THE APPLICATION OF AUTOMATIC TEST EQUIPMENT TO TRAINING DEVICES

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There are many concepts of and definitions pertaining to Automatic Test Equipment. In order to intelligently discuss the possible application and benefits to be derived by the inclusion of Automatic Test Equipment or Techniques in Training Devices, it is necessary to accept or establish a minimum number of pertinent terms and definitions. MIL-STD-1309, "Definitions of Terms for Automatic Electronic Test and Checkout," unfortunately did not define the single most important term—automatic test. Therefore, I am going to define Automatic Test Equipment as "any (automatic) testing device which requires a minimum of human participation." Within the confines of this definition I am including Built-in-Test (BIT), Built-in-Test Equipment (BITE), Self Test, and Self Check.

All automatic test equipment (ATE) and automatic test techniques must perform a minimum of two functions, performance monitoring and fault isolation. For some reason these functions are frequently misunderstood and confused. Performance monitoring consists of scanning a selected number of test points to determine if the unit under test is operating within specified limits. A single failure could result in a number of test points being outside the predetermined limits. Fault isolation is the act of locating a fault to a specific replacable unit or major component.

Training devices are different from operational equipments—such that it is necessary to establish a separate critique for their design and maintenance philosophy. The major differences are in the quantities procured. Frequently only one of a particular device is procured, and when more than one is procured, each may differ from the others. Production quantities are usually small, and the prototype is usually delivered as the first production unit.

The inclusion of, or the provision for automatic testing does cost money. It is usually justified by such magic words as Cost Effectiveness, Life Cycle Costing, Available Skill Levels, Equipment Availability, etc. Frequently elaborate computer models are written, which always prove that ATE is Cost Effective. Let's talk real world—ATE can be cost effective for training devices! It permits a lower level of technician—or the operator to perform the majority of the maintenance. It results in a significantly higher availability of the device. The time required to fault locate and fault isolate can frequently be reduced by an order of magnitude. Naturally, this must be supported by good mechanical design, permitting rapid replacement of the faulty component.

The three basic testing techniques that can be utilized are Self Check, Built-in-Test, and external Automatic Test. Self Check is normally associated with digital, programmable, equipment in which a diagnostic program exercises the equipment and locates a malfunction to the unit under test. Most digital and computerized devices already make optimum use of self check, so our discussion will be confined to Built-in-Test and external Automatic Test utilizing sensors.

Built-in-Test can be loosely defined as devices or circuits permanently mounted in the prime equipment for the express purpose of testing the prime equipment. It can include Self Test, and Introspective Testing.

Automatic Test Equipment was defined previously, but is usually considered as being both external to the prime equipment, and central to a number of equipments. Most Centralized Automatic Testers are designed for on line operation and depend on sensors to provide the necessary circuit isolation and signal conditioning to interface with the tester, or its multiplexer. Sensors are also utilized in many equipments incorporating Built-in-Test.

There are numerous examples of the application of Built-in-Test in military equipment. NAVAIR Specification AR-10 thoroughly covers the requirement for, and inclusion of Built-in-Test in Navy Avionic Equipment.

A good example of Built-in-Test is the Air Force AN/ARC-123 transceiver, developed by the Avco Corporation for the F-111 fighter and the C5 transport. The use of BIT provided performance monitoring, and in the event of a failure, fault isolation to the module level.

Basic guidelines, which are representative of most BIT applications, were established at the very beginning of the design phase.

They are:

1. Simplicity of read-out and provision for testing of this device.

2. Sequence of testing such thateach module requires only those modules previously tested as a signal source.

3. Operational circuits chosen (where possible) to provide readily available indication of operational condition and thereby minimize additional circuitry required for "test only" functions.

4. Testing methods and circuits carefully examined to determine how they may be used to substitute for operational circuits or to augment these circuits and provide more efficient design.

5. Minimize repeated excitation of high power circuits to prevent spreading the damage should a fault occur.

The transceiver is composed of three assemblies (figure 1). The control unit provides frequency selection, mode of operation, and all other operational controls for the transceiver. In addition, it contains the circuitry for the digital portions of the frequency synthesizer. The Receiver/Exciter unit performs all other Receiver/Exciter functions, incorporates the BIT circuits and readout. The Amplifier/Power Supply incorporates the RF power amplifier and all power supplies.

The packaging is broken down further into 13 replaceable plug-in modules (figure 2), each corresponding to one of the 16 positions of the rotary test selector switch on the Receiver/Exciter unit. This switch (figure 3), selects the circuit to be tested. It is necessary to press the push button to activate the specific test. However, the push button may be held depressed as the test switch is rotated slowly through its positions. Fail-safe procedures were established with a test lamp, as indicator, unlighted for a go condition and illuminated to indicate a no-go.

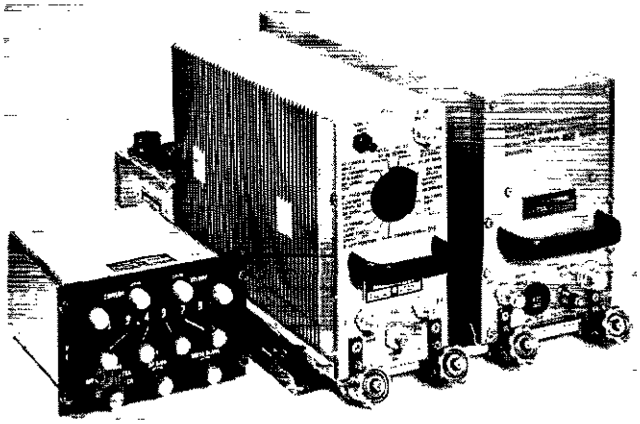

Figure 1. Transceiver

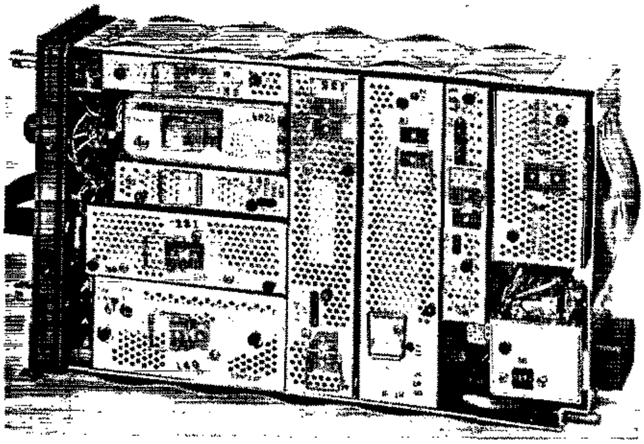

Figure 2. Plug-In Modules

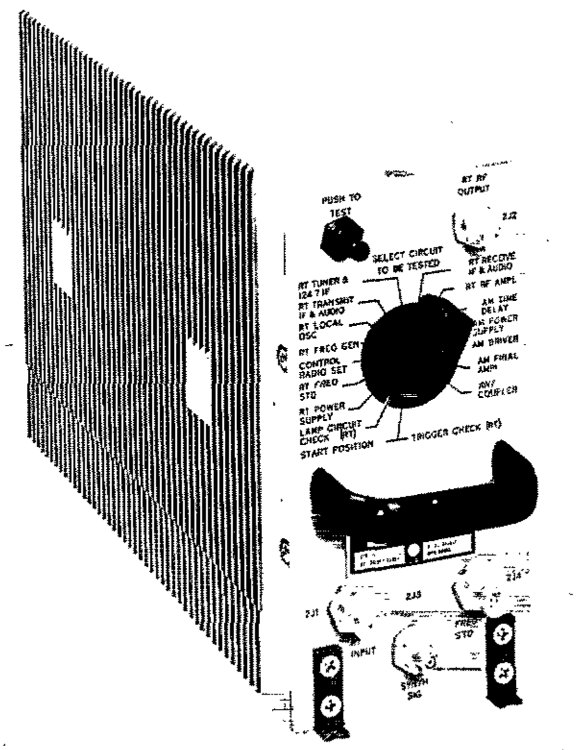

Figure 3. Receiver/Exciter Unit

TABLE I

TESTED MODULE	MODULE FUNCTION	TEST CIRCUITS AND METHOD	MEANING OF INDICATION
BIT Indicator		A false no-go signal is inserted.	Lighting of the lamp indicates that the circuit can be set into the no-go state.
BIT Indicator		A false go signal is inserted.	Circuit checked to insure that it can be set into go state.
RT Power Supply	Provides power supply function for entire Receiver/Exciter.	Voltage divider across each power supply output and combined in an AND Gate.	All DC voltages present and of required level.
RT Frequency Standard	1 MHz reference signal for all internal oscillators.	Level detector on oscillator.	Crystal controlled oscillator output is sufficient level.
Control Unit	Digital Synthesizer produces variable reference frequency for first local oscillator input 1MHz from frequency standard output 9.47 to 12.27 MHz.	Level detectors on output, reference signal input and phase detector error signal combined in an AND circuit.	Presence of reference signal, output signal and zero error voltage from phase detector.
RT Frequency Generator	Fixed frequency generation by whole number divider and harmonic multiplier. Input 1 MHz from freq. std. output 700 KHz and 124 MHz.	Level detectors on generator outputs.	All signals present and of sufficient level.
RT Local Oscillator	Variable frequency, multiplier, with sinusoidal output. Utilizes voltage controlled oscillator in phase locked loop - input 9.47 MHz to 12.27 MHz from control unit - output 94.7 to 122.7 MHz to parametric amplifier.	Level detector on reference and feedback inputs to phase detector combined in AND logic with phase detector error output.	Both inputs present and of sufficient level and low error signal.
RT Transmit IF & Audio	Modulation of 700 kHz IF Carrier and filtering for desired modulation type input: 700 kHz from RT Frequency Generator: modulated 700 kHz auxiliary functions: - 1 kHz Tone Gen. - Speech Processor	A self-contained 1 kHz oscillator is turned on to provide substitute audio input to modulator. IF output is checked for level.	Modulated output is of sufficient level.
RT Tuner & 124.7 MHz IF	Parametric Amplifier/first converter, first IF (124.7 MHz) and 2nd converter 700 kHz. Inputs (receive mode). - Antenna signal 2 - 30 MHz - RT Local Oscillator 94.7 - 122.7 MHz - 123 MHz from RT Freq. Gen. for second converter. - Output 700 kHz receive signal	Level detector on transmit mixer output combined with noise blanker output in an AND circuit. The noise blanker is rebiased for BIT operation to act as a high gain level detector since the signal at the second mixer output is too low in level to drive standard level detector.	Both transmit and receive paths are functioning properly in the RT Tuner module.

TABLE 1 (continued)

TESTED MODULE	MODULE FUNCTION	TEST CIRCUITS AND METHOD	MEANING OF INDICATION
RT Tuner & 124.7 MHz IF (con't)	Transmit Mode: Input: Modulated 700 kHz 124 MHz from RT Freq. Gen. 94.7 to 122.7 MHz from RTLO. Output: 2 - 30 MHz modulated. Auxiliary functions: Pump Amplifier Tuner AGC Attenuator Noise Blanker Detector.	The Pad connected across the T/R relay *receive path contacts* permits driving these receive only circuits during BIT.	
RT Receive IF & Audio	2nd IF (700 kHz) Amplification and demodulation to base-band audio. Input: Modulated 700 kHz from RT Tuner. - 700 kHz from RT Freq. Gen. Output: Base band audio. Auxiliary functions: Noise blanker switch 700 kHz IF AGC Selcal detection AGC detector & processor Volume Control Squelch	Level detector located at the audio output. This provides a virtual AND function since the entire path must function properly for an audio output signal to occur.	700 kHz IF amplifier and audio amplifier circuits are all functioning properly
RT RF Amplifier	Wideband (2 - 30 MHz) IF Amplifier. Provides .250 watt output to drive RF power Amplifier LRU.	Level detector operating on output signal.	Output level sufficient to drive RF power amplifier to rated output.
AM Time Delay	DC Voltage to Anode *supply relay is routed* through the contacts of a time delay relay, a pressure sensor and temperature sensor in series.	Voltage divider con*nected across* DC supply line after interlock switches.	All three interlocks are closed and circuitry can be operated with safe environmental conditions.
AM Driver	Solid state, linear RF amplifier raises exciter output (.250 watts) to level sufficient to operate final amplifier grids.	Envelope detector followed by Schmitt trigger and operating on driver RF load.	Drive to final amplifier grid is sufficient for proper operation.
AM Final Amplifier	RF Final Amplifier provides last stage of RF power amplifier prior to antenna feed.	Forward power detector monitoring output followed by Schmitt trigger.	Forward power delivered to antenna matching network is of sufficient level.
Antenna Coupler (AT-440 ONLY)	By means of reactive elements this device *modifies the antenna* impedance to that of the power amplifier output.	Reflected power detector monitoring coupler input followed by Schmitt trigger.	Antenna matching network has successfully transformed power amplifier output impedance to that of the antenna presenting an acceptable VSWR to the power amplifiers.

The transceiver circuitry, with the exception of the built-in-test, is rather straight forward and conventional.

Table 1 lists the module under test, as identified on the front panel of the R/T unit and on the modules themselves, the module function, the test circuit and method, and meaning of the indication. Normal procedure is to rotate clockwise, beginning at the Trigger Check or Start Position. This provides a representative no-go signal to test the BIT Indicator. In the next position a go voltage is presented to insure that the lamp circuit can be driven to a go or unlighted condition. The remaining positions in Table 1 are self-explanatory.

The ideal introspective test is one wherein the system tests itself end to end without any hardware included solely for testing purposes. The AN/ARC-123 is not Utopia, but it is a representative example of a good Built-in-Test concept making maximum usage of introspective testing techniques. The only additional signal or stimuli is an internal 1 kHz oscillator used for modulation. A minimum number of additional circuits are included to perform the BIT functions. These consist of level detectors, a phase lock detector, and comparitor and driver circuits. A representative block diagram (figure 4), shows the utilization of an "and circuit" to assure that all power supply voltages for the entire Receiver/Exciter are at the proper levels.

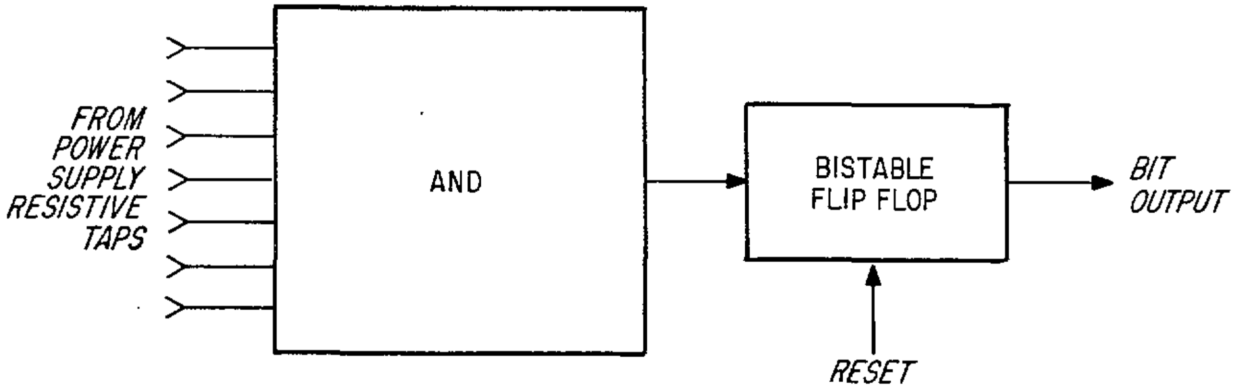

Figure 4. Block Diagram of High Voltage Power Supply BIT

Resistive dividers across each power supply provide the AND circuit input. When all supplies are up to proper level, the flip-flop is set and the power supplies shut-off. This permits high speed testing without placing time restrictions on the operator and avoids necessity of repeated keying of high power circuits.

Most of the techniques and philosophies used in this transceiver could be applied to training devices at nominal cost. It is interesting to note that the rotary switch could be replaced by a stepper switch thus providing semi-automatic operation.

NAVMAT INST 3960.4 directs centralized automated monitoring and testing. This policy is applicable to shipboard equipment and where the same equipment is used ashore. As such most or all training devices are excluded.

However, the techniques involved are applicable to training devices. It is highly improbable that a training device will have access to one of the major Navy Automatic Test Equipments. However, the inclusion of sensors does facilitiate the application of Built-in-Test and provides an external access to the equipment under test. All test parameters are converted to an analog voltage, which is scaled to a maximum range of 0 - 10 volts. Testing philosophy is now reduced to a digital volt-meter, possibly a frequency counter, and a means of switching the meter to the appropriate pin on the access plug. Several portable testers using this philosophy are under consideration by the Navy.

MIL-STD-1326A, "Test Points, Test Point Selection and Interface Requirements for Equipments Monitored by Shipboard On-Line Automatic Test Equipment" establishes the requirements for providing test points and the criteria to optimize test point selection.

Project SETE (Secretariat for Electronic Test Equipment) has just completed a compilation of compatible electronic sensors. Sensors presently available can measure voltage, current, frequency, time interval, phase, impedance, noise, modulation, bandwidth pulse and numerous other parameters These sensors are available as components, micro-circuits, or as design circuits

A sensor, in its simplest form (figure 5), would be an attenuator, providing DC voltage scaling and isolation to the test point under measurement.

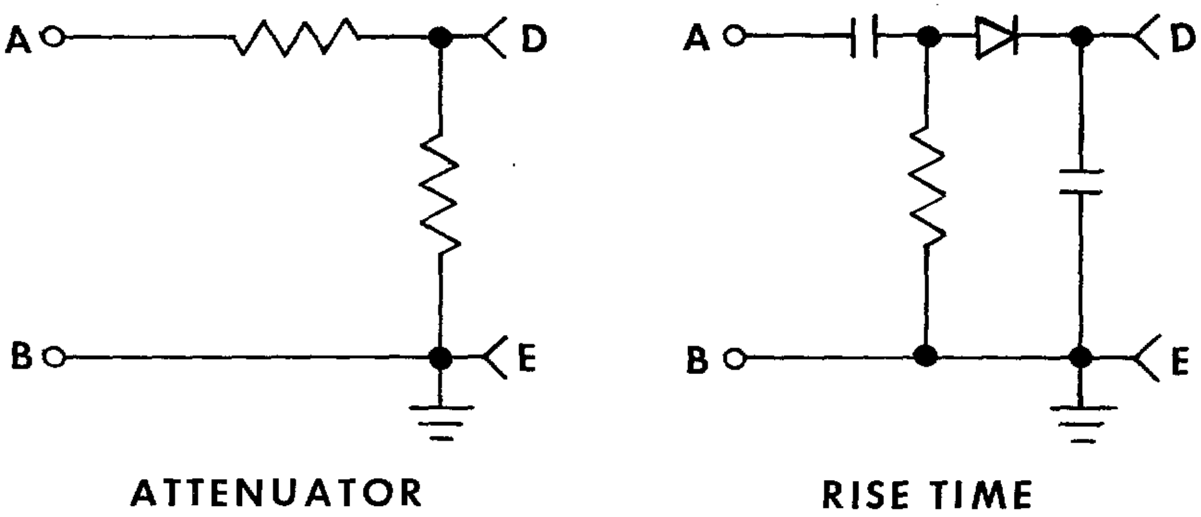

Figure 5. Sensors

Several configurations of manual and semi-automatic portable testers are being considered for use on small ships, shore stations, and as a local tester to supplement the centralized automatic tester. All of these configurations including the manual version, will permit rapid, on-line, performance monitoring and fault isolation to the same level as the centralized testers. However; at a fraction of the cost.

We will discuss one tester that is already in the breadboard stage (figure 6). This tester is proposed in both a portable and rack-mounted version. The portable configuration (figure 7), can almost be considered in the category of General Purpose Test Equipment.

The features are as follows:

a. Modularized circuitry permitting expandable capacity from 32 up to 256 test points.

b. Test point limits can be selected manually—using thumb wheels, or automatically from a tape cassette of the type used in automobile stereos.

c. The tape program and limits may be changed manually—if so desired—by the thumb wheels. However, provision can be made to lock out the operator.

d. The input is MIL-STD-1326 compatible, with 4 megohms minimum input resistance.

e. Accuracy is $\pm 0.5\%$ full scale $\pm$ sensor accuracy.

f. Size and weight will be less than 1 cubic foot and 40 pounds respectively.

g. Test time is 350 microseconds per test point.

Controls are:

a Test Point Mode Switch—which selects automatic, manual, or memory load mode of operation.

b. Test Point Select Switch—permitting automatic or manual sequencing of test points.

c Thumb wheel Selectors—to set upper and lower acceptance limits.

Displays are minimized and consist of:

a. A set of tolerance lights which indicate whether the test point is GO, No-GO High, or No-GO low.

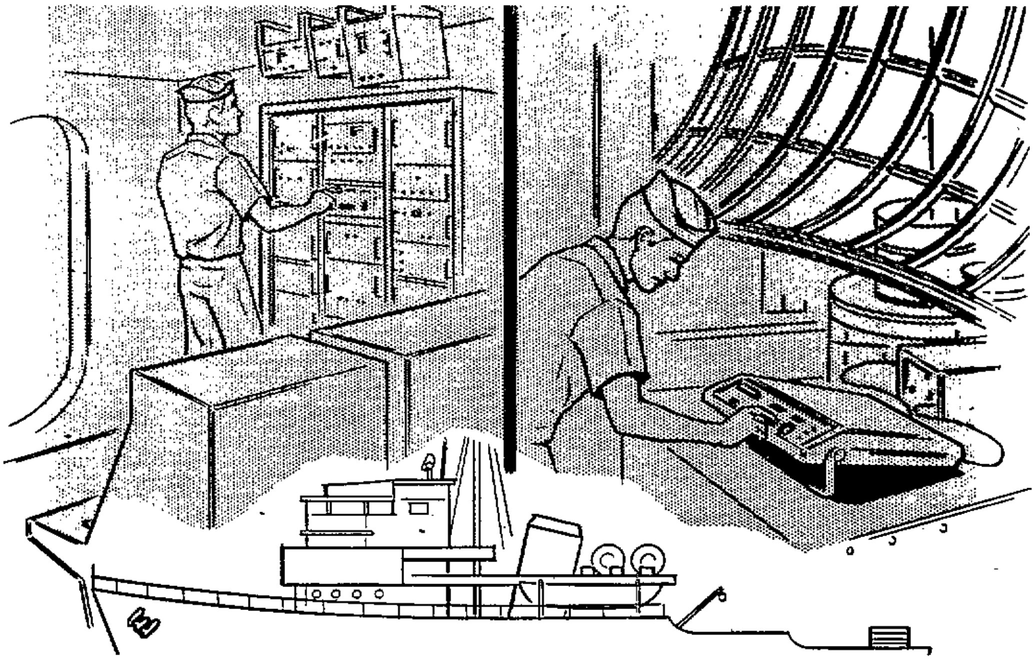

Figure 6. Rack-Mounted and Portable Versions

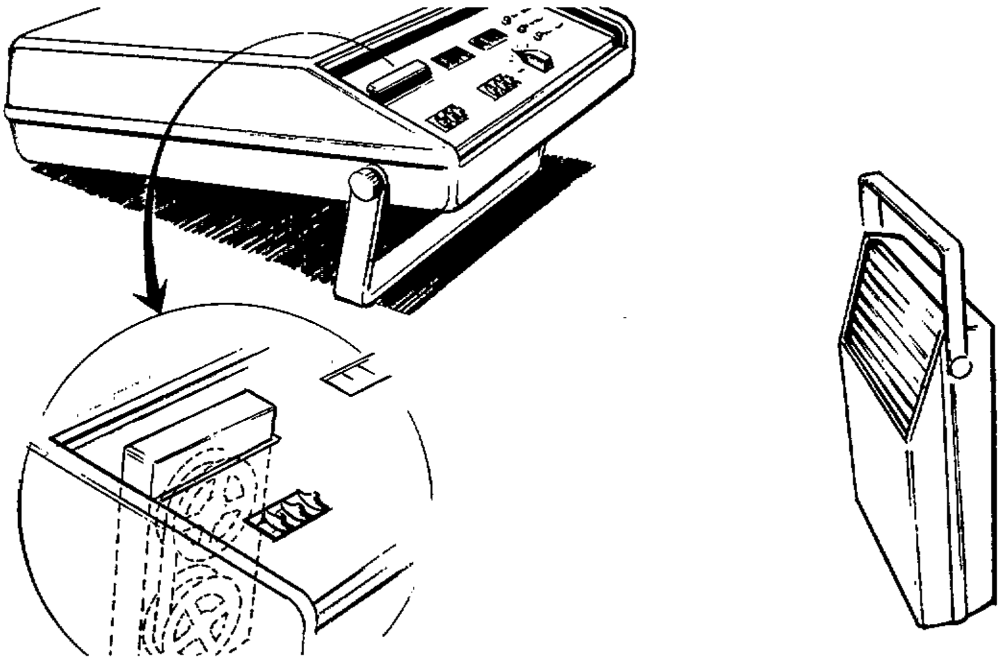

Figure 7. Portable Configuration

b. A Test Point Number display that indicates numerically which test point is being displayed.

c. A Test Point Value display that indicates numerically the value of the sensor output to three places. A conversion is necessary if the absolute value of the parameter being measured is required.

In Summary

ATE can be cost effective for Training Devices. Self Check techniques should be used with digital, programmable, or computerized devices. Built-in-Test techniques and philosophies are applicable, at a nominal cost, if the necessary basic guidelines are established at the very beginning of the design phase.

Sensors are available permitting measurement of the majority of electronic and mechanical parameters encountered in training devices. These sensors are applicable to Built-in-Test and external testing equipments. These techniques must be supported by good mechanical design--if optimum availability of the device under test is to be obtained.

By utilizing MIL-STD-1326, the prime equipment is compatible with Centralized Automatic Test Systems, the pending portable testers, or a simple voltmeter--internal or external to the device

I would welcome future visits, comments, or suggestions from Industry and Government in these areas.