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ADDENDUM TO
FINAL ENGINEERING REPORT
ON
AUTOMATIC TEST EQUIPMENT STUDY EXTENSION
FOR
DAYTON AIR FORCE DEPOT



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Appendix to
Final Engineering Report

on

AUTOMATIC TEST EQUIPMENT STUDY EXTENSION

for

DAYTON AIR FORCE DEPOT

Contract No: AF33-(604)-32036

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GENERAL DYNAMICS/ELECTRONICS

Military Products Division

Rochester

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Foreward

This addendum to the Final Engineering Report on Automatic Test Equipment Study Extension for Dayton Air Force Depot was prepared by the Electronics Engineering Department of General Dynamics/Electronics, a Division of General Dynamics Corporation, under the sponsorship of Dayton Air Force Depot, Dayton, Ohio under USAF Contract AF 33-(604)-32036. The study work covered in this report was performed by General Dynamics/Electronics personnel at Rochester, WRAMA, MOAMA and SAAMA.

Acknowledgement is made of the assistance provided by DAAFD, WRAMA, MOAMA and SAAMA personnel.

RECOMMENDATIONS

In the final Engineering Report on Automatic Test Equipment Study Extension for Dayton Air Force Depot prepared by General Dynamics/Electronics under contract AF 33 (604)32036, it has been recommended that a time shared ATE system be implemented. One result anticipated from this implementation is the finalization of building block specifications for stimulus generators, response monitors and programmable accessories such as loads. It is further recommended that in addition to implementation of a trial ATE system and its application to ten or twelve prime equipments, continued study of Air Force depot and Air Materiel Area test requirements be carried out as a parallel program. This will be a second source of information for finalization of building block specifications. As indicated in this addendum, specifications of four building blocks were modified as a result of the relatively limited study of other AMA test requirements. Whereas ATE implementation will uncover subtle building block specification changes involving new programming or stability or resolution or fail safe requirements, additional study will disclose new requirements in the building block basic characteristics such as frequency, output voltage or modulation as well as furnishing information to specify new building blocks. It has already been pointed out that additional building blocks will probably be needed until complete coverage of the RF spectrum is obtained.

If this additional study were conducted during early stages of building block development, some new information would be available in time to incorporate these additional requirements in the building blocks initially procured. Less redesign and cost to the Air Force would result.

It is also recommended that selected items serviced by other AMA's be added to the initial ATE workload at an early date together with equipments that are now or will be in the DAAFD repair inventory. This will definitely demonstrate that the DAAFD ATE system is applicable to other depot workloads.

1. INTRODUCTION

This is an addendum to the final engineering report on USAF contract AF 33(604)-32036, an extension of the Automatic Test Equipment Study performed on USAF contract AF 33(604)-28541 which was completed in February 1961. This addendum includes the final results of studies of selected equipments serviced by WRAMA, MOAMA and SAAMA.

The requirements of a depot oriented automatic test system ^{are} ~~were defined as a result of the original study. These requirements were~~ further defined and confirmed during the study extension by determining the extent to which the automatic test system is applicable to other equipments serviced by DAAPD and also to equipments serviced by three Air Materiel Areas: Warner Robins, Mobile and San Antonio. Besides including additional complex airborne systems, studies at these Air Materiel Areas involved application of the ATE system ~~defined~~ to the testing of special purpose AGE units at MOAMA and to special communications equipment at SAAMA.

2. STUDY RESULTS

2.1 Final Results on Study of Warner Robins Equipment

the Dayton Air Force Depot

2.1.1 Summary

The study of circuitry and functions of ten airborne black boxes serviced by WRAMA has been completed. Although manual participation in automated test routines is required in certain instances and some units require considerable manual overhaul effort, it is believed that application of automatic test equipment will result in a considerable increase in output production and reliability.

Study of WRAMA equipment indicates that in addition to building blocks already specified, one new building block is needed: an A.C. hi pot supply. All other stimulus and response requirements are met by existing building blocks and by specification changes to the 400 cps phase referenced power supply and to the synchro transmitter building block.

2.1.2 General

Stimulus, response measurement and load requirements for the following black boxes have been determined and are shown in Figure 1. This listing of building blocks is updated from that shown in Figure 37 of the Final Engineering Report on ATE Study Extension to eliminate those items classified as accessories and to include new building block additions.

a. AN/ASB-4

1. Velocity Integrator
2. Range Integrator
3. Longitudinal Data Computer

FIGURE I

WRAMA Airborne Equipment Survey
Building Block Requirements

	1. Vel. Integrator ASB4	2. Range Integrator ASB4	3. Long. Data Comp ASB4	4. Heading Error Comp. ASB4	5. Radar Trans. Rec. ASB4	6. Servo Central A3A	7. Computer Central A3A	8. Target Pos. Comp. A3A	9. Pulse Sweep Gen. A3A	10. Ampl. Racks K-4A
0 Programmer-Controller	X	X	X	X	X	X	X	X	X	X
1 Oscillator 0.1 cps - 30 KC										
2 Oscillator 30 KC - 40 MC								X	X	
3 Oscillator 40 MC - 400 MC					X					
4 Oscillator 950 MC - 1250 MC										
5 Oscillator 8.5Kmc - 12.4 Kmc					X					
6 100 Mc Cut-Off Video Amp										
7 Pulse Generator					X			X	X	
8 Delay Generator	X	X		X		X	X			
9 10 Mc Cut-Off Video Amp										
10 Transfer Osc 5 Mc - 175 Mc										
11 Transfer Osc 165 - 605 Mc										
12 Transfer Osc 475 - 1525 Mc										
13 Transfer Osc 1,475 - 10.5 Kmc										
14 Noise Generator										
15										
16 Osc. 2.0 - 4.0 Kmc										
17 Oscillator 12.4 - 18.0 Kmc										
18 Synchro Transmitter/Ratio Transformer	X	X	X	X		X	X			
19 Resistive Load	X	X	X			X	X			X
20 Inductive Load	X	X		X		X	X			
21 Capacitive Load										
22 Impedance Meter										
23 Multimeter	X	X	X	X	X	X	X	X	X	X
24 Time Interval & Freq. Meter	X			X		X	X		X	
25 Power Meter & Reflectometer					X					
26										
27 Waveform Analyzer								X	X	
28 Spectrum Analyzer					X					
29 Peak Power Meter					X					
30 Static Pressure Generator										
31 Spectrum Analyzer 12.4 - 18 Kmc										
32										
33 Phase Meter (RF)										
34 Amplitude Modulation Det.										
35 Power Supply .1-35V 2.5A DC							X			

FIGURE I (Contd)

	1. Vel. Integrator ASB4	2. Range Integrator ASB4	3. Long. Data Comp ASB4	4. Heading Error Comp. ASB4	5. Radar Trans. Rec. ASB4	6. Servo Central A3A	7. Computer Central A3A	8. Target Pos. Comp. A3A	9. Pulse Sweep Gen. A3A	10. Ampl. Racks K-4A
36 Power Supply 22-32V	X		X		X	X	X	X	X	
37 Power Supply 30-500 Vdc					3	4	4	3	3	2
38 Power Supply 500-6000 Vdc										
39 AC Supply 400 cps Phase Ref	X	X	X			X	X			
40 AC Supply 400 cps 16-300V										
41 AC Supply, Filament					X	X	X	X	X	X
42 AC Supply 30 cps										
43 AC Primary Voltage					X	X	X	X	X	
44 Transfer Osc 12.4 - 18 Kmc										
45 Function Generator										
46 AC Supply 600-1800V Hi Pot						X	X			

The ratio transformer replaces the programmable synchro transmitter previously called out.

The precision frequency 400 cps 2 phase requirements have been combined with the AC supply, 400 cps phase referenced, building block specified in the Final Engineering Report on Automatic Test Equipment Study Extension for Dayton Air Force Depot submitted August 3, 1961.

2.1.3 AN/ASB-4 Velocity Integrator, Range Coordinate Generator, Longitude Data Computer and Heading Error Computer

These units are similar in that they all utilize electromechanical positional servos as computing elements. Mechanical devices such as gear trains, clutches, differentials and switching cams are frequently employed. The basic motor generator, synchro and control transformer circuits are identical for each unit. Output shafts are driven so as to mechanically represent the computational problem derived from two or more variables. The output shafts generally drive potentiometers, cam operated switches and programming switches. The majority of dynamic tests on the above "black boxes" are as follows:

1. Measurement of resistances.
2. Measurement of servo "nulling" sensitivity.
3. Measurement of motor starting voltage.
4. Measurement of servo follow and slewing speed.
5. Measurement of potentiometer output voltages.
6. Check of switch closure continuity and timing.

There are no major problems that would exclude the use of automatic test equipment for these tests. Excellent circuit access is gained via the main connector plugs on the front panels. The stimuli generator and response measurement devices are straightforward and simply programmable. A question was raised by Shop Foreman as to the ability of Automatic Test Equipment to select servo motor speed of adjustment resistor values. It has been established that this function is entirely practical with little or no equipment outside the range of capabilities of that specified in the ATE study for DAAFD. A brief description is given of the likely techniques of such a measurement.

By means of photo electric, cam operated micro switch, or electrical signal output, the shaft revolution speed is measured and digitally compared to tape programmed limits. A GO NO-GO decision is automatically made on the test result. If the unit fails to meet the requirements, the resistor controlling motor speed is removed, and the terminals at its mounting place are connected to the ATE. These wires will actually be connected to the programmable resistive load unit. The ATE will command the starting of the servo-motor.

2.1.3 (contd)

The digital comparator will sense the direction and order of magnitude of the speed error, and issue programming commands to the resistive load unit. These "commands" will effect the insertion of a resistance value that will cause the motor to approach the tape programmed limits of speed. The test cycle time will allow for the motor to achieve constant speed. Two or three cycles might be required to establish the precise optimum resistance. Such a system would also be capable of trimming the motor for equal speed in forward and reverse directions, and in adjustment of anti-drift resistors.

Excessive friction in the servos will appear as abnormally high servo-motor starting voltage. Long term monitoring of switch closures may best be handled by means of a multi-channel event-recorder. This would indicate exactly which switch missed a contact, when it occurred, and the number of times it occurred.

Certain manual participation may be required in the testing of these computing units. In spite of this the dynamic test time will be drastically reduced from that required by manual testing. At this time it is not possible to accurately state the automatic test time, but as a rough guide the time could at least be reduced by one-tenth.

Some of these units require considerable mechanical inspection, cleaning, lubrication, and routine adjustment. Automatic test equipment is of little assistance in these tasks. It is not readily apparent from the technical manuals how much time is required to perform these mechanical tasks. Consideration must be given to the ratio of electrical testing time to mechanical overhaul time, the greater the electrical testing time, the greater the advantage of automatic checkout. For example, if the mechanical adjustments take ten hours and the electrical test one hour, then there is little to be gained by a ten to one reduction in electrical testing time since the total time required is still 10 hours and six minutes. However, if the mechanical adjustments take 1 hour and the electrical tests ten hours, then the total time may be reduced to two hours by automatic checkout.

It is felt that a considerable increase in output production and reliability may be obtained from the application of automated tests to the computing elements reviewed.

2.1.4 AN/ASB-4 Radar Receiver/Transmitter Unit

The R/T unit of the AN/ASB-4 system generates high power, short duration pulses of X band RF energy. The RF energy is fed directly to the antenna. Signals are received from the antenna from Radar Echos and Beacons. The R/T unit contains the necessary superheterodyne circuits, IF amplification, and detection to provide a video pulse output signal. The overhaul of an R/T unit consists of the following main functional checks.

2.1.4 (contd)

1. Tuning control unit checkout.
2. Power oscillator supply voltage and current measurements.
3. Power oscillator performance at high and low line voltage.
4. Peak power measurement.
5. IF amplifier bandwidth.
6. AFC discriminator checks.
7. VSWR measurements.
8. Attenuation measurements.
9. Arc-over checks.

Considerable manual participation is required in conducting these tests. A reduction in this participation may deteriorate the efficiency of component selection and alignment tasks. The precision called for in making microwave measurements is difficult to practically reproduce in automatic equipment. A thorough overhaul of an R/T unit requires almost complete disassembly, each section of waveguide being individually examined for signs of arc-over damage and electrically checked for attenuation and VSWR. The modulator pulse transformer is housed in a container filled with oil of high di-electric strength. Extremely high voltage insulation is mandatory in this unit. These containers are rigorously checked for leaks in a gaseous leak detector facility, and refilled with oil. The AFC, IF, and video amplifiers are contained in subminiature sealed modules with no accessible test points. These items are considered discardable or possibly factory repairable, and are at present very quickly checked by insertion into a semi-automatic test fixture.

It is felt that little advantage is to be gained by automating the testing of the R/T unit. The actual testing time is a small part of the total overhaul time, disassembly cleaning and assembly being relatively tedious.

2.1.5 A3A Servo Central and Computer Central

These equipments are basically alike in physical design, employing similar modular packaging, interconnection system and overall housing. The degree of access to individual modules within the main black box has been found to be good. This is inherent due to the fact that many independent functions are performed by these units, these functions in turn driving remote equipment.

It is therefore felt that an automatic checkout system may be applied to the testing of the Servo Central and Computer Central. While the Servo Central contains the majority of the servo drive amplifiers and some servos, the Computer Central contains the actual analog computing servo-mechanisms. Each computer module of the Computer Central has a window through which the computer output shaft dial reading may be viewed. The test operator may view all of the dials in a Computer Central by withdrawing the main chassis from its case. It should be pointed out that manual participation is required for the calibration adjustments to the Computer Central. This

2.1.5 (contd)

involves making servo adjustments to position the computer dials so as to exactly indicate parameters consistent with known stimuli signals. Such operations would be integrated with automatic tests in the following manner.

When the automatic test program reaches a point at which a calibration adjustment is required, the program will halt and an instruction indicated. This instruction may be either a number on a digital indicator from which the calibration can be referenced from a card; or a directly printed instruction directly showing the calibration value. Upon accomplishment of the calibration, the operator restarts the program. The modules have good accessibility via their connector plugs, and diagnostic testing of modules by means of automatic equipment appears favorable. Many of the tests outlined for the servo systems of the AN/ASB-4 computer units are valid for the A3A computer servos. 400 cycle AC voltage and phase measurements, null and friction tests are predominant.

Considerable mechanical inspection and overhaul is still necessary for the motor generators, synchros and gear assemblies.

2.1.6 A3A Target Position Computer and Pulse Sweep Generator

The Target Position Computer contains the electronic video circuitry used for converting RF information from the fire control radar to target/antenna error signals for the armament computer. The Pulse Sweep Generator contains the electronic circuitry necessary to produce calibrated CRT Sweep displays. The target IF amplifier and detector are included in this unit. These units are not constructed in an ideal modular fashion, and therefore do not permit rapid repair by plug in replacement modules. The equipment is comprised of four major printed circuit decks quadrantly mounted in the circular overall housing. These decks have cables with plugs interconnecting their power supply and low impedance signals. However, considerable interconnections are made to each deck using permanently soldered coaxial cables. These cables connect to the deck exactly at the appropriate circuit function point. In the event of changing a deck, some tedious unsoldering of such cables is necessary. It is therefore desirable to troubleshoot the equipment to the nearest circuit component level at once.

A good distribution of test points are provided by means of which a fault may be located to the circuit function level. This might include three tube stages of circuitry. These tubes may then be removed and adapter tube bases inserted so that the pins of each tube may be monitored for further fault isolation. It may be advantageous to insert such tube socket adapters under each tube prior to commencement of automatic checking.

Manual participation would be required in the precise adjustment and calibration of CRT sweeps and markers. There is no reason why considerable time cannot be saved by the automation of checkout of these units. There is little mechanical maintenance and adjustment unlike the servo mechanisms previously described.

2.1.7 K-4A Stabilization Amplifier

The stabilization amplifier consists of 16 modules mounted on a chassis which forms the input/output junction box and base on which main connectors are mounted. Of the 16 modules, there are 8 different types. The nature of electronic circuitry in the modules is somewhat similar. Vacuum tube pushpull servo power amplifiers are predominant. Good accessibility may be obtained via the main chassis connectors, so that a faulty module can be located by means of the application of automatic checkout to the whole unit. The modules also lend themselves favorably to automatic testing techniques. Cables and relays in the main chassis may be checked without serious problems. A little mechanical overhaul work is called for, but most of the total overhaul time for this unit is taken up by electronic tests. Maximum advantage in time saving may be gained by the automatic testing of the equipment of this type.

2.1.8 Number of Tests Required for WRAMA Equipments

For the Servo Central approximately 412 automatic electrical measurements, 238 switch closures and 132 manual adjustments and dial readings can be made. For the Computer Central approximately 40 electrical measurements, 125 switch closures, and 150 manual adjustments or dial readings are required. Approximately 75 electrical tests and 20 manual tests are needed for faulty component isolation of the Amplifier racks. The Pulse Sweep Generator requires about 30 electrical tests to isolate a faulty circuit.

2.2 Final Results on Study of Equipment at USAF Security Service, Kelly Air Force Base, San Antonio, Texas

2.2.1 Summary

Two engineers from General Dynamics/Electronics visited USAF Security Service at Kelly AFB, San Antonio, Texas. Four days were spent examining the hardware and manuals of six equipments. These included the KO-6, KW-26, KG-3, KY-1, KL-7 and KL-47. The general system operation and nature of circuitry was studied in order to evaluate the usefulness of automatic check-out techniques. Stimuli generators and response monitors applicable to these equipments were noted and are indicated in Figure 2.

Eighteen of the building blocks outlined in the DAAFD ATE study were found to be applicable to the maintenance of these systems. New requirements were a 5.25 VAC filament power supply, a pulse coincidence detector and a signal pattern generator. These building blocks can be assembled to form an ATE system for either printed circuit boards or functional assembly fault isolation.

2.2.2 Overall System Checkout

The equipments studied are not densely packaged. Some equipments already have good test point facilities provided, and no problems should be

FIGURE 2

USAFSS San Antonio Building Block Requirements

		<u>KW-26</u>	<u>KY-1</u>	<u>KO-6</u>	<u>KL-7</u>
0	Programmer-Controller	X	X	X	X
1	Oscillator 0.1 cps - 30 KC	X	X	2	
2	Oscillator 30 KC - 40 MC			X	
3	Oscillator 40 MC - 400 MC				
4	Oscillator 950 MC - 1250 MC				
5	Oscillator 8.5 KMC - 12.4 KMC				
6	100 MC Cut-Off Video Amp				
7	Pulse Generator	X	X	X	X
8	Delay Generator	X	X	X	X
9	10 MC Cut-Off Video Amp.				
10	Transfer Osc. 5 MC - 175 MC				
11	Transfer Osc. 155 - 605 MC				
12	Transfer Osc. 475 - 1525 MC				
13	Transfer Osc. 1.475 - 10.5 KMC				
14	Noise Generator	X	X	X	
15					
16	Oscillator 2-4 KMC				
17	Oscillator 12.4 - 18.0 KMC				
18					
19	Resistive Load	X	X	X	X
20	Inductive Load				
21	Capacitive Load				
22	Impedance Meter		X	X	X
23	Multimeter	X	X	X	X
24	Time Interval & Freq. Meter	X	X	X	
25	Pwr. Mtr. & Reflectometer				
26	Waveform Analyzer		X	X	
27	Spectrum Analyzer				
28	Peak Power Meter				
29	Static Pressure Generator				
30	Spectrum Analyz. 12.4 - 18.0 KMC				
31	Coincidence Detector			X	X
32	Phase Meter				
33	Amplitude Modulation Det.			X	
34	Pwr. Supply 0.1 - 35 VDC 2.5a		X		
35	Pwr. Supply 22 - 32VDC	X	X	X	X
36	Pwr. Supply 30-500 VDC	4	4	5	4
37	Pwr. Supply 500-6000 VDC				
38	AC Supply 400 cps Phase Ref				
39	AC Supply 400 cps				
40	AC Supply Filament	X	X	X	
41	AC Supply 30 cps				
42	AC Primary Voltages	X	X	X	
43	Trans. Osc. 12.4 - 18 KMC				
44	Function Generator				
45	AC Hi Pot Supply				

2.2.2 (contd)

encountered in the addition of extra points. Automatic Test Equipment may be used to rapidly assess the operational status of the complete systems, indicating faulty circuit functions or modules. It is felt that this application might have some tactical advantage in the actual operation of the equipment. For example, an establishment having five assorted equipments could have an automatic checkout system with test programs for each equipment instantly available on the tape reader. All necessary adapters and cables may be permanently left in position. At the selection of a test number switch, any one of the equipments could be evaluated within a few minutes. All five equipments might be checked out in half an hour. Equipment 'down time' would be drastically reduced and a more efficient state of readiness achieved. 'T' connectors would be required at connector plugs to drawers, and it is likely that several special test connectors would be added.

2.2.3 Replaceable Module Checkout

It is understood that a major task at maintenance depots would be the repair of faulty modules. Most of these modules are of the printed circuit board type. Some of these boards may be as large as 12" x 10", containing many circuit functions. The board's connector plug allows sufficient access to evaluate the overall board function, but in many cases several circuits may contribute to a particular board output signal. If this signal is lost, the responsible circuit is therefore not apparent. The use of special test point jigs for printed circuit boards has therefore been considered. Such a jig might employ sharp spike terminals to make contact with the printed circuit 'pads.' Proper circuit board locations would be effected by means of a locating pin or frame. A problem may be encountered in piercing any epoxy resin coating on circuit boards. These resins are frequently of the thermosetting variety. Four possible methods of countering this difficulty are:

1. Direct penetration with spike contacts.
2. Application of heat to lower tensile strength of epoxy resin.
3. Abrasive process to remove epoxy from printed circuit 'pads.'
4. Chemical application to soften epoxy in locality of printed circuit 'pads.'

In many cases the direct penetration method will be successful. The application of heat should be examined. The entire board cannot be heated, since this might damage electronic components, especially semi-conductors, and even where no damage occurred, test parameters would not be representative of those obtained at room temperature. A jig enabling spike contacts to be pre-heated and applied to a circuit board has been considered and is described in this report. The abrasive method, involving the grinding off of resin covering circuit board pads is not very promising since cumulative deterioration of boards would result. Chemical softening of epoxy resin is feasible but time consuming and may render the resin permanently soft.

2.2.3 (contd)

Figure 3 is a diagram of the jig to provide heated spike contacts for piercing epoxy resin coated boards. At the center of the jig is a test point adapter plate. Mounted in this plate are spring loaded spike terminals with flat heads protruding on the left hand side. By means of a spiral drive and handwheel, an electrically heated metal slab may be brought in contact with the flat heads of the spike terminals. The heated slab maintains approximately 400°F, and quickly heats the terminals to near 300°F. The slab is then moved away from the test point adapter plate, and a frame containing the circuit board moved up to the spike terminals by means of another 'spiral drive' and handwheel.

A mechanical stop allows the spikes to be compressed against their springs so as to ensure each terminal is in contact. The springs compensate for irregularities in solder terminal height, and together with the mechanical stop, remove judgement from the operator in applying pressure to the board. Melting of solder and ambient temperature rise of components would result if the heated slab were left in contact with the terminals.

Power and stimulus application and the evaluation of test points may be accomplished with automatic test equipment.

Disadvantages

1. A bad contact by one of the spikes is not readily apparent.
2. Varnish and epoxy resin coating on boards may not pierce easily and regularly.
3. Mechanical location of spikes on circuit points is difficult to attain, since printed circuits are not always oriented on boards in exactly the same position. This positional accuracy problem may be overcome in certain cases, depending upon the quality and uniformity of the boards under test.

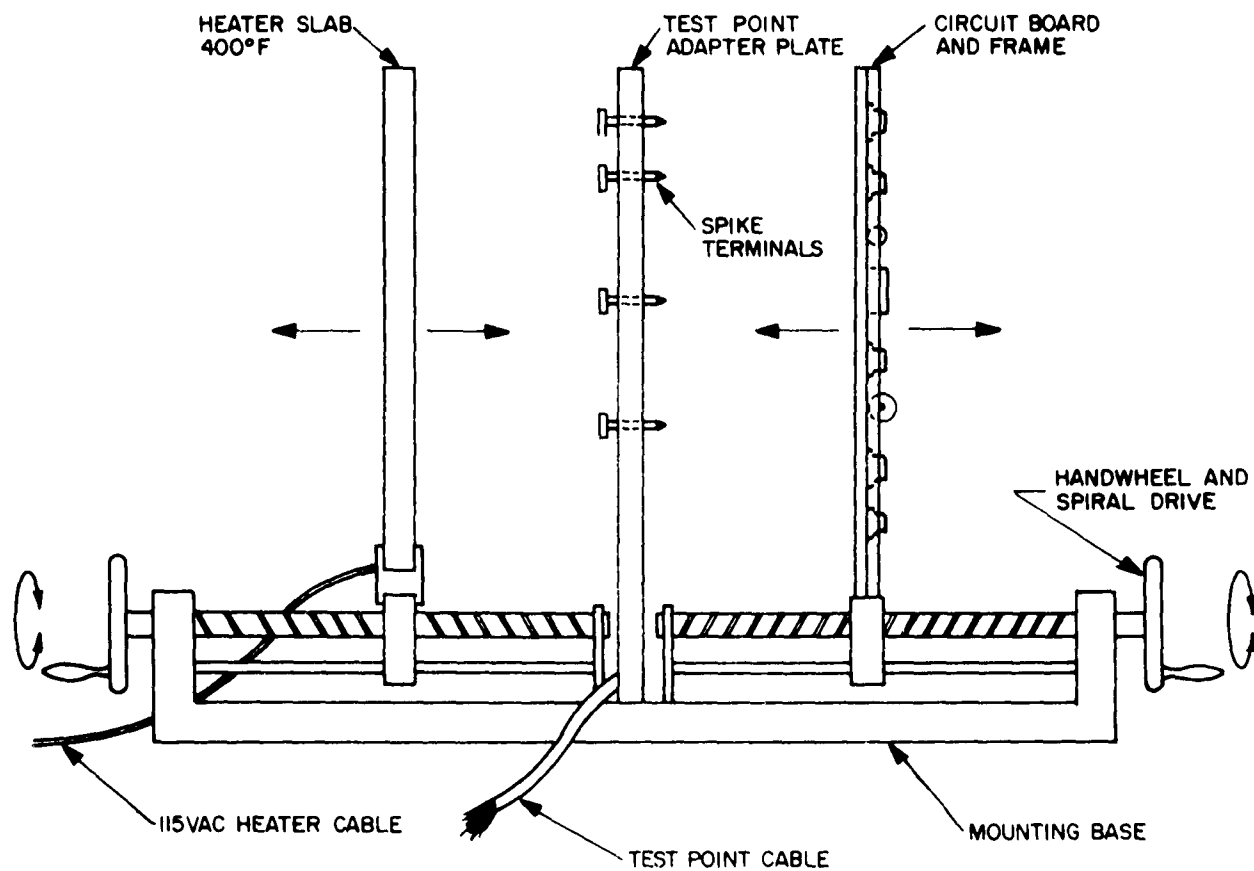
Considering the above disadvantages, particularly #3, it is considered doubtful that the jigs described would prove practical. Whereas the jig may be developed successfully for one board type, it would be difficult to make a universal model.

2.2.4 Card Tester ATE

The card tester ATE required for testing printed circuit cards for USAFSS, San Antonio can be assembled from the building blocks described in the "Final Engineering Report on Automatic Test Equipment Study Extension for Dayton Air Force Depot." Major units of the system are shown in Figure 4 and are as follows:

TEST POINT ADAPTER JIG
FOR PRINTED CIRCUIT BOARDS

Figure 3



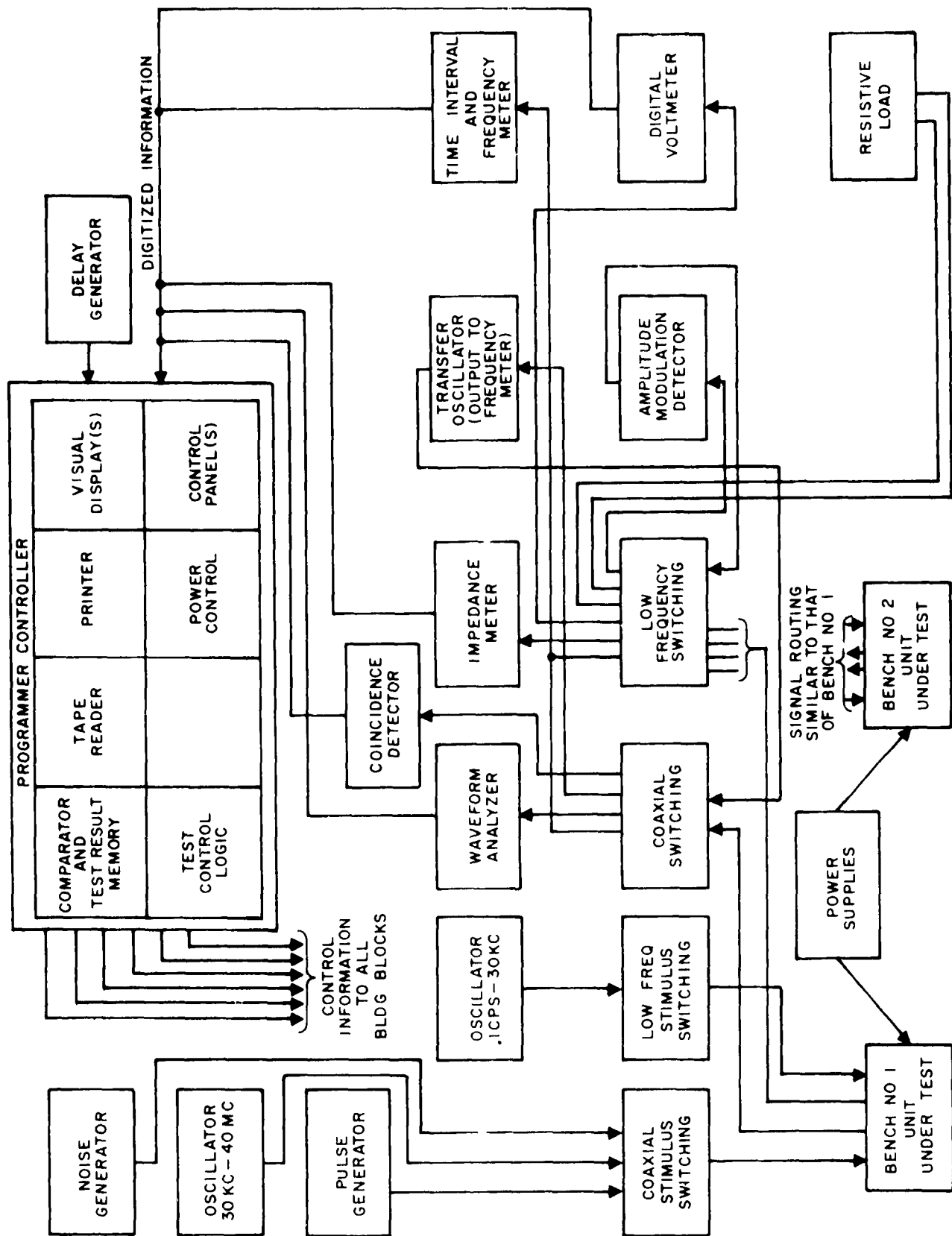


FIGURE 1
 Time Interval and Frequency Meter
 for USAFSS San Antonio Printed Circuit Board Tester

2.2.4 (contd)

A Programmer/Controller controls test sequence operation, evaluates and displays results. It includes a photo diode tape reader, test control logic which directs operation of the tester according to instructions programmed on the perforated tape, a digital comparator for simultaneous comparison of the digitized measured value against both high and low limits programmed from the tape, a printer for permanent recording of test results, display panels for indications of test results, tester status and control panels for tester power and mode controls and for test search to manually selected test numbers. A programmable delay generator furnishes programmed delays for equipment warmup or stabilization periods.

Controlled by the Programmer Controller are programmable oscillator, noise and pulse generator stimulus building blocks with associated switching to apply stimuli to the cards under test. Also controlled by the Programmer Controller are response monitor building blocks including a programmable amplitude modulation detector which extracts modulating components from an R.F. carrier, a pulse coincidence detector, a digital multimeter for measurements by analog to digital conversion of DC volts, AC volts and resistance, an impedance meter for measurement of capacitance and inductance, a time interval and frequency meter for time, frequency, period measurements, a waveform analyzer for measurement of pulse waveform characteristics and a transfer oscillator for calibration of stimulus generators and measurement of frequencies greater than 10 megacycles. High and low frequency response monitor switching units are used to route test signals from cards under test to the appropriate response monitor or measurement unit. Programmable power supplies furnish power to the card under test and a programmable resistive load is available for switching across card terminals. Figure 5 gives overall system specifications of the card tester ATE.

System Operation

The system functions as follows:

- a) The operator inserts the card to be tested into a fixture at Bench No. 1 or No. 2 and selects the first test number of the program for this card by means of rotary switches on the control panel. Upon completion of automatic search, the test number appears on the display. After verifying that the number is correct, he initiates the testing by pressing a test start button.
- b) The Programmer-Controller receives test program information from the tape consisting of building block identity and building programming information. This information is bussed to all building blocks. Each building block includes a decoder which decodes identity information to determine if that particular building block has been addressed. Each building block has its own address. If the decoded identity corresponds to a particular address, programming information (which determines range,

FIGURE 5

Card Tester ATE System Specifications

<u>Function</u>	<u>Frequency Range</u>	<u>Other Parameters</u>	<u>No. of Building Blocks</u>
A.F. and R.F. Generation	0.1cps - 40 MC		2
Noise Generation	1cps - 2 KMC	25db 1 cps - 10 MC 15db 10 MC - 2 KMC	1
Pulse Generation	.6cps - 3.3 Mc PRF	0.1usec - 1.5sec pulse width	1
Delay Generation		3usec - 1.6 sec	1
Freq. Measurement	99.9cps - 9.99MC 5 MC - 175 MC	.99usec - 999 sec time	1 counter 1 trans. osc.
Waveform Measurement	2pps - 83,300pps PRF	.05usec - 100 msec rise, fall time, pulse width	1
Impedance Measurement		10 uufd - 1000 ufd 10 uh - 100 h 100 ohms - 5 meg RC 5 ohms - Meg RL	1
Voltage Measurement	10 cps - 10 KC	.999V - 500 Vdc	1
Resistance Measurement		.999V - 500 Vac 9.99 ohms - 9.99 megohms	
DC Power		.1 - 35V, 2.5A 22V - 32V 27A 30V - 500V, 1A 500V - 6000V, 800 ma to 1 KV 250 ma to 6 KV	1 1 1 1
AC Power	400 cps	16V - 300V, 7A 4V - 16V, 10A	1 1
	400 cps	95V - 130V, 40A, 1 ϕ 104 - 130V, 15A, 3 ϕ	1
Loads		Res. 0.1 ohm - 7 megohm	1
AM Detector	400 cps - 30MC carrier 0-20 KC modulation		1

2.2.4 (contd)

frequency, output amplitude of stimulus generators and type measurement, range of response monitors or switching setup of switching blocks) is read into storage for use by that particular building block. This programming information is not accepted by any other building block.

- c) A typical test sequence would furnish a test number to the display unit and printer storage. It would then address the digital multimeter to select the measurement function or type and the range. The digital comparator would then be addressed for insertion of limits. If required for the immediate test, power, stimulus and loads for the card under test would be selected by addressing the power supplies, stimulus generators, and resistive load. Next the switching would be programmed to set-up the proper connections between the card under test, the stimulus and load (if required) and the digital multimeter. Finally the delay generator would be programmed for the appropriate delay before issuance of the "start-measurement" command to the digital multimeter. This delay will allow for warm-up or stabilization of the card circuit after switching. Different amounts of delay may be programmed depending upon the test conditions. A "measurement-complete" signal from the digital multimeter will initiate comparison of measured value against both high and low limits in the digital comparator. All test results are then displayed on the display and operate panel and printed out if desired.
- d) If the test result is a GO, the Programmer Controller will immediately perform the next test in the sequence on the program tape. In the event of a HI or LO test result, the test sequence will stop, and the operator will refer to a microfilm viewer or other device for instructions. The microfilm viewer could be modified to automatically search for and present the appropriate instructions corresponding to the test number yielding the HI or LO result. However, a viewer considered for this application already includes a high speed search feature requiring the operator to watch for alignment of lines (projected on the screen from the film) with numbered graduations adjacent to the screen. When alignment is observed, the operator reduces the scanning speed to find the particular instruction number in this region of the film.

Adequate self-test features and a special test program on the tape will establish a high confidence level in the test equipment by providing checks to insure correct programming operation and to insure measurement accuracy calibrations. Faults will be isolated automatically to the major ATE module, and further isolation will be assisted by built-in maintenance aids.

2.2.5 Recommendations

General Dynamics/Electronics has recently submitted the final report of the Automatic Test Equipment Study Extension conducted for Dayton Air Force Depot in which specifications have been prepared for an extremely versatile General Purpose Automatic Test System (GPATS), utilizing a "building

2.2.5 (contd)

block" approach. Basically, the system is formed by a Programmer-Controller, and a group of Programmable stimulus generators and response monitors. The printed circuit board testing requirements of USAFSS at San Antonio would be usefully served by a test system configuration assembled from these building blocks as shown in Figure 4. Approximately 18 stimulus generator, response monitor and load building blocks would be required to cover the range of equipment maintained by USAFSS.

It is recommended that printed circuit boards be automatically tested by such a system without the use of special purpose jig assemblies. Fault location would be conducted as far as possible via the terminals of the board plug. When this has been done, special instructions would be given so that the operator may manually connect a probe to specific circuit points for further fault isolation.

Such instructions may be obtained from a microfilm viewer. The viewer would contain a magazine of film upon which a series of instruction charts for various printed cards had been recorded. A No-Go for a particular test would result in the display of an instruction identification number. The operator 'slews' the microfilm viewer to the appropriate instruction chart-number and performs the manual tasks indicated. In this manner fault isolation to the component level may be achieved and diagnosis time reduced to a minimum. No thought is required by the operator in determining the optimum diagnostic approach.

2.3 Final Results on Study of Mobile AMA equipment

2.3.1 Summary

An investigation has been made of the B58 Hustler Bomb/Nav system Aerospace Ground Equipment to evaluate the feasibility of applying automatic test equipment techniques at the responsible maintenance depots to check out individual functions of the AGE system.

This particular application is somewhat unique as the AGE itself is an extremely sophisticated and complex automatic check out system. There are 5 major assemblies:

- a) Mobile Test Set
- b) Computer Test Set
- c) Amplifier Test Set
- d) Radar Test Set
- e) Inertial Test Set

Each major assembly is a specialized automatic tester programmed by punched tape via a mechanical tape reader.

2.3.1 (contd)

The complete system incorporates some 76 individual functions and approximately 1800 different module types. The equipment design includes integrated "self-test" features programmed by special tapes. This suggests that the equipment has the capability of fault isolating malfunctions within itself and additional depot work is unnecessary. This investigation however has assumed that faulty assemblies from the overall system will be returned for depot maintenance.

It will be appreciated that the allocated study period of 2 man months is totally inadequate for a comprehensive evaluation of an AGE system of this size and complexity. It should be noted, however, that the philosophy of "self-test" is reflected in the information contained in the relevant technical orders. In general circuit parameters and functional operation are described in broad outline only. More detailed information of sub-assemblies and modules will be required before test routines can be assigned to every function.

The maintenance instructions are particularly superficial and in most cases are limited to a sketch of one of the AGE major assemblies plus a reference to a self-test tape. This will be of no value whatsoever to depots not possessing the complete AGE system, the self-test tapes and a tape manual. However, with more detailed documentation most of the functions studied during the investigation are readily adaptable to automatic check-out techniques.

2.3.2 Major Functional Units Considered

The major functions evaluated during the investigation period are as follows:

- 1) GSE D.C. Power Supplies
- 2) GSE Load Simulators
- 3) Amplifier Test Set Central Routing Assembly
- 4) Inertial Test Set Central Routing Assembly
- 5) Computer Test Set Central Routing Assembly
- 6) Mobile Test Set Central Routing Assembly
- 7) Automatic Voltage Monitor
- 8) Precision Ratio Voltage Generator
- 9) Heading Data Generator
- 10) Synchro Signal Generator
- 11) 400 cps Voltage Generator
- 12) DC Reference Generator
- 13) 800 cps Voltage Generator
- 14) Quadrature Reference Generator
- 15) Step Function Generator
- 16) 380 cps Voltage Generator

2.3.2 (contd)

- 17) Doppler Video Signal Generator
- 18) Doppler I.F. Signal Generator
- 19) Stabilization Unit Control Unit
- 20) Automatic Frequency Control
- 21) Precision Ratio Reference Generator
- 22) Self Test Standards
- 23) Synchro Data Comparator
- 24) Servo Voltage Comparator
- 25) Comparator Pre-Amplifier
- 26) Sequence Timer
- 27) Inverse Regulator
- 28) Feedback Amplifier A
- 29) Variable Gain Amplifier
- 30) Amplifier Assembly C
- 31) Amplifier Assemblies BI and BII
- 32) Feedback Amplifier Assembly B
- 33) Feedback Amplifier Assembly A
- 34) Timing Oscillator
- 35) Servo Function Analyzer
- 36) Function Analyzer
- 37) Test Number Indicator
- 38) Ferrite Drive
- 39) Simulator
- 40) Video Target Simulator
- 41) Beacon Simulator
- 42) Synchronous Detector and Phase Shifter
- 43) Beacon Modulator
- 44) 400 cps Harmonic Filter
- 45) Video Delay Circuit
- 46) Radio Frequency Delay Circuit
- 47) Search Microwave
- 48) Precision Frequency Source and 250 cps Power Amplifier
- 49) Wattmeter Bridge
- 50) Vacuum Tube Voltmeter

Items not studied due to non-availability of technical orders were:

- 1) Programmers Radar Test Set
- 2) Spectrum Analyzer
- 3) Panel Remote Indicator
- 4) Tilt Test Generators
- 5) Servo Drive and Trigger Generator
- 6) Sweep Waveform Generator
- 7) Resolver Trigger Generator
- 8) Automatic Power Control
- 9) Tape Reader and Systems Data Historian

2.3.2 (contd)

- 10) Peak Power Meter
- 11) Pulse Analyzer
- 12) Two speed Memory Unit
- 13) Positional Memory Unit
- 14) Tuned Detector, Load and Synchronous Detector
- 15) Doppler Microwave Assembly
- 16) Automatic Frequency Limit Counter
- 17) Coherency Check
- 18) Digitalizer Tester
- 19) Sine Wave Generator
- 20) Oscilloscope
- 21) Power Supply Dummy Load
- 22) Power Transformer Assembly
- 23) Frequency Meter

Considered inapplicable and not studied:

- 1) Environmental Control Unit
- 2) Test Set Blower Console
- 3) Trailer

The equipment is constructed on a modular basis and provides excellent accessibility to test points for measurement and stimulus application.

2.3.3 MOAMA Study Results

Figure 6 shows the anticipated stimuli generator requirements for each of the functions. It will be noted that in addition to omissions due to the lack of technical information some of the functions studied have been excluded from the chart:

- a) Wattmeter Bridge
- b) Vacuum Tube Voltmeter
- c) RF Delay Circuit

These particular functions require a considerable amount of manual inspection, calibration etc., and it is considered that the overall check-out time will not be reduced significantly by automating the remaining tests.

It should also be noted that inclusion in the chart does not imply that every phase of a function check-out can be fully automated. It does mean, however, that it appears feasible that automated test routines could be evolved to evaluate the performance of these functions. Also automation would reduce considerably the overall testing time required by strictly manual testing. In addition, improvements will be achieved in reliability and test result validity. It is evident that the prescribed physical inspections cannot be automated and the replacement of faulty sub-assemblies or components will still require manual effort.

2.3.3 (contd)

It is anticipated that faulty sub-assemblies will be inserted in special adapters after removal from the main assembly and subjected to more detailed automated test routines. Some of the sub-assemblies are not readily adaptable to fully automatic check-out. For example, the Search Microwave and Beacon Simulator functions incorporate microwave circuits which include directional couplers, matched loads etc. If these components are suspected faulty they must be removed from the circuit, visually inspected for physical damage and individually checked for VSWR, bandwidth, coupling factor, directivity etc.

The overall testing time for these particular measurements may be reduced by using reflectometer techniques but manual operation and human evaluation will still be required.

For example, a microwave reflectometer system will generate a voltage proportional to the VSWR of the device under test. However, it can be shown that this is derived from the formula,

$$V \quad \text{VSWR} = \frac{P_I + P_R}{P_I - P_R}$$

where:

P_I P_R

P_I :- Incident or forward R.F. Power

P_R :- Reflected R.F. Power

This is a non-linear expression which requires a specially calibrated read-out for rapid interpretation. This type of read-out is not readily adaptable to digital read-out or computation.

However, it is not unreasonable to assume that, except for the microwave generator tubes, the remaining components in these low pwr. RF systems will not deteriorate significantly in time unless the equipment is subjected to severe physical stress. This is considered to be a valid assumption and the Search Microwave and Beacon Simulator functions are included as adaptable to automated test routines.

3. CONCLUSIONS

As a result of additional study of Warner-Robins, Mobile and San Antonio equipments, the specifications of some building blocks defined under study contract AF33-(604)-28541 were modified. These included the programmable synchro transmitter, AC supply 400 cps phase referenced, AC supply 6.3V, and programmable A.C. power supply 16-300 VAC. The programmable synchro transmitter was replaced by a programmable ratio transformer. The specification for AC supply 400 cps referenced was modified to include

3. (contd)

frequency regulation and higher output current. The AC supply 6.3V was modified to provide programmable output voltages from 4V to 16V and fixed output frequency of 400 cps. The programmable A.C. Power Supply 16-300 VAC was also modified for fixed output frequency of 400 cps. One new building block requirement arose, for an AC voltage high potential test supply. All other testing requirements are accommodated by building blocks specified to date together with occasional requirement for accessories. This result is significant in that the building blocks were originally defined for airborne equipments serviced by DAAFD whereas the other Air Materiel Areas service special purpose automatic checkout and communications equipment in addition to airborne fire control equipments. These results further verify the validity of the building block approach for stimulus generators, response monitors and accessories which was adopted during this study.

Another study result was definition of an ATE system configuration for printed card testing. This result indicates the flexibility of the ATE configuration and system design described in the Final Engineering Report on Automatic Test Equipment Study Extension for Dayton Air Force Dept.

Appendix I

Purchase Description

Programmable A.C. Power Supply Filament Voltage

1. Scope

1.1 Scope: This specification covers the general and detail requirements for a programmable A.C. power supply in the 4-16 VAC range.

2. Applicable Documents (MDNE-PD-63)

3. Requirements

3.1 General Purchase Description: The requirements of general purchase description No. MDNE-PD-63 apply as requirements of this purchase description. When the two purchase descriptions conflict, this purchase description shall govern.

3.2 The unit shall perform its designated function successfully within the operational and life requirements designated herein.

3.2.1 Service Life: 10,000 hours min.

3.3 Design

3.3.1 Controls: An auxiliary on-off switch shall be provided in an accessible location. All other functions are to be performed from a remote source.

3.4 Detail Performance Requirements

3.4.1 Power Requirements: 105-125V AC, 55-420 cps, single phase

3.4.2 Output Voltage: 4-8V RMS programmable in .2 volt steps, 8-16 V RMS programmable in 1 volt steps, programming accuracy $\pm 2\%$.

Output Frequency: 400 cps $\pm 1\%$

3.4.3 Output Current: 10 amps maximum

3.4.4 Static Regulation: A variation in input voltage ($\pm 10\%$ of nominal) shall not cause an output voltage change of more than $\pm .5\%$.

A no load to full load or full load to no load step change shall not cause an output voltage change of more than $\pm 2\%$.

3.4.5 Speed of Response: .55 volts/sec.

3.4.6 Output Frequency: 400 cps $\pm 5\%$.

- 3.4.7 Response to Simultaneous Line and Load Variations: The output voltage shall not change more than +2% for any combination of line voltage change (+10% of nominal) and load changes of +10%.
- 3.4.8 Output Impedance: Less than .01 ohm.
- 3.4.9 Short Circuit Protection: Provision shall be made to protect the power supply against short circuit.
- 3.4.10 Warmup Time: The time required after application of primary power for the output voltage to be within the accuracy specified in Paragraph 3.4.2 shall not exceed 45 sec.

APPENDIX 2

Purchase Description

Programmable A.C. Power Supply Hi Pot

1. Scope

1.1 Scope: This specification covers the detailed requirements for a programmable A.C. power supply in the 600-1800 VAC range.

2. Applicable Documents (MDNE-PD-63)

3. Requirements

3.1 General Purchase Description: The requirements of general purchase description No. MDNE-PD-63 apply as requirements of this purchase description. When the two purchase descriptions conflict, this purchase description shall govern.

3.2 The unit shall perform its designated function successfully within the operational and life requirements designated herein.

3.2.1 Service Life: 10,000 hours minimum

3.3 Design

3.3.1 Controls: An auxiliary on-off switch shall be provided. All other functions are to be performed from a remote source.

3.4 Detail Performance Requirements

3.4.1 Power Requirements: 105-125 VAC, 55-420 CPS, single phase

3.4.2 Output Voltage: 600 VAC RMS-1800 VAC RMS in 100 volt steps.

Programming Accuracy $\pm 2\%$ of programmed value.

3.4.3 Output Current: 10 milliamperes minimum

3.4.4 Output Frequency: 55-420 cps

3.4.5 Static Regulation: A variation in input voltage ($\pm 10\%$ of nominal) shall not cause an output voltage change of more than $\pm 2\%$.

3.4.6 Speed of Response: The power supply shall be capable of covering 20% of the programmed voltage range within 1 sec.

3.4.7 A meter shall be provided to cover the output voltage in one range. The accuracy of the meter shall be +2% of full scale.

3.4.8 Short Circuit Protection: Provision to protect the power supply against short circuit shall be provided.

3.4.9 Programming: All programming will be done by applying externally supplied D.C. levels to the power supply control lines.

3.4.9.1 Control Lines: The output voltage shall be programmed by means of five control lines weighted as follows:

1. 100
2. 200
3. 400
4. 800
5. 1000

3.4.9.2 Programming Time: The maximum time required to change from a given voltage to a new voltage shall not exceed 50 milliseconds

3.4.9.3 Transient Behavior During Programming: When programming a higher voltage than the previously programmed level, the transient voltage output shall not exceed the newly programmed level by more than 3%. When programming a voltage less than the previous programmed level, the transient voltage output shall not exceed the previous level nor fall below the newly programmed level by more than 3%.

3.4.10 Warmup Time: The time required after application of primary power for the output voltage to be programmable with the accuracy specified in paragraph 3.4.2 shall not exceed 45 seconds.

3.4.11 Waveform Distortion: Less than 5%.