

2.8 ALARM CONDITIONS

There are a number of conditions for which the A.T.S. 500 will produce a visual and/or audible alarm. Those conditions, indications and appropriate actions are shown in Table 2.1. The appropriate actions indicated are based on the most probable causes and should only be used as a guide. Other causes of alarm conditions may indicate need for other actions.

In addition to the conditions shown in Table 2.1, it is conceivable that a malfunction could occur for which the indications are unintelligible and unpredictable. It is very likely that the valves will be disabled causing the system to hold cuff pressure. It is also likely that a high pitched tone will be sounded under these conditions.

Most audible alarm tones may be silenced for 30 seconds by depressing the Alarm Silence pushbutton. The light in the Alarm Silence pushbutton will normally remain lit until the condition that created the alarm has been corrected. At the end of the silence period, tones will be reenabled. Depressing the Alarm Silence switch will cause the alarm tone to be silenced again.

It is possible for more than one alarm condition to be present at any time. In that event, the unit will announce the alarm conditions in sequence. The operator should identify the causes of the alarms and act on the condition that presents the most danger first. Note that the alarm silence switch will silence the audible tones associated with multiple alarm conditions in the same manner that it does for single alarm conditions.

To minimize nuisance pressure alarms that can be caused by vigorous movement of the patient's limbs, a 1.5 second delay has been designed into the tone generator. The pressure display will still flash during the 1.5 second period.

Under certain conditions, such as when a HELP indication appears in the PRESSURE display or the information that appears in the TIME and PRESSURE displays is unintelligible, the operator should conclude that a hardware failure has occurred rendering the unit unusable. The appropriate action in such an event is to set the ON/OFF switch to OFF. Since this removes power from the internal circuitry, all commands to the valves will cease which should cause the cuff to hold pressure (in the absence of leaks). Clamp the cuff lines with hemostats or the like and replace the A.T.S. 500.

The definitions for the hardware failure codes identified in condition 9 of Table 2.1 are delineated in Table 2.2.

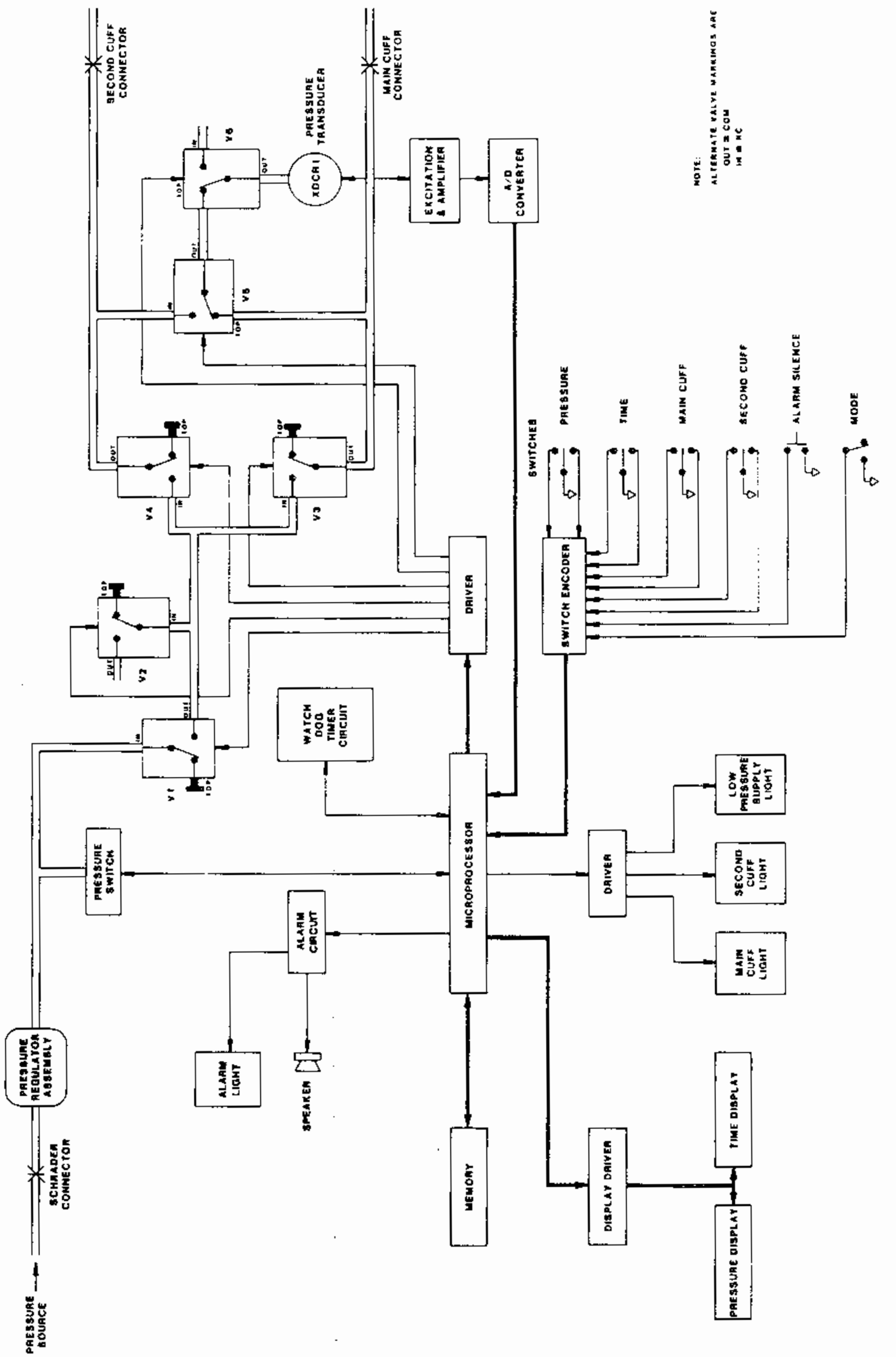
Table 2.1 Alarm Conditions

CONDITION	AUDIBLE TONE	PRESSURE DISPLAY	TIME DISPLAY	ALARM SILENCE PUSHBUTTON	PRESSURE SUPPLY LOW LIGHT	APPROPRIATE ACTION/REMARKS
1. PRESSURE LOW: 15 mmHg or more below desired setting.	STEADY HIGH PITCH	FLASHING SENSED CUFF PRESSURE		LIT		This condition is generally caused by a leak in the system or a tubing occlusion. All lines and connections should be checked.
2. PRESSURE HIGH: 15 mmHg or more above desired setting	STEADY HIGH PITCH	FLASHING SENSED CUFF PRESSURE		LIT		Normally caused by transient conditions such as controller overshoot, patient movement or tube occlusion. This condition for an extended period would indicate a hardware failure and the ATS 500 should be replaced.
3. INFLATION TIME IN EXCESS OF SETTING	STEADY MEDIUM PITCH		FLASHING ELAPSED TIME	LIT		Time should be set to new value.
4. PRESSURE SOURCE LOW	STEADY LOW PITCH			LIT	LIT	Unit needs to be connected to pressure source.
5. CUFF PRESSURIZED DURING POWER UP This will occur if, for example, the unit is turned off and back on without deflating the cuff	STEADY HIGH PITCH			LIT		If the cuff pressure is 50 mmHg or greater at the time that the POWER switch is set to ON the system assumes that a procedure is in progress. It adopts the sensed pressure of the cuff(s) as the desired setting and sounds the alarm to notify the operator that it has done so. The operator should immediately check the pressure setting to see if it needs to be reset to a different value.
6. UNIT OUT-OF-CALIBRATION	STEADY HIGH PITCH	HELP	-0-	LIT		Unit out of calibration. Pressure in error by at least ± 6 mmHg.
7. PROCESSOR ERROR	STEADY HIGH PITCH	HELP	-5- or -6- or -7- or -8- or -9-	LIT		Hardware has malfunctioned and failed self check. The unit is automatically disabled, unresponsive to any commands and not usable. Turn it off. See Operator's & Service Manual for specific meanings of these codes.
NON-ALARM CONDITION (Calibration)		0000	-1-			These indications are related to the Calibration Mode and should not be seen during normal operation. If seen, it suggests that the TIME and PRESSURE DECREASE switches were being depressed at the time that the POWER was set to ON. To get back to normal operation set the POWER switch to OFF and then back to ON.
		0000	-2-			
		Sensed Pressure	-4-			
		Sensed Pressure	-5-			
		WD Time (mSec)	-6- or -7-			
		Number Between 120 & 140	Number Between 120 & 140			
		Sensed Pressure	247			
		Sensed Pressure	Alternates between 195 and 395 every 2 min. 20 sec.			

Table 2.2 Hardware Malfunction Codes

Pressure Display	Time Display	Audible Tone	Alarm Silence Pushbutton	Meaning of Indications
HELP	-0-	STEADY HIGH PITCH	LIT	Unit is out of calibration.
HELP	-4-	STEADY HIGH PITCH	LIT	Improper combination of valve actuations
HELP	-5-	STEADY HIGH PITCH	LIT	Analog input voltage is out of normal input range for one of the required internal measurements or the A/D converter has failed.
HELP	-6-	STEADY HIGH PITCH	LIT	a) Unit failed watchdog timer hardware check during power up, or b) Watchdog timer failure during normal operation, or c) Processor timing in error.
HELP	-7-	STEADY HIGH PITCH	LIT	Processor failed to convert hexidecimal to binary coded decimal correctly.
HELP	-8-	STEADY HIGH PITCH	LIT	Processor failed a ROM check.
HELP	-9-	STEADY HIGH PITCH	LIT	Processor failed a RAM check.

Figure 3.1 A.T.S. 500 Block Diagram



THEORY OF OPERATION
SECTION 3.0
A.T.S. 500

3.1 BLOCK DIAGRAM

Refer to Figure 3.1

The A.T.S. 500 is a microprocessor controlled automatic tourniquet. The microprocessor takes inputs from various switches, the A/D converter, and the memory and uses this information to generate commands to the outputs (valves, displays, alarm circuitry) in order to regulate cuff pressure. The pressure source is lowered to approximately 600 mmHg by the pressure regulator assembly. This assembly limits the maximum pressure which could be introduced into a cuff due to multiple valve failures. The presence of a pressure supply is detected by the pressure switch. Since activation of the inflate valve (V1) during the absence of the pressure supply could lead to a decrease in cuff pressure, the pressure switch status is periodically read by the microprocessor. The six valves control the inflation, deflation, sensing and calibration of the two tourniquet cuffs. The inflate valve (V1) either connects or disconnects the pressure source from valves V3 and V4. The deflate valve (V2) either connects or disconnects valves V3 and V4 to the atmosphere. The Sense/Calibrate valve (V6) connects the pressure transducer to the atmosphere or valve V5. Valve V5 determines which cuff has its pressure sensed via valve V6. The remaining two valves, V3 and V4, either connect a cuff to the inflate/deflate valves or seal the cuffs off to prevent a loss in pressure. Please note the block diagram (Figure 3.1) shows all valves in their off (no power) conditions. Thus, should a power failure or other hardware failure occur, the valves automatically go into a "safe" position to prevent a loss in cuff pressure.

The pressure transducer is connected to the A/D converter via excitation and amplification circuitry. The digitized pressure signal is then used by the microprocessor to regulate cuff pressure.

The Watch Dog Timer is a hardware circuit that monitors a timing signal generated by the microprocessor. Should this signal become abnormal, indicating a problem with either the microprocessor or the software, the Watch Dog Timer circuit cuts off power to the valves and attempts a hardware interrupt of the microprocessor. If the microprocessor is able to act on the interrupt, a help code is displayed on the front panel displays and an alarm tone is emitted.

3.2 DETAILED CIRCUIT DESCRIPTION

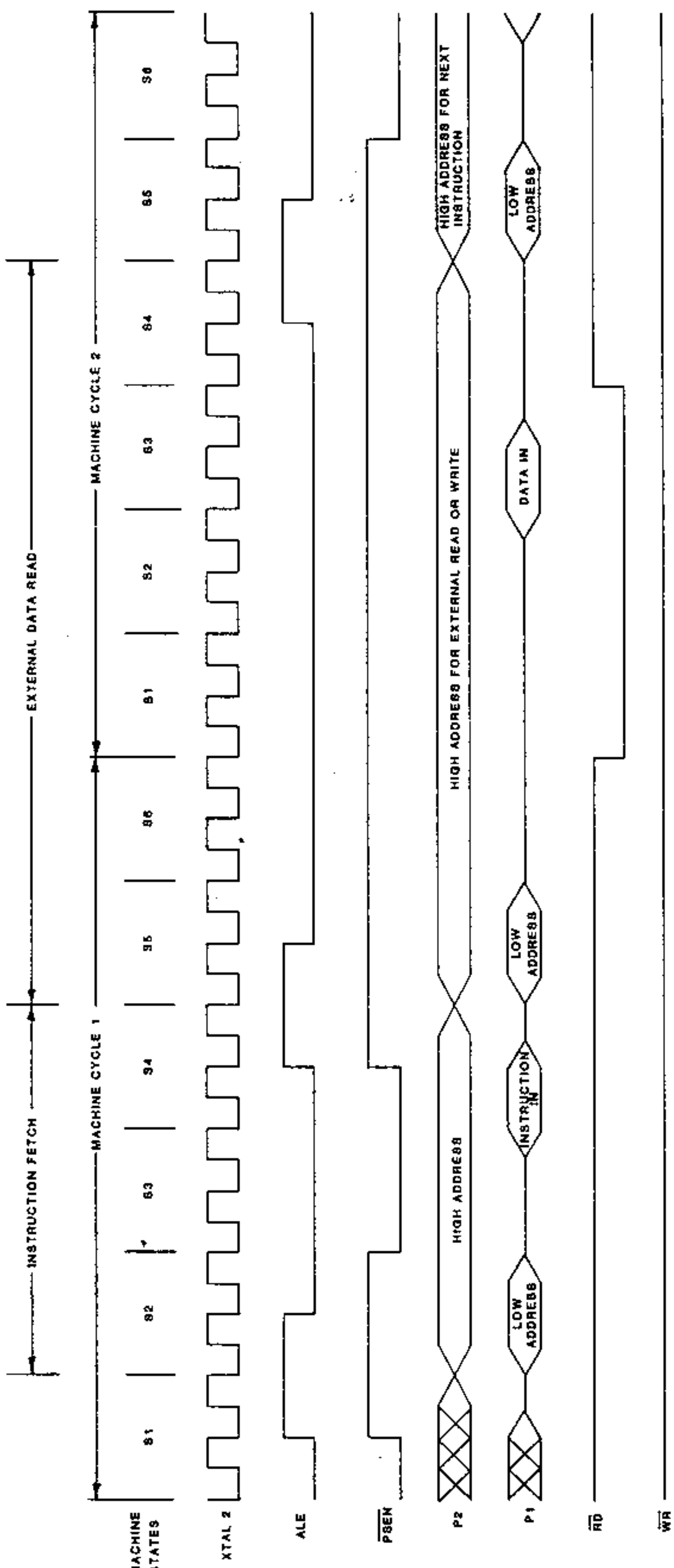
The following is a detailed description of the operation of the tourniquet's electronics on a circuit by circuit basis. The text is supplemented by the overall schematic of the tourniquet found in Figure 4.9.

3.2.1 Power Supply

Refer to Figures 4.2 and 4.5.

Primary AC power is supplied to the unit via the power cord and hospital grade plug. Fault protection is provided by the fuse (F1). This fuse should always be replaced with one of equal rating. The AC power is switched via the power switch (S2) and then goes to the primary of the power supply transformer. The power supply provides + 12 VDC to the A1 PWB via a power harness. A 5 volt regulator (VR1) and heat sink are mounted on the A1 PWB. Capacitors C9, C11, and C12 help provide stability and voltage ripple minimization.

Figure 3.2 Microprocessor Address/Data Bus Timing



The +12 volt line can be measured at TP12 and the + 5 volt line can be measured at TP6. Ground is at TP13.

3.2.2 Microprocessor And Memory

The microprocessor (μP) used in the A.T.S. 500 is an 8031 with external memory. The μP receives bypassed +5 VDC at pin 40. At power up, capacitor C6 and resistor R13 ensure a proper reset by causing the voltage at pin 9 to remain high for at least 24 oscillator periods. The unit uses a 3.58 MHz quartz crystal (X1) along with capacitors C7 and C8 to implement the μP oscillator at pins 18 and 19.

The μP has four 8 bit ports which can be configured or used in different ways for different applications. In the A.T.S. 500, port 1 (pins 1 through 8) is used to directly control the valves and cuff LEDs. Port 3 (pins 10 through 17) is used for a variety of inputs and outputs which will be discussed later. Ports 0 and 2 are used to implement a multiplexed address/data bus for outputting addresses and transferring data. The primary purpose of the bus is to input instructions from the program memory chip (U18). To do this the μP places the ALE and $\overline{\text{PSEN}}$ lines (pins 30 and 29 respectively) in a logic high state and then places the address on the address bus (please see Figure 3.2). The ALE line then goes low which causes the lower 8 bits of the address to be latched into U17, an 8 bit latch. The upper 5 bits of the address are present on pins 21 through 25 of the μP and held there until after the instruction is read in. The μP then returns $\overline{\text{PSEN}}$ to a logic low bringing the output enable line of the EPROM (pin 22 of U18) low. The program instruction is then output on pins 11 through 19 of U18 and is read by the μP one machine state later. The entire process is automatically repeated until a data read or write operation to an external address occurs.

A data read or write from an external address is different from a fetch from program memory in several ways. First, the μP does not pulse the ALE or $\overline{\text{PSEN}}$ lines. This is to insure that the 573 latch (U17) and EPROM (U18) do not interpret the address as a request for a program instruction. Secondly, every data read or write to an external address causes either the $\overline{\text{RD}}$ line (pin 17) or the $\overline{\text{WR}}$ line (pin 16) to go low during the time when the data is transferred on the address/data bus (please see Figure 3.2). Thus the μP constantly fetches instructions from the EPROM interrupting the process only when an external read or write is needed.

Pins 10 and 11 of the μP are inputs from the second cuff inflate/deflate switches. Pin 12 is an interrupt line that senses when the $\overline{\text{WDTFAIL}}$ line goes low. Pin 13 is an input for the pressure switch which senses low supply pressure. Pins 14 and 15 are outputs for the WDT circuit and the valve relay respectively.

3.2.3 Control Line Decoder

The control line decoder is implemented using one LS259 addressable latch (U7) and one quarter of AND gate U8. When the μP wants to read or write from an external address, the address is output on the address/data lines AD0 through AD15. The $\overline{\text{PSEN}}$ strobe line is held high. This prevents the EPROM (U18) from interpreting the address as a request for program memory. With $\overline{\text{PSEN}}$ high and the address available, either the $\overline{\text{RD}}$ or $\overline{\text{WR}}$ lines will cause the address to be latched into U7 by bringing $\overline{\text{E}}$ (pin 14 of U7) low. The top three bits of the 16 bit address determine which output of U7 will be active and bit 12 of the address acts as the data. Thus outputting an address of B000 Hex (1011 0000 0000 0000 Binary) would cause the top 3 bits (101) to select output 5 and cause that output to be a logic 1. This address corresponds to the switch latch. The switch latch will take this control signal and combine it with the RD signal to output its data.

The data present on the address/data bus is read by the μP which then brings the $\overline{\text{RD}}$ line high again. The end of the external read occurs when the $\overline{\text{PSEN}}$ line goes low as part of a read from memory (U18). This clears the output of U7 so that each strobing of a control line lasts only a part of a machine cycle. The process for an external write is the same except that the $\overline{\text{WR}}$ line from the μP is the one that goes low and the address/data bus outputs data from the μP which is latched into some external location using the $\overline{\text{WR}}$ line and the control line signal generated by U7. Outputting data to the display chip (address 3000 Hex), the A/D channel select (address 7000 Hex), A/D conversion begin (address D000 Hex), and the alarm circuit (address 5000 Hex) are all external write operations. Receiving data from the switch latch (address B000 Hex), and the A/D converter (address 9000 Hex) are external read operations.

3.2.4 Sound Generator

The sound generator is used to produce audible tones for various alarm conditions. The frequencies of the tones are 996 Hz, 488 Hz, and 244 Hz. To generate these and other frequencies we first begin with a 2 MHz crystal (X1) driven by an inverter from U9 and R10, R11, C3, and C4. This signal can be measured at TP2. It is divided into five other frequencies by the frequency divider

U10. Outputs Q11 (996 Hz) and Q12 (499 Hz) are used for generating their respective alarm tones. Output Q1 (1 MHz) is the clock signal used by the A/D converter (U16). Output Q2 (500 KHz) is the clock signal for the WDT circuit (U3). Lastly, output Q5 (62.5 KHz) is used by the second frequency divider as the input clock. This second divider generates 3 output frequencies. Outputs Q10 and Q12, 61 Hz and 15 Hz respectively, are used by the WDT circuit. While output Q8 (244 Hz) is used directly as an alarm tone.

Data selector U5 receives the 3 alarm tone frequencies from the two dividers as well as +5 VDC and connects one of these inputs to its output depending on the address present at pins 11, 12, and 13. The possible outputs are thus GROUND, +5 VDC, 244 Hz, 488 Hz, and 996 Hz. The output of the data selector (U5) is connected to one of the open collector drivers in U1 whose output is connected to the alarm light and the speaker. Both the alarm light and the speaker have +12 VDC applied to their other terminals. When an alarm tone is selected, U1 sinks current at the selected frequency. The resistors R2 and R7 limit power dissipation in the alarm light and speaker respectively.

The data selector receives the address information from U11, a four bit latch. To output an alarm tone, the µP writes the tone information to external address 5000 Hex. This causes the control line decoder to pulse the SOUND line high. This signal is AND'ed with the WR signal from U9 pin 12 and the tone information is latched into U11 from the three least significant bits of the address/data bus. The output of U11 remains constant until another write to it occurs, thus a tone will continue to sound until it is deliberately turned off by the µP.

3.2.5 Watch Dog Timer

The primary function of the WATCH DOG TIMER (WDT) is to detect timing errors of the µP (U14). If the WDT detects an error, the WDTFAIL is latched low which causes relay K1 to de-energize and the µP interrupt line at pin 12 to be pulled low. If the condition which caused the faulty timing in the µP is not too severe, the unit will output a 996 Hz alarm tone and display a help code on the front panel displays.

The basic operation of the WDT is relatively simple. The software has one main loop that is begun every 37 mSec. At the beginning of every loop the WDTSTB signal eminates from pin 14 of the µP. The WDT is reset by this 3.3 µSec negative pulse. There is a timing window implemented in the WDT such that if the pulse occurs too soon or too late the WDT fails. The maximum period is 40 mSec. The minimum period is 33 mSec.

The main portion of the WDT is implemented in a programmable array logic (PAL) chip (U3). This chip contains decoding logic as well as latched registers. Because the WDTSTB signal can occur randomly, the signal is first synchronized to the 500 KHz clock entering U3 at pin 1 (see Figure 3.3). Capacitor C1 and pull up resistor R6 ensure that the WDTSTB pulse eventually goes high even if the µP were to fail in the middle of outputting the signal. The WDTSTB pulse can be observed at TP1. It is inverted by part of U9 and used to reset the frequency divider U4 at the same time it resets U3. Thus all timing relationships begin from one zero point.

The timing window in the PAL is implemented as follows (please see Figure 3.4): A WDTSTB is synchronized by the PAL and the output STB is used to reset the latched outputs Q1 and Q2 (pins 13 and 14 of U3). At the same time, the WDTSTB pulse resets frequency divider U4 whose outputs Q10 and Q12 are connected to inputs J1 and J2 of the PAL (pins 8 and 9). The frequency divider then commences to count and eventually J1 and J2 are present. J2 is ignored by the PAL until J1 has gone high. When J1 does go high this causes latched output Q1 to go high and stay there until a STB pulse resets it. After Q1 goes high the next low to high transition of J2 will cause Q2 to latch high also. In part A of Figure 3.4 it is seen that the STB pulse occurs at its normal 37 mSec interval and J1, J2, Q1, and Q2 are all reset. In part B the STB pulse occurs outside of the timing window and both Q1 and Q2 are latched high. This causes the WDTFAIL line to latch low and further STB pulses are ignored. The WDTFAIL line interrupts the processor, causes the valve relay to open, and cannot be reset without removing power to the unit. Thus a timing error causes the unit to fail in a nonrecoverable "safe" condition where the valves seal the cuffs off.

It is also possible to have a STB pulse occur too early, before Q1 is high. If this occurs the WDTFAIL line is also latched low until power is removed.

In order to test the WDT, the PAL does not implement the permanent latching of the WDTFAIL line until after it senses a logic high at pin 12. This signal is a delayed sample of the relay switched +12V power to the valves. Right after power-up, but before enabling the relay with the VALVENA signal, the µP tests the WDT by varying the timing of the WDTSTB pulses and looking at the WDTFAIL line. If the WDT passes all of the tests the µP enables the relay. Resistors R4 and R5 insure that the voltage at pin 12 of U3 does not rise above +5V. Capacitor C19 insures that

Figure 3.3 $\overline{\text{WDTSTB}}$ Synchronization

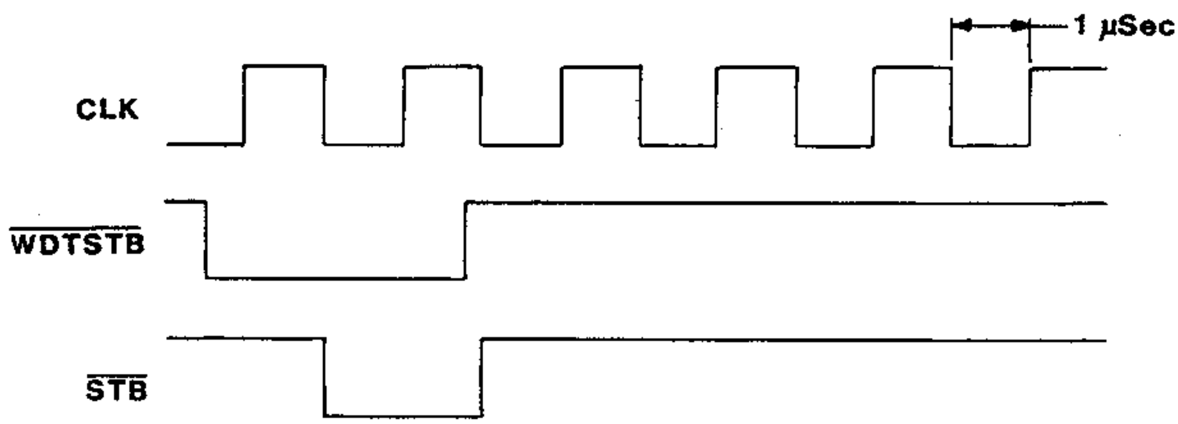
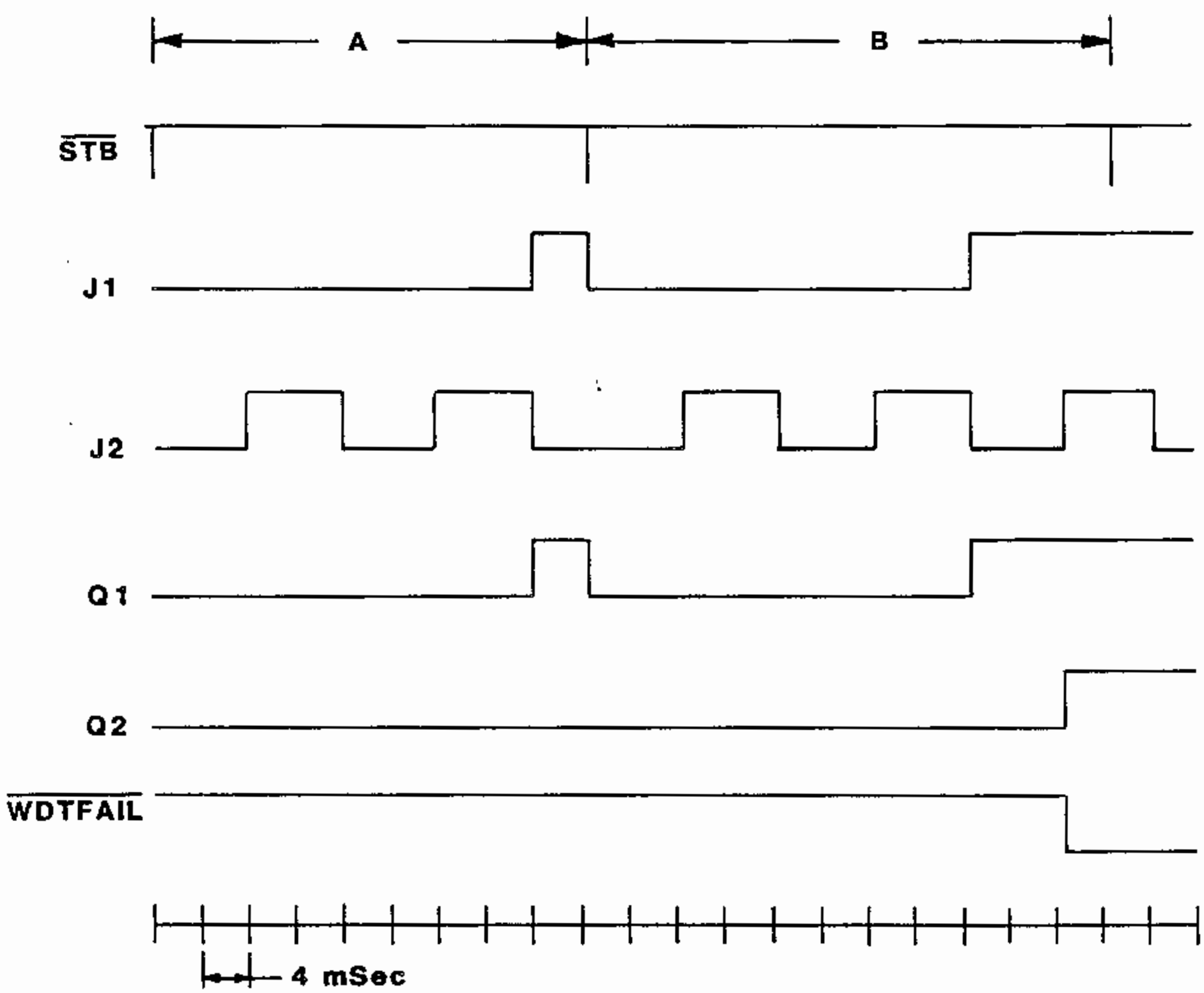


Figure 3.4 WDT Timing Diagram



the voltage at pin 12 rises more slowly than the voltages sensed from the valves. This insures that the inductive effects of the valves powering up are not sensed as failures by the PAL (please see Section 3.2.10 for more information on sensing valve failures). When pin 12 does reach a logic high, the PAL will then react to any timing error by latching the $\overline{\text{WDTFAIL}}$ line low.

3.2.6 Displays
The displays (I4 through I10) are common-anode, 7-segment, high efficiency LED displays used to convey data and error messages to the operator. I7 through I10 are referred to as the PRESSURE display while I4 through I6 are the TIME display. The anode drive, supplied to pins 3 and 8 of each display, is about 200 mA per digit at a duty cycle of about 12%. The display scan rate is approximately 250 Hz. The LED driver system (U13) also includes a memory and decoding for BCD, minus sign, blanking, and a HELP display. The MODE input of U13 (pin 9) must float for proper decoding. The display digit to be accessed is selected via the address inputs A0, A1, and A2. The display data is presented on inputs DA0, DA1, DA2, and DA3. The µP sends out an 8 bit word using an external write to location 3000 Hex. The control line decoder activates the DISPLAY control line which is NAND'ed to the WR line in one quarter of U6 causing $\overline{\text{WE}}$ to go low. The display chip (a 7218C) latches the address and data information off of the address/data bus and displays it on the correct digit until new data is written to that digit.

The decimal point drivers of I7 through I10 are used to drive the four segments of the PRESSURE SUPPLY LOW indicator. A quarter of NAND gate U6 is used to invert the decimal point data line so that a low active signal is available to the $\overline{\text{DP}}$ line of U13.

3.2.7 Switches and the Switch Latch
There are ten control switches on the A.T.S. 500. They are all implemented as +5 volt pull up lines that are grounded when a switch is activated. The resistor network RN5 provides the current limited pull up function. The eight most commonly used switch signals are connected to the switch latch (U12) which is an ALS-573. The switch is periodically read by the µP via a read from external memory instruction. The address of the switch latch is 8000 Hex which is decoded by the control line decoder (U7). The resulting SWITCHES control line is NAND'ed with the RD signal from U9 pin 2 to generate the output enable ($\overline{\text{OE}}$) signal and inverted to generate the ENA signal for the switch latch. The µP then reads the switch data from the address/data bus (AD0 through AD7). The remaining two switch lines go into pins 10 and 11 of the µP where their status can be read directly.

3.2.8 Pressure Transducer and Amplifier
In the A.T.S. 500, pressure is sensed by XDCR1, a double-ended silicon diaphragm pressure transducer. The transducer, along with its signal conditioning circuitry, converts sensed pressure into two proportional analog voltages which are translated by the A/D converter and used by the µP in the pressure control algorithm.

The transducer is supplied with a set of selected compensation resistors which either reside on the PWB as R101 through R105 or are included on a ceramic substrate attached to the bottom of the pressure transducer. The transducer and its associated resistors must always be replaced as a set.

The transducer has a full scale range of 500 mmHg. Its outputs are the voltages measured at TP4 and TP7. The transducer has a span of 120 mV with a null offset of -60 mV. A nominal excitation of 1.5 mA is supplied to the transducer by the constant current source comprised of Q1, one half of U20 and some associated resistors. The gain (SPAN) of the transducer, in mV/mmHg, is adjustable by verying this constant current excitation via R28. With zero gauge pressure applied to the transducer, its output is nominally -60 mV (V_{TP4} - V_{TP7}). The transducer is nulled at a gauge pressure of 247 mmHg.

The output of the pressure transducer appears at the input of a differential instrumentation amplifier comprised of U19, U21, and the second half of U20. The gain of U19, and U21 are set at 80 by R16/R19 and R22/R18 respectively. Capacitors C16 and C18 provide single pole, low pass filtering. Offset errors contributed by the transducer and amplifiers U19 and U21 are adjusted out by potentiometer R23 which is labelled ZERO. This is done with the transducer nulled (247 mmHg of pressure applied) during the calibration procedure. The level of the common mode output voltage of U19 and U21 is set by potentiometer R27 which is labelled COMMON MODE.

The outputs of U19 and U21 are supplied as inputs to the A/D convertor (U16) on pins 27 and 26 respectively. With zero pressure applied to the transducer, the nominal voltages at TP8 and TP5 are 98 mV and 4.902 V respectively. The differential voltage (V_{TP8}-V_{TP5}) is zero with a pressure of 247 mmHg applied to the transducer.

The A.T.S. 500 achieves an effective 9 bit resolution in sensed pressure readings despite the fact that it uses an 8 bit A/D converter. This patented method is accomplished by lowering the common-mode voltage at TP5 and TP8 by the equivalent of ¼ bit. This appears as a ¼ bit increase at TP5 and a ¼ bit decrease at TP8, or a ½ bit shift in the voltage V_{TP8}-V_{TP5}. The advantage of this method is that the digitized equivalent of the quantity (V_{TP8}-V_{TP5}) changes value when the pressure input changes only ½ bit of the resolution of the 8 bit A/D converter, hence the result is effectively 9 bit resolution.

3.2.9 A/D Convertor
The A/D Convertor (U16) is an 8 bit, 8 input, CMOS, microprocessor compatible device. The 8 bit address/data bus is connected to the data port on the A/D convertor, and the 3 least significant bits of the address/data bus (AD0, AD1, AD2) are connected to the 3 address lines of the convertor. The two analog voltages from the transducer amplifier are connected to IN0 and IN1 of the convertor and IN2 is connected to a signal called VFAIL which is normally about 2.5 volts and drops to 0 volts when an improper combination of valves has occurred. The CLK (pin 10) receives a 1 MHz clock signal from the frequency divider U10.

The microprocessor begins a data conversion by first outputting an address to the A/D convertor. The address describes the input pin from which U16 takes the signal to convert. The 3 least significant bits of the data output by the μP become the address for U16. Thus 001 would cause the A/D convertor to sense IN1 (the voltage from TP8 at pin 27). The μP outputs the information by writing it to external address 7000 Hex. The control line decoder pulses the A/D read line which is AND'ed with the WR signal from U9 in ¼ of U8 and then pulses the ALE line (pin 22) of the convertor. Thus the data is latched into the three address lines of the converter. To begin the actual conversion, the μP writes a zero to address D000 Hex which causes the control line decoder to pulse the A/D START line connected to pin 6 (START) of the convertor. With the 1 MHz clock the conversion takes approximately 100 μSec. The μP has a software wait loop while the conversion takes place. To read the 8 bit result, the μP does an external read from location 9000 Hex which causes the control line decoder to pulse the A/D read line high. When this is AND'ed with the RD signal from U9 in ¼ of U8, the result brings the output enable line of U16 (pin 9) high long enough for the data to be presented on the address/data bus and read by the μP.

3.2.10 Valves and Valve Relay
The six valves in the A.T.S. 500 are driven by open collector drivers connected directly to port 1 of the μP (pins 1 through 8). Resistor network RN1 provides a pull up for each driver to insure it turns on fully and quickly when the μP requests it. The SENSE/CALIBRATE valve (V6 in the Block Diagram Figure 3.1) receives +12 VDC power at all times when the unit is turned on. The other five valves only have +12 VDC power when the relay K1 is activated. During power up, if the μP completes all of its self checks without sensing an abnormal condition it brings the VALVENA line low. At this time the $\overline{\text{WDTFAIL}}$ line is high. After being inverted in ¼ of U15, the VALVENA line is NAND'ed with the $\overline{\text{WDTFAIL}}$ line in another gate of U15. Thus with no failure conditions, pin 3 of U15 is low. This is inverted in another quarter of U15 and the resulting logic high signal causes an open collector driver in U1 to turn the relay on. All of the valves now have +12 VDC power. If there is a failure due to the WDT timing out or an abnormal combination of valve actuations, the $\overline{\text{WDTFAIL}}$ line will go low and stay there. This causes the logic signal to the relay driver to go low and stay there. With the relay off and no valve power available to them, the five critical valves all go into a "safe" failure position to seal the cuffs off and prevent pressure loss.

An abnormal combination of valve actuations is sensed by U3 which receives a logic level voltage for each valve from the resistor dividers in RN2, RN3, and RN4. With a valve off, +12 VDC is present at the divider and is lowered to approximately 4.4 VDC which can be sensed by U3. If the μP requests an improper combination of valve actuations or if one of the valve drivers fails "on", U3 senses it and latches $\overline{\text{WDTFAIL}}$ low while also bringing VFAIL low. When the μP processes the interrupt brought about by the $\overline{\text{WDTFAIL}}$ line going low, it reads from analog input IN2 of the A/D converter. If it finds 0 V then it knows the failure is due to a valve problem (HELP -4-). If it finds approximately 2.5 volts then the problem is WDT related (HELP -6-).

MAINTENANCE

SECTION 4.0

A.T.S. 500

4.1 GENERAL MAINTENANCE INFORMATION
While the A.T.S. 500 has been designed and manufactured to high industry standards, it is recommended that periodic inspection and calibration be performed to ensure continual safe and effective operation. This section contains information intended to assist in that effort as well as serve as a guide to expediting unscheduled maintenance.

The unit is organized into easily accessible modular assemblies for ease of service. The major subassemblies of the unit are shown in Figures 4.1 through 4.5

4.2 ACCESS TO PARTS
CAUTION: BE CERTAIN THAT THE UNIT IS TURNED OFF AND THE POWER CORD IS UNPLUGGED BEFORE DISASSEMBLY.

CAUTION: MANY OF THE PARTS ON THE A1 PWB ASSEMBLY ARE STATIC SENSITIVE. TAKE APPROPRIATE PRECAUTIONS WHEN SERVICING THIS BOARD.

Access to all internal parts except the A1 PWB is accomplished by removing two screws from each side of the unit and lifting the Front Panel Assembly away from the Rear Panel Assembly. The Front Panel Assembly may be turned over and laid on its face beside the Rear Panel Assembly. Figure 4.5 shows the unit in this configuration.

To gain access to the A1 PWB assembly:

a)Disconnect the tubing from the OUT (or COM) port of Valve V6 (See Figure 4.4). Do NOT attempt to disconnect this tubing at the end going through the Valve Cover Assembly. Damage to the pressure transducer may result. To preclude tubing damage, always use your fingers to connect and disconnect the tubing.

b)Disconnect the tubing at the two cuff connectors.

c)Disconnect the tubing from the Pressure Regulator assembly to Valve V1.

d)Disconnect the Valve Cover Wire Harness at the connector on the A1 PWB.

e)Remove the four screws securing the Valve Cover Assembly. The assembly may now be carefully lifted to expose the A1 PWB.

To completely separate the two halves of the unit, disconnect the lower two power wires from the ON/OFF switch and disconnect the wire harness that connects the power supply to the A1 PWB.

4.3 PERIODIC MAINTENANCE

4.3.1 Cleaning
The interior of the unit may be vacuumed or blown out as required. The exterior of the unit may be cleaned by wiping it with a cloth that has been dampened (not dripping) with a mild detergent such as Windex® or 409®. Windex is the registered trademark of the Drackett Products Com-

Figure 4.1 A1 Printed Wiring Board Assembly

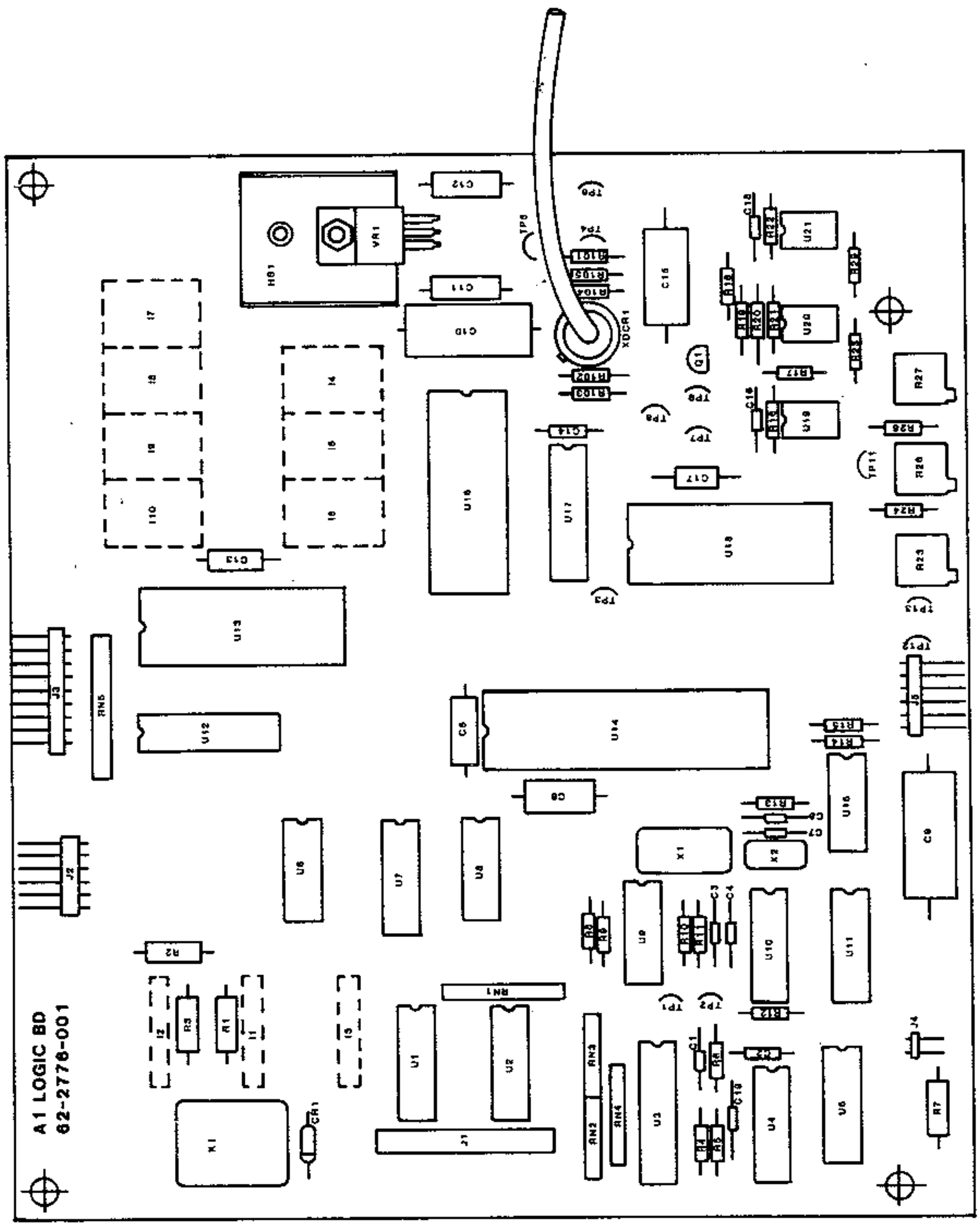


Figure 4.2 Rear Panel Assembly

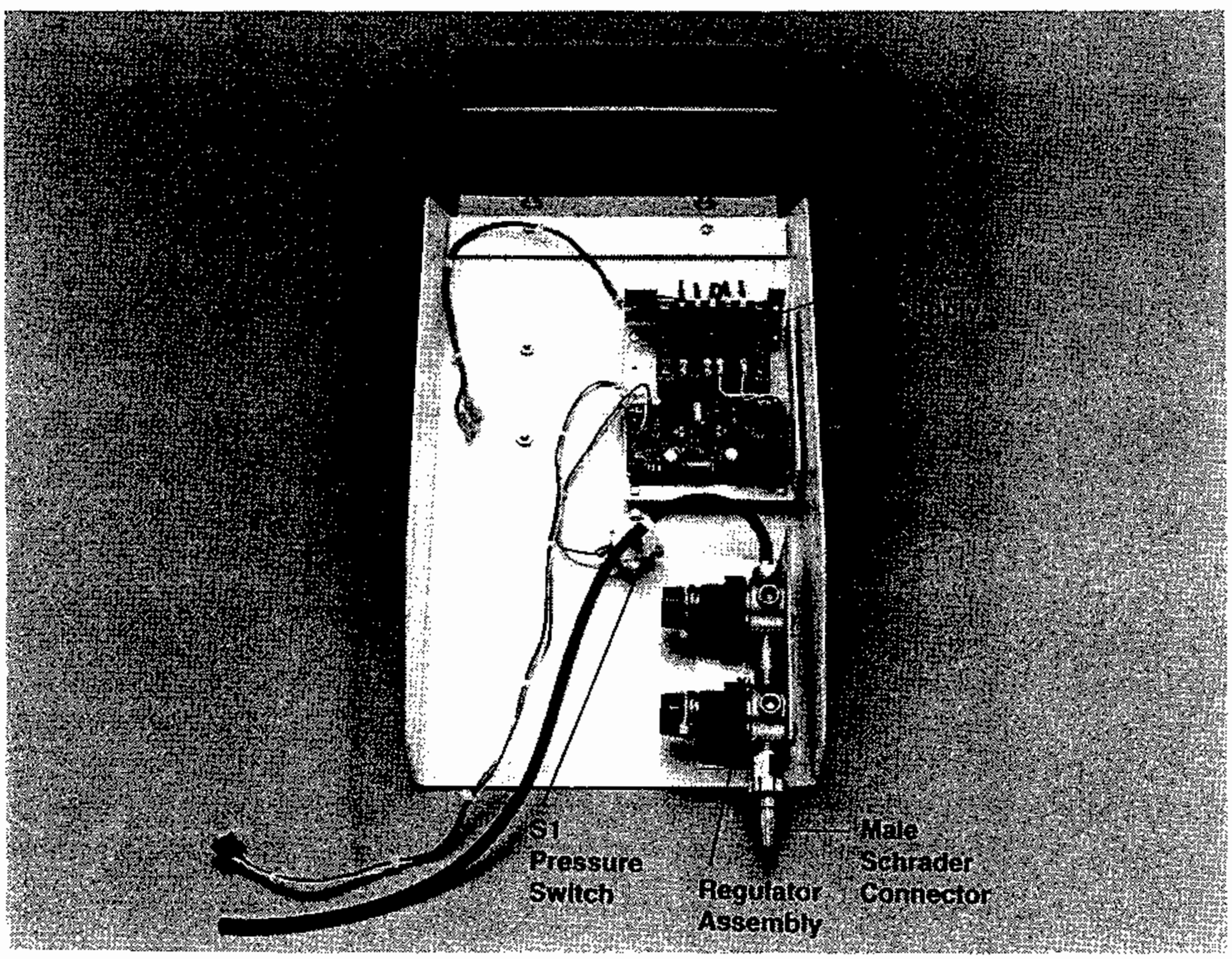


Figure 4.3 Front Panel Assembly

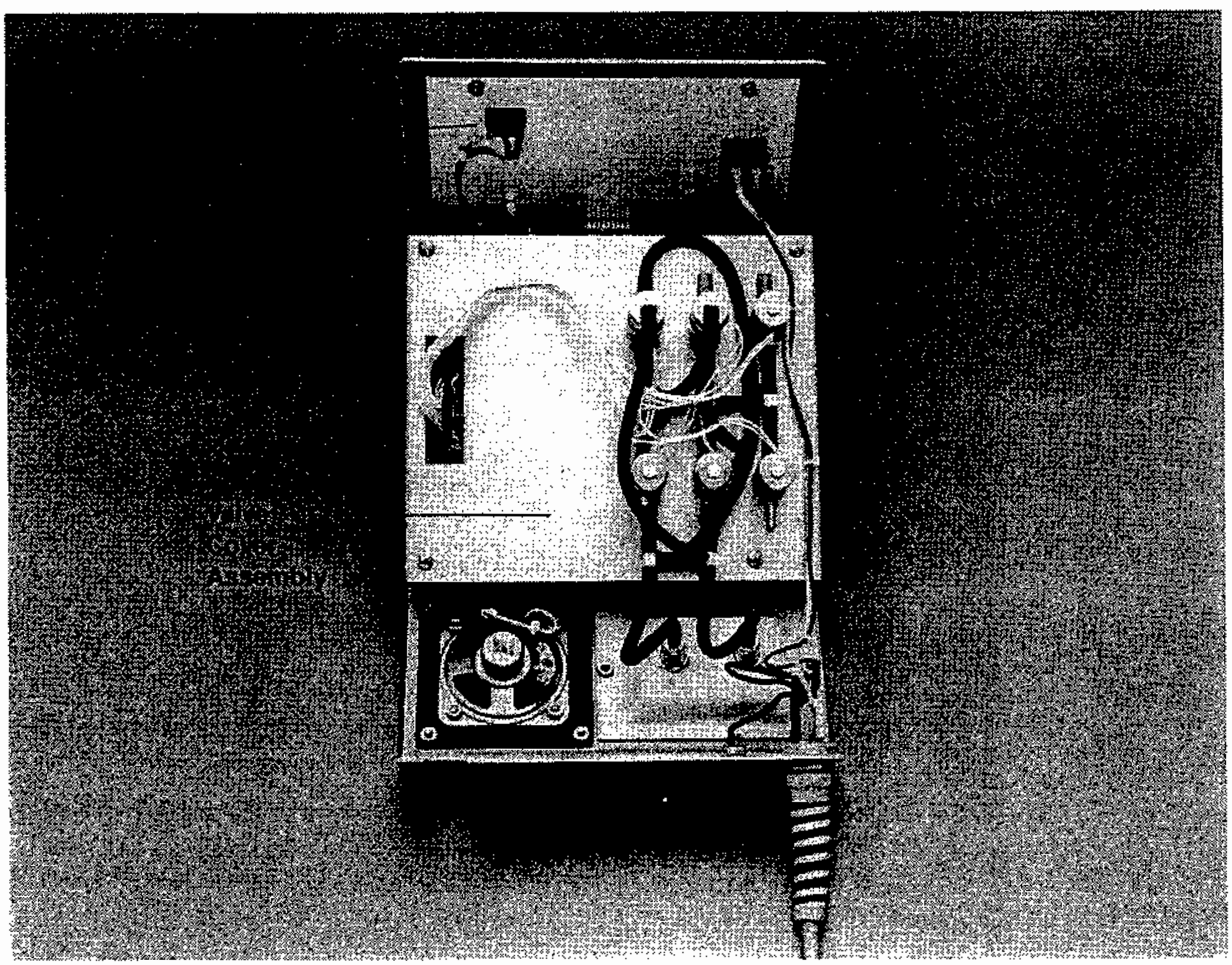


Figure 4.4 Valve Cover Assembly

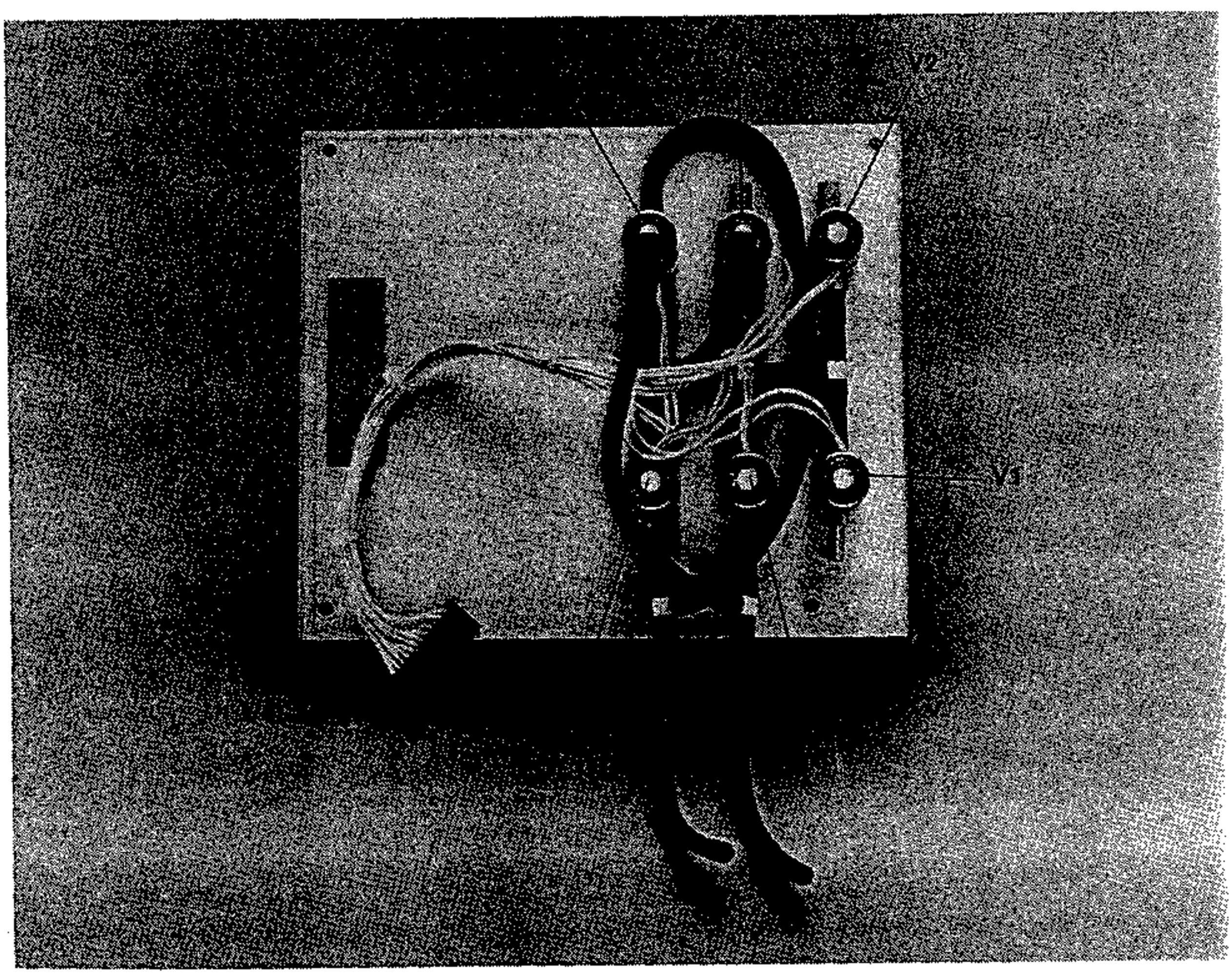
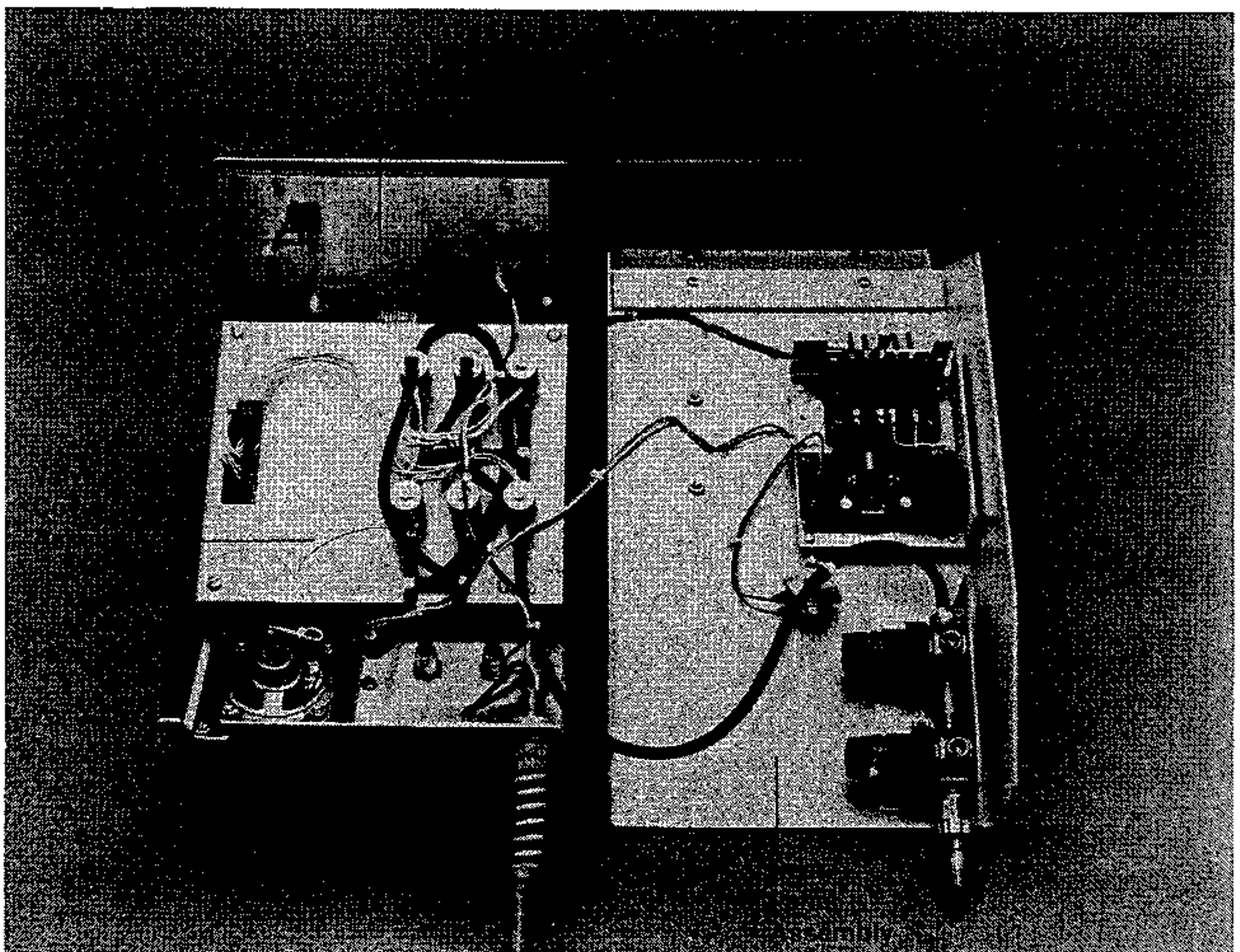


Figure 4.5 Front and Rear Assemblies



Company. 409 is the registered trademark of the Clorox Company.

Accessories of the A.T.S. 500 should be cleaned in accordance with their individual instructions.

4.3.2 Inspection

The unit should be inspected at regular intervals. We recommend that a visual inspection be performed by a qualified technician at least every six months. Points to be included in the inspection are:

- Obvious internal or external damage.
- Condition of the power cord.
- Tightness of the power plug and power cord strain relief.
- Tightness of pneumatic fittings.
- Condition of tubing.
- Accumulation of debris within the unit.
- Mating integrity of internal connectors.
- Security of the microprocessor (A1U14) and the EPROM (A1U18) in their sockets.
- Integrity of the cuff tubing O-Rings.

4.3.3 Functional and Calibration Check

In addition to the internal calibration check that the unit performs during each power-up sequence and the other periodic maintenance steps outlined by this section, it is recommended that Functional and Calibration checks be performed as described in paragraph 2.2. It is suggested that this check be performed on at least a quarterly basis.

4.3.4 Calibration

Calibration of the A.T.S. 500 consists of a series of tests during which a maximum of three potentiometers will require adjustment. The pressure transducer signal conditioning circuitry can be calibrated externally by inserting an adjustment tool through the holes provided just above the cuff connectors. See Figure 4.6.

The unit's software contains an instruction set for the Calibration Mode that is independent of the normal operating software. Within the Calibration Mode, individual subroutines may be called to perform specific calibration tasks. These subroutines are entered by appropriate operation of the unit's touch switches. The functions of each of these switches is described in Table 4.1. The Calibration Mode is entered by depressing the TIME DECREASE and PRESSURE DECREASE switches while the ON/OFF switch is set to the ON position. It is recommended that the unit remain in the initial calibration idling position for aty least ten minutes to allow the components to reach operating temperature. To return to normal operation, momentarily set the ON/OFF switch to OFF.

RECOMMENDED CALIBRATION INTERVAL: Every 6 months. Calibration should also be performed after any unscheduled maintenance and in the event that the unit fails self-test.

EQUIPMENT REQUIRED:

1. Manometer, 0-300 mmHg
2. Calibration Kit, Aspen Catalog No. 60-1468-002

NOTE: Since the calibration adjustments are interactive to some extent, calibration should be performed in the sequence shown to minimize reiteration.

4.3.4.1 Transducer Zero (R23)

A. Internal Pressure Source

1) Connect a 0-300 mmHg manometer to the output ports of the unit using the "T" hose assembly (See Fig. 4.7) of the 60-1468-002 Calibration Kit. Verify that the valve of the "T" hose assembly is fully closed.
2) Connect the power cord to an appropriate power receptacle. Connect a pressure source to the unit.
3) Enter the Calibration Mode.
4) Verify that the PRESSURE display reads 0000 and the TIME display reads -2-. It is recommended that the unit be allowed to warm up in this mode for at least ten minutes to allow the components to reach operating temperature.
5) Press the TIME DECREASE switch and verify:
   a. The TIME display reads 247.
   b. The manometer reading increases to the vicinity of 247 mmHg.
6) Using the adjustment tool provided in the Calibration Kit, adjust R23 (ZERO) until the PRESSURE display and manometer are in agreement (within 1 mmHg) with the TIME display. Allow about 10 seconds of settling time between successive adjustments.

B. External Pressure Controller

This procedure is an alternative method to 4.3.4.1A. This more accurate method is used during factory calibration and is recommended if the equipment is available. Equipment required is a precision pressure source capable of maintaining 247 mmHg. One such arrangement is a pressure controller, an actuator, a precision pressure transducer and a pressure display device. This mode may be entered by pressing the TIME INCREASE switch. The precision pressure source should be adjusted to 247 mmHg and connected to the unit's cuff connectors. The TIME display of the unit will read -5- and the PRESSURE display will read SENSED PRESSURE. Adjust R23 (ZERO) until the PRESSURE display reads 247 mmHg. Consult the factory for more detail on equipment requirements.

Figure 4.6 Calibration Adjustment Locations

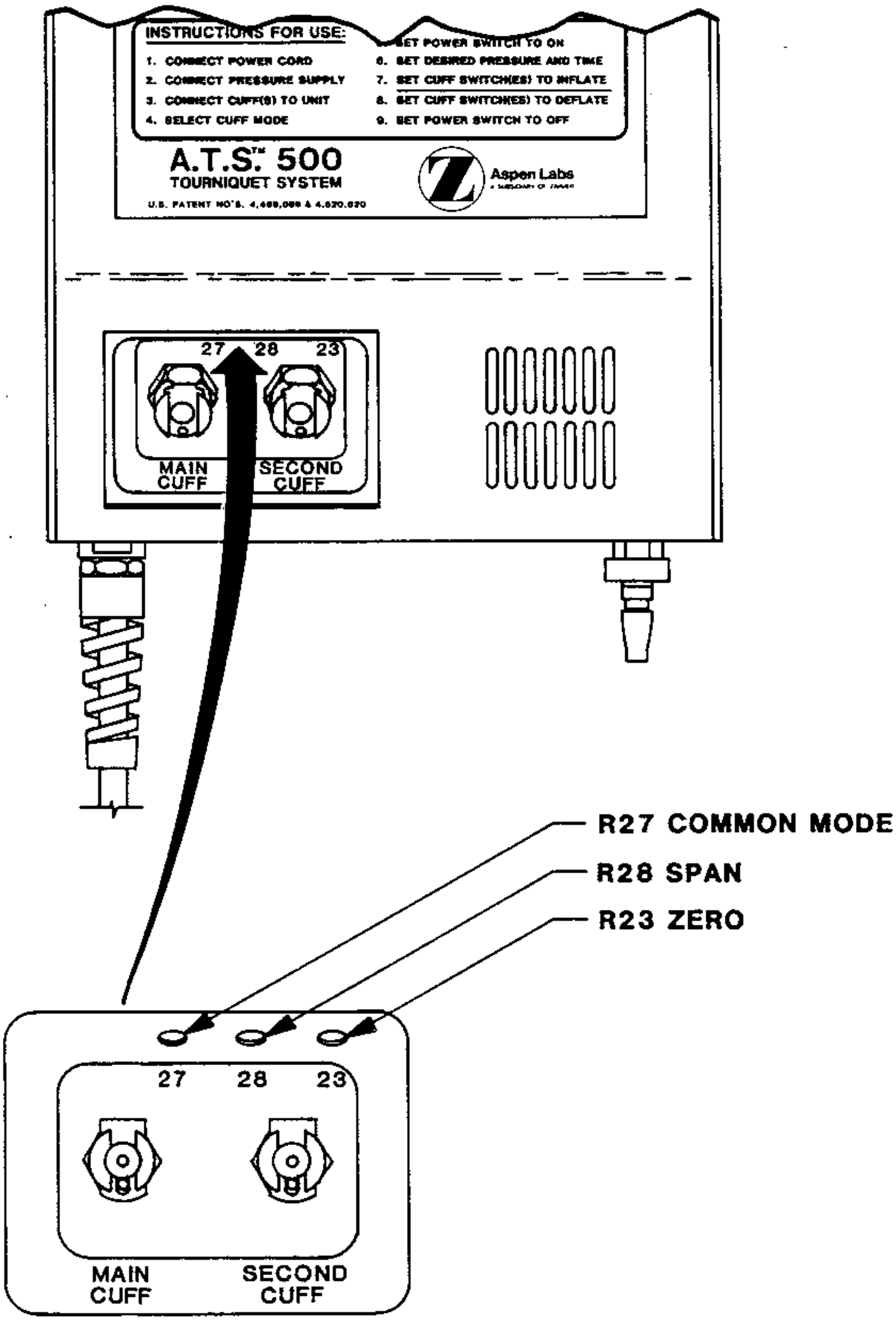
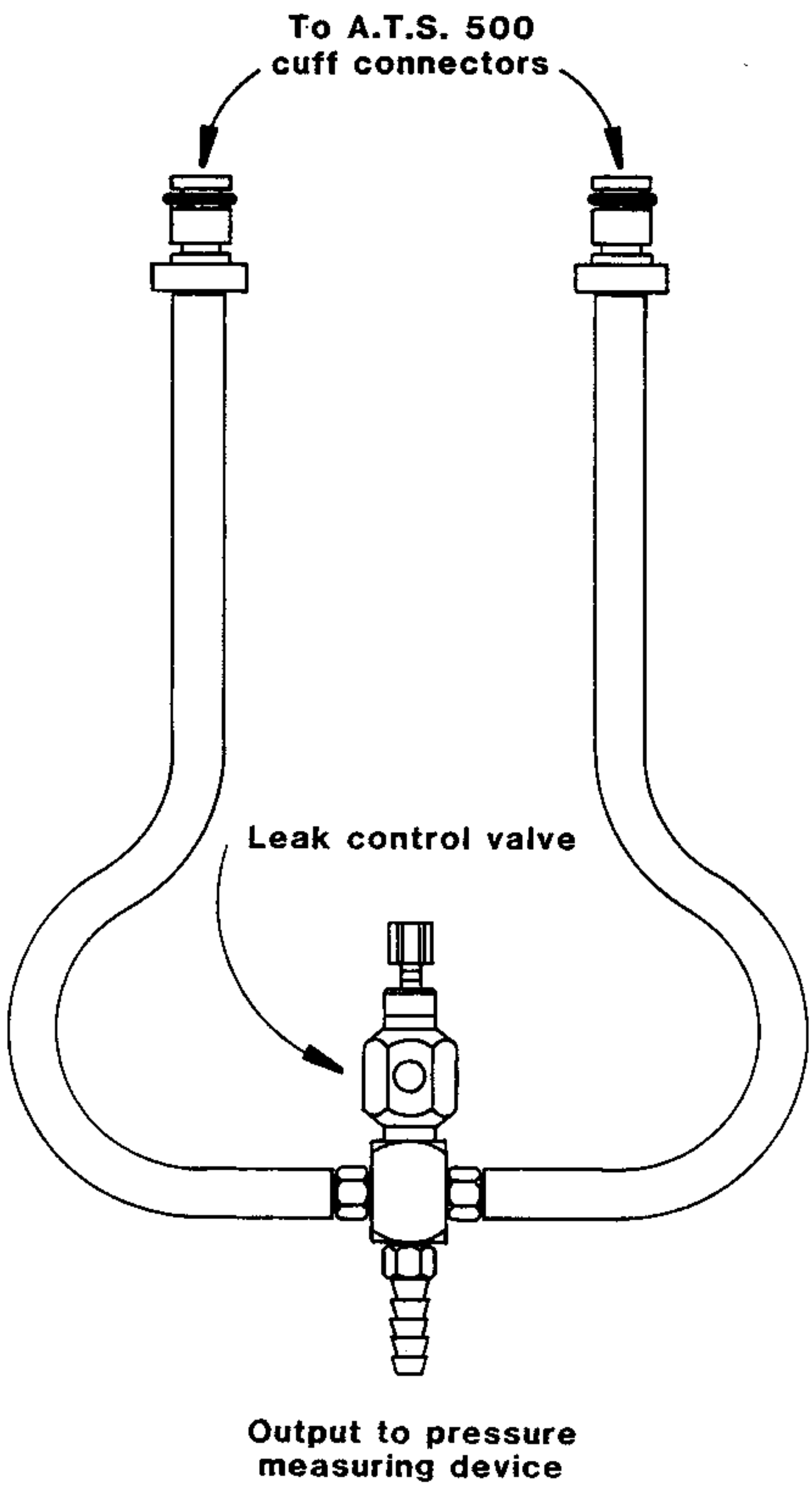


Figure 4.7 Calibration Kit: "T" Hose Assembly



4.3.4.2 Common Mode

CAUTION: The voltage at TP5 and TP8 with respect to TP13 must be kept lower than the voltage at TP6. Failure to do so may result in damage to the unit. Adjust R27 quickly to correct this condition. If R27 is ever replaced, it should be preset to its midpoint before applying power to the transducer circuitry. The voltages at TP5 and TP8 are nominally 2.50 VDC when 247 mmHg is applied, and should be given a quick check anytime repairs are made to the transducer signal conditioning circuitry.

1) Connect a manometer, cuff or suitable accumulator to the cuff connectors of the unit using the "T" hose assembly from the Calibration Kit.
2) Verify unit is in calibration mode (see section 4.3.4).
3) Momentarily press the PRESSURE DECREASE switch to enter the Common-Mode sequence.

In this sequence the unit will operate when sensed pressure is less than 240 mmHg and will turn off when pressure reaches 260 mmHg. The TIME display will be displaying a numerical value in the range of 120 to 140 that is proportional to the voltage at TP8. The PRESSURE display will be displaying a value, in the same range, proportional to the voltage at TP5.

4) Using the Leak Control Valve of the "T" hose assembly, create a small leak in the system. This will cause the readings on both displays to fall slowly.
5) Adjust R27 such that while the unit is not inflating, the TIME and PRESSURE readings are the same. This is not the final setting.
6) Closely observe the TIME and PRESSURE displays while carefully adjusting R27 until the TIME display appears to "lead" the PRESSURE display by 50%. That is, as the pressure slowly falls, the time interval that the TIME display reads ONE LESS than the PRESSURE display is equal to the interval that they are the SAME. It may be necessary to adjust the Leak Control Valve to facilitate this adjustment. Refer to Figure 4.8 for a graphic representation of this display sequence with R27 properly adjusted.

4.3.4.3 Span Adjustment (R28)

This adjustment sets the sensitivity (Gain) of the pressure transducer, XDCR1.

1) Disconnect any external lines to the cuff connectors.
2) Verify unit is in calibration mode (see section 4.3.4).
3) Press the CUFF DEFLATE switch. Observe that the TIME display reads -4-. The PRESSURE display will be showing sensed pressure (atmosphere).
4) Adjust R28 until the PRESSURE display reads 0 at about midway between those positions that cause readings of 1 and -1 mmHg.

4.3.4.4 Iteration of Adjustments

Due to the interactive nature of the adjustments, repeat steps 4.3.4.1 through 4.3.4.3 until all steps are within specifications without making further adjustments.

Figure 4.8 Common-Mode Display Sequence

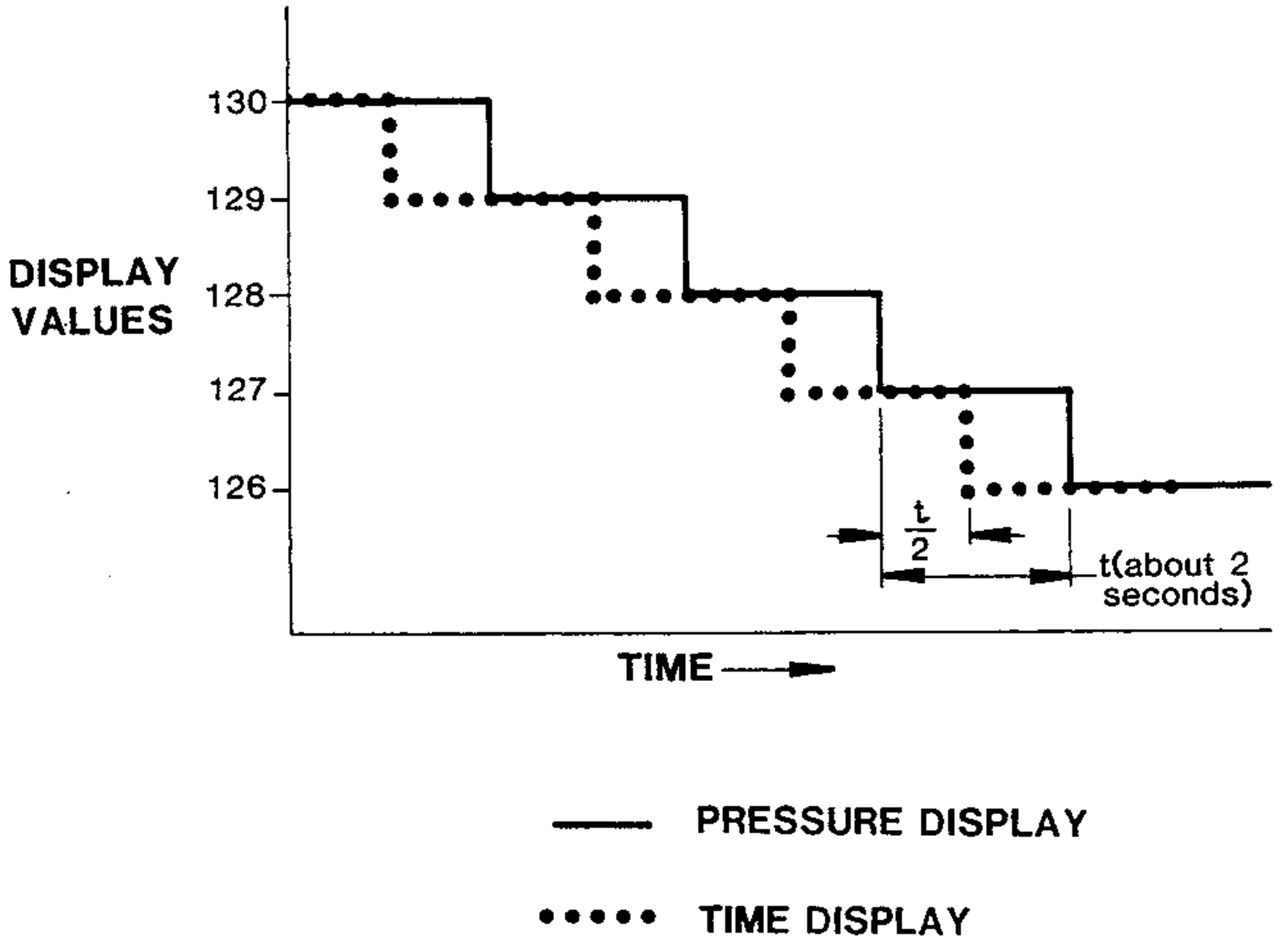


Table 4.1 Switch Functions & Display Indications in the Calibration Mode

Switch Action	Pressure Display	Time Display	Calibration Mode
NONE	0000	-2-	Waiting for a command. No specific subroutine entered
TIME DECREASE SWITCH PRESSED	SENSED PRESSURE	247	Transducer zero with internal pressure controller.
TIME INCREASE SWITCH PRESSED	SENSED PRESSURE	-5-	Transducer zero with external pressure controller.
PRESSURE DECREASE SWITCH PRESSED	Numerical conversion of positive side of transducer output. Display range = 120-140	Numerical conversion of negative side of transducer output. Display range = 120-140	Transducer Common-Mode
MAIN CUFF DEFLATE SWITCH PRESSED	SENSED PRESSURE	-4-	Transducer Span
MAIN CUFF INFLATE SWITCH PRESSED	SENSED PRESSURE	Set pressure alternates between 195 and 395 mmHg every 2 min, 20 sec.	Factory Test
PRESSURE INCREASE SWITCH PRESSED	37	-6- or -7-	Normal WDT strobe timing of 37 mSec.
SECOND CUFF INFLATE SWITCH PRESSED	43 or HELP	-6- or -7-	Long WDT strobe timing of 43 mSec.
SECOND CUFF DEFLATE SWITCH	30 or HELP	-6- or -7-	Short WDT strobe timing of 30 mSec.

NOTES:
1. This table assumes that the Calibration Mode has been entered by pressing the TIME DECREASE and PRESSURE DECREASE switches while the ON/OFF switch is set to ON.
2. To exit the Calibration Mode, momentarily set the ON/OFF switch to OFF.

Table 4.2 Expected Test Point Readings

Test Point	Nominal Reading	Tolerance	Conditions/Comments
TP1	3.3 μSec Negative Logic Pulse with 37 mSec. Period	± 2.5 mSec on Period	$\overline{\text{WDTSTB}}$ Signal
TP2	2 MHz Square Wave	± 2 KHz	Master Oscillator for PAL, A/D, and Alarm Tone Frequencies
TP3	0.56 μSec. Positive Logic Pulse. 1.68 μSec Period	N/A	ALE Signal. Changes period when external read or write performed.
TP4	+ 4.49 VDC	± 0.01 VDC	After proper calibration with 0 mmHg Sensed Pressure.
TP5	+ 4.907 VDC	± 90 mVDC	After proper calibration with 0 mmHg Sensed Pressure.
TP6	+5.0 VDC	±0.1 VDC	+5 V Power Supply
TP7	+ 4.43 VDC	± 0.01 VDC	After proper calibration with 0 mmHg Sensed Pressure.
TP8	+ 83 mVDC	± 2.0 mVDC	After proper calibration with 0 mmHg Sensed Pressure.
TP9	+ 0.33 VDC	± 0.60 mV	Subject to SPAN adjust. Values are after Calibration.
TP10	N/A	N/A	Not used.
TP11	+ 0.33 VDC	+ 96 mVDC - 121 mVDC	Tolerance due to maximum adjustment range.
TP12	+ 12.0 VDC	± 0.1 VDC	+ 12 volt supply
TP13	0.0 VDC	N/A	Ground

NOTE: ALL MEASUREMENTS ARE MADE RELATIVE TO GROUND WHICH IS FOUND AT TP13.

4.3.5 Watch Dog Timer Test

A. If this test follows one of the previous tests (Section 4.3.4.1 through 4.3.4.3) then the WDT circuitry has already been activated and you should proceed as follows.
   1) Press the PRESSURE INCREASE switch.
   2) The pressure display should show 37 (representing 37 mSec) and the time display -7-
   3) Press either the SECOND CUFF INFLATE or DEFLATE switch.
   4) The pressure display should show HELP and the time display -6-. The unit should emit a high pitched tone.
   5) The tone can only be silenced by turning the unit off.
   6) If the unit acted as described, the WDT circuitry is operating correctly.

B. If the test is done immediately upon entering the calibration mode the WDT circuitry is inactive and the test will proceed as follows:
   1) Press the PRESSURE INCREASE switch.
   2) The pressure display should show 37 (representing 37 mSec) and the time display -6-
   3) A 3.5 μSec negative going pulse may be observed at TP1 occuring at 37 mSec intervals.
   4) Press the SECOND CUFF INFLATE switch.
   5) The pressure display will show 43 (representing 43 mSec) and the time display -6-.
   6) The timing of the WDT strobe pulse at TP1 will change to 43 mSec.
   7) Press the SECOND CUFF DEFLATE switch.
   8) The pressure display will show 30 (representing 30 mSec) and the time display -6-.
   9) The timing of the WDT strobe pulse at TP1 will change to 30 mSec.

Part A is the correct test procedure to completely verify correct WDT operation. Part B of this test exercises part of the WDT circuitry and tests the timing of the microprocessor.

4.3.6 Leak Testing

The A.T.S. 500 is capable of keeping a cuff inflated with a substantial leak. Naturally is is desirable to keep internal plumbing leaks to an absolute minimum. For this reason, a check for significant leakage is recommended following any service procedure.

After verification of the operation of the A.T.S. 500, connect both cuff connectors to an accumulator or cuff. Set the desired pressure to 475 mmHg. Ensure that all the external connections are tight. Inflate both CUFFS. After the sensed pressure reading settles, set the ON/OFF switch to OFF. Set the ON/OFF switch back to ON after 10 minutes. Operation will resume under Cuff Inflated Start-Up conditions. Cancel the alarm with the Alarm Silence pushbutton. Activate the Pressure switch in either direction for 1 second. The pressure display should indicate no less than 400 mmHg. Lower values of pressure indicate a greater leak rate than is desirable.

4.4 UNSCHEDULED MAINTENANCE

The A.T.S. 500 is designed with several specific self-test features to assist in fault isolation. These features are designed to show a "HELP" message in the PRESSURE display along with a number in the TIME display. The meanings of these error codes are delineated in Tables 2.1 and 2.2.

Another particular mode of failure may occur in which a high pitched tone occurs that cannot be silenced by the ALARM SILENCE pushbutton. The valves will be disabled (the cuffs will not deflate or inflate). The displays may appear to show random numbers. If this occurs, the watchdog timer has detected a timing error by the microprocessor. The valves are disabled by the watchdog timer hardware. The microprocessor is not executing reliable instructions, and is not able to lock itself up with the "HELP -6-" display. This failure mode and all errors giving a "HELP" display might be cleared by cycling the ON/OFF switch.

The calibration error code, HELP -0-, may occur due to faulty circuitry, or may simply indicate the need for calibration.

The watchdog timer error code, HELP -6-, may be activated by faulty watchdog timer circuitry, by improper microprocessor timing, or by a +12 V power supply level that is too low to maintain reliable operation.

4.4.1 Troubleshooting Guide

To further aid in unscheduled maintenance, the following list delineates a number of possible malfunctions that could occur with the unit. The most likely causes are shown for each symptom. While it is not practical to enumerate every conceivable malfunction and all possible causes, this list in conjunction with the theory of operation will be of assistance in isolating the most common problems.

Expected readings on the PWB test points are shown in Table 4.2. The measurements are to be made at room temperature with the cuffs disconnected, and with the unit plugged in. All voltage measurements are with respect to ground. All measurements on the A1 PWB Assembly must be made with the ON/OFF switch in the ON position.

	SYMPTOM	POSSIBLE CAUSES	CHECK TEST POINTS
1	Cuff will not inflate	a) Trying to inflate 2nd cuff in Single Cuff Mode b) Touch switch panel connector not properly plugged into J3 on PWB c) Connector J1 not properly plugged into PWB d) Tubing inside unit may be pinched or improperly connected e) U12 defective f) WDT hardware fault g) Valve stuck	
2	Cuff will not deflate	a) Deflate switch not held down long enough in Dual Cuff Mode b) Touch switch panel connector not properly plugged into J3 on PWB c) Connector J1 not properly plugged into PWB d) U12 defective e) Valve stuck	
3	No displays or tones when ON/OFF switch move to ON	a) Unit not plugged in b) Fuse blown c) Wire harness not properly plugged into Switch S2 d) Switch S2 defective e) Power supply harness not plugged properly into J5 of PWB f) Power supply defective	TP6 or TP12
4	Alarm Silence Switch not working	a) Wire harness between switch and PWB not properly plugged into J2 b) Non-silencable alarm (LOW supply pressure or hardware failure) c) U12 defective d) Alarm Silence Switch defective	
5	Voltage at TP6 not in spec.	a) VR1 defective b) Heat sink grounded (should be isolated from ground)	TP6
6	Frequency at TP3 not in spec.	a) X2, C7, or C8 components damaged or defective b) U14 defective	TP3

7	Frequency at TP2 not in spec.	a) X1, C4, C3, R10, R11, or U9 damaged or defective b) +5V supply out of spec	TP2
8	Voltage at TP8 or TP5 out of spec.	a) Calibration required b) U19, U20, or U21 damaged or defective c) Resistors R101 through R105 not replaced as a set with XDCR1 d) Transducer faulty e) Q1 defective	TP8 or TP5
9	Voltage at TP4 or TP7 out of spec.	a) Calibration required b) Resistors R101 through R105 not replaced as a set with XDCR1 c) Transducer faulty d) Q1 defective e) U19, U20, or U21 damaged or defective	TP4 1 or TP7
10	Voltage at TP9 out of spec.	a) U20 damaged or defective b) Q1 damaged or defective c) XDCR1 damaged or defective d) +12 V out of spec.	TP9
11	Voltage at TP11 not in spec.	a) R24, R28, R26 damaged or defective b) +5 volt supply not in spec.	TP11
12	No sound during power-up	a) Wiring to speaker faulty or improperly connected b) No signal at TP2 c) U1, U4, U5, U10, or U11 damaged or defective	TP2
13	Abnormal operation at power-up	a) U14, U17, or U18 defective, damaged, or improperly seated in socket b) X1, C4, C3, R10, R11, or U9 damaged or defective c) +5 V supply out of spec.	TP3 TP3 TP6
14	Abnormal displays during power-up or operation	a) U13 damaged or defective b) U6 damaged or defective	
15	Abnormal displays during calibration	a) XDCR1 faulty b) Resistors R101 through R105 not replaced as a set with XDCR1 c) U19, U20, or U21 damaged or defective	TP7 TP4 or TP7 TP5 or TP8

4.5 REPLACEABLE PARTS

The following is a list of field replaceable parts. All of these parts are available from Aspen Laboratories; see paragraph 4.6 for ordering information. Many of the more common parts are available at local electronic suppliers.

Reference Designator	Aspen Part Number	Description
ASSEMBLY: Logic PWB (A1), 61-2775-001		
A1	61-2776-001	PWB, Logic Board, A.T.S. 500
C1	62-2718-004	Cap, Ceramic, 4700 pF
C2	62-2718-005	Cap, Ceramic, 0.01 uF
C3	62-2718-001	Cap, Ceramic, 22 pF
C4	62-2718-001	Cap, Ceramic, 22 pF
C5	62-2720-001	Cap, Electrolytic, 1.0 uF
C6	62-2720-002	Cap, Electrolytic, 10 uF
C7	62-2718-002	Cap, Ceramic, 33 pF
C8	62-2718-002	Cap, Ceramic, 33 pF
C9	62-2720-004	Cap, Electrolytic, 470 uF
C10	62-2720-004	Cap, Electrolytic, 470 uF
C11	62-2718-007	Cap, Ceramic, 0.33 uF
C12	62-2718-007	Cap, Ceramic, 0.33 uF
C13	62-2720-002	Cap, Electrolytic, 10 uF
C14	62-2718-005	Cap, Ceramic, 0.01 uF
C15	62-1680-001	Cap, Polycarbonate, 1.0 uF
C16	62-2718-004	Cap, Ceramic, 4700 pF
C17	62-2718-006	Cap, Ceramic, 0.1 uF
C18	62-2718-004	Cap, Ceramic, 4700 pF
C19	62-2718-007	Cap, Ceramic, 0.33 uF
CR1	62-0565-001	Diode, 1N4004
HS1	62-2726-001	Heat Sink, TO-220, PC Mount
I1	62-1360-002	Bar LED, Yellow
I2	62-1360-002	Bar LED, Yellow
I3	62-1360-001	Bar LED, Red
I4-I10	62-1361-001	Display, 7 Segment, Red
J1	62-2845-012	Receptacle, 13 Pin
J2	62-1390-005	Receptacle, 6 Pin
J3	62-2860-001	Right Angle Header, 9 Pin
J4	62-1390-001	Receptacle, 2 Pin
J5	62-1390-005	Receptacle, 6 Pin
K1	62-2576-001	Relay, PC Mount, 12V 3A
Q1	62-0412-001	Transistor, PNP, MPS-6533
R1	62-0365-043	Resistor, 150 ohm, ½ W, 5%
R2	62-0365-033	Resistor, 56 ohm, ½ W, 5%
R3	62-0365-043	Resistor, 150 ohm, ½ W, 5%
R4	62-0364-107	Resistor, 68K, ¼W, 5%
R5	62-0364-101	Resistor, 39K, ¼W, 5%
R6	62-0364-095	Resistor, 22K ohm, ¼ W, 5%
R7	62-0365-047	Resistor, 220 ohm, ½ W, 5%
R8	62-0364-087	Resistor, 10K ohm, ¼ W, 5%
R9	62-0364-087	Resistor, 10K ohm, ¼ W, 5%
R10	62-0364-095	Resistor, 22K ohm, ¼ W, 5%
R11	62-0364-167	Resistor, 22M ohm, ¼ W, 5%
R12	62-0364-087	Resistor, 10K ohm, ¼ W, 5%

Reference Designator	Aspen Part Number	Description
R13	62-0364-085	Resistor, 8.2K ohm, ¼ W, 5%
R14	62-0364-087	Resistor, 10K ohm, ¼ W, 5%
R15	62-0364-087	Resistor, 10K ohm, ¼ W, 5%
R16	62-0961-383	Resistor, MF, 95.3K, ⅛W, 1%
R17	62-0961-126	Resistor, MF, 200 ohm, ⅛W, 1%
R18	62-0961-201	Resistor, MF, 1.21K, ⅛W, 1%
R19	62-0961-201	Resistor, MF, 1.21K, ⅛W, 1%
R20	62-0364-077	Resistor, 3.9K ohm, ¼ W, 5%
R21	62-0364-098	Resistor, 30K ohm, ¼ W, 5%
R22	62-0961-383	Resistor, MF, 95.3K, ⅛W, 1%
R23	62-1359-003	Potentiometer, 100K, 20T, 10%
R24	62-0961-326	Resistor, MF, 24.3K, ⅛W, 1%
R25	62-0961-383	Resistor, MF, 95.3K, ⅛W, 1%
R26	62-0961-198	Resistor, MF, 1.13K, ⅛W, 1%
R27	62-1359-002	Potentiometer, 10K, 20T, 10%
R28	62-1359-001	Potentiometer, 1K, 20T, 10%
R29	62-0961-383	Resistor, MF, 95.3K, ⅛W, 1%
RN1	62-2861-001	Resistor Network, SIP, 4.7K, 9 Pin
RN2	62-2721-001	Resistor Network, SIP, 68K, 6 Pin
RN3	62-2721-001	Resistor Network, SIP, 68K, 6 Pin
RN4	62-2722-001	Resistor Network, SIP, 39K, 7 Pin
RN5	62-2723-001	Resistor Network, SIP, 10K, 11 Pin
TP1-9	62-2725-001	Test Point, 0.200 in. centers
TP11-13	62-2725-001	Test Point, 0.200 in. centers
U1	62-1374-001	I.C., O/C Driver, 2003
U2	62-1374-001	I.C., O/C Driver, 2003
U3	62-2672-001	I.C., Programmable Logic
U4	62-2572-001	I.C., CMOS, Ripple Counter, 4040
U5	62-1369-001	I.C., CMOS, Data Selector, 4512
U6	62-2573-001	I.C., CMOS, 2 Input NAND Gate, 4011
U7	62-2574-001	I.C., Addressable Latch, LS259
U8	62-2570-001	I.C., CMOS, 2 Input AND Gate, 4081
U9	62-1373-001	I.C., CMOS, Hex Inverter, 4069
U10	62-2572-001	I.C., CMOS, Ripple Counter, 4040
U11	62-2727-001	I.C., CMOS, 4 Bit Flip Flop, 14175
U12	62-2575-001	I.C., Octal Gate, ALS573
U13	62-1372-001	I.C., CMOS, Cisplay Driver, 7218C
U14	62-2569-001	Microcontroller, 8 Bit, 8031
U15	62-2573-001	I.C., CMOS, 2 Input NAND Gate, 4011
U16	62-2577-001	I.C., A/D Converter, 8 Bit, ADC0808
U17	62-2575-001	I.C., Octal Gate, ALS573
U18	62-2862-001	I.C., EPROM, 2764
U19	62-1363-001	I.C., Op-Amp, CMOS, 3160
U20	62-1362-001	I.C., Dual Op-Amp, LM358
U21	62-1363-001	I.C., Op-Amp, CMOS, 3160
VR1	62-0417-004	Voltage Regulator, 5V, 2%, TO-220
X1	62-1378-002	Crystal, Quartz, 2.00 MHz
X2	62-1378-001	Crystal, Quartz, 3.58 MHz
XDCR1	62-1376-001	Transducer, Pressure
XU14	62-1377-009	Socket, 40 Pin
XU18	62-1377-008	Socket, 28 Pin
	62-0272-001	Thermal Compound
	62-0343-001	Nut, Keps, #4-40
	62-1345-001	Hose, ⅛" I.D. Buna-N

Reference Designator	Aspen Part Number	Description
ASSEMBLY: Front Panel, 61-2839-001		
A1	61-2775-001	A1 Logic PWB Assembly
F1	62-1253-005	Fuse, 0.5A, Slo-Blo
S2	62-2421-001	Switch, On/Off, Marquardt 1802
S3	62-2422-001	Switch, SPDT, Marquardt 1803.112
S4	62-1384-001	Switch, Momentary Pushbutton
SP1	62-0333-001	Speaker
XF1	62-1254-001	Fuseholder
	61-1458-004	Power Cord Assembly
	61-1487-001	Harness Assembly, Speaker
	61-2481-002	Harness Assembly, Mode & Alarm
	61-2583-001	Cover Panel Assembly, A.T.S. 500
	62-0260-001	Cable Tie
	62-0288-004	Terminal, Slip-on, .187 x .032, Red
	62-0343-002	Nut, Keps, #6-32
	62-0343-003	Nut, Keps, #8-32
	62-0378-005	Screw, Binder Head, #8-32 x 3/8
	62-0436-002	Wire, 18 AWG Stranded, Brown
	62-1256-001	Strain Relief, Power Cord
	62-1257-001	Nut, Strain Relief
	62-1281-002	Output Panel
	62-1282-001	Speaker Panel
	62-1346-001	Stand Off, #8-32, M-F, 1 x ¼ Hex
	62-1385-001	Lenscap for S4
	62-1391-002	Lamp for S4
	62-1399-001	Cable Tie, Cord Organizer
	62-2532-001	Switch Panel, A.T.S. 500
	62-2578-001	Front Panel, A.T.S. 500
	62-2662-001	Front Panel Nameplate, A.T.S. 500
	62-2671-001	Pneumatic Coupling, Female
	62-2841-001	Label, Output Panel, A.T.S. 500
	62-2841-002	Label, Output Panel, A.T.S. 500
ASSEMBLY: Wire Harness, Mode and Alarm, 61-2842-001		
	62-0260-001	Cable Tie
	62-0434-001	Wire, 22 AWG Stranded, Yellow
	62-0434-002	Wire, 22 AWG Stranded, Grey
	62-0434-003	Wire, 22 AWG Stranded, Green
	62-0434-007	Wire, 22 AWG Stranded, Violet
	62-0620-004	Heatshrink, 3/16", Black
	62-1388-001	Terminal, Crimp, Fishhook
	62-1389-005	Connector, Plug, 6 Pin
ASSEMBLY: Valve Cover, 61-2583-001		
MF1-MF2	62-1340-001	Muffler
V1-V6	62-1339-001	Valve
	62-0377-003	Screw, Binder Head, #6-32 x ¼
	62-0649-001	Thread Sealer
	62-1342-001	Hose Fitting, Barb
	62-1343-001	T-Fitting
	62-1345-001	Hose, ⅛" I.D., Buna-N
	62-2580-001	Cover Panel
	62-2584-001	L-Fitting
	62-2585-001	Screw Plug

Reference Designator	Aspen Part Number	Description
ASSEMBLY: Rear Panel, 61-2699-001		
PS1	62-2698-001	Power Supply, 12V, 1.7A
S1	62-2711-001	Switch, Pressure
	61-2596-001	Regulator Assembly
	61-2696-001	Wire Harness Assembly, AC
	61-2697-001	Wire Harness Assembly
	62-0260-001	Cable Tie
	62-0343-003	Nut, Keps, #8-32
	62-0343-004	Nut, Keps, #10-32
	62-0376-009	Screw, Binder Head, #4-40
	62-0377-005	Screw, Binder Head, #6-32
	62-0378-005	Screw, Binder Head, #8-32
	62-0419-002	Flatwasher, #4
	62-0419-005	Flatwasher, #10
	62-0431-001	Wire, Bare Bus
	62-0620-005	Heat Shrinkable Tubing
	62-1283-002	Cover, Acrylic
	62-1284-001	Hinge
	62-1285-001	Hinge Plate
	62-1343-001	Tee Fitting
	62-1345-001	Tubing, ⅛", I.D., Buna-N
	62-2079-001	Screw, Machine, Truss Head, #6-32
	62-2360-001	Pole Clamp Knob
	62-2407-001	Pole Clamp Body
	62-2408-001	Pole Clamp Jaw
	62-2546-001	Pole Clamp Screw
	62-2547-001	Hex Nut, Pole Clamp
	62-2548-001	Pole Clamp Bearing
	62-2549-001	Washer, Pole Clamp
	62-2579-001	Rear Panel, A.T.S. 500
	62-2665-001	Hinge Trim Plate, Exterior
	62-2716-001	Bolt, Round Head, #10-32 5/8
ASSEMBLY: Regulator, 61-2596-001		
	62-0260-001	Cable Tie
	62-1342-001	Hose Fitting, Barb
	62-2016-001	Hex Nipple
	62-2053-001	Air Adaptor, Male, ¼" NPT
	62-2111-001	Pipe Sealant, Teflon
	62-2592-001	Bracket, Regulator Mounting
	62-2593-001	Regulator, Brass Body
	62-2595-001	Adaptor, Pipe to Female, ¼" NPT
	62-2724-001	Pipe Plug, ¼", Hex Socket
ASSEMBLY: Wire Harness, 61-2697-001		
	62-0260-001	Cable Tie
	62-0288-003	Terminal, Slip-on, .187 x .020, Red
	62-0434-001	Wire, 22 AWG Stranded, Yellow
	62-0434-005	Wire, 22 AWG Stranded, Red
	62-0434-006	Wire, 22 AWG Stranded, Orange
	62-0434-007	Wire, 22 AWG Stranded, Violet
	62-1388-001	Crimp Terminal
P5	62-1389-005	Plug, 6 Pin

Reference Designator	Aspen Part Number	Description
ASSEMBLY: Wire Harness, AC Power, 61-2696-001		
	62-0260-001	Cable Tie
	62-0288-004	Terminal, Slip-on, .187 x .032, Red
	62-0470-004	Wire, 22 AWG Stranded, Brown
	62-0470-008	Wire, 22 AWG Stranded, Blue
ASSEMBLY: A.T.S. 500 Tourniquet, 60-2700-001		
	61-2586-001	Valve Cover Assembly
	61-2699-001	Rear Panel Assembly
	61-2839-001	Front Panel Assembly
	60-1444-003	Operator's Reference Guide
	60-1444-004	Operator's Reference Guide
	60-2784-001	Operator and Service Manual
	62-0007-001	Nameplate
	62-0378-005	Screw, Binder Head, #8-32 x 3/8
	62-0438-001	Bead Chain
	62-0439-001	Link, Bead Chain