NASA CR–132522

REPORT

NASA–LANGLEY HELICOPTER TOWER INSTRUMENTATION SYSTEM

By S. W. Stoffel

Prepared for:

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA 23665

CONTRACT NUMBER NASI–12841

WYLE LABORATORIES REPORT NUMBER 50601

October 1974

WYLE LABORATORIES
SCIENTIFIC SERVICES & SYSTEMS GROUP
3200 MAGRUDER BLVD., HAMPTON, VIRGINIA

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NASA - LANGLEY
HELICOPTER TOWER INSTRUMENTATION SYSTEM

1.0 PURPOSE OF REPORT

The purpose of this report is to provide an overview of the existing instrumentation system capabilities at Langley Research Center's Helicopter Rotor Test Facility and to make recommendations for improving the instrumentation system within the facility.

2.0 BACKGROUND OF THE FACILITY

2.1 General

The Helicopter Rotor Test Facility is located in the Langley West Area near the intersection of Ames and Taylor Roads. The facility consists of a vertical conical shaped structure supporting a vertical drive shaft to which a helicopter rotor may be mounted. A control room is located at the base of the tower and a shop building is adjacent to the tower. The drive shaft is driven by a 3,000 horsepower variable frequency motor through a primary and a secondary gear box with a 6 : 1 or 3 : 1 reduction ratio. A double chain link fence of about 80 feet in diameter is mounted on poles in the plane of the rotor head. The roof of the control room is reinforced with closely spaced steel beams. Both of these items are to provide safety to the operating personnel and nearby areas in case of a rotor failure. Figure 1 shows an exterior view of the facility.

2.2 History of the Facility

The shell of the facility was built in the early 1940's with drive power derived from an internal combustion engine. In the late 1940's the base was modified and the 3,000 horsepower motor was installed. In the late 1950's the base was again modified to incorporate the control room.

The primary purpose of the Helicopter Rotor Test Facility is to test conventionally designed rotor blades, in the hovering mode, to determine the aerodynamic and acoustic effects of twist, taper, thickness ratio, camber, leading edge roughness, and tip Mach number.

Figure 1. NASA Langley Research Center
Helicopter Rotor Test Facility

In addition to conventional rotor blades, the tower has been used to test tip-mounted ram-jet, pulse-jet, and pressure-jet engines. The tower has also been used as a centrifuge to proof test live payloads for rocket fired nose cones. Facility capabilities and functions include:

Horsepower:	3,000 (equipped to utilize 1,500 HP)
Torque:	up to 22,000 foot pounds
Thrust:	up to 14,000 pounds
Speed:	up to 475 revolutions per minute
Measures:	pitch, lead-lag, feathering, flapping, pressures, strain gage forces and moments
Capabilities as a centrifuge:	radius of arm -- ten feet, maximum "G" - 60, maximum weight - 400 pounds on each end

3.0 MAJOR SUBSYSTEMS EQUIPMENT

3.1 General

The Helicopter Rotor Test Facility instrumentation system consists of a number of major pieces of equipment. These are listed in Tables I, II and III for each subsystem, i.e., Rotor Data Acquisition Subsystem, Facility Data Acquisition Subsystem and Spectral Analysis Subsystem, respectively. The equipment includes custom-made "black box" circuitry, standard vendor products, and "modified" standard vendor products.

The major components of the Helicopter Rotor Test Facility instrumentation system are located in standard relay racks located on the ground floor of the control room. Figure 2 shows a basic layout plan of this equipment arrangement. The Ampex FR-600, CEC VR-3400, and Honeywell 7600 magnetic tape recorders/reproducers are self-contained units on casters. Contents of racks 1, 2, 3, 4, 5, and 6 are shown in Figures 3 through 11. Figure 12 shows a general view of Spectral Analysis and Rotor Data acquisition equipment

TABLE I - ROTOR DATA ACQUISITION SUBSYSTEM EQUIPMENT LIST

Quantity	Description	Manufacturer	Model/Type
1	Magnetic Tape Recorder/Reproducer	Ampex	FR-600
1	Magnetic Tape Recorder/Reproducer	Bell & Howell (CEC)	VR-3400
1	Magnetic Tape Recorder/Reproducer	Honeywell	7600
1	Time Code Generator/ Search Unit	Systron Donner	8154
—	DC Amplifier (Quantity depends upon number of transducers)	Neff	122
1	Galvanometer Amplifier (six channel)	Bell & Howell (CEC)	1-172
3	Galvanometer Amplifier (two channel)	Bell & Howell (CEC)	1-172
1	Oscillograph (up to 24 channels)	Honeywell	1108
1	Beat Frequency Audio Generator	General Radio	1304-B
1	Graphic Level Recorder	General Radio	1521-B
2	Signal Input/Output Monitor Box	NASA	
2	Output Signal Squelch Box (14 channels each)	NASA	
3	Filter Box (8 channels each)	NASA	

TABLE II - FACILITY DATA ACQUISITION SUBSYSTEM EQUIPMENT LIST

Quantity	Description	Manufacturer	Model/Type
1	Oscillograph (up to 24 channels)	Honeywell	1508
1	Tower Parameter Interface Box	NASA	
4	Digital Voltmeter	ERC	Series 4000
1	Frequency Meter	ERC	Series 2700
4	0-20 DC Microammeter	Modutec	
2	25-0-25 DC Microammeter	Modutec	

SUPPORT EQUIPMENT IN THE CONTROL ROOM

Quantity	Description	Manufacturer	Model/Type
1	Dual Trace Oscilloscope	Hewlett-Packard	140A
1	Dual Trace Oscilloscope	Hewlett-Packard	120AR
1	Dual Trace Oscilloscope	Tektronix	585A
1	RMS Voltmeter/Log Converter	B & K	215
1	Digital Voltmeter	Fluke	8200A
1	Frequency Counter	General Radio	1153AP

TABLE III - SPECTRAL ANALYSIS SUBSYSTEM EQUIPMENT LIST

Quantity	Description	Manufacturer	Model/Type
1	Low Frequency Translator	Spectral Dynamics	SD 307
1	Real-Time Analyzer	Spectral Dynamics	SD 301C
1	Ensemble Averager	Spectral Dynamics	SD 302C
1	X-Y Display (Oscilloscope)	Spectral Dynamics	13116
1	Phase Meter/Resonant Dwell	Spectral Dynamics	SD 110-1
2	X-Y Recorders	Hewlett-Packard	7035B
1	Correlation and Probability Analyzer (with option 43040-8000 point precomputation delay control and option 43060 - normalization)	SAICOR	SAI-43A
2	Filters	Krohn-Hite	3202(R)

3.1.1 Rotor Data Acquisition Subsystem Equipment

The Rotor Data Acquisition Subsystem includes major pieces of equipment listed in Table I. The specifications for each major item of commercial equipment for this subsystem are furnished in Appendix I.

3.1.2 Facility Data Acquisition Subsystem Equipment

The Facility Data Acquisition Subsystem includes major pieces of equipment listed in Table II. The specifications for each major item of commercial equipment for this subsystem are furnished in Appendix II.

REVISIONS			
LTR	DESCRIPTION	DATE	APPD

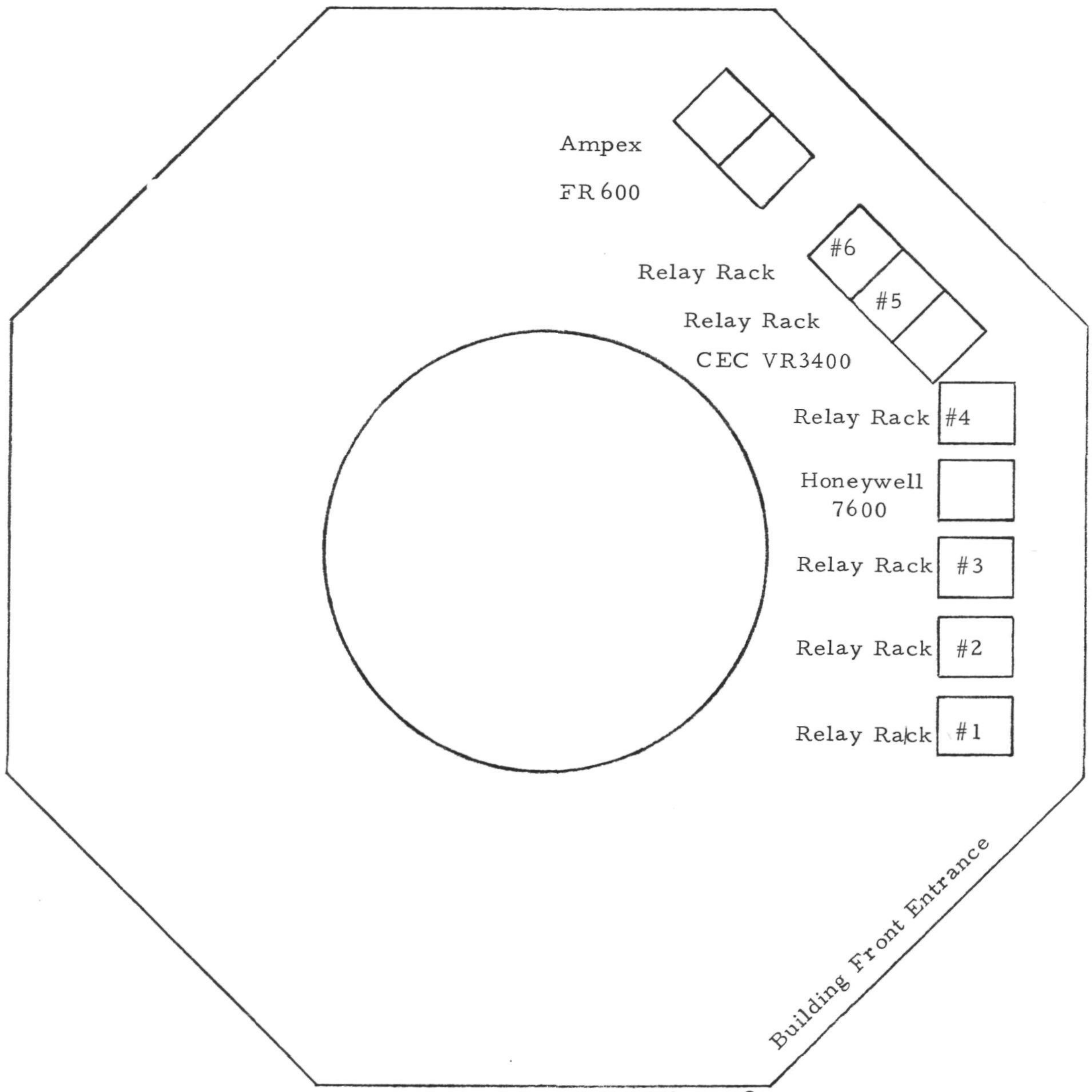


Figure 2.

PROJECT		WYLE LABORATORIES HAMPTON FACILITY, HAMPTON, VIRGINIA		
	DATE	EQUIPMENT ARRANGEMENT, HELICOPTER ROTOR TEST FACILITY		
DRAWN KSB	5-24-74			
CHECK SMS	5/24/74			
APPD [illegible]	5/26/74			
APPD				
		SIZE A	PART NO	DWG NO A74-50601-500
		SCALE NONE		SHEET OF

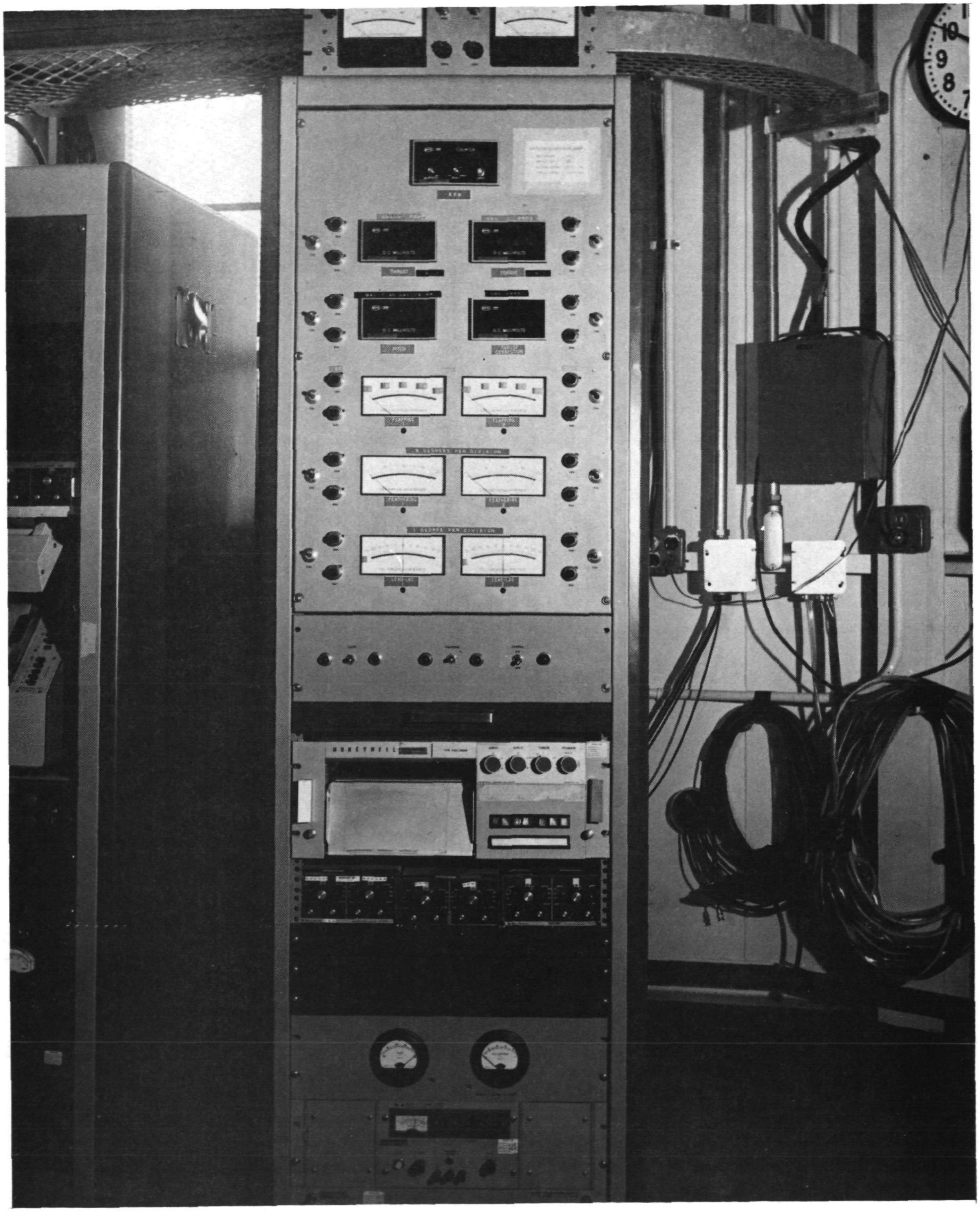


Figure 3. Facility Data Acquisition Subsystem
Relay Rack Number 1.

REVISIONS			
LTR	DESCRIPTION	DATE	APPD

A	Tower Parameter Indicators and Adjustments; RPM, Thrust, Thrust Correction, Torque, Pitch, Lead/Lag 1 and 2, Flapping 1 and 2, Feathering 1 and 2
B	Tower Parameter Interface, Pitch Control, Tracking Control, and Camera Control
C	Oscillograph, Honeywell Model 1508 (for pitch, thrust, thrust correction, torque)
D	Galvo Amplifiers, Bell & Howell Model 1-172 (6 channels)
E	Volt and Ammeter for G
F	Power Supply, Hewlett-Packard Model 6113A
G	Power Supply, Harrison Labs Model 6367A

Figure 4.

PROJECT		WYLE LABORATORIES HAMPTON FACILITY, HAMPTON, VIRGINIA			
	DATE	RELAY RACK NO. 1 FACILITY DATA ACQUISITION SUBSYSTEM HELICOPTER ROTOR TEST FACILITY			
DRAWN KSB	5-24-74				
CHECK SWS	5/25/74				
APPD JW	5/25/74				
APPD		SIZE A	PART NO	DWG NO A74-50601-501	
		SCALE NONE		SHEET	OF

REVISIONS			
LTR	DESCRIPTION	DATE	APPD

A	Squelch Boxes, (2)
B	Galvanometer Amplifier, Bell & Howell Model 1-172A (6 channels)
C	Oscillograph, Honeywell Model 1108
D	Frequency Counter, General Radio, 1153 AP
E	Beat Frequency Audio Generator, General Radio, Model 1304-B
F	Graphic Level Recorder, General Radio, Model 1521-B

Figure 5.

PROJECT		WYLE LABORATORIES HAMPTON FACILITY, HAMPTON, VIRGINIA
	DATE	
DRAWN KSB	5-24-74	RELAY RACK NO. 2
CHECK SMS	5/25/74	ROTOR DATA ACQUISITION SUBSYSTEM
APPD JW	5/25/74	HELICOPTER ROTOR TEST FACILITY
APPD		
		SIZE A — PART NO — DWG NO A74-50601-502
		SCALE NONE — SHEET OF

REVISIONS			
LTR	DESCRIPTION	DATE	APPD

A	Signal Monitor Box, NASA
B	Dual Trace Scope, Hewlett-Packard, Model 120AR
C	DC Amplifiers, Neff, Model 122 (8 channels)
D	Filter Box, NASA
E	Attenuators, Hewlett-Packard Model 350C (3 channels)
F	Low Voltage Power Supplies, Hewlett-Packard Model 6228B and Trygon Model HR 60-5B

Figure 6.

PROJECT		WYLE LABORATORIES HAMPTON FACILITY, HAMPTON, VIRGINIA
	DATE	
DRAWN KSB	5-24-74	RELAY RACK NO. 3 ROTOR DATA ACQUISITION SUBSYSTEM HELICOPTER ROTOR TEST FACILITY
CHECK	5/2?/74	
APPD	5/25/74	
APPD		
		SIZE A · PART NO · DWG NO A74-50601-503
		SCALE · SHEET OF

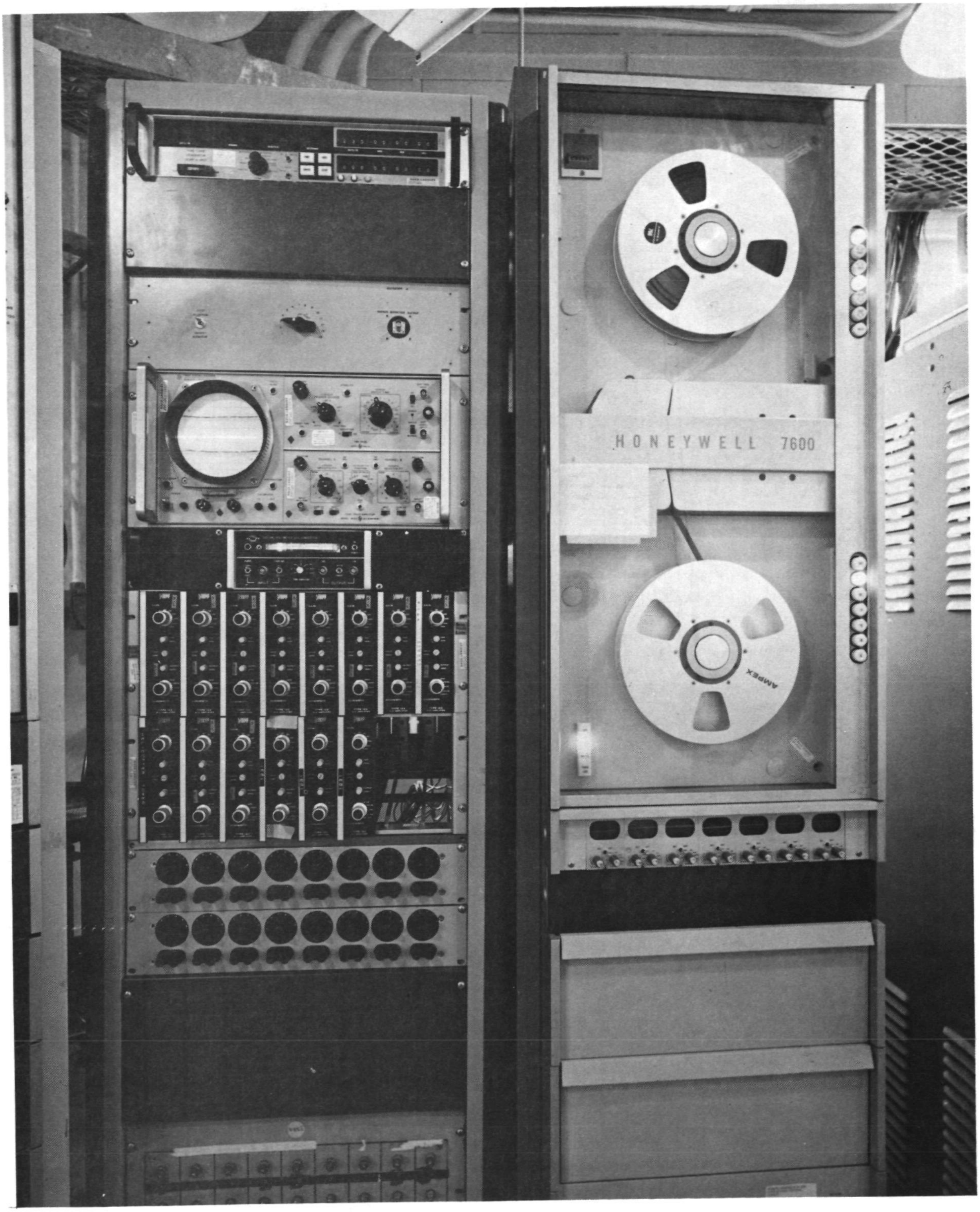


Figure 7. Rotor Data Acquisition Subsystem, Rack No. 4 and Honeywell 7600 Recorder

REVISIONS			
LTR	DESCRIPTION	DATE	APPD

A	Time Code Generator, Systron Donner, Model 8154
B	Signal Monitor Box, NASA
C	Dual Trace Scope, Hewlett-Packard, Model 140A
D	RMS Voltmeter, B & K, Model 215
E	DC Amplifiers, Neff, Model 122 (16 channels)
F	Filter Boxes, NASA (2)
G	Balance Box, NASA

Figure 8.

PROJECT		WYLE LABORATORIES HAMPTON FACILITY, HAMPTON, VIRGINIA
	DATE	
DRAWN KSB	5-24-74	RELAY RACK NO. 4 ROTOR DATA ACQUISITION SUBSYSTEM HELICOPTER ROTOR TEST FACILITY
CHECK [signature]	5/25/74	
APPD [signature]	5/25/74	
APPD		
		SIZE A · PART NO · DWG NO A74-50601-504
		SCALE NONE · SHEET OF

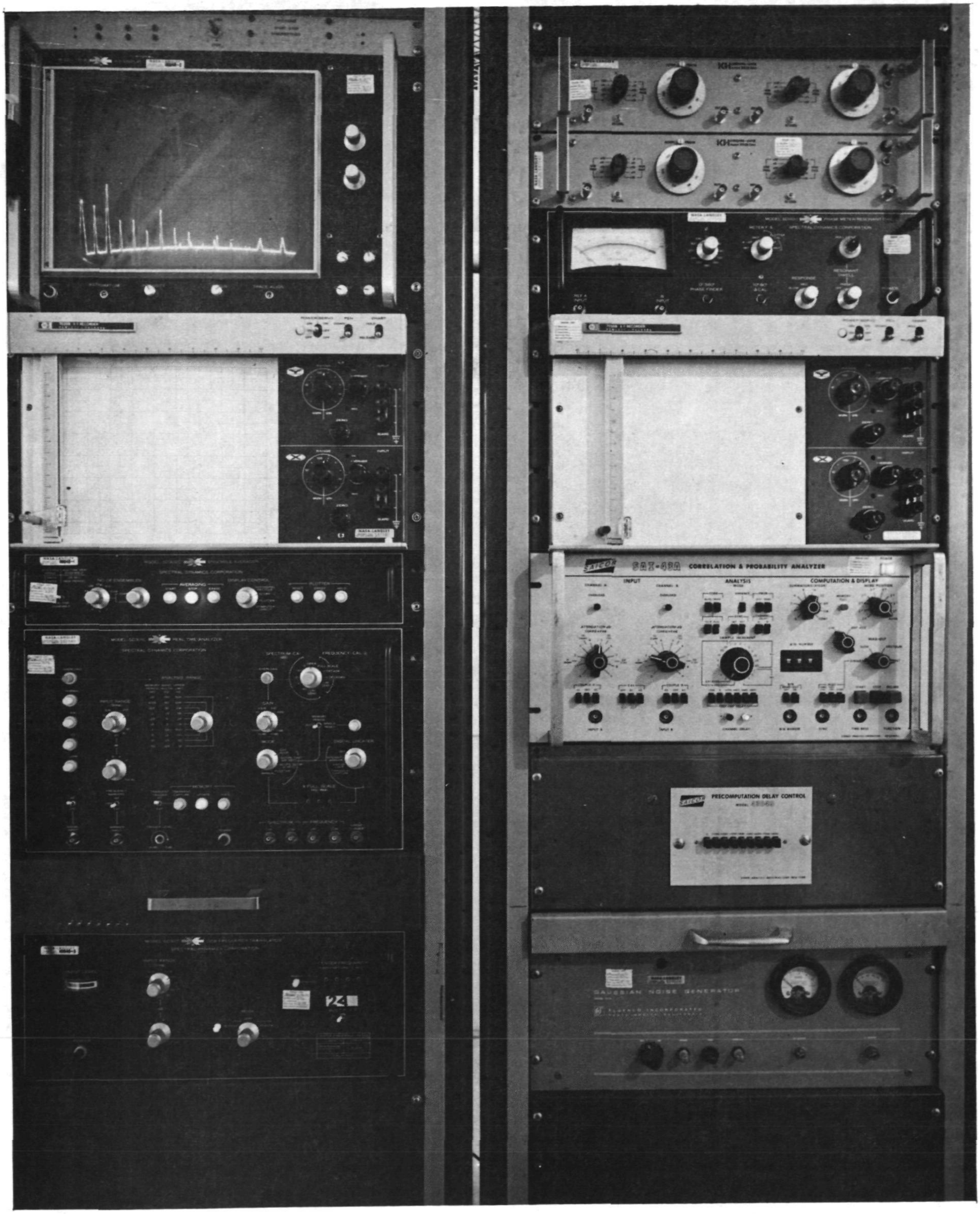


Figure 9. Spectral Analysis Subsystem, Relay Racks No. 6 (Left), and No. 5 (Right).

REVISIONS			
LTR	DESCRIPTION	DATE	APPD

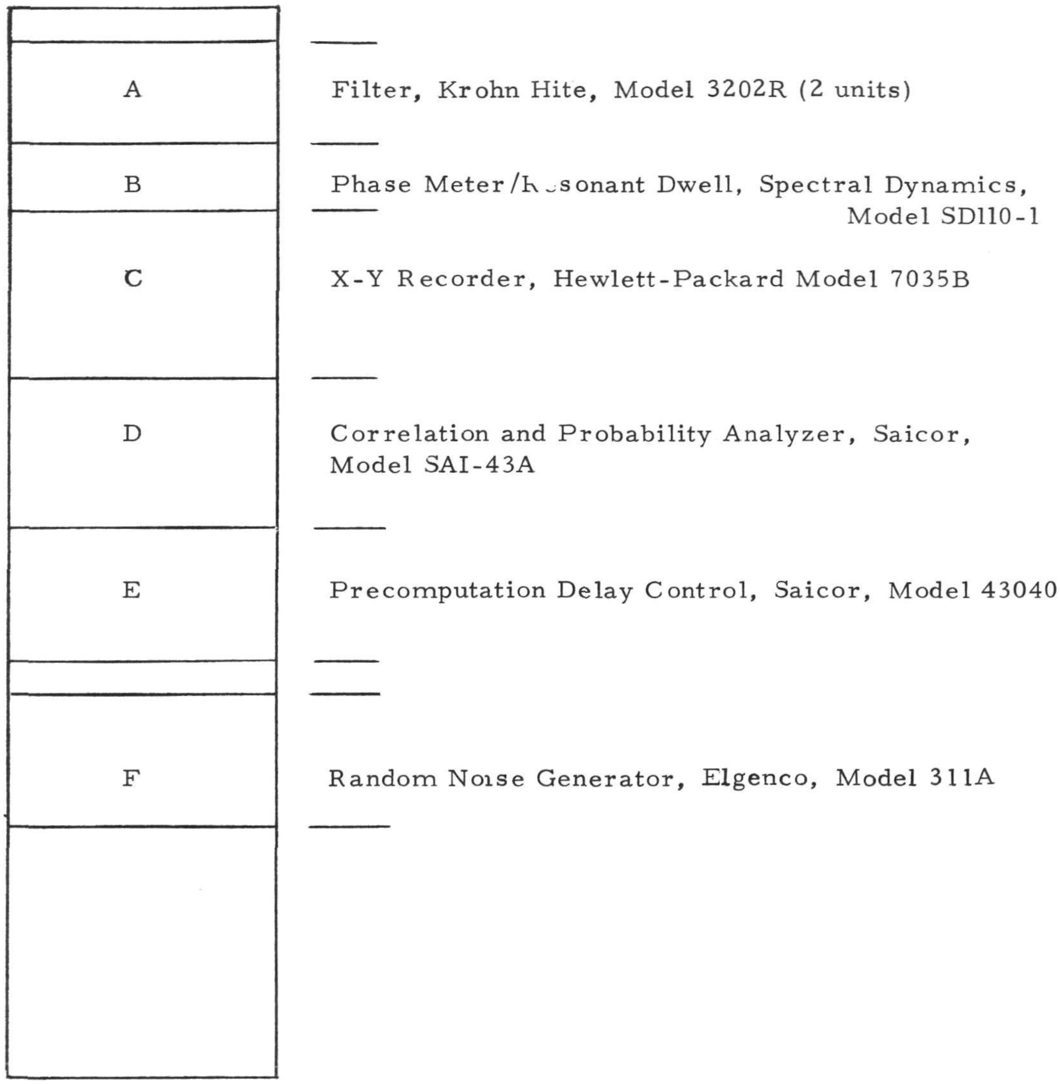


Figure 10.

PROJECT		WYLE LABORATORIES HAMPTON FACILITY, HAMPTON, VIRGINIA		
	DATE	RELAY RACK NO. 5 SPECTRAL ANALYSIS SUBSYSTEM HELICOPTER ROTOR TEST FACILITY		
DRAWN KSB	5-24-74			
CHECK SWS	5/25/74			
APPD Gw	5/25/74			
APPD				
		SIZE A	PART NO	DWG NO A74-50601-505
		SCALE		SHEET OF

REVISIONS			
LTR	DESCRIPTION	DATE	APPD

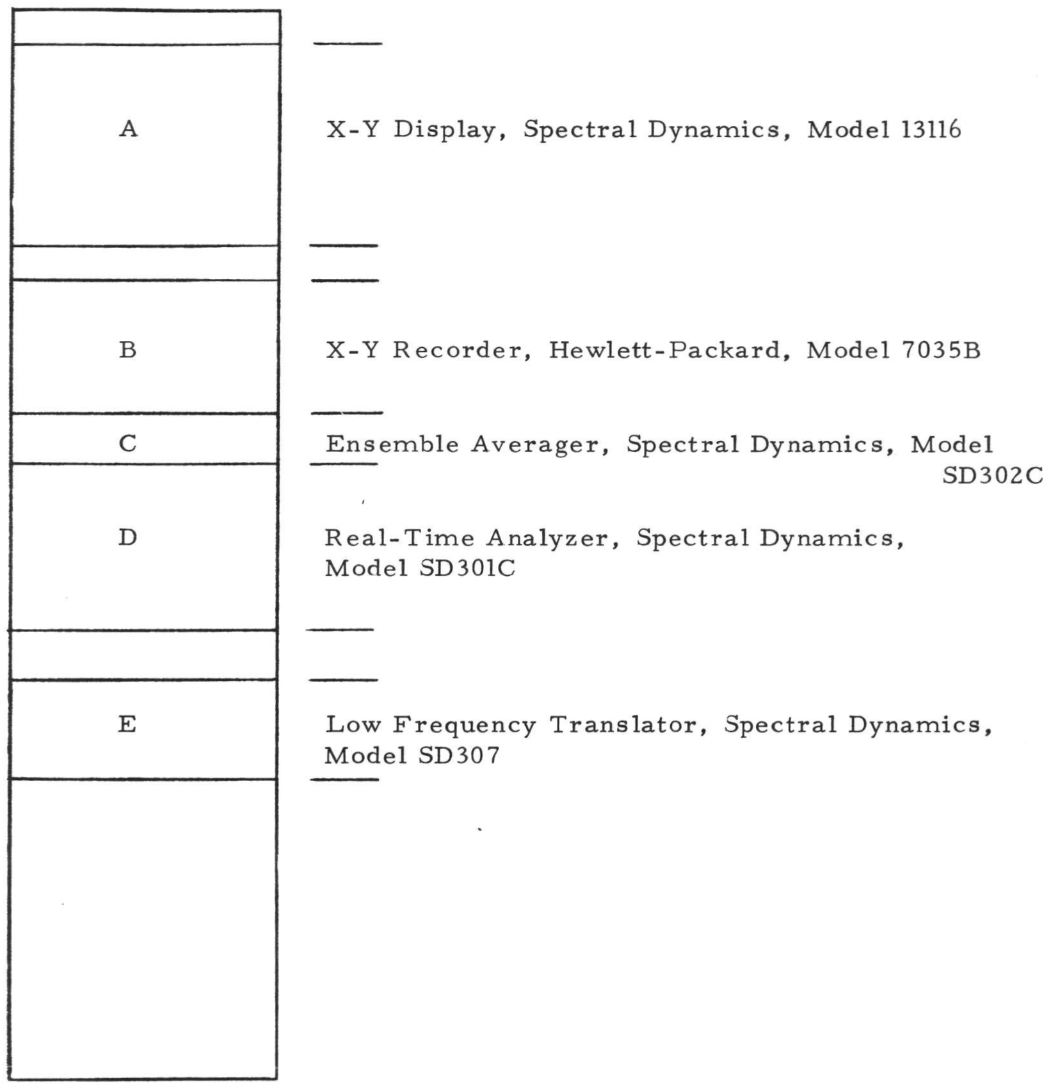


Figure 11.

PROJECT		WYLE LABORATORIES HAMPTON FACILITY, HAMPTON, VIRGINIA
	DATE	
DRAWN KSB	5-24-74	RELAY RACK NO. 6
CHECK SWS	5/25/74	SPECTRAL ANALYSIS SUBSYSTEM
APPD JW	5/25/74	HELICOPTER ROTOR TEST FACILITY
APPD		

SIZE	PART NO	DWG NO
A		A74-50601-506
SCALE NONE		SHEET OF

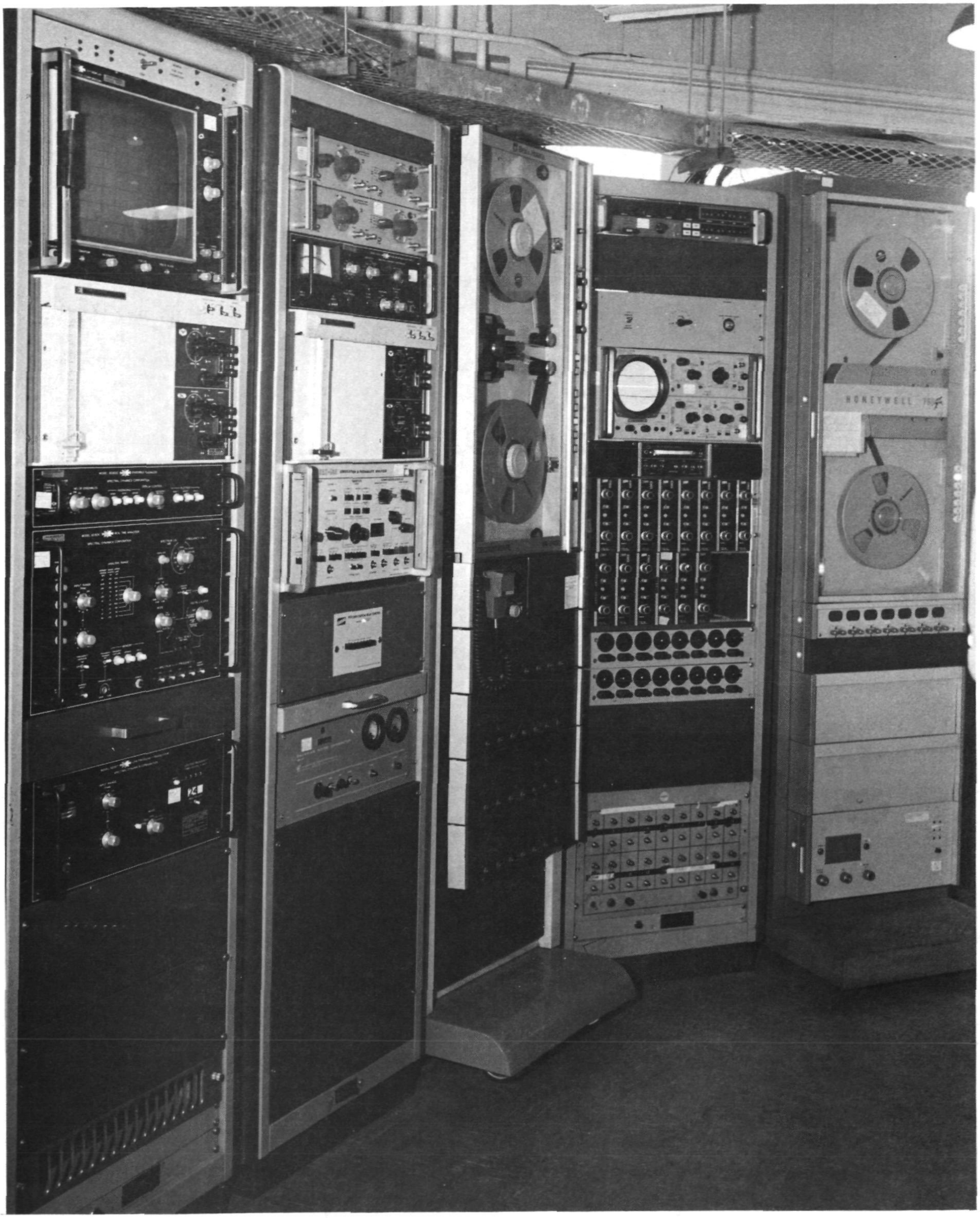


Figure 12. General View of Spectral Analysis Subsystem and Rotor Data Acquisition Subystem Equipment

3.1.3 Spectral Analysis Subsystem Equipment

The Spectral Analysis Subsystem includes major pieces of equipment listed in Table III. The specifications for each major item of commercial equipment for this subsystem are furnished in Appendix III.

3.2 Rotor Data Acquisition Subsystem

A typical data channel arrangement for the Rotor Data Acquisition Subsystem, shown in Figure 13, has been set up to acquire, monitor, condition, and record pressure and strain data from a rotor under test. Additional capabilities are provided for off-line playback of data from a magnetic tape unit. Conditioning equipment is configured for four arm bridge transducers, either of the wire strain gage or semiconductor strain gage variety. Bridge excitation, variable to a maximum of 10 VDC, is provided through slip rings to the transducers on the rotor.

3.2.1 Instrumentation

Data signals from the rotor transducers are routed back to the control room through the slip rings and the junction box to the balance box. A NASA designed balance box, shown in Figure 14, provides the facilities for span and balance adjustments and shunt resistance calibration for the transducers. The standard balance box has been modified, in this case, to additionally provide for simultaneous calibration of transducers. Data signals are routed from the balance box to a Wyle Laboratories designed filter box shown in Figure 15. Filter circuitry allows for selection of the following:

a. Shorting Neff input lines.

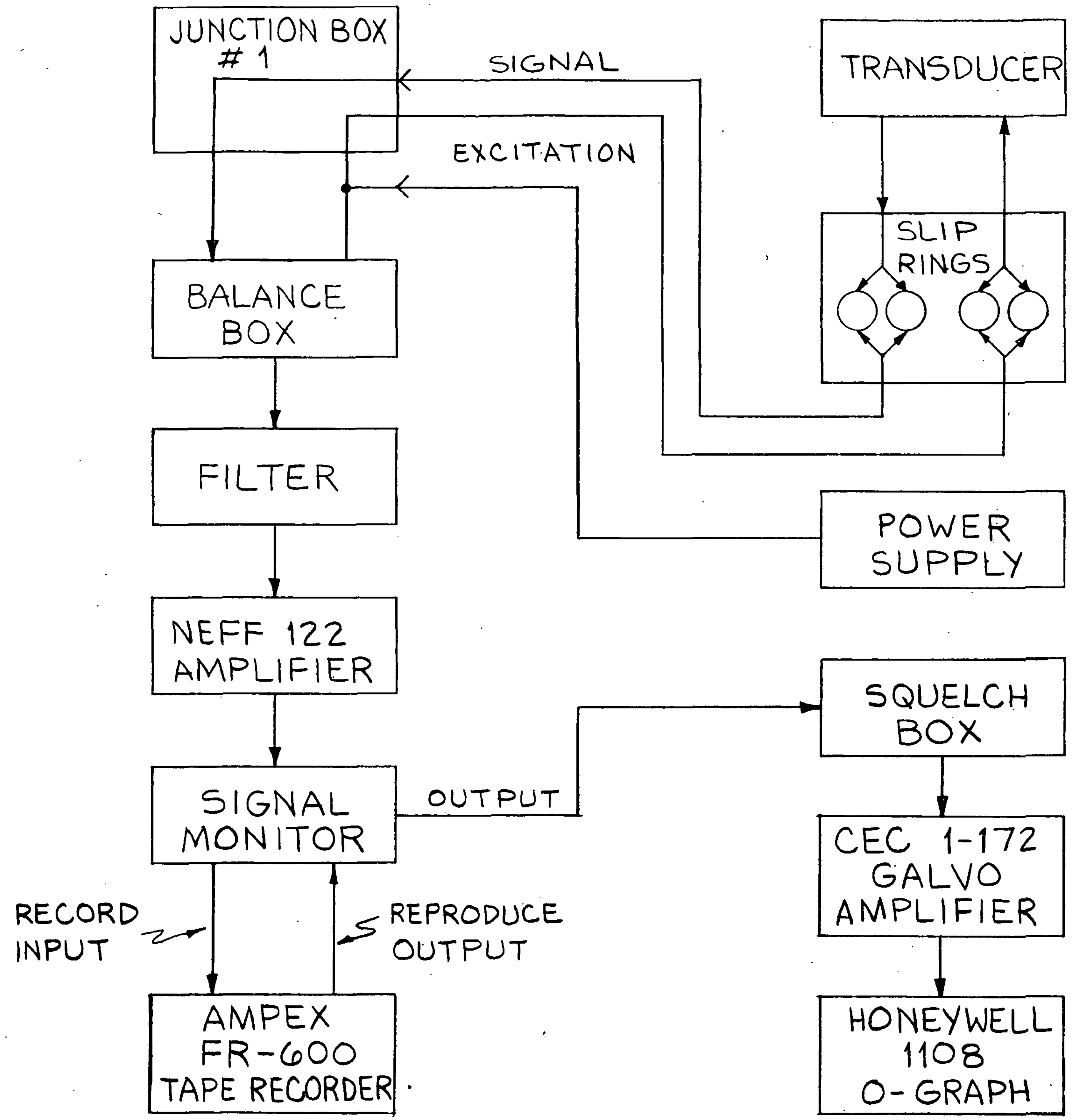
b. Passing all signal frequencies.

c. Blocking signal frequencies from DC to 100 Hz.

d. Blocking signal frequencies from DC to 1 Hz.

e. Voltage insertion calibration into the Neff amplifier.

f. Monitoring any of the above via red and black banana jacks at the Neff input.



REVISIONS			
LTR	DESCRIPTION	DATE	APPD

Figure 13.

PROJECT	DATE	
DRAWN KSB	5-24-74	
CHECK SWC	5/25/74	
APPD SW	5/28/74	
APPD		

WYLE LABORATORIES
HAMPTON FACILITY, HAMPTON, VIRGINIA

TYPICAL DATA CHANNEL ARRANGEMENT – ROTOR DATA ACQUISITION SUBSYSTEM, HELICOPTER ROTOR TEST FACILITY

SIZE	PART NO	DWG NO
B		B74-50601-000

SCALE | SHEET OF

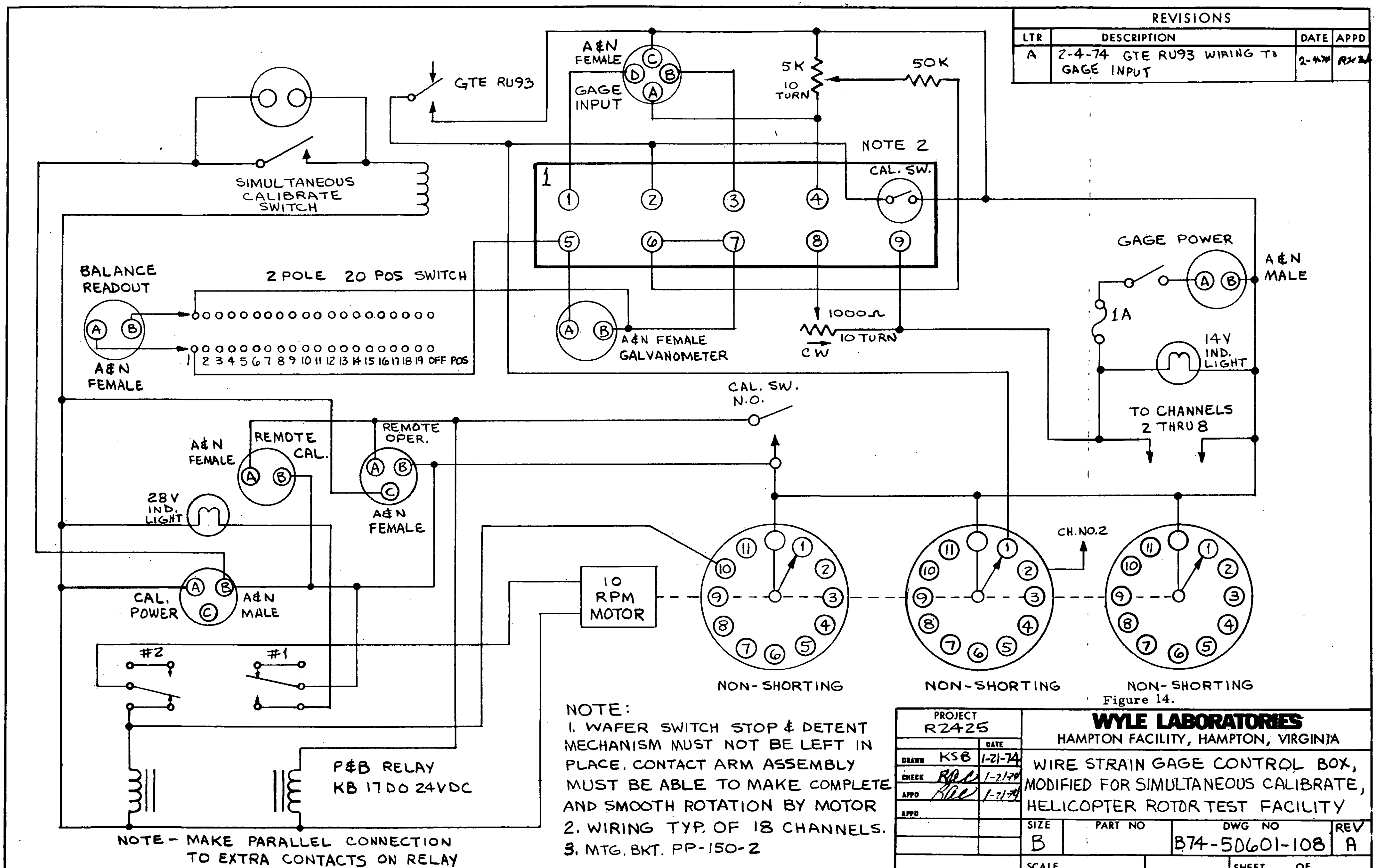
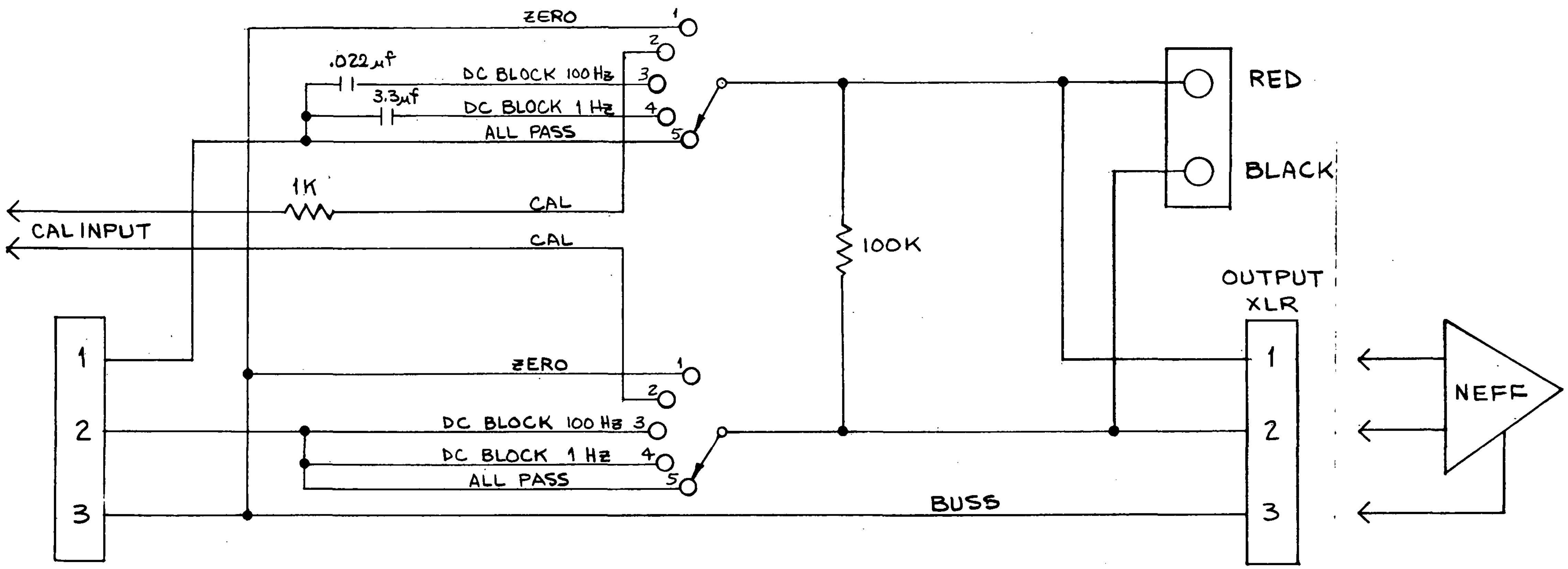
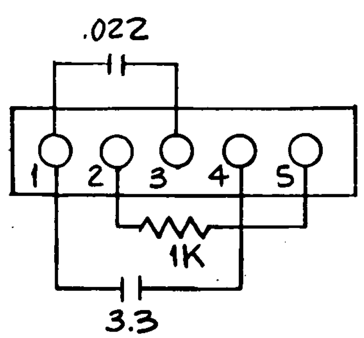

REVISIONS
LTR | DESCRIPTION | DATE | APPD
A | 2-4-74 GTE RU93 WIRING TO GAGE INPUT | 2-4-74
GTE RU93
A&N FEMALE
GAGE INPUT
5K
10 TURN
50K
NOTE 2
CAL. SW.
SIMULTANEOUS CALIBRATE SWITCH
BALANCE READOUT
2 POLE 20 POS SWITCH
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 OFF POS
A&N FEMALE
A&N FEMALE GALVANOMETER
1000Ω
10 TURN
CW
GAGE POWER
A&N MALE
1A
14V IND. LIGHT
TO CHANNELS 2 THRU 8
CAL. SW. N.O.
A&N FEMALE
REMOTE CAL.
REMOTE OPER.
A&N FEMALE
28V IND. LIGHT
CAL. POWER
A&N MALE
10 RPM MOTOR
CH. NO. 2
NON-SHORTING
NON-SHORTING
NON-SHORTING
#2
#1
P&B RELAY KB 17DO 24VDC
NOTE - MAKE PARALLEL CONNECTION TO EXTRA CONTACTS ON RELAY
NOTE:
1. WAFER SWITCH STOP & DETENT MECHANISM MUST NOT BE LEFT IN PLACE. CONTACT ARM ASSEMBLY MUST BE ABLE TO MAKE COMPLETE AND SMOOTH ROTATION BY MOTOR
2. WIRING TYP. OF 18 CHANNELS.
3. MTG. BKT. PP-150-2
PROJECT R2425
DRAWN KSB 1-21-74
CHECK 1-21-74
APPD 1-21-74
WYLE LABORATORIES
HAMPTON FACILITY, HAMPTON, VIRGINIA
WIRE STRAIN GAGE CONTROL BOX, MODIFIED FOR SIMULTANEOUS CALIBRATE, HELICOPTER ROTOR TEST FACILITY
SIZE B
PART NO
DWG NO B74-50601-108
REV A
SCALE
SHEET OF

Figure 14.

REVISIONS			
LTR	DESCRIPTION	DATE	APPD



TYPICAL OF 8 CIRCUITS



PHYSICAL LAYOUT, TERMINAL BOARD.

Figure 15.

PROJECT		WYLE LABORATORIES HAMPTON FACILITY, HAMPTON, VIRGINIA
	DATE	CIRCUIT DIAGRAM D.C. BLOCK HELICOPTER ROTOR TEST FACILITY
DRAWN KSB	1-11-74	
CHECK		
APPD		
APPD [signature]	10-18-74	

SIZE	PART NO	DWG NO
B		B74-50601-100
SCALE		SHEET OF

Filter output data signals are then applied to the Neff Model 122 amplifiers for amplification to high-level signals. A signal derived from the Neff differential amplifier output is routed to the signal monitor box shown in Figure 16. The signal monitor box permits the data signal to be paralleled to a magnetic tape recorder, such as the Ampex FR 600, and/or a signal monitor output connector. The signal monitor box also permits an output signal received from the magnetic tape reproduce amplifier to be connected to a signal monitor output connector. The outputs of the signal monitor box are connected to appropriate test equipment, or through the squelch box to the CEC Type 1-172 galvanometer amplifiers.

The squelch box is a device which prevents large noise voltage levels from the reproduce amplifiers from being input to the galvanometer amplifiers when the magnetic tape unit is not running. See Figure 17 for details of the squelch box circuitry. When the magnetic tape unit is not running, no voltage is present at the two-pin A & N connector and all relays are in the non-energized position shown. Consequently, the high sides and shields of all BNC's are shorted together and to each other, thereby preventing large noise voltage levels from being input to the galvanometer amplifiers. When the magnetic tape unit is put into RUN mode, either 28 VDC or 90 VDC is presented at the AN connector, depending upon the particular magnetic tape unit in use. The two-position switch shown must be placed in the matching 28 V or 90 V position. Both relays shown are thereby energized, removing all shorts from the BNC's. Data signals are then directly connected from input to output BNC's.

A data signal from the squelch box is then routed to a galvanometer amplifier for signal conditioning before driving a galvanometer in the Honeywell Model 1108 Oscillograph.

3.2.2 Analysis

3.2.2.1 Error Considerations

It is extremely difficult, if not impossible, to present a generalized error analysis applicable to all measurements at the Helicopter Rotor Test Facility. The approach taken herein is to describe a methodology of error determination and to present examples for typical measurement configurations. The reader may then apply the methods presented to particular measurement configurations and thereby derive estimates of system accuracy.

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LTR	DESCRIPTION	DATE	APPD

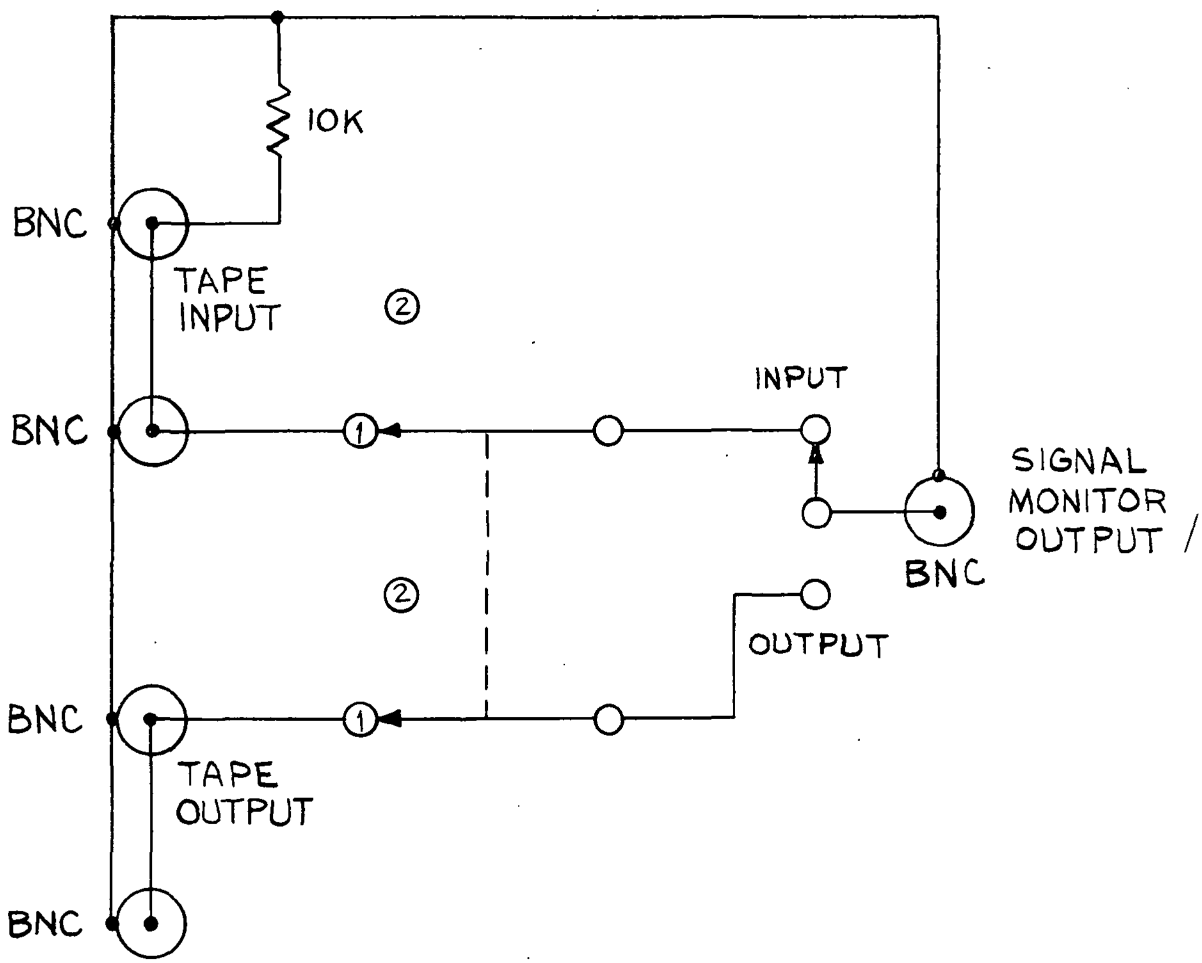


Figure 16.

PROJECT		WYLE LABORATORIES HAMPTON FACILITY, HAMPTON, VIRGINIA
	DATE	SIGNAL MONITOR BOX
DRAWN KSB	5-24-74	
CHECK SWS	5/24/74	
APPD SJW	5/25/74	HELICOPTER ROTOR TEST FACILITY
APPD		

SIZE	PART NO	DWG NO	
A		A74-50601-110	
SCALE		SHEET OF	

REVISIONS			
LTR	DESCRIPTION	DATE	APPD

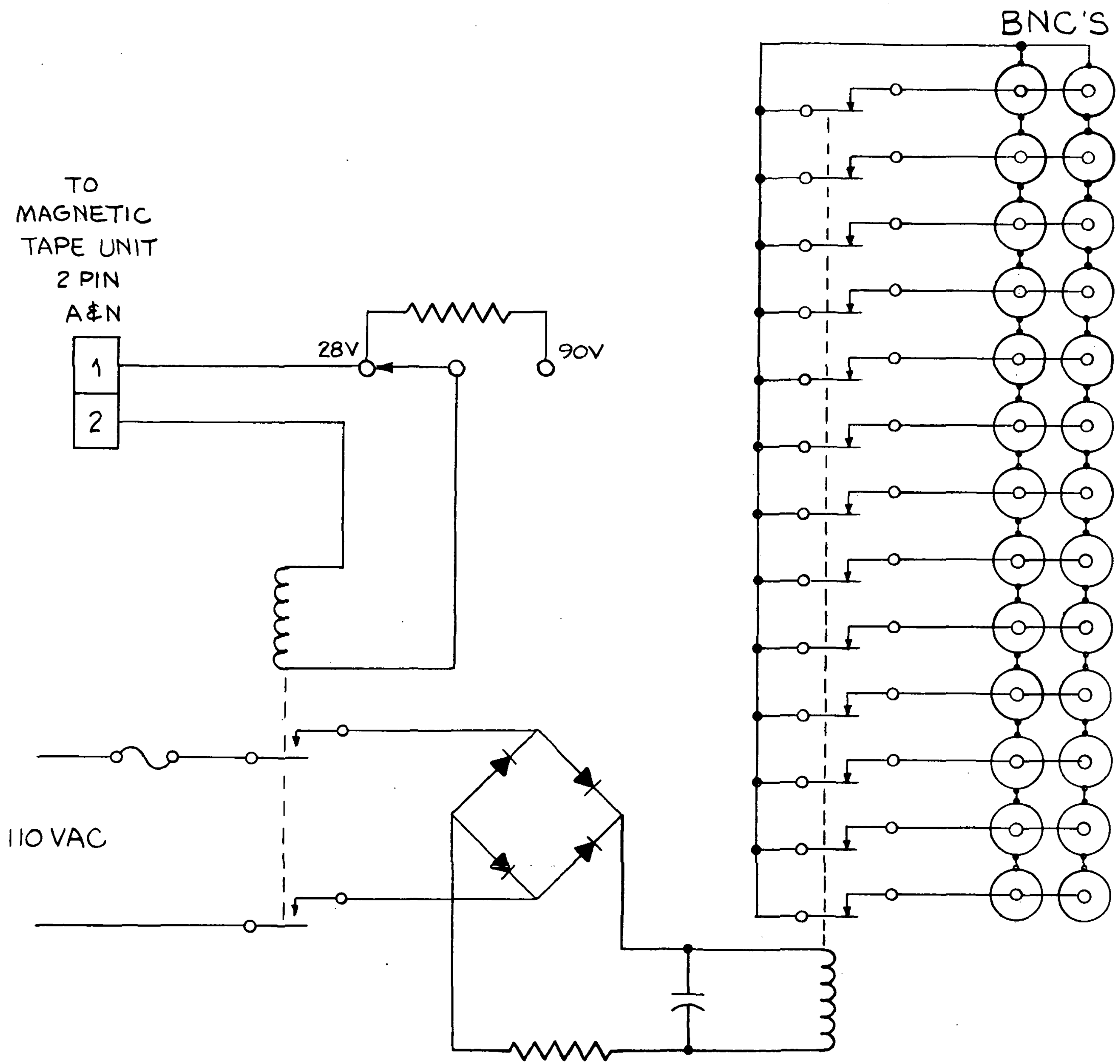


Figure 17.

WYLE LABORATORIES
HAMPTON FACILITY, HAMPTON, VIRGINIA

SQUELCH BOX CIRCUITRY
HELICOPTER ROTOR TEST FACILITY

PROJECT		DATE
DRAWN	KSB	5-24-74
CHECK		
APPD		
APPD		

SIZE	PART NO	DWG NO
B		B74-50601-107

SCALE | SHEET OF

A detailed analysis of total subsystem performance must include both random and systematic error estimates for all components of the subsystem under the specific, stated operating conditions of the manufacturer's specifications. In the case where commercial manufacturer's specifications are utilized, they are generally stated by the manufacturer as percent of full scale value. Engineering judgment, however, indicates that the manufacturer's specifications may be considered to apply to a typical measurement situation where the rms value of the signal is approximately 20-30% of full scale. This estimate is justified (1) by the fact that environmental conditions encountered at the facility are generally less severe than covered by the manufacturer's specifications and (2) errors are minimized by system calibration performed prior to a test.

In the case of NASA fabricated equipment, detailed specifications are not available and engineering estimates must be made.

Random errors are considered to be those systems errors whose behavior can be described only by statistical methods. All random errors are assumed to be independent, to follow a normal distribution with zero mean, have their sources in cascaded elements, and will be expressed as 3 - Sigma Gaussian values. Typical errors which fall into this category include:

- Thermal noise
- Magnetic noise
- Electrostatic noise
- Ripple
- Input and output noise
- Quantizing error

All random errors will be added as the root-sum-of-squares (RSS) method, i.e.

$$E_r = \left(E_{1r}^2 + E_{2r}^2 + \ldots\ldots\ldots\ldots + E_{nr}^2 \right)^{1/2} \qquad (1)$$

Systematic errors are deterministic, i.e., obey a well defined, but possibly unknown, mathematical relationship. All systematic errors are assumed to be independent, and have their sources in cascaded elements. They are assumed to have nonzero means so that their average over a large number of readings is nonzero. Any error source which is not clearly random will be considered systematic. Typical errors which fall into this category include:

- Gain inaccuracy
- Linearity
- Gain drift
- Offset drift
- Gain stability
- Cross talk
- Frequency response
- Common mode

All systematic errors will be summed linearly, i.e.,

$$E_s = E_{1s} + E_{2s} + \ldots\ldots\ldots\ldots + E_{ns} \qquad (2)$$

except for frequency response which is treated separately.

The total error is a combination of the random errors and systematic errors and will be expressed as:

$$TE = \left(E_r^{\,2} + E_s^{\,2}\right)^{1/2} \qquad (3)$$

3.2.2.2 Error Calculations

Neff 122 Amplifier

Systematic Error

Conditions assumed: Gain of 1000, 5°C temperature change, common mode voltage of 25 VDC or peak AC.

DC amplitude linearity:	0.005%
Intermodulation:	0.010%
Cross talk:	0.020%
Gain step accuracy (in cal. position):	0.100%
Zero stability:	0.091%
DC gain stability:	0.015%
Common mode error:	0.00025%
Systematic error:	0.24%

Random Error

Noise (wideband):	0.08%
Random error:	0.08%

Total Error

Total Neff 122 amplifier error:	0.25%

Ampex FR-600 Magnetic Tape Unit

Typical of 3 units used

Systematic Error

Conditions assumed: FM record/reproduce mode, high level, 60 inches per second.

Harmonic Distortion:	1.5%
DC drift:	1.0%
AC/DC linearity:	1.0%
Systematic error:	3.5%

Random Error

Noise:	0.5%
Random error	0.5%

Total Error

Total Ampex FR-600 error:	3.54%

CEC Type 1-172 Galvanometer Amplifier

Systematic Error

Conditions assumed: Gain of 0.2 volt per inch, 5°C temperature change, ± three-inch deflection, common mode voltage of 100 VDC or peak AC

Input offset voltage drift:	0.0625%
Linearity:	0.25%
Common mode error:	0.167%
Cross talk:	0.005%
Systematic error:	0.48%

Random Error

Ripple and noise:	0.04%
Random error:	0.04%

Total Error

Total CEC 1-172 error:	0.48%

Honeywell 1108 Oscillograph

Systematic Error

Linearity (using Type M galvanometers)	2.0%
Systematic error	2.0%

Random Error

Human Error in Reading	3% (Engineering Estimate)
Random error	3%

Total Error

Total Honeywell 1108 error	3.6%

Slip Ring Noise Error

Slip ring noise measurements have been made at the facility for different values of RPM. Conditions were Neff 122 amplifier gain of 1000, Neff filter bandwidth at 10 kHz, filter box at "all pass", hub grounded, transducer bridge resistance of 2000 ohms.

At 0 RPM, the average for 12 slip rings was a noise level of 1.6 microvolts rms. At 355 RPM, the average for 12 slip rings was a noise level of 8.8 microvolts rms.

Other Component Errors

Because of the lack of definitive data, engineering estimates must be made of errors contributed by other components in this subsystem. Typically, these errors could be:

Transducer Error	10%
Power Supply Error	1.0%
Balance Box Error	1.0%
Filter Box Error	2.0%

The signal monitor box and squelch box are switching circuits only and should contribute negligible error.

3.2.2.3 Combinations of Equipment Error Calculations

The total error for series combinations of various equipment can also be calculated by quadrature addition of the individual components. These calculations are shown below, excluding slip ring noise.

a. Recording data via the Ampex FR-600 recorder/reproducer:

Total Error = 10.3%

b. Recording data via the Honeywell 1108 oscillograph:

Total Error = 10.9%

c. Reducing data via Ampex FR-600 recorder/reproducer and Honeywell 1108 oscillograph:

Total Error = 5.1%

The transducer error of $\pm$ 10% used in the above calculations is considered to be typical of that to be encountered in work at the helicopter tower. Typically, boundary layer pressure fluctuations on the order of 0.01 psig are measured with 2.5 psig full scale piezo-resistive strain gage pressure transducers. Although in-place calibration of transducers minimizes errors, pressure errors of 20% of reading and greater are not unrealistic. Static pressures at much higher amplitudes can realistically be estimates at $\pm$ 2-3% of reading.

For strain measurements, the accuracy is determined to a great extent by the load or deflection calibration performed. Errors of 5-10% attributed to the strain gage/calibration combination are typical.

In any case, due to the multiplicity of possible measurement situations, the above system errors can only be considered as typical. Using this methodology, the reader can more accurately assess error values for particular measurement configurations with specific transducers.

The uncertain nature of the error contributed by slip ring noise caused it to be excluded from total error calculations above. More definitive slip ring noise data will be available in the future. Much care must now be exercised in analyzing data signals in order to separate the slip ring noise from the experimental pressure data.

3.2.2.4 Frequency Response

The frequency response characteristics of individual pieces of equipment have already been indicated in 3.2.2 above. In order to measure system response, the test setup shown in Figure 18 was used. These test indicated the frequency response was within three db at any Neff amplifier gain setting and any Neff amplifier filter setting. A typical response curve for Neff gain = 1, filter cut off at 10 kHz and no slip ring rotation is shown in Figure 19. Combining this data with that of the frequency response of the Ampex FR-600 Recorder/reproducer, of ± 0.5 db, indicates a total system response of (+0.5, -3.5) db to 20 kHz.

For recording data directly on the Honeywell 1108 oscillograph, the total response would be a combination of the circuit tested above (-3 db), the CEC 1-172 galvanometer amplifier (-3 db) and a Honeywell Type M galvanometer (±0.4 db) or (+0.4, -6) db.

As evidenced above, large amplitude errors may result if equipment components are used out to their upper frequency limit. The user should compensate for this as much as possible.

3.3 Facility Data Acquisition System

3.3.1 Instrumentation

3.3.1.1 Rotational Speed Display

Rotational speed of the rotor is measured, displayed, and recorded. This is accomplished by a large rotating disk with 600 alternate light and dark bars and a light emitting diode. A light-sensitive diode provides the mechanism for providing a pulse train proportional to shaft revolution. The signal is then conditioned through custom circuitry and scaled by the ERC counter for three-digit display reading in RPM as shown in Figure 20. Figure 20 also

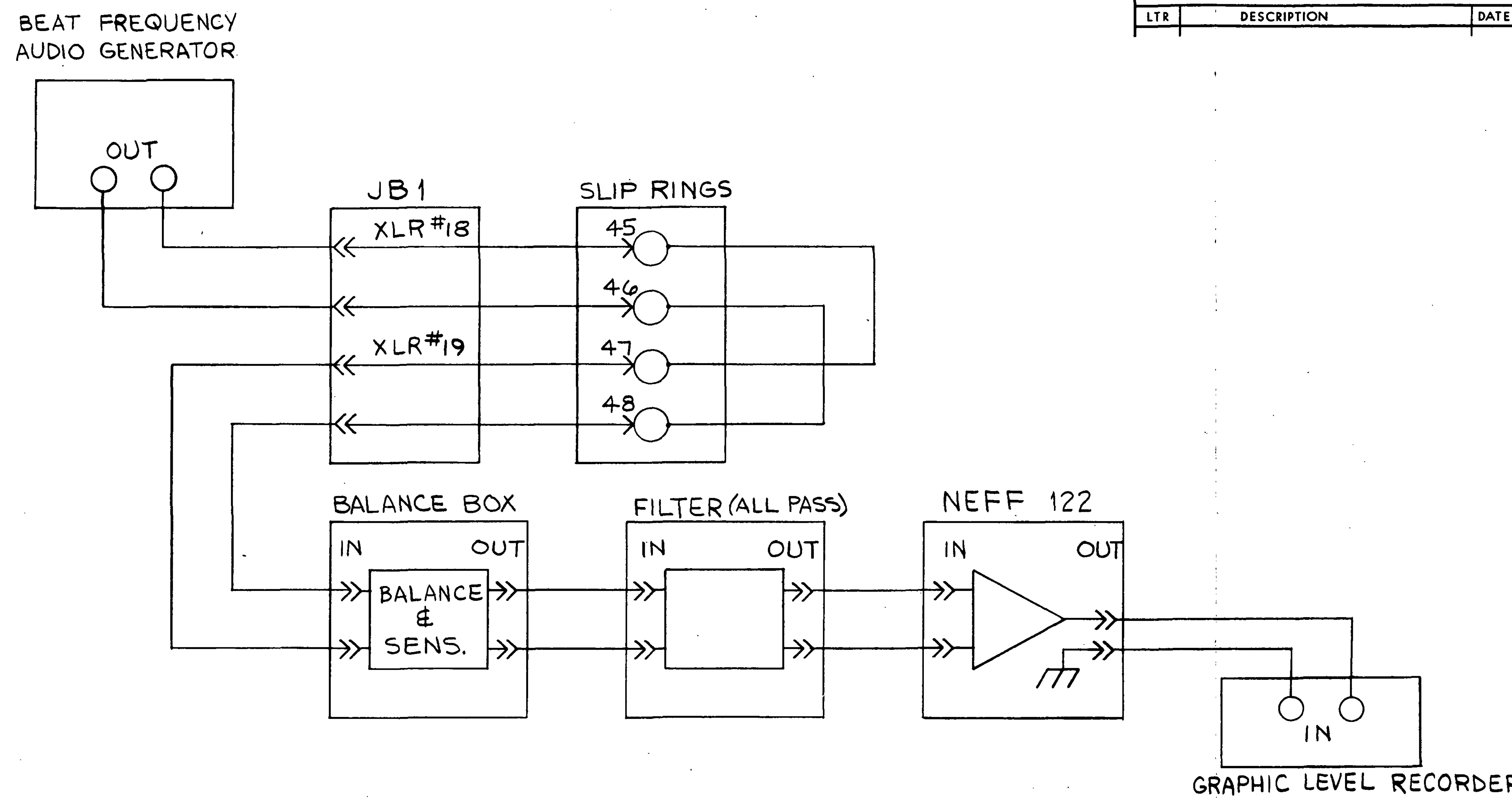


Figure 18.

REVISIONS			
LTR	DESCRIPTION	DATE	APPD

WYLE LABORATORIES
HAMPTON FACILITY, HAMPTON, VIRGINIA

GRAPHIC LEVEL RECORDER
SYSTEM RESPONSE TEST SET-UP
HELICOPTER ROTOR TEST FACILITY

PROJECT	DATE
DRAWN KSB	5-24-74
CHECK SWS	5/25/74
APPD JW	5/25/74
APPD	

SIZE B | PART NO | DWG NO B74-50601-106

SCALE | SHEET OF

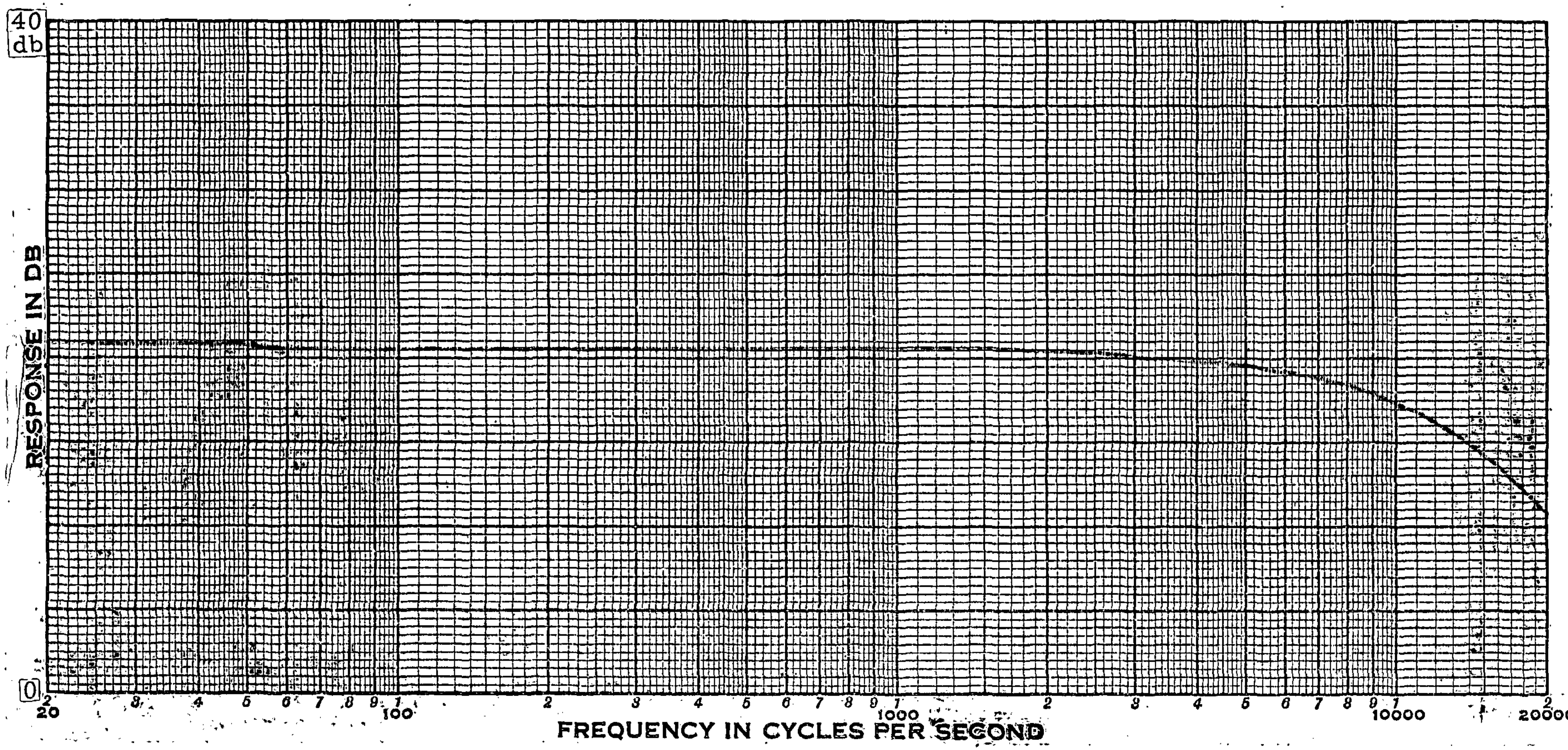


Figure 19.1 Typical Response Curve

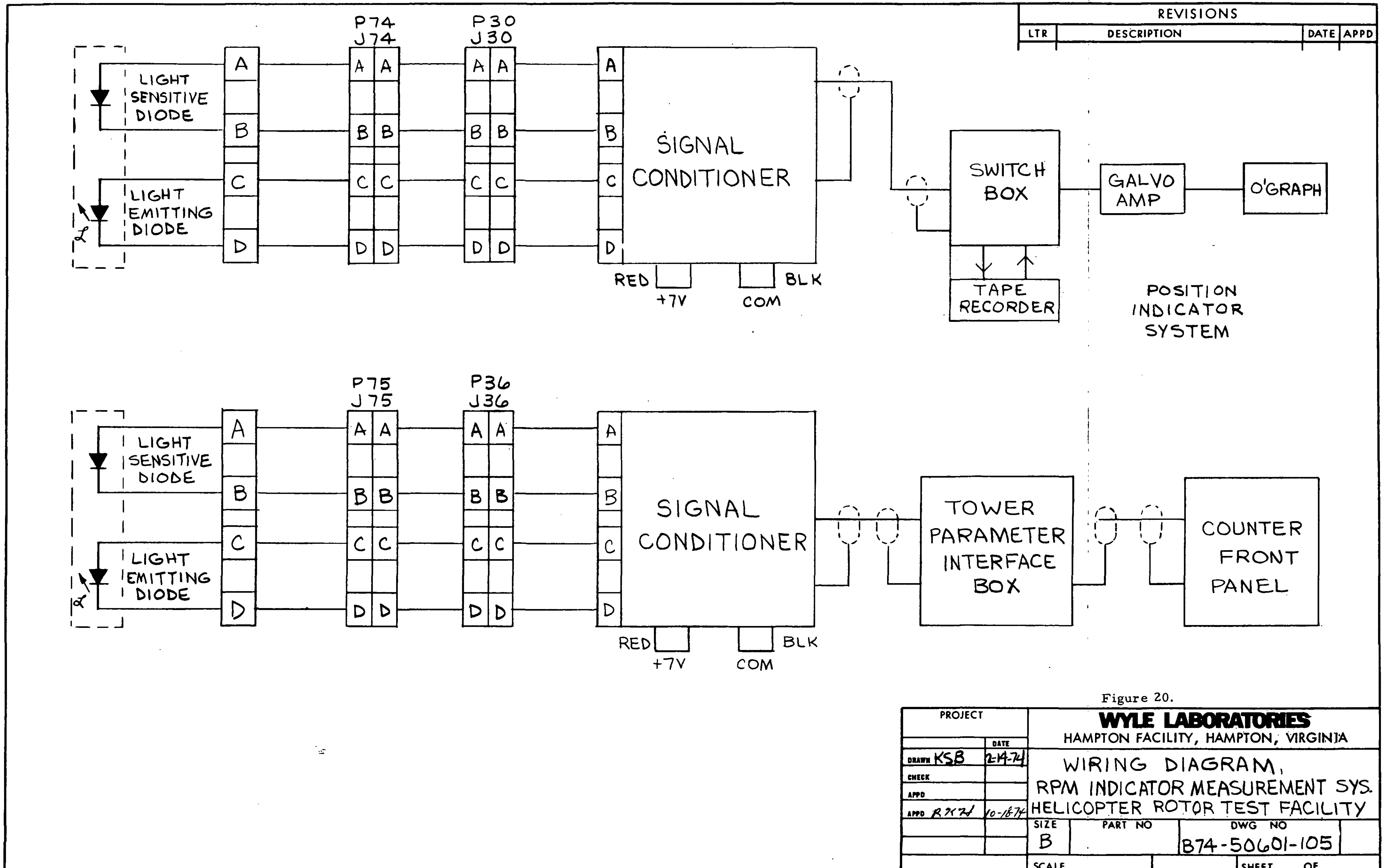

REVISIONS
LTR
DESCRIPTION
DATE
APPD
P74
J74
P30
J30
LIGHT SENSITIVE DIODE
LIGHT EMITTING DIODE
A
B
C
D
SIGNAL CONDITIONER
RED
+7V
COM
BLK
SWITCH BOX
TAPE RECORDER
GALVO AMP
O'GRAPH
POSITION INDICATOR SYSTEM
P75
J75
P36
J36
LIGHT SENSITIVE DIODE
LIGHT EMITTING DIODE
SIGNAL CONDITIONER
RED
+7V
COM
BLK
TOWER PARAMETER INTERFACE BOX
COUNTER FRONT PANEL
PROJECT
DATE
DRAWN KSB 2-14-74
CHECK
APPD
APPD 10-18-74
WYLE LABORATORIES
HAMPTON FACILITY, HAMPTON, VIRGINIA
WIRING DIAGRAM,
RPM INDICATOR MEASUREMENT SYS.
HELICOPTER ROTOR TEST FACILITY
SIZE B
PART NO
DWG NO B74-50601-105
SCALE
SHEET
OF

Figure 20.

details the circuitry for sensing and recording shaft position. This circuit supplies a single pulse per revolution for correlating data recorded on a magnetic tape and/or an oscillograph.

3.3.1.2 Thrust, Thrust Correction, Torque and Pitch Display

Thrust is measured by a load cell arrangement incorporated in a thrust ring assembly within the tower. Thrust correction is measured by a four-arm strain gage bridge located on the rotor pitch arm. This thrust correction is necessary because a component of force attributable to the pitch arm is linked to the tower structure itself and not the shaft. Therefore, this component must be added to or subtracted from shaft thrust to obtain a true thrust reading.

Shaft torque is measured with a four-arm strain gage bridge bonded to the shaft exterior surface at the base. A duplicate bridge is also provided.

Pitch is measured by a slidewire potentiometer on the pitch arm assembly near the top of the tower.

For each of these parameters, the front panel display is an ERC 4000 series digital voltmeter.

If recording of these parameters is desired, the CEC 1-172 galvanometer amplifier and the Honeywell 1508 oscillograph may be used. Characteristics of the CEC 1-172 are stated in Appendix I. Characteristics of the 1508 oscillograph are stated in Appendix II. Circuitry details for these measurements are presented in Figures 21 through 24.

3.3.1.3 Flapping, Feathering, and Lead/Lag Measurement and Display

Flapping 1 and 2, feathering 1 and 2, and lead/lag 1 and 2 are measured and displayed as shown in the typical circuit of Figure 25. Flapping 1 and 2 and feathering 1 and 2 are displayed continuously on 4 0-20-microampere panel meters calibrated in degrees. Lead/lag 1 and 2 are displayed continuously on 2 25-0-25-microampere panel meters calibrated in degrees.

REVISIONS

LTR	DESCRIPTION	DATE	APPD

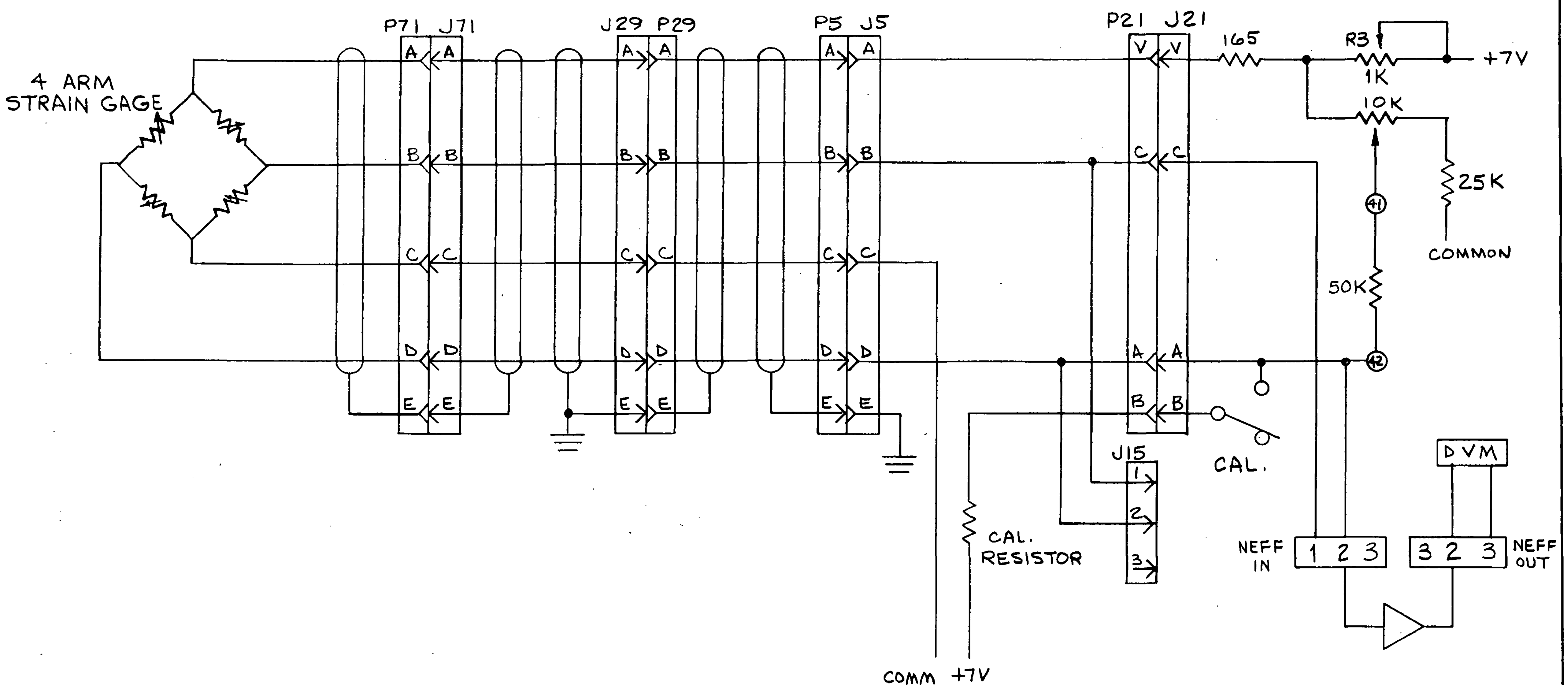


Figure 21.

PROJECT		WYLE LABORATORIES HAMPTON FACILITY, HAMPTON, VIRGINIA
	DATE	
DRAWN KSB	2-14-74	THRUST MEASUREMENT SYSTEM, HELICOPTER ROTOR TEST FACILITY
CHECK		
APPD		
APPD		
		SIZE B — PART NO — DWG NO B74-50601-103
		SCALE — SHEET OF

REVISIONS			
LTR	DESCRIPTION	DATE	APPD

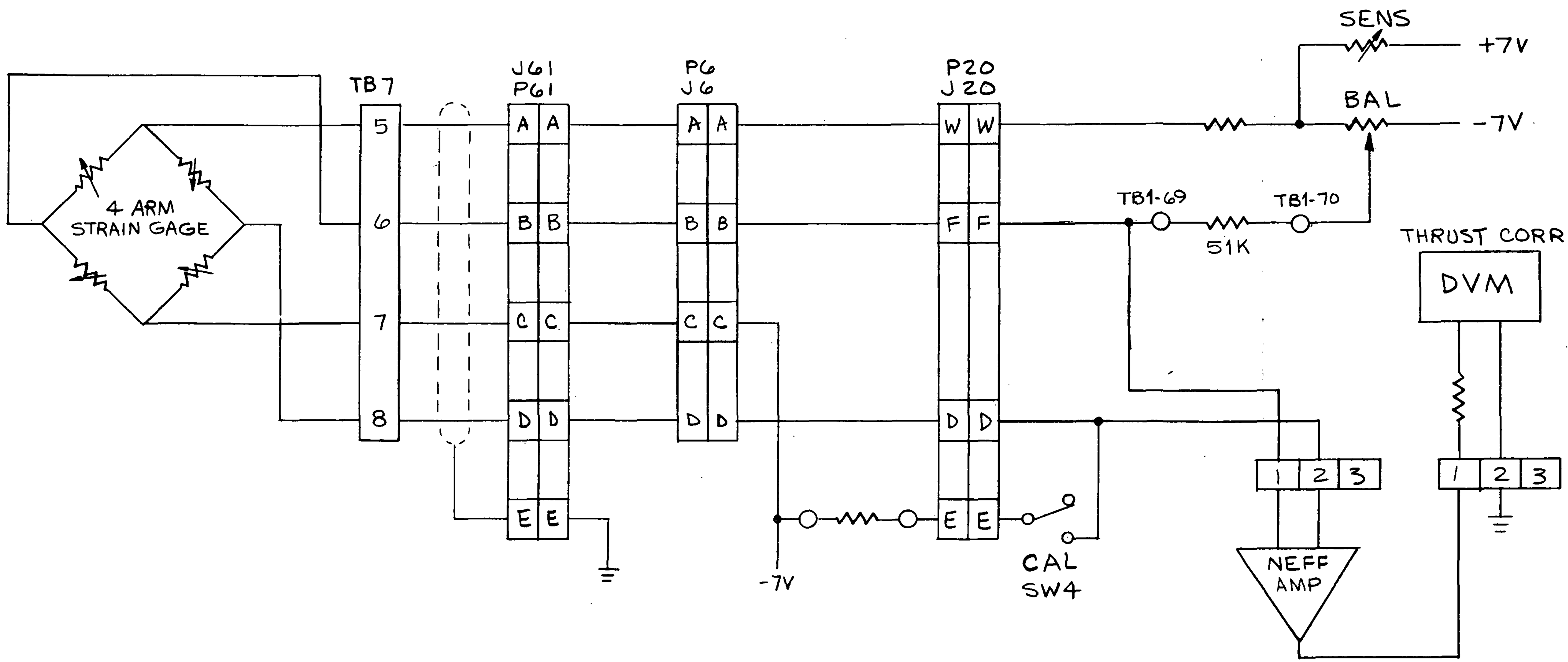
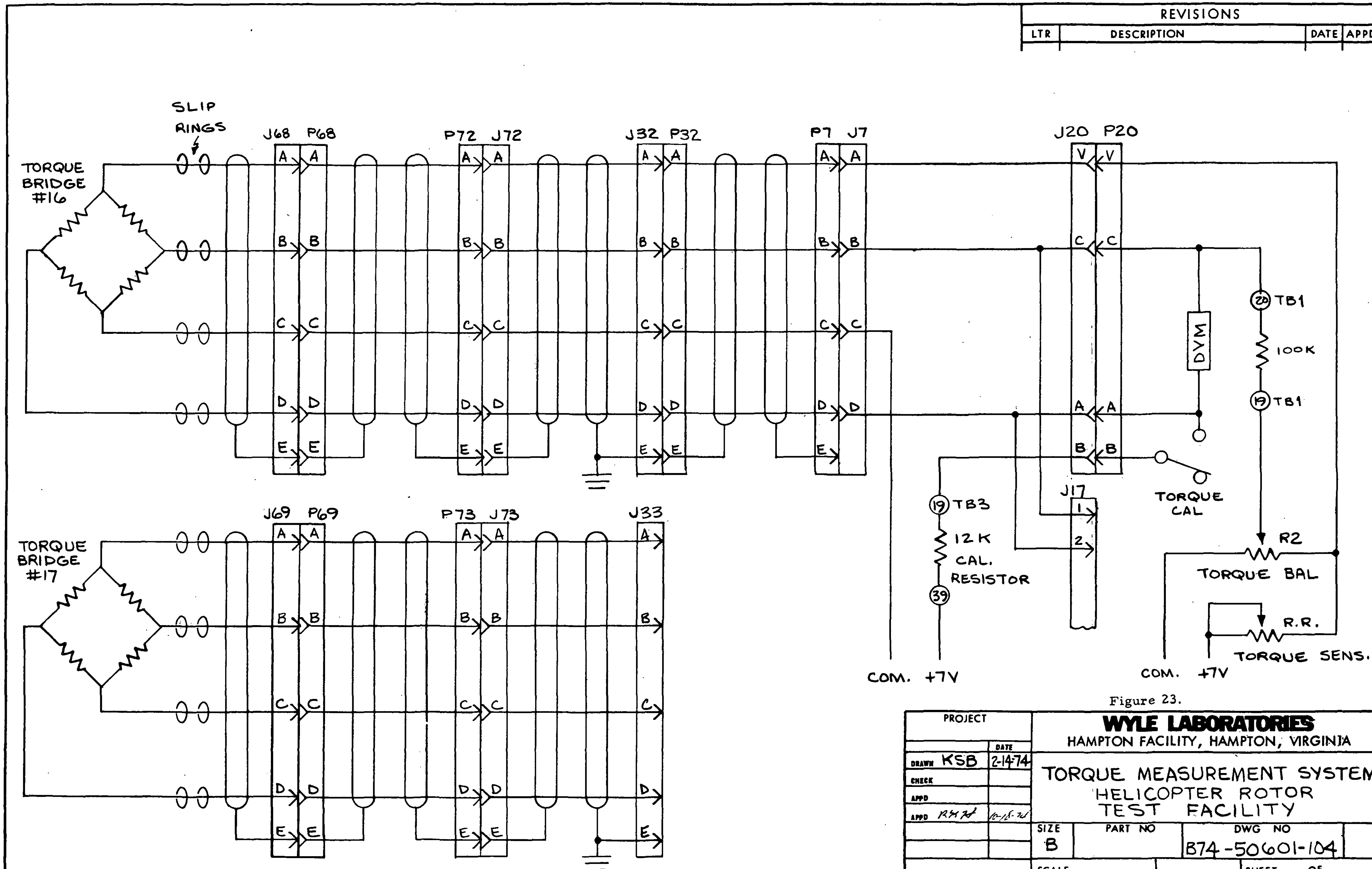


Figure 22.

PROJECT		WYLE LABORATORIES HAMPTON FACILITY, HAMPTON, VIRGINIA
	DATE	
DRAWN KSB	2-14-74	WIRING DIAGRAM, THRUST CORRECTION MEASUREMENT HELICOPTER ROTOR TEST FACILITY
CHECK		
APPD		
APPD	10-16-74	SIZE B · PART NO · DWG NO B74-50601-102
		SCALE · SHEET OF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DESCRIPTION
DATE
APPD
SLIP RINGS
TORQUE BRIDGE #16
TORQUE BRIDGE #17
J68 P68
P72 J72
J32 P32
P7 J7
J20 P20
J69 P69
P73 J73
J33
J17
DVM
TB1
100K
TB3
12K CAL. RESISTOR
TORQUE CAL
R2
TORQUE BAL
R.R.
TORQUE SENS.
COM. +7V
COM. +7V
PROJECT
DATE
DRAWN KSB 2-14-74
CHECK
APPD
APPD
WYLE LABORATORIES
HAMPTON FACILITY, HAMPTON, VIRGINIA
TORQUE MEASUREMENT SYSTEM
HELICOPTER ROTOR
TEST FACILITY
SIZE B
PART NO
DWG NO B74-50601-104
SCALE
SHEET OF

Figure 23.

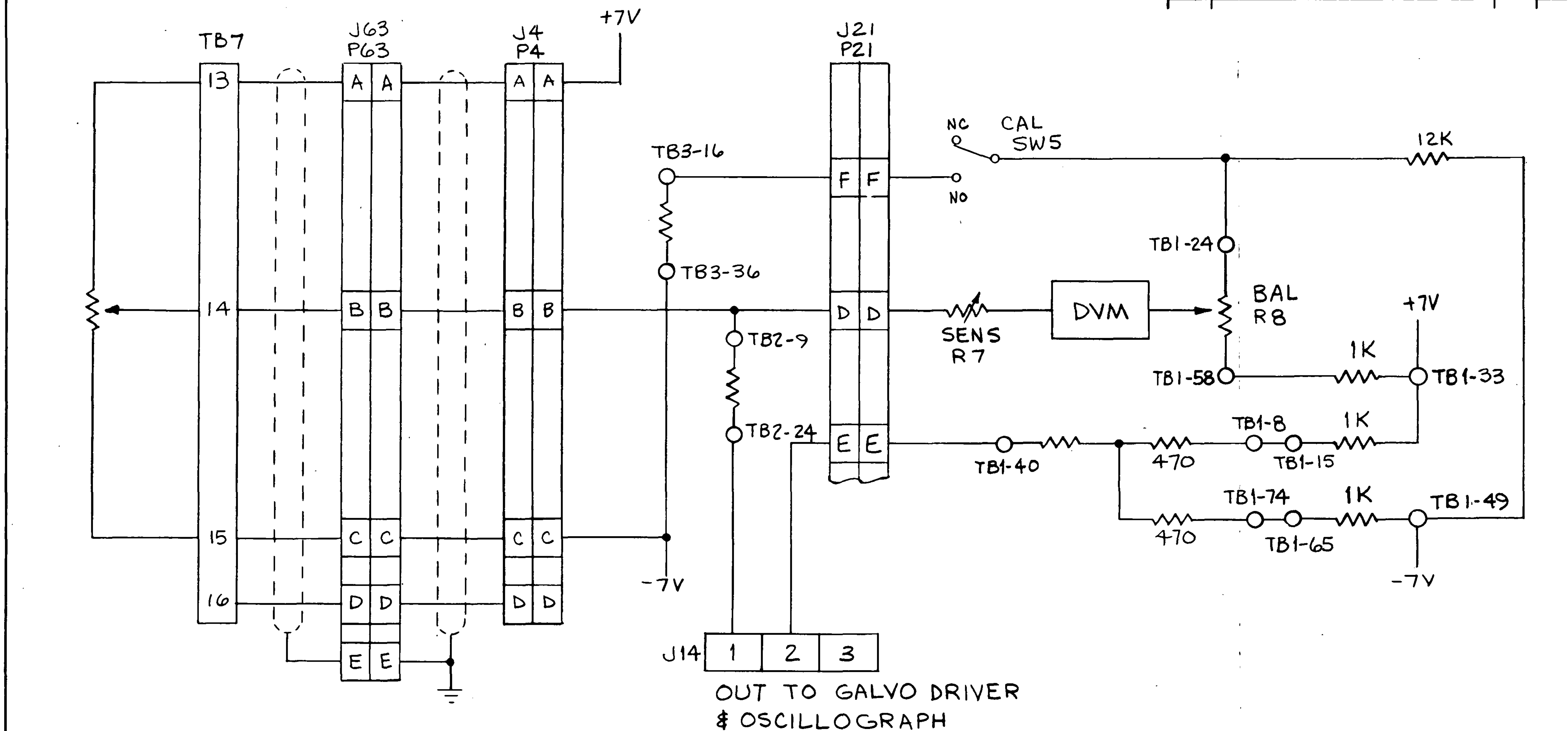

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Figure 24.

PROJECT		WYLE LABORATORIES HAMPTON FACILITY, HAMPTON, VIRGINIA
	DATE	
DRAWN KSB	2-14-74	WIRING DIAGRAM, PITCH MEASUREMENT SYSTEM HELICOPTER ROTOR TEST FACILITY
CHECK		
APPD		
APPD		
SIZE B	PART NO	DWG NO B74-50601-101
SCALE		SHEET OF

REVISIONS			
LTR	DESCRIPTION	DATE	APPD

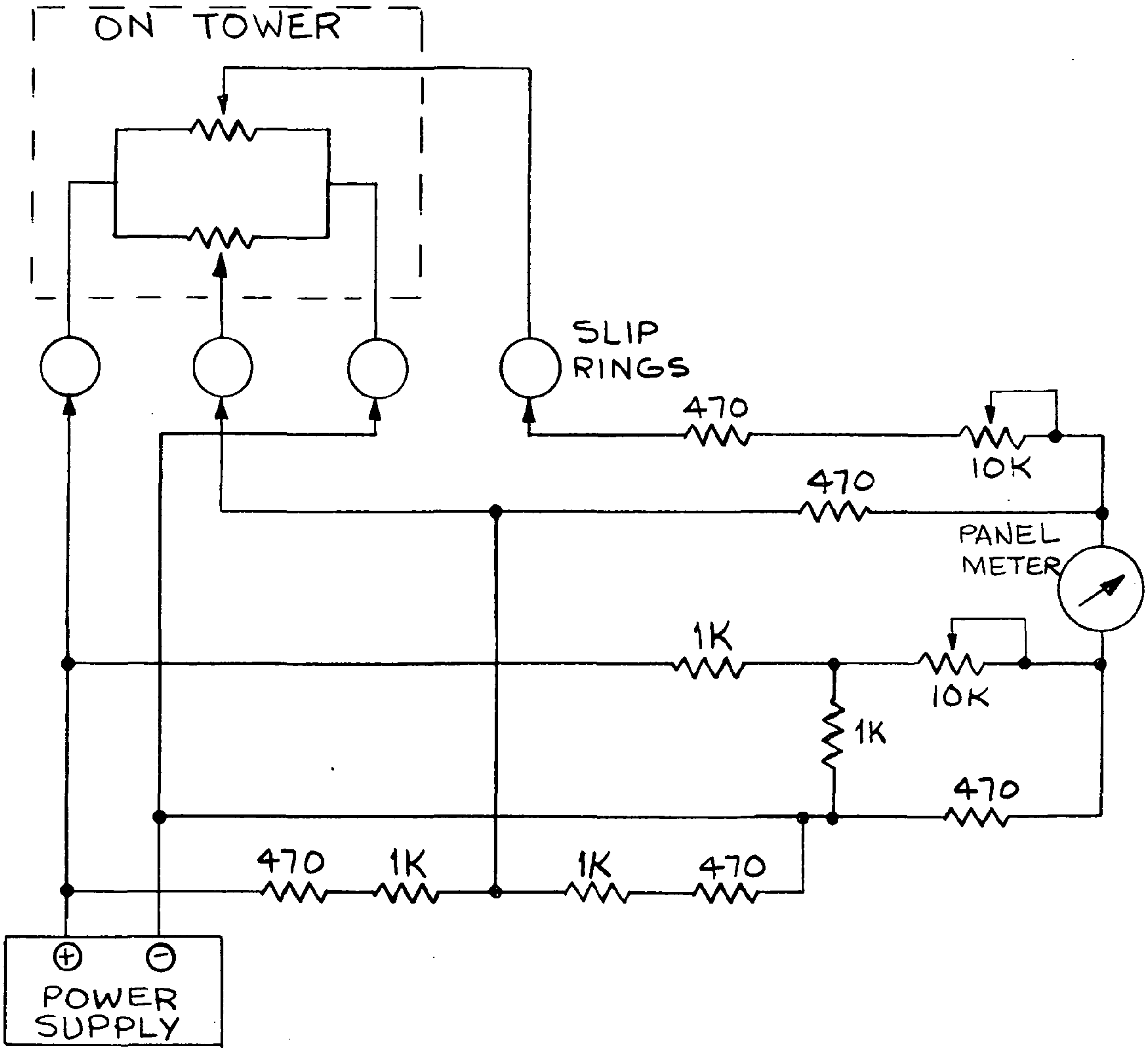

Figure 25.

PROJECT		WYLE LABORATORIES HAMPTON FACILITY, HAMPTON, VIRGINIA
	DATE	TYPICAL CIRCUIT – FLAPPING 1 AND 2, FEATHERING 1 AND 2, HELICOPTER ROTOR TEST FACILITY
DRAWN KSB	5-24-74	
CHECK [illegible]	5/24/74	
APPD [illegible]	5/25/74	
APPD		

SIZE	PART NO	DWG NO
A		A74-50601-109

SCALE | SHEET OF

3.3.2 Analysis

3.3.2.1 Error Considerations

The same error considerations detailed in 3.2.2.1 apply to this subsystem.

3.3.2.2 Error Calculations

ERC Series 4000 Digital Voltmeter

Systematic Error

Assuming a 5°C temperature change:

Resolution error:	0.005%
Accuracy:	0.0325%
Common mode error:	0.0001%
Systematic error:	0.038%

Random Error

None:	0%
Random error:	0%

Total Error

Total ERC Series 4000 error:	0.038%

ERC Series 2700 Frequency Meter

Systematic Error

Resolution error:	0.01%
Time base accuracy	0.0001%

Systematic error: 0.0101%

Random Error

None:	0%
Random error:	0%

Total Error

Total ERC Series 2700 error:	0.01%

Modutec DC Microammeter

Systematic Error

Accuracy (typical):	2%
Systematic error:	2%

Random Error

None:	0%
Randon Error	0%

Total Error

Total Modutec DC Microammeter error:	2%

Bell & Howell Type 1-172 Galvanometer Amplifier

Errors which are detailed in paragraph 3.2.2.2 are:

Systematic Error	0.48%
Random Error	0.04%
Total Error	0.48%

Honeywell 1508 Oscillograph

Systematic Error

Linearity (using Type M galvanometers)	2.0%
Systematic Error	2.0%

Random Error

Human Error in Reading	3%
Random Error	3%

Total Error

Total Error	3.6%

Other Component Errors

Because of the lack of definitive data, engineering estimates must be made for errors contributed by other components in this subsystem. Typically, these errors could be:

RPM Transducer Systematic Error (on-off device)	0%
RPM Signal Conditioner Systematic Error	1%
Thrust Bridge/Conditioning Systematic Error	3%
Torque Bridge/Conditioning Systematic Error	3%
Pitch Transducer/Conditioning Systematic Error	3%
Flapping, Feathering, Lead/Lag Transducers/ Conditioning Systematic Error	3%

3.3.2.3 Combinations of Equipment Error Calculations

The total error for series combinations of various equipment can also be calculated by quadrature addition. These calculations are shown below, excluding slip ring noise.

a. Acquiring pitch and torque via ERC Series 4000 DVM:

Total Error = 3%

b. Recording any parameter via Honeywell 1508 oscillograph:

Total Error = 4.7%

c. Acquiring thrust and thrust correction via ERC Series 4000 DVM:

Total Error = 3%

d. Acquiring RPM via ERC Series 2700 frequency meter:

Total Error = 1%

e. Acquiring lead/lag, feathering, and flapping via Modutec microammeter panel meters:

Total Error = 3.6%

For the same reason as detailed in paragraph 3.2.2.3, the error contributions due to slip rings was excluded from the total error calculations above.

3.3.2.4 Frequency Response

Frequency response is of little interest in this area because data is of a static or DC nature except for RPM. In the case of RPM, as long as the minimum acceptable input level is present at the ERC Series 2700 frequency meter, the instrument will read correctly.

3.4 Spectral Analysis Subsystem

3.4.1 Instrumentation

A typical arrangement of equipment for the spectral analysis of rotor data is shown in Figure 26. Through use of the signal monitor box, signals may be obtained from either the record or reproduce side of the magnetic tape unit. For a typical spectral analysis, the data signal is input directly to the real-time analyzer. On other occasions, the low-level translator is used prior to the real-time analyzer in order to translate input data to a lower

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LTR	DESCRIPTION	DATE	APPD

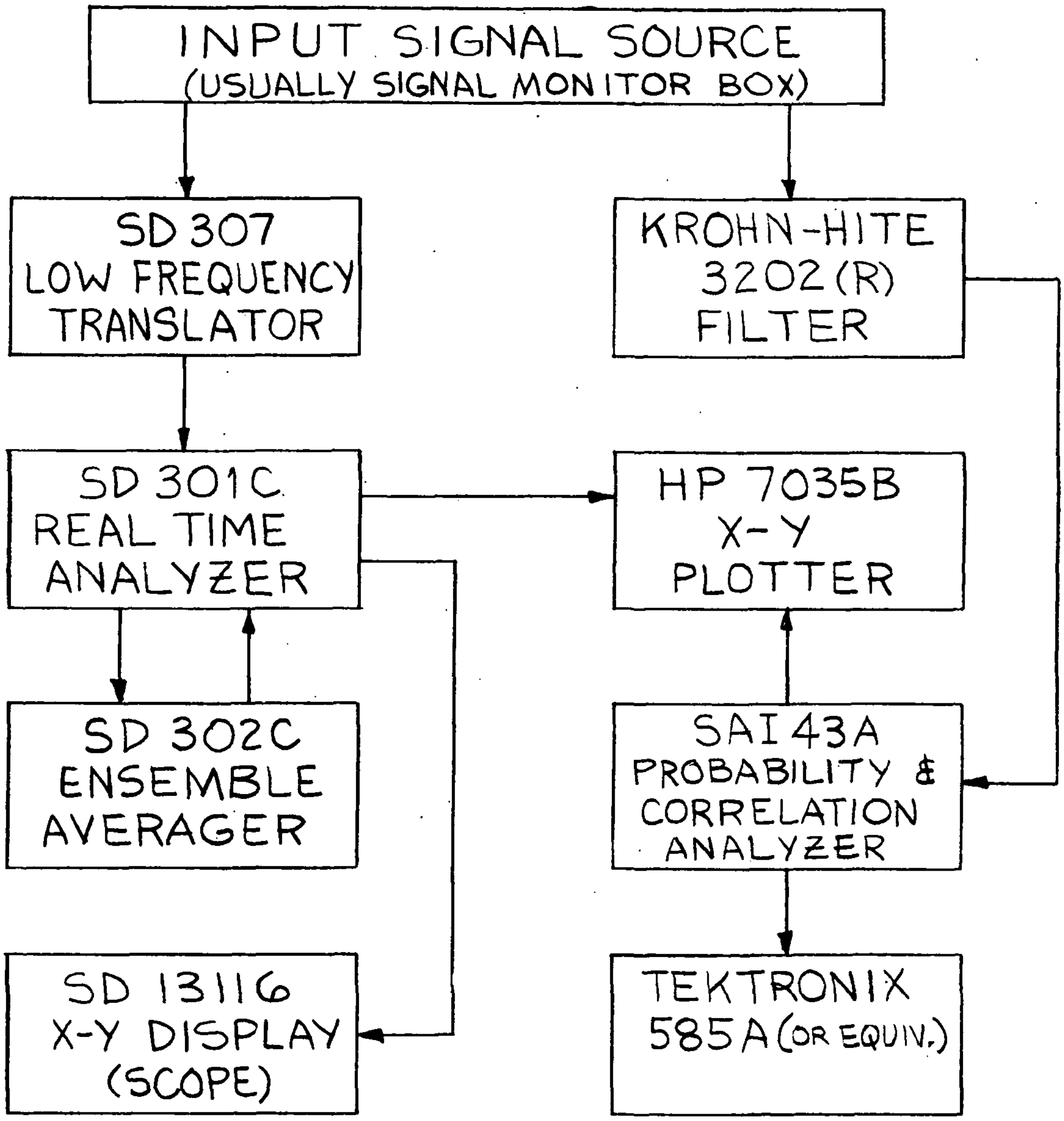

Figure 26.

PROJECT		WYLE LABORATORIES HAMPTON FACILITY, HAMPTON, VIRGINIA		
	DATE			
DRAWN KSB	5-24-74	TYPICAL ARRANGEMENT - SPECTRAL ANALYSIS OF ROTOR DATA		
CHECK [illegible]	5/24/74			
APPD [illegible]	5/25/74	HELICOPTER ROTOR TEST FACILITY		
APPD				
		SIZE A	PART NO	DWG NO A74-50601-001
		SCALE		SHEET OF

frequency range, and thereby achieving better filter resolution in the real-time analyzer itself.

The Spectral Dynamics SD 301C real-time analyzer is the instrument used to analyze the spectral content of a signal over a given frequency band. Data input is generally received from SD 307 low-frequency translator. Outputs proportional to spectral amplitude and frequency are provided to an oscilloscope for display purposes.

For the averaging of successive spectral estimates the Spectral Dynamics SD 302C ensemble averager is used in conjunction with the SD 301C.

A spectral content versus frequency display of the SD 301C data is displayed on an 8-inch by 10-inch Spectral Dynamics SD 13116 oscilloscope. Alternately, spectral content versus frequency may be plotted on the Hewlett-Packard 7035B, X-Y plotter.

For the analysis of probability, correlation, and coherence functions, the Saicor SAI-43A correlation and probability analyzer is employed. Data being input to the SAI-43A are generally filtered prior to this point by a Krohn-Hite 3202 (R) variable filter. If two channels are required, such as for cross-correlation analysis, two 3202 (R) filters are employed. The correlation and probability analyzer is used for the computation and display of the probability density function, probability distribution, auto and cross-correlation, and signal enhancement (coherence in repeated events).

For fast output, the function computed by the SAI-43A can be routed to a Tektronix model 585A oscilloscope or equivalent. Here again the function is displayed versus time. For slow output, the function computed by the Saicor SAI-43A is routed to a Hewlett-Packard 7035B X-Y plotter. There the function is plotted versus time.

Other equipment, not shown in Figure 26, used in spectral analysis is the Spectral Dynamics SD 110-1 phase meter/resonant dwell.

3.4.2 Analysis

3.4.2.1 Error Considerations

The same error considerations detailed in 3.2.2.1 apply to this subsystem.

3.4.2.2 Error Calculations

Spectral Dynamics 307 Low-Frequency Translator

Systematic Error

Assume full scale input:	
Linearity	6.6%
Systematic error	6.6%

Random Error

None	0%
Random error	0%

Total Error

Total Spectral Dynamics 307 error	6.6%

Spectral Dynamics 301C Real-Time Analyzer

Systematic Error

Linearity of spectrum output	0.5%
Systematic error	0.5%

Random Error

Noise level (54 db down from full scale)	0.2%
Random error	0.2%

Total Error

Total Spectral Dynamics 301C error	0.54%

Spectral Dynamics 302C Ensemble Averager

Systematic Error

Spectrum resolution error (14 bits)	0.006%
Systematic error	0.006%

Random Error

None	0%
Random error	0%

Total Error

Total Spectral Dynamics 302C error	0.006%

Spectral Dynamics 13116 X-Y Display

Systematic Error

Repeatability	0.15%
Linearity	1.0%
Systematic error	1.15%

Random Error

None	0%
Random error	0%

Total Error

Total Spectral Dynamics 13116 error	1.15%

HP 7035B X-Y Plotter

Systematic Error

Accuracy	0.2%
Linearity	0.1%
Resettability	0.1%
Systematic error	0.4%

Random Error

None	0%
Random error	0%

Total Error

Total HP7035B error	0.4%

Sacior SAI-43A Analyzer

Systematic Error

a. Amplitude resolution error (correlation and coherence modes)	0.098%
b. Amplitude resolution error (probability mode)	0.195%
Systematic error for a.	0.09%
Systematic error for b.	0.195%

Random Error

None	0%
Random error	0%

Total Error

Total SAI-43A error for (a)	0.098%
Total SAI-43A error for (b)	0.195%

Krohn-Hite 3202 (R) Filter

Systematic Error

Assume a 5^{o}C temperature change

Output DC level stability	0.33%
Systematic error	0.33%

Random Error

Hum and noise	0.003%
Random error	0.003%

Total Error

Total Krohn-Hite 3202 (R) error	0.33%

Tektronix 585A Oscilloscope

Systematic Error

Vertical Deflection Linearity (typical)	3%

Systematic error	3%

Random Error

Human Error in Reading	3% (Engineering Estimate)
Random error	3%

Total Error

Total Tektronix 585A error	4.2%

Spectral Dynamics SD 110-1 Phase Meter/Resonant Dwell

Systematic Error

Assuming 40 db amplitude range, low-pass filter in, 400 Hz input, and full scale input:

Detection accuracy	0.2%
Filter accuracy	0.8%
Output linearity	0.2%
Systematic error	1.2%

Random Error

None	0%
Random error	0%

Total Error

Total Spectral Dynamics 110-1 error	1.2%

3.4 2.3 Combinations of Equipment Error Calculations

a. Acquiring and displaying spectral data via Spectral Dynamics SD 307 low-level translator, the SD 301C real-time analyzer, the SD 302C ensemble averager, and the SD 13116 X-Y display:

Total Error = 6.7% (0.60 db)

b. Acquiring and recording spectral data via Spectral Dynamics SD 307 low-level translator, SD 301C real-time analyzer, SD 302C ensemble averager, and HP 7035B X-Y plotter:

Total Error = 6.6% (0.59 db)

c. Acquiring and recording probability, correlation, and coherence data via Krohn-Hite 3202 (R) filter, Saicor SAI-43A analyzer, and HP 7035B X-Y plotter:

Total Error (for correlation and coherence) = 0.53% (0.044 db)

Total Error (for probability) = 0.55% (0.048 db)

d. Acquiring and displaying probability, correlation, and coherence data via Krohn-Hite 3202 (R) filter, Saicor SAI-43A analyzer, and Tektronix 585A oscilloscope:

Total Error (for correlation and coherence) = 4.2% (0.37 db)

Total Error (for probability) = 4.2% (0.37 db)

e. Measuring phase angle via Spectral Dynamics SD 110-1 phase meter/resonant dwell:

Total Error = 1.2%

The analysis errors calculated above are optimistic for many applications since essentially ideal conditions were assumed. Helicopter rotor noise is extremely complex, contains both periodic and random components, and exhibits high crest factors. These signal characteristics place great demands on the dynamic range of instrumentation equipment. It is therefore estimated that for helicopter noise, errors may exceed the values quoted above by a factor of two or more.

The analyses errors described above are those attributed to the operational characteristics of the instruments utilized. One other major source of error must also be considered. For random data, the most significant errors are often described by the basic statistical considerations of signal analysis theory. It is therefore necessary to judiciously choose analysis parameters such as sample length, number of averages, and bandwidth to optimize resolution and accuracy. A great deal of engineering judgment is required in both selection of analyses parameters and in interpretation of results.

3.4.2.4 Frequency Response

The frequency response characteristics of equipment have been indicated, when available. The only data of significance is the frequency response of the Spectral Dynamics SD 301C real-time analyzer, $\pm$ 1 db to 50 kHz, and the Saicor SAI-43A analyzer, down 3 db at 1.25 MHz.

APPENDIX I

ROTOR DATA ACQUISITION SUBSYSTEM EQUIPMENT CHARACTERISTICS

Equipment characteristics for all major equipment items listed in Table I are presented in this Appendix to afford ease in locating necessary equipment operational information.

Bell and Howell, Type 1-172 Galvanometer Amplifier

Bell and Howell, type 1-172 galvanometer amplifiers are used for signal conditioning in this subsystem. Characteristics of this type galvanometer amplifier are:

Number of Channels:	Two, four, or six.
Controls:	1. Sensitivity (V/IN or V/CM), nine ranges with vernier intermediate control, tenth range 0. 2. GAIN (intermediate to sensitivity settings). 3. OFFSET (electrical galvanometer positioning). 4. Output polarity reversing switch, NORmal-OFF-REVerse. 5. AC power, ON-OFF switch. 6. Input selector switch (DC-CALibrate-AC).
Ambient Temperature:	0° to 50°C.
Input:	
Maximum Input Voltage:	400 VDC or peak AC without damage.

Impedance:	One megohm $\pm$ 1% shunted by 45 picofarads. This impedance is compatible with most oscilloscope probes.
Configuration:	Single ended, floating (circuit ground isolated from case).
Offset Current:	Less than 150 picoamperes at 25°C (doubles for every 10°C temperature increase).
Offset Voltage Changes:	Less than 150 microvolts/°C.
AC Input Configuration:	A 0.1 microfarad capacitor is switched in series with high input lead when input selector switch S3 is set to AC.
AC Power Input:	105 to 125 VAC, 60 Hz, or 210 to 250 VAC, rms, 50 Hz, as required.

Amplification:

Configuration:	Controlled by plug-in feedback network resistor boards.
High Current Galvanometers:	Feedback signal, proportional to galvanometer current.
Low Current Galvanometers:	Feedback signal, proportional to amplifier output before signal reaches a resistor in series with galvanometer coil.
Galvanometer Protection:	Instantaneous saturation in the amplifier output (Q1, Q2) prevents excessive galvanometer current.
Amplifier Protection:	Same saturation feature allows amplifier output to be shorted indefinitely without damage to any component.

Bandwidth:	Response is down less than three db at 10 kHz; with S3 in AC position, response is down 3 db at 1.0 Hz.
Rise Time:	Example: For Type 7-366 galvanometer, less than 17 microseconds, 10 to 90% of full amplitude.
Overload Recovery Time:	Less than 300 microseconds following a ten-times full scale signal overload.
Stability:	The input offset voltage change is less than 150 microvolts per degree centigrade change in ambient temperature.
Linearity:	± 0.25% of full scale from best straight line to ± 80 milliamperes or ± 6.8 volts from amplifier, whichever is less.
Maximum Capacitive Load:	2000 pF, each galvanometer wire to ground; greater capacities may produce a small, low level oscillation when the output voltage is near zero.

Honeywell 1108 Oscillograph

Galvanometer amplifier outputs are routed to a Honeywell, Model 1108 oscillograph for writing on light-sensitive oscillograph paper. Characteristics of a Model 1108 oscillograph are:

Recording Channels:	Capacity for 24 active channels plus four static reference traces. Use Type M subminiature galvanometers, interchangeable with galvanometers used in Honeywell Model 906-1, 1012, and 700C oscillographs.
Frequency Range:	Zero to 5000 Hz, depending on the type galvanometer being used.
Writing Speed:	Clear, legible traces from static to beyond 25,000 inches per second spot velocity.

Linearity:	± 2% of reading with deflections of 4" or less, when initially calibrated at the average left and right 3" deflection.
Optical Arm:	11.8 inches (30 cm).
Record Speeds:	8, 4, 2, 1, .5 inches per second with 10, 1, and .1 ranges, +7%, -3% of setting.
Record Capacity:	200 feet of standard-weight Honeywell Instant Trace paper or 350 feet of extra thin Kodak Linagraph direct print paper.
Time Lines:	Standard: .01, 0.1, or 1.0-second intervals, ± 1%. Optional slow speed: 0.1, 1, or 10-second intervals, ± 1%.
Gridlines:	0.1-inch spacing every fifth line accentuated 2-mm spacing for metric system with 5th line heavier.

Neff Wideband Differential Amplifier

The Neff Model 122 general purpose 100 kHz wideband differential amplifier has the following characteristics:

Fixed Gain Steps:	0, 1, 2, 5, 10, 20, 50, 100, 200, 500, and 1000.
Accuracy of Gain Steps:	± 0.1% of full scale when in calibrated position.
Variable Gain:	From 1 to 2.5 times fixed gain steps.
Isolation:	10^9 ohms input to output.
Input Impedance:	100 megohms, minimum, shunted by 100 pF.
Output Impedance:	0.1 ohms in series with 10 microhenrys.
DC Amplitude Linearity:	± 0.005% of full scale output or better.

Frequency response:	Less than 3 db down at all selectable filter settings and all gains from 1 to 2500
Noise:	Three microvolts referred to input and one millivolt referred to output from DC to 10 kHz. Seven microvolts rms referred to input and one millivolt referred to output from DC to 100 kHz with up to 1000 ohms source resistance.
Switch Selectable Filter Settings:	10 Hz, 100 Hz, 1 kHz, 10 kHz, and 100 kHz.
Outputs:	Separate wideband and switch selectable filtered outputs.

Systron Donner 8154 Time Code Generator/Reader/Tape Search Unit

Characteristics are:

Time Base:	Crystal controlled with overall stability of 1 part in 10^5 per day. Provisions for use of external 1-MHz time base.
Code Format:	Modified IRIG B in BCD hours, minutes and seconds, (day or year/ID No. optional). Other codes available.
Modulated Code Output (1 kHz):	1 to 10 volts pk/pk with modulation ratio from 2 : 1 to 6 : 1.
DC Level Shift Code Output:	0 to + 10 volts into 600 ohms.
Time Set:	Thumbwheel switches for selecting initial start time; toggle switch to preset time into clock registers.
Code Format:	IRIG B. Other codes optional.

Input:	Accepts modulated code with carrier frequency from 30 Hz to greater than 500 kHz with levels from 50 mV to 50 V pk/pk and modulation ratio from 2 : 1 to 6 : 1. Input impedance is 100 kohm, minimum.
Direction:	Forward or reverse selected by front panel controls.
Error Bypass:	Rear panel switch selects 0 or 3 frames of bypass.
Control Modes:	Manual SEARCH mode plus the following automatic modes: SEARCH TO START; SINGLE CYCLE; RECYCLE.
Transport Control:	8154 will automatically select the following transport functions: Forward; Reverse; Drive; Stop.
Interval Output:	Contact closure and DC logic level activated during reproduce period from start to stop time.
Start/Stop Time:	Desired start and stop times selected from front panel thumbwheels in hours, minutes and seconds (days/ID No. or milliseconds are optional).

Ampex FR-600 Recorder/Reproducer

One of the magnetic tape recorder/reproducer units employed in this subsystem is the Ampex Model FR-600. Some of its operating characteristics are:

a. Tape transport

Tape Speeds:	60, 30, 15 and 7-1/2 ips electrically switchable from the front panel of the system control bay.
Reel and Tape Sizes:	10-1/2" or 14" NAB standard reels interchangeable. Transport easily converted for either 1/2" or 1" width tape.
Flutter:	Below 0.3% peak-to-peak, cumulative, from DC to 10,000 Hz 95% of the time at 60 ips.
Fast Mode Times:	Fast mode rewind or fast forward time less than three minutes for 5000 ft. of tape.
Tape Speed Error:	Speed accuracy from record to reproduce better than 0.05% when measured over periods of one second and longer when recorded and reproduced on same machine. When recorded on one machine and reproduced on any machine of the same model, tape speed error in worst case no greater than ±0.2% when measured over periods in excess of one second, without the use of tape speed servo control equipment, and assuming constant 60-Hz power frequency for recording and reproducing, and independent of tape dimensional changes between the time of recording and the time of reproduction.

b. Servo Tape Speed Control System

Timing Stability:	
Initial Calibration:	1 part in 10^5
Daily:	2 parts in 10^5
Weekly:	4 parts in 10^5

Time Displacement Error Due to:

Random Disturbances (applicable to speed variations occuring at a frequency of less than 0.4 Hz)	±0.25 milliseconds at 60 ips ±0.25 milliseconds at 30 ips ±0.40 milliseconds at 15 ips ±0.75 milliseconds at 7-1/2 ips

Time Displacement Error Due to:

Differential Tape Dimension or Speed Change:	±0.5 milliseconds at 60 ips ±0.5 milliseconds at 30 ips ±0.5 milliseconds at 15 ips ±0.5 milliseconds at 7-1/2 ips
Acceptable Speed Deviations from Nominal:	± 5% maximum
Warm-up: (Stabilization Time)	45 seconds maximum
Lock-in: (Stabilization Time)	10 seconds maximum for speeds 7-1/2 to 60 ips 15 seconds maximum for speed of 120 ips

c. Direct Record/Reproduce System

Frequency Response	300 to 250,000 Hz ± 3 db at 60 ips 150 to 125,000 Hz ± 3 db at 30 ips 100 to 60,000 Hz ± 3 db at 15 ips 100 to 30,000 Hz ± 3 db at 7-1/2 ips
Signal-to-Noise Ratio:	60, 30, 15, & 7-1/2 ips, -25 db
Input Impedance:	10,000 ohms minimum
Input Level:	1.0 volt rms nominal, adjustable from 0.25 to 25 volts rms

Output Impedance:	Less than 100 ohms
Output Level:	1.0 volt rms nominal across 1000 ohms or greater load impedance, adjustable 0 to 2.0 volts
Harmonic Distortion:	Less than 1% total harmonic distortion of a 1000-Hz signal recorded at any one of tape speeds.

d. Frequency Modulation (FM) Record/Reproducer System (High-Level)

Frequency Response:	DC to 20,000 Hz ± 0.5 db at 60 ips (max. var.) DC to 10,000 Hz ± 0.5 db at 30 ips (max. var.) DC to 5,000 Hz ± 0.5 db at 15 ips (max. var.) DC to 2,500 Hz ± 0.5 db at 7-1/2 ips (max. var.)
Harmonic Distortion:	Less than 1.5% over specified passband
Signal-to-Noise Ratio (rms noise referred to normal operating level, ± 40% deviation):	46 db at 60 ips 46 db at 30 ips 46 db at 15 ips 46 at 7-1/2 ips
DC Drift:	Less than 1% of full output over 24-hour period.
AC/DC Linearity:	Within ± 1% of a zero-based straight line.
Input Impedance:	20,000 ohms, unbalanced to ground.
Input Level:	1.0 volt rms nominal, adjustable from 0.1 to 25 volts rms to produce full deviation of carrier.

Output Impedance:	1000 ohms
Output Level:	1.0 volt rms maximum 10,000 ohms or greater output load.
Output Filtering:	Variable by toggle switch to provide best frequency response or best transient response.

e. Frequency Modulation (FM) Record/Reproduce System (Low-Level)

Frequency Response and Maximum Amplitude Variation:

Speed (ips)	Frequency Response (Hz)	Maximum Amplitude Variation when system loaded with 10k ohms and 350 pf — INPUT LEVEL: 2, 5, 10, 20, 50, 100, 200 mv	500 mv, 1.0, 2.0v
60	0 to 20,000	0.8 db	1.0 db
30	0 to 10,000	0.8 db	1.0 db
15	0 to 5,000	0.8 db	1.0 db
7-1/2	0 to 2,000	0.8 db	1.0 db
3-3/4	0 to 1,250	1.3 db	1.5 db
1-7/8	0 to 625	1.3 db	1.5 db
15/16	0 to 312	1.3 db	1.5 db
12	0 to 4,000	0.8 db	1.0 db
6	0 to 2,000	1.3 db	1.5 db
3	0 to 1,000	1.3 db	1.5 db
1	0 to 500	1.3 db	1.5 db

Harmonic Distortion:	Less than 1.5% over specified passband
Signal-to-Noise Ratio (rms noise referred to normal operating level, ± 40% deviation):	46 db at 60 ips 46 db at 30 ips 46 db at 15 ips 46 db at 7-1/2 ips

DC Drift:	Less than 1% of full output over 24-hour period.
AC/DC Linearity:	Within ± 1% of a zero-based straight line.
Input Impedance:	20,000 ohms, unbalanced to ground.
Input Level:	1.0 volt rms nominal, adjustable from 0.1 to 25 volts rms to produce full deviation of carrier.
Output Impedance:	1000 ohms.
Output Level:	1.0 volt rms maximum 10,000 ohms or greater output load.
Output Filtering:	Variable by toggle switch to provide best frequency response or best transient response.

Honeywell 7600 Magnetic Tape Recorder/Reproducer

a. Tape Transport

Tape Speeds:	Seven: 120, 60, 30, 15, 7-1/2, 3-3/4 and 1-7/8 ips, electrically selectable by pushbutton. Speeds are bidirectional by pushbutton selection.
Reels and Tape:	10-1/2" maximum or 15" maximum, depending on transport selected. Tape widths 1/4", 1/2" or 1" standard.
NAB or ASA Hubs:	1.0 or 1.5 mil base tape.
Tape Speed Accuracy:	(Servoed from capstan tone wheel). Velocity tone servo ± 0.20%. Phase lock servo ± 0.15%.
Start Time:	6 seconds maximum at 120 ips.

Stop Time: 5 seconds maximum at 120 ips.

Fast Modes: 900 feet per minute under capstan control.

Static Skew: Reproduce head azimuth adjustable to reduce static skew to under 1 microsecond between outside tracks on a single head stack at 120 ips.

Dynamic Skew (ITDE): Measured between outside tracks of a single head stack.

Tape Speed (ips)	ITDE (microseconds, zero to peak)
120	1
60	2
30	3
15	5
7-1/2	10
3-3/4	20
1-7/8	30

Flutter: Cumulative, peak to peak.

Tape Speed (ips)	Bandwidth (Hz)	Pk-Pk Flutter (%)
120	0.1 to 10,000	0.25
60	0.1 to 10,000	0.25
30	0.1 to 5,000	0.35
15	0.1 to 2,500	0.40
7-1/2	0.1 to 1,250	0.45
3-3/4	0.1 to 625	0.50
1-7/8	0.1 to 312	0.60

b. Capstan Servo

Type: Two Capstan Servo Systems available. A velocity tone servo or a phase lock servo. Both operate from capstan tone wheel or tape using IRIG constant amplitude reference frequencies.

Time Base Error: (Phase lock servo only).

Tape Speed (ips)	TBE (microseconds)
120	± 1.0
60	± 2.0
30	± 2.0
15	± 2.0
7-1/2	± 4.0
3-3/4	± 8.0
1-7/8	±10.0

Servo Reference Frequency: 200 kHz at 120 ips. Proportional at other speeds per IRIG 106-66. Reference accuracy 2 in 10^5, reference stability 2 in 10^6.

c. Direct Record/Reproduce

Dynamic Characteristics:

Tape Speeds (ips)	Bandwidth ± 3 db (Hz)	RMS Signal/RMS Noise (db) Filtered	Unfiltered
120	400-700,000	34	30
60	400-500,000	34	30
30	400-250,000	34	30
15	300-125,000	34	30
7-1/2	200- 62,500	32	28
3-3/4	200- 31,250	30	26
1-7/8	200- 15,625	28	24

Harmonic Distortion: Normal record level set for 1% third-harmonic distortion of 1-kHz signal recorded at 60 ips.

Input Level: 0.1 to 10 VRMS, adjustable.

Input Impedance: Nominal 20kohms resistive, paralleled by 100 pf maximum, unbalanced to ground. Provision for insertion of termination resistor.

Output Level: 1 VRMS into 60 ohms.

Output Impedance: 50 ohms minimum.

Amplitude Equalization: Up to 7 amplitude equalizers (one per speed) electrically switched.

Phase Equalization: Up to 7 phase equalizers (one per speed) electrically switched.

d. FM Record/Reproduce

Dynamic Characteristics:

		Low Band		Intermed. Band		Wideband	
Center Freq. kHz	Data BW Hz within 1.0 db	Speed ips	RMS S/N db	Speed ips	RMS S/N db	Speed ips	RMS S/N db
432	0--80,000					120	46
216	0--40,000			120	48	60	47
108	0--20,000	120	52	60	48	30	47
54	0--10,000	60	52	30	47	15	47
27	0-- 5,000	30	52	15	47	7-1/2	46
13.5	0-- 2,500	15	52	7-1/2	47	3-3/4	45
6.75	0-- 1,250	7-1/2	50	3-3/4	46	1-7/8	43
3.38	0-- 625	3-3/4	49	1-7/8	46		
1.68	0-- 312	1-7/8	47				

Harmonic Distortion: With a single record level setting total harmonic distortion of any frequency within the band pass will be:

Low Band:	1.2%
Intermediate Band:	1.5%

	Wide Band: 2% With record level optimized for mode and speed, total harmonic distortion of any frequency within the band pass will be 1.2% maximum.
Linearity:	± 0.5% of full deviation from best straight line through zero.
DC Drift:	± 0.5% of full deviation over 8 hours and 20 degrees F after 10 minutes warm-up.
Input Level:	0.5 to 10 volts peak.
Input Impedance:	Nominal 20kohms resistive, paralleled by 100 pF maximum, unbalanced to ground.
Output Impedance:	50 ohms.
Output Level:	2 VRMS into 10,000 ohms. 1 VRMS into 600 ohms.
Record Speed Switching:	7 electrically switched center frequencies plus manual selection for total of 9 center frequencies.
Reproduce Speed Switching:	Up to 7 electrically switched CF/filter assemblies plus manual mode selection for total of up to 9 CF/filter assemblies.

Bell and Howell (CEC) VR-3400 Magnetic Tape Recorder/Reproducer

Operating characteristics for the Bell and Howell VR-3400 Recorder/Reproducer are as follows:

a. Tape Transport

Tape Speeds:	8 bidirectional speeds, rotary switch selectable: 240, 120, 60, 30, 15, 7.5 3.75, 1.875 ips.

Reels:	Standard EIA reels to 15-inch diameter are accommodated. CEC precision reels recommended. NOTE: System specifications are established using CEC precision reels, or equivalent.
Tape:	1/2" or 1" width standard, 1 or 1-1/2 mil base mylar or 1-1/2 mil base acetate. All specifications based on using CEC recommended tape.
Start Time:	6 seconds maximum for 120 ips to capstan controlled speed.
Stop Time:	4 seconds maximum for 120 ips, utilizing dynamic braking.
Wind/Rewind Rate:	1400 feet per minute.
Tape Speed Accuracy:	± 0.15% at all tape speeds when in tach mode. ±0.02% when in phase lock servo mode (tape).
Flutter (Cumulative Peak-to-Peak):	Less than 0.25% at 60 ips, from 0.20 Hz to 10 kHz.
Controls:	Illuminated pushbuttons for RUN FORWARD, RUN REVERSE, RECORD, FAST FORWARD, FAST REVERSE, and POWER (push-ON, push-OFF). Rotary speed selector, phase lock selector (Tape/Tach), and record test selector are front panel located. Remote control of all operating modes via connection at the transport by use of accessory CEC Remote Control Unit, or equivalent.
Dynamic Skew:	Less than ± 1.5 microsecond between outside tracks (on same headstack) at 120 ips.

b. Phase Lock Servo Drive

The Phase Lock Capstan Motor Control unit provides a closed loop servo operation for the D-C capstan motor. This unit provides two modes of operation, tachometer and tape. When in the tach mode the control loop is established from the slotted tonewheel on the capstan drive assembly. The tach mode is used for initial recording. The tape control servo mode uses the prerecorded signal from the tape to establish highly accurate speeds and low time base error when reproducing tapes.

Time Base Error:

Speed	Control Reference	TBE
120 ips	200 kHz	± 1 microsecond
60 ips	100 kHz	± 1 microsecond
30 ips	50 kHz	± 1 microsecond
15 ips	25 kHz	± 2 microseconds
7 - 1/2 ips	12.5 kHz	± 4 microseconds
3 - 3/4 ips	6.25 kHz	± 8 microseconds
1 - 7/8 ips	3.125 kHz	±12 microseconds

Fail Safe: Capstan control is automatically returned to tach mode whenever tape signal is lost or when system is placed in record mode, regardless of position of mode selector switch. Respective tach and tape lamps light only when transport is up to speed and in servo locked operation.

External Signal: External reference frequencies may be inserted for variable speed control with inclusion of optional input selector.

Data Channel: The servo control track may be used as a data channel when the optional bandpass filter card is included and provided none of the data is in the servo control frequency bandpass.

c. Direct System

Frequency Response:

Tape Speed-ips	Response ± 3 db Over Indicated Bandwidth	SNR
120	300 Hz to 600 kHz	32 db
60	300 Hz to 300 kHz	32 db
30	150 Hz to 150 kHz	32 db
15	100 Hz to 75 kHz	32 db
7-1/2	50 Hz to 38 kHz	29 db
3-3/4	50 Hz to 19 kHz	29 db
1-7/8	50 Hz to 10 kHz	29 db

Input Level:	0.1 to 15 volts rms (25 V rms maximum without damage) to produce normal record level via input potentiometer control.
Normal Record Level:	1% ± 0.1% third harmonic distortion of a 1 kHz signal recorded and reproduced at 60 ips.
Input Impedance:	20 kohms minimum, shunted by a 120 pF maximum capacitance.
Output Level:	0 to 1.0 volt rms into a 91 ohm terminated cable.
Output Impedance:	Less than 91 ohms, single-ended.
Intermodulation Distortion:	Less than 0.6% for $F_1 + F_2$ components, referred to normal record level.
Phase Response:	The system is phase equalized for optimum reproduction of pulse and transient wave forms.
Bias Frequency:	3.0 MHz.

d. Standard FM System

Input Level: 0.5 to 10 volts rms for ± 40% deviation (100% modulation).

Input Impedance: 20 kohms (D-C Coupled) single-ended, 120 pF shunt capacity maximum.

Linearity: ± 0.5% of full scale from a best straight line through zero.

Output Level: 1.0 VRMS into 10 kohms, shunted by less than 880 pF.

Output Impedance: 5 kohms, nominal.

Frequency Response, Carrier Frequency, SNR, and Distortion:

Tape Speed (IPS)	Carrier Frequency (kHz)	Information Freq. Response (kHz)		Signal/Noise (RMS Signal/ RMS Noise)	Total Harmonic Distortion (%)
60	108	0-20	± 0.5 db	51 db	1.2
30	50	0-10	± 0.5 db	51 db	1.2
15	27	0-5	± 0.5 db	50 db	1.2
7-1/2	13.5	0-2.5	± 0.5 db	50 db	1.2
3-3/4	6.75	0-1.25	± 0.5 db	48 db	1.5
1-7/8	3.375	0-0.625	± 0.5 db	46 db	1.5

APPENDIX II

FACILITY DATA ACQUISITION SUBSYSTEM EQUIPMENT CHARACTERISTICS

Equipment characteristics for major equipment items listed in Table II are shown in this Appendix to afford ease in locating necessary equipment operational information.

<u>ERC Model 2700 Series Frequency Meter, Digital RPM Display</u>

The Digital RPM display is an ERC Model 2700 series frequency meter with the following characteristics:

Frequency Range:	1 Hz to 20 MHz.
Sensitivity:	100 mV rms, 1 Hz to 20 MHz.
Input Impedance:	1 megohm shunted by 20 pF.
Time Base Accuracy:	1 MHz $\pm$ 1 ppm at 25°C $\pm$ 10 ppm 0°C to 50°C
Time Base Duration:	Selectable; 1 msec, 10 msec, 100 msec, 600 msec, 1 sec, 6 sec, 10 sec and 60 sec.
Decimal Point:	Remote programmable.
Over Range:	Front panel indicator plus logic level output.
Temperature Range:	0°C to 50°C.
Power:	115/230 VAC 50-60 Hz, 10 watts max.
Mode Control:	Front panel select; Test, MHz, kHz, Remote.
Sensitivity Control:	Front panel; max. sens. to approx. 10 Vp-p.
Output:	Time base gate, E-O-M, over range and BCD.

ERC Model 2700 Series Frequency Meter, Digital RPM Display (continued)

Inputs:	Time base select, external clock, external clock select, remote hold and decimal point select.

ERC 4000 Series Digital Voltmeter

The front panel display is an ERC 4000 Series DVM with the following characteristics:

Full Scale Response:	Zero to full scale in one conversion cycle.
Conversion Rate:	10/sec.
Amperture Time:	33.3 milliseconds.
Polarity:	Automatic.
Display:	LED indications.
CMRR:	120 db at 60 Hz.
NMRR:	60 db at 60 Hz.
Isolation:	500 V (input to system ground)
Calibration:	Biannually.
BCD Outputs:	Yes.
External Conversion Control:	Yes
End of Measurement Output:	Yes
Out of Range Output:	Yes
Operating Temperature Range:	$0^{o}C$ to $+50^{o}C$
Temperature Coefficient:	25 ppm/^{o}C

ERC 4000 Series Digital Voltmeter (continued)

Power:	115/230 VAC 50-60 Hz, 15 watts max.

Honeywell, Model 1508, Oscillograph

Recording Frequency Range:	Zero to 5000 Hz, depending upon the type of galvanometer used.
Writing Speed:	Clear, legible traces from static to beyond 25,000 ips spot velocity.
Linearity:	± 2% of reading with deflection of 4 in. or less, when initially calibrated at the average left and right 3-inch deflection.
Time Lines:	100 lines/sec., 10 lines/sec., 1 line/sec., or 10 sec./line, ± 2% at 117 VAC.
Grid Lines:	0.1 in. spacing, every 5th line heavier. 2 mm spacing for metric system with every 5th line heavier.
Recording Channels:	Up to 24 active channels plus 4 auxiliary channels.
Recording Lamp:	100W high pressure mercury arc, two electrode, vertically mounted.
Record Capacity:	100 feet of standard weight Heiland Instant Trace (307097) or Kodak Linagraph Direct Print Paper (200333), 150 feet of extra-thin Kodak linagraph direct-print paper (200333), 3-1/4" max. roll diameter.
Operating Temperature:	Basic visicorder with fluid-damped galvanometers +50° to 115°F.
Direct Recording:	Records in full view of the operator with the frequency and sensitivity of a photographic type oscilloscope.

Trace Identifier:	Galvanometer traces receive 1/32-inch interruptions at intervals of approximately 8.7 inches along the record to provide identification of each channel.
Trace Numbering:	The trace numbering system provides a means of positive trace identification by printing a series of numbers, corresponding to the galvanometer positions, on the right-hand edge of the recording paper.

APPENDIX III

SPECTRAL ANALYSIS SUBSYSTEM EQUIPMENT CHARACTERISTICS

Equipment characteristics for equipment items listed in Table III are shown in this Appendix to afford ease in locating necessary equipment operational information.

The Spectral Dynamics 307 Low Frequency Translator

Frequency Ranges:

Analysis Band Width	Analyzer Resolution	Input Center Frequency Range	Frequency Range of Translated Data
50 Hz	0.10 Hz	25 Hz -49.9 kHz	5 Hz - 55 Hz
100 Hz	0.20 Hz	50 Hz -49.9 kHz	10 Hz - 110 Hz
500 Hz	1.00 Hz	250 Hz -49.9 kHz	50 Hz - 550 Hz
1000 Hz	2.00 Hz	500 Hz -49.9 kHz	100 Hz - 1100 Hz

Data Output:

Amplitude: 0.316 Vrms = full scale

Linearity: ± 0.5 db to 50 db referenced to full scale

Impedance: 500 ohms

Reference Signal Output:

Amplitude: 4.5 Vp-p square wave

Impedance: 600 ohms

Range: 25 - 49 kHz; 1 Hz increments to 10 kHz and 10 Hz increments from 100 Hz to 49 kHz.

Stability: Short term; 0.002% in 24 hrs.
Long term; 0.01% in six months.

Input:

Amplitude and Impedance -- 0.1 Vrms to 10 Vrms into 100 kohms.

Spectral Dynamics 301C, Real-Time Analyzer

Upper Frequency Limit	3 db BW (Hz)	Memory Period (sec)
50 kHz	150	0.010
20 kHz	60	0.025
10 kHz	30	0.050
5 kHz	15	0.100
2 kHz	6	0.250
1 kHz	3	0.500
500 Hz	1.5	1.000
100 Hz	0.3	5.000
50 Hz	0.15	10.000
10 Hz	0.03	50.000

Sensitivity: (For full scale output). 1 Vrms to 28.2 Vrms adjustable in 1 db steps.

Level Indication: Five digitally driven indicator lamps provide correct indication input level regardless of waveform.

Impedance: 100 kohms.

Coupling: Selectable DC/AC.

Spectral Dynamics, 301C, Real-Time Analyzer (continued)

Dynamic Range:	(Full scale to minimum discernible signal) 50 db.
Noise Level:	Average level 54 db down from full scale with no input signal.
Frequency Markers:	Ten equally spaced points or external input.
Modes of Operation (selected manually or remotely):	Update -- Memory continuously updates with new data. Hold -- Last data in memory is continuously recycled -- no new data is added. Transient Capture -- Number of data points loaded into memory selected manually by % full scale switch otherwise 1500 points are loaded. Triggering of transient capture mode (start of load cycle) may be done externally with a pulse input or from the data itself. The DC coupled triggering level is adjustable (for internal or external operation) from -5 db to -35 db. Remote Operation -- Application of an external DC level shift (nominally 5V -2 μsec. minimum to either the Update, Hold or Transient Capture input will automatically cause the selected mode to be activated.
Internal Calibration:	Calibrates entire analyzer from signal input to DC outputs. Spectrum Axis -- (Lin) Full scale and zero (Log) Full scale, -10 db, - 20 db, -30 db, -40 db Frequency Axis -- (Lin) Full scale and zero (Log) Full scale, -1 decade, -2 decades

Spectral Dynamics, 301C, Real-Time Analyzer (continued)

Sweep Speed	Oscilloscope fast -- sweeps every 50 msec.
	Oscilloscope slow -- sweeps every 100 msec.
	Plotter -- plot completed in 32, 64 or 320 seconds as determined by an internal jumper; automatically controlled by SRF.
	Manual -- sweep position is controlled by % full scale switch.
	External Averager -- displayed sweep rate is placed under control of SD302.
Sweep Initiation:	Automatic -- spectra are presented repeatedly.
	External/Manual -- a complete spectrum is swept each time a trigger pulse is provided or each time the sweep button is depressed.
	Memory Period -- a sweep is initiated each time a memory load cycle is completed. Each sweep is statistically independent of previous displays.
Digital Locater:	Provides subfunctions of Sweep Speed modes; provides intensity markers, sweep limit and transient capture, all controlled by % full scale switch.
Position Marker:	Provides a marker pulse output independently controlled by % full scale switch.
Outputs:	
Spectrum Axis:	Linstep -- 0 to 5V detector output; one step for each synthesized filter location.
	Lin -- 0 to 5V (nominal) smoothed output of detector.

Spectral Dynamics, 301C, Real-Time Analyzer (continued)

	Log -- 1V Log smoothed output of detector.
Frequency Axis:	Lin step -- 0 to 5V stepped ramp.
	Lin -- 0 to 5V (nominal) smooth ramp.
	Log -- 1V smooth log ramp.
	Sweep Trigger -- provides transition from 5V to 0V synchronized with start of sweep; transition at end of sweep is back to 5V.
	Pen lift -- isolated contact closure when sweeping in plotter mode.
	Retract blanking --0V during sweep 5V during retrace.
Memory Contents:	500 mV p-p full scale signal displaying the speeded up signal stored in memory.
Frequency Response:	±1 db over entire range
Linearity:	±0.5% of full scale or ±1 db, whichever is greater.
Separation:	Two equal amplitude sinusoids two filter bandwidths a part, applied simultaneously will average a 6-db valley between peaks.
Selectivity:	Filter response is -20 db at a frequency 0.2 bandwidths from center frequency and -40 db at 4.5 bandwidth, ±15%.
Frequency Linearity:	±0.2% of best straight line of full analysis range.

Spectral Dynamics 302 Ensemble Averager

Singal Inputs: 500 Lin step voltage levels per analysis spectrum ensemble from analyzer.

500 sample timing pulses per analysis spectrum ensemble from analyzer.

Number of Spectrum Ensembles Averaged:

1, 2, 4, 8, 16, 32, 64, 128, 256, 512, 1024, 2048, or 4096. Ten-bit words are averaged for one to 1024 ensembles; 9 msb for 2048 and 8 msb for 4096.

Averager Gain: Unity ± 1%

Spectral Dynamics, 113116 Oscilloscope

Inputs: Spectrum Lin and Log.

Frequency Lin and Log.

Z input: + 1V for full intensity
- 1V for blanking

Settling Time: Less than 7 μsec to within a trace width of final value.

Repeatability: Less than 0.15% error for readdressing a point from any direction.

Linearity: ±1% of full screen over 8 x 10-inch screen; any inch with respect to any other inch, within 10%.

Cathode-Ray Tube: Accelerating potential - 20 kV Writing Rate - 20"/μsec. Spot Size - less than 30 mils throughout 8 x 10 screen at 100 foot-lamberts light output; nominally 20 mils at center screen (shrinking raster). Phosphor and Graticule - Aluminized P1 phosphor with 8 x 10 graticule.

Hewlett-Packard 7035B X-Y Plotter

Input Range:	1, 10, 100 mV/in., 1 and 10 V/in. Continuous vernier between ranges.
Input Resistance:	1 mV/in. - potentiometric (00 at null) variable - 11 kohms. 10 mV/in. - 100 kohms variable - 100 kohms. All other ranges - 1 megohm variable - 1 megohm.
Maximum Allowable Source Resistance:	20 kohms on 1 mV/in. range; all other ranges, no restriction.
Normal Mode Rejection:	30 db (18 db/octave roll of above 60 Hz).
CMR:	1 mV/in. - 130 db DC (CMR) 100 db AC(CMR) 10 mV/in. - 110 db DC(CMR) 80 db AC(CMR) 100 mV/in. - 90 db DC(CMR) 60 db AC(CMR) 1 V/in. - 70 db DC(CMR) 40 db AC(CMR) 10 V/in. - 50 db DC(CMR) 20 db AC(CMR)
Slewing Speed:	20 in/sec.
Accuracy:	± 0.2% of full scale.
Linearity:	± 0.1% of full scale.
Resettability:	± 0.1% of full scale.
Reference Stability:	Zener reference with temperature stability of 0.002%/degrees C

Frequency Range: High-Pass and Low-Pass cutoff frequencies continuously adjustable from 20 Hz to 2 MHz in five bands.

BAND	MULTIPLIER	FREQUENCY (Hz)
1	1	20 - 200
2	10	200 - 2,000
3	100	2,000 - 20,000
4	1K	20,000 - 200,000
5	10K	200,000 - 2,000,000

Frequency Dials: Each channel has a single decade frequency dial (calibrated from 10 to 210) and an associated high-pass/low-pass band switch providing five multiplier ranges for each mode.

Cutoff Frequency Calibration Accuracy:

$\pm$5%-bands one to four, $\pm$10%-band five, with Response Switch in Max. Flat (Butterworth) position; less accurate in R-C position. Relative to mid-band level, the Filter output is down 3 db at cutoff in Max. Flat position, and approximately 13 db in R-C position.

Bandwidth: Low-Pass Mode - Frequency response from DC to the cutoff frequency set within the range from 20 Hz to 2 MHz.

High-Pass Mode - Continuously adjustable between 20 Hz and 2 MHz with upper 3 db point at approximately 10 MHz.

Band-Pass Operation Model 3202 - Continuously variable within the cutoff frequency limits of 20 Hz to 2 MHz. For minimum bandwidth, the high-pass and low-pass cutoff frequencies are set equal. This produces an insertion loss of 6 db, with the -3 db points at 0.8 and 1.25 times the midband frequency.

Band-Reject Operation Model 3202 - Continuously variable within the cutoff frequency limits of 20 Hz and 2 MHz or sharp null at any frequency between 40 Hz and 800 kHz. The low-pass band extends to DC. The high-pass band has its upper 3 db point at approximately 10 MHz. The null is sharper than that of a balanced "parallel T" filter, and is obtained by setting the high-pass cutoff at approximately twice the desired null frequency, and the low-pass cutoff at approximately one-half the desired null frequency.

Response Characteristics (selected by Rear Panel Switch):

Butterworth - Each channel exhibits maximally flat fourth order Butterworth response for optimum performance in frequency domain.

Simple RC - Fourth order RC response for transient-free time-domain performance.

Note: Higher order characteristics may be obtained by cascading individual channels.

Attenuation Slope:	Nominal 24 db per octave per channel in high-pass or low-pass modes.
Maximum Attenuation:	Greater than 80 db.
Insertion Loss:	Zero ± 1/2 db to 2 MHz; 3 db at approximately 10 MHz. 6 db in Band-Reject operation.
Input Characteristics:	Maximum Input Amplitude - 3 V rms up to 2 MHz, decreasing to 1V rms at 10 MHz. Maximum DC Component - Low-Pass Mode: Combined AC plus DC should not exceed 4.2 V, peak. High-Pass Mode: 200 V.
Impedance:	100 kohms in parallel with 50 pF.

Krohn-Hite 3202 (R) Variable Filter (continued)

Output Characteristics:	Maximum Voltage - 3V, rms to 2 MHz (1.5V, rms, in Band-Reject operation). Maximum Current - 10 mA (less in Band-Reject operation). Internal Impedance - 50 ohms, approx. (higher in Band-Reject operation).
Floating (Ungrounded Operation):	A switch is provided on rear of chassis to disconnect signal ground from chassis ground.
Hum and Noise:	Less than 100 microvolts rms for a detector bandwidth of 2 MHz, rising to 150 microvolts for a detector bandwidth to 10 MHz.
Output DC Level Stability:	± 2 millivolt per degree C.
Front Panel Controls:	Cutoff Frequency Hz Dial and Multiplier/Function switch. Power-ON Switch.
Connectors:	Front panel and rear of chassis, one BNC connector for INPUT, one for OUTPUT.

Saicor SAI-43A Analyzer

Available Options:	Option 43020 - Additional Precomputation delay 2000 points. Option 43030 - Additional Precomputation delay 4000 points. *Option 43040 - Additional Precomputation delay 8000 points.

Saicor SAI-43A Analyzer (continued)

The above options are available in a separate box that is connected to the SAI-43A via a multipin connector and corresponding cable.

Option 43050 - Digital Outputs - BCD format. This option provides for digital outputs from the SAI-43A in BCD format. Normally, the digital outputs provided are in binary form. The extra logic and circuits required for this option are added to an existing logic board.

*Option 43060 - Digital Outputs - ASCII Code. The extra circuits required for this option are added to an existing logic board.

Option 42050 - Rack Mount with slides.

Option 401 - Auxilary Scope Display - Standard rack-mounted Tektronix scope.

Option 402 - Chart Recorder - Small MFE chart or strip-chart recorder.

Option 403a - Tape Punch Interface for a standard tape punch device Model 528.

Option 403b - Tape Punch Machine - Mode 528 Roytron.

Option 404 - Teletype Machine Interface - Standard ASR-33 Teletype machine interface from SAI-43A.

Option 405 - ASR-33 Teletype Machine - Standard ASR-33 Machine.

Option 406 - ASR-35 Machine.

*Saicor SAI-43A Analyzer options currently in use in the Helicopter Rotor Test Facility.

Saicor SAI-43A Analyzer (continued)

Operating Modes:	Correlation - Probability - Signal Enhancement
Input (each channel):	Two identical, independent channels (A and B).
Full Scale Input:	100 mV rms (sine wave).
Attenuators:	One per channel, 39 db total in 1 db steps.
Overload:	Peak overload indicator.
Coupling:	DC and AC (3 db low frequency cutoff at 1.0 Hz).
Maximum Input:	200V peak.
Dynamic Range:	48 db.
Maximum Frequency:	Input amplifiers down 3 db at 1.25 MHz.
Correlation Mode:	Auto and Cross-Correlation 400 lag values; simultaneous computation and display of all 400 values.
Time Scale:	0.2 μsec to 1 sec (total delay span from 80 μsec to 400 sec) in 1, 2, 5 sequence with internal clock. Other delay increments with external clock 0.2 μsec, min. no upper limit.

Standard Precomputation Delays:

First point selectable from 0 to -800 Δt in multiples of 200 Δt. (Δt is incremental log value, selectable from 0.2 μsec to 1 sec).

Quantization:	Full - Effective 8 bits each channel.
	Slipped - One bit each channel.

Saicor SAI-43A Analyzer (continued)

Averaging: Switch selectable from 2^9 (512) to 2^{17} (128 x 1024) sums/points in powers of 2. Resume integration permits retention of previous sums and accumulation of new additional average. START, STOP and RESUME commands are manually and remotely controllable. A continuous average selection results in averaging until any of the accumulated lag values reach storage saturation, at which point averaging automatically stops. Overriding STOP control permits any predetermined number of sums/point.

Vertical Resolution: One part in 1024 switch selectable over a 2^9 range plus automatic mode. In automatic mode, a full scale input signal results in full scale presentation of the correlation function regardless of SUMMATIONS (integration) switch position.

Probability Mode: Probability Density Function (p. d. f.) and Probability Distribution (Integral of p. d. f.); 400 discrete levels (channel A or channel B).

Distribution Vertical Resolution:

One part in 512 with highest level normalized to 100%.

Density Vertical Resolution: One part 512 switch selectable over a 2^9 range plus automatic mode as in correlation. Manual override, as in correlation.

Measurement per Function: Switch selectable from 2^9 to 2^{17} total points per curve (see correlation mode discussion of averaging flexibility).

Horizontal Resolution: 400 discrete voltage bins; full scale established by input attentuator settings.

Sampling Rate: 1 Hz to 2 kHz in 1, 2, 5 sequence. Other sampling rates with external clock, max rate 2 kHz no lower frequency limit.

Saicor SAI-43A Analyzer (continued)

Signal Enhancement Modes:

Detects coherence in repeated events. After internal or external sync pulse, a series of 400 samples from each repeated series are averaged. The 400 averaged samples are simultaneously collected and displayed.

Vertical Resolution:	One part in 1024 switch selectable over a range of 2^9 plus automatic modes as for correlator.
Synchronization:	Either internally or externally triggered. In internal trigger, the start or sync point is marked by an output pulse (available at rear panel marked STIM) used to simulate or trigger the experiment.
External Trigger: (to be supplied)	Positive going transition from min $0 \left(^{+0.4}_{-0}\right)$ to $2.4 \left(^{+2.6}_{-0}\right)$.
Internal Trigger:	Stimulus output positive pulse 2.4 to 5V. Width 200 μsec.
Time Scale: (interval between samples)	0.2 sec to 1 sec in 1, 2, 5 sequence. Other intervals available with external sync, min interval 0.2 sec, no upper limit.
Sums per Point:	From 2^9 to 2^{17} in powers of 2.
Improvement in S/N:	Improvement equals square root of number of sums.

Output Modes:

Fast (Scope):	Trigger pulse provided for external synchronization of oscilloscope. Time base provides 40-msec ramp which can be used as an external horizontal drive for the oscilloscope (an alternate means of utilizing an oscilloscope). All functions displayed continuously during and after processing on a 40-msec time base (flicker free)

Saicor SAI-43A Analyzer (continued)

Spectrum:	Correlation function presented continuously after processing with a 4-sec time base (compatible with SAICOR SAI-51A spectrum analyzer for providing spectrum analysis of correlation functions)
Slow:	Function presented continuously after processing with a 20-second time base for use with chart recorders
Single:	Function presented during one sweep (for use with X-Y plotter) when PLOT button is depressed. Sweep speed automatically varies in relation to vertical signal excursion (20-sec minimum sweep)
Calibration Signals:	ZERO CAL depressed X=0, Y=0; FULL CAL depressed X=full scale, Y=full scale
Bin Marker:	15V pulse one bin width in duration. Depression of BIN READOUT button causes value of function corresponding to bin number selected to appear as a DC voltage at FUNCTION jack with corresponding lag position voltage appearing at TIME BASE jack. Thumbwheel control varies horizontal position of pulse for accurate digital X-axis locator.
Digital Outputs:	Correlation functions - 2's complement 10 bits for amplitude
	Probability functions - binary 9 bits for amplitude
	Enhance function - 2's complement, 10 bits for amplitude
	Bin number (x scale, all modes) - binary 9 bits (399 maximum)
	Binary format - "1" equals 2.4V min, 5V max. "0" equals 0V min 0.4V max.
Programming Capabilities:	Remote start, stop, resume (with override capability)

Saicor SAI-43A Analyzer (continued)

External sample and sync inputs

External sync for signal enhance

All front panel connections appear in parallel on the rear panel as follows:

Front Panel	EQUIVALENT REAR PANEL
INPUT A	A IN
INPUT B	B IN
BIN MARKER	MKR
SYNC	SYNC
TIME BASE	X OUT
FUNCTION	Y OUT

Tektronix, Model 585A, Oscilloscope

Vertical Deflection System

Characteristics	Performance Requirement
Frequency Response: (Bandwidth)	DC to $\geq$85 MHz (at -3 db point) displays at 100 mV/cm
Deflection Factor:	0.1V/cm

Tektronix, Model 585A, Oscilloscope (continued)

Horizontal Deflection System

Characteristics	Performance Requirement
Sweep Rates Time Base A:	Accuracy within ±3% of the indicated rate for all calibrated front panel positions
Variable Range:	From 0.05 μs/cm to 5 s/cm
Time Base B:	Accuracy within ±3% of the indicated rate
Length:	From 4 cm to 10 cm
5 X Magnifier:	Accuracy is within ±2% of the sweep rate accuracy

Triggering

Time Base A Characteristics	Supplemental Information
Source:	Line; internal (from trigger pickoff circuit in the vertical amplifier); and external
Coupling:	Internal and External.
Slope:	Trigger on positive or negative going slope of the trigger signal
Level:	Adjusts to permit triggering at any selected level on either the rising or falling portion of the waveform and up to ±10V (external) in amplitude

Tektronix, Model 585A, Oscilloscope (continued)

Time Base B Characteristics	Supplemental Information
Source:	Line; internal; external
Coupling:	Internal and External.
Slope and Level:	Same as time base A except triggering level range is up to ±7.5V (external) in amplitude

Variable Time Delay

Characteristics	Performance Requirement
Delay Time:	Accuracy is within ±1% of Time Base B sweep rate accuracy
Multiplier Incremental Linearity	Accuracy within 0.2% of total range.

External Horizontal Amplifier

Frequency Response:	DC to 350 kHz or more, at maximum gain (at -3 db point)
Input Characteristics:	Approximately/ Ω paralleled by 47 pF
Deflection Factor:	
X1:	0.2 V/cm maximum (VARIABLE 1-10 control fully clockwise)
X10:	2.0 V/cm maximum

Tektronix, Model 585A, Oscilloscope (continued)

Amplitude Calibrator

Voltage Output:	Peak-to-peak amplitude accuracy is within $\pm$3% of indicated front panel setting when working into an impedance of 1 MΩ or higher
Frequency:	1 kHz $\pm$25%, positive-going square wave with zero-volt baseline
Risetime:	Equal to or less than 2 μsec into 15 pF

Front Panel Output Signals

Sawtooth A:	140 V $\pm$20 V increasing to approximately 180 V $\pm$20 V at the faster sweep rates and having the same time duration as the A sweep. Recommended load ≥100 kΩ.
+ Gate A and + Gate B:	Within the range of 20 to 40 volts. Positive-going gate pulse with the baseline at zero volts. Time coincident with the respective sweep. Recommended load ≥5 kΩ.
Dly'd Trig:	A positive - going pulse of approximately 5 V $\pm$ 2 V into a load ≥10 kΩ. Pulse occurs at the end of the delay period.

External Signal Connectors

Tektronix, Model 585A, Oscilloscope (continued)

CRT Cathode:	An applied 20-volt peak-to-peak signal from 1.0 kHz to 1 MHz will produce noticeable modulation. Positive portion of the signal blanks CRT beam

Cathode-Ray Tube

Type:	T5810-31; P1, P2, P7 and P11 phosphors optional. Other phosphors available on special order
Accelerating Potential:	10 kV
Usable Viewing Area:	4 cm high by 10 cm wide
Graticule:	Internal, adjustable edge lighting. 4 x 10 cm with vertical and horizontal 1 - cm divisions with 2 - mm markings on the centerlines

Spectral Dynamics 110-1 Phase Meter/Resonant Dwell

Phase Meter Section

Frequency Range:	5 Hz to 1 MHz continuous (input L.P. filter in OUT position); 5 Hz to 20 kHz when using filter
Input Amplitude Range:	40 db referenced to 3 Vrms
Input Impedance:	3 MΩ or greater shunted by 20 pF
Input Signal Bias:	Will accommodate up to $\pm$150 V offset on each signal input

Spectral Dynamics 110-1 Phase Meter/Resonant Dwell (continued)

Detection Accuracy:	
Absolute	±0.75 degrees over 40 db amplitude range at 400 Hz
Relative (wideband)	20 db amplitude range 10 Hz--200 kHz, ±0.75 degree 5 Hz--400 kHz, ±1.5 degrees 40 Hz--200 kHz, ±1.5 degrees
Input Low-Pass Filter	
Relative	5 Hz--20 kHz, ±3.0 degrees at F.S. Input
Outputs:	
DC ∝ Phase:	Suitable for external recorder and digital readout
Voltage:	0-3.6V at 10 mV/degree nominal
Impedance:	Less than 100Ω. Load impedance should be a minimum of 10 kΩ
Linearity:	Less than ±0.75 degrees at full input and at 400 Hz
Calibration:	0, 180 and 360-degree positions provided for rapid calibration of external recorder or monitor
Response:	Three-position selectable switch: slow 50%, medium≈1200°/s, fast≈3600°/s

Spectral Dynamics 110-1 Phase Meter/Resonant Dwell (continued)

Front Panel Meter	
Phase Range:	0 to 360 degrees, -180 to +180 degrees and 0 to 30 degrees (expanded phase +30 degrees).
Linearity:	±1% of F.S.
Accuracy:	±1% of F.S.
Phase Finder:	Push button provided to locate phase angle when on expanded ranges.
External Meter/Recorder:	Floating signal available for driving external meter or differential input recorder.
Voltage:	Approximately 125 mV DC at full scale on any meter range.
Min Diff Load Impedance:	1 MΩ.
Cal:	A front panel adjustment provides a phase offset, adjustable from ten to ninety degrees which may be inserted during dynamic modes of operation.
Resonant Dwell Section	
Input:	
Dynamic Control Range:	Provides resonant dwell control at any input phase angle, 0 to 360 degrees.
Signal Voltage:	0V to ≈+3.6 VDC from phase meter section.
Output:	
Voltage:	≈-1.8V to ≈+1.8 VDC for driving VCO in system Sweep Oscillator, such as SDC Model SD104A-5 or SD114 Sweep Oscillator Servo.

Spectral Dynamics 110-1 Phase Meter/Resonant Dwell (continued)

Impedance:	1 kΩ
Safety Interlock:	1. Closed-circuit interlock, normally closed for series interlock system, automatically opened by application of ≈+15V to either of two inputs; +15V inputs normally supplied from Sweep Oscillator upper and lower sweep limit reset circuitry 2. Additional single-pole double-throw relay contacts available (part of interlock circuit described above), can be used for low-level signal switching such as the audio between Sweep Oscillator and shaker power amplifier

APPENDIX IV

LIST OF RELATED EQUIPMENT MANUALS

Title of Manual	Manufacturer	Date or No.
FR-600 Recorder/Reproducer	Ampex	68611-16
Instruction Manual SD307 Low Frequency Translator	Spectral Dynamics	August 1971
Instruction Manual SD301C Real-Time Analyzer	Spectral Dynamics	June 1971
Instruction Manual SD302C Ensemble Averager	Spectral Dynamics	May 1971
Instruction Manual Model 13116-2 X-Y Display	Spectral Dynamics	June 1971
Operating and Service Manual X-Y Recorder 7035B	Hewlett-Packard	HP7035B
Instruction Manual Model SAI-43A Correlation and Probability Analyzer	Saicor	
Operating & Maintenance Manual Solid-State Variable Filter Model 3202(R)	Krohn-Hite	
Instruction Manual Model 8154 Time-Code Generator/Reader/ Tape Search & Control Unit	Systron Donner	
Operation & Maintenance Manual Model 122 DC Amp	Neff	
Operation & Maintenance Manual Model 1-172A-XX Universal Galvanometer Amplifier	Bell & Howell	992346-0007
Instruction Manual Type 1304-B Beat Frequency Audio Generator	General Radio	Form 1304-0100-M ID 1419
Instruction Manual Type 1521-B Graphic Level Recorder	General Radio	Form 1521-0150-C ID 1395

APPENDIX IV (continued)

Title of Manual	Manufacturer	Date or No.
Instruction Manual SD110-1 Phase Meter/Resonant Dwell	Spectral Dynamics	May 1970
Operating & Maintenance Manual VR-3400 Magnetic Tape Recorder/ Reproducer	Bell & Howell	992560-0004
Operating & Service Manual Model 215 RMS Voltmeter Log Converter	B & K	1970
Introduction Manual Model 8200A D.V.M.	John Fluke	June 19, 1972
Technical Manual, Visicorder Oscillograph Model 1108	Honeywell	16850351-001J
Operation and Maintenance Manual, Visicorder Oscillograph, Model 1508	Honeywell	January 1963
Instruction Manual, Tektronix Type 585A Oscilloscope	Tektronix	070-0391-01

APPENDIX V

RECOMMENDATIONS FOR SYSTEM IMPROVEMENT

It has become obvious from personal examinations and consultations with Wyle instrumentation personnel that there is a necessity for an in-depth engineering study of the wiring, shielding, and grounding scheme, or lack thereof, employed in the Helicopter Rotor Test Facility. In order to be effective, shields should be continuous through all junctions and all instruments from the transducer to the recording device. All shields should be grounded to a single point, preferably at the source transducer. Presently, no shielding exists from the rotating slip rings up to the hub. This situation is the result of an inadequate number of available slip rings. Wyle is presently investigating and will incorporate some new ideas into the system to alleviate these problems.

Signal/noise ratio improvement through the slip rings is desirable. Future plans call for installation of preamplifiers on the rotor hub to boost signal levels prior to slip rings. Assuming temperature drift problems may be minimized, this basic idea is recommended. Another possibility for signal/noise improvements is to research the market for sealed or mercury wetted contact slip rings.

Another area that should be researched further is the possible use of FM/FM or pulse coded telemetry to acquire data. Data bandwidth restrictions may preclude use of either of these systems. Costs will also be high because of the microminiaturization and reliability incorporated into these products.