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WANL-TME-1690

October 1967

Westinghouse Astronuclear Laboratory

PLAN FOR TEST CELL "C" ACCURACY STUDY
STEP II

MAILED

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Subject: (1) WANL-TME-1716, "Test Cell 'C' Accuracy Study - Phase I
Results," dated November 1967
(2) WANL-TME-1690, "Plan for Test Cell 'C' Accuracy Study -
Step II," dated October 1967

Dear Mr. Dooling:

Transmitted herewith for your information are ten (10) copies each of the above subject reports. These reports were prepared in accordance with the work statement for Project NE-3030 in Contract Year 1967.

As stated in WANL-TME-1716, the accuracy values determined are valid based on the Phoebus data, but do not include cable effects between the test car and Test Cell "C", thermocouple referencing effects, crosstalk and frequency response. WANL-TME-1690 provides the test plan to obtain additional data on these effects should this information be deemed necessary in the future.

These reports do not include any data or information on the recently completed NRX-A6 TMR accuracy test. Results of this test will be transmitted by separate correspondence.

Respectfully,

ORIGINAL SIGNED BY

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October 1967

WANL-TME-1690

PLAN FOR TEST CELL "C" ACCURACY STUDY
STEP II

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1.0 INTRODUCTION

Accuracy tests have been performed on the Test Cell "A" narrow-band Data Acquisition System, and WANL has been requested by SNPO-C to prepare a description of plans for conducting a similar test for the Test Cell "C" Data Acquisition System. Certain arrangements must also be included with this plan:

- (a) That the plan and procedure for this test should be reviewed and agreed upon by all parties concerned.
- (b) That the statistical method of selecting channels and analyzing data, and the tests employed, should result in an accuracy value for each of the eight possible channel configurations, and that these accuracy values should be used by all parties concerned.
- (c) That, while the tests will be performed on specific channels typical of NRX-A6 configurations, the results will be used to predict the accuracy of similar narrow-band channels.

2.0 TEST OBJECTIVES

The evaluation tests are designed to determine the following objectives for high and low level channels:

- (a) Overall channel accuracy (error band limits).
- (b) Channel linearity, drift, and noise.
- (c) Channel frequency response.
- (d) Adjacent channel multiplexer crosstalk.
- (e) Contribution of various multiplexer types to channel inaccuracy.
- (f) Extent of anomalies in accuracy test evaluation.

2.1 Definition of Test Parameters

The accuracy parameters used in the data analysis are defined as follows:

2.1.1 Linearity

Linearity is determined by defining a function such that $V_i = f[V_i']$

where: V_i = the computer-calculated output voltage,

V_i' = the input voltage as recorded to the system,

i = one to six voltage calibration levels (20% full scale steps).

Therefore, linearity is defined as the maximum of the absolute differences $V_i' - \bar{V}_i$ found on any single step, where $\bar{V}_i$ is the measured output voltage as read from the recorded output tape. Results are expressed in percentage of full scale.

Linearity thus includes contributions from both the data system and the reduction system.

2.1.2 Drift

For a full scale input voltage applied at several distinctly separate times, some variation in indicated voltages can be expected. This variation represents (primarily) full scale drift (or gain instability) in the channel. In a similar manner to full scale drift, zero offset drift is represented by the variation of the digitized values representing zero input signals taken at separate times. Full scale drift and zero offset drift will be combined into one overall drift figure by comparing the linearity curves taken at several distinctly separate time intervals. Then the overall channel drift is defined as the variance estimate between these curves over the zero to full scale span, from which drift is calculated in percentage of full scale. Thus, drift is obtained by comparing the linearity curves taken at several separate time intervals.

Drift at Test Cell "A" was found to be random, insofar as time was concerned. For this reason, the drift tests described may be performed over varying amounts of time; it is not necessary to begin the test or portions of it at a precise time.

2.1.3 Noise

Noise is determined by using the peak-to-peak deviations of signal on the six-step signal levels to form a standard deviation, expressed later as percentage of full scale input.

The average of all values on a single step is determined, and the deviation from this average calculated. The standard deviation is then determined.

2.1.4 Frequency Response

Frequency response is the amplitude fidelity of the data system in reproducing signals of varying frequency. Attenuation of signals by active components, particularly amplifiers, results in degraded frequency response.

2.1.5 Crosstalk

Crosstalk, per se, is not an accuracy parameter but is an evaluation of all previously defined parameters in the presence of coupling. Thus, crosstalk may be considered in terms of its effect on the parameters of noise, linearity, and drift in controlled tests. Because other effects are generally minimal, only adjacent channel multiplexer crosstalk is being considered.

2.1.6 Data Anomalies

Unexpected results or non-correlatable results will be reported as data anomalies.

3.0 TEST PROCEDURE AND DESCRIPTION

3.1 System Description

The narrow-band data acquisition system at Test Cell "C" consists of a high level and a low level Pulse Amplitude Modulated/Frequency Modulated (PAM/FM) system. This system records transducer output variations in the range of zero (DC) to about 20 Hertz

by frequency modulation of a carrier by pulses which are amplitude modulated by information. A low level signal is defined as one whose full scale input to the multiplexer is 10 to 100 millivolts. A high level signal presents five or ten volts full scale to the multiplexer. These signals are derived either from high level transducer outputs or from amplified low level transducer outputs. These input signals are converted in the multiplexer to pulses of finite widths whose amplitudes are proportional to the value of the signals themselves. This PAM signal is next converted to a frequency modulated (FM) signal by a voltage controlled oscillator (VCO). The resulting PAM/FM signal is then transmitted over approximately two miles of transmission line to the Control Point where it is recorded on magnetic tape.

Figures 1 through 8 indicate the eight basic channel configurations with a test signal source shown in place of the transducers normally found on high and low level channel measurements. These channel configurations are typical; they cover most of the NRX-A6 diagnostic measurement possibilities. Figures 1 through 4 illustrate high level channel configurations, whose PAM/FM signals are transmitted to the Control Point via wide band long lines for magnetic tape recording. Associated with each of these channels is a separate analog long line assignment to transmit the signal for Sanborn (strip chart) display, meter display, etc. Figures 5 through 8 are low level channel configurations whose signals are transmitted to the Control Point via wide-band long lines for magnetic tape recording. The configurations covered are:

- Figure 1 - High-level Thermocouple Channel - Referenced in Cell
- Figure 2 - High-level Thermocouple Channel - Unreferenced or With On-car Referencing
- Figure 3 - High-level Full Bridge Transducer Channel
- Figure 4 - High-level Bridge Completion Channel
- Figure 5 - Low-level Thermocouple Channel - Referenced in Cell
- Figure 6 - Low-level Thermocouple Channel - Unreferenced or With On-car Referencing

Figure 7 - Low-level Bridge Transducer Channel

Figure 8 - Low-level Bridge Completion Channel

3.2 Test Description

Figures 1 through 8 show the eight basic channel configurations. The same signal source levels (except for the crosstalk test) will be inserted simultaneously into four or eight channels (depending upon whether or not Phases I and II are performed concurrently), via the test car instrumentation module, by a programmable power supply. These tests are to be performed on channels which are wired as close as possible to the NRX-A6 configuration.

This accuracy test shall be completed in two phases, which may be performed concurrently if desired. The first phase will test the channel configurations and the multiplexers as shown in Table 1. The second phase is outlined in Table 2. Because channelization is not yet completed, these tables will be completed as a portion of the Test Procedure.

Phasing refers primarily to the manner in which data will be reduced, and not to test timing. A two-day test period will be required for performance of the test schedule (if phases are concurrent). The tests to be performed during the test series are shown in Table 3. If test phases are not performed concurrently, the same test series is to be performed for the second phase on the third and fourth days.

The frequency response test will be performed on two high level multiplexers (TI's) and two low level multiplexers (new SEL's) at the close of the second day. The primary purpose in this test is to determine the amplifier response while coupled into the channel. The Neff amplifiers are studied in the high level checks, and the SEL multiplexer built-in amplifiers in the low level runs.

3.2.1 Data System Calibration

In order to correctly utilize existing data reduction programs, an ordinary system voltage calibration will be performed before and after the accuracy test.

3.2.2 Linearity Tests

The programmable power supply system will be used to insert test signals in 20 percent steps from zero to full scale at the test car instrumentation module. In providing the 20 percent steps the power supplies will provide data needed to fulfill the linearity, drift, and noise test objectives. A total of 64 channels will be sampled during this test. These linearity runs are to be run consecutively according to the schedule of Table 3. When the channels are selected, care must be taken that adjacent channels on a multiplexer are NOT chosen for this test. This will eliminate the possibility of crosstalk during the linearity testing.

3.2.3 Crosstalk Tests

Channel crosstalk testing will be accomplished by connection of a separate 5 Hertz AC source multiplexer channel adjacent to the test channel at the instrumentation module. Determination of the level of crosstalk will be accomplished in the following manner.

The test channels will have zero to full scale (in 20% steps) inputs while the adjacent channel on each side has a 5 Hertz full scale signal input. Channels on both sides of all test channels (128 channels) are so connected.

3.2.4 Frequency Response Tests

A sine wave generator will be used to insert a constant amplitude test signal, steadily increasing from 0.1 Hertz to at least 100 Hertz for the frequency response test. An oscillograph will be used to monitor the output (frequency and voltage) of the generator with respect to time. The graphs from the oscillograph and the reproduced data system (Cal Comp plot) output may then be compared to locate the frequency response of the data system. The frequency response will be determined in the following manner.

A trace similar to curve of Figure 9 will be available from an oscillograph channel connected to the output of the sine wave generator. This curve will

show frequency slowly increasing with time, with a constant amplitude. The 10-volt channel output from the high level portions of this test will also be recorded on the oscillograph (four channels) to aid in location of the half-power points. Two channels from each of four multiplexers will be tested for frequency response, as delineated in Tables 1 and 2.

The response curves from the eight channels tested will be plotted on Cal-Comp plotters, yielding curves similar to Curve 2 on Figure 9.

This curve will show an increasing frequency to about 20 Hertz. At that point aliasing will begin to occur. Amplitude will decrease as the plot approaches the frequency response frequency. By using Curves 1 and 2, a plot can be drawn of oscillator input frequency versus data system output frequency, similar to Curve 3. The frequency response of the data system may be located by determining where the amplitude of the data system output frequency (Curve 2) is down 3 db or to 70.7% of the input. To aid in data correlation, the time code signal must be recorded on the oscillograph also.

3.3 Recording

3.3.1 Tape Signals

The programmable power supply system will be stepped off in 20 percent increments for the linearity tests and the PAM/FM channel (multiplexer output signals) will be recorded on magnetic tape at the Control Point. A 10-second data sample will be recorded for all measurements for each step. All measurements will be simultaneously recorded on two tape recorders. Each of the runs indicated in Section 3.2.1 will be recorded on tape for each phase. The time code generator will be running during the entire test. A log book will be kept on the test portion being conducted; time and anomalies will also be logged.

4.0 STATISTICAL BASIS FOR TEST PLAN

Previous results (taken at Test Cell "A") have indicated that the accuracy of data channels is primarily affected by multiplexer type, channel configuration, and a random

time effect. The principal parameters affecting channel accuracy (noise, linearity, and drift) have been seen to vary among multiplexers and configurations, and possibly from configuration to configuration within multiplexers. Noise and linearity are most affected by multiplexers and configurations, and drift most affected by time. Thus, the emphasis in this test plan is on these three factors.

In Section 3.0, this emphasis is easily seen. Four channel configurations for both the high level and the low level systems have been selected. Considering the two multiplexer types that can be used in each system, two multiplexers for each type, four configurations for each multiplexer, and two channels for each configuration, the basic plan to evaluate channel accuracy from 64 channels is derived. This plan can be considered as a complete set of 64 representative channels or as two sets of 32 channels (representing the two test phases), the difference being that data may be collected in a single phase or in two phases respectively. In either case, data are to be recorded for two calibration runs (pre and post), six linearity runs, two crosstalk runs, and a frequency response test.

Results found on the analysis of the linearity runs will be the basis for establishing the overall channel accuracy values. Data from the crosstalk runs will be directly compared to the linearity run data to establish any additional crosstalk effect that may be significant. The technique of analysis that will be used is analysis of variance as described in the report on Test Cell "A" accuracy study (WANL-TME-1372), and as described in more detail in Chew, V., Experimental Designs in Industry, John Wiley and Sons, New York City, and in Davies, O. L., Design and Analysis of Industrial Experiments, Hafner Publishing Company, New York City. From the proposed plan and the use of the analysis of variance techniques appropriate for this plan, valid estimates of each of the accuracy parameters will be readily determined. These estimates can then be further assessed so as to yield a single accuracy value for all channels.

4.1 Source of Analysis Data

Analysis will be performed using the N3 digital data tapes, except for the frequency response test, which is analyzed from the oscillographic responses and Cal-Comp plots.

Data tapes are to be pre-processed using both the NDRS and the LASL Processing Codes. Sampling rate is to be 40 samples per second.

4.2 Reports

The final analysis report will describe the results of all testing, conclusions, and recommendations. The data reduction and analysis technique will be described, and examples given.

The completed draft report will be submitted for review by all interested parties. Appropriate comments will be incorporated into a final version which will be presented orally as agreed upon by program participants and SNPO-C. The written final report will then be issued.

TABLE 1
PHASE I CHANNEL AND MULTIPLEXER ASSIGNMENTS

High Level Configuration

	Texas Inst.		New SEL	
	HLXX	HLXX	HLXX	HLXX
Figure 1	*Channel _____		Channel _____	
	Channel _____		Channel _____	
Figure 2	Channel _____			Channel _____
	Channel _____			Channel _____
Figure 3		Channel _____	*Channel _____	
		Channel _____	Channel _____	
Figure 4		Channel _____		Channel _____
		Channel _____		Channel _____

Low Level Configuration

	Old SEL		New SEL	
	LLXX	LLXX	LLXX	LLXX
Figure 5	*Channel _____		Channel _____	
	Channel _____		Channel _____	
Figure 6	Channel _____			Channel _____
	Channel _____			Channel _____
Figure 7		Channel _____	*Channel _____	
		Channel _____	Channel _____	
Figure 8		Channel _____		Channel _____
		Channel _____		Channel _____

Note: Both the high-level and low-level capability of the new SEL multiplexers are tested as indicated above.

*These channels are to be used for frequency response testing.

TABLE 2
PHASE II CHANNEL AND MULTIPLEXER ASSIGNMENTS

High Level Configuration

	Texas Inst.		New SEL	
	HLXX	HLXX	HLXX	HLXX
Figure 1		Channel _____ Channel _____		Channel _____ Channel _____
Figure 2		*Channel _____ Channel _____	Channel _____ Channel _____	
Figure 3	Channel _____ Channel _____			Channel _____ Channel _____
Figure 4	Channel _____ Channel _____		*Channel _____ Channel _____	

Low Level Configuration

	Old SEL		New SEL	
	LLXX	LLXX	LLXX	LLXX
Figure 5		Channel _____ Channel _____		Channel _____ Channel _____
Figure 6		*Channel _____ Channel _____	Channel _____ Channel _____	
Figure 7	Channel _____ Channel _____			Channel _____ Channel _____
Figure 8	Channel _____ Channel _____		*Channel _____ Channel _____	

Note: Both the high-level and low-level capability of the new SEL multiplexers are tested as indicated above.

*These channels are to be used for frequency response testing.

TABLE 3
TEST TIMING

	<u>First Day</u>	<u>Second Day</u>
AM	Voltage Calibration Linearity Run 1 Linearity Run 2	Crosstalk Run 2 Linearity Run 4 Linearity Run 5
PM	Linearity Run 3 Crosstalk Run 1	Linearity Run 6 Voltage Calibration Frequency Response

FIG. 1. HIGH LEVEL THERMOCOUPLE CHANNEL - REFERENCED IN CELL

Example: CH/AL THERMOCOUPLE

FIG. 2. HIGH LEVEL THERMOCOUPLE CHANNEL - UNREFERENCED OR WITH ON-CAR REFERENCING

Example: W/WR THERMOCOUPLE

FIG. 3. HIGH LEVEL FULL BRIDGE TRANSDUCER CHANNEL

Example: STRAIN GAGE PRESSURE TRANSDUCER

FIG. 4. HIGH LEVEL BRIDGE COMPLETION CHANNEL

Example: RTT OR HALF BRIDGE STRAIN GAGE

FIG. 5 LOW LEVEL THERMOCOUPLE CHANNEL - REFERENCED IN CELL

Example: CU/CON THERMOCOUPLE

FIG. 6

LOW LEVEL THERMOCOUPLE CHANNEL - UNREFERENCED OR WITH ON-CAR
REFERENCING

Example: W/WR THERMOCOUPLE

FIG. 7 LOW LEVEL BRIDGE TRANSDUCER CHANNEL

Example: STRAIN GAGE PRESSURE
TRANSDUCER

FIG. 8 LOW LEVEL BRIDGE COMPLETION CHANNEL

Example: RTT OR HALF BRIDGE STRAIN GAGE

FIG. 9. FREQUENCY RESPONSE TEST CURVES